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JANUARY, 1938

The Locomotive

. Quarterly Magazine Devoted to Power Plant Protectior

Please Show to Your Engineer

Welding Engineering

By William D. Halsey, *Assistant Chief Engineer, Boiler Division*

POWER plant owners in all parts of the country are today interested in fusion welding, not only for new construction, but also for repairs. Their interest in and their use of this means of fabrication, however, are along many channels not governed by uniform standards. Their work is subject to variables which prevent welding from being carried on under an established routine, so that expert and experienced "welding engineering" is necessary for the success of each separate undertaking.

When welding first began to be substituted for riveted construction, the natural tendency was to retain the details adapted to riveting, but it is becoming more and more appreciated that, in the design of pressure vessels to be fabricated by fusion welding, the peculiarities of welding must be taken into consideration. However, the use of welding as a means of fabrication makes possible much simplification that may lead and has led to very faulty design. An outstanding example of this in the use of dished heads without a flange. (See Figure 4). Many failures have resulted from this type of construction. The weakness lies in the fact that the weld comes at the point where the greatest stresses are concentrated.

Not only must the design of the welded joint be considered, but the distribution, magnitude, and effect of stresses must be carefully analyzed and correctly provided for. Suitable attention to all the numerous details can be given only by those who have been properly trained and instructed and are, therefore, familiar with the details of construction best adapted to the work in hand and who also have the knowledge and appreciation of the stresses that are set up both by the pressures to which the vessel may be subjected and of those stresses resulting from temperature differentials.

While there are efforts under way to reduce many welding details to definite standards, the design, fabrication and installation of fusion welded vessels and piping are still to a great extent "custom-made." New designs and new installations often bring up new problems of welding engineering and emphasize the need of caution in the progress that welding is making.

The official regulation embodied in various codes already is proving of much value in the establishment of universal standards for safe fusion welding.

Welding and the Codes

The A.S.M.E. Power Boiler and Unfired Pressure Vessel Codes now recognize fusion welding for new construction. A brief review of those codes here will help to explain the problems of welding discussed later.

The A.S.M.E. Codes do not specify how welding shall be done, but they do require that certain standards be met. It is left to the manufacturer to select the means he will employ to attain those results. In

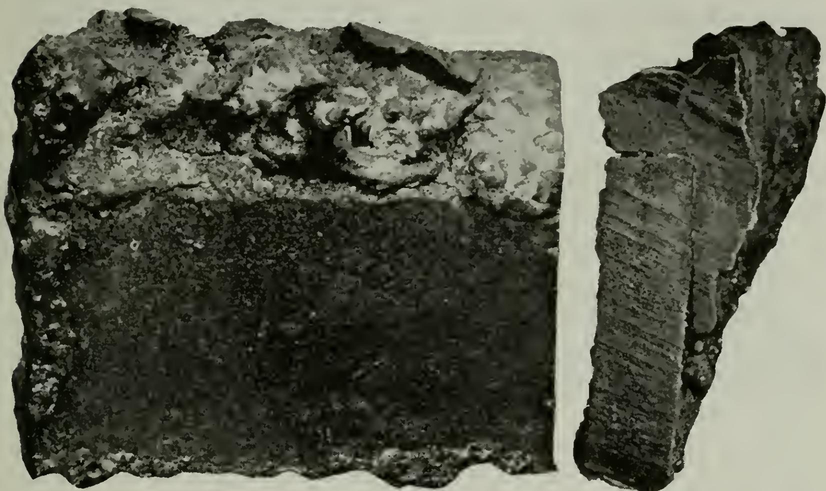


Figure 1. An example of uncontrolled welding. Parts of a 36" x 24" patch on a high pressure boiler are shown. The patch was welded flush with the shell plate and there was very little fusion. How little may easily be ascertained from the photograph at the right showing the cross section of the seam.

the fabrication of a fusion welded power boiler drum it is required that a test weld be made for every drum, this weld to be made by exactly the same welding technique as is employed in the fabrication of the drum itself, and to be tested for physical properties such as tensile strength, ductility, soundness, and specific gravity. The longitudinal and circumferential fusion welded seams are examined by X-ray to ascertain that they are within the tolerance for soundness permitted by the Code. All fusion welded power boiler drums must be stress relieved.

For those unfired pressure vessels formerly referred to as Class 1 vessels, but now designated as U-68 vessels, the requirements are the same as for fusion welded power boiler drums. Such vessels may be used for any class of service, pressures, and temperatures, within the practical limits of the material of which the vessel is constructed.

For a limited type of service, wherein the pressure does not exceed 400 lb, a temperature of 300°F. if the vessel contains a liquid, or 700°F. if a gas, and where the contents of the vessel are not lethal, the welding requirements are somewhat less exacting. For this class of vessel, formerly designated as Class 2 but now referred to as U-69, it is required that a definite procedure for welding be adopted, that this procedure be tested to determine that it will produce welds of acceptable tensile strength, ductility, and soundness, and that the welding operators demonstrate that, when they follow this process, they can make sound welds. No X-ray examination is required. Dependence is thus placed upon the supervision of the welding procedure and on the ability of the welding operator to obtain in production what he has demonstrated be can obtain on test. The physical test requirements such as tensile strength and ductility are somewhat less exacting than for power boiler drums or U-68 vessels, but, where the wall thickness is relatively great in comparison with the diameter, stress relief of U-69 vessels is required.

U-70 vessels, formerly referred to as Class 3 vessels, are restricted to uses where the pressure does not exceed 200 lb per sq in. and the temperature does not exceed 250°F. For such vessels the requirements are still less exacting, notably in the matter of ductility of the weld metal, but there is the same dependence upon supervision of welding process and qualification of welding operators as for U-69 vessels. Stress relief of U-70 vessels is not required.

The American Tentative Standard Code for Pressure Piping recognizes the fusion welding process for fabrication and the requirements are essentially the same as for U-69 vessels. However, pressure vessels are usually so constructed that the welding can be done in the flat or downhand position, whereas so-called "fixed position" welds are usually necessary for piping. Therefore, the A.S.A. Piping Code calls for qualification tests in several positions.

Qualification of Processes and Operators

The principle of adopting a specified method of welding, checking that method, and subsequently qualifying welding operators under that method is fundamentally sound. However, there are many instances where those fundamental principles are not followed.

Those who fabricate fusion welded boiler drums or U-68 vessels that are examined by X-ray and who thus see the defects that develop in poorly welded seams have had brought forcibly to their attention the necessity for close adherence to approved methods of welding. In the fabrication of fusion welded power boiler drums or U-68 vessels, where physical tests are made and where the major seams are X-rayed, there is a rather high degree of assurance that the welds have the desired physical properties and are sound. On the other hand, there is a tendency on the part of some who do not have the restraining influence of X-ray examination and physical tests on all vessels to take the

Figure 2. The shell, the hole where the patch shown in Figure 1 was attempted, and some of the debris which followed the explosion. Two other boilers were blown from their settings, the failing boiler rocketed 75 ft, the boiler house was wrecked, and one man was killed. It was reported that the boilers were not insured.

welding largely for granted. There is some feeling that the requirement to adopt a fixed method of welding and to investigate that process is an imposition and there is further a tendency, even when such tests are made, to permit the welding operator to do about as he sees fit.

The American Welding Society has recently issued a set of Rules for the Qualification of Welding Processes and the Qualification of Welding Operators and those rules have focused more direct attention upon the distinction between the investigation of a process and the qualification of an operator. For the qualification of a process it is required that all its variables be determined and limits set upon them, that welds be made by that process in various thicknesses of material, and that these welds be tested for tensile strength, ductility, and also for soundness. It is the belief of welding engineers that, if it has been proved that a certain welding procedure will produce welds of good tensile strength, and ductility, there is no need for testing every welding operator's ability to achieve those properties. He need be tested only for his ability to make a sound weld by that process. This is sound logic and gives good results provided the operator follows that process in all essentials.

A great many seem to be inclined to think of a qualified welding operator in the same way that the average person looks upon the master machinist or the master carpenter. However, a qualified welding operator is merely one who has demonstrated he has the ability to do a certain thing under certain circumstances. The point that is usually overlooked is that there must be a great deal of welding engineering done before a welding operator is permitted to do work. The development of a technique of welding for a particular job requires appreciation and knowledge of many items. The testing of a welding operator answers only one question and that is whether he can properly manipulate the welding electrode or welding torch and control the flow of the molten metal in such a way as to obtain thorough fusion and a clean weld.

Stress Relief

There has been, is now, and undoubtedly will be a great deal more heated discussion concerning the question of stress relief. Few if any dispute the point that in any process of welding some residual stresses must result. Some claim that such stresses are dissipated over such an area that they are not highly localized. Others claim that these stresses tend to disappear with the passage of time. Still others point to the vast amount of welding that has been done where no stress relief has been applied, and that few, if any failures have taken place which could be directly attributed to the lack of stress relief. The weakness in this latter contention is that a great deal of the welding that is referred to has been done in structures which were relatively flexible, rather than in rigid structures on which stress relief has been required by the Codes. It is further claimed that stress relief, as sometimes carried out, may aggravate rather than relieve the stress condition.

In view of the general belief that stress relieving is of benefit from the standpoint of safety, it is well to be guided by the requirements of the various Codes until such time as there is more positive knowledge on the subject.

X-ray Examination

X-ray examination of fusion welded vessels has been of undoubted benefit in assisting manufacturers to improve their technique of welding.

Without doubt the knowledge that a weld is to be X-rayed has a restraining effect upon the welding operators and others to prevent short cuts being taken. Whereas such examination, where practicable, does give a record of the soundness of the seams, its restraining effect can be exerted in other ways, such as by competent and honest supervision by those who understand fully what may or may not be done, or by periodic sampling of the weld, as, for instance, by the trepanned plug method. Where X-ray examination can be made under favorable circumstances, it is the best non-destructive method known today to reveal defects in welds. However, it has its limitations, and there are certain types of defects, such as cracks in the welds, that are extremely difficult to find.

Weldability and "Stretchability"

There are two major problems in welding. The first is the weldability of the base metal. The second is the "stretchability" or ductility of the weld metal and the adjoining base metal.

By weldability is meant in general the metallurgical stability after rapid heating to the fusing temperature and relatively sudden cooling. Low carbon steels are relatively stable under these conditions, whereas high carbon steels and others with abnormal amounts of certain alloying elements may undergo severe metallurgical changes. Such changes may cause brittleness in the weld or adjacent thereto and lead to cracking.

"Stretchability" is the ability of the weld and the base metal to stretch and thus avoid cracking that might re-

Figure 3. This uninsured air tank failure was traced by the inspector to lack of fusion in the welded longitudinal seam. The blast blew out a cement foundation and the air compressor and motor were hurled against the ceiling of the service station where the tank was used.

sult from expansion and contraction stresses set up during the inevitable heating and rapid cooling that takes place when a weld is made.

The Welding of Alloys

The earlier applications of fusion welding were confined principally to low carbon steel plate. With the advent of some of the higher strength steels in which there were introduced increasing amounts of carbon and other alloying elements such as manganese and molybdenum, difficulty has been experienced. In many cases the trouble has been overcome when the parts were pre-heated. It must be remembered that when a weld is made the base material is brought to at least the melting temperature and undoubtedly somewhat higher in a very short period of time. The weld and the adjoining base material, if the latter is not pre-heated, cools very rapidly because of the conduction of heat by the base material. The greater the mass of that base material, and the greater the amount of the alloying elements which will tend to cause air hardening, the greater will be the tendency of the weld or the base metal to crack in the heat-affected zone. To overcome such difficulties it is now the practice to pre-heat the material. The degree of pre-heat necessary will depend largely upon the amount of alloying element and the mass of the object. With the carbon molybdenum pipe being welded today, it is common practice to pre-heat to not less than 300°F. and some go as high as 500°F. While such pre-heating has overcome some of the cracking difficulties formerly experienced, there is still some possibility, particularly with high amounts of alloying elements, for a somewhat brittle condition to exist. For such cases many feel that, when the weld

Figure 4. Head of a pneumatic tank which blew out when seal welding failed. Passing through a tile wall, the head damaged supplies in an adjacent room. The shell skidded in the opposite direction, breaking piping and sewer connections. Above the tank, floors and plaster were damaged. Insurance was not carried on the tank.

has been completed, full annealing to about 1600°F. is necessary.

Cast iron with its relatively large amount of graphitic carbon may, when fusion welded, produce a weld which is very hard or one which is very porous. So-called "bronze-welding" is favored by many for cast iron because extensive melting of the base material is not involved and because the bronze joint has ductility to carry the shrinkage stresses. Some materials such as brass may change entirely in their metallurgical composition because of volatilization of the zinc. Some of the chrome nickel steels may be so affected by the heating and cooling during the welding process that their resistance to some types of corrosion may be destroyed.

Wreckage following the explosion of a shell type brine cooler, the accident being attributed to tearing at the welded head and along the entire length of the longitudinal seam. There were points on both the longitudinal and head seams which indicated that the welds penetrated only about 1/8". When the exploding cooler struck high voltage lines, a fire ensued which completed the destruction of the entire building.

As regards "stretchability," if the structure is relatively flexible and the weld or base material is of high ductility and does not pass through a "hot short" range, it may stretch under the shrinkage stresses and no cracking results. On the other hand, the base material may be originally so brittle or have become so through metallurgical changes in the welding process that cracking is almost sure to result.

Fusion Welding for Repairs

When consideration is given to some of the disasters that have occurred because of the failure of fusion welded construction or repairs, it is not surprising to find that insurance companies and state regulating bodies frown upon or prohibit repair by fusion welding except in those cases where the stress is carried by other known construction.* Only a widespread application of welding engineering coupled with competent welding operators will overcome those objections, and permit a more extensive application of the process in the making of repairs.

There is a very great amount of research in welding being done and various interested groups are taking an active part in such work. When the problems in welding, enumerated or suggested here, are considered, the necessity for "welding engineering" rather than reliance solely on "qualified operators" or designers not fully informed about the numerous points involved in welded construction is apparent if safe fusion welded fabrication is to result.

*"Rules for Repair by Fusion Welding on Boilers and Pressure Vessels" issued by the National Board of Boiler and Pressure Vessel Inspectors will be helpful in determining what repairs may be made by fusion welding. A copy of these rules may be obtained by writing THE LOCOMOTIVE.

Drawing Water from Steam Boiler Proves Disastrous

The danger of removing water from a steam boiler for any purpose is illustrated by an accident at a dairy in October. Although insurance was not carried, an inspector was permitted to investigate the case and learned that the dairy was in the habit of using water from the boiler for washing cans and such other service as requires hot water around a dairy. However, as there was no automatic feed, it was necessary to keep the boiler supplied with water by manual operation of the valves, which practice, it was understood, had been neglected at least once prior to the accident. Nor was there an automatic fuel cut out to shut off the fire in case of low water. The boiler, which was a fire tube type of welded construction, literally blew apart, the explosion wrecking the building and killing a man who was in an office about 20 ft from the boiler setting. While the accident was attributed to over-pressure, it is considered more likely that over-heating due to low water actually was the cause.

Failure and Repair of Turbines

By T. B. Richardson, *Chief Engineer, Turbine and Engine Division.*

WHEN the operation of a turbine changes in any respect from its normal characteristics, there must be a definite reason for the change. Just what is wrong is in some cases obvious, but in other cases the difficulty is more obscure and requires careful and expert search for and investigation of all contributing facts. Among these facts is, of course, the actual cause of the failure, because many times the repair of a broken part is not a satisfactory repair at all if the cause of the failure is not at the same time eliminated.

There is only one way to determine the cause of a failure accurately and that is by a first-hand study of the installation itself. The operators often contribute facts about an accident which are helpful, but at other times it is impossible to get a satisfactory account of what happened.

A recent accident illustrates well the necessity for such an investigation. In this accident broken blading, which might have been the aftermath of deterioration, was found in one of the stages. New blading was on hand to replace that particular row during an overhaul that was scheduled within a few months. However, loose blading was discovered in two of the lower stages that had been in service for only one year. Although this blading had only a few nicks on the inlet edges and was otherwise apparently in good condition, arrangements were made to renew these two rows also. Later when the loose blading was being removed, it was discovered that the blading dovetail was stretched. Further investigation revealed that the steam equalizing holes in the wheels were badly distorted and this condition could only have occurred as a result of serious over-speed. If the over-speed had been reported by the operators, not only would the cause but also the extent of the damage have been established much more easily. In this case, four new wheel discs, in addition to other new parts, were necessary before the turbine could be returned to service.

Once the nature of the failure has been determined conclusively, it is desirable that any major local repair, such as the re-bucketing of a large turbine, be performed under the supervision of the manufacturer's service engineer. When transportation costs are not too great, as in the case of a small turbine, however, it is often good practice to return the rotor to the factory for re-bucketing.

When there is a main bearing failure on a turbine, an attempt to re-babbitt the bearing locally should not be made except in cases of emergency. It is desirable to have a spare set of bearings on hand so that the worn or damaged bearings may be returned to the factory, where the latest and best facilities are available for producing a uniform and homogeneous casting of the proper babbitt. The same recommendations, of course, apply to thrust bearing failures. In both cases the condition of the lubricating oil is generally involved. Therefore, the entire oiling system should be cleaned, including the piping, and the oil re-conditioned or replaced by new.

An inherent feature of steam turbine economy is high bucket velocity. Therefore, rotating parts are designed to operate at the maximum possible speed commensurate with safety. Since steel forgings of the very best known materials must enter into the construction of rotating turbine parts, the building up or repair of a turbine shaft by means of fusion welding is not sanctioned, since a shaft that is already subjected to high stresses should not have additional and unknown stresses introduced in it by welding. Neither should repairs by welding be permitted on any other part of the turbine rotor or the generator rotor.

It is appropriate here to discuss the seriousness of cracks in cast iron turbine casings, such as are frequently found in the reinforcing ribs and in the wheel case head. Cracks in ribs are of little consequence unless they extend into the casing itself and are likely thereby to permit steam leakage. The ends of such cracks should be drilled to prevent further extension. When a crack in the casing permits steam leakage, a plate patch and smooth-on cement has been used successfully as a temporary repair. For short cracks, "stitching" can be employed. Bronze welding has been used with success to close cracks in cast iron, but such repair is not recommended and should not be attempted except under competent engineering supervision. It is easy to ruin completely a valuable part by improper methods when welding what appears to be a comparatively simple defect. If the steam temperatures are in excess of 450°F. to 500°F., cracked cast iron parts should be replaced with cast steel.

Vibration in a turbine is frequently the result of misalignment, which may be caused by deterioration of the grouting, by settling of the foundation, or by permanent metal growth resulting in distortion of the turbine casing. As a result, it is often necessary to place a tight line through the bearing pedestals and realign the bearings and casing to secure improved operation. Usually, this may be done by the use of shims at the bearings without the necessity of re-grouting the turbine sole plates. The distortion of a turbine casing also frequently causes excessive steam leakage at the horizontal joint. Distortion and leakage at the horizontal joint may also be a result of metal growth of the diaphragms, which causes the horizontal joint to be pushed apart at the inner edge, so that the steam, in addition to leakage to the outside, will also by-pass the diaphragm nozzles. The obvious remedy is to remachine the diaphragms and scrape the horizontal joint, but such leakage has been reduced effectively by using raw unvulcanized rubber in the joint.

The question as to when turbine blading should be replaced is often asked. The wastage of buckets is caused either by corrosion or erosion. Corrosion is the result of moisture in the steam or of excess oxygen when deaerators are not used. It is more common below the dew point in the turbine and appears in the form of oxide scale. In many instances there may be small pit holes that extend through the blade adjacent to the thin edge. Such holes should be considered as a dangerous condition, depending upon their extent. Cracks are likely to start at the thin edge, extend to the holes and ultimately progress through the entire cross section of the blade.

On reaction type turbines, erosion usually appears below the dew point and is found on the back of the inlet edge of the blade. If such erosion extends into the lacing wire fastening, renewal of the blading is recommended. In any event, any broken lacing wires should be repaired by silver soldering. On impulse buckets, erosion is found at the inlet edge and may extend for a distance of one-quarter of the original width of the bucket before renewal is justified from an efficiency standpoint. From the standpoint of safety, the erosion may extend half way through the original width of the buckets before replacement is required.

The builders of large turbines have been placing a very thin covering on the inlet edge of the last row of blading and sometimes on the adjacent row in order to prolong the life of the blading. The covering is silver-soldered to the blade and is made of Stellite, which is one of the hardest known metal alloys. However, its cost is high and there is a question as to whether it is justified except on very expensive blading 24 or more inches in length.

There are a number of turbine repairs that cannot be fully described in a general discussion and must be given consideration based on all conditions applying to each particular case. Such repairs include the correction of certain kinds of vibration, such as shaft whipping and also include such problems as the proper method of reclaiming a sprung turbine shaft or spindle. These and and many other problems, such as tightening a loose wheel on the shaft, the proper material to be used in replacing buckets, and repairs to an eroded shaft, require special attention and procedure in each individual case.

An Avoidable Turbine Explosion

THE railroads of the country have long made famous the saying, "Stop, Look and Listen." As was suggested by a recent accident, power plant employes might well adopt for themselves a slogan which goes about like this, "Stop, Check and Re-check." The accident was just another of those cases in which re-checking might have prevented trouble—in this case the loss of a new machine and damage to a condenser.

The turbine which failed was rated at 125 kw. It drove a D. C. generator for supplying the excitation for three turbo-generators and had been installed only two weeks. Another auxiliary turbine nearby was being removed from service and the necessary valves were closed by the repair crew. During this procedure the exhaust valve from the exciter turbine was closed in error so that the turbine exhausted into a short section of closed pipe. Boiler pressure quickly built up throughout the entire turbine casing, causing the casing to explode.

Although the turbine was protected with the conventional casing sentinel valve, this proved entirely inadequate. The damage was so extensive that the machine had to be returned to the factory.

The loss of field excitation caused all the turbo-generators to drop their load, thus stopping the electrically driven equipment, including motors used for driving the condenser pumps. When the plant feeder was re-energized, two of the pump motors were on the line and started up simultaneously. The resulting surge of water cracked a condenser head.

"INSPECTOR OF THE MOON"

Aberdovey, North Wales, famous for its bells, earns more fame still with invention of newest civic job. Street lamps there are not lit on moonlight nights, so Councillor Josiah Jones has been appointed "moon inspector," will have responsibility of deciding just what is a moonlight night. The local Council created the appointment because they feel it's a whole time job keeping tab on a moon that will lose itself behind clouds, disappear in mountain mists.—*North Wales Chronicle.*

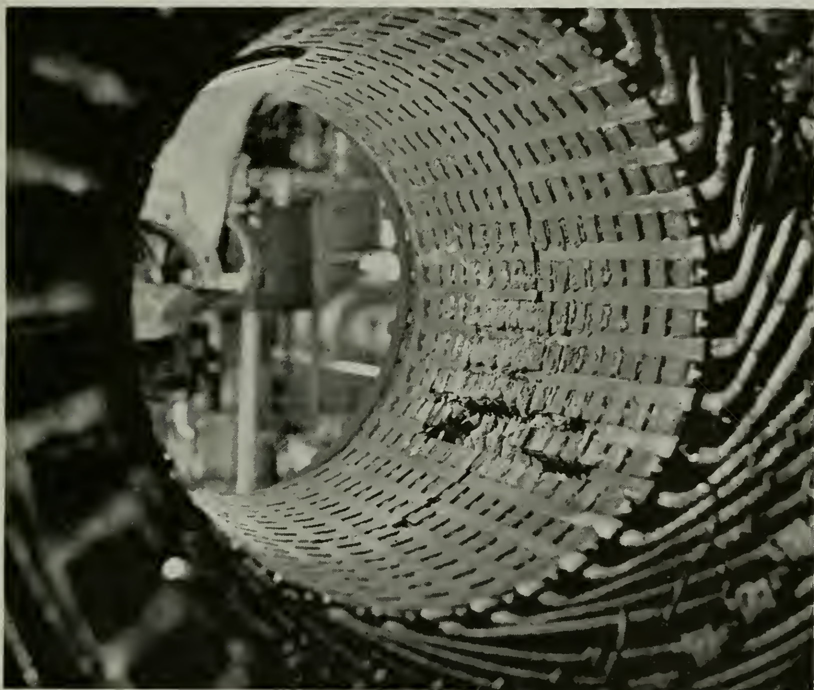
Game Warden: "What's the idea of hunting with a last year's license? You know better than that, don't you?"

Hunter: "Nothing wrong in that, as far as I can see. I'm only shooting at the birds I missed last year."—*Enka Voice.*

Defective Cable Causes Generator Burnout

IN THE October, 1937, LOCOMOTIVE is an article under the title, "Corrosion of Lead Covered Cables." That such corrosion can lead to cable failure and also to damage to other expensive electrical equipment is demonstrated by an accident at a New England plant.

Although the accident originated in the short-circuiting of a 1½ million circular mil cable in a junction box where the cable entered a



Stator burnout caused by short circuit in a cable.

conduit, the most serious damage occurred to a 1250 kw turbine-driven generator.

The short circuit resulted in failure of both the windings and the stator iron, as shown in the accompanying photograph.

Windings were fused and the entire stator so damaged that all of the iron had to be re-stacked and the stator re-wound. This repair required more than four weeks with the crews working 24 hours a day. The rotor was but slightly damaged.

Ventilating to Avoid Furnace Explosion

An accumulation of unburned gases in the furnace of a boiler can cause serious damage if and when it is ignited. This sort of an accident occurred recently in New York City.

Such gases may accumulate with the fire extinguished if the fuel is left "on," and the only way to get rid of them is to ventilate the furnace. If it is possible to ventilate the furnace quickly through a fire door, an interval of five minutes is sufficient to purge the furnace and flues of the unburned gases. However, when it is impossible to "air" the furnace quickly through a fire door, the interval for ventilation should be longer, at least 10 minutes. Of course, these precautions presuppose a reasonably clean furnace, flues and chimney to avoid the dangers inherent in oil-soaked soot.

Just what was the sequence leading up to the New York explosion is not clear, but it is known that the oil burner was not operating properly previous to the explosion. The ignition points failed to ignite the oil vapor when the burner was started at about 11 P.M. Finally, they functioned and the burner began operating. Shortly after 1 A.M. there occurred a violent explosion. Between 11 P.M. and 1 A.M. the burner was inspected by the owner several times. Of a number of possibilities, one of the following three presents itself as the most plausible cause of the accident:

1. There might have been poor timing, producing delayed ignition.

2. The safety control (stackswitch, "protectostat" or other device) may have been inoperative, and the time switch shut the burner down. Manual re-starting by pushing the control button without ventilating the furnace and flues could result in an explosion.

3. Faulty ignition points and continued efforts at manual re-starting might eventually produce a proper spark. Again, lack of ventilation would be a factor.

In all of the above cases it is evident that a quantity of fuel would be permitted to enter the combustion chamber before ignition took place. An explosion, its violence depending on the quantity of volatile gas present, would be the result when the gas was ignited.

The furnace explosion at the New York location was so severe that it cracked the top section of a round cast iron hot water heating boiler, a type used in thousands of homes and small apartments. A steam explosion then ensued and the top section of the boiler tore loose from the rest of the vessel and damaged flooring and piping in a bathroom. Numerous windows were broken. Doors on the front of the building were thrown across the street. Furniture was damaged. The owner estimated his loss at several thousands of dollars. Three families were inconvenienced.

Blowing Down Boilers Equipped With Water Walls

By E. R. Fish, *Chief Engineer, Boiler Division.*

THE most outstanding feature in the development of modern boiler units has been the widespread use of water walls. In the earlier installations much trouble was experienced because of faulty circulation. But it is now fully understood that unless all of the heat-absorbing tubes are afforded an adequate supply of water, overheating is likely to result, and therefore, anything that disturbs the orderly circulation invites trouble.

Serious interference with boiler circulation can be brought about through improper blowing down procedure. Consequently, the following suggestions are offered to promote satisfactory water wall operation.

Boilers should be blown down through the water walls, that is, from the blow down connection to the lower water wall header, *only* when the boiler is practically shut down. The boiler may be hot and with fires out or banked, but should not be steaming at more than a very low rating.

The reason for this is that blowing down from a water wall header is very likely to cause a serious disturbance in the circulation that takes some appreciable time to subside after the blow-down operation ceases. It is during this re-adjustment period that tube trouble may develop. Experience has shown that over-heating of water wall tubes can take place in a very short interval of time.

Blowing down of boilers is principally for the purpose of reducing the concentration of foreign matter in the boiler water, thereby avoiding the consequent tendency to foam and prime. To keep the concentration within allowable limits, "continuous blow-down" is frequently used. The connection for this purpose should preferably be made to one of the boiler drums, although it is sometimes made to a water wall header. This latter practice should be resorted to only with the approval of the boiler manufacturer. This company is of the opinion that it should not be used at all.

One large manufacturer objects to blowing down high duty boilers from the boiler proper in the generally accepted way, since there is the same possibility of checking circulation in some of the boiler tubes as there is in the water wall tubes.

The conclusion, briefly stated, is that for high duty boilers and all water walls *the opening of blow-off cocks must be avoided or done with great caution when boilers are operating at more than a very low rating*, and that the continuous blow-down system is the preferable method.

Engineer Killed When Gauge Glass Bursts

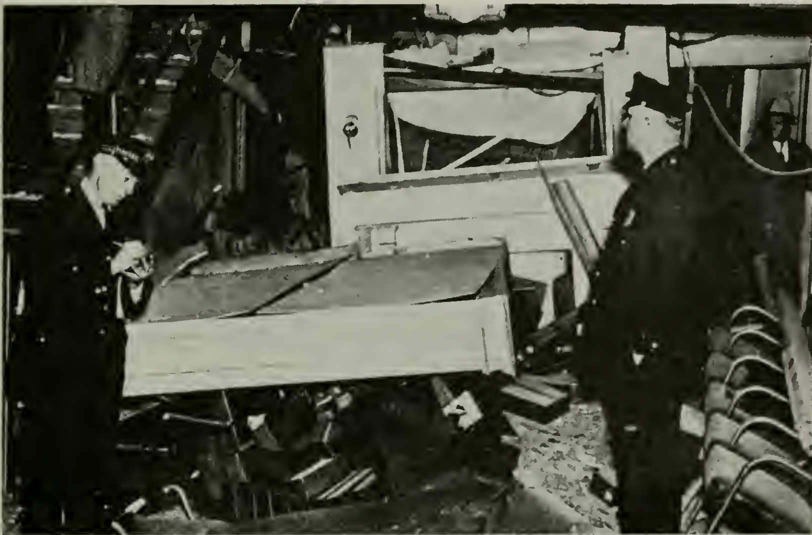
Gauge glasses used in connection with power boilers seldom cause serious trouble, but the bursting of such a glass at a New England plant recently cost the life of an engineer. He had installed a new glass and stood near the gauge, opening the valves to put it into service, when the glass exploded. The accident illustrates the need for remote control for the gauge glass valves, the use of protecting screens around the gauges, or both.

The chief danger is to the operating personnel in case the new glass is for any reason unable to withstand the effects of the heat and pressure put upon it by the incoming water and steam.

Explosion of Hot Water Supply Boiler

THREE persons were injured and property damage estimated at nearly $10,000 resulted recently from the explosion of a single flue type steel hot water supply boiler in an Indiana hotel. Rupturing in the furnace sheet about 8″ from the bottom of the boiler, the vessel tore loose from its setting, passed through a reinforced concrete floor above it, through the second floor of the building, struck the third floor and crashed down on an office desk. On the first floor was a store, the fixtures in which were wrecked, as is shown in the accompanying photograph.

Those who were injured were three of a score of persons waiting



Acme

Damage in a shoe store after an exploding hot water supply boiler had crashed through the floor and the ceiling.

nearby for buses. They were cut by shattered glass which was blown from the front windows of the store. For some unexplainable reason, people inside the building escaped injury, perhaps the most miraculous escape being that of a stenographer who was returning to her desk on the second floor when the boiler crashed down upon it.

The exact cause of this accident was not determined, but it is typical of accidents to hot water supply boilers. Since corrosive influences are apt to thin the metal of the lower part of the furnace sheet, it seems probable that the water was heated above 212° and that pressure set up by the gradual expansion of the water as further heat was applied was sufficient to rupture the weakened furnace sheet, thereby releasing with destructive results the energy stored in the water.

"Did you enjoy your dinner, sir?" asked the solicitous restaurant proprietor.
"Yes, except the sweet. That was terrible."
"Did you have the plum tart or lemon pie?"
"I don't know. It tasted like glue."
"Ah! It was the plum tart. The lemon pie tastes like paste."

—*Union Electric Magazine.*

"Boy, dem ain't feet you got. Dem is ya'ds."

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

Sidney B. Coates, *Editor*

HARTFORD, CONN., January, 1938

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The Locomotive *of* The Hartford Steam Boiler Inspection and Insurance Co.

E. Mason Parry

After three decades of meritorious work in the inspection and engineering services of the Company, Mr. E. Mason Parry died suddenly at his desk on October 4, 1937. For the past four years he had been associated with the boiler division staff of the Home Office engineering department, had served as Chief Inspector of the New York Department for ten years and as Chief Inspector of the Home Office department at Hartford for five years.

Mr. Parry was born in 1876 at Menai Bridge, Isle of Anglesey, Wales, and attended the Menai Bridge and Beaumaris Schools. Following an apprenticeship with Harland & Wolff, ship-builders and engineers at Belfast, Ireland, he became assistant engineer in the Dominion line. In 1900 he was awarded a first class marine chief engineer's license by the Lords of Privy Council, for the Board of Trade, and for some years was engineer officer in the White Star Line.

He became associated with The Hartford Steam Boiler Inspection and Insurance Company in 1906 as an inspector in its Boston department, and in 1913 was transferred to the Home Office department at Hartford as directing inspector. Promoted to the position of chief inspector in 1918, he served at Hartford until 1923, when he went to the New York office. The rigorous responsibilities of this large department were Mr. Parry's for the next decade. In the spring of 1933 he was granted leave of absence for rest and recuperation from a long-continued illness and spent the next several months in England. On his return he came to Hartford where he served until his death.

Mr. Parry was a member of the American Society of Mechanical Engineers and of the Society of Naval Architects and Marine Engineers.

Newton C. Brainard to Board of Directors

Newton C. Brainard

Newton C. Brainard, president of The Case, Lockwood & Brainard Company of Hartford, printers and bookbinders, has been elected to the Board of Directors of The Hartford Steam Boiler Inspection and Insurance Company. A man prominently identified with the civic, educational and business life of his home city, Mr. Brainard has served as Mayor of Hartford, is a trustee of Trinity College and is identified with several prominent businesses as an officer, director or trustee. He is a graduate of Yale College in the class of 1902. It is of interest regarding the company which Mr. Brainard heads that it printed the first issue of The Locomotive in 1867 and has printed the magazine continuously since that time.

"So your name is George Washington," mused the old lady. "You try hard to be like him, don't you?"

"Like who?"

"Like George Washington, of course."

"Ah kaint help bein' lak George Washington, 'cause dat's who I is."

—*U. P. Magazine.*

Engineer Added to Home Office Staff

E. C. Korten, formerly office engineer in the New York department, has succeeded to the position of engineer of the boiler division, Home Office engineering department. He was born in Brooklyn N. Y., October 18, 1896. After completing the engineering courses at Stevens Institute of Technology where he received a degree in Mechanical Engineering, he was from 1922 to 1928 associated with Thomas E. Murray, consulting engineer. In 1928 he went to the New York Edison Company and was assistant to the chief mechanical engineer until 1930. Mr. Korten joined the New York department as inspector in March, 1931, and became office engineer in 1935. In his new position he is successor to the late George H. Stickney.

Mr. Korten's experience in the design, operation, maintenance and inspection of boilers and pressure vessels fits him well for the new duties he has assumed.

Paragraphs of Progress

WASTE HEAT BOILER

With improvement in gas engines has come the development of a satisfactory waste heat boiler for use with them. The Bethlehem Steel Company has used such boilers for some time, and T. A. Lewis, combustion engineer for that company, has outlined in *Power* results which show reduced operating costs from generating steam in this way in an amount to justify eight such units. The boiler contains horizontal water tubes in five banks, one for an economizer, three for the boiler proper and one for a superheater, the exhaust from the engines entering at approximately 1200°F. and leaving at 350°F. Further utilization of the gases for water heating is possible, but local conditions determine the justification of this further refinement. While waste heat boilers have long been used, particularly with marine Diesel installations, their development in connection with various types of internal combustion engines ashore has been somewhat slow.

HEAT AT LOW PRESSURE

The process industries, particularly those engaged in the refinement of organic oils, have occasion to use temperatures of 400°F. to 800°F. in unfired vessels. Because the use of steam at high temperatures involves also high pressures, and because such pressures are not ordinarily available in industrial plants, various other substances are being used for heat transfer purposes. Among these are several mixtures of diphenyl and diphenyl-oxide, depending on the heat desired. For instance, one of the mixtures has a melting point of 56°F., a boiling point of 495°F. and a temperature of about 650°F. at 50 lb per sq in. pressure. The vapor, produced in conventional type boilers usually of welded construction or in newly developed electrical equipment, is used in closed heaters to bring the oil to be processed to the desired temperature, and also to superheat available steam to temperatures for mixing with the hot oil to carry away objectionable odors. Other processes circulate hot oil as a liquid at temperatures up to 600°F. and seldom exceeding 10 lb pressure, the heat transfer to the product being made in suitable heaters. The use of high temperatures results in several advantages, the most important of which are increased production and a better product.

ONCE-THROUGH BOILERS

The Russian 1937 industrial program provided for the building of 26 once-through boiler units, generating in all 1,300,000 kw. Nineteen of these units will generate 1,000,000 kw, and will operate at 2,000 lb pressure. From the standpoint of the Russian boiler industry the cardinal advantage of the once-through design lies in the absence of heavy drums.—*Mechanical Engineering* from the *Steam Engineer.*

UTILIZING SEWAGE GASES

Internal combustion engines utilizing gases given off at sewage-treatment plants have been installed in nearly 50 locations, it is pointed out by W. B. Walraven in *Mechanical Engineering.* He estimates that the daily sewage from 480 persons is sufficient to develop 1 boiler hp continuously.

AVAILABILITY

"Boiler availability has been greatly improved in recent years until it now equals turbine availability. It has, therefore, become possible to schedule boiler outages with the same regularity as turbine outages. In a boiler designed for such availability there appears to be little economic justification for the extra cost of a multiple boiler plant on an interconnected system where the necessary safeguards exist. Old time plants always had one or more spare boilers because it was a commonly accepted fact that boilers could not operate more than a month or two continuously, whereas now plants are being installed and operated successfully with a single boiler per turbine. At Lakeside (Milwaukee) boiler availability is 94.7 per cent for 1934, 98.1 per cent for 1933 and 97.1 per cent for 1932 as reported. Based on the experience of the American Gas and Electric Company, better than 90 per cent availability can be obtained regularly on 1400 lb boilers." —E. H. Krieg, before the eleventh general meeting of the National Board of Boiler and Pressure Vessel Inspectors in New York City, as summarized by *Combustion.*

DIESEL HAMMER

A Diesel pile-driving hammer of unusual simplicity is described by *Engineering* (London). A hollow tup acts as a cylinder which moves up and down on two guides. The piston is fixed and forms part of the anvil. For the lower part of its travel, the hollow tup covers the piston and compression is obtained as the space between the end faces of the piston and bore diminishes as the tup continues to fall. At the proper moment fuel is injected into the "cylinder" through the piston, explodes and raises the tup for the next stroke. No special scavenging or cooling arrangements are necessary. The hammer is started by merely hauling the tup to the top position.

SENTENCES OF PROGRESS

The conventional black for the casings and frames of rotating electrical machines is giving way more and more to colors of light hue.

Live cork sheets, mechanical dampening devices of the spring type, and cork blocks are being used to lessen trouble from vibration of Diesel engines.

A new chemical process obtains practically pure CO_2 from flue gas, thus permitting local manufacture of dry ice (solid CO_2).

A young man, his face flushed with anger, burst into the office of the electrical company.

"Didn't I ask you yesterday morning to send a man to mend our doorbell?" he demanded. "And didn't you promise to send some one around immediately?"

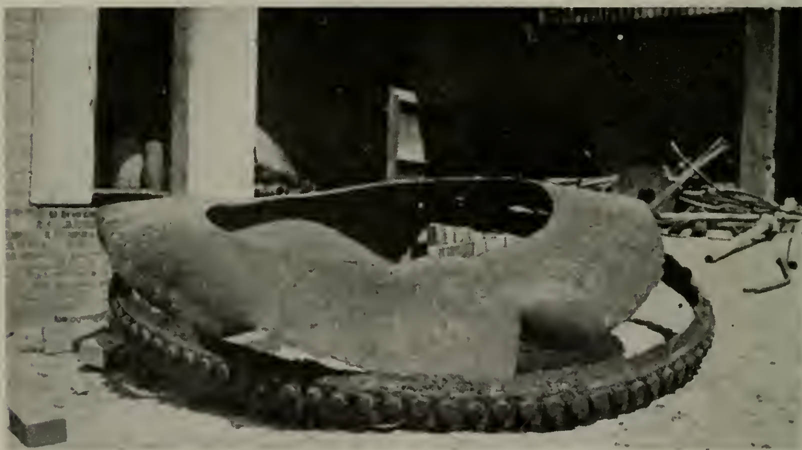
"But we did send some one," replied the manager. "I'm certain of it. Hey, Yeagley," he called to a workman, "didn't you go around to Park Lodge yesterday to attend to that job?"

"Yes, sir," answered Yeagley. "I went around all right and I rang the bell for about ten minutes, but I couldn't get no answer."—*Whatyoumay.*

Rendering Tank Failure

RENDERING tanks are subject to unusual corrosive influences because of their contents. They also deteriorate because of corrosion on the external surfaces due to moisture. The latter hazard was demonstrated effectively in an accident at a Western packing plant where a large tank, 17′2″ in height and 6′ in diameter, was used in the rendering of hoofs and hair.

The top head of this tank had become so thinned that it ruptured at an operating pressure of about 72 lbs. The initial tear spread around

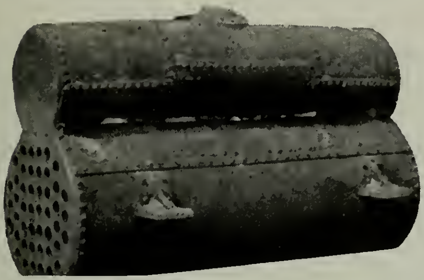


Head and seam of rendering tank which exploded after serious thinning because of external corrosion

the head at the knuckle just above the seam, and both head and tank crashed into 6″ steel I-beams supporting the floor above. One of the beams was bent and two others dislodged from the brickwork. Wiring, piping and windows were also damaged.

While the head plate was somewhat corroded on its internal surface, the greater part of the thinning, from a normal thickness of ⅜″ to an average of ⅛″, was on the outside. As the head of the tank was only 9″ below the charging floor, it had been frequently subjected to moisture when the floor was washed. The photograph shows the defective part of the head, and the seam, which was cut away from the shell following the accident. The tear started at a point just to the left of the lap seam. The rip at the right occurred when the head hit a steel beam.

Boiler Retired after 60 Years of Service



The boiler illustrated on this page was recently retired from service at a Maine laundry after about 60 years of operation. It was built in 1876, and is of interest chiefly with respect to its now obsolete construction details, and long life. The lower drum is 34″ in diameter and is crowded with fire tubes. The upper drum is 20″ in diameter with a 12″ manhole in the head away from the reader. It is interesting that the lower drum, which is 7′ 6″ long, is of one course with a double-riveted lap seam, while the steam drum is in three courses of single-riveted lap construction. Heads are flat. The boiler was operated at 60 lb pressure. Dimensions secured included the following: Shell plate thickness ¼″, diameter of rivet holes 11/16″, pitch in the upper drum 2″, in lower drum 3″, head thickness ⅜″.

Test for Oil in Condensate

A practical test for the presence of oil in condensate is suggested by C. O. Dibble in *Power*. He advises that satisfactory results may be obtained by making a ¼″ valved tap-off from the feedwater intake line, placing white cotton cloth over the tap and discharging feedwater through the cloth for several minutes. Any trace of oil or other foreign matter will show on the cloth.

THE COVER

An inspector examining the exciter end of a large turbine generator. Inspections of such machines often lead to the avoidance of expensive shutdowns and lessen the likelihood of accidents.

Throwing Stones Produces the Desired Effect

A boiler inspector and the engineer of a North Louisiana sawmill were engaged in conversation near the boiler shed when a negro fireman suddenly bolted out of the building yelling that the pump which supplied the boiler from a nearby pond had lost its suction.

The engineer excused himself for a moment, called the darky over and said: "Now you listen here, Joe. I want you to get five stones, throw one into the pond on each side and one into the middle. Then you open that suction valve again and see if you don't get water."

The darky followed directions and, sure enough, the remedy had worked. When asked for an explanation by the mystified inspector, the engineer solemnly replied that so many turtles were out of the water sunning themselves on land that they had caused the water to drop below the intake, and that he had thrown the rocks to frighten the turtles back into the pond. Anyway, opening the valve brought the supply of water that the fireman desired.

Oil Well Drilling Boilers Explode

In any comprehensive group of power boiler explosions there are apt to be failures of oil-well drilling boilers.* Six such recent accidents caused 8 fatalities. Because the boilers involved are usually in the open or at best under open shelters, the chief damage to property is to the boilers themselves. As they are of the same general type as the railroad locomotive boilers, their failure is apt to be caused by the dropping of the crown sheet because of low water and consequent overheating.

One of the accidents, which occurred in an Oklahoma field, killed two workmen and injured three others, two of whom later died. The exploding boiler was reported to have been hurled a quarter of a mile. Two other boilers were blown over and one leg of the drilling rig was severed. The five other explosions occurred in Texas oil fields with results similar to those in the case described above.

*The characteristics of oil field boiler operation and the reasons for the large number of accidents to them are discussed in THE LOCOMOTIVE, July, 1936, Page 87.

"In the management of affairs, people constantly break down just when they are nearing a successful issue. If they took as much care at the end as at the beginning, they would not fail in their enterprises."

Taps From the Old Chief's Hammer

TOM PREBLE, assistant to the Old Chief, sat at his desk smoking his pipe and reading the evening newspaper. The office had closed for the day, but Tom was still on hand in case his chief wanted any additional facts about a big new application he was reviewing.

"Sure enough," thought Preble as he heard the Chief call, "Tom," and then did a mental flipflop when his superior added, "I thought you were going to bowl duck pins Friday nights."

"Oh, I gave that up," answered the younger man. "I went up to the alleys to watch; they left me behind years ago. I think I am doing well if I bowl 90. *They* complain at 125, and they get spares nearly every box."

"That's too bad," commented the chief, "but I hope you don't give up bowling."

"Oh, I won't do that," answered Tom. "I like the game well enough, but I'm not in the professional class by a long, long way."

The Chief sat down on one of the desks and filled his pipe.

"Tom," he said, "Your bowling experience reminds me of Mike Pickening and the mountaineer."

"Who?" replied Preble, sensing a story was on the way.

"Pickening—one of our inspectors in Pennsylvania. He had gone to a little village in the Southern part of the state to examine two saw mill boilers of the horizontal tubular type for which there recently had been applications for insurance. At the first location he started work as usual, getting into his overalls . . . . Tom, I'll try to tell it to you as he told it; Mike loves to tell this story.

" 'Chief,' he said, 'I started in on the boiler, just as I always do by examining it internally first. As I climbed up to the manhole, I noticed a native lolling against a post.

" ' "Crawlin' in?" he drawled.

" 'Sure.'

" ' "Kin I look?"

" 'If you like.'

"Mike said the fellow watched him carefully throughout the entire inspection.

" 'Chief,' he told me, 'I gave him the whole show . . . checked the shell plates, heads, rivets, and tubes for corrosion, pitting or grooving . . . . examined all the seams for broken rivet heads, cracks and signs of leakage . . . checked the flanges of the head and manhole for grooving . . . made sure the braces were sound and in proper tension . . . checked up on the internal feed pipe to see that it was in place and properly supported to prevent its resting on the tubes and made sure it wasn't choked with scale or sediment. I checked the openings to the water column connection, the dry pipe, opening to the safety valve, and the blow-off opening.

" 'I would look up now and then and as far as I could see, the mountaineer never missed a tap of my hammer. He even stuck his head into the manhole when my light got out of his line of vision.

" 'Then I climbed out and went to work on the external. The native didn't say anything, so neither did I. When I climbed into the furnace he leaned into the fire door and watched me as thoroughly as before. He seemed interested in every detail.

" 'When I had finished, he said, "You don't miss a thing, do you?"

" 'I try not to.'

" ' "Are you goin' to see another boiler in this neighborhood?" he asked.

" 'Yes.'

" ' "Will you go over it like you did here?"

" 'Certainly.'

" ' "Oh."

" 'Why, stranger?"

" 'Nothin'. Is the boiler at the Valley Mill?"

" 'I believe it is, why?'

" ' "Nothin' . . . . Say Mister, if you don't mind, Valley Mill's mine, and you won't have to go there—yet."

" 'What's wrong?'

" ' "Nothin' much . . . . Guess I better get me that new boiler I been thinkin' about first, that's all. Then you can inspect *it*. Thanks." And the native turned and sauntered down a path nearby.'

"Mike accepted this information as a cancelation of the order and the local agent agreed. I believe we eventually insured the boiler at Valley Mill, and that the native watched Mike all over again there—probably to see whether the job was done right."

Preble laughed.

"Chief," he said, "would you call that a 'too good' inspection?"

"Not by a lot," answered the older man. "Mike's thoroughness probably prevented one of those gruesome mill boiler explosions that the papers tell about every so often. I wish every backwoods boiler operator could watch Mike, or for that matter any of the boys do their stuff."

"Fine, Chief," enthused Tom. "Why not have the men invite such boiler operators to visit when an inspection is being made?"

"Good idea, Tom," but most of them wouldn't come. I've had boiler owners say to me, 'I've got a good boiler. Never gave me a bit of trouble,' but they ought to have added . . . . 'Yet.' "

He Slept . . . at All Costs!

A horizontal tubular boiler, used for heating purposes, over-heated on several occasions because of low water so that the tubes leaked and had to be re-rolled. The boiler maker, on being asked what could be done to prevent this condition, suggested a high and low water alarm and feed water regulator. A very good regulator with a warning bell was installed. Shortly after its installation, the boiler maker was again called in to roll leaky tubes. He asked if the regulator was working and the reply was, "Oh, yes; but the bell rang so much it kept me awake, so I stuffed a rag in the contacts."—*California Safety News.*

A young man we have heard about recently landed a job with a firm that makes and installs oil burners. He was given a desk, a telephone, some memorandum cards, and a pencil, and was told to listen to all complaints that might be phoned in, summarize them, and turn the cards over to his superior. Coming in for work the morning of his second day, he was approached by one of the higher-ups, who seemed to be in a temper. "What's the idea of this?" the official asked, waving a card. Our young man looked at the card, which was one he had filled in the day before; it was just a summary of a customer's complaint that his burner had exploded. "What's wrong?" he asked. "Young man," said his superior, breathing fire, "you won't get very far in this business until you learn that we do *not* have explosions. We have puff-backs."—*The New Yorker.*

An enterprising pastor, called to a parish in a small Scotch mining town, worked faithfully, added many new members, and finally built a new church. A steam heating plant was put in, and the little meeting house seemed to be complete in every way, except it had no bell. Members had given so liberally that the pastor decided to raise enough funds from outsiders to buy a bell.

"Ye say ye've a noo choorch?" one hard-handed Scotch miner replied to the pastor's appeal.

"Yes," said the pastor.

"An' noo ye want a bell for it?"

"Yes."

"An' ye say the choorch is 'eated by steam?"

"Yes."

"Mon," said the miner, "wy dunt ye put a whistle on ut?"—*Kreolite News.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

December 31, 1936 *Capital Stock, $3,000,000.00*

ASSETS

Cash on hand and in banks		$904,668.68
Premiums in course of collection (since October 1, 1936)		1,000,760.69
Interest accrued on mortgage loans		4,169.65
Interest accrued on bonds		88,854.77
Loaned on mortgages		290,275.00
Home Office real estate and Philadelphia branch office		642,331.05
Other real estate		332,274.83
Bonds on an amortized basis	$8,970,348.42	
Stocks at market value	7,154,705.00	
		16,125,053.42
Other admitted assets		6,903.34
Total		$19,395,291.43

LIABILITIES

Premium reserve		$6,765,042.57
Losses in process of adjustment		463,395.19
Commissions and brokerage		200,152.14
Difference between market and book values of stock		507,096.59
Other liabilities (taxes incurred, etc.)		504,352.01
Liabilities other than capital and surplus		$8,440,038.50
Capital stock	$3,000,000.00	
Surplus over all liabilities	7,955,252.93	
Surplus to Policyholders		**10,955,252.93**
Total		$19,395,291.43

WILLIAM R. C. CORSON, President and Treasurer

Incorporated 1866 *Charter Perpetual*

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ATLANTA, Ga., . . . Citizens & So. Nat. Bk. Bldg.	W. M. Francis, Manager. C. R. Summers, Chief Inspector.
BALTIMORE, Md., . . . 704-9 Garrett Building . .	D. W. Little, Manager. R. P. Guy, Chief Inspector.
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TORONTO, Ont., Canada, . Federal Building . . .	H. N. Roberts, President The Boiler Inspection and Insurance Company of Canada.

An inspector inside the combustion chamber of a 2000 hp Water Tube Boiler

POWER'S LOOKOUT GOES ALOFT . . . . Intent on probing into every nook and cranny, this typical Hartford "lookout" swings aloft in a bosun's chair. He is living up to Hartford Steam Boiler tradition . . . . . . scorning discomfort in order that no flaw may go undetected. Hartford Steam Boiler inspectors bring to your power problems the assets of unflagging vigilance, instant resourcefulness, and a skill fostered by 71 years of Company experience.

Vol. 42 No. 2 April, 1938

The Locomotive

Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Turbine Rotor Straightening by the Heat Method

By T. B. Richardson, *Chief Engineer, Turbine and Engine Division*

One way to avoid accidents is to learn through the experience of others. Such opportunity for gaining valuable knowledge, not only for the avoidance of trouble but also for the making of a difficult repair, is illustrated in a recent case involving a 750 kw reaction turbine, the spindle of which had become distorted or sprung, probably through an improper method of starting the unit. The starting procedure, its results and the method employed to straighten the spindle are described herein and should be of general interest.

The turbine was a standby unit and had not been in regular use for several years. When operating conditions indicated that the unit would be required to carry the load, the throttle valve was opened slightly and steam, for warming up, was passed through the unit for an extended period without turning the rotor. This steam went to the top of the casing and passed to the exhaust, thereby heating the top of the spindle to a higher temperature than the bottom. The steam that was in the casing remained at the top so that the spindle continued with the temporary bow and, therefore, ran eccentrically when sufficient steam was admitted to revolve the rotor. This condition caused ends of the stationary blades to rub against the high side of the spindle and the frictional heat thereby generated increased the amount of eccentricity, so that the rubbing became worse and caused the spindle to bow still more. By the time the unit had reached half-speed, the vibration became so severe that the turbine had to be shut down.

Some of the blading was found to be stripped as a result of the heavy rubbing, and one side of the spindle (the bottom as shown in Figure 1) was deeply grooved, and blue in color, an indication of excessive heat. The ends of the stationary blading had been rubbed around the entire circumference, and the ends of the revolving blading had rubbed heavily on one side of the spindle only, in line with the grooves. After the spindle cooled it took a permanent set and was bowed 15½ mils (corresponding to a reading of 31 mils on the truth gage) at the 14th row of revolving blades, where the deepest groves were cut. The high side of this permanent bow was located on the side opposite the grooves.

After the damaged blading had been removed, the spindle was replaced in its bearings and the point of maximum deflection was determined by slowly revolving the spindle and applying a dial truth-indicator.

The top and bottom halves of the Nos. 1 and 2 bearings were bolted together and the spindle, with the two bearings, was raised from the casing. Short lengths of I-beams were placed on the bearing pedestals and the spindle bearings rested on these beams, thus supporting the spindle in an elevated position above the casing where it was accessible and could be readily revolved.

The high side of the spindle was turned to the top. A dial indicator was fastened to the turbine casing for registering readings at the low side or bottom of the spindle and the indicator was set at zero. Heat

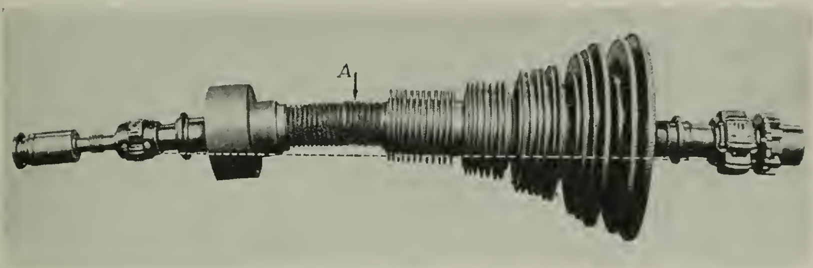

Figure 1—The photograph was purposely distorted to make clear how the shaft was bent and just where heat was applied. The distortion of the shaft is, of course, absurdly exaggerated.

was then applied at "A" (Figure 1) on the top of the spindle (the high side) by means of two oxy-acetylene torches. An asbestos ring was placed around the point that was to be heated, so that a quick heat could be obtained at that location. As soon as the heat was applied at the top, that side of the spindle began to expand and to rise, so that the bow in the spindle was even greater than before the heat was applied. This was seen on the dial indicator, which immediately began to show a plus reading. For the various heats, the torches were applied for periods ranging from 20 to 90 seconds which caused the indicator to show a maximum plus reading of 70 mils for the longest heat, but the best results were obtained by using a heat that raised the spindle only about 30 mils at each heating. As soon as the torches were removed and the top of the spindle began to contract, the drop of the spindle was rapid at first and then more gradual until the indicator again read zero within ten minutes' time. With further cooling of the spindle, the indicator began to show a minus reading until from minus 4 to minus 12 mils for each application was secured after 30 minutes of cooling. This meant a reduction in the spring of the spindle of from 2 to 6 mils for each heat.

After each heat the spindle was lowered into the bearing pedestal supports and then turned in its bearings for the purpose of taking readings with the dial indicator along the entire length of the rotor. Although a total of 16 heats was required to straighten the spindle, the final 8 heats were for short periods. After heat No. 12 the permanent set was reduced to a total reading of 3½ mils or within 1¾ mils of being straight. On heat No. 13 the spindle became bowed with the high-point on the opposite side. It was then necessary to apply the heat on that side, 180 degrees from the other points of heat application. After the final heat had been applied, the maximum eccentricity was ¾ mil and all points along the spindle were true within less than ½ mil.

When the new blading had been installed, the unit was reassembled and placed in successful operation. Since then, no further vibration has occurred.

As has been pointed out, oxy-acetylene torches were used in the above case. In other instances where a shaft or rotor has been straightened by the heat method, large kerosene torches have been employed to secure quick heating.

When a turbine is to be started, the rotor should be revolved when steam is first admitted. The valve opening may then be reduced, so that the rotor will continue to revolve slowly while all parts are warmed up, after which the unit can be brought to full speed. Furthermore, consideration must be given to the possibility of a rotor becoming temporarily bowed after it is shut down. The heat inside the casing will rise to the top and if the admission valves leak slightly, the condition is made worse, so that any attempt to start the turbine within a few hours will result in rubbing. Turning gears are commonly used on the larger units to keep the rotor revolving at about 2 or 3 rpm for several hours to prevent this temporary bowing while the unit is cooling. Such a unit can be started again at any time without danger of rubbing. The present universal trends to higher steam temperatures and pressures make the above considerations all the more important.

Vanes in Water Turbine Runner Break

The runner of a 580 hp vertical water turbine had to be replaced at a New England factory following the breaking of all the vanes and the dropping of the balancing ring into the draft tube. The accident was attributed to a lateral vibration in the vanes which produced a condition of fatigue at a point near the balancing ring. The turbine was used to drive shafting through a bevel gear.

Over-heating Because of Oil, Scale and Mud

When oil, scale or mud or possibly all three have caused over-heating, bulging, rupturing or cracking of boiler plate or tube metal, the owner of the boiler will, if he is prudent, definitely determine the source of the deposits and will take steps to forestall repetition of the trouble.

This is particularly true in a plant where there are several boilers, and where over-heating in one of them has become evident. Of course, adequate feedwater treatment and testing, by preventing deposits in the boiler, will safeguard against over-heating, but, unfortunately, there are still too many careless operators, or operators who have not been informed or who have not informed themselves of the correct way to operate the particular equipment in their charge. In addition, if it is known that scale-producing substances and sediment are present in the feedwater, adequate treatment and cleaning routine are essential if trouble is to be avoided, as will be discussed later in this article.

Of all the enemies of satisfactory boiler operation probably the most subtle is oil. Any steam-operated machinery, in which the steam comes in contact with oiled parts such as the cylinder of an engine, is a possible source of oil. If condensate is to be returned to the boilers the oil so picked up will—if not removed—combine with certain solids in the average boiler water to form an insoluble sludge which is an extremely poor conductor of heat.

Such a condition in a large all-welded fire tube boiler caused a bulge that measured 7½ feet each way and 9″ deep. The metal cracked in several places along the welded seam and was generally so weakened by the bulging that an entire new front course would have been necessary to restore the boiler to a serviceable condition. Just what sequence of events caused the accumulation of the black, gummy deposit that brought about the over-heating was not satisfactorily explained, but all of the plant equipment connected with the operation of the boiler was carefully studied after the occurrence to avoid a repetition of over-heating from this cause.

The instance brought up also the subject of repair following the bulging of an all-welded boiler. Manufacturing and insurance company engineers were agreed that there was no reason why such bulges in welded boilers could not be driven back into proper curvature and patched in the conventional way, if the extent of the bulge was not too great.

Sometimes an accumulation of soft scale and sediment can be definitely anticipated because of the characteristics of the feedwater.

If such deposits, which are relatively harmless, if they are removed as they accumulate, are allowed to settle too thickly on the boiler shell, the result will be of the sort pictured in Figure 1. In this case a rupture 22″ long was caused when deposits of soft scale and sediment built up 10″ thick within the boiler. The fact that the boiler was operating at only 10 lb pressure when it failed probably prevented an explosion of the first magnitude. As it was, the boiler was so damaged that it was decided to remove it from service.

Another similar case of over-heating, at a plant on the shores of Lake Michigan, resulted in a less serious rupture which was repaired satisfactorily. (For detailed instructions with respect to such repairs, see THE LOCOMOTIVE for July, 1937, Page 194.) An accumulation of scale and sediment caused a bulge about 20 inches back from the front head of a horizontal tubular boiler. The boiler split open and the discharge of steam put out the fire, but there was no other damage, except that the plant, a pulp mill, was shut down by the failure. Steam for 50 per cent operation was obtained in about 9 hours by running 600 ft of pipe to a dredge in the harbor nearby. By means of day and night work the bulged metal was driven back and a crescent-shaped patch was riveted on, caulked and the setting repaired in 3½ days.

Although over-heating of parts other than tubes because of heavy accumulations of mud and scale is most frequent in boilers of the fire tube type, it sometimes occurs in water tube boilers.* Such a case is illustrated by the bulging and cracking of front steel headers on a cross-drum water tube boiler. In this case about 3 inches of scale accumulated at the bottom of the front headers and this, coupled with a lack of adequate protection by the refractories, caused the over-heating of 13 headers.

Because nearly a fifth of all power boiler accidents are the result of internal accumulations of mud, oil or scale, the importance of the problem cannot be stressed too heavily. Sometimes unusual feedwater conditions or accidents beyond the control of operators will permit over-heating, but most such accidents are preventable with careful maintenance and the prompt following of recommendations for adequate examination of feedwater, proper feedwater treatment and proper cleaning routine. Over-heating of a boiler practically always calls for repairs to the boiler itself and it is easily understood how over-heating

* This article confines itself to the results of heavy deposits which have not been removed from boiler drums or headers. The frequent difficulties because of scale in tubes of water tube boilers are not treated here because they involve problems of boiler design, circulation and blow-down, in addition to feedwater treatment and cleaning routine.

Figure 1. A serious rupture caused by over-heating.

and rupture can be sufficiently serious to result in an explosion which not only would destroy the boiler, but also much property in the vicinity of it.

An owl which perched on a switch at Oswestry, England, was electrocuted, the short circuit which it caused fusing wires adjacent to the switch and putting four villages into darkness.

Peep-Holes in Settings

Because a common source of trouble and expensive repair in horizontal return tubular boilers is bulging of the shell plate over the fire, some owners have found it advantageous to install peepholes in the settings of boilers of the fire tube type which have shells exposed to direct furnace heat.

The Company favors the practice because many boilers are set so high above the firing doors, and because of other obstructions, that the external surfaces of the shell cannot be seen except by entering the firebox. Furthermore stokers, small fire doors and brick-lined openings prevent proper visibility. Since the shell plates of some boilers are never seen between idle periods, bulges can occur and not be found or looked for until the boiler is shut down for cleaning or other reasons.

The shell plates should be observed with the same frequency that the blow-off valve or the water column is operated, as by frequent observation of the shell through the peep-hole, the progress and possible rupture of bulges may be prevented, if the start of a bulge is noted in time.

Sometimes a cone-shaped opening is constructed in the wall, about 12″ below the shell, and at other times a pyramidal hole, a design more easily built, is formed in the furnace wall. A peep-hole should be so located and shaped that the observer can look down the length of the shell, preferably at a half-quarter view. As an alternative several small peep-holes can be made in the longitudinal wall.

The visibility afforded by the holes of either plan should include the entire length of the shell exposed to direct heat.

Explosion on River Steamer

As a river steamer was towing seven loaded barges up the Mississippi river between Cairo and St. Louis, one of the four horizontal flue type boilers exploded, the blast killing two firemen and injuring four other persons, including the captain. The boat was towed to shore, and when an inventory of the damages was made, repairs were found to necessitate an expenditure of approximately $70,000.

The cause of this accident was not immediately determinable because part of the boiler was blown into the river. Later the failing part of the shell was found. It revealed the probable cause of the accident to be over-heating and bulging of the second course of the boiler because of an accumulation of mud and scale.

As the section of plate which failed went overboard, it took with it the two firemen, who were on the deck. The rest of the boiler moved aft about 23 feet so that the rear head struck a condenser and an evaporator, damaging both. The smokestack and breeching which served the exploded boiler and another mounted with it were damaged, and the other boiler was badly dented. Living quarters of the crew and

Figure 1—Results of an explosion because of over-heating.

captain above the boiler room were wrecked, as is shown in the photograph, and there was other damage to the pilot house, coal bunkers, pipes and machinery.

Witnesses on the shore reported that a barrel of flaming oil was thrown 300 feet to the shore where it set brush afire. An unsuccessful search for the two firemen was made. One of the bodies was later discovered by a fisherman 30 miles down-stream opposite the home of the man's parents.

Discussing the merits and demerits of lengthy sermons, a writer in the *Cincinnati Enquirer* tells of an Ohio minister who declares he doesn't mind members of the congregation pulling out their watches on him, but it gets his goat to have them put the darn thing up to their ears to see if they are going.—*Think.*

A boy in the natural history class was asked to describe a skunk.

"A skunk," he wrote, "is a small animal with a bushy tail and a white stripe down its back. It looks like a cat and is quite beautiful. It eats asparagus.—*Kreolite News.*

"Don't you know, Rastus, that you can't sell life insurance without a state license?"

"Yes, Boss, I knowed I couldn't sell it, but I didn't know the reason."—*What You May.*

Hot Water Tank and Heater Explosions

BOILERS and tanks used in hot water supply service are exposed not only to many of the hazards to which steam boilers are subject, but also to another which arises from the following: The equipment and the connected system are completely filled with water, which, when heat is applied, must expand. As the capacity of the vessels and the system does not change, this expansion of the water will cause it to exert pressure on its containers and thus set up stresses in them, unless there is some way in which water is automatically released from the system as the expansion takes place.

Because of the various hazards to which hot water supply equipment is subject, precautions against the sort of accidents pictured on the opposite page are several, and all are important. The first is to select a tank so designed and constructed that it will be capable of withstanding the normal pressures to which the vessel is put. The second precaution is to have installed adequate and reliable relief devices. The third is to see that the installation is inspected periodically in order to make certain that relief devices will function and that destructive factors, such as corrosion, have not rendered the tank unsafe.

Vessels used for hot water service are apt to be subject to corrosive influences, both internally and externally. The longer corrosion eats into a vessel the weaker the vessel becomes. If it is weakened until it cannot withstand the normal working pressure, the chances are it will burst without violence and the water contained in it will run out on the floor. But if it should burst at a time when the temperature of the water is higher than the boiling point at atmospheric pressure, an explosion will occur.

The reason for this is, of course, that the water has stored in it a quantity of heat sufficient to turn part of it into steam at atmospheric pressure. When a rupture of the shell of the vessel suddenly releases the pressure, part of the water flashes into steam. This change of state takes place in a fraction of a second and the degree of violence attending it depends on both the quantity and temperature of the water in the

Figure 1—Top—Exterior of a factory building following a hot water tank explosion. Bottom Left—Part of the damage at a garage when a steel hot water heater failed. Bottom Center—Two views of serious damage following a hot water tank accident at an apartment. Bottom Right—The bathroom of a residence that was rendered uninhabitable when a small hot water tank exploded.

bursting container, for these factors determine the amount of energy to be freed.

True, this happens only in "closed" systems, but all systems may become closed and make the conditions favorable to such an explosion. In many cities check valves in the cold water inlet pipe are mandatory; sometimes a one-way pressure reducing valve prevents "backing up" of hot water; sometimes the wrong valves are closed, and even in so called open systems inlet pipes may freeze or become clogged with rust or scale. In these ways conditions are favorable for an accident through the application of too much heat and hence too much pressure to a system without relief devices or with such devices so neglected that their functioning is prevented. Pressure relieving devices are designed and set to open at a few pounds above the maximum city water pressure, which, of course, varies from city to city. Temperature relief devices are designed and regulated to shut off the heat supply before the water in the tank reaches 212° (usually between 120° and 140°).

The accidents described below all happened in recent months and are typical of hot water explosions in industrial, business and domestic installations.

At a large industrial plant in the Middle West, hot water for shower baths was stored in a vertical tank 5′ in diameter by 6′ in height with the top head concave to pressure and the bottom head convex to pressure. Two men were killed and 10 injured in an explosion that followed the reversal of the bottom head of the tank and the failure of the shell. Completely shearing off about 1″ above the bottom head seam, which was welded, the shell and top head passed through a concrete and steel reinforced roof and continued for several hundred feet. The building was wrecked as shown in the photograph at the top of Page 43. The tank received hot water from a coal-fired heater and also from a coil in a cast iron steam heating boiler. Just what the sequence of events was is obscure, but it is certain that hot water seeking to expand caused the failure of the bottom head, the construction of which was inherently weak, so that a continued rise in pressure would logically have brought about failure at that point, even in a tank which was practically new as this one was. A pressure relief valve was said to have been installed in the hot water discharge line. There was also in the debris a temperature relief valve set 140° to 180°F. However, little evidence remained after the explosion to explain exactly what happened, except that it is known that too much heat was applied, since shower bath water is not needed at a temperature anywhere near 212°F.

Events are more clear with respect to an explosion at an Iowa garage. In this case a plumber was renewing some of the hot water lines and in order to make a connection it was necessary to shut off the city water supply as well as the hot water outlet pipe from the tank. The automatic gas-fired hot water heater of the garbage burner type, however, was not turned off and continued in operation. This time the failure occurred in the heater, which was reported by an inspector to be the weaker of the two objects. The plumber sustained a skull fracture, and damage to the building and equipment was estimated at about

Figure 2—Basement of an automobile showroom after the explosion of hot water equipment. Three automobiles fell through into the basement when the floor was destroyed by the blast.

$3,000. The condition of the garage wall following the accident is shown in the picture on Page 43, at the lower left.

An explosion involving a hot water heater and tank in an auto dealer's showroom in the Chicago area demolished the basement, ripped up the floor and lifted three automobiles up against the ceiling. They fell back into the basement. Inasmuch as the system was of the closed type and the accident occurred in the evening when no water was being used, it was concluded that over-pressure was the cause. The storage water heater was completely demolished and the bottom head of the tank, which was welded to the shell, blew out. A view of the basement after the automobiles and part of the debris had been removed is shown in Figure 2.

In a New England apartment a forgotten gas burner led to a tank explosion which caused extensive property damage, as is shown in the picture on Page 43 at the bottom center. Two persons asleep in a bedroom miraculously escaped with minor injuries. The tank itself passed through the roof and came to rest on the roof of another apartment.

A similar accident in a New England residence so damaged the dwelling that a building inspector pronounced it unsafe for occupancy. The picture at the lower right on Page 43 shows where the tank went through the bathroom floor. According to newspaper accounts, every floor in the house was lifted out of position, walls buckled, and all window glass was smashed. The owner and his wife were sleeping when the blast occurred, and although both suffered from shock, they were able to make their way out of the house safely. Damage was estimated at between $6,000 and $7,000. The tank was equipped with a spring-loaded relief valve, but the device obviously failed to function. Windows in an adjacent house were blown in by the force of the explosion. The tank in this case was copper, the pressure having caused the failure at a brazed head seam.

A tank explosion in a three-story duplex apartment house in Boston buried a tenant beneath a pile of debris, tossed six other persons from their beds and caused damage estimated at $1,500. The tenant, sleeping directly over the furnace room, received serious head injuries when the explosion tore a hole in the floor beneath his bed and threw him across the room.

At Albany a tank explosion, in wrecking a residence, hurled a dresser across the room and tipped it over on top of two persons as they slept. They were cut and bruised. The tank rocketed through the first floor, ceiling and roof, and soared over five other houses, coming to rest on a neighbor's lawn.

Similar accidents are reported periodically in all parts of the country, and demonstrate the need for inspections of hot water supply equipment. Such inspections include careful checking of the installation, the adequacy and condition of relief devices, and a search for the presence of corrosion or other weakness.

Liquid Ammonia Used as Substitute for Gasoline

In Italy interesting experiments are being made with liquid ammonia as a substitute for gasoline, both for automobiles and for motor trains. Satisfactory results are said to have been achieved, and it is proposed to try out motor trains operated by ammonia gas.—*Ice and Refrigeration.*

Diesel Wrecked by Over-Speeding

When fuel oil tanks overflowed and some of the oil found its way unnoticed into the air ducts beneath the floor, the resulting over-speed wrecked a modern 2-cycle crankcase-scavenging 600 hp Diesel engine at a Middle West municipal utility. Replacement cost of the machine was estimated at $35,000.

The over-speeding caused the operators to shut off the regular fuel supply, but a combustible mixture was entering the scavenging inlet

Figure 1—Above—This pile of metal contains parts of a 600 hp Diesel engine which was destroyed in a second or two when it over-speeded. Below—One side of the engine base after the broken engine parts passed through it.

ports, and the engine, out of control of the governor, continued to race, until it went to pieces. Parts pierced the sides of the crankcase and a piston crashed through its cylinder head.

A few minutes before the accident a tendency to gain speed was noticed, and the engine was shut down. Operators suspected trouble with the governor, but this was found to be in good operating condition. The engine was again started, and it ran normally for about 3 minutes, when it again began to gain speed. The fuel cut-off was immediately tripped and the hand wheel control was closed. However, the engine continued to accelerate, and the superintendent warned his men to run for safety. He started for the valve in the cooling water line in an attempt to shut off the water and thereby protect the generator from water damage when the Diesel went to pieces.

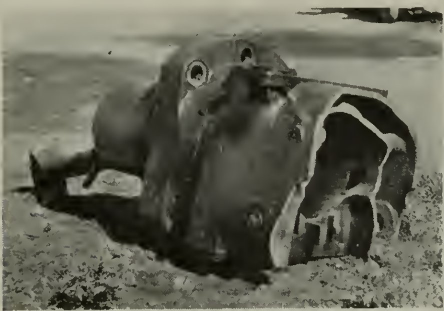

Figure 2—A cylinder from the wrecked engine.

The wreck occurred before he reached the valve. A heavy crankshaft counterweight came through one side of the crankcase and fragments rained into the part of the room from which the crew had just fled. A connecting rod and other parts came out of the other side of the crankcase.

Despite the damage, the engine continued to run and black smoke poured into the room. Meanwhile, the superintendent looked for a crowbar to force open an explosion plate, and another employe shut off the cooling water. Finally the engine stopped of its own accord.

As the city commissioners were in session near-by, they were called to the scene to see the engine they had spent $6,000 to overhaul a short time previously. They saw broken windows and doors showing the path of large fragments of metal. Some of the pieces are pictured in Figure 1. Holes were battered in the engine base. Oil and smudge covered the entire room.

It was estimated that the engine was running about 1000 revolutions per minute when the breakdown occurred, and although the centrifugal force caused the flywheel to crack, it did not explode and add to the havoc already wrought.

Except for irritation in his eyes caused by the smoke the superintendent sustained no injury and his men were unhurt.

This accident comes under the "unpreventable" classification. Of course, the overflow of the fuel tanks could have been checked, if it had been noticed, but usually such accidents reveal their causes only after they occur. In this case, so far as is known, no insurance was carried.

Diesel Lubricating Oil Treatment

A CHEMICAL method of treating Diesel lubricating oil with a 25 per cent solution of alkali soda ash is described by *Diesel Power* in a recent issue as a prominent factor in the exceptionally high output of 3,452 kw hours per gallon of lubricating oil obtained by a Southern municipality.

A 250 gallon tank with a water-heating coil in the bottom, a bottom drain valve, and a water-inlet pipe is used. A solution of 30 gallons of soda ash and water is mixed with 220 gallons of oil. Hot water from coils in the engines' exhaust mufflers is piped to the heat-treating coil to raise the temperature of the mixture to between 150 and 180°F. The hot water is kept circulated by a small motor-driven centrifugal pump. The soda solution is agitated and is brought to the top, and in percolating through the oil, it washes and collects from the latter the small particles of carbon usually found in the crankcase lubricating-oil system of trunk-piston engines. Washing the oil with the alkali solution removes the finer carbon. After a 36- to 48-hr treatment at this temperature, agitation is stopped until the temperature drops to 130°F, where it is held for another 24 to 30 hr. Upon cooling, the oil is found not only free from carbon, but from other foreign matter and acid content. The oil is then centrifuged and pumped to the engines' supply systems.

The chemical part of the system is shown in Fig. 1. The operation is as follows:

As waste oil is collected, it is poured into oil drums at floor level and when a sufficient amount has accumulated it is elevated by a small rotary pump to tank A, into which about a 12 in. depth of water has already been put from the city main or other supply by opening valve V-2. The commercial soda ash is added to it in tank A, valve V-3 is then closed and valve V-4 is opened, which enables the pump to circulate the mixture in A. By this means the contents of tank A are agitated and at the same time the temperature of the mixture is raised to about 185°F. Heating and agitation are kept up for 8 to 10 hours, after which both are stopped.

The mixture is then allowed to settle

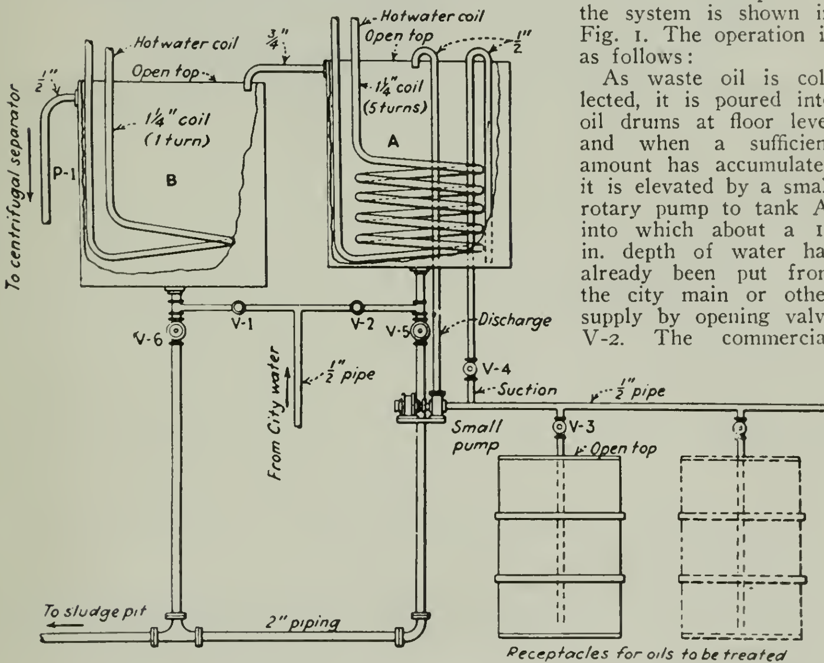

Figure 1—Diagram of chemical system for treating lubricating oil.

for about 24 hours, after which it is again heated to about 180°F, when city water is introduced into the bottom of the tank through valve V-2, which causes oil to overflow through the pipe at the top of the tank A into tank B. When the overflow begins to show "dirty" oil, valve V-2 is closed, and the sludge from tank A is drained through valve V-5 to the sump pit outside of the plant for future disposal. The Tank A is then washed and drained into the sump, so that the tank will be ready for another batch.

The treated oil in tank B is then displaced by water entering through valve V-1, and flows to the centrifugal separator through pipe P-1.

Breakage of Shafts on Rotating Electrical Apparatus

A Summary of Principal Causes

ACCIDENTS to shafts of electrical apparatus are quite common, and, while they occur under widely varying circumstances, a few basic factors contributing to such accidents may be summarized:

1. Misapplication. The application of the machine to the work to be done is of prime consideration if shaft breakage is to be avoided.

2. Over-hanging pulleys. There is a limit as to the size and weight of such pulleys for motor shafts of specific dimensions. The mere fact that a pulley may be fitted to the shaft is not sufficient to make it acceptable, because its weight may easily be enough to cause the eventual distortion and breakage of the shaft. Even if the shaft does not break, such an installation can lead to sufficient wear on the bearings to cause vibration and even elimination of the necessary air gap between rotor and stator.

3. Loose pulleys and gears. These may cause pounding which often starts fatigue cracks.

4. Belt tension. Belts that are too tight, either because of a poorly designed drive, or because some operator thinks a belt is slipping unless it is operating tight on both sides, frequently cause bearing and shaft failures.

5. Misalignment. Misalignment of the drive is a common cause of shaft difficulty. Such apparatus as magnetic and mechanical clutches should be checked at frequent intervals to prevent excessive stresses being produced in certain portions of the shaft. Mechanical clutches should also be adjusted so that "grabbing" does not occur.

6. Improper machining. Lack of or inadequate fillets have been responsible for many shaft breakages at the reduction of shaft diameters, or at the end of keyways or wherever else sharp corners require fillets. In some cases careless machining results in scoring and this may pro-

A shaft failure that occurred on a 300 hp wound rotor motor driving rubber rolls through a magnetic clutch and reduction gears. This failure occurred at the inboard end of the journal and at a location not ordinarily accessible for inspection. Vibration developed suddenly and the machine was taken out of service before breakage actually occurred. The shaft was broken in order to study the character of the crack, which was attributed to misalignment or improper adjustment of parts at some prior time.

vide the start for a progressive crack.

7. Improper repairs. Worn or scored journals are often built up by fusion welding, and if this is not properly done, cracks will result at or beneath the surface and, with the shaft in service, will gradually progress until actual failure occurs. Shafts are frequently lengthened by welding an extension to the original shaft. This is often followed by failure at or adjacent to the weld. Furthermore, shafting is sometimes built up by welding to improve the fit of ball bearing races, and this usually results in failure of the shaft.

A Business Man Is Puzzled

C. B. Axford, editor of the *American Banker,* intimates that he is slightly dazed by a sentence in a recent advertisement in *Business Week:* "No attempt will be made here to describe how this extraordinary pump works—except to say that a helical, eccentric rotor rolls with a hypocycloidal motion in a stator molded to form an internal double helix."

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

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The Locomotive *of* The Hartford Steam Boiler Inspection and Insurance Co.

Charles Ross Summers

Charles Ross Summers, chief inspector of the Atlanta Department of the Company, died on March 12th following an extended illness. He had directed the engineering and inspection activities of the Atlanta Department as chief inspector since 1920 and had been with Hartford Steam Boiler for 32 years.

Grounded in the practical side of power plant operation in several industries prior to his coming to the Company, he continued on a program of constant study and advancement. As a result, he was unusually well informed in power plant practice and safety, and was recognized as an authority in his field. Mr. Summers used his knowledge generously in the training of his associates. Besides, the warmth of his personality and his understanding of human nature made him a leader that men liked to follow.

Born at Stilesboro, Georgia, June 8, 1875, Mr. Summers' formal schooling was confined to a few months each year at public schools until he was 16. He then went to work, but proceeded diligently to broaden his viewpoint through correspondence courses with industrial power plants as his laboratory, first as a fireman and later as boiler room foreman.

He joined the Company as an inspector on February 1, 1906, in the St. Louis department, being located at Little Rock, Arkansas. From April 1, 1908, until August 1, 1909, he was an inspector out of Louisville, Kentucky. For the next five years until June 1, 1914, he was a shop inspector in two boiler shops in Chattanooga, Tennessee.

With the growth of the Atlanta department under Manager and Chief Inspector William M. Francis, it became expedient to increase the staff, and Mr. Summers was made assistant chief inspector on June 1, 1914. In January, 1920, he was promoted to the rank of chief inspector, which he held until his death.

Mr. Summers was well known throughout the large territory serviced by the Atlanta department. The high standards which he advocated in the furtherance of Company practices benefited policyholders in Georgia, Alabama, Florida, South Carolina, and parts of North Carolina and Tennessee.

Automatic Stokers for Heating Boilers

The practice of installing automatic stokers under heating boilers is not new, but in the past few years it has spread rapidly. For a new heating installation it is easy to have all conditions properly coordinated, but when a stoker is applied to an old boiler, there may be some details that are not properly arranged.

From an accident prevention point of view, two very important precautions should be taken when installing automatic stokers. The first is to have sufficient head-room between the fire and the crown of the boiler to avoid impingement, and the second is to protect the legs of the boiler against over-heating.

The head-room required depends upon the kind and grade of fuel, the thickness of the fuel bed, the rate of fuel feed and the draft. The head-room also affects the economy of operation. By head-room is meant the vertical distance between the fuel bed and the under side of the shell or tubes or crown of the boiler.

Even with proper head-room local concentration of heat may occur, if the coal bed is not watched carefully because of holes that are likely to develop in the fire, particularly if the forced draft is too strong. However, if the fuel bed is kept thick enough in proportion to the forced draft, this will not occur. Some stoker fires have appeared like blast furnaces and in one case the flames could be seen in the flue 25 ft away from the boiler, indicating not only hazardous but also inefficient operation. In this case both the rate of fuel feed and the draft were cut down by the installation of a lower speed motor. Sections had cracked repeatedly in this boiler, but after the changes were made failures ceased and, furthermore, fuel was saved and better heating results were obtained. In general a fire that burns quietly will give the most satisfactory operation.

For boilers of the internal furnace type, the need of protection of water legs by a refractory lining depends upon the setting, the fuel and the type of boiler. It is frequently necessary to install a stoker in a pit and this usually places the fuel bed level below the bottom of the boiler water leg. In such a case care must be taken to protect the undersides of the water legs from the direct heat of the fire. Unless this is done collection of sediment and scale will inevitably cause over-heating and damage. The legs of cast iron sections on the sides, front and rear of the firebox should be protected by refractory to a suitable height when exposed to furnace temperature, and refractory protective materials should be maintained in serviceable condition.

Where there are two boilers, the practice of installing a stoker in only one and operating it up to its maximum capacity should be avoided. This practice has resulted in many cases of cracked sections because the single boiler was over-loaded. Instead each boiler should be equipped with a stoker and be operated at a normal load.

A stoker can be either too small or too large for a boiler. If of inadequate capacity, it has to be pushed to the limit and the chances are that a hot concentrated fire will be developed, which is likely to be detrimental to the boiler. If the stoker is of excessive capacity, to the extent that, at its lowest rate of fuel feed and lowest blower speed, a hot fire is developed even at minimum load, damage may be done to the boiler and the operation may be very uneconomical.

If the capacity of the stoker is proper for the load and the size of the boiler, it can be run at a normal rate with moderate furnace conditions that will give economical results and adequate heat.

The 'off' and 'on' periods will give some indication of the adequacy of the stoker. A long 'on' period with the fire burning gently is certainly preferable to short but frequent 'on' periods with the fire burning fiercely.

It is important that the pressure and temperature limiting devices and emergency water feeders be kept in good working order and properly adjusted; since, if they fail, serious results may ensue even to the extent of an explosion due to over-pressure, or to a badly burned or cracked boiler due to loss of water through a blowing safety or relief valve.

A reliable low water cut-out device is very desirable and is recommended for all stoker-fired installations.

Paragraphs of Progress

SAFER TRANSFORMERS

Since all oil insulated electrical apparatus has a potential hazard with respect to both explosion and fire, the increasing use of fire-proof dielectric liquids in conventional transformers has materially reduced the fire hazard with respect to these objects. Improvement in this direction also has been made in the materials used in the assembly of current-carrying parts.

LARGEST COMPRESSOR

A German chemical manufacturer has ordered a 40,000,000 Btu per hour refrigerating compressor to be driven by a 4,100 hp motor. This unit is believed by *Ice and Refrigeration* to be the largest in the world. A 32,000,000 Btu per hour unit is now being used by the concern. Figuring 1 ton of refrigeration as equivalent to 12,000 Btu per hour, the larger compressor would have a capacity in excess of 3,300 tons of refrigeration.

1700 LB ACCUMULATORS

High pressure steam accumulators at Simmering Power Station, as described in *The Electrical Times* (London), are 4′ in diameter and 30′ long, constructed of forged steel, and filled at 1700 lb pressure from a forced-circulation, oil fired boiler. The steam from the accumulators, of which there are eight, goes to a reducing valve where it is brought down to 500 lb pressure.

STEEL DIESEL HEADS

After relacing 100 per cent of the Diesel cylinder heads on its boat engines in five years, a large ferry company conceived the idea of fabricating the heads completely of steel by fusion welding. All parts of the heads, according to *The Welding Engineer*, are made of steel plates or tubes except the intake and exhaust passages which are steel castings.

NEW HEAT CONTROL

New heating systems have as an additional refinement an outdoor thermometric bulb so connected that it will turn on the fuel when the weather chills rapidly. Conversely, it will cause the fuel to be reduced when weather outside becomes suddenly warm.

"HOT AIR CURTAINS"

To protect final assembly workers from wintry drafts, a Michigan automobile manufacturer is reported by *Business Week* to have put in "hot air curtains." At each doorless door leading to the shipping docks a huge rotary fan drives heated air downward as an invisible screen against outside cold.

WELDED BLAST FURNACE

"Included in the recent 40-million-dollar expansion plan announced by Ford for River Rouge is a 1,000-ton blast furnace, to cost $4,500,000. The unit will be all-welded, first of its type."—*Power.*

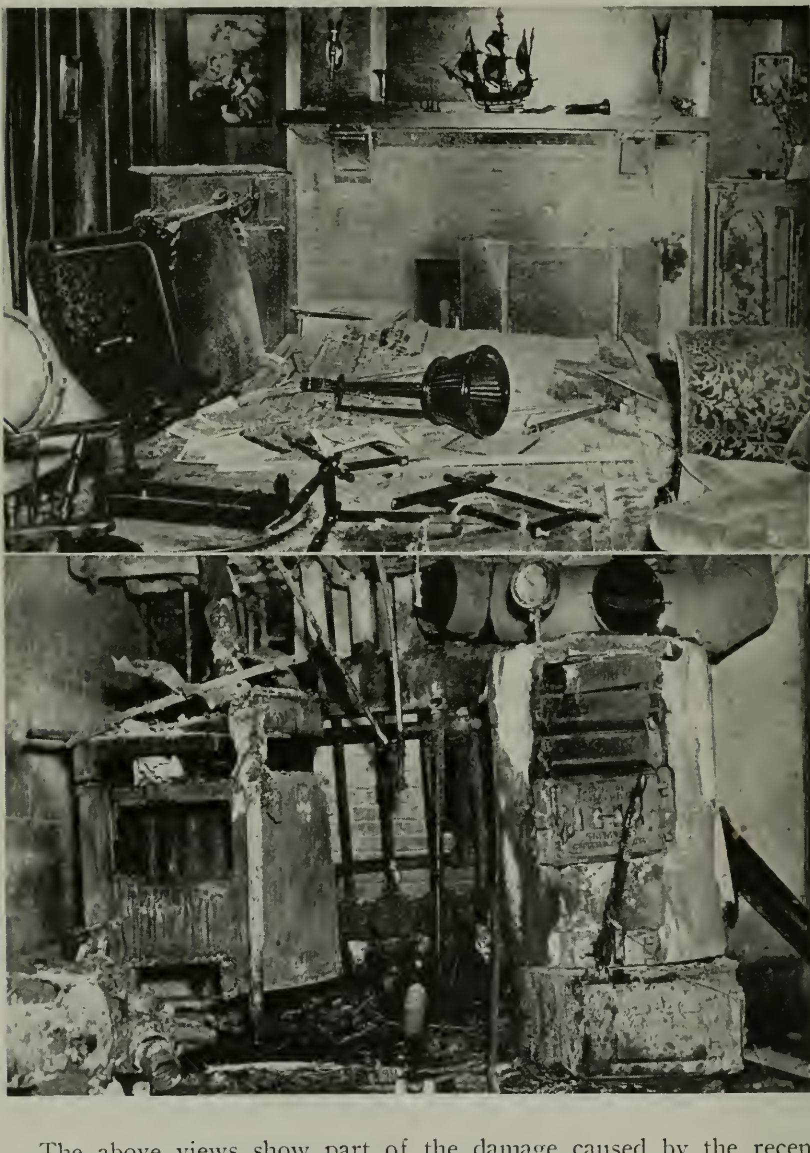
SENTENCES OF PROGRESS

A new valve arrangement, combining the sleeve and poppet valve principles, permits easier operation for variable-speed unaflow engines.

German engine builders recently have constructed a reciprocating unaflow engine (1500 hp at 500 rpm) to operate at 1400 lb steam pressure and 750°F. total steam temperature and to exhaust at 28 lb to process.

Improvement of absorption type refrigerating systems has led to several new installations which are said to give a performance vastly superior to the old type design.

Hot Water Heating Boiler Explosion in Residence



The above views show part of the damage caused by the recent explosion of an oil-fired hot water heating boiler in a residence. Occurring in the boiler at the left, the explosion blew the top section into the floor above, damaging the living room as shown. The foundation of the boiler was destroyed and walls of the house weakened. Fortunately, no one was injured, but property damage was estimated at $3,000. An investigation revealed that, because the boiler had been out of service, the supply and return valves on it were both closed, and that there was no direct communication between the boiler and the expansion tank on the third floor. Therefore, when a new oil burner was started, it soon heated the water in the closed boiler to a pressure sufficient to cause the failure.

Explosions in Furnace Prove Mystery Until Manager Uses His Nose

A SERIES of explosions that occurred one morning in the furnace of a coal-fired horizontal tubular boiler at a New England plant proved puzzling indeed until an alert manager with a good sense of smell discovered the cause.

It was the practice at the plant to bank the fire each evening at the close of the day's work. On the morning of the explosions the fireman loosened the banked fire preparatory to getting up steam. Soon afterward a series of detonations occurred within the setting. The first was severe enough to crack the masonry, but subsequent ones were of less intensity.

Of course, there was considerable anxiety among the plant personnel. The fuel was examined closely, as were also the dampers. However, when the manager was called to the powerhouse, he at once detected the odor of illuminating gas.

This was puzzling since the plant had no gas connection in the boiler room. The source of the odor was traced to a crack in the concrete floor directly in front of the ash pit doors. It was decided that gas from this source was the cause of the explosions, it being reasoned that when the banked fire was broken and the ash pit doors opened, the draft drew the gas rapidly into the setting.

When gas company men had dug down to a gas main near the building, they found a small hole the size of a dime in the main at a point approximately 22 feet from the ashpit doors. The sandy texture of the ground surrounding the main permitted the gas to seep to the crack in the boiler room floor.

Steam power plants in the United States burn about the same amount of coal now as in 1920, but they generate twice as much electricity with it.

Soldered Joints

In recent months there have been reported several accidents of a serious nature involving steam pressure vessels with soldered joints. Unless such seams are adequately strengthened by means of rivets or other sufficient means, these vessels are obviously unsafe, because most solder, at 212° F., has negligible strength, and all of the stresses must be carried by some other form of construction. The failure of soldered vessels, such as tanks, range boilers, sterilizers, etc., with subsequent damage to property and injury to attendants should be a definite warning to all owners of such vessels.

The A.S.M.E. Code for pressure vessels does not mention ordinary solder, nor are soldered joints satisfactory for vessels constructed under the Code.

Some of the municipal and state pressure vessel codes prohibit the use of solder which fuses at a temperature below 600°F., except when employed only to procure tightness, so that they automatically prohibit the use of low-melting-point solders and indirectly require that all pressure vessels be either brazed or silver soldered, or else be constructed by means of welding, with riveted seams or by a combination of the two methods.

In ordering new vessels for pressure uses the safest procedure is to specify that the vessels be constructed in accordance with the A.S.M.E. Code, which eliminates the use of ordinary soldered joints by not countenancing this type of construction.

THE COVER

An inspector examining a large engine. Such machines are inspected with meticulous care, both while they are at rest and in operation, for the parts are so massive that the failure of any of them would probably mean disaster.

Taps From the Old Chief's Hammer

Big Joe Morse, field man in the lake counties, had come into the department office to attend an inspectors' meeting and was the subject of much banter.

He had bought glasses and they made him look unusually dignified, but, as Joe put it, "They'll listen to me now."

"How did you know you needed glasses, Joe?" asked one of the men.

"I didn't. Thought some headaches I had were on account of my stomach, but after the doctor had pumped my life's history out of me, it didn't take him long to fix things. A good doctor's a blessing, though. My policy is, 'Tell them all you know. and let the chips fall where they may.' "

"It's not mine," laughed Jim Murphy. "I tell them nothing. Let them find out; it sharpens their wits."

The Old Chief, who had sauntered over to the group, entered the conversation with, "I don't know about that, Jim; it works both ways."

"What do you mean, Chief?" several of the men asked simultaneously.

"Just this; that we don't like it much when an assured treats us like Jim treats his doctor. Let me tell you of a typical case," and the Old Chief was started on one of his stories.

"We received a letter from an assured who had two horizontal tubular boilers in a flour mill," the Old Chief began. "The letter said they were having trouble and asked that an inspector visit the plant on a certain date. Inspector Frank Drier made the call and I'll try to tell the story in his words.

" 'On arriving at the plant, I found that the mill was not running,' Frank told me. 'The boilers were cool and empty, and ready for inspection. Internally, the shell plates, heads and tubes, except for some light scale, were clean and in good condition.

" 'Externally, I found both fire sheets had been over-heated. There was no decided bag, but both sheets were sprung over a large area. The girth seams and several rivets in them showed signs of leakage, as did all the tubes at the rear end. Besides, several of the tubes were loose in the sheet.

" 'When I finished my inspection, the superintendent and engineer wanted a verbal report. I told them the fire sheets, while sprung, were not dangerous in their present condition, but that the girth seams would have to be caulked and made tight and that all the tubes at the rear should be re-rolled and re-beaded.

" ' "What caused the trouble?" the superintendent asked.

" ' "Oil," I told him, for with the open feedwater heater, the hookup to the engine, and freedom from scale both then and in the past, there was no other reasonable cause.

" 'The superintendent and engineer then both wanted to know how I could say the trouble was caused by oil when none was found in the boilers. I replied that indications showed there *had* been oil in the boilers.

" 'They argued against me. After some discussion they wanted to know whether they should use lye to remove oil, if ever any oil should get into the boilers.

" ' "Assuredly not," I told them, "unless you want to wreck the engine on account of the boilers priming. Boilers are supposed to generate steam and not to be used for soap kettles." '

"Inspector Drier heard later that the superintendent was just trying to draw him out. There *had* been oil in the boiler and they *had* removed it by using lye. The fact that the engine escaped a breakdown was more a matter of luck than of judgment.

"Frank's comment when he heard about his correct diagnosis with respect to the oil was, 'What did they think I was going to do, jail them if they told the story straight?' "

Jim Murphy, who said he didn't give his doctor all the facts, spoke up then.

"Chief," he said, "you've got me dead to rights. Now that you speak of the principle of the thing there was another actual case of just this sort described in the last copy of The Locomotive. As I remember it, there was an accident to some turbine blading, which might have been the result of deterioration, but when we started to dig, we found other loose blading, a stretched dovetail, and distortion at the steam equalizing holes—all of which pointed to just one thing, over-speed.

"Chief," Jim continued, "now that I think of it, plenty of operators have held back information I needed. I guess they were afraid of bad news."

"Aren't we all?" was the older man's comment. "Let's get our meeting started. You know good trouble-men get their facts from the patient, whether boiler, turbine . . . or man."

Daily Inspections Advocated

In a recent issue of *Power* under the title of "Making Boiler Inspections" the following was contributed by an interested engineer. There would be fewer unnecessary shutdowns, if all plants were to follow the routine suggested here, relying on the insurance company inspector to give an unbiased check on the chief engineer's inspections.—Editor.

"When boiler inspectors visit plants to make external inspections, some chief engineers take little interest, being content to sit at their desks, or go about other duties. This is poor practice; in fact, the chief engineer or a competent assistant should perform such inspections every day the plant operates.

"On such inspections the following routine is recommended:

"Test the condition of the water columns and gage glasses. Operate drain valves and thoroughly blown down connections. Observe action of water returning to the glasses to check possibility of an obstructed connection. Try gage cocks to be sure that they are free. Check the water level indicated by the glasses.

"Lift safety-valve levers to guard against freezing or accumulation of deposits. If safety valves do not blow at least once a week, raise the boiler pressure to the value for which the valves are adjusted. Check the pressure observed on the gage with that at which the safety valves blow.

"At least twice a year check the accuracy of the pressure gage by comparing it with a standard test gage. Provide a ¼" valved branch connection in the gage line for this purpose. If this connection is not at the lowest part of the pressure-gage piping, provide a drain cock so that any sediment in the line can be blown out periodically. Take care not to blow the water out of the syphon leg when the boiler is under steam pressure, or the gage may be over-heated and damaged.

"Examine all accessible parts of the boiler plant for leaks. Leaks should be traced to their source and stopped, for they are costly and may be a warning of a dangerous condition.

"After checking water level in the boilers, open blowdown valves long enough to show that the line is clear and to remove any sludge or sediment. It is well to impress upon the operator the dangers of water hammer, if blowdown valves are manipulated carelessly or too quickly.

"Cleanliness and neatness of the boiler room are essential. A dirty, cluttered-up plant is an invariable indication of careless personnel. Accident prevention starts with good housekeeping in the power plant.

"Open the fire and cleanout doors to permit examination of fire surfaces so far as possible. Look for bulges or blisters on tubes or boiler shell. These conditions generally necessitate immediate shutting down of the boiler. Note condition of the baffles. Broken baffles allow high-temperature gas to short-circuit part of the passes and cause poor efficiency.

"Check condition of the brickwork, sidewalls, arches, etc. Many accidents result from these sources. Try the main stop valves to make sure they are not jammed open. Loss of a few seconds to free a jammed valve is a serious matter in time of emergency.

"Give attention to anchors, supports, drains, and expansion points of the steam piping. Slight settling of foundations or building members may cause an unequal and serious strain on the steam piping. Settling of piping itself may present the additional hazard of low points in which water pockets form."

"Now, be sure to write plain on those bottles," said the farmer to the druggist, "which is for the horse and which is for me. I don't want anything to happen to that horse before the spring plowing"—*Onward.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

December 31, 1937 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,365,891.78
Premiums in course of collection (since October 1, 1937)		835,315.16
Interest accrued on mortgage loans admitted as an asset		3,584.34
Interest accrued on bonds		85,190.24
Loaned on mortgages		206,015.00
Home Office real estate and Philadelphia branch office		642,331.05
Other real estate		328,934.52
Bonds on an amortized basis	$9,244,042.06	
Stocks at market value	6,421,042.00	
		15,665,084.06
Other admitted assets		16,201.39
Total		$19,148,547.54

LIABILITIES

Premium reserve		$8,719,926.02
Losses in process of adjustment		290,746.35
Commissions and brokerage		172,985.00
Taxes		265,000.00
Other liabilities		270,149.49
Liabilities other than capital and surplus		$9,718,806.86
Capital stock	$3,000,000.00	
Surplus over all liabilities	6,429,740.68	
Surplus to Policyholders		9,429,740.68
Total		$19,148,547.54

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Incorporated 1866 *Charter Perpetual*

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READY TO HELP

In good weather or bad, men of the Coast Guard stand ready to respond to trouble at sea. Just so do Hartford Steam Boiler engineers stand ready at all times to aid every policyholder. Whether their visits are for inspections or for emergencies, they bring to the policyholder the benefits of knowledge backed by the Company's 71 years of experience in power plant practice.

Vol. 42 No. 3 JULY, 1938

The Locomotive

THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE CO.

Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Boiler Embrittlement—1938

Still a Serious Problem

Although definite progress has been made in the past two years in the avoidance of what is known as "caustic embrittlement" in boilers, digesters and kiers, the problem is still a serious one. A review of more than 30 recent cases in 17 states is gratifying to the extent that it reveals no serious accident as the result of embrittlement, but the fact that 30 recent cases of this insidious ailment have been discovered indicates that it is still a matter for concern.

Studies of the actual cases as well as laboratory research have brought out a number of new interesting facts with respect to the development and avoidance of this intergranular disintegration of boiler steel, and the results of this work are already of benefit to industry. To present these facts in a non-technical way is the purpose of this article.

Discovery and Investigation of Defects

The characteristic fissures left in plate steel because of the action of sodium hydroxide have been found principally in the riveted seams of boiler drums, and in those of digesters and kiers in which caustic materials are used. Luckily embrittlement usually gives warning in one of two ways: Either persistent leakage occurs, with deposits of caustic frequently an accompaniment, or else rivet heads fall off during operation or are snapped off by the impact of the inspector's hammer. When one of these symptoms is discovered, embrittlement should be suspected and rivets should be removed to permit examination of the rivet hole either with the Hartford Steam Boiler magniscope or by other means. Experience has shown that the magniscope permits the best practical method of study of the condition of the plates. A typical view through the magniscope in an affected boiler is shown in Figure 1. For those unfamiliar with the magniscope, it may be described as a magnifying periscope that permits critical examination of the wall of the rivet hole. If evidences of serious disintegration are found, more rivets and in some cases the butt straps are removed to permit examination of the plate surfaces, although the examination of a sufficient number of rivet holes usually will determine whether the steel has been so affected as to make the vessel unsafe. A refinement in use with the magniscope is a camera which may be clamped to it for the purpose of micro-photographing the defect appearing in the rivet hole wall.

Depending on the extent of the intergranular disintegration, the fissures may be so small as to be visible only with magnifying apparatus.

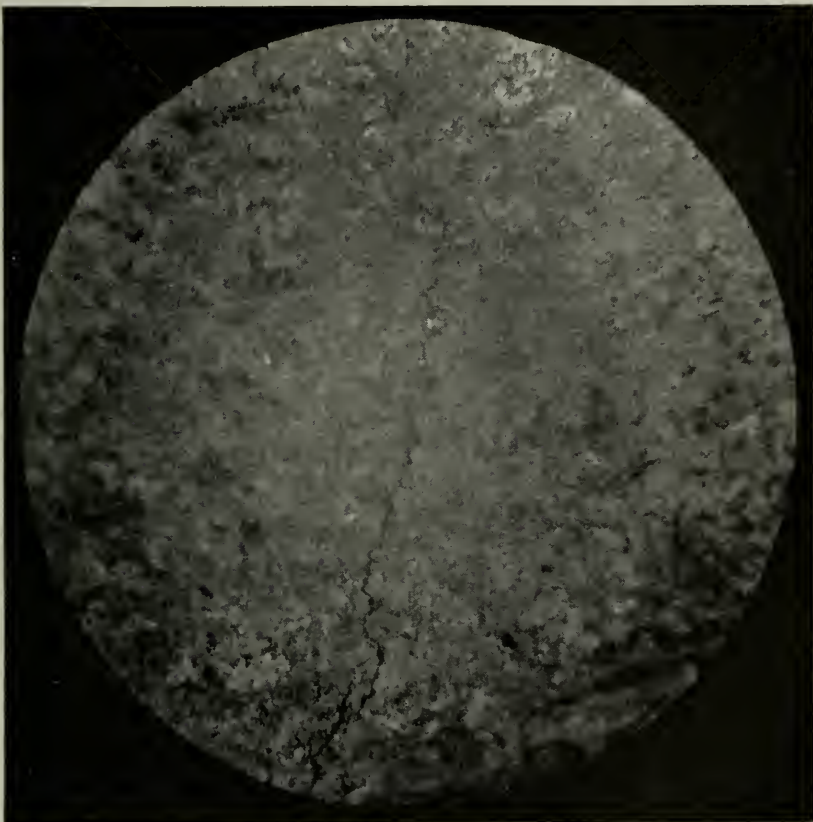


Figure 1—An embrittlement defect at about 100 magnifications. This is what the eye sees when using the regular Hartford Steam Boiler magniscope on a highly polished wall surface of a rivet hole.

or the separations may be sufficiently large to be visible to the naked eye.

When such conditions are found in one boiler in a battery, it is likely, if the feedwater is the same for the other boilers, that they also will be affected, even though neither of the positive symptoms is yet manifest.

For instance, at a New England plant, embrittlement was discovered in one boiler and the examination of three others proved them also to be affected, although they had not yet developed the customary outward symptoms. In the South discovery of embrittlement in a single boiler brought under suspicion not only the other boilers in the plant, but also boilers in other plants in the vicinity which were using water from the same source. Careful watch is being kept on this equipment. A third example in the Middle West was the discovery of embrittlement in the longitudinal seam of one of a battery of 40 digesters. In this case the difficulty had advanced to such a point that it was decided to modernize the process and to install new equipment rather than to undergo expensive repairs and run the risk of defects showing up in unrepaired parts.

In all of the cases considered the magniscope was successfully used in determining the location and extent of the disintegration.

Significance of a Plant's Feedwater History

As will be discussed later, advances have been made in feedwater treatment to avoid embrittlement, but to date no discoveries have been made which will stop the slow development of the disintegration, once it is started. In many of the recent cases of embrittlement the feedwater at the time of the discovery of trouble was not of an embrittling sort, but a careful check into the history of the boiler showed that at some time in the past poor feedwater had been used or else there was evidence that, while a proper treatment had been started at some prior time, it had not been continued without interruption.

An example of an extreme sort is represented by the experience of a paper mill in the Middle West where deep-well water contains considerable sodium carbonate with an absence of sulphate or other inhibitant. Some years ago, before such a thing as embrittlement was known to exist, a boiler explosion demolished the mill. When the mill was rebuilt it was equipped with two horizontal tubular boilers with butt-strap seams. Within nine years, both of the new boilers had been consigned to the scrap pile on account of cracks in the seams. This failure was investigated quite carefully at the time and was attributed to the feedwater. However, as the well water in its natural state was practically perfect for paper making, no treatment was attempted and new water tube boilers were continued with the same feedwater. They in turn had to be rebuilt a few years later because of the failure of riveted seams. Since that time the boilers have been supplied with feedwater treated in accordance with the best known practice and no further difficulty has occurred.

A Study of the Disintegration of Steel

In many laboratory experiments, commercial soda ash or caustic soda has been made to produce the defect characteristic of caustic embrittlement. As this chemical or its equivalent is commonly an ingredient of feedwaters, and as it has invariably been present in the feedwater of boilers in which "embrittlement" has been found, the presumptive evidence that it was the cause of the trouble was very strong. However, about two years ago, investigators for the Bureau of Mines were unable in a series of experiments with *chemically pure* caustic soda, to produce embrittlement, and thus came the discovery that some impurities or catalysts must be present with caustic soda to cause the embrittling action. These investigators found that silicates are among the impurities capable of enabling the caustic to act on the steel.

The fact that commercial caustic soda contains a small amount of silicon and that silicates are present in many boiler feedwaters brought laboratory findings and field experience together on a common ground. Subsequent investigations* by the Bureau of Mines investigators showed that, under certain conditions of stress and temperature, intercrystalline failure of steel will occur also in sodium nitrate solutions and in nitric acid solutions, and that the action bears a relation to a number of substances, besides silica, which apparently act as catalysts. For the chemist and the metallurgist this work offers much new information on the subject. For the boiler owner it illustrates the complexity of the subject and the need for reliance on competent advice with regard to the chemical reactions which may go on within his boiler.

The authors of the paper referred to in the footnote conclude that

> "not only one solution but a variety of caustic solutions of different compositions may promote failure. To be destructive it seems necessary that the solution produce a non-continuous film on the steel and corrode the grain boundaries.
>
> "Since the reactions may be started or stopped by surface conditions on the steel, they will obviously be extremely sensitive to small changes . . . This sensitivity to changes in conditions gives the study somewhat the complexity of the corrosion problem and indeed in a number of aspects similarities are indicated. . . . The results definitely show that it is not necessary to have an applied load on the steel to produce cracking. The internal stresses resulting from cold work or other treatment will allow the solutions to attack the steel. If an applied load is present it may of course hasten ultimate failure."

Many of these tests were carried on in a special "bomb" with a stressed core inside the bomb. It is significant that with some of the solutions not only the core but the bomb itself was affected by embrittlement.

Repairs Are, So Far, the Only Field Remedy

Thus, in the laboratory the conditions of plate embrittlement have been studied and conclusions reached. In the field when the results of

* See "Intercrystalline Cracking of Steel in Aqueous Solution" by W. C. Schroeder, A. A. Berk and R. A. O'Brien, published in *Metals and Alloys*, November, 1937.

embrittlement have been found, the boiler owner's reaction may be summed up by the question, "Now what?" So far in the history of this boiler ailment, when a "cure" has been possible at all, it has involved a "major operation." By such means years of life for the boiler can sometimes be obtained by making carefully considered repairs. Sometimes the installation of a new drum or drums is needed to remedy the difficulty. Or, if the trouble is found early enough, diseased metal may be eliminated by reaming rivet holes. In many cases the use of extra-wide butt straps has effected a satisfactory repair. Of course, to guard against a recurrence of the difficulty, after such repairs, the proper feedwater correctives must be used.

A.S.M.E. Ratios and High Pressures

For more than 10 years the A.S.M.E. "Suggested Rules for the Care of Power Boilers" have included as precautionary recommendations to avoid embrittlement a set of ratios of sodium sulphate to sodium hydroxide and sodium carbonate alkalinity calculated to equivalent sodium carbonate for various pressures, the ratios being 1:1 from 0 to 150 lb pressure; 2:1 from 150 to 250 lb and 3:1 above 250 lb. In actual operation these ratios in general have proved satisfactory, but there has been an effort on the part of operators of boilers in the higher pressure ranges to find protection by means other than the use of sodium sulphate because high concentrations of this material in the boiler water cause foaming and priming and annoying carryover to the superheater tubes and to turbines. Then, too, some have doubted whether a 3:1 ratio of sulphates to alkalinity affords adequate protection of boilers at high pressures and temperatures; and, for that matter, whether any sulphate ratio is the solution to the problem.

The University of Illinois Research

An exhaustive research at University of Illinois Laboratories* has produced findings of unusual interest on embrittlement prevention. These studies were carried out under controlled conditions which resemble those in actual boiler operation. It was reasoned that in boilers the action of embrittlement takes place in capillary spaces around rivets and between plates. Therefore, such a capillary space was provided in each test specimen by inserting a core in a specially designed cylinder† so con-

* See: "Boiler Water Treatment—New Methods for Preventing Embrittlement" by F. G. Straub and T. W. Bradbury, in *Mechanical Engineering* for May, 1938.

† The University of Illinois has applied for a patent on the device used in these tests.

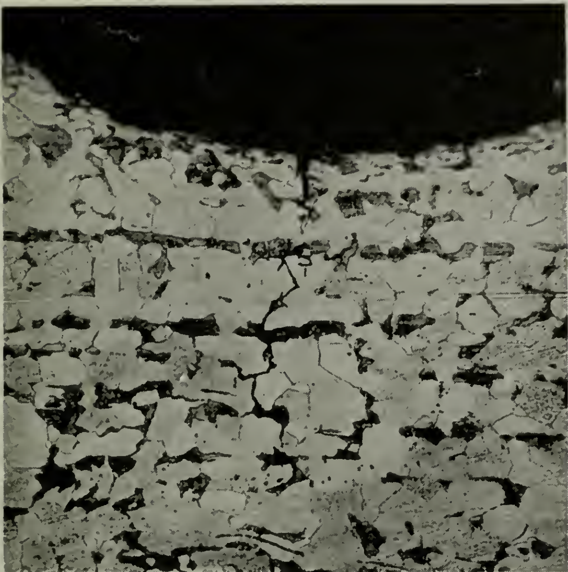


Figure 2—Embrittlement at 225 magnifications. The defect shown here was produced in the University of Illinois tests. The progress of the fissure may be compared to that in Fig. 3.

structed that a desired stress could be put upon the wall of the capillary space. In each test 7 c.c. of boiler water was used. Various controlled temperatures, corresponding to those at several boiler pressures, were produced, the heating being done in an electric furnace. Most of the tests were made at a stress of 40,000 lb per sq in.

Embrittling waters caused failures in most cases in 24 hrs or less.

Actual boiler waters were used and a careful analysis of each was made for comparative purposes. Furthermore, when waters of certain compositions were found to cause embrittlement, inhibitants were added until the test specimens were unaffected even after a month of continuous heating and stress. Attention is called to Figures 2 and 3 which permit comparison of embrittlement as it actually occurs in the boiler and as it was produced in the laboratory.

This laboratory work has been carried on for more than 18 months during which time boiler waters from more than 150 steam boilers have been tested. These boilers have operated at steam pressures ranging from 150 to 1400 lb per sq. in. Several plants from which these waters were obtained, have already modified their boiler water treatment to conform to the results of these tests and are having these modified waters tested to see whether they are consistently non-embrittling in nature.

Unlike the Bureau of Mines experiments in which heavy concentrations were used to start with, the University of Illinois tests produced embrittlement with water containing alkalinities as low as 150 ppm.

It was found that the impurities concentrated in the capillary space in quantities sufficient for destructive effect. In fact, even in tests which did not cause embrittlement, analysis of that part of the water above the capillary space was found to have a less concentration than it did prior to the test, showing that the capillary space had "attracted" some of the impurities in the feedwater.

The Importance of Sodium Chloride

The University of Illinois tests were divided into three pressure divisions—up to 250 lb (400°F), between 500 and 1400 lb (470° to 570°F) and at 350 lb (425°F). Tests in the first group showed that embrittlement resulted even when the sodium sulphate was present in concentrations that were 3.13 times the total alkalinity. The significant point developed from the tests in the first group is that apparently sodium sulphate alone will not prevent embrittlement, but that there must be, in addition, a minimum of 0.60 per cent of sodium chloride to total alkalinity. Also the tests show that up to 250 lb pressure in the presence of enough common salt, a sodium sulphate ratio of 1:1 is apparently a safe minimum. Evidently the reason that the generally accepted ratios have been so satisfactory for so many years is that in most boiler waters there is common salt in excess of 0.60 per cent to total alkalinity. In addition there is nearly this much NaCl in commercial caustic soda. At boiler pressures for which the A.S.M.E. ratios were originally worked out (up to about 300 lb) and where they were carried out, trouble from embrittlement has not been reported in the many cases studied by Hartford Steam Boiler. For that matter sulphate treatment apparently has proved satisfactory from a practical standpoint in preventing embrittlement at pressures higher than 250 lb, but feedwater treatment in the higher pressure brackets has been subject to constant change and variation in recommendations by various feedwater experts ever since the advent of higher pressures, and practices are far from standard. In the high pressure ranges the use of evaporated makeup helps to lessen feedwater difficulties. If treated water is used, however, even with a high percentage of condensate, a constant check of the feedwater and the advice of experts relative to treatment are necessary.

Tests at 250 lb pressure also were made with waters treated with phosphates. In these sodium chloride appeared to have some effect and phosphates did not appear to be effective if the chloride-alkalinity ratio was below 0.20. Phosphates alone do not appear to be effective, but further tests are necessary before definite conclusions can be drawn regarding the phosphate action.

Aluminum Oxide as an Inhibitant

Tests at 470°F (500 lb pressure) showed that the chloride-sulphate combination, which proved to be so effective at the lower pressures, does not appear to have this inhibiting action at the higher temperatures. Instead tests seemed to show that the critical factor was the total of iron and aluminum present as oxides. In the waters analyzed, aluminum oxide (Al_2O_3) appeared to predominate. In their report the investigators used the symbol R_2O_3 to represent the combination of iron and aluminum oxides. (Additional tests are being carried out to study the relative effect of the iron and aluminum.)

A conclusion reached as a result of these tests, however, is that embrittlement does not occur if the ratio of R_2O_3 to silica, SiO_2, is greater than 0.60. In fact, in tests so far, the presence of Al_2O_3 in quantities greater than 0.60 times the silica has proved effective in preventing embrittlement. As small an amount as 2 parts per million of R_2O_3 appeared to be effective if the ratio to the silica was adequate.

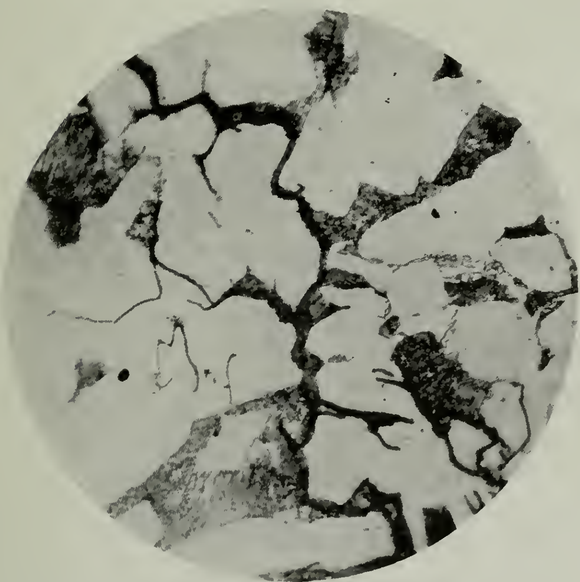


Figure 3—Embrittlement at 500 magnifications. This defect developed in a boiler under ordinary operating conditions. The characteristic intercrystalline path of the disintegration is clearly shown and is directly similar to the disintegration produced in the laboratory and shown in Figure 2.

The above approach to the subject of embrittlement prevention is from a point of view markedly different from that taken when considering sulphate as the chief inhibitant.

This new approach concerns itself with means for overcoming the catalyzing effect of silicon, which, as discovered in the Bureau of Mines research, is a key factor in producing the embrittling action. In the light of the new findings the prevention of embrittlement at high pressures appears not so much associated with the sulphate-to-alkalinity ratio as with the neutralizing of the embrittlement-aiding silica by apparently "tieing it up" as a complex chemical, so that it cannot assist the sodium hydroxide in producing embrittlement. Results similar to those at 470°F were obtained at 570°F (1350 lb pressure).

The third pressure group, 350 lb (425°F), was segregated because it appears to be a dividing line between the effectiveness of the two forms of prevention. Tests at this temperature appeared to indicate that the chloride-sulphate effect is still noticeable and that the R_2O_3-SiO_2 effect might also be active. A conclusion drawn was that 425°F was about the upper limit for the use of sulphate and chloride and the lower limit for the use of R_2O_3 to prevent embrittlement.

The results of these tests appear to be particularly helpful because the inhibitor effective at the higher temperatures is one that can be used in relatively small quantities and hence concentration difficulties can be avoided. The authors of the paper announcing this work also comment that in the majority of the boiler waters obtained from the higher-pressure boilers, the inhibitor R_2O_3 occurs as a natural balance without any effort to introduce it. In practically all the cases where the R_2O_3 content has been increased to prevent failure, the quantity needed has been so small that practically no problem is involved in treating the boiler water so as to give the desired ratios.

The universal increase of R_2O_3 at higher pressures is not recommended, however, because of a potential danger that the R_2O_3 will combine with the silica to form troublesome scale, but the removal of silica is seen as beneficial because such removal improves the R_2O_3-SiO_2 ratio. In the successful tests (in which failure did not take place) at 570°F the A.S.M.E. sulphate to total alkalinity ratio varied from 0.01 to 5.55 and the NaCl ratio to total alkalinity varied from 0.08 to 0.86.

It is of interest to boiler owners that arrangements have been made whereby the Chemical Engineering Department of the University of Illinois will analyze and test waters at nominal cost for any interested parties, individual results to be reported to the parties sending in the water samples and the cumulative results to be published from time to time. In these published reports the source of the samples tested will not be revealed.

Bureau of Mines Studies of Inhibitants

Still further light is thrown on the subject of embrittlement prevention by the Bureau of Mines investigators* who, over a period of three years studied the effectiveness, as inhibitants, of sodium sulphate, sodium phosphate, other inorganic compounds and a number of organic materials. A great many tests were conducted under controlled laboratory conditions. Among the conclusions reached were the following:

"A high concentration of sodium sulphate will prevent failure of boiler steel in the tension tests in sodium hydroxide-sodium silicate solutions if two conditions are satisfied: (a) the stress in the metal does not vary materially while it is in contact with the solution at elevated temperature, and (b) the sodium hydroxide concentration does not greatly exceed 25 g (grams) per 100 g (grams) of water. Sodium sulphate dissolved, or present in excess as loose crystals did not prevent failure between 150 and 250° C (302°F and 482°F) if either condition (a) or (b) was violated.

"Sodium phosphate will not prevent failure in the tension tests unless the sodium silicate-sodium hydroxide ratio is well below that encountered in most feedwaters.

"No inorganic salts with the exception of oxidizing agents have been found to prevent failure under conditions of changing stress at elevated temperature and with sodium hydroxide solutions containing appreciable amounts of sodium silicate.

"Lignin sulphonate, concentrated sulphite waste liquors, Philippine cutch and quebracho (organic compounds) did prevent cracking even when a very high stress was applied at elevated temperature. Protection was not destroyed by high sodium silicate or high sodium hydroxide solutions. The sulphite liquor was found to be suitable at all temperatures up to 250°C (482°F), but in the case of the other compounds it was found that definite temperature ranges had to be observed."

These investigations were carried on almost entirely from a laboratory viewpoint and such problems in actual boiler operation as possible decomposition of the inhibitants, especially the organic compounds, the formation of scale, possible acceleration of corrosion, foaming and priming were not investigated. However, further experiments are now under way with small riveted boilers and some of the protective compounds are being tested in large-scale operation.

For the feedwater expert the findings touched on here may open new avenues of progress. For the boiler owner this activity should mean eventually safer and more economical operation as the cause of embrittlement and how to prevent it become better understood.

From a practical standpoint the sulphate ratios in the A.S.M.E. Code are the best available guides to embrittlement prevention for pressures below 350 lb, and the recommendations of qualified feedwater experts

* Reported in a paper, "Protecting Steel against Intercrystalline Attack in Aqueous Solution" by W. C. Schroeder, A. A. Berk and R. A. O'Brien, College Park, Maryland, in co-operation with the Joint Research Committee on Boiler Feedwater Studies at the annual meeting of the American Society of Mechanical Engineers in New York, December 6-10, 1937.

should be sought for higher pressures. However, the present intensive investigations, most of which have active industrial and insurance company support, probably will lead to some revision of standards, especially for high pressure installations, in the not far distant future.

Sulphuric Acid as an Embrittlement Preventive

The presentation of an article on the subject of embrittlement requires mention also of a practical treatment now being used in a few large plants. This is the feeding of sulphuric acid to the boiler water to maintain the sulphate to carbonate ratios. The use of sulphuric acid requires proper engineering skill in the design and installation of the acid feed and a proper routine of operation and control. The chief advantage is a lessening of sludge or scale-forming concentrations. Here, of course, the sulphate requirement is met by use of the acid. Probably sulphates also result from the reaction of such inhibitants as the concentrated sulphite waste liquors—a by-product of the paper industry.

Tube Embrittlement

A discussion of embrittling action in mild steels is usually confined to the failures that occur in riveted joints. However, whether the seam of the boiler be riveted or welded, the method of securing the tubes into the tube holes in the plates may be identical. The capillary spaces between the tube and the wall of the tube hole afford opportunity for accumulation of high concentration which has at times resulted in failures of the same character as those occurring in riveted seams. The development may be discovered in the tube where it is expanded to form a seating in the tube hole. Failures of this kind follow a circumferential path. The material surrounding the tube hole also may be affected and the path of the development may extend from one tube hole to the adjacent hole either in a longitudinal or in a girthwise direction depending upon the magnitude of the stresses.

Because some of the failures are accompanied by cracks in the tube outside the drum or header, there is reason to believe that a combination of stress cracks and embrittlement decomposition may occur. The embrittlement failures adjacent to the capillary spaces between the tubes and the plate are similar to results obtained in the testing device used at the University of Illinois. The initial failure in both instances occurs in the comparatively thin, stressed tube of the boiler and in the thin stressed wall of the testing equipment. Tube failures of this nature have been experienced for years, but their association with the problem of embrittlement and feedwater treatment has come but recently with the present day problems of tube maintenance in the modern high pressure boiler.

Steam Turbine-Driven Generator Operation

By J. B. Swering, *Chief Engineer, Electrical Division*

Notwithstanding the vast amount of literature that has been written regarding power equipment operation, maintenance and accident prevention, serious and costly outages are being experienced continually because of accidents to such equipment. It is the purpose of this article to present information which may prove helpful to owners and operators of turbo-generators and other electrical machines.

Many accidents could be prevented if the early symptoms of trouble were recognized and the proper treatment prescribed. However, there are accidents of a sort that are not preventable at the time of their first occurrence, because new and untried designs tend to introduce unpredictable operating difficulties, the nature of which is difficult, if not actually impossible, to forecast due to the use of new materials of unknown operating characteristics.

Deterioration plays a much more important part in respect to the operating life of an electrical machine than it does in respect to mechanical equipment. This is so because of the nature of the basic materials which determine the life of the machine. Aside and apart from any question of obsolescence, the physical condition of the object is vital in considering the life of electrical apparatus. Throughout years of operation, much data has been collected, from which the expected average life of certain types of objects has been determined. While authorities have not reached a mutual agreement in their deductions, nevertheless they are close enough in their final results so that fairly definite figures are available. However, there are many operating factors that require careful consideration if the average life is to be obtained.

The operation of generators, whether they be large or small, is largely dependent upon the material used as an insulator between the individual conductors and between the conductors and ground. Insulation of an electrical machine should provide a high resistance area to the flow of current. Therefore, any factor which affects the life of insulation and therefore decreases the resistance of this area increases the probability of potential breaking through the insulation, thus resulting in short circuits and the grounding of the conductors. There are a number of factors which affect the life of an insulator and which should receive the consideration of every designer and operating engineer. These factors include:

1. Age.
2. Temperature of operation.
3. Moisture content of cooling medium.
4. Oil soaking of the windings.
5. Acid.
6. Alkali.
7. Mechanical injury, such as rubbing, vibration, etc.

The base materials in the insulators are practically the same as those used for many years, but many improvements have been made in their fabrication and application. Nevertheless, it is very important that they be carefully maintained.

The temperature to which any insulator is subjected in operation should be closely watched in order to prevent its rapid deterioration. It is, therefore, necessary to follow the manufacturer's guaranteed rating for any electrical machine, if an average life of a winding is to be expected.

Thermocouples are usually installed in the armature windings of a generator to provide means for indicating hot spot temperatures. These devices should be kept in good condition so that actual temperature readings may be regularly and accurately recorded, thus indicating any unusual change in operating conditions.

An electrical machine has a nameplate placed upon it by the manufacturer and on this is stamped the operating characteristics to be expected from the object in accordance with the manufacturer's guarantee. *These ratings should not be exceeded if the normally anticipated life of the windings is to be obtained.* Although some degree of extra capacity may exist in the design, it is not common practice to use the additional capacity in regular operation. Even though the ambient temperature may be low, the unit should not be run over-load at normal voltage.

It must be realized that the armature temperature gives no indication of the temperature of the rotor—that part of the machine for which temperature readings are difficult to obtain when the unit is in service. There seems to be a misunderstanding, or a disregard by many operators, with respect to the safe field current at which a turbo-generator may be operated. The manufacturer now stamps the normal full load field current value on the generator nameplate. Whenever such values are exceeded, more rapid deterioration of the field insulation results.

There are several tests which are used to check the physical condition of an insulator. The most common method of checking insulation resistance in the field is by the use of a megger. Such an instrument is portable and can be readily connected for test.

If the readings are properly taken and interpreted they will give, to a fair degree, the physical condition of the insulation. Generally speaking there are two possible leakage paths, one of which is through the body of the insulator and the other over its surface. Therefore, it can be readily seen that many low insulation resistance readings can be improved by cleaning the surface of an insulator, thus removing any surface film of oil, a thin coating of dust or other foreign materials. There is also a very marked difference between readings taken at low humidity and those taken at high humidity. It should also be understood that to obtain reliable readings the insulator must be fully saturated with electric charge.

Most insulators have a negative temperature coefficient, which means that their resistance will decrease with rising temperatures.

Insulation resistance values vary with the capacity of the machine, voltage rating, etc., and, therefore, these factors must be given consideration in interpreting any insulation resistance reading.

Insulation resistance readings of turbo-generator fields taken at rest, at half speed and at full speed are considered to be very important, as any differences in such readings tend to indicate some abnormal condition that needs attention. It may be that the field is very dirty or that a movement of the windings is taking place. When such variable readings are found, it is most advisable to remove the field from service and clean it thoroughly. After cleaning, if it is found that no change in readings has occurred, the manufacturer's representative should be called in and the end rings removed in order to make a further examination of the windings.

Several years ago it was more or less common to find operators testing the windings of their generators by the over-potential method in order to determine reliability for continued operation. This is often a dangerous procedure on an old winding which has deteriorated to some extent and from which it is impossible to completely remove all the dust and dirt. Even though the windings may withstand such an over-potential, there is the possibility that the test may cause damage to the insulation which will show up after the machine has been placed in service. The A.I.E.E. standards pertaining to high potential testing of new apparatus are accepted by electrical manufacturers and others. It is, therefore, general practice to apply such a high potential test to all new windings.

The removal of a generator from the bus in case of trouble, before complete failure of the insulation and damage to iron occurs, is most important. Today there are high speed differential relays that function effectually to remove the generator from the bus due to internal fault. However, such devices do not protect the generator against dangerously unbalanced polyphase loads or single-phase operation in cases where the fault occurs outside the differential circuit. Therefore, the present day problem is to know just how far an engineer should go with this kind of protection. In many installations engineers have placed additional differential protection on the busses in the outside switchyard.

It might be interesting to recite a case representing a recent accident in respect to a 12,500 kv-a turbo-generator. This generator was located in a utility plant and the winding of the machine had proper differential protection. A fault occurred at the main bus in the outdoor switchyard and resulted in a single-phase load being imposed on the generator. This caused a complete burning out of the stator windings and there was sufficient damage to the rotor of the machine so that a complete rewinding of the unit and some new stator iron was necessary before it could be restored to service. In this case the single-phase fault occurred outside of the differential protection and, therefore, the protection afforded no relief to the generator from the single-phase condition. The cost of this accident was approximately $42,000.

There have been a number of turbo-generator rotors damaged in the last few years due to this same trouble of a decidedly unbalanced polyphase load or a single-phase load. The only time, unless complete failure results, that the symptoms of such damage can be determined is when the rotor is removed from the stator for examination. The results of such a decidedly unbalanced load or single-phase operation are manifest at the point of contact between the wedges and between wedges and retaining rings. A turbo-generator without an amortisseur winding should not be permitted to operate with an unbalanced current greater than 10 per cent at normal load without the manufacturer's approval.

In most plants it is standard practice to connect turbo-generators solidly to the station bus through oil circuit breakers and depend upon feeder sectionalization in case of load faults. It is advisable, however, where small industrial plants are operated with an outside system of considerable capacity, to provide relay protection to guard against the dumping of such a load on the small unit through fault in the outside system. The same is also true of an unattended automatic water wheel station of nominal rating, and, in addition, field failure protection for such units is advisable.

It is not only good practice to install protective devices, but it is also equally essential that such protective devices be properly maintained if they are to be effective. Therefore, when load conditions permit, the protective relays should be periodically tripped manually to assure that the tripping circuits in allied mechanisms are in good order and will actually function; and relays should be tested with a phantom (artificial) load to check the calibration and determine whether they will operate at a predetermined setting.

On a closed system of ventilation it is important to provide an alarm device in the generator housing to indicate water leakage in the cooler system. In case of loss of water in the cooler of an enclosed cooling system the object can continue operating for only a very short time at maximum load before serious conditions will develop.

It is good practice to open a generator periodically and examine the windings, end turn supports, lacings, and wedges, and to see that the spacing blocks are tight and in place. The rotor should be examined for cracked or loose retaining rings. Not infrequently retaining rings have been found to be loose and this is usually indicated by a rust discoloration at the point where the rings are shrunk onto the forging or sometimes where the disc is secured to the shaft.

Statistics show that the breakdown of insulation between conductors or between conductors and ground accounts for 23.4 per cent of the total number of accidents to electrical apparatus. Considering the initial part broken, stationary armature winding failures account for 40.3 per cent of the total number of accidents to rotating electrical machines.

The foregoing figures on failures and the recommendations given are based on insurance experience over thousands of electrical machine-years under widely differing operating conditions. Aside and apart from the observance of these suggestions, however, the safety of any individual machine depends on the intelligence with which it is handled. Therefore, the operation should be entrusted only to operators who can be relied upon and who have a thorough understanding of the principles involved both in regard to the proper operation and to the dangers arising from improper operation.

The largest LaMont boiler in the world is to be installed in the Deptford West Power Station of the London Power Company, Ltd., it is reported in *The Steam Engineer*. The new steam generator is designed for an evaporation of 350,000 lb per hour at a working pressure of 375 lb and 780°F. temperature. In the LaMont boiler there is forced circulation of water.

Dismantled Inspections of Engines

Good engine maintenance, of necessity, includes periodic dismantled inspections as a means of reducing accidental shutdowns, because such procedure is the only way known for preventing some of the more serious breakages, which are apt to wreck a costly machine.

Most of the trouble which it is sought to avoid by means of dismantled inspections is caused by progressive cracks which are hidden with the engine fully assembled, but which in many instances are apparent on dismantling. By dismantling is not meant the complete over-hauling of the engine at one time, but rather the establishment of a routine for staggered dismantling of various engine parts to permit what amounts to a continuous check of the most prolific trouble sources. It has been conclusively proved that engine life is prolonged by such an orderly program of examinations.

Usually it is possible to make one of the vital engine parts accessible for inspection and overhaul without disturbing the rest of the unit. This is particularly true in the case of steam engines. Therefore, at convenient times, such as over a week-end, some one part may be removed and its condition ascertained in a satisfactory manner without any loss in production. At subsequent times other parts may be examined until the entire unit has received attention. Once such a schedule has been set up (and Hartford Steam Boiler inspectors will be glad to give full assistance to any policyholder in perfecting such a routine), it is an easy matter to schedule its repetition throughout the life of the engine.

Certain parts, such as crossheads, connecting rods, crankpins, piston rods, follower bolts and crankshafts, are most susceptible to trouble from progressive cracks, which may develop from a variety of causes. Cracks in reciprocating engine parts often occur because of some unusual shock, but it may not be possible to discover them until several months of operation bring about an extension of the cracks so that they may be found by dismantling this part.

Of all engine parts the crosshead appears to be the most vulnerable. Broken crossheads have led to more engine breakdowns than any other of the reciprocating parts. These accidents have been serious because they affect not only the crosshead but also the entire engine. For example, a progressive crack on the inside of a cast iron crosshead recently brought about the wrecking of the high pressure side of a large cross-compound Corliss engine. It is likely that a dismantled inspection would have averted the breakdown which resulted in an extended shutdown of the plant.

In another case, a progressive crack started from the inside of the cast iron crosshead at the corner of the box and extended to the pin. The outside end of the pin was held rigid while the other end was moving back and forth with the thrust of the piston. This made the crack travel until the crosshead broke in two with one part attached to the connecting rod and the other part to the piston rod. The connecting rod and the part of the crosshead still attached to it continued to travel back and forth with each revolution of the flywheel, pounding against the loose end of the piston rod and thereby breaking the cylinder head and

Figure 1—Broken parts following the failure of a cast iron crosshead. A dismantled inspection probably would have prevented this accident.

part of the cylinder. The only manner in which this crack could have been discovered and the failure prevented, would have been by dismantling the crosshead, as the inside of the crosshead could not otherwise be seen. The direct damage amounted to more than $11,000.

Figure 1 illustrates a failure that occurred on a cross-compound Corliss engine having a 56″ low pressure cylinder. A crack on the back side of the cast iron crosshead, on the high pressure side, progressed until the solid metal on the front side was broken. Both cylinder heads were pushed out with subsequent breaking of other reciprocating parts. The damage amounted to more than $8,000.

(Continued on Page 88)

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

SIDNEY B. COATES, *Editor*

HARTFORD, CONN., July, 1938

Single copies may be obtained free by calling at any of the Company's offices.
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each.

Paul Edward Terroy

Paul Edward Terroy, Chief Inspector for the past 10 years at the Baltimore and New Orleans departments respectively, died April 10, 1938, at New Orleans, following a major operation. Mr. Terroy joined Hartford Steam Boiler in May, 1917, and for the next 11 years devoted himself diligently to field inspections, boiler shop inspections and inspection department office matters in the Atlanta department. His training with the Company was under the late Charles Ross Summers, for many years chief inspector at Atlanta, and Mr. Terroy showed himself an apt pupil under the latter's generous leadership.

He was promoted to the position of Chief Inspector of the Baltimore department on April 1, 1928, and on January 1, 1934, was transferred to the chief inspectorship at New Orleans.

Born on January 27, 1889, at McGantic, Quebec, he came to Massachusetts as a boy and attended primary schools there until 1904. This much formal schooling, however, did not satisfy him and he continued his studies, completing a correspondence course in steam engineering, a course in higher mathematics, and an 18 months' night course in electrical engineering, the last named at the Georgia School of Technology.

Mr. Terroy's ability brought about his continued advancement in the Company and his death cut short a meritorious service in the furtherance of Hartford Steam Boiler's inspection and engineering standards.

Burt Orman Burhans

Burt Orman Burhans, Directing Inspector in the Chicago Department and for 34 years a member of the inspection staff of the Company, died April 16, 1938, following an extended illness. During the later years of his service Mr. Burhans became unusually proficient in training the younger members of his department. He assisted in organizing an inspectors' class, a sort of round table, of which he was the recognized leader and guide. Not only did he pass along to his associates the rich experience which he had gained, but through constant study up to the time of his final illness kept his guidance in tune with the latest engineering developments. The veteran Chicagoan was held in extremely high esteem not only by those policyholders who knew him but by every member of the Chicago Department. Mr. Burhans was born August 28, 1872, at Essex, Iowa. He had beeen associated with the Company since March 14, 1904, and was made directing inspector in the Chicago Department on August 1, 1929.

Arthur H. Kelly

Arthur H. Kelly, retired inspector in the Baltimore Department, died April 7, 1938. He was born in 1869 in Great Britain, served at sea until 1910 and for 21 years, until July, 1931, was an inspector serving policyholders in the Company's Baltimore Department. Mr. Kelly did particularly meritorious work during the trying years of the World War and his entire service was characterized by an intense loyalty. He retired with an enviable record.

THE COVER

A view in The Hartford Steam Boiler Inspection and Insurance Company feedwater laboratory where hundreds of boiler feedwater analyses are made annually.

N. F. Bailey New Chief Inspector at Atlanta

N. F. Bailey, formerly office engineer in the Atlanta department, has been promoted to the post of Chief Inspector of that department, effective May 27, 1938. He succeeds the late Charles Ross Summers.

Born at Demopolis, Alabama, February 25, 1900, Mr. Bailey has resided principally in the South and his experience with Hartford Steam Boiler has been in the Atlanta department where he served under Mr. Summers as an inspector for about seven years from May 1, 1926, first in the Birmingham district and later out of Jacksonville. He was made office engineer in 1934.

After attending grammar school and high school at Demopolis, he entered Alabama Polytechnic Institute, from which he was graduated in 1923. His next years until his coming to Hartford Steam Boiler were with the Westinghouse Electric and Manufacturing Company, with which he served first as a test engineer in the Pittsburgh Manufacturing division and later as a service engineer in the Atlanta-Southeastern division. His 12 years with the Company have been marked by a broad experience in inspection and engineering work.

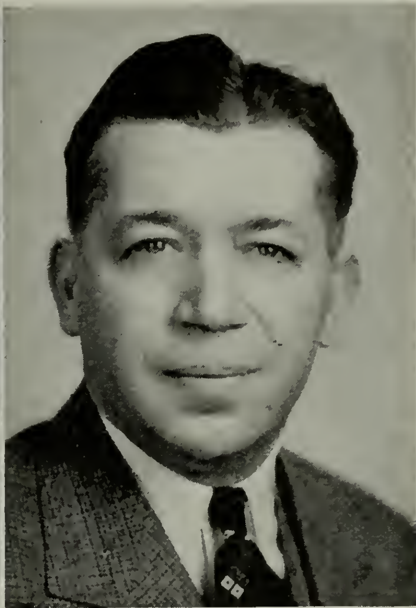
Arthur R. Keiler to New Orleans as Chief Inspector

Arthur R. Keiler, formerly of the St. Louis and New York departments, has been appointed chief inspector of the New Orleans department effective May 24, 1938, to succeed the late Paul Edward Terroy.

Mr. Keiler entered the employ of the Company in May, 1929, and served as a field inspector in the New York department until October, 1934, when he was made an office engineer. After a year in that capacity in New York he was transferred to the St. Louis department as office engineer.

Mr. Keiler was born in Jersey Shore, Pennsylvania, December 28, 1898. He studied mechanical engineering at Bucknell University and later took extension work at both Pennsylvania State College and Pratt Institute. For 11½ years prior to his coming with Hartford Steam Boiler he was employed in the boiler shops of the New York Central Railroad Company. His extensive training in the field of locomotive work and his wide experience with Hartford Steam Boiler fit him ably for the new responsibilities he now assumes.

N. F. Bailey



Arthur R. Keiler

Embrittlement Prevention

(An Editorial)

Elsewhere in this issue is a somewhat comprehensive article on the subject of embrittlement in boiler steel. The article, among its other subject matter, contains accounts of research by both the University of Illinois and the Bureau of Mines whereby the knowledge of embrittling action is advanced to a considerable extent. Of particular import is the offer by the University of Illinois Chemical Engineering Department to make available to all interested parties the results of boiler water testing in a testing device which has been designed to produce conditions simulating those in boilers. Research of this sort is to be highly commended, first, because it is an important step in accident prevention, and second, because it should help save boiler owners the heavy expense associated with the weakening of steel boiler plates because of embrittlement.

The history of embrittlement research is more than a quarter-century old and Hartford Steam Boiler has throughout that period been consistent in furnishing to research workers the practical results of its discovery of hundreds of cases of embrittlement in boilers throughout the country. The Company concentrates its efforts on the early detection of defects and on remedial measures where the trouble is found. It also seeks in every way possible to keep its assured in touch with research on the prevention aspects of the subject and through its own feedwater analysis service to guide boiler users in accord with tested practices. Embrittlement and, for that matter, all feedwater problems are important to all boiler users and the Company's laboratory and engineeering staff are always available to assist them in any way possible.

Dismantled Inspections of Engines

(Continued from Page 83)

The frequency of cracks in crossheads has brought a recommendation for the replacement of cast iron crossheads with crossheads of steel. The reason for this lies in certain inherent properties of the two metals. Cast iron has very little elasticity or ductility so that the shocks which inevitably occur on a reciprocating engine will more readily start a crack in a cast iron crosshead.

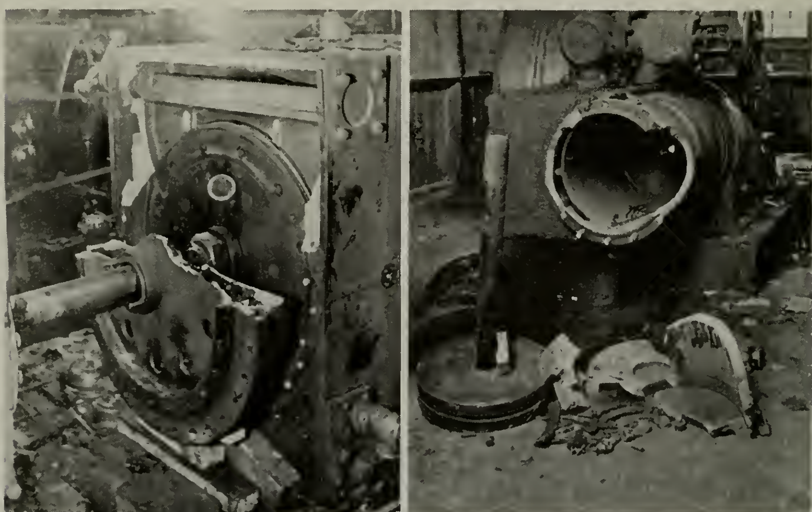


Figure 2—(Left) the result of a connecting rod crack. Figure 3—(Right) the result of a failure in the threads on the piston rod just inside the crosshead.

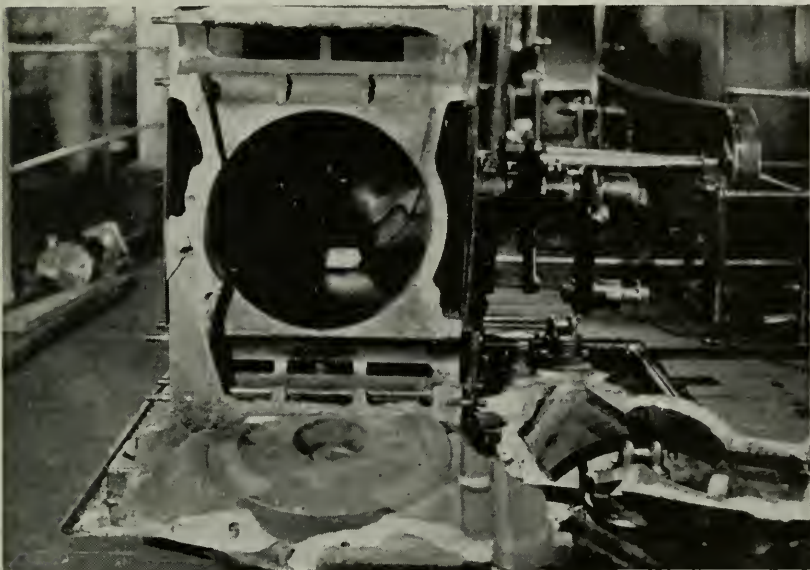


Figure 4—An accident attributed to the failure of follower bolts.

Recently, the connecting rod on one side of a large twin-tandem-compound steam engine broke and caused this side of the engine to be almost completely wrecked. The failure resulted from a progressive crack in the eye of the rod at the crosshead end. An accident not involving the connecting rod, had occurred to the same side of this engine several years previously and, at the time of this first accident, a close examination of the connecting rod revealed no defects. However, the previous accident probably started the crack and if a definite routine of dismantled inspections had been carried out, this costly failure could have been avoided. Figure 2 shows what happened to the cylinder after the connecting rod broke.

The breaking of the crankpin of a side crank engine is usually the result of the engine having suffered some severe shock, such as from water in the cylinder, during its operating history. Such a shock may start a surface crack which eventually extends through the cross section of the pin until the remaining sound metal is over-stressed to the extent that sudden failure occurs.

Piston rods that are threaded into the crosshead have often failed in the threads just inside the crosshead. Figure 3 illustrates the damage resulting from such a failure. Piston rods with tapered ends and fitted with a gib key are also subject to failures of the rod or of the crosshead neck itself.

It is a rather common mistake, when piston follower bolts are screwed "home," to place excessive leverage on the wrench. This is almost certain to damage the bolts in that a small crack is started at the root of a thread or directly under the bolt heads. This practice has led to numerous serious cylinder breaks such as the one shown in Figure 4, in which a follower bolt failed from a progressive crack. Follower bolts should be regularly inspected because they are especially subject to fatigue cracks.

The failure of center-crankshafts is, in a large majority of cases, due to a progressive crack that has existed for some time and its extension has finally so weakened the shaft as to cause complete failure. Such cracks start because of the constant bending action that may take place in the shaft or the crank webs as a result of (a) misalignment of the bearings, (b) the effect of a heavy over-hung flywheel, or (c) heavy belt tension. The procedure of exposing the shaft for inspection has permitted the discovery of a large number of cracks before failure actually occurred. In plants where dismantling routine has been established there is an increased confidence on the part of the operators, for this routine permits operation with fewer outages because of accidents.

Temperature Control for Hot Water Supply—A Correction

In an article in the April Locomotive entitled "Hot Water Tank and Heater Explosions" it was stated on Page 44 that "temperature relief devices are designed and regulated to shut off the heat supply before the water in the tank reaches 212° (usually between 120° and 140°)." The sentence should read temperature "control" devices instead of temperature "relief." The latter, of course, are usually set to function between 200° and 212°. Temperature control devices should shut off the heat when the water has reached a temperature between 120° and 140° as stated in the article. In some instances, when hotter water is desired, control devices are set as high as 180°, but water at this temperature is too hot for average domestic use.

Boss—You are 20 minutes late again. Don't you know what time we start work at this factory?

New Employee—No, sir, they're always at it when I get here.

"With feet like yours you should get a job with the government."
"What doing?"
"Stomping out forest fires." —*Zip 'n' Tang.*

Taps From the Old Chief's Hammer

It was the day after the department picnic and Tom Preble and the Old Chief were commenting on the good time everybody had had on the previous afternoon.

"A great game of ball," commented Preble.

"A fine feed," said the Old Chief.

"With no exceptions," added the younger man. "I thought a hamburg was just a hamburg, but Dad Jim's were masterpieces. I'd like a picture of him in colors—squatting over that fire, his face flushed by the heat, his white hair a bit mussed, his sleeves rolled up, and turning out that meat—his own special recipe and cooking. Proud? He loved it."

"He certainly did, but heat always was the environment Dad Jim loved best before he retired. He gave us an illustration as we talked while the rest of you went for a swim. Dad Jim was in just as good form then as he was later at the fire."

Tom knew that the Chief was hankering to tell a story or two from the picnic, and that when tongues are loosened about old times many a useful bit of information is apt to be forthcoming, so he said, "I'm sorry I missed the circle, Chief. What happened?"

"Nothing much, but Dad Jim harked back to a good story I hadn't heard. It was about a hot job," . . . and the Old Chief was away with a free rein.

"It seems one of our assured had purchased a new boiler and was having plenty of trouble. Dad Jim was sent down. I'll try to tell the story in his words.

" 'When I arrived at the plant, the boiler was in operation and they were attempting to burn slabs of green wood from a sawmill nearby.

" ' "What's the matter?" I asked.

" ' "Too much," replied the fireman, who was also the engineer. "I don't seem to be able to make enough steam to run the plant."

" 'The new boiler was big enough all right, but it was never made to burn wood, so I said, "Why don't you try coal?"

" ' "That's just what we did," was the reply, "but it won't work either. After we had used wood for a week or so with poor results, we shifted to coal, but things were just as bad. That's why we sent for you."

" 'A peek into the ash pit showed that it was very dark—no glow from the fire, which, of course, meant that there wasn't much draft even with the door open.

" 'I had the fireman clean the grate bars in front as much as possible and found that the air spaces appeared to be completely closed, so that the only air for combustion was through the fire doors.

" 'Then I asked the owner for enough coal to run the plant all of the next day and for the fireman to meet me at the plant after supper, when we put on our overalls, and as soon as we could stand it, got into the furnace.

" 'What a job! The sap from the green wood had fused with the ashes to form a hard paste that completely sealed the air spaces. We worked a good part of the night, but we got that grate clean.

" 'After firing up—with coal this time—I stayed with the boiler until the whistle blew the next night. There was no trouble getting enough steam that day and we had no more complaints, so I guess the medicine cured the patient.' "

"How old was Dad Jim when that happened," asked Tom.

"How old? Oh he'd been with us about 10 years. He worked 30 more before his retirement, and he's spry enough yet, as you saw yesterday afternoon."

"He certainly is, but look at those other Old Timers. They seem to keep hale and hearty, too."

"Sure, Tom," mused the Old Chief. "There's dirt and soot around a boiler, but there's exercise as well in climbing through furnaces and boiler shells."

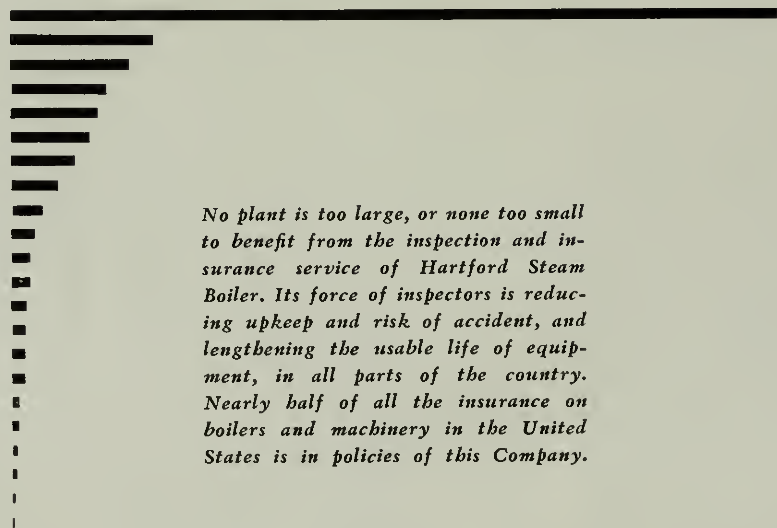
"There's something else, too," Preble broke in. "Dad Jim's like an old country doctor who keeps on working year after year. Late hours and long roads don't tire him for long, and hard work is his medicine . . . and Chief, don't you think being able to do a good turn now and then helps?"

The old man smiled and said, "Well, son, I couldn't rightly say. That's something maybe you should ask Dad Jim."

City banker (visiting the farm): "I suppose that's the hired man."
Farmer (who has visited bank): "No, that's the first vice president in charge of cows." —*The Standard.*

HARTFORD STEAM BOILER'S LEADERSHIP IN THE FIELD OF ENGINEERING INSURANCE IS THE RESULT OF 72 YEARS OF CONSTRUCTIVE SERVICE TO INDUSTRY—1866-1938

The extent of that leadership in 1937 is presented graphically below. At the right are the boiler and machinery insurance premiums of all the companies writing these lines of insurance in 1937, as taken from the official returns filed with the several state insurance departments. The heavy lines show graphically the proportion of the total business written by each company.



HARTFORD STEAM BOILER	$ 7,305,815
No. 2 Company writing the line	1,371,055
No. 3 Company " " "	1,180,856
No. 4 Company " " "	909,352
No. 5 Company " " "	844,125
No. 6 Company " " "	777,562
No. 7 Company " " "	627,676
No. 8 Company " " "	435,993
No. 9 Company " " "	310,774
No. 10 Company " " "	265,236
No. 11 Company " " "	217,418
No. 12 Company " " "	215,771
No. 13 Company " " "	155,375
No. 14 Company " " "	135,664
No. 15 Company " " "	134,194
No. 16 Company " " "	125,790
No. 17 Company " " "	97,368
No. 18 Company " " "	91,013
No. 19 Company " " "	68,158
No. 20 Company " " "	37,983
No. 21 Company " " "	3,583
No. 22 Company " " "	3,010
	$15,313,771

No plant is too large, or none too small to benefit from the inspection and insurance service of Hartford Steam Boiler. Its force of inspectors is reducing upkeep and risk of accident, and lengthening the usable life of equipment, in all parts of the country. Nearly half of all the insurance on boilers and machinery in the United States is in policies of this Company.

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

December 31, 1937 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,365,891.78
Premiums in course of collection (since October 1, 1937)		835,315.16
Interest accrued on mortgage loans admitted as an asset		3,584.34
Interest accrued on bonds		85,190.24
Loaned on mortgages		206,015.00
Home Office real estate and Philadelphia branch office		642,331.05
Other real estate		328,934.52
Bonds on an amortized basis	$9,244,042.06	
Stocks at market value	6,421,042.00	
		15,665,084.06
Other admitted assets		16,201.39
Total		$19,148,547.54

LIABILITIES

Premium reserve		$8,719,926.02
Losses in process of adjustment		290,746.35
Commissions and brokerage		172,985.00
Taxes		265,000.00
Other liabilities		270,149.49
Liabilities other than capital and surplus		$9,718,806.86
Capital stock	$3,000,000.00	
Surplus over all liabilities	6,429,740.68	
Surplus to Policyholders		**9,429,740.68**
Total		$19,148,547.54

WILLIAM R. C. CORSON, President and Treasurer

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The Best in Porcupine Protection

UP go the porcupine's quills with quick efficiency whenever danger signals. Similarly, Hartford Steam Boiler has a sixth sense for danger in the equipment it insures. But, unlike the porcupine, the Company wasn't born with its present abilities in power plant protection. That proficiency has been developed throughout the 72 years of the Company's experience.

When your equipment is insured by Hartford Steam Boiler, your inspector brings to you the results of new lessons being learned daily by the more than 400 inspectors like himself and broadcast to him by a unique engineering staff organized for just this purpose. Thus, the Hartford Steam Boiler plan is one of constant betterment—*The Best in Power Plant Protection.*

Vol. 42 No. 4 October, 1938

The Locomotive

Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Tube Failures in Water Tube Boilers

In spite of the increased reliability of modern steam generating equipment, plant outages because of tube failures in water tube boilers continue to occur in considerable number and severity. As larger and larger boilers replace former batteries of smaller boilers, gains in efficiency of operation are effected, but at the same time the power plant engineer must assume a new and heavier responsibility. In a word, "all of his eggs are now in one basket" and the failure of a tube in a main generating unit is likely to shut down not only the boiler itself, but also the entire plant.

Physically most tube failures are not serious accidents. Burned out or corroded tubes may be replaced for a comparatively small expenditure, but there is much more to the problem today than the mere failure. Plant engineers must keep outages to a minimum if production is to be maintained. The plant superintendent's responsibility, that of his men and that of the insurance company inspector have materially increased.

Under the old plan of operation, in boiler plants where there were 8 or 10 boilers in a battery, a tube failure would shut down one boiler, but would not seriously inconvenience the plant. If a tube failed, the firemen would simply tell the engineer, who would shut down the boiler with the defective tube and start up another boiler without interrupting operations. At their convenience they would replace the tube in the idle boiler, possibly without even reporting the matter to the management. The total cost might be as little as $25 and the engineer's comment probably would be, "Well, we should have cleaned that boiler last week anyway."

Today a tube failure in one of the large modern boilers is a serious accident, because of its cost in time. Modern water tube boilers are sensitive structures that must not be cooled quickly. Consequently hours and sometimes more than a day elapses before the drums and tubes can be drained and men can enter the combustion spaces to replace the damaged parts. Meanwhile turbines and engines are stopped or run at reduced load because of insufficient standby, and processes requiring steam may be suspended. Sometimes valuable material in process is spoiled because sufficient steam is not available after a boiler tube failure.

Water tube boilers until very recent years were not usually equipped with superheaters and never with water walls. These early steam generators were operated at low rates of evaporation and at relatively low

Figure 1—Deposits of scale at the bends in these tubes permitted general over-heating of an entire row. Finally one of the tubes burst (second from the left in the picture), but the warning came too late.

pressures and temperatures, in comparison with the ratings, pressures and temperatures (both furnace and steam) in use today. The modern steam generator is a complicated structure composed largely of boiler, water wall, superheater and economizer tubes. Within them water and steam should circulate uninterruptedly, if they are to survive the temperatures resulting from modern scientific firing—whether with stoker-fed solid fuel, pulverized fuel, oil or gas.

The Importance of Adequate Circulation

An important principle of the modern steam generator is adequate circulation, and, in the newer designs, more and more rapid circulation as greater amounts of water are turned to steam in ever smaller generating equipment, that is, smaller per unit of steam-generating capacity. This development has necessitated the design and construction of boilers that are as sensitive as turbines. Their successful, efficient and safe operation is dependent on proper speed—of fuel to the burners, of gases through the passes of the boiler, of water from the feedwater heaters to the pumps and from the pumps into the boilers, of steam from the tubes and drums, and of steam through the superheaters and piping to the turbines or other prime movers.

The modern boiler is like a prizefighter. The proficiency shown by the latter in the ring is dependent upon many factors—coordination of legs, body, arms, head, eyes—all moving smoothly, shifting to meet the opponent's attack or defense. If any of the many factors is inadequate, it is likely that that deficiency will lead to defeat. So it is with modern boilers and particularly with the tubes in those boilers. If any element of circulation on which the rapid absorption of heat through the tube walls depends is disturbed, burnt tubes are apt to result.

Most failures of tubes in water tube boilers are definitely attributable to over-heating, but the primary causes of that over-heating are several, the most prominent having to do with the problems of feedwater treatment and circulation. It is a primary principle of satisfactory operation that tubes must be adequately cooled by means of the water or steam passing through them. Yet, this elementary principle of boiler operation is frequently violated, if recent accidents furnish the proper clue by which to judge.

Failures Because of Scale and Sediment

Figure 1 shows 6 of 17 water wall tubes in a medium sized boiler. One of the tubes has ruptured and wherever an "X" has been placed on the photograph, there, bulging and thinning has occurred. The eleven other water wall tubes were similarly damaged. Several factors may have played a part in this accident. Examination after the accident revealed the presence of 1/32″ to 1/16″ scale at the bend in the water wall tubes immediately above the stoker at a point of high radiant heat impingement. As an identical boiler in another part of the country operates satisfactorily scale-free, it was evident that the troublesome variable at the plant where the accident occurred was the feedwater or the feedwater treatment. In this case a condition which may have aggravated the situation was an attempt to operate at extremely high ratings by means of forced draft.

In another case a slag cradle tube in a high pressure boiler failed after two weeks of operation because of phosphate deposits. Pending the installation of softening and filtering equipment, the slag cradle tubes were washed out and carefully inspected at 10-day intervals.

At a paper mill, baffle wall tubes cracked in several places as the result of from 1/64″ to 1/32″ scale, coupled with flame impingement. It was advised that if tubes showed in excess of .01″ scale in such boilers (this installation operated above 600 lb pressure) the tubes should be bored.

Figure 2 shows two superheater tubes from boilers in widely separated plants and owned by different companies. Both of these tubes,

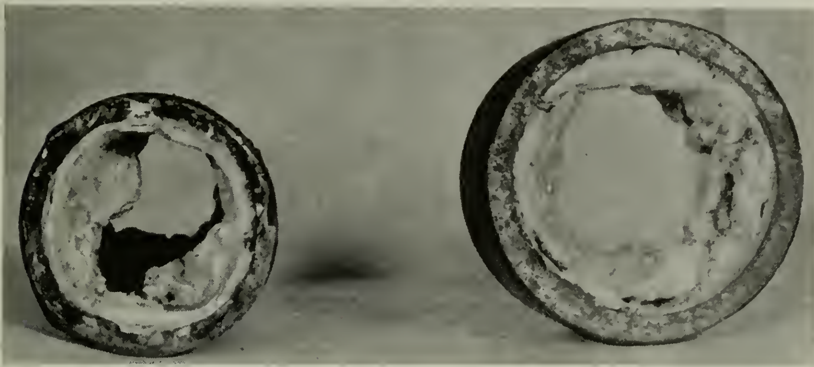

Figure 2—Superheater tubes from two boilers in widely separated parts of the country. Carry-over of solids in the steam rapidly builds up such deposits.

from affected sections of the superheaters, contain a hard scale which in some of the tubes nearly filled the steam space. These deposits occurred in boilers operated only four or five weeks and were from wet steam carried over from the drums. Impurities in the feedwater were the primary cause, but other factors such as the height of the water in the boiler, the arrangement of steam scrubbers, circulation and gas passes were contributory.

Feedwater difficulties with respect to all boiler tubes are a problem because of the rapid changes which sometimes occur in the composition of the feedwater. In a large boiler a change in feedwater treatment was made, although no trouble had resulted from the prior treatment. A tube in the bottom row burned out because of scale deposited as a result of the new treatment and the burnout was the first indication that something was wrong. If any change in feedwater treatment is made, it is best to watch the boiler with unusual care for a few months, but even such watchfulness does not always avert trouble.

Changes in the raw water supply are also an aggravating cause of tube troubles. At a New England metal working plant an increase in the amount of sediment in the boiler supply from a pond produced a thin scale which gradually worked off and collected in the tubes where the circulation was slow.

But scale is not a necessary requirement for tube failures because of faulty feedwater. Free oxygen in boiler water that had not been properly deaerated has brought about serious pitting and subsequent failure of tubes (before proper deaerating was carried out). In such tubes there was almost absolute freedom from scale.

Figure 3—A bank of tubes in which magnetic oxide formed due to excessively high temperatures.

Difficulties with Superheater Tubes

Sometimes superheater tubes are "starved" because of improper operating practices in starting the boiler and in shutting it down. A recent article in *Combustion* discussed this problem as follows:

"For a considerable period during these operations (starting up and shutting down) the boiler stop valve is closed and no steam passes through the superheater to the steam main, although hot gases are passing over the superheater surface. To meet this condition the superheater is provided with a suitable drain valve on both the saturated and the superheated-steam headers. The purpose of the drain valve on the saturated-steam header is to remove any condensed steam in the header and thereby permit free movement of steam from the boiler to the superheater units. This valve is closed as soon as the condensate is drained away. The drain valve on the super-heater header when open will permit some circulation to take place through the superheater units which protects them while the boiler is gradually brought up to the operating pressure.

"Too frequently operators give only a half turn to the drain valve, having in mind the saving of steam. Although some circulation is set up thereby, it may not be enough to protect the superheater. The size of the valve is selected with the express purpose of passing sufficient steam to get the desired circulation, and boiler operators should take advantage of it. It is far better to lose a few dollars in steam then several hundred dollars in superheater tubing. The drain can be directed to a sewer through piping of the same diameter as the valve. It should never be connected to a trap or any contrivance which might hinder the free flow of steam. When the boiler has reached the operating pressure and is on the line, then and only then, should the drain valve be closed. When the boiler is being taken off the line the drain valve should be opened again as soon as the stop valve is closed, and remain open until the boiler is placed on the line again.

"In some plants it is necessary to bring the boiler on the line far more rapidly than is normal practice. This requires a large release of heat in the furnace in order to generate steam rapidly. To meet this condition plenty of steam circulation and velocity is necessary through the superheater units. Drain valves larger than those usually furnished will aid the situation. Under extreme conditions as with a radiant-type superheater, it may be necessary to furnish steam from another boiler in sufficient quantity to keep the superheater cool until the boiler reaches the operating pressure and is placed on the line.

"The boiler operator will find it very convenient to insert a thermometer in a thermometer well located in the superheated-steam header, and, as the boiler is building up pressure, make periodic observations of the steam temperature. This will permit close control of the drain valve so as to keep the temperature down to a safe limit of about 800° F. and at the same time drain only as much steam as is necessary to keep within this limit."

Figure 4—A close-up of the tube which signalled the difficulty illustrated in Figure 3. The rupture is 7" across.

The Formation of Magnetic Oxide of Iron

Another type of failure involving circulation and combustion difficulties is the oxidizing of the interior tube surfaces. In several recent cases a combination of high furnace temperatures and insufficient steam velocity in the tubes has resulted in the formation of magnetic oxide of iron, Fe_3O_4. When in contact with steel at elevated temperatures, steam breaks down into hydrogen and oxygen, the latter combining with the iron to form magnetic oxide. At temperatures of 1000°F. the rate of oxidation by decomposition of the steam becomes rapid enough to be serious. Figure 3 shows a bank of tubes in which the above type of failure occurred and in which considerable quantities of the characteristic black magnetic oxide adhered to the inner surface of the tube in sufficient amount to bring about the tube rupture shown in Figure 4. When the bursting of one tube signalled that there was trouble in the boiler, the over-heating had progressed so far that it was necessary to remove 272 tubes. This boiler contained no oil, scale or sediment and there was no evidence of low water. It is sought to prevent a repetition of the difficulty by a change in the arrangement of baffles.

In another case involving the failure of water wall tubes because of the formation of magnetic iron oxide additional water wall circulators were installed as a cure.

Operation at High Ratings

Operation at high ratings was blamed for the bulging and bursting of several tubes at another plant. When the boiler was being pushed, the combination of insufficient furnace volume, high furnace temperatures and flame impingement caused the over-heating of clean tubes. In this instance, at a pulp mill, two sulphite "cooks" were lost as a result of the boiler outages.

Actual Operation the True Test of a Boiler

During the months that a new boiler is on the drafting board, is being built and being erected, many problems can be solved, but not all. The first few weeks of operation of a large-capacity high-rating boiler are the most important because it is in that period that the essential item of field experience is added to cumulative power plant practice and the betterments that have gone into the design. Because of the varied conditions to be met and the wide variety of fuels encountered, each unit presents an individual problem for the designer. His task would be simplified and results could be predicted more definitely, however, if there was assurance that the unit would be operated under the load conditions and fuel specified; but local practices often have altered these anticipated conditions with subsequent cases of tube difficulty.

Tube failures of the sorts discussed in the foregoing material are somewhat complicated as to cause and remedy, because so many factors have a bearing on satisfactory results. Difficulties from improper operation involving the human element are simpler to account for, but harder to anticipate and prevent—the first time, at any rate.

Blow-Down Practices

Although it has been common practice to open the blow-off valves with boilers in service to reduce the concentration of the boiler water, such practice is very likely to be detrimental to boilers with water walls. Boilers should be blown down through the water walls, that is, from the blowdown connection of the lower water wall header, only when the boiler is practically shut down. It may be hot and with fires out or banked, but not steaming at anything more than a very low rating.

Blowing down from a water wall header is likely to cause a serious disturbance in the orderly circulation, and some appreciable time is needed to re-establish that circulation after the blowdown operation ceases. It is during this period of restoring circulation that tube trouble will result with the boiler in operation. Repeated experience with this difficulty shows that the overheating takes place in a very short time.

In some installations, in order to keep the concentration within allowable limits, continuous blow-down is used. The connection for this purpose should preferably be made to one of the boiler drums, although it is sometimes made to a water wall header. This latter practice should be resorted to only with the approval of the boiler manufacturer. It is the Company's recommendation that such a connection should not be used at all.

One large boiler manufacturer even objects to blowing down high duty boilers from the boiler proper, to say nothing of blowing down from the water wall headers, because of the possibility of checking circulation in some of the main generating tubes.

Figure 5—Rear wall of the furnace after forgotten open blow-off valves had drained the tubes.

Figure 5 illustrates the costly results of a forgotten open blow-off line with the boiler in service. Forty tubes were burned in the manner illustrated. Other instances of low water have been brought about by improper manipulation of feed valves, a sticking check valve, and an inoperative water level gauge. In the last case the water in a 425 lb boiler appeared too high, so the blow-off valves were opened. As the level of the water in the glass did not change, the operator sensed that there was something wrong and immediately closed the blow-off valves and put the automatic water regulator into operation, but not before seven tubes had seriously over-heated and one of them had ruptured. It was found that the rubber gasket at the bottom of the gauge glass had been forced down in such a way as to practically close the opening, so that there was no passage for the water to the glass.

Of course, low water is caused also because of the carelessness of attendants and because of the failure of mechanical equipment.

Other accidents having to do with mistakes, but not involving low water, illustrate a few of the many things that should be considered in boiler operation. A ruptured superheater tube in an 800 lb. boiler was attributed to the fact that one of the superheater elements had been removed, thus changing the flow of gas in such a fashion that there was a direct impingement against the remaining superheater elements. It was decided to attempt a remedy by inserting refractory material between certain of the top tubes.

In another case steam from an improperly located soot-blower cut through a superheater tube. This failure in turn permitted the superheater steam to impinge on and damage four generating tubes, one of which finally burst, shutting down the boiler.

Six Important Ways to Avoid Tube Accidents

There are many other examples that could be cited of the failures suggested in this article, but enough of them have been given to illustrate the complexity of over-heating and other tube problems. Although many of the cases have similarities, as a rule no two of them involve exactly the same set of circumstances. In other words, the avoidance of tube failure is an individual problem in each power plant and, for that matter, in each boiler. Despite this, there are a few general remedial precautions which, if carefully followed, will avert many outages because of tube failures.

The more important are:

1. In ordering new boilers be sure that all operating factors are accurately presented to the boiler designer and manufacturer.

2. Once a boiler is installed, do not change its operation from that for which it was designed without first consulting the manufacturer and the insurance company engineers.

3. Do not operate boilers at excessively high ratings.

4. Provide a constant check on feedwater. After any major change in treatment watch the boiler carefully for several months. The accumulation of deposits sometimes does not reveal itself until a tube fails, but usually such difficulties can be anticipated and averted by proper analysis. Of course, concentration leading to foaming and priming should be avoided.

5. Modern boilers are designed with a certain fuel or fuels in mind. If a change of a major sort is contemplated, the characteristics of the new fuel should be carefully studied before an expensive piece of equipment is seriously affected by excessive furnace heats, changed characteristics of the ash, or marked differences in the gases of combustion.

6. Be sure that all persons who have to do with the operation of boilers be instructed thoroughly in the routine that they are to follow both in time of normal operation and in an emergency. A system of checks, one man against another, will often avoid the results of inadvertent mistakes.

Boiler Embrittlement—1938

The Importance of Sodium Chloride

On Page 72 of the July, 1938, issue of the THE LOCOMOTIVE was presented a discussion of the relation of sodium chloride to the prevention of embrittlement, as revealed in recent research. The discussion should have cited a 0.60 *ratio* of sodium chloride to total alkalinity instead of a *percentage* of 0.60 as stated. With this change the assumption with respect to a possible source of sufficient sodium chloride is not well sustained. However, as sodium chloride appears to be a determining factor, a sufficient amount of it must have been present in boilers under Company supervision, because trouble has not ensued when the proper A.S.M.E. sulphate to carbonate ratios were followed.—Editor.

THE COVER

This view shows a furnace of the kind used for the stress relieving and heat treating of welded vessels. In the case depicted a vessel made of stainless steel is undergoing heat treatment rather than stress relief. The furnace was opened while at maximum temperature to permit photographing.

Escaping Steam from Burst Water Tube Stops Auxiliary Motors and Production

ORDINARILY water tube boiler tube failures shut down the boiler in which they occur, but cause little other property damage. This was not the case in an accident in May at a Midwestern manufacturing plant. Before the accident sequence was finished many of the auxiliaries for two large boilers had been put out of service when escaping steam saturated the power house and damaged the motors driving the auxiliaries.

A corner of the furnace of a pulverized-coal-burning, 220,000 lb per hour, 700 lb pressure boiler had pushed out, permitting the escape of molten slag. An employe was directing water on the slag in an attempt to solidify it and plug the hole. Meanwhile the slag over-heated a water wall tube so that it burst, spraying the workman with steam and hot water and filling the powerhouse with steam.

The escaping moisture damaged 17 motors on auxiliaries, including feed pump, pulverizer, exhauster, coal feed, scale and forced draft motors, and rendered inoperative not only the boiler in which the tube had failed but also a 240,000 lb per hour boiler in the same powerhouse. It was nearly two days before the larger boiler could be returned to service and four days before the tube and furnace were repaired and the other boiler was on the line. The repair of this boiler was slowed up because of the necessity of removing a quantity of solidified slag which was about the consistency of cast iron. Property damage amounted to nearly $4,000 and there was a large Use and Occupancy loss in addition.

Part of the property loss included the cost of resetting about 400 blocks in the furnace of a third large boiler which was under construction. Condensate from the escaping steam had gathered on the tubes of this boiler and had softened the plastic material between newly installed blocks and the tubes. (This plastic material must be subjected to a high temperature before it will set.)

In seeking to avoid a recurrence of the slag trouble, the expansion joints of the water walls were re-designed, as the accident was attributed to slag getting between the plate forming the expansion joint and the furnace wall, pushing the latter out far enough to permit molten slag to escape.

During a visit to a British factory, several management experts were baffled by one of the workmen. All the other employees pushed their wheelbarrows, but he pulled his. After much conjecture, one of the experts asked him why.

"Well, Guv'nor," he replied, "I 'ates the sight of the bloomin' thing."—*London Times.*

Fire Tube Boiler Accidents

Causes and Remedial Measures Discussed.

TWENTY-NINE persons were killed and 46 injured in 34 boiler accidents which have come to the attention of THE LOCOMOTIVE since the first of the year. These accidents occurred in 19 states in manufacturing plants and other business establishments, oil drilling operations, domestic properties, and on railroads. Reasons for them and other recent accidents of the same sort in which persons were not injured, and precautions against the occurrence of similar accidents to any power or heating boiler should be of interest to every boiler owner.

Figure 1—300 tons of locomotive toppled into a Montana river by the explosion of the boiler.

The most serious accident was the explosion at about 11:00 P. M. on July 7 of a large Z-6 type freight locomotive (4-6-6-4 wheel arrangement) in Montana. The 300-ton locomotive up-ended, fell across transmission wires and crashed into the Clark Fork River as shown in Figure 1. In addition to the engine, property damage included destruction of about 200 feet of track and 7 boxcars. The engineman, fireman, brakeman and two transients were killed and four transients were seriously injured when the sudden stop knocked them from the train or piled them up inside of cars. The fact that the accident occurred at night added to the confusion.

A similar accident with less serious damage to the train, but one which caused the death of the engineman and fireman, occurred at Cedarville, Ohio, on August 25. The dropping of the crown sheet flooded the cab with steam, but the boiler did not leave the trucks. The two men were either blown out or jumped, and the train, a passenger flier, coasted three miles to a stop as the steam pressure fell.

This last accident brings to mind a famous explosion in France of a passenger locomotive pulling a train en route to Paris between St. Gervais les Bains le Fayet and Dijon shortly after August 1 midnight, in 1935. Passengers who were awake heard a loud explosion, although a violent storm was raging at the tme. When the train came to a stop, trainmen and passengers alike were amazed to find that the boiler of the locomotive had disappeared. The explosion, which killed both the engineman and fireman, occurred on a curve, the boiler traveling tangentially about 500 feet into a field, while the frame and wheels were pushed around the curve on the track by the momentum of the train. In this case the breaking of the compressed air connections automatically applied the brakes and the train came to a stop from a speed of about 50 miles an hour in a little over a quarter of a mile.

The railroads of the United States and the Interstate Commerce Commission (which government agency supervises the inspection of locomotives on public railroads) are doing everything in their power to stop the kind of accidents described above, the prevention of which appears to be the most difficult of all safety problems in connection with the locomotive type boiler. Such accidents are usually caused by low water, followed by the over-heating and pulling loose of the crown sheet from its supporting stays. Insurance companies also are studying the problem, because the same conditions are a menace to privately owned locomotives and to the locomotive type of firebox boiler, especially when used in oil field drilling operations. In fact, in recent months most of the explosions of insured boilers of this type have been in the oil fields, but the frequency of such accidents is growing less.

Figure 2 shows a typical oil field drilling location. The picture at the top depicts a well site after the explosion of one of four boilers, the exploding vessel having been set just to the left of the other three. The lower photograph shows the wrapper sheet of the exploded boiler after it had traveled several hundred feet. Luckily the engineer in charge was only cut and bruised and property damage other than to the boilers and fittings was confined to a small factory in which the windows were broken. Although the reason for the low-water condition was not readily evident, a Hartford Steam Boiler inspector who was permitted to examine the installation, attributed the difficulty to dirt and scale clogging the lower water column shut-off valve, thereby preventing equalization of the water in the gauge glass and boiler, thus giving a false reading.

Figure 2—Above—An oil field drilling scene. Below—Outside wrapper sheet of the fourth boiler after it had traveled 900 feet.

The locomotive type boiler, because of its construction and operating characteristics, has long been considered as best suited for both railroad and oil field use, but it has been adapted satisfactorily to many other kinds of work calling for both stationary and portable installations. The advantages of mobility and low initial installation costs may be enjoyed safely if general rules of boiler safety, plus the special rules necessary for the operation of locomotive fire box type boilers, are followed. Of course, such boilers, as well as all power boilers, should be kept free of accumulations of scale and sediment, and should be tended by competent operators—constantly if possible, and regularly at short intervals when constant attendance is impracticable.

In connection with oil field drilling boilers and any others, whether for power or heating use, the attendance of which may be intermittent, it is recommended that the equipment include a low water fuel cut-out with the following specifications:

1. It should be actuated by the level of the water in the boiler through a float or thermostatic element entirely independent of the regular water column, and there should be an emergency fuel control valve in the fuel supply line (with oil and gas-fired units).

2. The operating mechanism should be so designed and so located that it will function positively and immediately when the water has reached the lowest permissible level. This level should be at least 2″ above the highest point of the crown sheet and is that at which the lowest visible part of the glass water gauge should be set.

3. The device should be provided with a dependable means of testing its operating condition when the boiler is in service without materially decreasing the amount of water in the boiler. This may be accomplished by the use of a drain or a special test valve.

4. The pressure for which the boiler is designed should be cast or stenciled on an integral part of the device in easily legible characters.

5. Valves installed for any reason in the steam or water connections between the device and the boiler should be of the straight-way type and secured in the open position. The size of the pipe connections should be not less than 1″ and should be provided with cross fittings at right angle turns in accordance with the requirements of the A.S.M.E. Boiler Code for water column piping.

6. The water level operating mechanism should be connected by a steam or water pipe or by levers to a special emergency fuel control valve located in the fuel branch pipe between the supply header and burner. The steam or water pipe arrangement is preferred to a lever connection.

7. The size and arrangement of piping or levers should be such that the fuel control valve will be closed positively and immediately when the water level mechanism operates.

8. The emergency fuel control valve should be independent of the valve normally used to control the supply of fuel to the furnace. It must be of the manual reset type so that after it has been closed automatically it must be reopened by hand.

Figure 3—Damage following a boiler explosion at a laundry.

Figure 4—A building demolished by an explosion of a vertical tubular boiler which had been poorly patched by welding.

9. A diaphragm operated type of fuel control valve is preferred.

10. The material, design and workmanship of all parts of the combined apparatus should be rugged so that the equipment can be depended upon to operate under the most adverse conditions as respects feedwater, exposure to the elements and neglect. The device should be easily maintained and tested.

11. The low water fuel control should not be connected in any way with an emergency low water feeder.

12. The addition of a small steam whistle connected so as to blow simultaneously with the operation of the water level device is very desirable.

Although low water fuel cut-outs are recommended especially for oil and gas fired boilers, there is no reason why this safety device is not a wise installation for coal fired boilers as well, the operation of the device stopping a stoker motor or at least blowing a warning whistle so that the boiler may be tended in time to prevent a serious accident.

Railroad locomotives and other locomotives privately owned are in some instances being equipped with such safety devices as are outlined above, despite the fact that there is always an operator in attendance. Excellent progress also has been made by the railroads in the design of fusible plugs.

Difficulties because of low water in a locomotive type boiler also were responsible for the accident depicted in Figure 3, an application of this type of boiler to a stationary installation. The laundry where it was used was stopped because of the accident. It so happened that the boiler was hurled across the street into a cemetery instead of into the main part of the laundry, so that employes escaped injury.

Figures 4 and 5 reveal the tragic effects of attempts to repair fire tube boilers by means of welded patches. Although welding engineering has advanced rapidly in recent years, the technique of welding boiler

Figure 5—Wreckage after the failure of a welded patch on a Scotch-Marine type boiler.

patches on fire tube boilers of all types is still far from standardized. Such repairs are not yet recommended.

Two men were injured by the explosion of a vertical tubular boiler at a New Jersey rag laundry in April, the results of which are pictured in Figure 4. The welded patch which failed was roughly 63″ x 14″, and the weld was porous, filled with slag, and had penetrated only ⅛″ into plate 5/16″ thick. The force of the blast demolished the brick building containing the laundry and catapulted the boiler and stack 75 feet.

In the case shown in Figure 5 at a Southern tailor shop, the explosion of a Scotch-Marine type boiler, which failed at a welded patch, leveled a part of the building and blew out the front of the structure. Part of the boiler went through a neighboring store and windows were broken in buildings across the street.

Inspectors who examined the equipment at both of the above locations reported that the hazardous conditions would have been clearly evident had the boilers been subject to inspections. Inspectors reported

Figure 6—Left—Scene of an explosion in which two persons were killed and two injured. Right—Result of a lap seam crack. Three persons were injured by the explosion.

similarly with respect to several explosions at Southern lumber mills. Corrosion, failure to maintain relief devices properly or actual lack of them, lap seam cracks and careless operation figure in most of these explosions with their toll of deaths and injuries. Figure 6 shows two lumber mill scenes, that at the left revealing a plant demolished by a boiler explosion and that at the right showing parts of a boiler at rest in a wooded area.

In the first accident the explosion ripped the boiler from the mill, blasted a large hole in the ground where the machinery had stood, and sent brick and debris flying through the air many yards distant from the mill site. Two men were killed, one being crushed against a pile of heavy timber, and the other being struck in the forehead by a piece of flying metal. Newspaper accounts said a 13-year-old boy who was repairing a pump in a 5′ excavation at the top of an open well was blown out of the hole. The boy was cut and bruised.

The second accident demolished the mill and injured 3 men. Insurance was carried in neither case. In fact, an inspector, on visiting the second accident scene, wrote, "Had this boiler been subject to inspection, its hazardous condition would have been detected and the catastrophe averted."

Other accidents similar to those described brought about most of the other casualties. The remainder were the result of water tube boiler tube failures which are discussed in detail elsewhere in this issue of The Locomotive.

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

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Glass Insulating Material

ALTHOUGH spun glass was known and experimented with as far back as 1890, its practical use as an insulation for electrical windings has been made possible only in recent months. The development of a method and apparatus for producing ultra-small diameter fibres is responsible for the remarkable degree of flexibility of the threads and the thinness of the woven materials. The glass filaments of which the threads are made average .0002″ in diameter and it is possible to make them with a diameter of .00005″.

There are two types of glass fibres, "staple" and "continuous filament." Both are of the same chemical composition, but their methods of manufacture and physical properties differ widely. "Staple fibres" are produced by the processes which were first developed and which consist of using steam to blow molten glass through small dies. The expansion of the steam causes further stretching and reduction in diameter of the glass fibres which range from 8″ to 15″ in length.

"Staple fibres" are less expensive to produce, and although slightly fuzzy, may be used for a heavier thread, particularly where a certain amount of stretch or varnish absorption is desired.

The "continuous filament" fibres are a newer development and are made by a combination of extrusion of molten glass through small dies and further stretching of the hot fibres (to reduce their diameter) by mechanical drawing. These fibres are made up of seemingly endless filaments much like rayon. Their tensile strength is comparable to that of steel and they are especially applicable to designs that require strong, thin insulation. A piece of ½″ x .005″ tape woven of continuous-filament glass will support the weight of an average man, the actual breaking load being 172 lb. These fibres produce threads and textiles that are much like silk in appearance, are smooth to the touch and pleasing to the eye.

Both the "staple" and "continuous" fibres are in turn converted into yarn and thread from which tape, cloth and other textiles are fabricated. This glass cloth is used for a backing for mica splittings and slot insulation.

The outstanding properties of glass textiles, which are said to be entirely inorganic, are presented by their manufacturers as follows: High tensile strength, chemical purity (absence of free iron, etc.), low power factor, low dielectric loss, high insulation resistance, good flexibility, good insulation space factors, non-hygroscopic characteristics, high degree of chemical stability, resistance to weathering and resistance to high temperatures. The material also is vermin proof and will not rot or decay. The most serious objection to glass textiles at the present stage of their development is the low resistance to mechanical abrasion when untreated with some form of varnish or compound.

It would appear that glass insulation should produce a heat resistant winding, since it does not contain any inflammable cotton or paper backing, which latter materials are now permissible in A.I.E.E. Class B insulation. However, it must be remembered that the present day organic varnish binders are used for treating the glass tape to seal and bond the insulation and to afford mechanical abrasion resistance for the glass textiles. Therefore, the heat resistance of the varnish is a determining factor and the A.I.E.E. Class B insulation temperature rating still applies to windings using this kind of insulation.

One company manufacturing coils states that all organic binders tested in their laboratories lose their essential properties when subjected to constant temperature in excess of 230°C. or about 450°F. This, they claim, applies to phenol-anhydride resins, natural resins, phthalic anhydride resins, synthetic rubber, etc. Therefore, an inorganic flexible binder is being sought which has better heat resistance than present day binders afford.

Natural glass textiles are white. Colored glass stock produces white fibres because the fineness of the filaments so diffuses the color as to give only tints. Dyes suitable for temporarily coloring glass textiles are available in colors—red, blue, black, yellow and green. However, these dyes produce colors that are unstable and are used only for identifying rather than beautifying the cloth.

The electrical manufacturers are naturally reluctant to predict the future results that may be expected with this kind of insulation. Nevertheless, there are now in operation a large number of machines in which the windings are insulated with glass tape and mica, the two being bound together with a synthetic varnish. The most important applications of glass insulated coils are said to be for windings operating at high temperature, in strong chemical fumes, in very humid air, or where a minimum of space is allotted for the insulation.

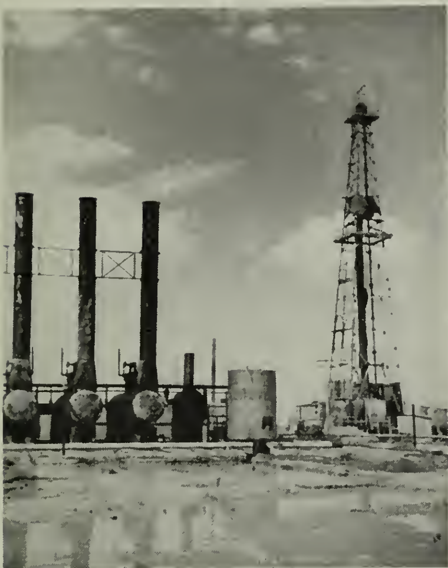
Unusual Circumstances Cause Furnace Explosion

Failure of the flame in an oil burner, plus an unusual combination of atmospheric and draft conditions, led to a furnace explosion which broke many windows, dislodged the stone top of a chimney and loosened and distorted a skylight over an elevator shaft in a 12-story bank building in Philadelphia. The explosion also caused the bursting *outward* of four large plate glass windows half a block distant, this latter phenomenon being attributed to an unusual movement of air due to the position of surrounding buildings.

A 5000-gallon water tank on the roof of the building was so situated with respect to the chimney that, under the existing wind conditions, it cut down the draft to a point where the draft was not sufficient to remove the oil vapors that had collected in the flue when the flame went out. A ventilating duct leading from the roof and intended to supply air to the boilers had been known to act as a chimney, just the reverse of its normal function, as had an elevator shaft near the boiler room. Both may also have contributed to the lack of draft in the furnace.

To prevent a recurrence of such an accident, it was suggested that the height of the chimney be increased and that at least one of the windows in the boiler room be kept open at all times.

Deepest Well and Tallest Stack



Derrick for the world's deepest well and three of the four boilers and the superheater which supplied steam for the drilling engine. The well, 15,004′ deep, surpassed the former world's record by 2,218 feet.

California this year laid claim to two of the "—ests" among engineering achievements. One of these is the "world's deepest well" and the other the "tallest smokestack in the world."

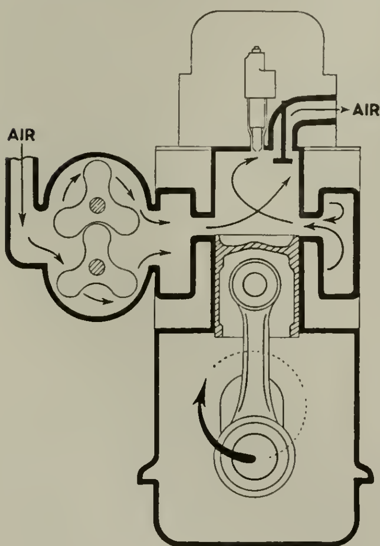
The "deepest well" was completed this year by the Continental Oil Company at Wasco, California. In drilling this well two new records were set—one of reaching 15,004′ depth and one of producing oil below 13,100′. Steam was supplied by four 100 hp, 250 lb boilers, together with a separately fired superheater which heated the steam to 485°F. The engine was a 12″ x 12″ twin cylinder. A standard 122-foot steel type derrick of 465,000 lb capacity was used with a 6-foot extension. The wire was 1⅛″ with eight lines to 11,583 feet and 10 lines below that point. In considering wire line loads, the approximate weight of 15,000 feet of 3½″ drill pipe was about 241,000 lb and it was assumed that the additional weight of the block, swivel and drill collar roughly equalled the supporting action of the drilling fluid. The job required 285 days.

The stack was erected by the American Smelting and Refining Company on the edge of the eastern arm of San Francisco Bay where the plant is engaged in the smelting and refining of non-ferrous ore. Because of complaints against obnoxious gases that resulted from process, it was decided to build a stack high enough so that gases and ash would be carried away from surrounding hills, which were 200′ to 300′ high, and would not settle in towns adjacent to the plant. A stack 620′ or about 35 stories high was the result. It is 44′ in diameter at the base and tapers to 14′ at the top.

Paragraphs of Progress

UNIFLOW DIESEL

A two-cycle Diesel engine is being introduced by the General Motors Corporation, the engine being operated at 1200 rpm and being built in sizes up to 125 hp. The engine is supercharged, as the scavenging air is supplied by a



rotary blower at 7 pounds pressure. The air intake is at the end of the stroke and the air ports are located around the entire circumference of the cylinder. The cylinder heads have two exhaust valves so that the unit operates on the uniflow principle, as illustrated in the accompanying diagram.

LARGEST AT 3600 RPM

The new 40,000 kw turbine now being installed at the South Meadow Station of the Hartford Electric Light Company at Hartford, Connecticut, is the largest 3600 rpm condensing machine to date. Steam conditions at the throttle are 850 lb at 900°F. A 25,000 kw 3600 rpm condensing unit has been in operation at the Montville, Connecticut, plant of the Connecticut Light and Power Company for about a year.

SMELTER GAS SULPHUR

Successful reclamation of sulphur from smelter gases is reported abroad. Two processes are used, according to World Trade Notes on Chemicals and Allied Products, both of the methods producing sulphur dioxide from which the sulphur is obtained. It has been estimated that throughout the world 2,000,000 tons of sulphur is lost annually in smelter gas. Upwards of 20,000 tons of sulphur are being produced annually by the two processes.

RECIPROCATING FEED PUMPS

A feature of No. 2 unit at State Line is the use of reciprocating boiler feed pumps. There are two of these pumps, rated at 3,000 gpm. These pumps have the Rossman drive, a variable speed device combining an A.C. and a D.C. motor in one machine. Integral with the D.C. armature, centering on the same axis, is what would be the stator of an induction motor. The squirrel cage rotor is on the drive shaft. The speed of the rotor is the algebraic sum of the speeds of the A.C. and D.C. elements, that is, the D.C. armature may be held stationary or driven forward or backward to accomplish any desired rotor speed.—*Electrical World.*

CO_2 COOLING

Carbon dioxide cooling with a closed circuit system of ventilation is being used on two 50 cycle, 1000 hp, 3000 rpm, 2300 v, two pole induction motors recently placed in oil refinery service. The machines have surface air coolers for removing heat. A non-inflammable atmosphere slightly above atmospheric pressure is maintained within the motor.

MAGNIFYING 5000X

For the making of photomicrographs for metallographic study a new microscope of German manufacture is reported to give excellent definition at 5,000 diameters and has an ultimate limit of 7,000 diameters.

PURE COMPRESSED AIR

In order to produce compressed air of the purity required in certain industrial applications, a vertical type reciprocating compressor designed for operation without cylinder oil has been developed abroad, it is reported in *Power Plant Engineering*. The piston of the compressor is covered with antifriction metal in which circular grooves are cut to form a labyrinth to retard the passage or leakage of air. Stuffing box lubrication has been eliminated by using a compressed carbon made up of annular segments shaped so that there is no direct rubbing contact with the rod. The cylinder is made of special "rustless" cast iron. Power required is said to be less than for a rotary compressor of the same capacity.

SOLAR ENERGY STUDY

The Solar Energy Fund, a capital gift of $647,700 by Godfrey Lowell Cabot, has been created for the Massachusetts Institute of Technology. Income from the sum will be devoted to a quest for methods of harnessing the energy of the sun in the form of useful power by converting that energy into power or by storing it for future use. It has been proposed to divide the research into three major fields of investigation: (1) Means for utilizing solar heat to operate engines to deliver mechanical power, (2) employing electrical apparatus for converting solar radiation into electrical energy, and (3) chemical conversion of sunlight into forms available for work.

91 TONS AT 1800 RPM

The rotating parts of the new 30,000 kw steam turbine for Quindaro power station, Kansas City, Kansas, weigh approximately 91 tons and will turn at 1800 rpm. The rotor of the steam end was made from a 92" steel ingot which weighed approximately 54.5 tons after it had been rough machined.

LARGE WELDED CRANES

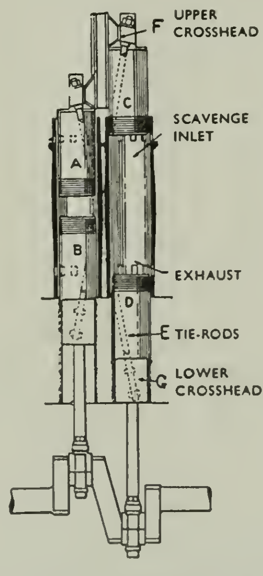
All-welded cranes of 120-foot span are now being built. No rivets are used in the fabrication of the major sections and these latter are bolted together only because of shipping and erection limitations. The complete crane weighs 275,000 lb.

KEEPING PIPING ALKALINE

In order to alleviate losses from corrosion in steam and return lines, certain amines (substances derived from ammonia by the replacement of hydrogen by hydrocarbon radicals) have been recommended for introduction into the boiler water, according to an article in *Power Plant Engineering*. The amines, the application of which to steam systems has been patented, vaporize with the steam. Their purpose is to keep the steam and condensate lines alkaline and thus reduce corrosion, grooving and pitting.

OPPOSED PISTON DIESEL

An opposed-piston, two-cycle, 3500 hp Diesel has been constructed for use in Bermuda. In the engine, as described in *Power Plant Engineering*, the cylinders are in pairs. Each cylinder has two pistons, and the top piston in each cylinder is connected by diagonal tie-rods



to the bottom piston in the opposite cylinder. Fuel is injected between the top and bottom pistons in each cylinder alternately. Thus, the design gives in effect a double acting engine without cylinder heads. There are eight 19 x 22" cylinders. The arrangement of the pistons is illustrated in the accompanying diagram.

Engine Crankshaft Failure

THE breakage of this crankshaft in a 140 hp Diesel engine used at a New England ice plant was attributed chiefly to torsional vibration. Starting around the circumference of the shaft under a fillet at a web, cracks progressed into the shaft and so weakened it that it broke after about one year's service. The failure, which was roughly conical in shape, is typical of torsional vibration breaks with their radial failure lines. In this installation the timing gear was immediately adjacent to the break. Beyond it (to the left in the top picture) was a main bearing and outside this a 5,700 lb flywheel. It is felt that the weight of the wheel added to the stress at the point of failure and hastened the break. The direct damage loss, which amounted to nearly $4,000, was covered by Hartford Steam Boiler.

The examiner was questioning a candidate for the position of engine driver.

"You are driving an engine down a steep incline at an excessive speed. What do you do?"

"Make a brake application," said the candidate.

"Doesn't act," shot back the examiner.

"Put brake handle into emergency position."

"Does not reduce speed sufficiently," went on the examiner.

"Reverse the engine and turn on steam," said the candidate.

"The wheels refuse to grip the metals."

"Pour sand on the metals."

"Sand is damp and won't pass through the pipes." The examiner put the question with an air of triumph. "Now what do you do?"

"Let her rip. We've reached the level now." —*Montreal Gazette.*

Taps From the Old Chief's Hammer

ONE stormy night in mid-September Tom Preble and Old Chief were comfortably seated before an open fire at the latter's home. A chess game was in progress and both men were studiously quiet. Outside the rain beat against the windows and thunder crackled occasionally.

After some time the Old Chief said, "Mate, Tom," and sat back. "I've beaten you again. What's the trouble, son, the storm bother you?" he chuckled. "You were just too easy."

"Chief," Preble said, as he sat back and relit his pipe, "you were right about the storm—interfering with my game, I mean—but it doesn't bother me. A while ago the lights dimmed for a few seconds and that set me to thinking about how thoroughly the transmission lines are tied in these days. There's hardly a catastrophe that could stop our source of light and power for long."

"Don't be too sure," replied the older man. "A night like this I'm apt to keep one ear cocked more than usual for the telephone. Even with tie-in and stand-by a storm can do queer things. Accidents have a way of happening at the wrong times.

"Tom, did I ever tell you about that night at Hartston—out west that was, about 30 years ago? There wasn't any storm to make things exciting, but we put in a good night's work."

Preble knew a story from his superior's rich experience was on the way.

"I don't think so, Chief," he said.

"Good, this will take your mind off the game for a few minutes and then we can play one more.

"I had gone to bed and was asleep when the phone rang. Still foggy, I squinted at the alarm clock. It was 11:00 P. M. At the other end of the wire was 'Big Jerry' Dillon (you've heard me tell of him before. He was just starting then.)

" 'John,' he boomed, 'can you come here and help us? We're in a mess of trouble.'

" 'Sure, Jerry, I'll be there the first thing in the morning,' I told him, still half asleep.

" 'Morning! No, No. John. I said TROUBLE. The lights are out—plant, streets, town—everything. Can't you catch that 11:30 train and come right away?'

" 'What's the matter, storm?'

" 'Storm? No. But I can't make any power. I've tried everything. Hurry up and catch that 11:30.'

"Fully awake by that time I realized that there wasn't much to be learned over the phone from a man as excited as Jerry was, so I shouted, 'O.K., I'll try,' and banged down the receiver.

"I threw on my clothes, shouted something or other about the 11:30 and Hartson to Mary and set out at a dead run for the station.

"Two hours later I climbed off into the blackest night I can remember. I had no sooner left the train than it pulled out. Nobody else got on and I was the only one to leave it. I noticed a dim glow on the rails and stumbled back toward it, when from behind me boomed, 'That you, John?' It was Dillon.

"We literally felt our way up the street toward the power house. There were no street lights and apparently nobody up but us. It was a a bit eerie—like being in a strange woods after dark.

"To make a long story short, Jerry and his crew couldn't get the generator to build up voltage. When it was tested at rest everything seemed O.K. The field was energized, but the generator refused to percolate."

"Sounds like loose collector rings, Chief," Preble interrupted.

"Right, Tom. When I tapped the rings they were obviously loose."

" 'There's your trouble, Jerry,' I told him.

" 'Well I'll be ....,' shouted Dillon, 'and I got you out of bed for that.'

" 'Not so fast, Jerry,' I told him. 'There's a first time for everything, and this apparently is the first time you've had this kind of trouble.'

" 'O.K., what do we do now? It means new rings, doesn't it—at 3:00 o'clock in the morning. John, where does one get new collector rings at 3:00 A. M.? The factory up the line will be wanting power at 7:00 sharp and they're busy.'

" 'Guess we'll have to tighten the rings,' I volunteered, which we did by putting mica under them and then sweating them on to the leads. It was a temporary fix, but as the sun came up to make our lanterns no longer necessary, we finished the job and had the generator ready to run."

"Nice work, Chief," commented Preble.

"Nothing unusual about it," commented the older man. "What bothered me was to see Dillon take it so hard. He seemed to think I'd saved his neck."

"But, Chief, we didn't insure generators 30 years ago," said Preble.

"No," was the answer, "but we did our clients a good turn when we could. A fellow couldn't go to dozens of power plants then, any more than he can now, without picking up little things that might help in an emergency. I had come in contact with the same kind of trouble two or three times before. . . .

"Come on, I'm talking too much. Let's get on with that game."

"O.K., but watch out for me this time," answered Preble.

But the Chief beat him again. After Preble had driven out of the yard, the Chief returned to the fire. "Beat him easily," he mused. "Waiting for the phone to ring, he was. Well, perhaps it will. The night is young."

Over-speed Damages Inching Motor.

The failure of a 25 hp squirrel cage induction motor used for inching a large machine is described in *Power Plant Engineering* by W. E. Warner of Sussex, England. The motor was connected to the machine through a clutch and speed reduction gear, the clutch being arranged to free the motor at a pre-determined speed when the main motor was started. The failure occurred when the clutch failed to release the rotor of the inching motor, with the result that it was driven by the main motor at a speed of almost 4,000 rpm instead of 415 rpm at which it normally was operated. The excessive speed caused the rotor bars to fail.

Steam Coil in Oil Tank Carries Oil to Boiler

In the April, 1938, Locomotive there was an article on "Over-heating Because of Oil, Scale and Mud." One source of oil in boilers was given as engine cylinders. C. H. Kroeschell of the Kroeschell Boiler Company, Racine, Wisconsin, contributes information about another oil source, a steam heated oil tank. A leak in the steam coil in the tank permitted oil to find its way into the coil from which it was carried with the condensate back to the boiler. The plates of the boiler became covered with oil, over-heated and bagged to such an extent that it was necessary to remove a portion of the plate and install a patch.

If you have a dime and I have a dime, and we trade dimes, each of us has only one dime, but if you have an idea and I have an idea, and we trade ideas, then each of us has two ideas.—*The Model Custodian.*

"Dad," said his son, Charlie, "do you think they will ever find a substitute for gasoline?"

"They have one now," replied his dad, "and I wish you'd give it a trial."

"Huh," rejoined Charles, "I've never heard of it. What is it?"

"Shoe leather," retorted his father.—*Whatyoumay.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

June 30, 1938 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,080,718.10
Premiums in course of collection (since April 1, 1938)		863,850.85
Interest accrued on bonds and mortgages		84,472.49
Mortgage loans		203,097.10
Home Office real estate and Philadelphia branch office		642,331.05
Other real estate		315,786.37
Bonds on an amortized basis	$9,494,346.88	
Stocks at market value	6,635,672.25	
		16,130,019.13
Total		$19,320,275.09

LIABILITIES

Unearned premium reserve		$8,419,769.83
Losses in process of adjustment		326,305.02
Commissions reserve		194,249.76
Taxes reserve		275,057.81
Other liabilities		267,233.03
Liabilities other than capital		$9,482,615.45
Capital stock	$3,000,000.00	
Surplus over all liabilities	6,837,659.64	
Surplus to Policyholders		**9,837,659.64**
Total		$19,320,275.09

WILLIAM R. C. CORSON, President and Treasurer

Incorporated 1866 *Charter Perpetual*

Department	*Representatives*
ATLANTA, Ga., Citizens & So. Nat. Bk. Bldg.	W. M. Francis, Manager. N. F. Bailey, Chief Inspector.
BALTIMORE, Md., 704-9 Garrett Building	D. W. Little, Manager. R. P. Guy, Chief Inspector.
BOSTON, Mass., 87 Kilby Street	Thomas F. Rice, Manager. W. A. Bayliss, Chief Inspector.
BRIDGEPORT, Conn., City Savings Bank Building	W. G. Lineburgh & Son, General Agents. A. E. Bonnet, Chief Inspector.
CHICAGO, Ill., 175 West Jackson Boulevard	P. M. Murray, Manager, C. W. Zimmer, Chief Inspector.
CINCINNATI, Ohio, 1904-12 Carew Tower	James P. Kerrigan, Manager. W. E. Glennon, Chief Inspector.
CLEVELAND, Ohio, 1040 Leader Building	Arthur F. Graham, Manager. John L. Scott, Chief Inspector.
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TORONTO, Ont., Canada, Federal Building	H. N. Roberts, President The Boiler Inspection and Insurance Company of Canada.

For A Longer Life

Because power equipment represents so large an investment, it is to the owner's advantage to obtain from his installation the longest possible span of safe usefulness. If equipment is not given proper care or is not operated correctly, it "wears out" too soon. The owner is obliged prematurely to replace it.

For nearly three-quarters of a century The Hartford Steam Boiler Inspection and Insurance Company has studied methods of protecting power equipment from accident and from undue deterioration. The lessons learned from this continuous research are applied to all inspections of insured equipment. Lengthened useful life, with a corresponding reduction in the cost of doing business, often results from the Company's recommendations in regard to operation or maintenance.

The insurance of your boilers and machinery in Hartford Steam Boiler is your guarantee of getting the best in power plant protection. It pays to insist on "Hartford Steam Boiler."

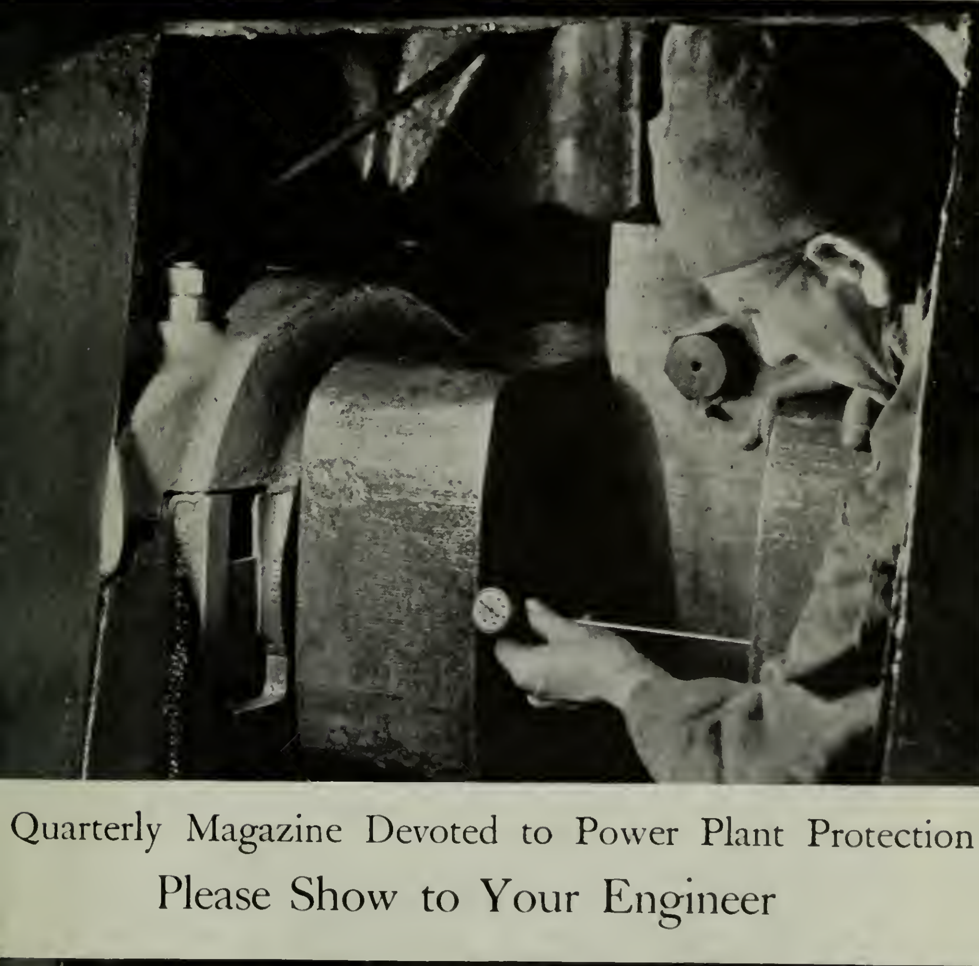
"Embrittlement in Lap Seams"

Vol. 42 No. 5

January, 1939

The Locomotive

THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE CO.



Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Embrittlement in Lap Seams

The following article is a report of a recent serious accident. It digs deeply into the possible causes of the accident, narrows down those possible causes to a single one—embrittlement, describes how embrittlement can destroy an almost new boiler when feedwater conditions are unsafe, and finally suggests measures for avoiding disaster because of embrittlement and such other threats as lap seam cracks. —Editor.

By J. P. Morrison, *Assistant Chief Engineer, Boiler Division*

THE STEAMER

An Ohio river steamer 146½′ feet long and 30′ beam, operating as a barge tow, was propelled by a stern wheel, driven by a compound non-condensing engine with 12″ x 24″ x 72″ cylinders at a pressure of 240 lb, the highest permitted on the boilers.

DESCRIPTION OF BOILERS AND OPERATION

The steamer's three boilers were what is known as the "Western Rivers" type and had been built in accordance with the general rules and regulations of the Bureau of Marine Inspection and Navigation of the Department of Commerce in force at that time and were installed on the steamer in April, 1935. Each boiler was approximately 26′ in length, 42″ in diameter and contained eight 6″ diameter flues, the ends of which were riveted to the heads. There were two mud drums and one steam drum connecting the three boilers, which were operated as a unit. A steel casing enclosed the three boilers, without division walls, so there was a single furnace with one set of hand fired grates approximately 12½ ft in width extending entirely across the setting. Furnaces of this description are generally known as "steamboat settings" and with some modifications have been used to a considerable extent in stationary practice. The spaces between the boilers were closed with special tiles which were shaped to fit the sides of the cylindrical shells above the line of the horizontal diameters but below the line of the longitudinal seams. Above the tile, the boilers, including the longitudinal seams, were covered with insulating material to prevent radiation of heat.

The cylindrical shell of each boiler was composed of four rings or courses. The first ring was 12″ in length, a distance sufficient to permit the use of a girth seam near the front end of the furnace. The second ring extended the full length of the grate and was approximately 8′ long. It was composed of two sheets and thus had two longitudinal seams. These seams, together with the first girth seam, were so located that the work of replacing a damaged fire sheet would be simplified as much as possible. The third and fourth rings were slightly greater in length than the second ring and had but one plate each.

The longitudinal seams were of the double-riveted lap joint type with the rivets spaced or pitched 2½″ apart and driven in 13/16″ diameter holes.

In other respects the construction of the boilers follows the standard design of the "Western Rivers" type.

About 500,000 lb of untreated Ohio river water was used in the boilers daily. The condition of the water changed according to the location of the steamer on the river and with the seasons of the year, taking into account the drainage basin, as well as the pollution in the metropolitan area of Cincinnati.

The operation of the boilers had developed minor difficulties such as leakage at a safety valve nozzle seam, leakage at mud leg seams and girth seams, all of which were repaired by re-riveting, and by seal welding, although the amount of metal deposited in the seal welding process exceeded that necessary or desirable for satisfactory work.

When the boilers were new in 1935, they were subjected to a hydrostatic test of 360 lb per sq in. and a similar test was applied in September, 1936.

Inspection reports referred to pitting, probably due to oxygen and organic acids in the untreated river water. The accumulation of scale was sufficient to elicit comment, but appeared no more than that usually encountered in Ohio river and Mississippi river boilers. Inspection reports contained recommendations regarding improvement in the condition of various attachments.

The pitting and accumulation of scale led to several analyses of the feedwater to determine what treatment could be used advantageously to correct those conditions, which, of course, are just as troublesome with river boiler as with stationary boiler operation. Actually, they are even more difficult to overcome aboard ship because of the limited space for water treating apparatus, lack of stand-by boilers, impossibility of maintaining a regular operating and cleaning program, great variations in the water level due to the roll of the boat, and opposition of the operators to the use of the boiler blow-down when a boat is under way.

The record is not entirely clear with reference to the boiler compound used during the entire time the boilers were in service, but the samples of that stored on the steamer for use as needed was found to be 98.8 per cent commercial soda ash. One feedwater investigator had previously reported that the amount of sulphate in the feedwater was no more than half the amount needed for the carbonate-sulphate alkalinity ratio that should be maintained as an embrittlement preventive.

ACCIDENT TO BOILER NO. 2

The steamer had stopped at a landing on the Ohio river a few miles above Cincinnati, where four barges had been delivered. With four other barges, it was maneuvering preparatory to starting downstream to Cincinnati, when the center one of the three boilers exploded quite violently.

Two men were injured and the damage to the steamboat made it necessary to accept a tow to a landing in Cincinnati.

So far as could be learned the boilers had been operating at 230 lb pressure with other operating conditions normal when the explosion occurred.

The initial rupture took place in one of the second course longitudinal seams. The seam which failed would be to the right when facing the front of the boiler. The separation, which occurred along a line approximately parallel to the center line of the rivet holes in the outer row nearest to the caulking edge of the plate and which, in fact, bisected many of those rivet holes, extended for a distance of 31 in. (lengthwise) of the boiler. At that point, the line of rupture turned abruptly and continued in a girthwise direction over the top of the boiler until it reached the longitudinal seam on the other side. It passed through several brace rivet holes as it "snapped" along.

Simultaneously the rivets of the girth seam securing the second course to the short front course sheared for a distance of 39 in. The section of the shell plate was thus freed at three sides, but was still secured at the side of the boiler opposite to that in which the failure originated. To an extent the section resembled a trap door and was forced against the top of No. 1 boiler as shown by Figure 1. As the three boilers were connected together, the energy contained in them was liberated through the opening in boiler No. 2.

Because the opening was in the top of the boiler, the force of the explosion was directed upward so that the boilers on either side were uninjured and the hull and main deck on which the boilers were located showed no evidence of damage, although some of the main deck superstructure, such as coal bunker bulkhead plate, various channels, stiffeners and stanchions, as well as the electric wiring needed renewing.

The boiler deck, that is, the deck above the boilers, and the hurricane deck supporting the pilot house and navigating mechanism suffered considerable damage. The two smoke stacks fell to the main deck.

Figure 1—The failure in Boiler No. 2. The break along the rivet holes near the caulking edge of the seam at the left is clearly evident.

The number of persons injured, the value of the property damaged, the accident prevention instinct, and the traditional interest in a steamboat boiler explosion resulted in an earnest effort to determine the underlying cause and to establish standards of design, inspection and operation which are intended to prevent similar accidents in the future.

As the initial rupture occurred in a longitudinal joint of double-riveted lap seam construction, an early conclusion was that the explosion was the result of a "lap seam crack."

Nevertheless, the exploded boiler was examined thoroughly and specimens were cut from defective seams for microscopic investigation.

PROPERTIES OF THE BOILER STEEL

The original manufacturer's test record of the marine steel forming the shell plates of the three boilers gave the following chemical and physical properties:

Carbon	.22	Thickness .355″ to .370″
Manganese	.47	Tensile Strength 80,800 per sq in. to 86,400 per sq in.
Phosphorus	.038	Percentage of elongation 25.5 to 26
Sulphur	.037	Percentage of reduction of area 48.8 to 57.0.

After the failure, an analysis of a section of the plate from the exploded boiler gave the following chemical properties:

Carbon	.25
Manganese	.500
Phosphorus	.040
Sulphur	.038
Silicon	.17
Copper	.12
Nickel	.17

The average of physical characteristics of four test specimens was 80,500 per sq in. ultimate tensile strength, 68,000 lb yield stress, 23 per cent elongation in a 2″ test specimen, 40.2 per cent reduction in area, and 182 Brinell hardness.

These values are within the range of the limits of open hearth steel permitted by the general rules and regulations of the steamboat inspection service in force when the boilers were built. The amended rules applying to marine steel for use in steamboat boilers, which became effective July 1, 1935, a couple of months after these boilers were completed, are similar to A.S.T.M. specifications A114-33 which stipulate a minimum tensile strength of 60,000 lb and a maximum of 70,000 lb per sq in.

The Brinell hardness number of firebox steel used in stationary boiler construction where the plates are exposed to products of combustion, and referred to as A.S.M.E. specification S-1 (identical with A.S.T.M. Specification A70-36) will average 110 as compared to the Brinell number of one of the specimens tested which ran as high as 184.

Fabricating difficulties encountered with both riveted seams and welded seams point conclusively to the need of special attention to the fabricating processes where high tensile strength material is used.

NATURE OF DEFECTS FOUND

The line of rupture was found to have followed a series of defects which started at the walls of the rivet holes near the interface, or hidden surface of the shellplate forming the inside lap of the seam. It should be understood that the hidden surface becomes the outside surface beyond the line of caulking.

In a general way, development of those defects was in the zone of greatest stress and was toward the adjacent rivet holes. As the defects progressed, they penetrated the sheet to a greater distance from the interface. The result of this combination of developments was a number of areas where the grains of the steel were in intimate contact, but without the strength afforded by the grain binder. A similar defect is shown in Figure 2 in which the dark areas are those in which grain binder corrosion has developed and the bright areas show the break

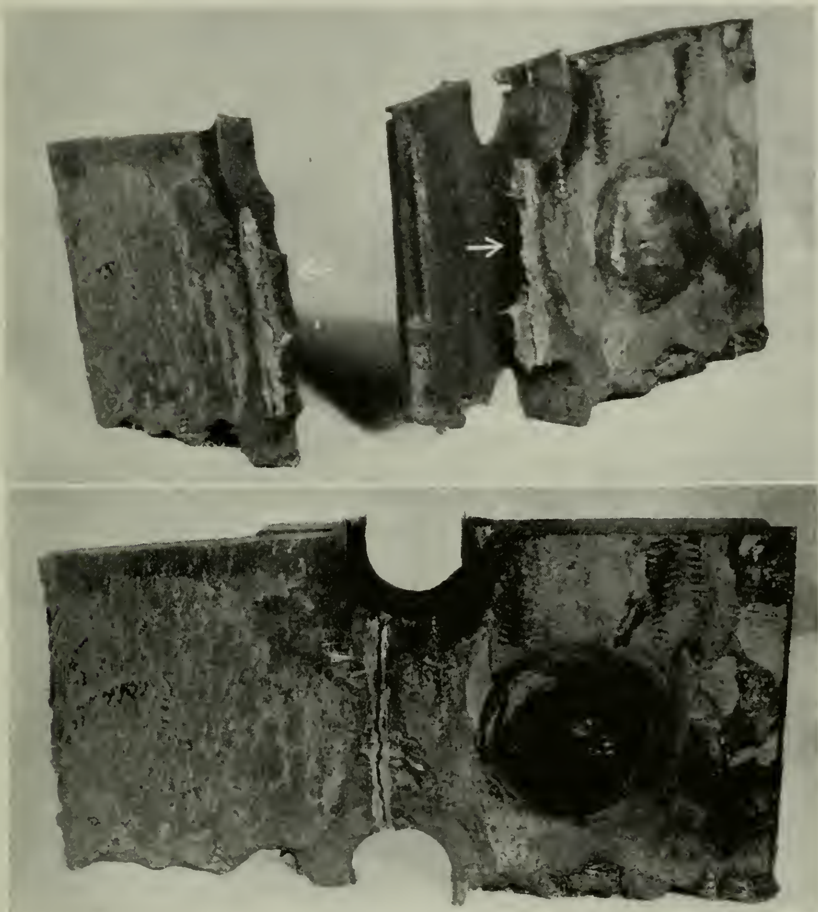


Figure 2—A fully developed embrittlement defect in metal from one of the steamer's boilers. The lower picture shows the rivet hole to rivet hole direction of the disintegration. The top picture is of the same pieces of metal as the lower, the dark areas in the break illustrating the development of the embrittlement (see arrows).

produced by stress in the laboratory. Defects of this kind may be mistaken for fatigue corrosion, which develops where there is a concentration of stress such as is known to exist in the material surrounding a rivet hole or tube hole, provided the intensity of stress approaches the yield point of the material and the stress is carried through a sufficient number of cycles. A fatigue fracture or stress crack takes a comparatively straight path, passing both across and between the grains of material along the line of greatest stress.

Intercrystalline defects, however, develop even where there is a comparatively low concentration of stress carried through a greatly decreased number of cycles, provided the feedwater contains certain impurities, including sodium hydroxide, and provided those impurities are allowed to concentrate in the capillary spaces which exist in riveted seams, even where the workmanship is above criticism. This combination of stress and impurities results in a disintegration of the grain binder, and so is said to cause intergranular or intercrystalline separation, although, where the growth of the intercrystalline defect has progressed to such an extent that the operating stress exceeds the strength of the remainder of the shellplate, a fatigue or transcrystalline failure may result.

The examination of the walls of the holes from which rivets were removed from the longitudinal seams of the exploded boiler beyond the point of failure led to the discovery of defects identical to thousands of rivet hole defects that had been found to have resulted from a combination of stress and improper feedwater conditions and ordinarily termed "caustic embrittlement."

INVESTIGATION OF BOILERS NOS. 1 AND 3

It was a logical conclusion that boilers Nos. 1 and 3, built of material of the same specifications by the same boiler manufacturer and operated under the same conditions, were likely to be similarly affected, so arrangements were made to conduct a thorough examination, including a test to destruction, if necessary, to determine their condition and degree of dependability.

The program of investigation involved a thorough internal and external examination of both boilers including:

1. A study of their design, workmanship, and operating conditions;

2. The slotting of each longitudinal seam between 10 per cent of the rivet heads in the inner row, or row most distant from the caulking edge, to check for a lap seam crack;

3. The application of a hydrostatic pressure test of 360 lb, which is equivalent to one and one-half times the maximum safe working pressure of 240 lb as permitted by the then existing steamboat boiler rules; and

4. The removal of at least ten per cent of the rivets from the row next to the caulking edge of each longitudinal seam so that the walls of those rivet holes could be examined according to Hartford Steam Boiler standard practice to determine whether hairline embrittlement

defects had developed similar to those found in the seams of No. 2 boiler.

1. DESIGN, WORKMANSHIP AND OPERATING CONDITIONS

The boilers had not been thoroughly cleaned internally for some time prior to the accident, so that there was some scale upon the shellplates and flues. In places on the heads the coating measured as much as ½″ in thickness. The pitting of the shellplate and heads was not of special importance, but the corrosion of the flues was of a greater extent than would be expected to result from less than two years' service with Ohio river water.

External parts not ordinarily accessible could be examined closely after the boilers were removed from the steamboat. Evidences of leakage were found at the longitudinal seam on the right side of the second course of both No. 1 and No. 3, and the longitudinal seam of the third course of No. 3 also had leaked during the time the boiler was in service.

These seams had not been accessible for examination either when the boilers were in service or when they were subjected to a hydrostatic test after being installed in their settings.

The rivets used in the double-riveted lap seams had been driven with an air hammer and had been of insufficient length to form a normal head for a rivet of that size, so that grooves had been cut in the sheet surrounding many of the rivet heads by the rivet head die. The scarfing and fitting up as well as the workmanship in general were quite crude and hammer marks appeared at various places where the plates had been "laid up" as the riveting had proceeded. The holes from which rivets were removed later had been drilled to finished size. Some of the holes in the two plates forming the seams were not concentric, or "fair" to use a trade expression, although they were not "out of line" a greater amount than would be expected where the plates forming the seams had not been in close contact when the holes were drilled and thus had had to be brought into "metal to metal" contact by hammer blows during the riveting process. At the laps a heavy "fuller" caulking tool had been used to overcome lack of proper scarfing and at several places that method of making a tight joint had resulted in cracking the plate between the rivet hole and the caulking edge. The effect of the use of oversize fitting-up pins was evident in the holes of the outer plate of the lap.

From the foregoing it might be concluded that antiquated shop methods were responsible for the failure, except for the fact that the effect of rough workmanship was most pronounced in the outer plates

Figure 3—Failure in the longitudinal seam of No. 1 boiler during the hydrostatic test. A few of the paths of embrittlement defects are exposed and clearly show the progress from rivet hole to rivet hole. This boiler has been slotted as a means of detecting a lap seam crack. The slots are indicated by the arrows. See also Figure 4.

of the longitudinal seams, and it was in the inner plates in which the defects were discovered.

In accordance with the investigation program, 10 per cent of the rivets in the rows next to the caulking edge were marked for removal, the number being increased to 20 per cent in those regions where leakage had existed. Their removal and the test for embrittlement was to come after the hydrostatic test.

2. SLOTTING

The plan followed in slotting the outside plate between the rivet heads in the inner row of the longitudinal seams was a modification of the plan outlined in THE LOCOMOTIVE of October, 1914. The slots were cut 5/16″ deep, ¼″ wide, and approximately 1½″in length. The girthwise centers of the slots were approximately on a longitudinal line that would touch the edges of the rivet heads, as illustrated in Figures Nos. 3 and 4.

Figure 4—Failure in Boiler No. 3 after the hydrostatic test. The break at the right is clearly from embrittlement. The continuation of the failure across the boiler is a stress tear similar to that in Boiler No. 2, which exploded under steam pressure. The lap seam crack slots are indicated by the arrows.

If a lap seam crack had developed to a depth of ⅛ in. from the inside surface of the plate, where such a crack normally develops on a line close to the edge of the rivet heads, as shown in Figure 5, some of the slots would have reached the crack and permitted leakage when the hydrostatic test was applied. Such leakage did not occur.

3. THE HYDROSTATIC TEST

After the various openings such as manholes, handholes, steam drum, and mud drum connections had been closed, the seam slots had been cut and the water connections made, the boilers were filled with water and the hydrostatic pressure increased slowly.

When 240 lb pressure, corresponding to the certified working pressure, had been reached, leakage had developed at the right side longitudinal seam of the second course of Boiler No. 1 and at the longitudinal seam of the third course of Boiler No. 3. That leakage increased as the pressure increased until a slight movement was noticeable at the leaking seam of Boiler No. 1. The distortion and leakage increased steadily until failure occurred at 360 lb.

The separation extended for a distance of 32 in. The extent of the rupture and distortion is shown by Figure 3. The line of separation was from hole to hole, along the center line of the rivets adjacent to the caulking edge of the plate, and to that extent was identical with the failure in the corresponding seam of No. 2 boiler when the explosion occurred.

The escape of water from the openng in the seam of No. 1 boiler released the pressure on No. 3 boiler also, but in anticipation of such a contingency, provisions had been made for separating the boilers by closing either one of two valves. Pressure was re-established on

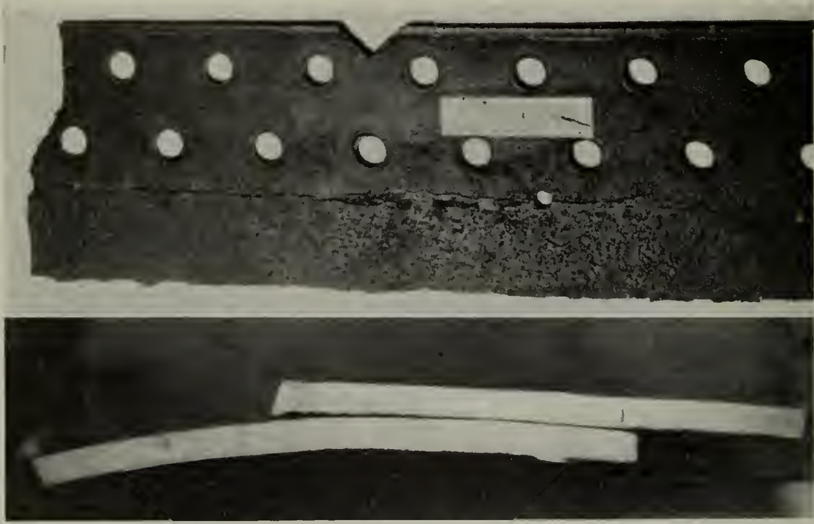


Figure 5—Top and end views of a typical lap seam crack. Notice that this defect is on the opposite side of the seam from the failures shown in Figures 1, 3, and 4. The picture at the upper right shows a lap seam failure under hydrostatic test.

Boiler No. 3. The results were comparable to its behavior when the previous test was applied, although greater leakage developed at the longitudinal seam of the third course where the distortion was greater.

When the pressure reached 300 lb the water escaping from the seam equaled the amount then being delivered by the pump, so that the pressure ceased to increase until the speed of the pump was increased.

At 350 lb pressure the leakage approximated the capacity of the pump so the shell plate was struck a sharp blow with an 8 lb sledge above the point of greatest leakage at the caulking edge. Failure occurred instantly.

The line of separation extended along the longitudinal seam from

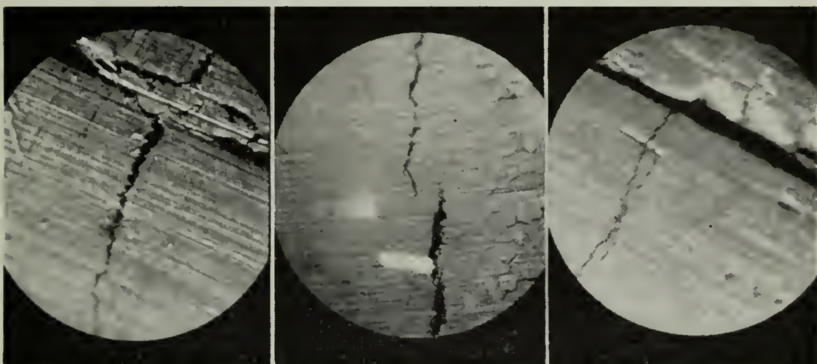


Figure 6—Embrittlement defects from Boilers Nos. 1, 2 and 3 (from left to right) as seen in rivet holes through the Hartford Steam Boiler magniscope.

rivet hole to rivet hole for a distance of 45 in. from the third girth seam as shown in Figure 4. At that point the path of the break changed to a girthwise direction with another change to a longitudinal direction when the top of the boiler was reached. There was a third change to a path diagonal with the girth seam and longitudinal seam. The entire length of the rupture was nearly 100 in.

To the extent of combining a failure that originated in a defective longitudinal seam, with one extending through solid plate, the bursting of No. 3 boiler was similar to that of No. 2, and had either Boiler No. 1 or No. 3 failed under steam pressure, instead of under hydrostatic pressure, it seemed certain that the event would not have been of less violence than the explosion of No. 2.

The edges of the plate where the seam of each boiler had separated showed old defects almost identical with those in the seam of No. 2 boiler, but developed to a lesser extent.

4. EXAMINATION OF RIVET HOLE WALLS

Following the hydrostatic tests that ended with the failure of each boiler, the rivets which had been marked were removed with the exception of those along the lines of separation already described. The walls of the holes were then cleaned and examined through the Hartford Magniscope for defects similar to those discovered in the undisturbed section of the seam removed from No. 2 boiler. Such defects were easily visible at 20 magnifications in the plate at each of the rivet holes. Those holes were then reamed ⅛″ larger in diameter, finished with a grinding point and washed with hydrochloric acid to facilitate the investigation. Many of the defects were then visible to the naked eye. Photographs of these defects at 40 magnifications in boilers Nos. 1, 2 and 3 are shown in Figure 6. In Fig. 7 is shown a defect of the same sort at 225 magnifications as photographed at the University of Illinois laboratories during recent embrittlement research. In Figure 8 is a photograph at 500 magnifications of an embrittlement defect from the No. 1 boiler.

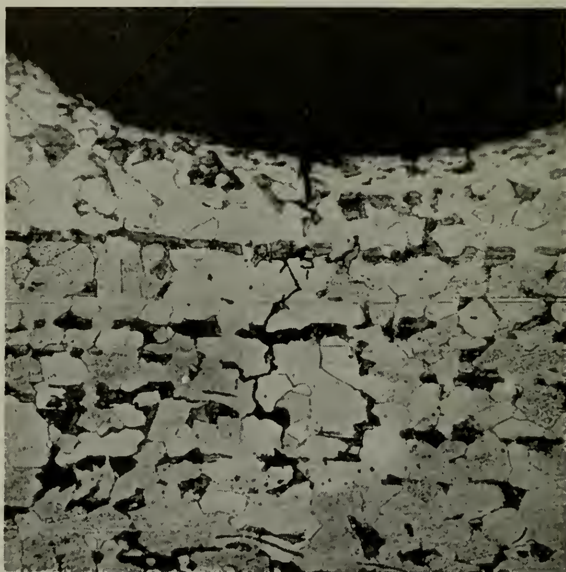


Figure 7—Embrittlement disintegration at 225 magnifications as produced in the laboratory.

CONCLUSIONS AND ACCIDENT PREVENTION RECOMMENDATIONS

As a result of the foregoing investigation, the explosion and the two failures under hydrostatic test were definitely attributed to unsuitable material and obsolete design, excessive stresses and feedwater of an embrittling type. The investigation also strengthened certain established recommendations with respect to the construction of boilers and with respect to preventive measures after such vessels have been placed in operation, namely:

1. Those forms of construction that involve clearly identified inherent weaknesses must be avoided. A properly designed fusion welded seam or a double butt strap seam possesses greater strength, may be used at higher maximum working pressure for a given plate thickness, and represents more dependable construction than does a lap joint type seam. The use of riveted longitudinal seams of the lap joint type should not be permitted in new construction for a pressure in excess of 15 lb.

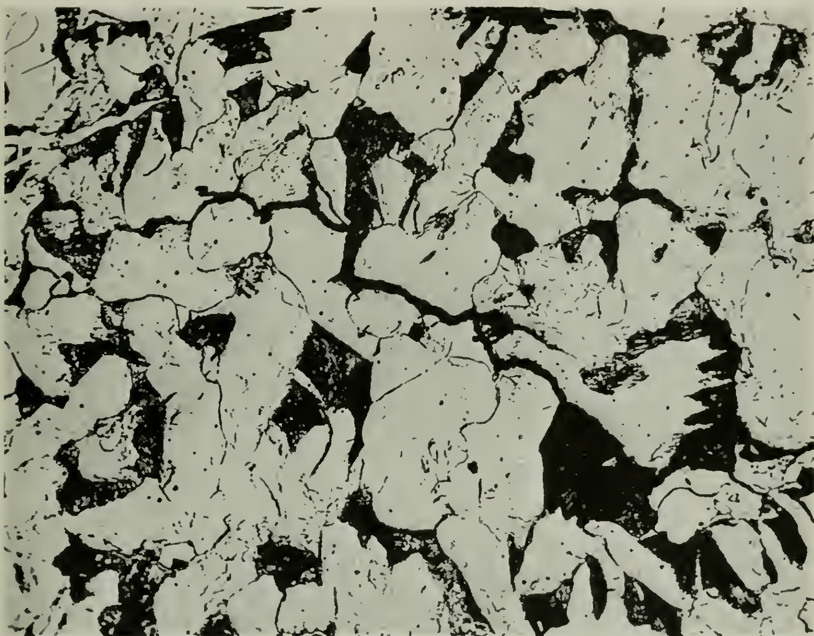


Figure 8—Embrittlement at 500 magnifications in a section of plate from Bolier No. 1.

2. Any part of a boiler that experience teaches should be looked upon with unusual suspicion such as, for example, a longitudinal seam of lap joint construction or a shallow dished head of a boiler drum, should be accessible for a thorough examination of the surfaces in which defects are likely to develop. Accordingly, any insulating material should be installed so as to be easily removable when the boiler is out of service for cleaning and inspection.

3. Because the path taken by the typical lap seam crack can be charted, the slotting of the shell plate in the manner followed in the

investigation of boilers Nos. 1 and 3 has been successful in each case where slotting has been applied, and it would have been successful in several cases investigated after the occurrence of accidents. Therefore, all such longitudinal seams should be slotted at intervals of not more than 10 rivets in order to safeguard against failures from lap seam cracks.

4. When a lap seam or a butt strapped seam suffers the loss of a rivet head or leaks persistently, re-riveting is necessary. Before re-riveting, however, the rivet hole must be cleaned and examined thoroughly to detect whether embrittlement defects are developing.

Detection of a Lap Seam Crack in a Vertical Tubular Boiler

An inspector was making an external examination of a vertical tubular boiler which supplied steam for pile-driving operations in New England harbors. He had nearly completed his work and was walking around the boiler when he felt a wisp of moisture on the side of his face. This puzzled him, for although the moisture came from the direction of the boiler there was no sign of leakage on the boiler itself. Returning to the original spot where he had felt the moisture, the inspector again felt it, and he found that by standing at an angle he could see faint traces of vapor now and then issuing from the side of the boiler near the longitudinal seam.

Here was evidence of a defect of some kind. An explosion could be serious, for there were between 15 and 20 workmen and on-lookers near the boiler attending to and watching the operation of the pile driver. Mindful that the leak most likely was evidence of a lap seam crack, he warned the engineer-in-charge to stop operating immediately and to clear the space around the boiler. Because the engineer was working under rush orders, he was reluctant to stop, but did so even though there were but 17 more piles to drive to finish the job.

Another pile driver was ordered to the location and the defective boiler shipped back to the firm's yard, where, under hydrostatic test and hammering, the results were as shown in the photograph on Page 140. It was felt that the prompt action of both the engineer-in-charge and the inspector prevented what might have been a disastrous accident because of a lap seam crack.

Game fish swim upstream.

Stator Failure in 450 HP Hoist Motor

A TEMPORARY repair of an unusual nature was resorted to at a mine following the failure of the stator winding and the extensive burning of the iron of a 450 hp hoist motor. The iron in three of the slots was badly burned for about the width of the laminations and there was burning also in one of the rows of teeth about 11 slots from the major damage.

The machine was a 20-pole unit with 240 coils—4 coils per group, 80 coils per phase, connected series delta.

As the motor was badly needed, the damage was immediately studied to see whether any time could be gained by making a quick temporary

Figure 1—Failure of 450 hp hoist motor showing the iron burns after three laminated teeth had been cut away.

repair, deferring permanent repairs until the machine could be spared without loss of production. It was realized that a patch job might give trouble because several rows of teeth of the laminated core would have to be removed and dummy coils substituted. However, such a repair seemed the best under the circumstances. It also was decided not to make a permanent repair, but rather to purchase a new stator.

Figure 1 shows part of the preparations for the temporary repair, which was done in a manufacturer's shop approximately 170 miles from the mine.

In order to expose the damaged area and to separate the iron laminations which had been welded together by the arc at the time of the accident, it was necessary to remove about 30 coils and the three teeth as shown in the photograph. In reassembling, coils were left out of the top and bottom of four slots at the point of principal damage, the omission involving a total of eight coils, six in one phase and one in each of the other phases. Fibre blocks were then made to replace the missing coils and were fitted to support the teeth of the iron laminations. The blocks were made secure by means of two brass screws threaded into the fibre and running up through the air duct space in the iron laminations, and by tieing at each end with hemp cord.

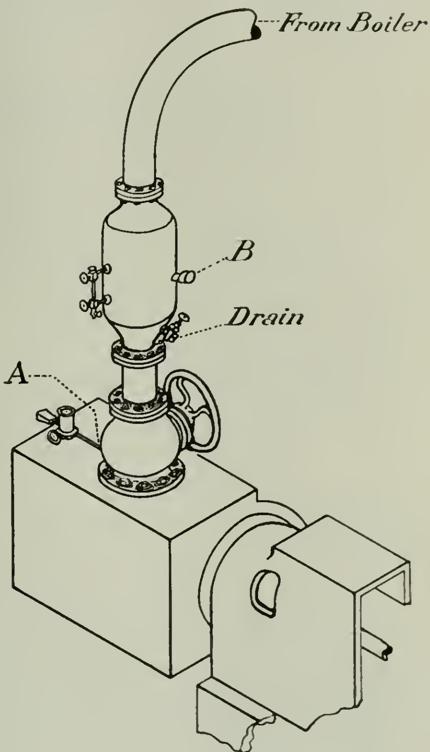
When the coils were in place and tested, it was found that the winding was out of balance electrically. Therefore, eight additional coils were cut out, making 16 coils in all—six in one phase and five in each of the other two. A further test showed that the machine was quite well balanced and that there was practically no circulating current. The current tests on the windings were made by applying approximately 550 volts to the winding connected in a normal manner and by using a clip-on type ammeter in order to check the line currents and the currents in each of the delta legs.

From the readings thus obtained, it was possible to plot a triangle of currents and then to add the currents vectorially to be certain that the line current agreed with the currents measured in the deltas. In this way the readings could be accurately checked. It was then only necessary to measure the angles of the triangle to see that they were 60°, and also to check and see that the line current was 1.73 times the current in the delta.

As all tests were satisfactory, the permanent connections of the machine were made, the coils which would not be supported by wedges were laced down, and fibre spacers were provided to take the place of the bottom side of the coils which were missing. In order to support the end turns of the coils in the damaged area, a bull-ring approximately 4′ in circumference was made up and the ends of the coils or knuckles were laced to this bull-ring. Finally, the windings were given a coating of a good quality of black air-drying insulating varnish.

The job, which had been completed between Tuesday night and Friday morning and had involved the making up of 15 new coils besides the other work, was not one to instill confidence, but it was the best that could be done under the circumstances, so the 6-ton stator was returned to the mine. Operation of the hoist motor was continued for between five and six weeks until a new stator could be obtained and installed.

A Case of Steam Engine "Trouble Shooting"



AT a laundry in the Middle West the engineer was having serious difficulty with a steam engine, which, although it would run, could not be brought up to normal speed and made to carry its load. After an engine repair man had checked the governor and valve setting without finding a clue to the difficulty, the matter was put up to a Hartford Steam Boiler inspector who diagnosed the trouble as an obstruction in the steam line.

To locate the obstruction a test pressure gage was installed at connection "A" on the engine. It showed full boiler pressure until the engine had operated about 30 seconds, when the indicated pressure dropped suddenly from about 100 lb to 30 lb, and severe vibration of the needle indicated wire drawing of the steam. The test was then repeated with the gage at "B" on the separator. While the engine acted as before, the gage now remained at boiler pressure, indicating that the obstruction was between "A" and "B". The separator was removed and the trouble was found to be a loose baffle. Vibration had worn away the threads of a bolt securing the baffle, which had dropped across the steam opening. A new bolt was made as secure as possible, the separator reinstalled and the engine returned to service.

Although in this case the inspector quickly located the trouble and the remedy proved to be a simple one, it is a well known fact in power plants that a slight derangement may often assume the proportions of a baffling problem and lead to embarrassing outage of the prime movers.

Little Mary: "Mother, they are going to teach us domestic silence at school now."
Mother: "Don't you mean domestic science?"
Father: "There is a bare hope our little girl means what she is saying."—*Boston Evening Transcript.*

When a man says: "This is a difficult problem," he really says: "I am a soft drill on a hard piece of steel."—Charles F. Kettering in *Think.*

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

SIDNEY B. COATES, *Editor*

HARTFORD, CONN., January, 1939

Single copies may be obtained free by calling at any of the Company's offices.
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each.

The First Citizen of Hartford

Friends of our president, Wm. R. C. Corson, were singularly pleased to learn that, at a dinner in his honor on November 14, 1938, he had been proclaimed Hartford's "First Citizen." The dinner appropriately was made to coincide with the opening of the 1938 campaign of the Hartford Community Chest of which Mr. Corson was an organizer and first president in 1924 and 1925. He has been active in the Chest's support ever since, and in addition finds time for a wide diversity of service for the welfare of the people of Hartford.

THE COVER

This photograph shows an inspector making a dial micrometer test of the crankshaft of a large compressor. The instrument is the Hartford Strain-gage which was specially developed in order to secure more accuracy in checking the alignment of engine parts.

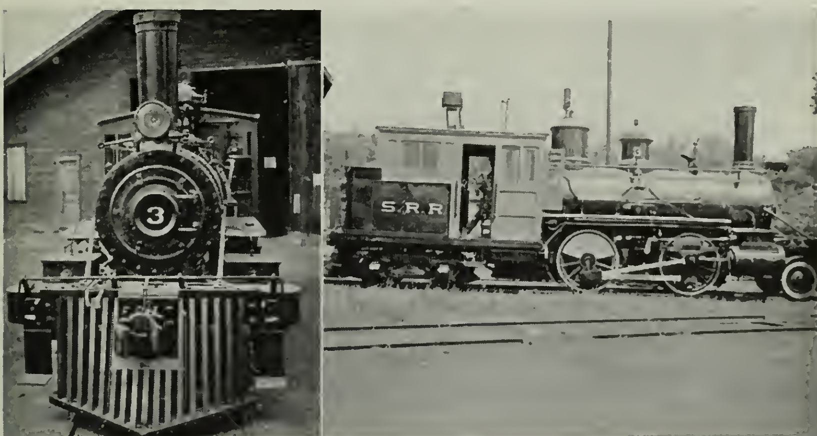
Philadelphia and Cleveland Department Changes

Three inspection staff changes of importance to policyholders in the parts of Pennsylvania, Ohio, New Jersey, New York and Delaware served by the Philadelphia and Cleveland departments were announced in December.

In the Philadelphia department the services of the engineering staff are enhanced by the addition of John L. Scott as Chief Inspector. This change makes it possible for S. B. Adams, Philadelphia Chief Inspector for the past 23 years, to devote his energies to company work of a consulting engineering nature which has been close to his heart for many years. As Consulting Engineer in the Philadelphia department Mr. Adams will now have much-to-be-desired time for more intensive work on the subject of pressure vessel design and construction which is unusually important in the Philadelphia department because of the number of boiler and pressure vessel manufacturers in that territory.

Coming with the Company at the age of 24, Mr. Adams has served Hartford Steam Boiler in an outstanding fashion for the past 46 years. His patience at all times, his extreme calm in the face of any emergency, and his emphasis on thoroughness have earned for him the respect of

Three Score and Twelve Years



Built by Rogers in 1866, this old Fortney type locomotive still pulls an occasional load for the Skaneateles Railroad. Because the railroad route includes an 11 per cent grade, the locomotive heads up the grade and backs down again in order to keep water over the crown sheet.

the many policyholders in his department. Added to these qualities is a humanness of outlook and a sense of absolute fairness that have endeared him not only to his men, but to the entire company. All are happy that he can now devote his capacities to his specialty without the countless interruptions that are the routine of a Chief Inspector.

F. E. LeGates

Mr. Scott takes the helm in Philadelphia after 6 years as Chief Inspector of the New Orleans and Cleveland departments respectively. He joined the Company in its Cleveland department on May 16, 1923, at the age of 24, after several years as a marine engineer on vessels on the Great Lakes. In 1925 he was made Adjuster and in March, 1929, was appointed Directing Inspector. He was promoted to the rank of Chief Inspector of the New Orleans department on May 16, 1933, and returned to the Cleveland department as Chief Inspector in January, 1934.

The changes involving Mr. Adams and Mr. Scott were effective December 16, 1938.

Mr. Frank E. LeGates, who has succeeded Mr. Scott as Chief Inspector at Cleveland, effective December 14, 1938, is a man of broad experience in all branches of the company's engineering and inspection work. He entered the employ of Hartford Steam Boiler on November 1, 1920, at the age of 23 as an inspector in the Philadelphia department. His coming to the Company was preceded by 6 years in marine engineering work. From April, 1933, to January, 1937, he served in the Boston department as office engineer, returning in 1937 to the Philadelphia office. Mr. LeGates brings to the Cleveland department policyholders the results of a rich experience and a thorough grounding in the Company's engineering and inspection procedure.

Two old settlers, both bachelors, were sitting in a cabin in the back woods. The conversation finally drifted around to cooking. Said one:

"I got me a cookery book once, but all the recipes were impossible. Every darned one o' them began with: 'Take a clean dish.' "—*Winnipeg Tribune.*

No matter how handsome or how homely you are, you still look better when you smile.

Recent Steam Turbine Accidents

RECENT accidents to steam turbines illustrate two important principles with respect to failures in such machines: (1) that in spite of rigorous inspection procedure accidents will occur, and (2) that these accidents happen so speedily that almost instant attention must be given to vibration or other sign of trouble if a major repair is to be avoided.

Of course, certain parts are more subject to failure than others, but which of them will give way in a particular unit is a factor that makes turbine operation a job for highly trained men and makes turbine insurance and inspection valued assets.

Blades and buckets, discs, the auxiliaries, the governor and the reduction gears were involved in recent breakdowns. Although the deterioration of the turbine casing was not blamed as the direct cause for any of the accidents considered, an investigation in one instance after an accident to blading revealed serious corrosion under the cylinder lining, a condition which surely would have brought about trouble if it had been allowed to continue. As it was, several screw heads were snapped off due to corrosion "growth."

Accidents Caused by Blade and Disc Failures.

It is often difficult to determine exactly what caused a blade failure. In one case the operator noticed a noise in a 500 kw reaction type machine, but as the noise ceased and the turbine kept on running under its then light load, he did not stop it. However, it was later discovered that the machine seemed incapable of picking up more load, so it was opened up and examined. Both the stationary and the rotating blades from the 5th to the 28th rows were destroyed and 4 additional rows of blades in the intermediate stage were so damaged that they had to be replaced. After the accident, all passages were found free from deposits, there was no evidence of either erosion or corrosion and there was ample radial clearance between the rotor and stator. As the blades in the first four rows were intact, it was considered likely that a blade had broken in the 5th row and had led to the destruction of 14 rows of blading. No evidence remained, however, to indicate the location of the original break.

A similar accident to a 1500 kw reaction type turbine ripped out six rows of blading just after it had been placed under load. The accident was attributed to an old crack in a blade, but again the damage to the blading hid the facts as to the cause.

The reasons for two other blading failures were more accurately traceable. A 500 kw turbine lost buckets in the last stage when the barometric condenser flooded back into the machine, after the water circulating pump had stopped. In the other case fatigue cracks at the roots of the blades were blamed for the failure of a 550 kw turbine of the impulse type.

Early in 1938 four men were injured and damage estimated at about $50,000 resulted when a piece broke out of the third stage wheel of a second-hand 2500 kw impulse type turbine while the emergency governor was being tested. An old fatigue crack had extended through the wheel disc to such an extent that a slight increase above normal operating speed led to failure. A similar accident is described in the April, 1936, LOCOMOTIVE.

Because the turbine was badly needed, Hartford Steam Boiler was asked to help locate another turbine of the proper size and characteristics. (An interesting incident in connection with this failure was that a workman had been on a ladder underneath the unit just a few minutes prior to the accident, but had gone for a tool when the failure occurred. The ladder was demolished.)

Trouble from Over-speed.

Difficulties which prevented the tight closing of steam valves led to over-speed and a $15,000 accident to a 1250 kw mixed pressure turbine. When the load (about 450 kw at the time of the accident) was lost, both the high and the low pressure automatic steam valves fell to their closed position. A few moments later the operator noticed that the turbine was accelerating gradually and he tried to tighten both valves without success. He signalled his helper to open the hand operated vacuum breaker, but, as this was small, the turbine responded slowly. When the casing was removed it was found that the 2nd, 3rd and 4th stage wheels had stretched so much that it was necessary to replace them. Some damage also was noted in the diaphragm packing and in the high and low pressure packing rings. Windage had so weakened the insulation on the No. 1 coil in each pole of the generator rotor that the insulation had to be renewed. After repairs were made, it was decided that an automatic vacuum breaker was absolutely necessary for future safe operation. The exact cause of this accident was not determined, but contributing factors were governor trouble, which had manifested itself during the life of the turbine, and a screw that had become loose and lodged under a large crosshead nut on the valve stem in such a way that the low pressure valve did not completely close.

Auxiliary Oil Pump Difficulties

Failure of the main bearings on a 7500 kw turbine resulted when the reciprocating auxiliary oil pump could not be started while the turbine was being removed from service. The operator reported that when the load had been removed from the turbine, he tripped and reset the oil operated throttle valve, and stood by the auxiliary oil pump which ordinarily started automatically with a drop in oil pressure. When the pump did not start, he opened the by-pass valve but even then the pump would not start. The steam cylinder drains were opened and considerable effort made to start the pump, but without immediate success. An attempt was then made to open the turbine throttle in order to build up the oil pressure with the main pump, but by that time the oil pressure had dropped to the extent that the throttle would not open. Finally, the auxiliary reciprocating oil pump was started, but it was observed that the turbine came to rest within ten minutes from the time the steam was cut off, whereas it usually took 20 to 25 minutes to come to rest. The main bearings were damaged and had to be re-babbitted, even though it was estimated that only three minutes elapsed from the time the auxiliary pump should have started until it was operating. To prevent a recurrence of the difficulty it was recommended that the auxiliary reciprocating oil pump be replaced with a turbine driven auxiliary oil pump.

Three bearings burned out on an 800 kw machine following the breakage of the main oil pump shaft. Here again the damage was done before an auxiliary oil pump could be placed in operation.

Air Pressure Tank Explosion in School

Failure at a welded seam brought about the bursting of an air tank used in connection with an air lift water supply system in a Wisconsin school on October 18, 1938. The tank, which was mounted horizontally in the basement beneath a school room floor, shot through a partition and pierced a basement wall below ground level after the concave or "minus" head failed.

In Figure 1 is shown the room immediately above the tank. The force of the explosion caused this and other damage estimated at about $20,000. A class of children was in session at the time of the blast and six of them were cut and bruised, but all escaped serious injury because they were at the front of the room listening to an educational radio program.

An investigation revealed that the tank, which was 3′ in diameter

Figure 1—School room after air lift water system tank exploded.

and 12′ long, was not equipped with a safety valve, nor was there a pressure cut-off on the motor operating the compressor. However, neither safety device would have helped in this case because the tank was operated normally at from 80 to 90 lb pressure and was reported to be at the latter pressure when the accident occurred.

This installation is similar in principle to many others which employ air to raise water to the surface from wells. Compressed air is conducted into the well below the normal water level, is allowed to mix with the water and enables this mixture of air and water to rise above the ground because it is lighter than "solid" water. Usually the water thus obtained is conducted to a tank from which it is pumped through or flows through the system by gravity.

Smith: "My wife asked me to take our old cat off somewhere and lose it. So I put it in a basket and tramped out into the country for about eight miles."

Jones: "Did you lose the cat?"

Smith: "Lose it! If I hadn't followed it I'd never have got back home." —*Houston Chronicle.*

"Is a ton of coal very much, papa?"

"That depends, my son, on whether you are shoveling or buying it."

—*Boston Evening Transcript.*

Taps From the Old Chief's Hammer

"CHIEF, the coils for that special motor came in on schedule and I delivered them at 2 A.M. The motor should be on the line again by to-night."

"Good work," was the veteran's comment.

The first speaker was Tom Preble, assistant to the Old Chief, reporting on an emergency case. He had met a plane from the east at 1 A.M., had driven the parts some miles to the plant and was back at the office after spending the rest of the night at the scene of repairs.

The details with regard to the motor were quickly explained.

"I take it things worked out all right at the airport," the Old Chief commented.

"Sure thing," was the reply, "but I certainly got a thrill out of that big plane gliding down out of the clouds. That's flying. The attendants at the field said the pilot had been flying on instruments for three hours and had come in on the radio beam. We could hear him up there in the clouds as he carried out the instructions from the dispatcher and came down as easily as he would have in broad daylight—or that's the way it looked anyway. This business of harnessing electrical waves certainly is a boon."

"It is indeed," the Chief remarked, "unless they get out of control."

"What do you mean, Chief?" asked Preble.

"I remember a case out near Southston involving an unharnessed electrical wave in the audible range that bothered the telephone company for a year. Sit down, boy, and I'll tell you about it."

Preble was only too glad to sit, for he hadn't slept for 24 hours, and a story from the Chief's broad experience was worth while at any time.

"What happened?" he asked.

"It seems that the telephone company had been experiencing a loud hum on the telephone lines for a year or so," the Chief began, "and this noise had led to several complaints from local subscribers. Nothing that the phone company did seemed to help in the least. They knew that the hum was at 2100 cycle frequency and continued to study it with a cathode ray oscilloscope* and in other ways.

"One day two of the telephone company's engineers had an oscilloscope connected across the line at Tarrydale, about 5 miles from Southston, and were watching the 2100 cycle frequency, which is the 35th harmonic of 60 cycles. As they watched, the harmonic suddenly disappeared.

"The utility lines were checked at once to find out what change had been made. It was found that a generator at the Southston textile mill had been removed from the line and a little experimenting proved that the hum was caused by this machine.

"A careful study of the design of the generator indicated that the harmonic might have been caused by a tooth ripple or because of an inherent characteristic of the machine, but why it had apparently developed suddenly after a number of years of operation without it, is somewhat of a mystery.

"We had known of the hum for some time, and as we insured the generator, we were as interested as the telephone company in assisting in the investigation.

"Further analysis indicated that a ripple might be caused either by the short circuiting of some of the turns in one of the poles of the rotor or else from a disturbance of the magnetic circuit from an unbalanced phase condition resulting in the burning of rotor wedges and the rotor iron. The assured was, therefore, asked to obtain from the manufacturer the rotor resistance and other design features of the machine.

"With this information the telephone company engineer and Inspector Timkin. . ."

"Chief," interrupted Preble, "I remember him—when I first came here. He built his own oscilloscope, didn't he?"

"Yes, that's right. He digs deeper into radio, television and those subjects than most of us. . . Anyway, they connected the oscilloscope to the line and conducted several tests with the generator in operation. By arranging a system of condensers to filter out the 60 cycle wave the 2100 cycle wave was increased in amplitude until it gave a full sized image on a 3″ cathode ray screen.

"Timkin knew of one other instance where a harmonic was caused

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* A cathode ray oscilloscope is an apparatus for the visual study of electrical vibrations by focusing a cathode ray on a fluorescent screen. A pattern is formed on this screen which tells a story to a person trained in the use of the instrument. This apparatus is the heart of the radio television receiver and is called a videoscope in the television industry.

by poor commutation in an exciter, so the excitation was removed, but the 2100 cycle wave persisted, although at much less amplitude.

"A further check of the resistance of the field windings gave values so close to those supplied by the manufacturer that any possibility of defects in the windings was eliminated. Later the rotor was taken out and carefully examined, but it was found to be in good order.

"Timkin and the telephone company men concluded that a special filter would be needed to eliminate the troublesome harmonic. It was found that when the generator was operating at full voltage, the amplitude of the 35th harmonic was approximately 15 volts superimposed upon a 2300-volt 60-cycle wave. The harmonic rode the telephone company apparatus into all of the receivers over an extended area and became audible on lifting the receivers."

"Chief," asked Preble, "did the harmonic interfere with the operation of the machine?"

"Not in any way that we could discover, but all parties concerned were glad to find out what was causing the telephone line trouble. . . Say, young fellow, why didn't you flag me. Here I've kept you with my talking when you should be at home sleeping. Can you drive home without falling asleep?"

"Oh, I won't have any trouble about that."

"All right, get going. I'll call you if we need you. Nice job you did last night . . . and give me a ring when you reach home, will you?"

SINGLE-CASING 80,000 KW

Among the new central station generating giants is the 80,000 kw, 1800 rpm, 1250 lb, 900° F, condensing turbine generator under construction for Niagara Hudson Power Corporation at Oswego, New York. Built in a single casing, it is regarded as marking an advance from tandem-compound or cross-compound construction. The unit will be about 63′ long and 13′ in height, and will be supplied with steam from a generator rated at 850,000 lb per hr. The new unit is expected to produce a kw-hr of electricity from .85 lb of coal.

BLAST FURNACE GAS

Raw, uncleaned blast furnace gas is used as fuel in two new 4-drum bent tube type boilers installed by Dominion Steel and Coal Corporation at Sydney, Nova Scotia. *Power* magazine reports that the boilers are rated 186,000 lb of steam per hour continuously at 475 lb pressure and a total temperature of 750° F. when burning pulverized coal, and 165,000 lb per hr burning blast furnace gas. Coal is a supplementary fuel and is burned only when there is insufficient gas, and to start up a furnace. Among the problems that called for solution in the use of blast furnace gas was the disposition of about 17.5 tons of unburnable dust in the 70,000,000 cu ft of gas used by the two boilers in a day.

PULVERIZED COAL LOCOMOTIVE

A new German 4-6-4 locomotive designed for a speed of 109 mph is fired with pulverized fuel. *Mechanical Engineering* reports that the pulverized coal is conducted from the tender to the cab at the front of the engine where it is fed into the furnace. The smokestack is at the rear of the engine, immediately in front of the tender. Large wide windows at the front of the cab provide the engineman with an uninterrupted view.

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

June 30, 1938 — *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,080,718.10
Premiums in course of collection (since April 1, 1938)		863,850.85
Interest accrued on bonds and mortgages		84,472.49
Mortgage loans		203,097.10
Home Office real estate and Philadelphia branch office		642,331.05
Other real estate		315,786.37
Bonds on an amortized basis	$9,494,346.88	
Stocks at market value	6,635,672.25	
		16,130,019.13
Total		$19,320,275.09

LIABILITIES

Unearned premium reserve		$8,419,769.83
Losses in process of adjustment		326,305.02
Commissions reserve		194,249.76
Taxes reserve		275,057.81
Other liabilities		267,233.03
Liabilities other than capital		$9,482,615.45
Capital stock	$3,000,000.00	
Surplus over all liabilities	6,837,659.64	
Surplus to Policyholders		**9,837,659.64**
Total		$19,320,275.09

WILLIAM R. C. CORSON, President and Treasurer

Incorporated 1866 *Charter Perpetual*

Department	*Representatives*
ATLANTA, Ga., ... Citizens & So. Nat. Bk. Bldg.	W. M. Francis, Manager. N. F. Bailey, Chief Inspector.
BALTIMORE, Md., ... 704-9 Garrett Building . .	D. W. Little, Manager. R. P. Guy, Chief Inspector.
BOSTON, Mass., ... 87 Kilby Street	Thomas F. Rice, Manager. W. A. Bayliss, Chief Inspector.
BRIDGEPORT, Conn., . . City Savings Bank Building .	W. G. Lineburgh & Son, General Agents. A. E. Bonnet, Chief Inspector.
CHICAGO, Ill., ... 175 West Jackson Boulevard .	P. M. Murray, Manager. C. W. Zimmer, Chief Inspector.
CINCINNATI, Ohio, . . . 1904-12 Carew Tower . .	James P. Kerrigan, Manager. W. E. Glennon, Chief Inspector.
CLEVELAND, Ohio . . . 1040 Leader Building . .	Arthur F. Graham, Manager. F. E. Le Gates, Chief Inspector.
DENVER, Colo., ... Gas & Electric Building . .	J. H. Chesnutt, Manager. Jesse L. Fry, Chief Inspector.
DETROIT, Mich., ... National Bank Building . .	L. L. Coates, Manager. Thomas P. Hetu, Chief Inspector.
HARTFORD, Conn., ... 56 Prospect Street . . .	F. H. Kenyon, Manager. A. E. Bonnet, Chief Inspector.
NEW ORLEANS, La., . . 333 St. Charles Street . .	R. T. Burwell, Manager. Arthur R. Keiler, Chief Inspector.
NEW YORK, N. Y., ... 90 John Street	C. C. Gardiner, Vice President. J. F. Hunt, Chief Inspector.
PHILADELPHIA, Pa., . . 429 Walnut Street . . .	A. S. Wickham, Manager. John L. Scott, Chief Inspector.
PITTSBURGH, Pa., ... Arrott Building	William P. Wallace, Manager. W. C. Nicol, Chief Inspector.
ST. LOUIS, Mo., ... 319 North Fourth Street . .	Chas. D. Ashcroft, Manager. Eugene Webb, Chief Inspector.
SAN FRANCISCO, Cal., . . 114 Sansome Street . . .	C. B. Paddock, Manager. L. E. Grundell, Chief Inspector.
SEATTLE, Wash., ... Arctic Building	E. G. Watson, Manager. William J. Smith, Chief Inspector.
TORONTO, Ont., Canada, . Federal Building . . .	H. N. Roberts, President The Boiler Inspection and Insurance Company of Canada.

PLUS VALUE

It is the Company's aim, with your co-operation and that of your engineers, to hold at a minimum the chance of accident to your power plant equipment. If you have been one of the fortunate many among Hartford Steam Boiler policyholders who have not had a serious accident to insured equipment, the result we both desire has been achieved, but there is one "plus value" of our service which you have not had an opportunity to observe. This is Hartford Steam Boiler's exceptional engineering help in time of emergency and the promptness with which that help is made available.

Accidents will occur in spite of all efforts to prevent them. Those of our Assured who have experienced such a misfortune have witnessed the sure, efficient way in which our men co-operate with a client's organization to work out the quickest and most economical plan for shortening the delay in production. They have seen how the breadth of the Company's experience frequently enables it to be of inestimable assistance in accomplishing permanent repairs. They are familiar with the facility with which the Company can locate and procure substitute equipment, if such be necessary. These Assured know also that losses under the policy are paid fully and promptly.

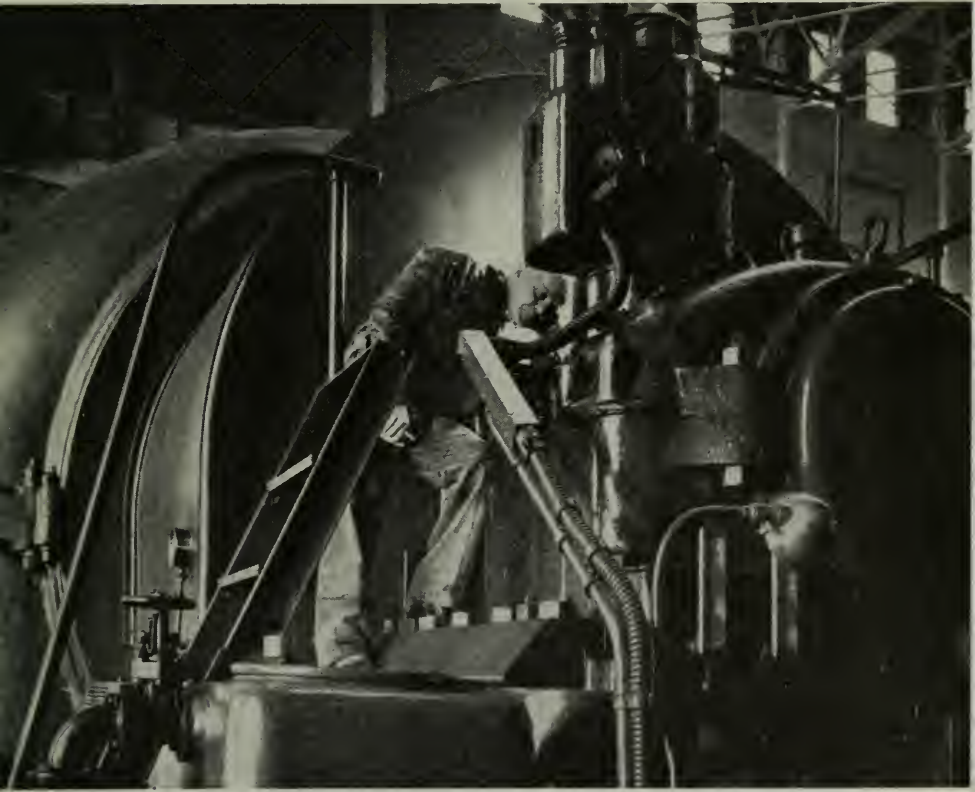
The fact that Hartford Steam Boiler has had longer and much more varied experience than any other company in inspecting and insuring boilers and machinery makes this outstanding service possible. It is this that justifies the choice of Hartford Steam Boiler as your carrying company.

"Crack Detection in Turbine and Engine Parts"

Vol. 42 No. 6 April, 1939

The Locomotive

The Hartford Steam Boiler Inspection and Insurance Co.



Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Crack Detection

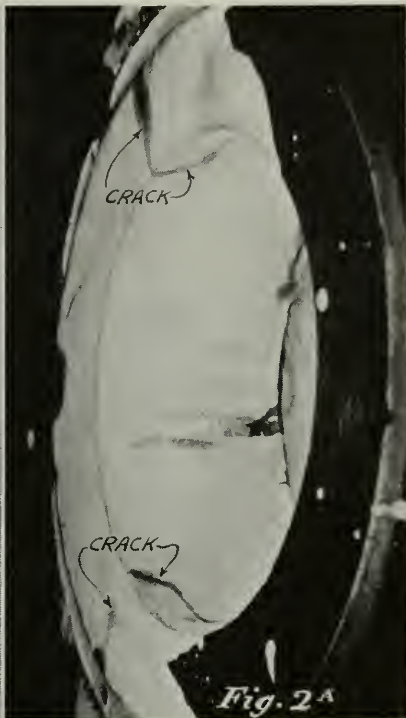
Application of Whitewash and Magnetic Tests to Reciprocating Machines and Turbine Parts

By H. J. VanderEb, *Assistant Chief Engineer, Turbine and Engine Division.*

EXPERTNESS in the art of crack detection in engine and turbine parts is acquired only through extended experience, particularly as respects the vulnerable locations of stress concentration—the places where stresses are most conducive to trouble. In his work the experienced investigator can make use of two effective aids to assist both in the detection of a crack and in the study of its extent after it has been found. These aids are the whitewash test and magnetic testing.

Whitewash testing consists of soaking a suspected surface with kerosene, carefully drying and then painting with whitewash. Surface

Figure 1—Crack in the fillet of the crankweb and crankpin of a Diesel engine. It was located by means of the whitewash test without dismantling the engine.



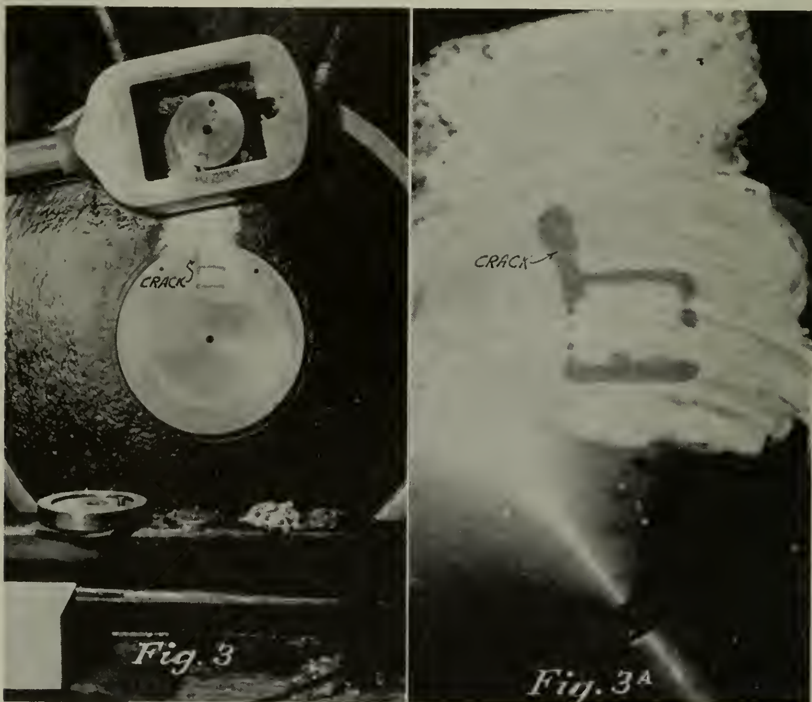
Figures 2 and 2A—Whitewash test showing crack across one of the eyes on the inside of a crosshead.

cracks deep enough to hold oil will show up as the oil works out and discolors the dried whitewash. Magnetic testing consists of magnetizing the part to be examined, and distributing over its surface fine iron particles, in powdered form or suspended in a liquid, which accumulate at a crack.

WHITEWASH TESTING

Figures 1, 2 and 3 present good examples of the results obtained with whitewash tests. There is an extensive field for this simple and effective method, because it permits examination with a minimum of dismantling. Figure 1, for instance, shows a crack in the fillet of the crankweb of a Diesel engine and was photographed through the regular crankcase inspection opening. In order to make the suspected parts accessible, the crank bearing was merely disconnected and the connecting rod temporarily supported from the wrist pin. By being thoroughly acquainted with the vulnerable locations where cracks may be expected in crankshafts, cracks of the kind shown in Figure 1 may be found by means of the whitewash test without doing extensive dismantling. It is not necessary to dismantle the whole engine at any one time for whitewash testing.

Figure 2 shows a crack across one of the eyes on the inside of a steam engine crosshead. Figure 2A is a magnification of the same defect Figure 3, and the accompanying magnification in Figure 3A, show—at the corner of the keyway in a steam engine crank—a crack which



Figures 3 and 3A—A fine crack in the keyway of a steam engine crank. Figure 3A is a magnification of the defect.

was believed to exist because of a severe shock to which the engine had been subjected.

Frequently the oil seeps out of such cracks and discolors the whitewash as soon as it has dried, but often considerable time must elapse before a trace of oil becomes visible. In some cases, when there is no trace of oil to be seen immediately, a crack has shown up after a waiting period as long as 12 hours.

The whitewash test will not give results in the case of incipient hair line surface cracks that have practically no depth. If a crack has a depth of less than about .010″, it is not likely that there will be an oil trace through the whitewash, because the thorough wiping of the surface to remove the excess oil is likely to absorb all of the oil from the shallow crack.

When an engine sustains a severe shock, a surface disturbance that eventually may develop into a crack is apt to start in one of the reciprocating parts. However, it usually is not deep enough at the outset for the oil to give a trace. In such cases a considerable time may elapse before the working stresses of the engine cause a crack to develop to a depth sufficient to permit its discovery by means of a whitewash test. However, after a period of 3 months or longer of exposure to the normal working stresses, it is likely that the crack will have developed to such a depth that it can be detected by this means.

Examinations of turbine parts by means of the whitewash test follow much the same procedure as examinations of engine parts.

MAGNETIC TESTING

The testing of power plant equipment by means of magnetic testing is a development of the last ten years. An ingenious application of the old principle of showing the direction of magnetic force by means of iron in powdered form is known as the Magnaflux method of crack detection. It is particularly effective for fine shallow cracks, such as quenching cracks, in hardened steel parts.

In the power plant it is used extensively in the search for fine cracks in steam turbine wheel discs, bucket or blade edges, and shroud bands. Figure 4 shows a section of turbine blading ready for testing.

On the reciprocating parts and shafts of engines and compressors the Magnaflux method has been used to detect:

1. Hairline cracks of shallow depth.
2. The invisible extensions of cracks which have been found with the unaided eye.
3. Cracks in fusion welding or metal spraying and cracks existing below such surfaces.

Cracks under a coating of fusion welding, which has been applied on a shaft for the purpose of building it up to a slightly larger diameter, have been successfully located, although the weld metal itself did not contain a crack. The locating of such hidden cracks by magnetic testing is considered practicable only if the coating of weld metal is thin—about 1/16″ or less.

The Magnaflux method is also of value in locating the extremely fine, shallow surface cracks in metal-spray coatings on shafts.

Frequently it is desirable to use the Magnaflux method in testing reciprocating parts and shafts of old engines which are known to have received a shock. Such an occurrence may have started incipient cracks which have not developed to such an extent that they would be disclosed by a whitewash test.

In some cases the application of a Magnaflux test can be made at a considerable saving of time and cost in comparison with a whitewash test, particularly on small objects such as crankbolts of Diesel engines or small diameter shafts or the ends of connecting rods.

The most common method of applying a magnetic field is by the "solenoid" method, that is, by winding a number of turns of insulated wire around the part to be investigated and by sending the proper current through the wire. It is not possible to standardize the directions for creating the correct intensity of the magnetic field for various machine parts for the reason that, in actual practice, there are no two situations exactly alike as regards surface finish, cross-section, permeability and the influence of any surrounding masses of magnetic material. By experimenting a little with the number of turns of wire around an object, it is a comparatively simple matter to get the exact desired behavior of the Magnaflux powder in the magnetic field. This lies in a very narrow margin which can be determined best in any given case by experimentation.

It is always well to remember that the tendency is rather to over-magnetize than to under-magnetize. If an object is over-magnetized it is not possible to obtain the proper results, because the iron powder will build up radially away from the surface and will stand out like hair. When such a condition occurs, the magnetic field must be greatly reduced until the right amount of magnetism is obtained. In many cases that have been experienced the outline of the crack by means of the metallic powder was best visible in a very weak field or even with all of the current switched off so that only some residual magnetism remained.

The appearance of the outline of a crack defined by means of the Magnaflux powder, can be seen in Figure 5. The grayish white line of the crack is rather wide because the crack stood open to such extent that it could be easily seen with the unaided eye. For very fine, tight-lipped cracks, the line will be of similar color but much narrower. When such a Magnaflux powder line is detected, it should be wiped away and

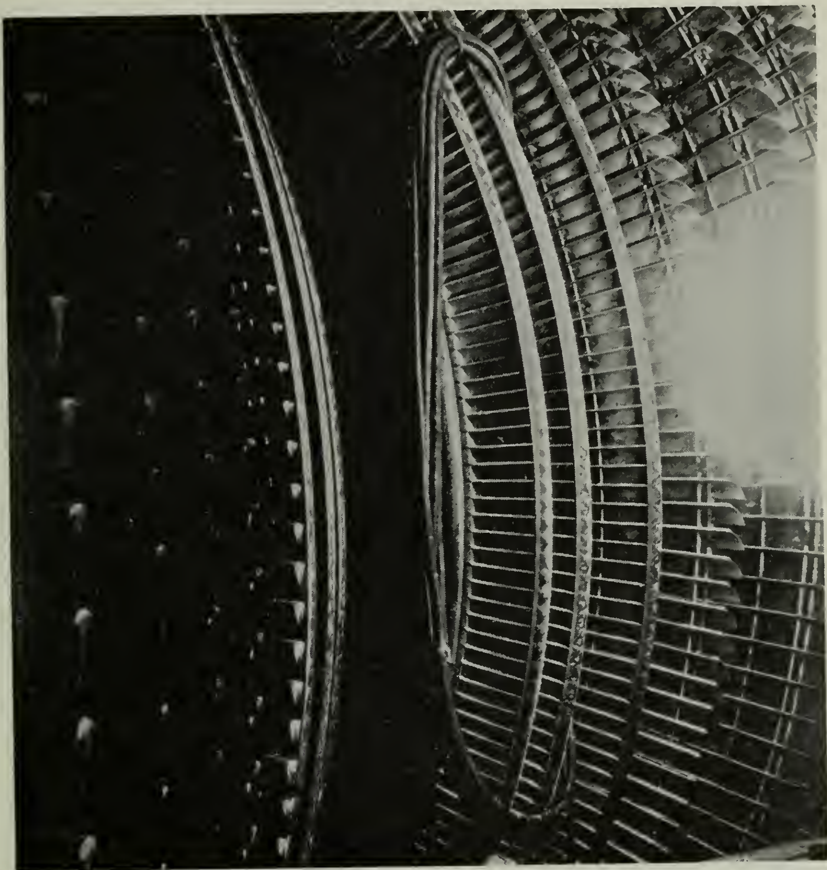


Figure 4—Applying the Magnaflux method of crack detection to steam turbine blading.

the application repeated a number of times in order to be sure that there actually is an incipient crack.

It is necessary also to make certain that a crack actually exists and that the Magnaflux powder is not outlining merely a deep scratch. While most scratches will not cause the formation of a line of the powder, there have been a few cases where a deep scratch has given the same reaction as a crack. The application of emery cloth will quickly decide the question of whether a crack exists.

The Magnaflux method will "show up" surface disturbances (incipient cracks) caused by the over-stressing of a machine part, but it is usually possible to rub out such evidences of incipient cracks with

Figure 5—Magnaflux method applied to a shaft to determine the extent of a crack which had been detected by means of the unaided eye. The magnetizing coils are shown at the right.

emery cloth. For instance, in the web of a crankshaft which was known to have been exposed to undue distortion over a period of about a year, a short forked line was "shown up" by the Magnaflux powder in exactly the place where it was expected. However, when emery cloth was used on this surface disturbance, the Magnaflux powder line could no longer be obtained. There was no doubt that there actually was a surface disturbance in the form of an incipient crack, due to the overstress that had occurred in this crankweb, but the crack had not penetrated to more than a few mils, so that it could be removed by polishing with emery cloth.

The Magnaflux method is not entirely suitable for detecting cracks in the threaded part of bolts unless the crack crosses the threads. The metallic powder lines that form at the bottom of the threads will invariably give false impressions that cracks exist. Therefore, it is always well to supplement a Magnaflux test on threaded parts with a whitewash test or at least to use a very powerful magnifying glass in case the Magnaflux indicates a crack.

There is a considerable possibility of error with the use of Magnaflux by the inexperienced, so that cracks may be overlooked. This arises from the fact that, in addition to the need of having exactly the right field strength, the magnetic flux must be in such direction that it crosses the crack. Even for the more experienced, it is desirable to try several different ways of applying the magnetic field on any given object.

Since both the dry Magnaflux powder and the paste are metallic and abrasive and the powder is easily carried about by air currents, it is necessary that bearings and electrical equipment be protected against any possibility of damage.

Because of the wide variations in machines and in plant conditions, the choice of the whitewash or the magnetic methods or the use of both should be left in the hands of those who have had wide experience in the making of such tests. In fact, the entire matter of crack detection is one calling for highly specialized skill.

In spite of precautions, however, hidden cracks may and do occur in parts that are inaccessible. Furthermore, the dismantling of certain closely fitted parts is often undesirable, because of the dangers of overstressing which the dismantling will actually introduce when such parts are forced apart.

THE COVER

An inspector listening for unusual noise as a 20,000 kw turbine generator is operating under load. This practice in the inspection of turbines is one of many for the detection of minute changes, the discovery of which may permit the avoidance of major breakage.

Testing Steam Boiler Safety Valves

By J. P. MORRISON, *Assistant Chief Engineer, Boiler Division*

IN THE early days of steam engineering, boilers were relatively small and steam pressures were so low that a single safety valve was of sufficient capacity for each boiler and it was the exception, rather than the rule, that any boiler was provided with more than one. The steam pressure fluctuated greatly during the day's operation so that the safety valve was caused to operate automatically one or more times each day. Furthermore, the feedwater was of poor quality, in the average plant, so that the boiler was cooled for internal cleaning frequently. In fact, boilers in some cases were cooled for cleaning on Wednesday and on Sunday. Unfavorable feedwater conditions resulted in priming or "carryover" when the safety valve was located on the main steam pipe connection, but there was ample opportunity to give safety valves the necessary cleaning and regrinding at intervals of a few weeks at most.

From such operating practices there grew the traditional requirement of causing the safety valve to operate daily, either automatically by increasing the boiler pressure to the popping point, or manually by operating the hand-lever, even where the size of the boiler required the use of two or more safety valves.

However, as boiler pressures increased it became apparent that causing the safety valves to operate automatically should be avoided, if dependability of the valves could be obtained in any other way, on account of the effect of the high velocity and high temperature of the escaping steam on the seat, disc and spring of the valve. The drop in pressure necessary to permit the valve to seat properly was overcome by manually operating the safety valve momentarily when the pressure was considerably below the seating point. That practice resulted in the valve closing quickly and avoided both the erosive effect of steam escaping at high velocity and the change in characteristics of the valve parts due to the high temperature of the steam.

However, in many large generating stations of the public utilities and in large industrial plants, the operating pressure is now maintained quite uniformly within a small percentage of the popping pressure. Hence, unless the pressure in the boiler and in many cases the pressure in a large battery of connected boilers can be lowered considerably before a safety valve is caused to operate manually, the use of the hand-lever may interfere seriously and needlessly with the plant output. The A.S.M.E. Boiler Code, in Paragraph P-281, provides for a maximum blowdown of 4 per cent of the set pressure. For example, in a 1200 lb boiler the "blowdown" would be approximately 50 lb, closing at 1150 lb. Therefore a safety valve operated manually with a pressure in excess of the closing point might result in a considerable drop in pressure on the entire battery of connected boilers and the waste of much steam.

It is possible to cause some safety valves to operate sufficiently to determine that they are free to open at the proper pressure by pulling or jarring the try lever just enough to cause a "spit," but without causing it to actually blow, even when the boiler pressure is above the seating point of the safety valve, but unless the operator has had considerable practice and is acquainted with the peculiarities of each valve, he is likely to exert too much force over too long a time and set the valve to blowing with the attendant drawbacks as described.

However, when a boiler is to be taken from service, the main steam stop valve, the feedwater valves and the furnace may be manipulated to control the pressure over a wide range, without affecting the other boilers at the plant, so at that time there is afforded an excellent opportunity for testing all of the safety valves of that boiler by causing them to blow automatically.

For these reasons, the Company recommends to operators of high pressure boilers that a log be kept of safety valve tests when the boilers are taken from service for any purpose. Record should be made of the date of the test and the performance of each valve for each boiler. The elapsed time between such tests depends on the type of valve and plant conditions in general, but six months should be considered the maximum safe interval, and then only for boilers with favorable feedwater conditions and expert maintenance. Of course, if any abnormal conditions are discovered as the result of a safety valve test, prompt remedial measures are necessary.

Safety valves for the protection of vessels other than steam boilers, such as those used in refrigerating and compressed air systems and many chemical processes, should be tested at such intervals and by such methods as conditions dictate. It is not the province of this article to discuss the treatment of safety valves used for such purposes. Mention of them is made in order to emphasize the need for the proper attention that they merit.

"These rock formations," explained the guide, "were piled up here by the glaciers."

"But where are the glaciers?" asked a curious old lady.

"They've gone back, Madam, to get more rocks," said the guide.—*Kreolite News.*

Air Tank Explosions and Their Prevention

Widespread indeed are the uses of compressed air, but it is evident from reports of recent air tank explosions that safe methods of handling air under pressure have not, in many instances, accompanied those uses. In recent months, news has been received of 30 air tank explosions which left as their toll 3 dead and 24 injured, besides widespread property damage.

Time after time investigations of these accidents brought forth the same conclusion: Some one had thought that any tight tank would do for compressed air. In fact, one instance was reported in which a cooking retort, made for pressure not to exceed 10 lb, was installed for operation as a compressed air receiver at a pressure up to 300 lb. The lower head blew through the floor long before any such pressure was reached.

Just any tank won't hold compressed air safely, and an accurate knowledge of the pressure-carrying capabilities of a tank is essential if it is to be relied on for safe operation.

When air receivers are to be insured, they are checked carefully at the first inspection as to inherent strength of construction and condition. The inspector cannot be satisfied, however, to know merely that a tank has been built in accordance with A.S.M.E. specifications and has no defects, because an air receiver which is safe at one pressure has the qualities of dynamite if it is operated at a pressure greatly in excess of that for which it was designed. The entire installation, therefore, is examined from the standpoint of the pressure to be used.

In spite of these primary conditions of safe use, it is amazing to observe the carelessness with which compressed air is handled. The operators and owners may realize that an accident is possible, and they may have read in the newspapers or elsewhere about such an occurrence, but unless they have actually seen the results of an air tank explosion, they are not apt to attach much importance to the hazard. Surprising as it may seem, it is usually necessary to see walls blown out, equipment disrupted, glass shattered and fellow employes on the way to the hospital before compressed air receives the respect it deserves. There is an all too prevalent feeling that "it won't happen to me."

In several of the 30 cases, the investigator discovered that, although the design in general was adequate for the pressures carried, some defect in construction had led to the failure. Among the immediate difficulties were poor brazing, poor welding, and in one case soldering

Figure 1—Typical damage as the result of an air tank explosion. This accident occurred in a paint spray room. A workman was injured.

in place of welding at a head seam. Designs which call for crimping of the shell over the heads have an inherent danger because of stress cracks as the result of the crimping. In one case such a crack progressed until the head blew out, carrying with it the crimped end of the shell. This last accident illustrates the amount of confusion and inconvenience that can be caused by an air tank explosion. The exploding head struck another air tank, burst its head, and knocked a motor off of its base. The tank itself went in the opposite direction, striking and wrecking an ammonia compressor motor. A brass plate on this tank indicated that the manufacturer considered it safe for use at an operating pressure of 150 lb. Calculations revealed that actually this figure should have been 106 lb.

Another accident was quite definitely traced to a head of an original thickness insufficient for the pressure carried.

The list of accidents included two cases of cast iron air tanks which were so weakened by progressive cracks that they exploded. One of the explosions killed a workman.

Several of the accidents were directly attributable to corrosion—on the outside when tanks were mounted on the floor, and on the inside due to the collection of moisture in the undrained section of a tank mounted vertically with a minus head at the bottom. Preventive measures in order to avoid such accidents are:

1. To mount the tank so that it does not rest on a damp or wet floor, or be subject to the dangers of damp dirt or other debris which may be swept or may collect against it.

2. To mount air tanks with the minus head at the top if set vertically and provide a drain at the lowest point of the vessel. Two plus heads are preferable.

Figure 2—Reversed minus head An improperly adjusted safety valve permitted the building up of excessive pressure.

The cause most frequently claimed for air tank failures was the non-operation of safety devices. Sometimes these were stuck shut, but more often the accidents were brought about because of tampering with the valve spring or valve weight, depending on the kind of relief device used on the tank. One owner said the safety valve had given him trouble by blowing at 140 lb and not seating until the pressure had dropped to 120 lb, so he screwed down on the valve as far as he could. After that, when the pressure reached 225 lb, the belt started slipping on the compressor and the motor switch was "thrown" by hand, as the compressor had no safety relief device. This method of operation worked well for about a week until one day the minus head reversed and was torn out. All the windows in a two story building were broken and considerable equipment destroyed.

Safety valves of the ball and lever type had been provided in another instance. Two of these valves were installed in the compressed air system and the third was on the receiver itself. The installation was well protected if left alone, but some one had been annoyed at having the safety valves blow and had slid the weights so far out on the levers as to make the relief valves useless for the pressures generated. The vessel exploded with serious damage to property.

An investigation in a New England factory revealed that some one had screwed down the adjusting screw of a safety valve so that the valve could not operate. Subsequent excess pressure caused a violent explosion.

Figure 3—Failure of the longitudinal seam. Faulty welding was given as the cause of this accident.

Two of the thirty cases were detonations because of combustible mixtures within the receivers. In a paint spray room of a furniture store, the intake to the compressor was inside the room, and the character of the explosion which occurred was such as to point conclusively to a detonation. Such an accident could have been avoided by extending the intake pipe to the outside or at least to a room in which there were no explosive fumes. In the second case, the detonation was brought about by accumulations of grease and oil on the internal surfaces of the tank and the subsequent ignition of a mixture of oil vapor and air. Witnesses reported flame and smoke when the tank burst and the internal surfaces revealed a heavy coating of oil and grease. Avoidance

Figure 4—Where an air tank head passed after an explosion. The photograph gives an idea of the force of compressed air suddenly released.

of such combustion explosions is best accomplished by good maintenance, by not over-lubricating the compressor and by being careful that the intake to the compressor is not at a point where oily fumes are prevalent. Good maintenance should include not only the periodic cleaning of the vessel itself and examination of its safety appliances, but it should also apply to proper maintenance of the compressor, especially the discharge valves, and the water jackets and other cooling surfaces such as the intercooler and aftercooler. These last should be kept clean to prevent excessive temperatures.

Included in the group of accidents were two others which were not strictly air tank explosions, but were accidents of the same type—

the result of testing new vessels with air. Both led to personal injury and property damage. Repeated warnings with respect to this testing practice have been issued, but such accidents continue. The proper practice is the hydrostatic test to the required pressure. If the vessel is defective, it merely leaks, but does not explode or rip open as in the case of an air-filled receiver. The reason for the use of air, dangerous as it is, is the increased trouble and expense of supplying and emptying the water.

Reasonable air tank safety is not difficult to obtain, if a few precautions are observed. It is well to insure such tanks because they and their safety devices are inspected periodically and if unforeseen accidents do occur insurance is available to cover losses under the policy. When buying a new vessel, the legal requirements, if any, of the state, city or other jurisdiction should be specified. Such regulations are either identical with or similar in most respects to the A.S.M.E. Unfired Pressure Vessel Code, which is the standard for construction recognized by all reliable manufacturers. If there are no local regulations, it is always best to specifiy A.S.M.E. code construction and stamping.

When installing air tanks, best results will be obtained by mounting them off the floor, and by keeping them and their surroundings clean. Intake air should be obtained from a clean, dry source, and the tank itself should be in a well ventilated location. Air tanks should be equipped with drains to eliminate dangers from condensed moisture during idle periods. Lubrication of the compressor should not be excessive. In general, safety is at a maximum if good industrial housekeeping prevails.

Hydro-Pneumatic Tank Failures

Also subject to the explosive forces of released high pressure air are the hydro-pneumatic tanks so widely used in connection with water supply systems which rely on the air pressure to force water to various levels. Pressures up to 100 lb are common in these tanks, which, when they fail, cause damage and personal injuries similar to those resulting from air tank failures. In eight accidents on which reports were secured three persons were injured and others were in jeopardy. Two of the eight accidents were in schools.

The causes of these accidents were much the same as those for air tanks. One failure (See Figure 5) occurred because of progressive cracks in the crimped edges of the shell, five were over-pressure failures such as that shown in Figure 6, one resulted from a lap seam crack and the eighth because the minus head was made of steel which was too light for the pressures carried. In four of the five accidents

Figure 5—Broken shell of a hydro-pneumatic tank in which the shell had been crimped around the head and welded.

Figure 6—Hydro-pneumatic tank which ripped open because of over-pressure.

caused by over-pressure the failure was attributed to non-operation of pressure relief valves or electrical cutoffs to the motor or both. The fifth tank was equipped with no relief devices whatsoever.

As in the case of air tanks, hydro-pneumatic tanks should be properly constructed for the pressures carried, should be protected by reliable and adequate relief devices, and should be inspected periodically to check on the system in general, the operation of relief valves, and the growth of defects from such causes as corrosion.

In the section of this article devoted to the dangerous practice of testing vessels with air, is a recommendation that hydrostatic tests should be used. The latter tests have a hazard also if care is not taken to vent the tank as it is being filled with water. Otherwise conditions will be similar to those in a hydro-pneumatic tank and the pressure will increase as the water is pumped into the tank. Any failure of a tank under pressure and partially filled with air is apt to be violent.

Steam Turbine Condenser Explosion

The chief engineer was killed and one of his assistants badly injured at a West Virginia mine in November when a turbine condenser 10′ long and 40″ in diameter exploded and broke a 5″ steam line. As the condensate pump had not been operating properly, the repair crew had set about fixing it. Some one had thought it was necessary to close the stop valve in the vacuum pump suction and had done so. This, as it turned out, blanked off the condenser, because the atmospheric relief valve proved inoperative. Pressure built up rapidly in the condenser until a whole side of it blew out, one of the pieces hitting the steam line. The escaping steam scalded the two men who were working near the condenser. The accident probably would have been averted if the atmospheric relief valve had functioned, but it was stuck, probably because of deposits and long inactivity. The condenser was made of ribbed cast iron 1″ thick.

The Theory of Creep

"The mechanism of creep is not well understood. In a high-speed turbine, an hourly change in length of one part in 100,000,000 is not unreasonable, and test equipment can detect such movements in a week's time. Yet, scientists tell us that the spacing between atoms of iron measures approximately 1/100,000,000 inch. Perhaps the imposed stress gradually pries an atom loose from its neighbor so it can grasp the next atom beyond. If this divorce and remarriage occur as often as once per hour per inch of length, the material maintains its continuity and strength. But, if they get to happening oftener, the material is unsuitable to withstand the temperatures and pressures in turbines."—E. L. Robinson in *Power Plant Engineering.*

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

SIDNEY B. COATES, *Editor*

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THE LOCOMOTIVE *of* THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE CO.

Assistant Managers at New Orleans and Detroit

Lewis M. LeMeilleur and William H. Kerrigan have been promoted to the rank of Assistant Manager in the New Orleans and Detroit Departments respectively, the former as assistant to Manager R. T. Burwell and the latter as assistant to Manager L. L. Coates.

In both departments increases in business have necessitated this enlargement of the administrative staff, and in both instances the men chosen are excellently qualified by reason of their long service to policyholders and their broad knowledge of the many aspects of the Company's business to handle the more responsible duties now given them. In their new posts their abilities will be more completely available in servicing the Company's clients and friends.

Mr. LeMeilleur has been a Special Agent in southern territory since September 7, 1919, and for a number of years was stationed at Houston, Texas. His experience in serving policyholders there and in other sections of the New Orleans territory has given him a seasoned preparation for his new position, which is effective April 1, 1939. Mr. LeMeilleur joined the Company as an inspector on March 26, 1915. He was born at Pine Bluff, Arkansas, June 12, 1886.

Mr. Kerrigan has been a Special Agent in the Detroit Department since October, 1930, and was promoted to his new position effective March 1, 1939. His years of service in the Company's employ and his successful handling of the needs of policyholders in the Detroit area give him a well rounded background for his new duties. Mr. Kerrigan joined the Company as a clerk in the Philadelphia Department in 1922 and was made a Special Agent in August, 1930. He was born in Wilmington, Delaware, June 2, 1894.

Furnace Explosion in Stoker Fired Boiler

A LOSS of $4,640 resulted from a fuel explosion in a stoker-fired water tube boiler at a paper mill in September. The stoker was of the quick dump type and the dumping mechanism had been operated a few minutes before the accident. Apparently, immediately after the dumping of the clinkers and while the draft was retarded, unburned gases accumulated in this boiler, in another boiler and in the breeching for both. These gases exploded with a violence sufficient to damage the settings of the two boilers, to cause a bulge in the economizer housing, and to destroy the breeching.

Accidents of the above type are the result of the presence of fuel in excess of the amount needed for immediate operating conditions, with lack of sufficient draft to clear the gas passages. The prevention of such mishaps lies in avoiding conditions favorable to the accumulation of combustible gases, either hydrocarbon or carbon monoxide, and the maintenance of sufficient draft to carry off those dangerous gases promptly, if they are formed.

Accident to 75 hp Coal Pulverizer

The grinding parts of a 75 hp turbine-driven pulverizer were wrecked when a bolt in one of the wearing plates broke and jammed so that 88 stationary pegs were broken off, the rest knocked out of line, and other damage done to scratching pegs and wearing plates. The property loss, which amounted to approximately $1500, was paid by Hartford Steam Boiler.

Steam enters a turbine at a temperature hot enough to set fire to a piece of wood and less than a thirtieth of a second later leaves it at a temperature too cool for a comfortable bath. It may enter at a pressure of 1200 lb per sq. in. and leave at the low vacuum of one-thirtieth of an atmosphere. The peripheral speed of recent large turbine rotors is approximately 820 miles per hour—80 miles faster than the speed of sound.—W. E. Blowney, General Electric turbine engineer.

Hot Water Tank Explosion

THE explosion in January of a hot water storage tank mounted in a basement room of a Michigan garage resulted in a property loss estimated at $5,000. The tank was beneath an office, which was virtually demolished by the blast. Cement floors were ripped open and brick walls were either blown out or weakened beyond repair for

Figure 1—Damage to the exterior of a large garage because of a hot water tank explosion.

a distance of 30 feet each way from the corner of the building, as shown in Figure 1.

The boiler which supplied water to the tank was blown from its base and a steel heating boiler damaged. The brick chimney, part of which is shown in the photograph, was so damaged that it had to be torn down. As the safety valve opened readily at 100 lb when tested after the accident, it was considered that the most likely cause of the explosion was a minus head of a construction which was inadequate for the pressure carried. This head reversed as shown in Figure 2.

It should be remembered in connection with such equipment that it is subject to whatever city water pressure exists in the mains and that the expansion of water due to heat in a system from which no water is being used increases the pressure rapidly, provided there is a check valve in the inlet pipe, as there was in this case. This increase in pressure can set up high stresses in the tank, and if during this process enough heat is applied to raise the temperature considerably above the atmospheric boiling point, conditions are ripe for a violent explosion in case a rupture of any part of the shell occurs.

Witnesses said the safety valve in this instance was blowing steam prior to the explosion, but the remedial measure of pulling the fire in

Figure 2—The tank which failed. The reversed minus head is clearly shown.

the hot water supply boiler did not permit a rapid enough lowering of the temperature and pressure before the tank failed. Although the safety valve tested satisfactorily after the accident, it may not have functioned fully before because it might have been partially stuck. Stuck valves have often been jarred loose by the force of an explosion.

Copper Hot Water Unit Explodes in Residence

When a New England housewife forgot to shut off the heater unit used with a copper hot water tank, the tank exploded, badly damaging the foundation of the building and the interior of the first floor. Walls were thrown out of alignment, doors and windows were broken and a large furnace near the hot water unit was wrecked.

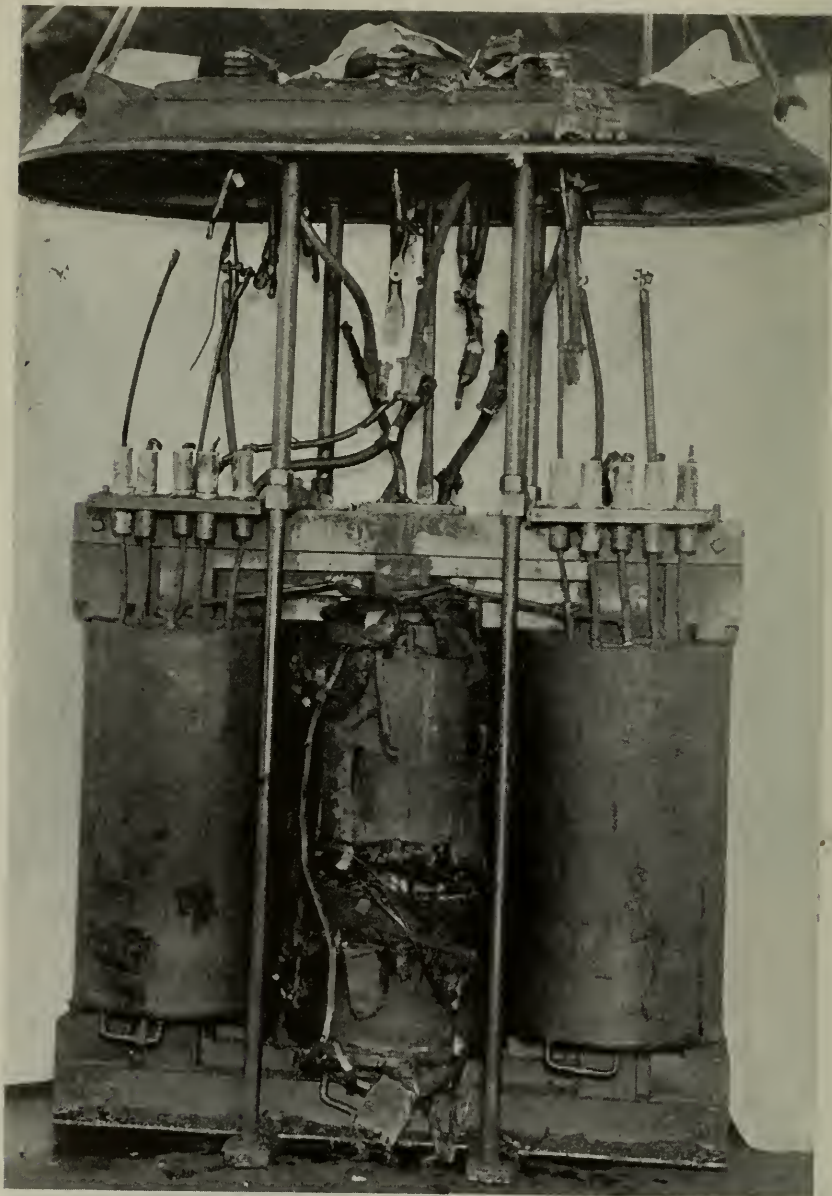

Figure 1—Coils of a 500 kva transformer after a short circuit in the primary windings. The photograph shows the high voltage terminal side of the transformer.

Age Brings About Transformer Failure

A 500 KVA transformer, which was important in the conduct of an eastern manufacturer's production, failed a few months ago when an internal short circuit in the primary winding of the center phase burnt through the insulation and curtailed the plant's supply of alternating current.

As indicated in Figure 1 (Page 184), the short circuit damaged the insulation in the center phase, but examination of the other two coils, after the oil had been drained and the casing removed, revealed that all of the insulation was so brittle due to service and age as to be practically useless. It could be torn off easily with the fingers. The case is an excellent example of the effect of age on transformer windings.

Before the transformer could be returned to service, it had to be rewound, a repair requiring more than four weeks to complete.

Paragraphs of Progress

DIESEL WITH HIGH TURBULENCE

A Diesel engine feature which is finding favor in this country is the so-called Lanova system of combustion which was evolved by Franz Lang in Munich, Germany. This provides high turbulence within the main combustion chamber by means of a violent blast from an "energy chamber" in which

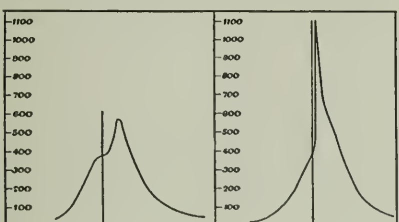

Figure 2

pressures said to be as high as 1400 lb per square inch are created by pre-combustion of a small part of the fuel injected. The highest pressure during the combustion stroke in the main combustion space is comparatively low, around 600 lb. *Diesel Power,* in an ex-

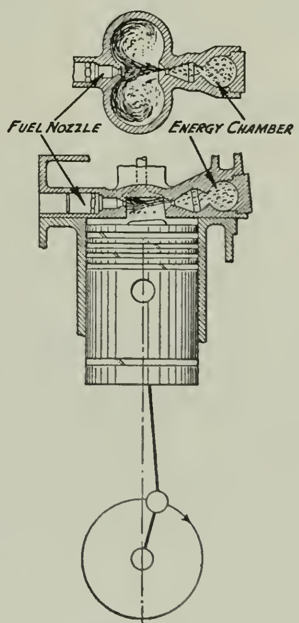

Figure 1

haustive treatment of the subject, lists among the advantages, a quiet running engine and a very complete burning with resultant high fuel economy. Figure 1 shows diagrammatically the action of the "energy chamber" at the beginning of the combustion stroke. Figure 2 shows typical pressures in pounds per square inch in the main combustion chamber (left) and energy chamber (right) at full load.

LARGEST GENERATORS

Three of the main generators for the Grand Coulee project are now being built. The *Electric Journal* points out that these machines, each with a rating of 108,000 kva, are about 30 per cent more powerful than the largest existing machines in this country. Each generator weighs more than 1,000 tons, is 24′ high and 45′ in diameter. Lighting and power needs for a city of 650,000 persons could be supplied by these three machines, the output from which will be used principally to drive 12 motor-driven pumps. The pumps will lift water from the Columbia river into a reservoir from which it will be distributed for irrigation purposes over 1,200,000 acres of now arid, but potentially fertile, farm land.

STEAM-ELECTRIC LOCOMOTIVE

Completion of a 5000 hp steam-electric passenger locomotive for the Union Pacific Railroad marks the inauguration for service of a new power source for railroading. After nearly two years of work since the announcement of an experimental steam-electric locomotive (The Locomotive, April, 1937), engineers of the railroad, General Electric Company, Babcock and Wilcox Company and the Bailey Meter Company have designed and built such a locomotive capable of pulling a 12-car train from Chicago to Los Angeles over 2.2 per cent mountain grades without helper. Temperatures en route for various seasons range from −40° to 115° F. and some of the mountain passes are more than 8000 feet above sea level.

The boiler utilizes forced circulation, the steam passing from the tubes through a separator to the superheater and then at 1500 lb and 920° F. to the high pressure and low pressure turbines. Exhaust steam is condensed in an air-cooled condenser in which turbine-driven fans drive air against finned tubes. The electric generators, motors and automatic control are similar to those now in operation on trains. It is said the overall thermal efficiency from fuel to the driving wheels in the new locomotive is double that of a conventional steam locomotive. The new locomotive consists of two complete identical 2500 hp units capable of either dual or independent operation under the control of a single engineer.

COAL TRANSPORTED BY BLOWING

To avoid the cost of moving a railroad spur, a Michigan firm has erected 800 feet of piping from the coal storage to a new power plant and is successfully supplying the fuel requirements of a 110,000 lb-per-hour boiler by blowing its coal supply to it through the pipe.

POLLUTION REMEDY

One after another the industrial discharges that pollute streams are being diverted to useful purposes. Among the most troublesome of such substances has been so-called "pickle liquor," the aftermath of pickling steel in sulphuric and other acids to remove scale and oxides. *Business Week* describes the product into which "pickle liquor" is converted as a plastic suitable for wallboard, pipe covering, building block and brick, and insulating "clay" for boiler settings.

SENTENCES OF PROGRESS

An oil circuit breaker has been built by the French for use at 500 kv.

"Twenty years ago there were few boilers that developed over 5,000 lb of steam per hour per foot of width, whereas today 20,000 lb per foot of width is not unusual and a few are producing 25,000 lb per foot of width."—John VanBrunt.

Poor Golfer: "Well, how do you like my game?"
Caddy: "I suppose it's all right, but I still prefer golf." —*Whatyoumay.*

Taps From the Old Chief's Hammer

THE Old Chief sat staring out of his window. The office boy brought in the afternoon mail, but his superior apparently did not hear him enter the office. An hour later the boy returned with some reports, and laid them on top of the untouched mail. He was about to speak, and thought better of it, but did go at once to the Old Chief's assistant, Tom Preble.

"Something's wrong with the Chief," he said.

"Why? What makes you think so?" asked Preble.

"He hasn't touched the mail. All he does is look out of the window. He didn't even know I came in either time."

"Thanks, Johnny, I'll see whether anything's the matter."

Preble went at once to the Old Chief's office and was much relieved to see that the older man was reading his mail.

"Has there been anything wrong, Chief?" he asked. "Johnny was much concerned because you hadn't even looked at the mail. He said you didn't even seem to realize he had come into the office."

"Johnny's a good boy," the older man replied. "Yes, there is something wrong. Inspector Mel Scott is up at Grand Bend in the hospital with some bad burns. They phoned me just after lunch."

"What happened?" asked Preble. "Scott is as careful as they make them."

"Don't know, except that there was an explosion. My hunch is that that it was a natural gas explosion; natural gas is the fuel they use. . . . Scott is under the best of medical care, but I wish you and Matt Jacobson would drive to Grand Bend, make sure that Mel has everything he needs and then go to the plant and see what you can learn about the accident. Stay with it until you know what happened."

"O. K., Chief," said Preble, and hurried on his way.

As he and Inspector Jacobson drove along, they discussed the case. "The old man takes a thing like this mighty hard," said Preble. "I've seen him before, when something happened to one of us—like that automobile accident last fall. He knows accidents happen. Who doesn't in this business? But the Chief believes that they don't have to happen, and he seems to blame himself in some way or other when one of the men gets hurt."

"We're lucky to have a boss like that," Matt answered. "Nobody does a better job than the Chief, and if anybody can show us how to prevent an accident, he can, but accidents *will* happen."

. . . At the hospital they found Scott swathed in bandages, but cheerful enough.

"Why'd you fellows come way up here? I'm all right," he grinned. "Just a little bad luck."

"The Chief sent us . . . said to be sure you were comfortable as possible."

"You tell him I was just plain lucky," Scott answered. "I was making an internal inspection of the water spaces of a fire tube boiler. You know how the Chief always says to test the air in a boiler before you climb in? I was using an acetylene torch and started to put it inside the boiler before I crawled in, when flame just exploded out of the manhole into my face. If I'd gotten into that boiler and pulled my torch after me, I'd have been a goner."

"Where'd the gas come from?" asked Preble.

"I've been thinking about that," answered Scott. "The only place I can figure is the boiler feed pump. They operated it with natural gas pressure when the boiler was down."

"The Chief asked us to make an investigation," Preble said, "and we'll tell you what we find before we go back to town."

At the plant Preble and Jacobson found that Scott's deductions were entirely correct. The pump was operated by means of steam ordinarily, but when the boiler was empty, the natural pressure of the gas, about 80 lbs, was used to operate the pump for washing the boiler or filling it as need be.

A leaky valve in the steam line from the pump to the boiler permitted the gas to leak past the valve and into the water spaces of the boiler. . . .

When the two men returned to the Chief, they found him in good spirits, which fact surprised them a little.

After they had made their report, he remarked, "That's fine, but what pleases me as much is a report from the doctor. He just telephoned me that Scott's burns aren't particularly serious and that he'll be out in 10 days or so if no trouble develops. Now what are *you* going to do?"

"What do you mean, Chief? We'll prepare a written report as usual."

"Not enough. To be sure, write your report, but let's see what you two can develop as a foolproof method of operating and maintaining these gas-driven pumps. In the meantime I'll find out what Hartford can tell us about the problem. When you've finished, we'll call the boys in for a powwow. It seems to me that this is a case where we had better ape the monkey."

"What do you mean, Chief?" asked Jacobson.

"Well," mused the older man, "you don't find a monkey touching a hot stove more than once."

Joking with the Coal Man, Who, It Appears, Can "Take It".

The following letter is presented by *Powerfax* as having been received by a coal operator who had sold a carload of coal to one of his good friends. After using some of the coal, the friend suggested to the coal operator that he send out the following letter to the trade. The coal operator appreciated the joke so much that he framed the letter and has it hanging in his office.

"SHORTWEIGHT CLINKER CORP.
Augustus Asbestos Shortweight, Pres.
We specialize in Asbestos Coal, the fuel with less fire—Your money back if it burns your furnace.

Gentlemen:

We are shipping you today 99.9 tons of our special asbestos coal, for a trial run in your boilers. We are confident you will find this fireless fuel different from any other you have ever used. Note the following special merits:

1. The coal, as shipped, contains plenty of water, so that cars do not require wetting down before unloading.
2. Analysis shows unusually big percentage of sulphur, iron and other by-products which will be of untold value to a chemical plant like yours.
3. High yield of clinkers, absolutely guaranteed. Think what this will mean in a year's time on the value of cinders sold.
4. Extraordinarily low b.t.u. content practically eliminates all danger of over-heating boiler walls and arches, thus effecting a great saving in furnace repairs. You cannot overheat with this fireless fuel.
5. Layers of asbestos distributed throughout the coal help to keep down fire losses and, in the opinion of our company, render the coal safe for use with no danger of complete combustion—a menace to all boiler room operators.

Trusting that you will enjoy this new fuel and give us your future business, we are

Very truly yours,
Shortweight Clinker Corp."

The excited sportsman heaved a mighty heave, then reeled madly till the poor troutling was nine feet aloft, with its head against the tip of the rod, flapping feebly there.

"Now what'll I do?" he demanded.

"So fur ez I can see," said the puzzled lumberjack, "there ain't nuthin' fur you to do except climb the pole." —*Think.*

The husband drew up his chair beside his wife's sewing machine.

"Don't you think it's running too fast?" he said. "Look out! You'll sew the wrong seam! Mind that corner, now! Slow down. Mind your finger! Steady!"

"What's the matter with you, John?" said his wife, alarmed. "I've been running this machine for years!"

"Well, dear, I was only trying to help you, just as you help me drive the car."

—*Trumbull Cheer.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

December 31, 1938 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,017,829.88
Premiums in course of collection (since Oct. 1, 1938)		1,269,900.12
Interest accrued on bonds and mortgages		85,116.22
Mortgage loans		180,987.10
Home Office real estate and Philadelphia branch office		642,331.05
Other real estate		307,636.37
Other admitted assets		14,884.43
Bonds on an amortized basis	$9,308,558.22	
Stocks at market value	7,148,374.50	
		16,456,932.72
Total		$19,975,617.89

LIABILITIES

Unearned premium reserve		$8,357,631.77
Losses in process of adjustment		263,976.82
Commissions reserve		257,243.37
Taxes reserve		300,000.00
Other liabilities		279,426.16
Liabilities other than capital		$9,458,278.12
Capital stock	$3,000,000.00	
Surplus over all liabilities	7,517,339.77	
Surplus to Policyholders		**10,517,339.77**
Total		$19,975,617.89

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You are the one who profits—in actual dollars—when the productive life of your boilers, machines, or electrical equipment is extended, when your power plant is made more efficient, when you are able to maintain continued production without expensive accidental shut-downs.

For over seventy years The Hartford Steam Boiler Inspection and Insurance Company has devoted its energies exclusively to the job of learning how to prevent accidents to power equipment—how to make machines operate efficiently and without failure for the longest possible time. This continued effort has given Hartford Steam Boiler an unequalled knowledge of construction, installation, operation and maintenance of such equipment as is insured under your policy. Years of specialization in an exacting work have developed in the Company's personnel a deep-rooted tradition for thoroughness. This plays an important part in making Hartford Steam Boiler protection a profitable investment for the Company's clients.

The insurance of your boilers and machinery in Hartford Steam Boiler is your guarantee of obtaining the best (and, thus, the most economical) in power plant protection.

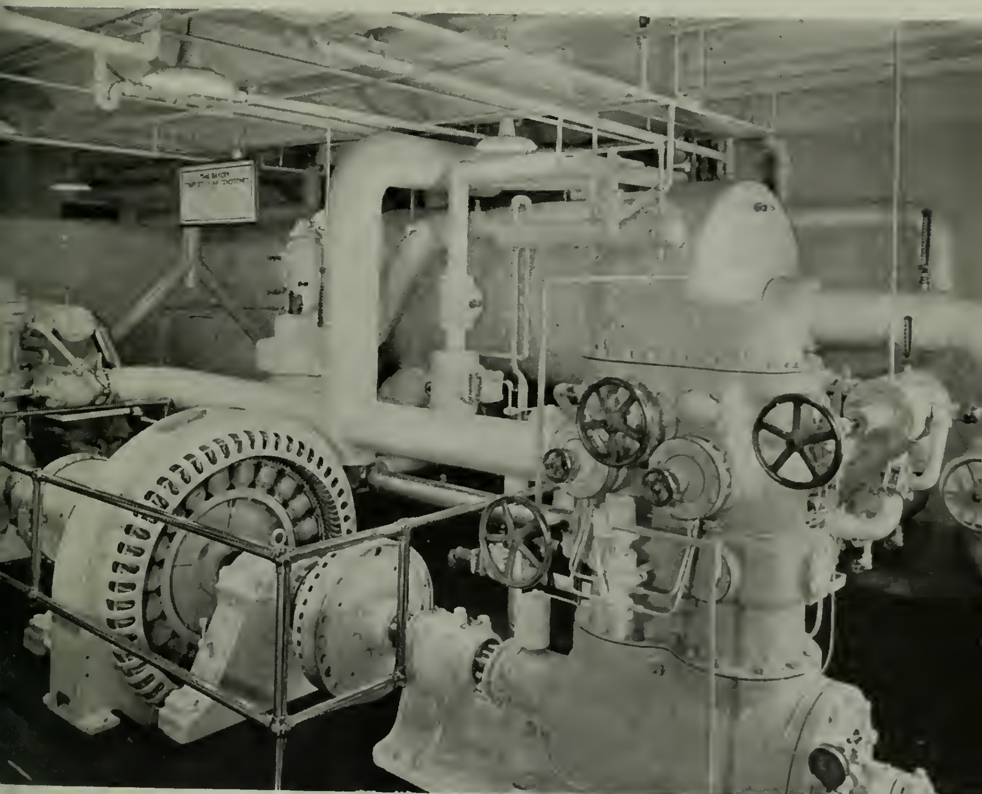
"Lessons from Accidents to Compression Type Refrigerating Systems"

Vol. 42 No. 7

July, 1939

The Locomotive

The Hartford Steam Boiler Inspection and Insurance Co.



Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Lessons from Accidents to Compression Type Refrigerating Systems

Refrigeration, which makes it possible for us to have manufactured ice, air conditioning, and protection against the spoilage of foodstuffs and a variety of other products, is a complex and important part of the power plant picture, whether for business, industrial or domestic purposes. Hence, it is desirable to guard against anything that interferes with the continuity of service and safety of the equipment involved.

Much careful engineering has gone into the design and manufacture of the various machines, pressure vessels and piping which comprise refrigerating systems; standards of construction have been improved and made uniform; tendencies once somewhat prevalent of over-rating equipment have been definitely lessened. Today the public, when it goes out to purchase refrigerating equipment from reliable manufacturers, can do so with confidence that the equipment is specially designed for its work and is relatively safe to operate.

However, in spite of all this preparation for efficiency and safety, company records show such a continuance of accidents as to warrant consideration of the various hazards involved and the methods of avoiding those hazards.

Pressure Vessels Containing Refrigerant

From the standpoint of catastrophe, the most vulnerable parts of a refrigerating system are the receivers, shell and tube type condensers, and brine and other types of coolers. Such pressure vessels are now being built almost entirely of welded construction, and the present checks on construction and supervision in the manufacturers' shops are such as to inspire the confidence of the purchaser. Under adequate manufacturing procedure, welding by properly qualified operators is considered safe.

To the insurance company the history of pressure vessels in a refrigerating system is a matter of importance and such history is easily and quickly available for most recently constructed vessels. However, this is not always the case even today, and for welded vessels constructed prior to 1930 such information is seldom forthcoming. Defects in the seams of vessels "without pedigree" may be located by X-ray, but as this method is not yet practicable for field use, there is general recommendation made to trepan plugs from doubtful welded seams (See The Locomotive January, 1936, Page 2)—a method which gives definite and conclusive evidence of the condition of the seams tested.

The need for and wisdom of such testing are demonstrated in spectacular fashion by several recent explosions of such vessels because of the failure of welded seams. In most cases there was evidence of over-pressure, but it was sometimes the case that the welded seam failure occurred at the normal operating pressures.

In considering 11 accidents to receivers, condensers and coolers—accidents which took a toll of eight lives and injured a score of persons—eight of the explosions were found to be definitely attributable to inadequate welding. Although the equipment was not insured, permission was given in a number of cases to make a thorough examination of the vessel which failed. The welds examined revealed lack of penetration, gas pockets, slag inclusions and porosity. It has been said sometimes that the vessels used in refrigerating systems do not explode with violence, but there was sufficient force released in these accidents to send tanks several hundred feet through walls and partitions, to send the head of a tank through a 6″ brick wall, to shatter plate glass windows, to move machinery from its foundations.

Figure 1—Head from a refrigerating vessel which failed at 150 lb pressure when the welded head seam gave way.

In at least two of the explosions the damage to the failing vessel was supplemented by further loss due to an explosion of an ammonia gas and air mixture. This latter hazard also results when ammonia is released because of accidents to piping and fittings. No matter what the refrigerant, its loss involves expense and inconvenience, but with ammonia especially combustion explosion is a very real danger when this refrigerant is mixed with air.

The failure of the condenser cooling water supply led to one of the explosions. Cooling water was piped from a tank outside the building. When water in this piping froze during cold weather, pressure in the condenser built up rapidly and the vessel burst. Failure of the condenser water always puts a strain on the system, but such a strain can be avoided, if adequate temperature indicators are watched and heeded, and high pressure cut-off and relief devices are installed and kept in good working order.

Lack of a relief device, which is as necessary on the low-pressure side of a refrigerating system as on a heating boiler, accounted for the explosion of several brine coolers and the rupture of low-pressure piping. One of the worst refrigerating system catastrophes in recent years, involving property loss estimated at nearly $100,000, originated

Figure 2—Condenser which exploded when poor girth seam welding permitted a 34" piece of plate to tear out.

in a brine cooler. Details were not readily available, but primary factors included the failure of a welded seam and either the lack of or non-operation of a pressure relief device. A few moments after the original brine cooler failure, there occurred an ammonia-air detonation which destroyed the building. Luckily the accident occurred at a time when the plant's numerous women employees were not present. Another accident much like it, that is, the explosion of a brine cooler because of poor welding, led to even greater damage when fire ensued. One man was killed and five injured. At Bellevue, Ohio, on June 2, an explosion caused the death of an ice company employee and injury to eight other persons when ammonia fumes were released.

Protective Devices

These accidents, and others similar to them, demonstrate the wisdom of protective devices generously distributed. Any vessel in the system which can be isolated by means of stop valves should be protected independently by a standard relief valve. When such valves are used, in order to facilitate repairs should leakage occur, stop valves are necessary between the pressure vessels and the relief valves, and such stop valves should be sealed or locked in the open position before the system is placed in operation.

Another important control is the pressure limiting device or so-called high pressure cut-out, which is the primary safety device in the operation of the plant. It functions to shut down the compressor and is regulated to operate at a pressure below that for which the relief valve is set. This plan, under normal operation, causes the compressor to stop before the pressure builds up excessively and actuates the relief valve, thus avoiding wastage of the refrigerant.

There is much to be said also for the convenience and value of thermometers at important locations in the system. Recommended locations are near the suction outlet from each unit of the evaporating coils, in the suction and discharge lines near the compressor, in the main liquid refrigerant line leaving the condensers, and in the water lines to and from the condensers. Irregular conditions anywhere in the system will be indicated on such thermometers and will permit adjustments or shutdowns before the relief valves function. Some systems also have an automatic temperature control device which will shut down the system before the pressure rises to a point at which the relief device will operate.

Warning and relief devices are of assistance under a variety of circumstances. If the head or discharge pressure is indicated as excessive, any of several factors may be the cause. These include the presence of non-condensible gases in the system, insufficient or too warm condensing water, particularly during the summer period, insufficient condenser capacity, and accumulation of oil or scale on condensing surfaces. Non-condensible gases can be removed by more frequent purging or by the installation of an automatic non-condensible gas remover. If the trouble is caused by lack of or too warm condensing water, the volume of water over or through condensers should be increased or a new source of water supply obtained. It is essential, of course, that, in plants where boiler make-up and condenser supply water come from the same system, adequate check valves be installed to prevent the backing up of water into the water mains from a feedwater heater or other source of hot water.

Figure 3—Lard cooler which exploded under normal use because of the failure of a defective casting.

Lack of water supply is shown up quickly by gauges in or near the condenser. Usually a water shortage is caused by the water to the condenser being momentarily shut off for repairs or because of a mistake in closing valves. However, heavy demands by the fire department, stoppage of pipes from a cooling tower and failure of a circulating pump may prevent a sufficient supply of water to the condenser. Of course, the locating of pipes in heated areas or in places where they will be exposed to the direct rays of the sun should be avoided. The condensers themselves should never be installed where the direct rays of the sun can strike them.

As was noted earlier in this article, too much cold constitutes a hazard. Frozen condenser water permitted one of the explosions previously described. Another occurred when the temperature in a water cooler, part of a freon system, became too low and water froze and ruptured the tubes. This system was equipped with thermostatic control which either failed to function or had been set too low. A property loss of $1,300 resulted. Frozen water in cooler tubes has caused a number of accidents in refrigerating systems used for air conditioning.

A defective casting permitted the explosion of a lard cooler which was equipped with a relief valve, but which failed at a pressure below that at which the valve was set. A lard cooler is a large cylinder into which liquid ammonia under pressure is permitted to vaporize and cool the shell on which lard is congealed. About a half hour before the end of the run, the inlet valve is closed. This leaves sufficient ammonia in the roll to complete the run, following which the outlet stop valve is closed and the temperature is thus allowed to increase. This practice is followed so as to prevent frosting and subsequent rusting of the outside of the roll. The accident, which caused about $4,700 damage, occurred at a pressure somewhere between the 20 to 25 lb operating pressure and the 75 lb setting of the relief valve. The break in the casting is shown in Figure 3.

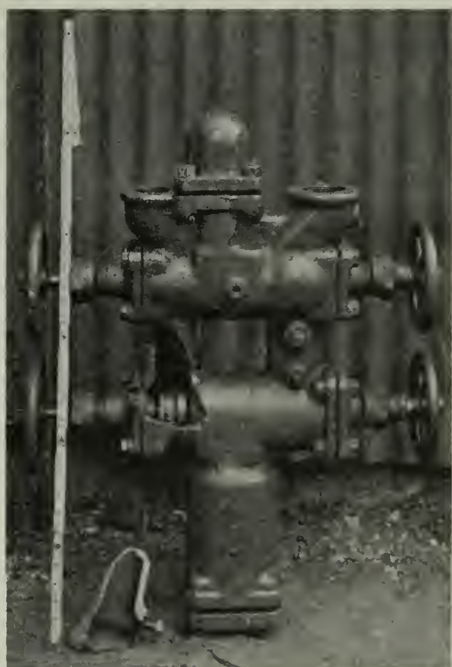


Figure 4—Ammonia compressor manifold which exploded because of an excess of pressure within it. The failure led to the death of an engineer, who was drenched with the refrigerant.

Piping and Fixtures

Attention thus far has been directed toward the various pressure vessels that are included in a refrigerating system. Equally important in the functioning of the system is the interconnecting piping, the failure of which will shut down the system. As a matter of fact the frequency of accidents to piping, joints and fittings is higher than to the pressure vessels themselves. The causes of these accidents include excess pressure, poor welding, deterioration of weld metal, undue weight on the piping, vibration, a blow while under pressure, failure of soldered connections, brittle metal, expansion and contraction, faulty design and improper location.

When piping carrying refrigerant fails, the resultant escape of the refrigerant constitutes a definite loss, and if the refrigerant is ammonia, there is apt to be injury to persons and damage to foodstuffs exposed to it. An example or two will serve to illustrate the possible extent of damage. In a meat storage plant a ruptured high pressure ammonia liquid line freed enough ammonia to cause $7,000 damage to meats in storage through direct contact and another $3,000 consequential damage loss due to lack of refrigeration. Repair of the pipe cost $140. At a fish packing plant ammonia leaking through a flaw in a pipe caused $1,200 damage to fish. A long list of such accidents could be given.

Corrosion

An accident because of normal corrosion in air is easily avoidable in connection with a refrigerating system. Wire brushing down to bare metal followed by the use of a good corrosion-resisting paint is an effective preventive of corrosion in air.

The importance of maintaining the proper density of brine cannot be over-emphasized in any consideration of corrosion. If brine becomes acid, which it has a natural tendency to do, the corrosion of coils, ice cans and fittings submerged in it will be rapid and require too-frequent replacement. Failure of piping or other refrigerant-containing parts of the system suspended in brine usually so permits contamination of the brine that salvage is not possible.

Whether such failures are from corrosion or some other cause, the results are the same. There have been numerous cases of failure of evaporating coils that have not been sufficiently protected from ice cans in brine tanks. In other cases careless handling of ice cans has brought about the rupture of submerged refrigerant piping. A weak solution of brine will lead to the freezing in brine cooler tubes or the formation of ice on the pipes of a tank coil. The results are probable rupture and certain reduction in heat transmission.

Mistakes in Operation

Mistakes in operation sometimes play an important part in accidents. Figure 5 shows a piece of stainless steel pipe which blew open for a distance of 67 inches. The pipe was a part of a cooling coil installation in a brewery, the beer being cooled by running it over the coil. Contrary to orders, a workman had used boiling water to wash this piping while it was under pressure with the system charged, a procedure which is believed to have cracked the piping along a special fin. Its

Figure 5—Stainless steel ammonia piping which tore open in a brewery.

subsequent failure released a large amount of ammonia and shut down the plant.

It is essential that operators refrain from tightening bolts or disconnecting pipe lines while parts are under pressure. When the refrigerant is ammonia, it is dangerous to work on the system before making certain that all ammonia has been removed. Ridding sections of a system of ammonia is best accomplished by the use of hot water. The application of heat by this method will not cause excessive pressure and temperature. A blow-torch never should be used for this purpose.

When withdrawing the ammonia charge, care should be exercised so that the weight of ammonia in the drum or cylinder does not exceed the amount specified on the shipping tag, and the drum should be stored away from heat even though such containers are protected by temperature and pressure devices that will allow boiling ammonia to escape before the safe pressure of the container is exceeded. The same precaution against over-filling should be taken when the charge of ammonia is transferred from one part of the system to another, as is sometimes necessary in making repairs, or when the system is being initially charged.

There have been numerous instances where ruptures have occurred because an excessive amount of liquid ammonia had been stored in a confined space. Avoidance of this difficulty consists of following the manufacturer's instructions and in using and heeding a liquid level indicator.

Charging a system through the compressor is a dangerous practice, for even a machine equipped with safety heads cannot handle a large slug of liquid, and a cracked cylinder or cylinder head may result. A connection at the liquid receiver and the introduction of refrigerant through the evaporating coils will greatly lessen the possibility of damage to the compressor from liquid.

In laying out a refrigerating system, piping should be so installed as to avoid its being placed so close to walls or floors as to interfere with cleaning. Lines now existing with this hazard should be relocated before a leak occurs with subsequent loss of refrigerant, and possibly greater damage from explosion and burning with such a refrigerant as ammonia. Insulation on piping should be kept in good repair in order to prevent warm air from coming in contact with cold surfaces with resultant condensation, frost and rapid corrosion.

It is important, of course, that persons working about refrigerating systems thoroughly understand the equipment in their charge and recognize the dangers in operating mistakes.

Compressors

Thus far in this article attention has been centered on pressure vessels and piping in compression type systems. Equally important in the satisfactory operation of such systems, are the compressors, motors and pumps. These machines are, of course, subject to breakdown as parts of a refrigeration layout, but the hazards for the most part do not rise out of their specialized use.

A review of failures in a large number of compressors, both of the steam and separately driven types, will throw some light on the kinds of accidents that are happening. In brief, the general types of accidents are: Breakage or loosening of valves; breakage of the main shaft or other part because of a progressive crack; failure of the connecting rod, cylinder head or some other part when the compressor is started with the discharge valve closed; the blowing out of a cylinder-head or the breaking of some other part because of a slug of liquid; the failure of lubrication, and the failure of welded repairs.

These accidents involved chiefly ammonia, freon and carbon dioxide compressors used for a variety of refrigeration purposes, including air conditioning. Most of the accidents might have been avoided

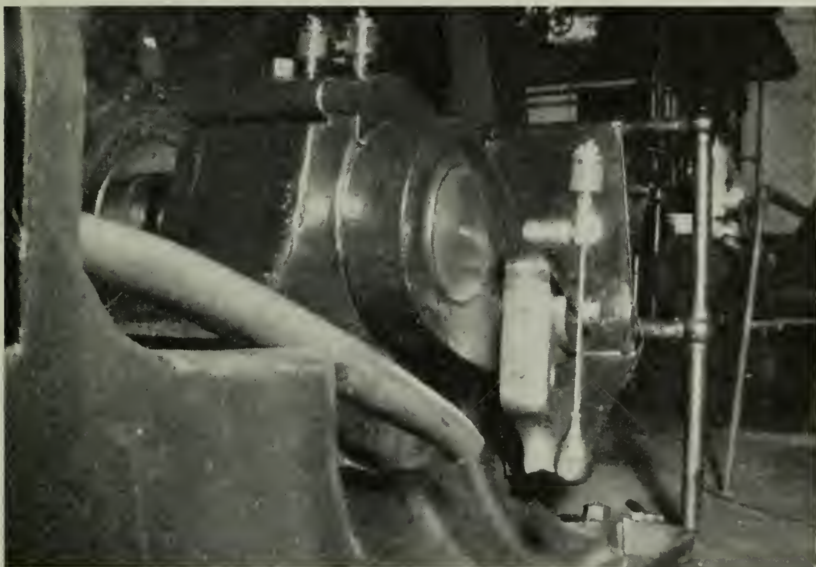


Figure 6—Broken connecting rod of a 150 lb ammonia compressor. The accident was attributed to an attempt to start the compressor 3 times in spite of burned out fuses. The discharge valve had not been opened.

through: Periodic dismantled inspection to detect incipient cracks and other faulty conditions such as valve troubles, adequate purging of non-condensible gases, proper draining of lines and proper charging to eliminate slugs of liquid, proper attention to compressor cooling water and compressor lubrication, opening of discharge valves on starting, and not using welding for repair purposes when there is a likelihood that that repair may set up stresses which will lead to cracks.

One in every three accidents to insured ammonia compressors is caused by the breaking or loosening of the compressor valves. When this occurs, the resulting damage is frequently quite large, sometimes involving the replacement of the compressor cylinder or of the cylinder block when two cylinders are made in block.

Valves of ammonia compressors of modern high-speed type are, as a rule, spring-loaded and there is a small dashpot provided to prevent slamming. Furthermore, the suction valve is spring-loaded to open while the discharge valve is spring-loaded to close. Both the spring and the dashpot are of great importance for the shockless seating of the valves. When such parts need renewing, they should be obtained from the manufacturer of the compressor or from his representative. Shocks will cause fatigue cracks that ultimately result in breaking of the valve and they also may cause loosening of the nut that secures the dashpot piston to the suction valve stem. When either of these kinds of failure occurs, the suction valve gets adrift in the cylinder above the piston and it becomes easily possible for the cylinder and the piston to be broken or at least badly scored.

In order to prevent such accidents, it is desirable that the compressor valves be inspected very carefully at regular intervals—at least one a year, preferably just before the heavy-duty summer season. Such an inspection requires the removal of the cylinder heads and the pulling of the pistons. The cost and inconvenience of such dismantling are not negligible items, but such inspections are well worth the cost if, thereby, a serious accident can be avoided.

Aside from the question of accident prevention, the annual dismantling for inspection of the compressor valves is desirable from the standpoint of economy. Leaky valves are wasteful of the power supply, so that it is well that the valves be tested for tightness and ground in if necessary once a year.

The testing of the discharge valves on single-acting vertical type compressors can be accomplished most conveniently by creating a good vacuum in the crankcase. This can be achieved by operating the compressor for several minutes with the suction stop valve in closed position. After ascertaining that a good vacuum exists in the crankcase (by holding the thumb over the oil intake pipe and slowly opening the valve) the discharge stop valve should be closed and the cylinder head removed. The tightness of the discharge valve is then proved if the vacuum holds it fast to the seat. If the discharge valve leaks, the vacuum is quickly lost and regrinding of the valve is necessary.

The testing of the suction valve on single-casting vertical type compressors can best be done by turning the piston upside down and pouring kerosene on the underside of the valve. It is necessary, of course, to hold the valve tightly against the valve seat for this test.

The principal causes of compressor valve breakage are: Fatigue cracks caused by the slamming that results from loss of dashpot action, loosening of the nut on the end of the valve stem, permitting slugs of liquid ammonia to enter the compressor, continual entry of wet ammonia gas, and operating the compressor at too high a speed.

Lubrication plays an extremely important part in the safe operation of refrigerating compressors. Certain refrigerants are active on the oil itself and not only tend to "thin out" the oil or go into solution with it, but have a definite chemical effect upon the lubricant. Lubricants for use in refrigeration or air-conditioning must obviously be so pure in their initial refinement that they will not react chemically or precipitate any unstable hydrocarbons, which constitute a portion of any oil that has not been specifically refined for refrigeration purposes. The necessity for moisture-free oil has led to specifications which call for high dielectric strength, in fact, a dryness equal to that for transformer purposes. This attention to oiling precludes actual accidents to the lubricating system, such as a recent breakdown of a turbine-driven dielene compressor which failed when an oil cooler tube cracked and permitted water to mix with the lubricating oil.

A great many of the accidents to compressors cause the release of refrigerant with the well-known panic, personal injury and property damage hazards attendant on the release of such refrigerants as ammonia and sulphur dioxide.

Accidents to pumps, motors and electric control will not be discussed here, but it is clear that the dependence of the system on them makes their maintenance and their periodic inspection of an importance comparable to that of the compressor and of the system itself.

Summary

The avoidance of a maximum number of accidents to refrigeration systems involves many details as has been pointed out or suggested. Summarized these preventive measures appear to fall under the following heads:

1. Follow the manufacturer's instructions implicitly in the choice, erection, operation and maintenance of the complete system.
2. Entrust the equipment to men competent to carry out these instructions.
3. Follow established safe practices for the handling of refrigerants.

4. See that the system is properly protected by pressure relief, temperature and liquid level devices and controls.
5. See to it that periodic inspection is made of the entire system in order to discover conditions that may lead to accidents.

Full Automatic Turbine Control

A new 60,000 kw "topping" turbine recently was placed in operation at a West Virginia utility plant. This unit, having steam conditions of 1250 lb, 925° F. inlet and 235 lb exhaust, is unique in that it is the first steam turbine to be equipped for operation under full automatic control. A transfer switch on the operator's control board can be set to place the unit under either manual control or under full automatic control. These two methods of operation are discussed briefly below.

Every necessary function for starting the turbine, bringing it to speed, operating the unit or shutting it down can be performed by manipulating switches on the operator's control board. All valves, by-pass valves, and drain valves in both the steam inlet and exhaust lines can be operated by motors. A motor and cam arrangement moves an oil relay for opening the steam emergency stop valve any desired amount. Similarly, another motor-driven cam will raise or lower the auxiliary pilot valve which, in turn, will so elevate the main pilot valve as to cause the steam controlling valves to be closed or opened. Any adjustment of the speed governor and of the exhaust pressure regulator is accomplished by a motor on each of these devices. A solenoid, when energized, will move a relay valve to admit oil to the emergency governor oil nozzle, which will shut down the turbine by operating both of the emergency trip valves. Another solenoid will move a relay valve to admit oil underneath a piston for resetting these emergency trip valves. The combined trip and test valve for opening, tripping or testing the emergency stop valve in the steam inlet line can be operated by one solenoid to open or trip and another solenoid to test the valve. All solenoids are mounted at the side of number one bearing and can be moved manually by a lever handle in case of any emergency.

For automatic starting and control of the unit, the transfer switch is merely moved to "automatic control." Thereafter, all motors and solenoids that have been listed above are under the control of a multiplicity of relays on the automatic control panels.

A permanent-magnet generator on the turbine drives the actuating motor of a Woodward governor and it is this governor, in conjunction with time relays, that is used to bring the unit up to several levels of speed within the proper intervals of time. When the unit is ready to take load, an automatic synchronizer is employed to tie it in with the system. During operation of the turbine there are a number of safety devices such as a differential pressure regulator, eccentricity meters, vibrometers, differential expansion indicators, bearing oil thermometers and other temperature devices that will automatically limit the load or shut down the unit when excessive conditions arise.

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*Disruption of Turbo-Alternator

A SERIOUS accident occurred at the power station of the Portsmouth Corporation (England) on August 5th in connection with a recently installed turbo-alternator. The rotor of the alternator, described as a solid forging weighing 18 tons, is said to have burst without warning, completely wrecking the machine and damaging the steam turbine.

"A piece of metal weighing more than 150 lb was hurled onto a beach more than a quarter of a mile away, and another heavy piece of the machine fell into the harbor. In the station itself the damage was much less than might have been expected, although an auxiliary switch was severely damaged by flying fragments, one panel being destroyed. One of the boilers had three water tubes bent but not broken. The damage to other plant property was slight. Fortunately there was only one casualty, an employee of the contractors who was burnt about the face and arms by the resultant fire.

"The machine was part of a 30,000 kw turbo-set running at 3,000 revolutions per minute. At the time of the mishap it was carrying a load of 20,000 kw and running in parallel with the grid and two other machines in the station, having been on load for ten days. The grid maintained the supply, though there was some fluctuation of voltage, and the other two sets were reconnected to the line and running on load again within a few minutes.

The breakdown resulted in a fire within the machine and among some connecting cables, but this was effectively dealt with by the fire brigade."

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* Reprinted from *Vulcan* for January, 1939.

"Sambo, I don't understand how you can do all your work so quickly and well."
"I'll tell you how it is, Boss. Ah sticks the match of enthusiasm into the fuse of energy, and then Ah just naturally explodes." —*Grounds and Shorts.*

Boiler and Pressure Vessel Accidents

THIRTY-TWO boiler and pressure vessel accidents, which have come to the attention of THE LOCOMOTIVE in the first four months of this year, killed 8 persons and injured 34. In few of these cases had the owner secured the protection of insurance and inspections, so that in most instances he suffered not only the inconvenience of a disastrous accident, but the cost as well. The pictures illustrating this summary indicate to some extent how serious that cost was.

In the paragraphs which follow, the highlights of some of the accidents will be presented. Where possible, the causes will be given.

POWER BOILER

When steam from ruptured tubes of a water tube boiler at a Southern utility struck the control board for the fuel system of an entire battery of boilers, the plant and the city's power supply were shut down for two hours during the morning rush period. It was reported that direct property damage, in addition to the inconvenience of the interruption, amount to approximately $8,500.

Low water and over-heating were responsible for several accidents to oil-field boilers used in drilling operations. Outside of the loss of the boiler and its housing, there was seldom additional property dam-

Figure 1—Firebox of a locomotive type boiler in an oil field after its explosion due to low water and over-heating.

Figure 2—Two courses of a three-course horizontal tubular boiler which exploded because of corrosion.

age, but the loss of life was serious. One explosion killed four persons and two others one person each. This type of accident and its avoidance is discussed more fully in THE LOCOMOTIVE for July, 1936, Page 87.

A Virginia lumber mill collapsed like a house of cards when a horizontal tubular boiler exploded in February. One man was killed and

Figure 3—Wreckage following the explosion of a horizontal tubular boiler in New Mexico.

three others were injured. An investigation revealed that the boiler was seriously thinned by both internal and external corrosion.

An engine room and other buildings were wrecked, as shown in Figure 3, by the explosion of a horizontal tubular boiler at a plant in the Southwest. Parts of the building were thrown as far as 500 feet. Four men were injured and property damage was estimated at approximately $3,000.

HEATING BOILER

Four hundred fifty persons walked in orderly fashion from an Illinois theater after a cast iron hot water heating boiler exploded beneath the stage. Although the stage was wrecked and some of the debris was blown into the seating floor of the theater, all but two women escaped, and they suffered but minor injuries. The boiler exploded, it was said, because of the non-operation of the relief valve. A piece was blown out of the boiler as shown in Figure 4 and sections were torn apart. It was estimated that the damage was approximately $4,000.

Figure 4—Failing section of a hot water heating boiler in a theater.

UNFIRED PRESSURE VESSEL

Corrosion and a relief valve which did not function were blamed for the explosion of a hot water supply tank in a Virginia residence. The explosion tore a hole about 8 feet square through the foundation of the building as shown in Figure 5 and knocked cast iron heating and hot water supply boilers off their bases. Considerable damage was done to the first floor rooms and their furnishings, as well as to neighboring buildings in which windows were broken.

Condensate receivers are apparently safe enough if operated as intended, but the possibility of their being subjected to boiler pressure should be considered. Such an occurrence at a North Carolina plant brought about the explosion of one of these vessels with the subsequent death of an engineer. Condensate was piped to a trap which failed to function properly and permitted high pressure steam to flow through it to the receiver. This in itself would not have caused the accident, if the vent pipe from the receiver had not been obstructed.

An air tank explosion in a North Carolina automobile repair shop caused the death of a workman and resulted in extensive property damage to a building and an automobile. The exact cause of the blast was not determined, but over-pressure was a factor.

When a 1000 lb vulcanizer door blew off at a New Jersey plant, two men were injured. The door went 15 feet across the room and

Figure 5—Left—Hot water tank after its explosion. Right—Hole in brick wall made by the exploding tank.

through a wall. In this case also the cause was not apparent, but worn door bolt threads or carelessness in tightening the bolts, or both, may have permitted the failure at a comparatively low pressure.

The explosion of a steam separator at a Southern mill so injured the foreman, when he was caught in steam pouring from a broken 4″ main which was discharging at 125 lb, that he required hospital treatment. The accident occurred at a time when the main engine was just being started.

At Boston three men were burned when a copper cheese kettle exploded, its contents being thrown to all parts of the room.

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

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Subscription price 50 cents per year when mailed from this office.
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GEORGE S. REYNOLDS

George S. Reynolds, from 1919 to 1934 manager of the Pittsburgh department, died in the hospital at McKeesport, Pennsylvania, on June 4, 1939, following a brief illness. He had recently returned from Florida to his summer home at Slippery Rock, Pennsylvania. Mr. Reynolds' service with the Company began in 1913 when he enrolled as a special agent at Pittsburgh where the 26 years of active service until his retirement in 1934 were spent. He was born in England on November 19, 1866. The former Pittsburgh manager held the respect and friendship of many business and industrial men in and about Pittsburgh, and his interest in this work has fostered a continued close feeling between the Company and its many clients in western Pennsylvania and West Virginia.

JAMES A. SUBLETTE

James A. Sublette, special agent, who was associated with the St. Louis department of the Company for 40 years, died April 11, 1939, at St. Petersburg, Florida. He had been on the retired list since July, 1937. The veteran special agent was well known and well liked by the numerous policyholders and agents in the St. Louis territory in which he spent his entire period of service with the Company. Mr. Sublette was born July 1, 1861.

DONALD E. McHENRY

Donald E. McHenry, retired inspector, died April 16, 1939, at his home in Paterson, New Jersey. He had been employed from 1900 until 1932 as an inspector in the New York department. The policyholders served by him received not only the benefit of his long training and service with the Company, but also of a thorough marine experience prior to his enlisting with Hartford Steam Boiler. Mr. McHenry was born January 21, 1867, in North Wales.

ELLIS J. THORNTON

Ellis J. Thornton, inspector in the St. Louis department for 28 years, died May 25, 1939, at St. Louis following an extended illness. Prior to this he had been active in the St. Louis section where he had earned the confidence and respect of numerous policyholders. He was a quiet and unassuming man, but was endowed with a pleasantness which made him thoroughly liked. He gained his early training under the late Chief Inspector C. R. Summers when both were employed in a Georgia textile mill. Mr. Thornton was born in Tennessee on February 29, 1876.

CHARLES HUMPHREYSON

Charles Humphreyson, an inspector in the New York department beginning in 1913, died in Vassar hospital, Poughkeepsie, New York, his home city, on May 23, 1939. He was popular with the policyholders in the Poughkeepsie section in which he had served for so many years. Of Scotch ancestry, born in Liverpool, England, April 21, 1880, he brought to his work a sturdy thoroughness which he combined with extreme good nature and friendliness.

Fifty Years with Hartford Steam Boiler

Halsey Stevens, Assistant Secretary

"Mr. Stevens' half-century of service began when our company was still young and struggling to establish itself in its new and peculiar field of steam boiler protection. It covers the long period of the company's growth and of the expansion of its field and protective methods to include all classes of power apparatus. In that growth and expansion he participated as he advanced from office boy through positions of increasing responsibility to that of Assistant Secretary of our company, in administrative charge of an important department of its business operations.

"It is with sincere and grateful appreciation of the loyal and able service he has given our company in this long career, that we would join his friends and associates with hearty congratulations on his fiftieth anniversary, which he attains at an age which promises the many years of continued activity which all hope lie ahead of him."

The foregoing paragraphs are from the Board of Directors' minutes in appreciation of the long and sterling service which Assistant Secretary Halsey Stevens has accomplished since he went to work for Hartford Steam Boiler at the age of 14. Mr. Stevens is now in charge of the accounting and personnel divisions of the Company.

In the picture accompanying this article Mr. Stevens is shown at his desk on the anniversary day, April 10. He has been Assistant Secretary of the Company for the past 17 years, having been promoted to that position from the post of chief clerk to which he was appointed in 1916.

Bearing Failures in Diesel Engines

By H. J. Vander Eb, *Assistant Chief Engineer, Turbine and Engine Division*

Bearing failures account for approximately one-third of the total number of accidents to insured Diesel engines. In view of this unduly large proportion, the following discussion of the causes underlying such failures should be of interest to owners and operators of this type of engine.

Excessive bearing temperatures, produced either by high rubbing speed at the bearing surfaces or by the heat transmitted from the pistons to the lubricating oil, reduce the load-carrying ability of bearing babbitt. The melting temperature of babbitt is only about 460° F. and tests have shown that at 212°F. the compressive strength of babbitt is about one-half what it is at normal room temperature of 70°F. Of course, its strength is further reduced at temperatures higher than 212°F. The temperature of the oil is used as an indication of the condition of the bearings, but the actual temperature of the bearing lining is frequently as much as 50°F. higher than that of the oil leaving the bearing. From these considerations it should be clear that temperature plays a most important role in bearing life and that every possible precaution should be taken to keep the bearing temperatures within reasonable limits.

The recommended limit for oil temperature, as the oil comes from the bearings, is 130°F. This is regarded by some engineers as being rather conservative, but the experience, as quoted above, shows that there is ample justification for some conservatism.

Aside from the question of high temperature in bearings, it does not appear to be generally understood that the bearing loads in Diesel engines are likely to be extremely unstable, that is, the unit load (pounds per square inch) in Diesel engine bearings, under certain conditions, may increase suddenly to many times the designed unit load. If, for instance, an engine has a tendency to have a sticky piston, there are produced severe impact loads on the bearings which tend to squeeze the babbitt unduly and thereby cause fatigue cracking of the babbitt linings. Once such cracks are started, it is usually but a short time before loose "crumbs" of babbitt come out of the cracks and begin to obstruct the flow of oil so that the bearing heats up excessively and melts. Bearing over-loads are undoubtedly the primary cause of the majority of bearing failures in Diesel engines.

The most important precautions for the preservation of Diesel engine bearings are the following:

1. Use only the best lubricating oil and renew the oil at regular intervals expressed in operating hours as prescribed by the engine manufacturer.
2. Limit the oil temperature from the bearings to 130°F. If necessary, install an oil cooler in order to obtain this temperature.
3. For engines having pressure lubrication, it is desirable to have an automatic fuel cut-off device which is actuated when the oil pressure drops dangerously.
4. For engines having pressure lubrication there should be at least an alarm device such as a siren which will operate through an electrical contact that is made by a low oil pressure condition.
5. For engines having pressure lubrication always check to see whether oil pressure has been established immediately after the engine is set in motion. The position of the oil pump relative to the oil sump should be such that the pump is automatically primed. When, on any engine, trouble has been experienced because the oil pump does not function immediately upon starting the engine, there should be installed a small hand operated plunger pump for priming the main oil pump before the engine is started.
6. Sludge should be cleaned out from the crankcases and the oil piping at regular intervals expressed in operating hours.
7. The correct oil level in the oil sump or reservoir should be maintained at all times.

For the majority of crankcase-scavenging type engines it is possible to apply only recommendations 1, 6 and 7 because in such engines there is no pressure on the oil in the bearings.

The main bearings of crankcase-scavenging engines are usually oiled by means of rings which dip in a small reservoir provided under each bearing. The crank bearings are oiled by a centrifugal oiling device attached to each crank. The lubricating oil that is spilled from the crank bearings and from the pistons into the crankcase is constantly voided into the "used oil" sump from which it is pumped by the "used oil" pump to the oil filter tank and reservoir.

To maintain the lubricating system on such crankcase-scavenging engines properly the following routine is recommended:

1. At least once each day lift the covers of the main bearing caps to see that the main bearing oil rings are running properly. See that the lubricating pump is maintaining the oil in the lubricator to the level of the overflow. Check the feeds of the lubricator.
2. Once a week, clean the lubricating oil sump at the governor end of the engine.
   Remove the plugs from the bottom of the lubricator to drain off water and sludge.
   Clean the oil filter.
3. Once every three months, drain the entire lubricating system and wash out, with kerosene, all sediment from main bearing reservoirs, governor housing, oil storage tanks, lubricator oil pumps and piping.

Oil Burner Control Device Installation

It is imperative that domestic oil burner control devices be installed in the "hot" (live) side of the line and not in the grounded side. If a ground or fault occurs in the control system with all devices on the hot side, the burner will be shut down because the short circuit either will burn itself out or cause a fuse to blow. If a ground or fault occurs on the grounded side, the motor will continue to operate normally, but the control devices in the hot side will function if pressure, temperature or water level conditions cause them to operate.

The reason for this is clearly demonstrated in a recent investigation. It had been reported that the water in a boiler was low and that the boiler had reached quite a high temperature. When the inspector arrived, the motor was running and it apparently had operated all night without stopping. The control thermostat and the mercoid switch of the low water cutout were both in the open position, but the motor continued to run until the line switch was opened. It was found that a ground had occurred on the wiring system at a point which shunted out all of the control devices, which were installed in the grounded side of the line between the ground for the system and that caused by defective insulation. Although the over-temperature protective device and the low water cut-out had functioned, they could not shut off the burner because their functioning did not break the circuit.

Furnace Explosion with $150,000 Damage

A FURNACE explosion in a large water tube boiler at a Western utility early this year caused damage estimated at $150,000 to the boiler, breeching, smokestack and powerhouse. It was learned that the boiler casing at one end of the boiler had been blown down and that the casing on the remaining portion of the boiler was bent and distorted to such an extent that it was necessary to remove all of it. A large number of tubes were bent and all of the refractory had to be renewed. The superheater tubes also were badly bent and the breeching and uptake damaged. A 125′ concrete smokestack required replacement. Considerable damage was done to the boiler room proper as respects doors and windows. No one was injured.

While the complete details regarding the occurrence are not available, it seems possible that it may have been caused when air was suddenly admitted to the combustion space by manual or other means after failure of an automatic gas valve had introduced an excess of natural gas into the furnace.

The boiler had been in use but 9 days when the explosion occurred. So far as could be learned, the methods of fuel control, air supply and damper regulation were standard for such installations.

THE COVER

A modern freon refrigerating system installed in a bakery is shown on the front cover of this issue of THE LOCOMOTIVE. It is a system of which the owners and the manufacturers can well be proud. An interesting feature is the use of magnetic clutches. This installation is protected by insurance in The Hartford Steam Boiler Inspection and Insurance Company.

Tommy, aged sixteen, set out to get a job. He asked a foreman of a local engineering works for one.

"What can you do, Sonny?" asked the foreman.

"Anything," repied Tommy.

"Can you file smoke?" asked the foreman.

"Yes, sir," replied Tommy with a grin, "if you'll screw it in the vise for me."

He got the job!

Denison—"Who are you working for now?"

Muskogee—"Same people—wife and three kids!" —*Kreolite News.*

Taps From the Old Chief's Hammer

MARY DULLIVAN, chief clerk, was a very smart young lady indeed, and besides, she was of an inquiring disposition. To those in her department she was an authority of no mean accomplishments on the many details of the underwriting and bookkeeping in connection with boiler and machinery insurance.

Sometimes, when opportunity arose, she asked questions of an engineering nature, and the inspectors and engineers were surprised at first how readily she understood boilers and why they exploded, turbines and what made them turn so fast, and a great many other things that most people associate with engineers, and leave to them.

So, when she entered the Old Chief's office on a routine matter late one spring afternoon, he wasn't surprised when she became interested in some photographs on his desk.

"Pretty pictures, Chief?" she asked.

"Emphatically not, Mary," said the veteran engineer, "but in a way I'm downright proud to have them. Inspector Benson sent them to me with a report of an accidental inspection."

"Do you mean an inspection after an accident? These pictures look like something had broken."

"You're right about that, Mary. The pictures are of a broken shaft. but the inspection was made before the shaft became broken, not afterward.

"It seems that Benson, who inspects the boilers at the Manton Works, was talking to their chief mechanic and was asked about our dismantled inspections of machines. He was having some difficulty in describing his procedure, so he offered to demonstrate by making a sample inspection of a large steam engine. His offer was accepted, so I guess that makes it an accidental inspection.

"He had been told that the 18″ shaft on this particular engine had been built up by applying weld metal some two years ago when a new flywheel was installed, so he knew that in addition to the regular inspection procedure, he should pay particular attention to this part of the shaft.

"You see, Mary, when a shaft is made larger by means of depositing weld metal on it, the welding arc results in an intense localized heat on the surface of the shaft, which results in excessive stresses in the metal and it may even cause a tiny crack to form."

"Do you mean that this break I am looking at is in a shaft of steel 18″ in diameter?"

"Yes, the size doesn't make much difference. Notice this picture showing the shaft in two pieces. When Benson found the crack it was

"The darker metal shows how far the crack has progressed."

a tiny irregular line on the surface of the shaft. To how great a depth it extended wasn't certain.

"A cracked shaft might be operated for a short time and not give way, but sooner or later it will break.

"So the machine was dismantled and the shaft broken by impact. The darker metal shows how far the crack had progressed when Benson found it. In the other picture the two ends are held together to show the crack with respect to the location of the built-up section of the shaft."

"I noticed a report to inspectors one time about 'locked up' heat stresses," said May. "It this . . . it?"

"Smart girl," replied the Old Chief, "and such stresses may manifest themselves as a wrecked engine or compressor or pump. You see, as such a crack grows, or, as we say, progresses, the shaft becomes steadily more limber, so that the speed with which the crack develops is accelerated. If this shaft had been kept in operation much longer, I am afraid there would have been a serious wreck with much inconvenience and expense."

"Now what?" asked Mary.

"What more do you want?" the Chief asked.

"It seems to me a rather satisfactory climax . . . Benson is asked about steam engine inspections, he answers questions, he demonstrates, and, maybe to his surprise and again maybe not, he finds

"The two ends of the shaft are held together."

exactly what he says may be found with such methods."

"Sounds like Julius Caesar," laughed Mary. "*'Veni, vidi, vici.'*"

"What?"

"You know, what Caesar wrote—'I came, I saw, I conquered.'"

"Well, maybe, girl. Benson came, and he saw all right, but I think he wouldn't exactly have used the word 'conquer'. You can't conquer very well when the finished job is all in the day's work. You see we are a suspicious crowd . . . where shafts as well as a lot of other things are concerned. Besides, Benson apologized about making that inspection. You see it wasn't insured equipment."

"And did you scold him?" laughed Mary.

"Well," mused the Chief, "not exactly."

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

December 31, 1938 — *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,017,829.88
Premiums in course of collection (since Oct. 1, 1938)		1,269,900.12
Interest accrued on bonds and mortgages		85,116.22
Mortgage loans		180,987.10
Home Office real estate and Philadelphia branch office		642,331.05
Other real estate		307,636.37
Other admitted assets		14,884.43
Bonds on an amortized basis	9,308,558.22	
Stocks at market value	7,148,374.50	
		16,456,932.72
Total		$19,975,617.89

LIABILITIES

Unearned premium reserve		$8,357,631.77
Losses in process of adjustment		263,976.82
Commissions reserve		257,243.37
Taxes reserve		300,000.00
Other liabilities		279,426.16
Liabilities other than capital		$9,458,278.12
Capital stock	$3,000,000.00	
Surplus over all liabilities	7,517,339.77	
Surplus to Policyholders		**10,517,339.77**
Total		$19,975,617.89

WILLIAM R. C. CORSON, President and Treasurer

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"*Unfired Pressure Vessel Catastrophe*"
"*The Care of Cast Iron Boilers*"

Vol. 42 No. 8 October, 1939

The Locomotive

The Hartford Steam Boiler Inspection and Insurance Co.

Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Unfired Pressure Vessel Catastrophe

Figure 1—Top page 226—Damage after the explosions of a creosote tank and a water tube boiler at a southern plant.

Figure 2—Center page 226—A tank similar to the upper vessel in the center of the picture exploded. Timbers to be creosoted are placed in the lower cylinder.

Figure 3—Bottom page 226—A building 450 feet from the creosoting plant which was struck by parts of the tank and flying debris.

Figure 4—Above—Debris in the boiler room after the creosote tank and water tube boiler had exploded. A fireman on duty here was killed.

One man was killed, three persons were injured and property damage estimated at between $150,000 and $200,000 resulted from the explosion of a creosote tank at a Charleston, S. C., wood treating plant on September 6. The fatality was suffered by a fireman who was in the boiler room.

Witnesses reported a great burst of yellow and orange flame accompanied by two explosions. The first was reported to have occurred in a tank (Reuping tank) in which creosote was heated by means of steam coils, and the second was believed to have been in a water tube boiler which was said to have been struck by the exploding tank.

The two explosions virtually levelled the plant, as is shown in the accompanying photographs, Figures 1, 2 and 4, and heavy structural steel and parts of the tank struck a building 450 feet distant, Figure 3.

An explanation of the process may be helpful in visualizing this accident. A creosoting cylinder, in which is placed the wood to be treated, is mounted horizontally below the Reuping tank in which creosote is stored when the cylinder is being emptied and filled. When the cylinder has been closed, the hot creosote is forced into it by means of air pressure. Once the upper or Reuping tank is empty of creosote, the remaining compressed air is bottled up in it for future use by closing the valves.

Earlier in the night the creosote had been heated and the air pressure applied to force out the creosote. At midnight the tank was "empty" and no change was noted except that the tank cooled and the compressed air gradually dropped in pressure to about 70 lb. The blast came without warning at 3 o'clock in the morning.

Although the exact cause was not determined, presumably the explosion in the 9′ x 80′ Reuping tank was a combustion detonation. One end of the tank blew away and the rest slid into the boiler room, striking or knocking debris against a water tube boiler operating at 150 lb pressure. The blow caused a girth seam to fail and brought about the second explosion. Most of the boiler was hurled about 100 feet.

COVER

The cover on this issue of The Locomotive shows an inspector at work in a drum of a large power boiler. The equipment pictured is spectacular as to size, but to the inspector it is merely another boiler in which every point of possible weakness must be checked.

Three ideas stand out above all others in the influence they have exerted and are destined to exert upon the development of the human race: The idea of the Golden Rule; the idea of natural law; the idea of age-long growth.

Robert A. Millikan in *Think*.

The Care of Cast Iron Heating Boilers

The following article presents some of the fundamentals of cast iron heating boiler care and operation for the guidance of building superintendents and janitors. Editor.

Cast Iron and Sudden Stresses

TREATED properly, cast iron, as used in heating boilers, is satisfactory material, but it is not well suited to withstand sudden heating or sudden cooling. In other words, it is likely to crack when subjected to severe or sudden expansion stresses such as are brought about by forcing the fire, or to a sudden contraction set up by turning cold water into an over-heated boiler.

If this characteristic of cast iron could be kept well in mind by attendants, cast iron heating boiler troubles would be lessened materially.

It is essential for safe operation of a cast iron boiler that time be taken in firing up and in cooling after a condition of low water, so that one part does not expand or contract excessively faster than another.

Two Kinds of Systems

Cast iron heating boilers are used in two kinds of systems—steam and hot water. In the former steam is circulated from the boiler through the piping and radiators and is returned as water of condensation. In the latter hot water is circulated through the piping, radiators and back to the boiler.

It is obvious that in both systems a sufficient supply of water is required at all times, but the hazard of low water is more serious in a steam boiler, because the boiler is never entirely full of water and there is little safety margin if the water is depleted for any reason. Therefore, the return of the condensate from the radiators to the boiler is of prime importance.

Methods of Condensate Return

Three methods are employed to return the condensate to the boiler.

1. The gravity return system in which the condensate flows to the boiler without mechanical aid.

2. The gravity return assisted by traps.

3. The pump return system in which, because of low or distant radiation, water is returned by gravity to a receiving tank from which

it is pumped to the boiler. The pump is usually controlled by a float within the tank which opens or closes an electric circuit as required. (A pump is also used in the so-called vacuum system to lessen the effect of the friction of piping and fittings by creating a partial vacuum in the system.)

Systems relying on the operation of a pump have additional hazards because there are more things to go wrong, namely, the pump itself, the motor driving it, the control mechanism, a fuse, or something on the

Dont's for Every Cast Iron Boiler Operator

1. Don't fail to determine promptly the reason for loss of water from the system.
2. Don't draw water from the boiler for any purpose, other than for flushing at the end of the heating season. Cast iron heating boilers should be drained only sufficiently to flush out rust and sediment and then refilled. Boilers should be kept entirely filled with water when idle.
3. Don't neglect to have repairs made at once if there is any leakage from steam or return pipes.
4. Don't forget to try the safety valve frequently.
5. Don't forget to open the try-cocks and blow out the gage glass each morning.
6. Don't put water in an over-heated boiler.
7. Don't burn rubbish in the boiler.

current supply line itself. Anything which stops the pump interferes with the prompt return of water to the boiler.

What to Do When Water Is Low

Periodic inspections of a boiler and its appurtenances by experts comprise long-range protection of a cast iron boiler. Day-to-day protection lies, among other things, in frequent examination of the water gage. A water gage reading lower than normal in the glass of a steam heating system should be a warning to the attendant that the condensate is not returning. The cause of the water shortage should be determined immediately.

If no water shows in the glass, the situation is serious and calls for prompt action. The fire should be smothered at once with wet ashes or wet slack coal, or the oil or gas should be shut off. All dampers and ash pit doors should be closed and the fire doors opened to allow the fire to die down. Under no circumstances should water be added to the boiler before it has cooled sufficiently to allow the bare hand to be placed on the fire side of a section. When this can be done, water may be fed into the boiler until it reaches the level of one-half glass. If an examination shows that no harm has been done to the boiler, a slow fire may then be rekindled and steam raised.

Consequences of Hasty Firing

Cracking of the boiler because of unusual temperature stresses may likewise occur if the boiler is fired up too quickly. There is particular need to avoid this hazard by observing reasonable care in starting up the boiler in the morning. The boiler should be brought up to the steaming point gradually and not as rapidly as draft and fuel will permit. On no account should waste paper, crankcase oil or other quick-burning combustibles be used to raise steam rapidly.

Normal Variations in Water Level

When a steam heating boiler and system have fully or partly cooled off, the water level in the boiler should be considerably higher than when the radiators are hot, because the steam that is normally up in the system has condensed and returned to the boiler. If there is not sufficient water in the boiler, it may get out of sight at the bottom of the glass as the steam is raised. This condition also may occur if the boiler is too small for the system it serves, in which case too great a percentage of the water passes into steam before condensate starts back to replenish the boiler supply.

Very often during the night, especially in extremely cold weather, the steam in the system will condense, resulting in at least a partial vacuum if non-return air vents are used. Water of condensation will remain in the system until the pressure and temperature are equalized. In the meantime, the water may have become so low in the boiler that over-heating has occurred.

The correct procedure for the attendant in a case of this sort is to shut off the drafts until the water shows in the gage glass, then open them slowly, continuing this procedure until the entire system has been brought up to pressure and a temperature somewhat higher than existed when the boiler commenced generating steam.

When an idle section of a steam heating system is to be placed in service, care should be observed in opening valves. The steam valve should be opened first and, if the entire system has a common return header with but one check valve, the part of the system being placed in service should reach the desired temperature before its return pipe valve is opened. If each section of the heating system has a check valve and an independent return pipe to the boiler, the return pipe stop valve may be opened after the steam pipe stop valve has been opened.

The fire should never be disturbed in the morning until the attendant has ascertained by observing the gage glass and operating the try cocks that there is ample water in the boiler. A glass water gage frequently becomes so dirty that it is almost impossible to see the water level. Before a glass gets in this condition, it should be cleaned or renewed. Not infrequently the connections to the boiler, particularly the water connections, become obstructed. They must be kept free.

Some heating boiler systems are single pipe installations, that is, the condensate returns through the same pipes that carry the steam. Radiator valves on such systems should always be entirely closed or fully open, never partly closed, as that practice is likely to cause water to accumulate in the radiators, and result in lowering the water in the boiler to a dangerously low level. It also may lead to water hammer and undesirable noises.

Each boiler is equipped with a drain valve or cock for the purpose of emptying the boiler when necessary. This drain should never be used for any other purpose. To enforce this rule, if necessary, the handle should be removed from the drain cock and kept where it will be available to the attendant only. If an ordinary stop valve is used, the wheel should be removed and similarly guarded. These precautions are to prevent the unauthorized withdrawal of water from the system for any reason while the boiler is in service.

Danger of Scale Accumulation

Whenever makeup water is added, there are introduced new scale-forming solids which in time will collect on and adhere to the water side of the sections in such quantity as to interfere with the transfer of heat from the hot gases to the water. Obviously, this will lessen efficiency. It may also cause the cast iron to over-heat and crack.

Every steam and hot water heating system will, in one way or another, lose a little water from week to week and from month to month. If this amount becomes abnormally large, immediate steps should be taken to locate the leak and make repairs. Such loss of water may result from either internal or external corrosion of return piping, from leakage at joints and fittings and even slight leaks in the boiler itself. If piping is buried, the first indication of leakage because of a defect in that piping will be the loss of water.

A Few Elements of Safe Firing

Conditions discussed so far have to do almost entirely with the maintenance of a sufficient amount of water in steam boilers. A few additional hazards arise from faulty firing practices, other than those discussed previously. One of them is using a cast iron boiler for a rubbish burner to get rid of papers, wood scraps, excelsior, old crankcase oil, etc. The danger lies in the rapid heating of the fire side of the sections with a comparatively slow heating of the water side.

Sometimes forced draft is used in connection with stokers and oil or gas burners. It is necessary in such cases to see that flame does not impinge on the portions of the sections forming the gas passages above the water line and that the temperature at these locations is not above normal.

Other Conditions Causing Cracks in Cast Iron Boilers

Cracking accidents also are caused by rust growth between the sections, the discovery of which requires expert knowledge and experience. When external moisture is present, iron corrodes (rusts or oxidizes). This oxidized material is much greater in volume than the original iron. The force exerted by this rust is enough to cause the remaining iron to crack unless the rust is removed before it becomes too thick. Such removal usually can be accomplished by entering the furnace and passing a hack saw blade between the sections.

Additional Good Maintenance Practices

Many safe practices have been suggested, but there are a few more which are in keeping with an article of this sort:

The boiler room should be kept dry and reasonably clean.

All safety and control devices should be tried frequently, preferably daily, and kept in proper working order. The condition of vacuum and circulating pumps should be checked daily.

An open hot water heating system should be filled occasionally to a height which will permit water to discharge from the expansion tank overflow pipe.

Furnace inspection doors and cleanout openings which can admit excess air should be closed tightly or sealed up. These frequently become warped and do not fit properly. This condition can often be rectified by the use of boiler putty. Spaces between sections should be properly sealed. Keeping out excess air above the grates greatly increases the efficiency of operation.

Ashes, clinkers, or other debris should not be permitted to accumulate against boilers or piping, as such practice inevitably results in corrosion of the metal.

Discontinuing Use at End of Season

When discontinuing a boiler from service at the end of the heating season, all unburned coal and ashes should be removed from the grate. All heating surfaces should be thoroughly cleaned with a wire brush. A steam boiler should be left with water to the top of the gage glass, and a hot water system should be filled.

If it is found at the beginning of a heating season that, for any reason, the boiler is not to be used and if there is to be no heat in the building, all water should be drained from both the boiler and the system to prevent damage from freezing.

Hot water supply heating devices are sometimes used throughout the year in connection with a heating boiler. During the summer months the valves in the heating system flow and return lines are closed. The normal operating procedures in such cases will depend upon the type of boiler and type of water supply heating device, but will not differ greatly from those already described.

Proper Cleaning Routine Important

Whenever a boiler in a battery with others is to be cleaned, it is, of course, essential that it be carefully shut off from the others. It is just as important never to open a valve on an idle boiler without making sure that all maintenance men have left the boiler and that there are no uncovered outlets from which steam can emerge and injure workmen. At a Mid-West paper mill an experienced fireman had completed the cleaning of a small water tube boiler. Because he wanted to make sure whether the blowoff pipe was clear, he asked another fireman to blow an adjacent boiler with the valves open on the idle boiler. Apparently he misjudged the time necessary for the fireman to carry out these orders, for the steam entered the boiler while he still had his arm and shoulder inside the manhole. He was burned before he could make his escape. As he sought to leave the vicinity of the boiler he was further scalded in the back by steam from the feed line, from which the plug had been removed where the pipe enters the drum. The man died in a hospital.

Recent Steam Turbine Experience

By T. B. Richardson, *Chief Engineer, Turbine and Engine Division*

Experience with steam turbines in the past 12 months confirms that of prior years in that the "failure of the human element," especially when such failure is accompanied by non-operation of or lack of needed safety devices, is apt to lead to costly results.

In contrast is the averting of a number of accidents during the year through the discovery, by inspections, of defects or misadjustments of vulnerable parts.

Among the accidents was one at a large New England plant where a turbine operator was instantly killed by the explosion of a small mechanical drive turbine, an uninsured unit, operating a condenser pump. The engineer attempted to start it without opening the turbine exhaust valve. As the throttle valve had been opened slightly for warming up the unit and the relief valve on the turbine casing had failed to function, there was no warning that pressure was being built up within the casing. It was reported that the operator stooped to close the turbine drains. and while he was doing so additional pressure built up in the casing until it tore asunder.

The importance of installing an atmospheric relief valve between the turbine exhaust and the first stop valve cannot be over-emphasized. This relief valve should have sufficient capacity to pass all the steam that can be admitted through the throttle valve without building up an over-pressure within the turbine exhaust casing. Such a valve, if tested regularly so that its functioning can be relied upon, will prevent an explosion in the event that an operator closes the exhaust valve in error with the turbine carrying load. The next best expedient is to install a small sentinel valve on the turbine casing to warn the operator of an attempt to start the turbine with the exhaust valve closed. However, all sentinel valves should be removed and tested regularly.

A case emphasizing the necessity for testing automatic valves regularly occurred at a paper mill. When a surge caused a 1250 kw bleeder type turbine generator to drop its load, the non-return valve in the bleeder line failed to close. Although the emergency governor closed the throttle valve, steam passed through the unit from the bleeder line so as to cause serious over-speed and considerable damage to the blading before the operator could close a stop valve in the bleeder line.

Negligence on the part of operators is illustrated by a recent instance in which the operator started a 500 kw turbine without opening the valve in the oil feed supply line from an overhead tank. The reduction gear with its bearings and the other main bearings were badly damaged.

Another similar accident occurred at a municipal power plant in connection with a 3000 kw turbine when the operator closed the steam valve in the line ahead of the regulator for the auxiliary oil pump. Lack of oil as the turbine came to a stop caused damage to all of the main bearings.

An accident not preventable by reasonable means of inspection occurred to a 600 hp turbine used to drive a boiler feed pump. The turbine, which had been installed in a utility powerhouse in 1929, had been operating normally for several days prior to the accident, when suddenly it began to vibrate. The operator, who happened to be close by, attempted to close the throttle valve. Before he could shut off the steam, however, the turbine went to pieces. Parts of the governor flew past him on one side and a section of the coupling on the other. The latter hit a 12″ I-beam, considerably bending it. Steam continued to escape until the operator managed to crawl to another stop valve and shut it. The accident was caused when a shaft nut, which held the single wheel disc, backed off because a lock washer was not properly secured in that it had not been driven into the wheel keyway before the nut was tightened. Probably the nut became wedged against the casing, causing the No. 1 bearing pedestal to break and permitting the rotor to drop. The severe rubbing of the wheel against the stationary parts caused a complete wreck. It was necessary to replace the turbine.

Another unusual situation was discovered in a turbine at a municipal power plant. Although the turbine had been installed for a number of years, it had, from the beginning, at higher loads, leaked steam excessively from the high pressure labyrinth packing. The axial clearance of the packing had been reduced from time to time by changing the thrust bearing adjustment to reduce leakage, until finally the packing failed after the lands had been worn away. Subsequent investigation revealed that a steam leak-off pipe from the packing was connected to the turbine casing at a flange that could not pass steam to the lower stages because the opening had not been cored out on the inside.

A somewhat similar case involved a 15,000 kw high speed, high pressure unit. When new parts for a thrust bearing were shipped, a plug was left in a cored oil passage. The item was overlooked in assembling and when load was placed on the unit, the thrust bearing failed because it did not obtain the proper amount of oil. All of the packings were damaged and the steam rotor was returned to the factory for repairs to the buckets and installation of one new row of buckets.

Along with the reports of accidents to both uninsured and insured equipment, there have been numerous recent cases in which defects have been located in time to avert losses. This has been true particularly with respect to cracks that have been discovered in blading. On an 18,000 kw reaction type turbine one crack was found in the 15th row and 21 cracks in the 27th row. All of the cracks except one were ⅜″ or less in length and could be removed by filing away the metal adjacent to the cracks at the edges of the blades. The one blade, however, had to be removed, as did an opposite blade for balance. If these cracks had not been discovered, they undoubtedly would have progressed and might have caused serious damage before the turbine was again dismantled.

In another case, six cracked blades were discovered.

A third instance of cracking occurred in a 1000 kw turbine which was recently dismantled. A broken bucket was found in one of the lower stages and other buckets in the same row were found to be cracked. The outer end of the broken bucket had not yet been thrown out, but was wedged against an adjacent bucket and held by the shroud band. The entire row of buckets was replaced, thereby preventing damage to the other rows of blading.

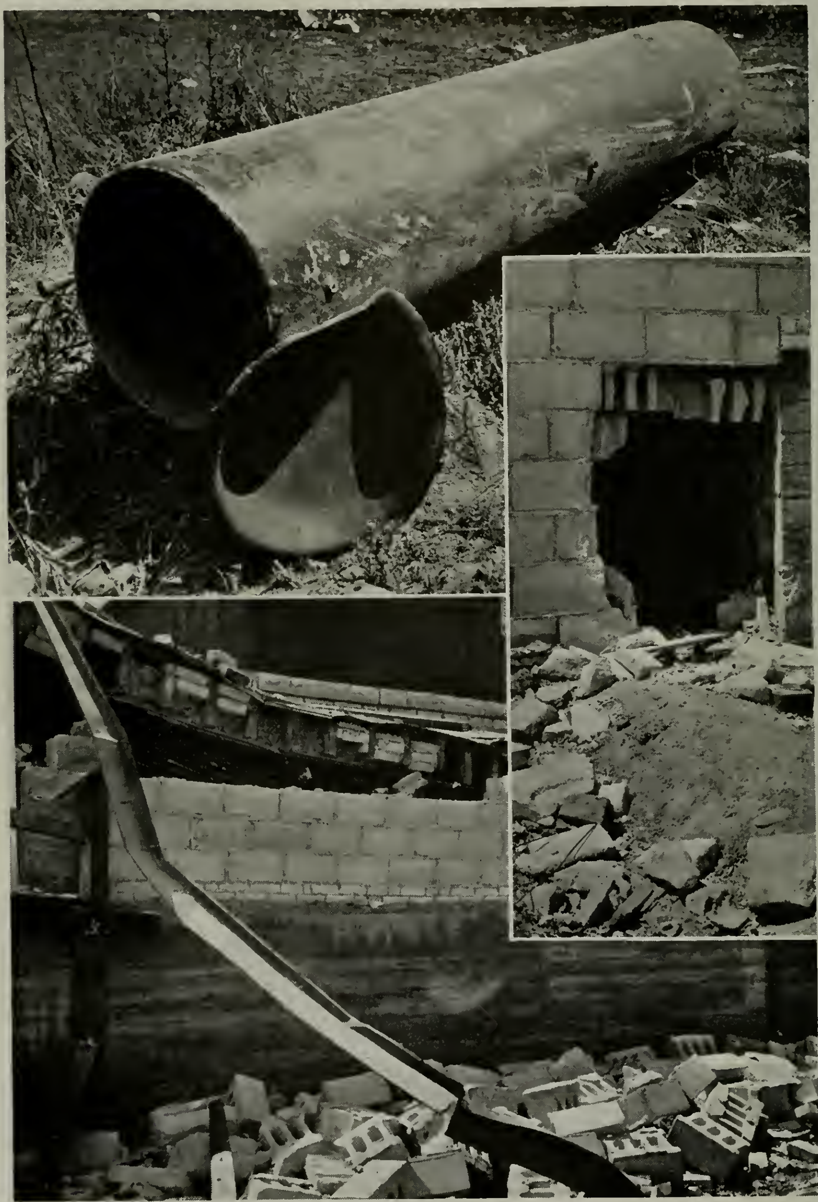
On the generator end, there have been several cases where cracks were found in the end retaining rings of the rotor. It is obvious that their discovery and the replacing of the defective rings avoided serious damage.

Many other instances could be cited regarding defects that have been discovered during dismantled inspections. In fact, experience shows that in almost every case a program of dismantled inspections of turbines reveals conditions, the correction of which greatly offsets the cost of the dismantling. The economic advantages of a program of dismantled inspections cannot be too strongly emphasized with respect to both the physical safety of any turbine and the machine's continuity of service.

Gentleman (at police station): "Could I see the man who was arrested for robbing our house last night?"

Desk Sergeant: "This is very irregular. Why do you want to see him?"

Gentleman: "I don't mind telling you. I only want to ask how he got in the house without awakening my wife." —*Lampoon.*



Damage following the explosion of an ammonia receiver after the city water supply was reduced and hot refrigerant gas was pumped through the condenser into the receiver. This accident occurred some months ago in Toronto. The pictures recently became available.

Recent Accidents to Refrigerating Equipment

THE summer just past brought the usual increase in the frequency of accidents to refrigerating systems and compressors. Most serious among the accidents were tank explosions with their heavy property damage, personal injuries and in some instances loss of life.

In an ice plant at a hospital five men were overcome and burned by ammonia fumes and twelve women were either cut by falling glass or affected by fumes when an ammonia tank exploded in the basement. The blast blew out a skylight in an adjoining courtyard, sending fragments of glass and wood up to a height of three stories. The women, who worked in the hospital laundry, were in the courtyard during the noon-hour and were struck by falling glass. A favorable breeze prevented fumes from reaching the hospital patients.

While defrosting operations were being carried on in connection with quick freezing units, at an ice and cold storage plant, a fitting was reported to have exploded after hot water was applied to it. A workman was sprayed with liquid ammonia, according to an account in *Ice and Refrigeration*. The man died of his burns three days after the accident.

The entire front was blown from a packing company's warehouse by the explosion of an ammonia tank used in connection with the firm's refrigerating system. Flooring was ripped up and furniture upset. As the accident occurred at 2:35 A.M. no one was near the tank or in the office or street at the time.

At a brewery a portable steel ammonia tank attached to an ammonia refrigerating system exploded, causing considerable property damage. The tank, which contained an extra supply of ammonia, tore longitudinally, the break starting at a deteriorated spot.

So far as is known none of the above accidents was to insured equipment. Among accidents to refrigerating systems covered by insurance, the following are typical:

When a cooling coil broke at a cold storage warehouse, the ammonia charge was lost.

When a brine cooler tube ruptured and permitted brine to enter the ammonia lines, a "hammer" was set up which blew out six gaskets and permitted most of the ammonia to escape. A packing house was deprived of the use of the equipment for a week.

At an ice plant the failure of an ammonia pipe in the brine caused the loss of a considerable amount of ammonia and shut down the ice-making system.

When a 100 lb chunk of frozen meat slid off of a pile at a meat storage warehouse, it hit a ½″ pipe drain and released the entire supply of ammonia from the system.

Other accidents of the same general character involved systems using ammonia or freon in a variety of businesses including a printing plant (air conditioning installation), a hotel, and a restaurant.

Insured losses during the summer to both separately driven and steam compressors handling ammonia, freon and methyl chloride, involved broken valves, scored cylinders, burned out bearings, failure of seals, and cracked cylinder walls. Owners of such equipment included a cafeteria, a salt manufacturing company, breweries, a milk plant, an office building, ice plants, a hospital, an abattoir and a wholesale grocer.

Explosion of Vertical Tubular Boiler

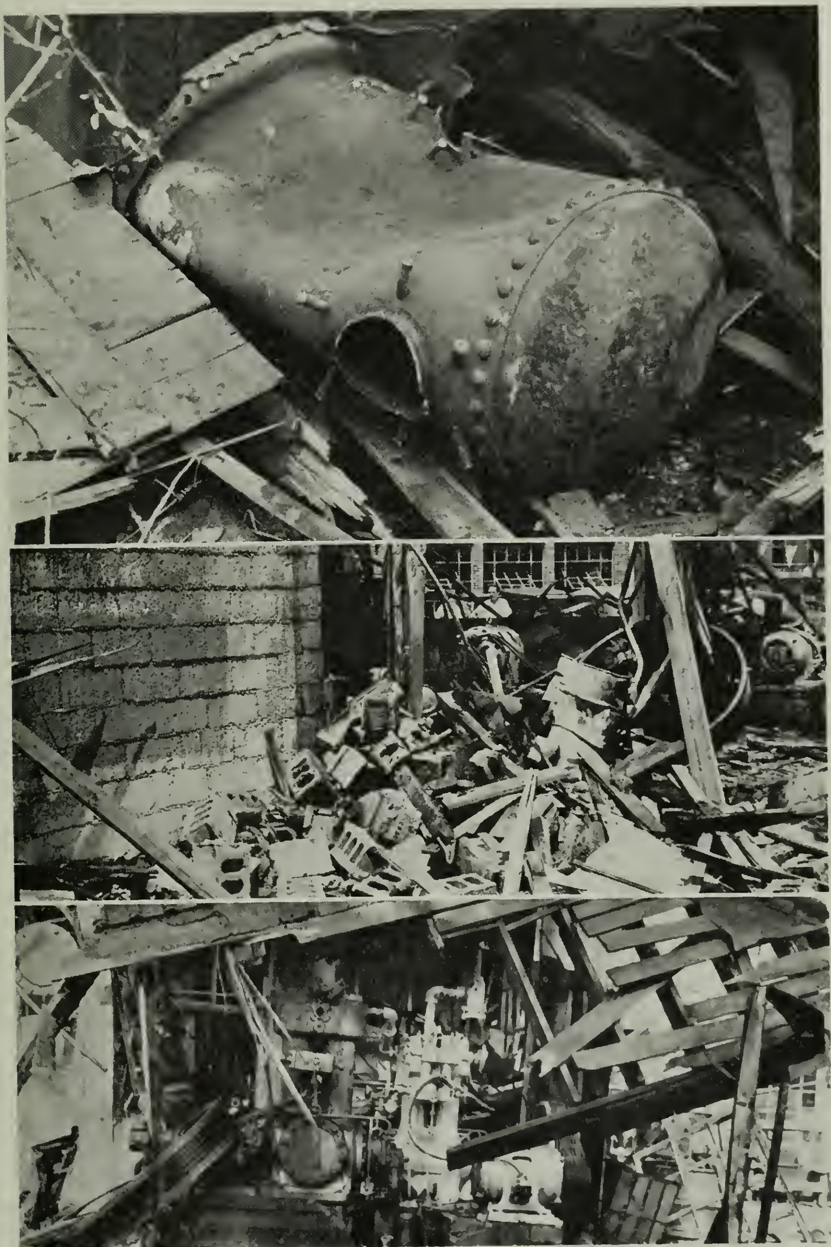
The explosion on August 2 of a vertical tubular boiler used to supply steam for sterilizing cans in an Ohio ice cream plant demolished an end of the building and alarmed an entire neighborhood. The only person injured was a six-year-old boy who was cut by flying glass as he was playing near the plant, although the force of the explosion hurled debris over a wide area and broke windows far from the scene of the blast. The 250 lb top head of the boiler traveled three blocks, hit a sidewalk and came to rest in a residence yard. Blocks of concrete were hurled through the windows of nearby homes, window frames were torn loose and three large plate glass windows were blown out.

Immediate investigation was complicated by a flood of ammonia gas from the plant's refrigerating system, pipes of which were broken by the explosion.

Although the cause of the accident was not specifically determined, the explosion probably resulted because of corrosion of the lower section of the boiler near the base.

In general this is a vulnerable spot in vertical tubular boilers both internally and externally; internally, because of deposits from untreated feedwaters that promote corrosion and cause over-heating; externally, because of the piling against the boiler of coal, ashes or other refuse which, in the presence of moisture, often sets up serious corrosive action.

Pictures of some of the wreckage at the ice cream plant are presented on Page 241. The upper photograph shows the boiler after the accident to it. The lower two pictures give an idea of the property damage.

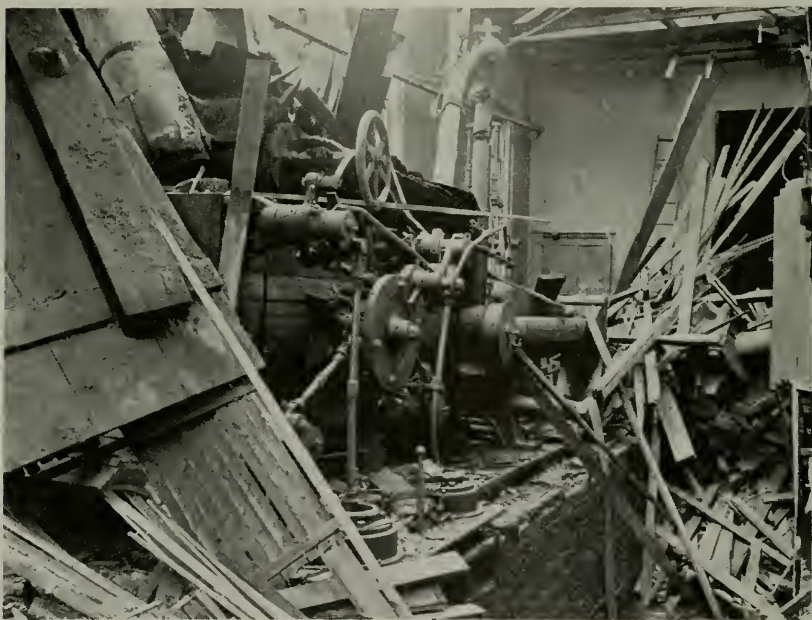


Three views of wreckage following the explosion of a 42" x 8' vertical tubular boiler at an ice cream plant on August 2.

Wreckage Following Flywheel Explosion

A FLYWHEEL explosion at an eastern manufacturing plant caused the havoc presented in the accompanying photograph.

Parts of the wheel went through the roof of the engine room, causing it to fall, and also crashed through an adjacent roof into a room where about 100 women were working. In the ensuing confusion, according to a newspaper account, two of the women were injured when



they fell to the floor. An operator who was near the engine was killed. The steam engine was wrecked, and several other machines were damaged because of the over-speed. To reassemble the control devices following an accident of this sort in a search for the cause of the accident is not easy. In this case two factors probably contributed to the failure. One was a breaking governor belt and the other the fact that the safety cams were undoubtedly out of adjustment because, although they were set at the farthest point of adjustment away from the latch arm, they did not prevent the opening of the steam valves with the governor in its lowest position, as they should have done. There was no insurance on the engine.

Explosions of Other Steam Engine Flywheels

Two men lost their lives in four other recent steam engine flywheel explosions.

Breaking of main belts was blamed for two accidents, each of which caused a fatality, and the other two explosions were attributed to a defective governor and to a governor belt pulley which became loose on its shaft. One case was unusual in that parts of a 5′ wheel went 1800 feet and 1500 feet in opposite directions.

Property loss in one instance involved damage to two large rotary pumps and the wrecking of an entire rope-drive. In this case a part of the wheel struck another plant about 800 feet distant and severed a power line. An end of the live wire contacted the sheet-iron building and when an employe started into this building, he received a severe shock. The explosion also broke an 8″ main steam pipe at a time when an entire battery of eight boilers was in service at a pressure of 145 lb. As there was no way to shut off the steam except by the individual stop valves on each boiler, the pressure dropped to 20 lb and the water in the boiler became dangerously low. However, the boilers escaped damage.

Flywheel on Steam Type Pump Explodes

When the flywheel of a steam-driven pump, used in connection with a turbine condenser, exploded early in the year at a Southern factory, parts of it damaged the building and broke a 6″ steam line. The released steam saturated a motor so that it had to be dried out, and so diluted a quantity of circuit breaker oil that it had to be renewed. Two barrels of engine and cylinder oil were lost when sections of the wheel hit them.

The accident occurred after a bunch of cleaning waste got caught in the governor gears and jammed them, which occurrence caused the governor valve to go into the wide-open position. Instead of immediately closing the throttle valve of the pump, the operator ran to shut down the turbine. Meanwhile the wheel exploded because of over-speed.

Release of steam through the 6″ piping caused the water to drop out of sight in the gage glasses on two bent tube type boilers, but the fires were extinguished in time to prevent over-heating.

Pieces of the wheel narrowly missed a switchboard and a motor generator set, and a 275 lb section passed upward over two buildings and came to rest 360 feet away.

Liquid air is the power source for a unique Japanese engine.

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

Sidney B. Coates, *Editor*

HARTFORD, CONN., October, 1939

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The Locomotive *of* The Hartford Steam Boiler Inspection and Insurance Co.

CHARLES D. STILLEY

Charles D. Stilley, for many years special agent in Arkansas, died August 12, 1939, at the age of 70, at Jonesboro, Arkansas, while on one of his regular business trips in his territory. He had served the Company since 1912 in Kentucky, Tennessee, Missouri and of late years in Arkansas and was well liked for his good-natured manner and his dry humor, and respected for his long contact with and knowledge of boiler and machinery insurance problems. Mr. Stilley was born in Edinburg, Indiana.

AUGUSTUS L. REYNOLDS

After more than 29 years of loyal service, Augustus L. Reynolds, Chicago department inspector, died suddenly at his home in South Bend, Indiana, July 24, 1939. He joined the Company March 1, 1910, and through the following years the Company's interest was his first consideration. His continued popularity with the many policyholders in Northern Indiana gave evidence of his ability. Although on vacation, he took care of an emergency inspection call on the morning of the 24th. He died following dinner that night. Mr. Reynolds was born in Arkansas in 1872.

EDWARD D. BEISER

Edward D. Beiser, retired inspector in the Cincinnati department, died in Dayton, Ohio, August 30, 1939, after a short illness. Joining the Company on June 1, 1900, Mr. Beiser served continuously out of Cincinnati until his retirement on May 1, 1933. The veteran inspector was known by the policyholders he served not only as a "good boiler man" but also as a gentleman and a friend. Mr. Beiser was born in Cincinnati in 1869.

Change in Internal Combustion Engine Rates

As the use of Diesel engines for stationary power plant purposes has expanded, owners in increasing numbers have taken advantage of the benefits to be gained through insurance and the accompanying inspections of these machines in order to avoid accidents. Insurance protection of such engines against full breakdown losses has been available for many years.

During the past decade there has been an unusually rapid growth in the use of Diesel engines. As more engines have been placed in service and more of them have been insured and inspected, insurance company experience has helped greatly in establishing more correct operating requirements.

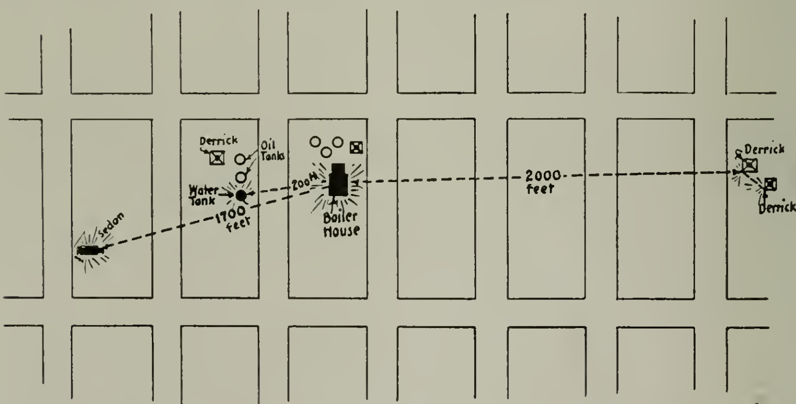
Diesel and other internal combustion engine insurance rating plans have been changed a number of times in keeping with the experience as respects the improved installation procedures, operating practices and conditions of maintenance, the last such change being made effective September 1, 1939. Up to that time Diesel insurance rates were determined in accordance with the capacity of the engine, its age and the type of cooling system (open or closed) used in connection with it.

The new rating plan omits the age classification, but retains the differentiation as respects cooling systems, and, of course, the capacity. It provides separate rates for different kinds of industries. There are four industrial groups, the lowest-rated group including such industries as public utility plants, pumping plants and buildings not used for manufacturing. The second group includes general manufacturing plants, flour and grain mills, and paper and fibre mills; the third group includes ice and cold storage plants, laundries, creameries and dairies, packing houses, tanneries, dredges and farms, and the fourth cotton gins and cotton oil mills, garages, general contracting, mining and quarrying, and lumber and saw mills.

Special new rates have been issued for engines using gas for fuel because of favorable experience.

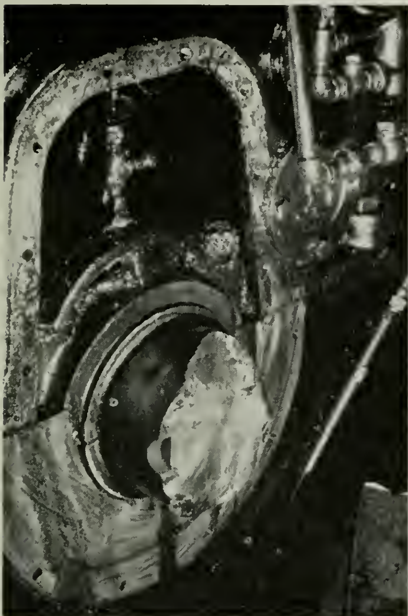
As respects the insurance contract, the new arrangement retains the broad insurance provisions hitherto prevailing.

Illustrating the Versatile Marksmanship of an Exploding Boiler!



This diagram represents several sparsely settled city blocks in a western town where oil drilling operations are under way. The explosion of a horizontal tubular boiler early in the year demonstrated more than the terrible force of such failures; it gave evidence of uncanny marksmanship. About 1700 feet away was a small automobile. A piece of the boiler tubing crashed into it. About 2000 feet in the opposite direction was an oil derrick. The door of the boiler not only hit it but ricocheted into another derrick nearby. About 200 feet away was a water tank, an easier mark, into which smashed the shell of the boiler, crushing the tank nicely. A partially wrecked boiler house, an automobile buried in debris beside it, and bricks scattered like bird shot in all directions were other details. The accident was attributed to mud choked safety valves and over-pressure.

Diesel Shaft Torsional Break



A GOOD example of a shaft break because of torsional vibration is illustrated by the two photographs on this page showing the faces of the break, which started at the keyway and progressed about 40 per cent of the way through the shaft before the final separation occurred. The picture at the left shows the engine end of the shaft and that at the right the coupling end.

The shaft was 9′ in length and 7″ in diameter and served a 5-cylinder Diesel engine in driving a 100 kw AC generator and a 50 kw DC generator. The engine was less than three years old. When the shaft failed, the rotating field of the larger generator rubbed so badly that 75 coils were damaged and had to be replaced. In all, including extra cost of power during a repair period of about four months, the cost of the accident was approximately $10,000.

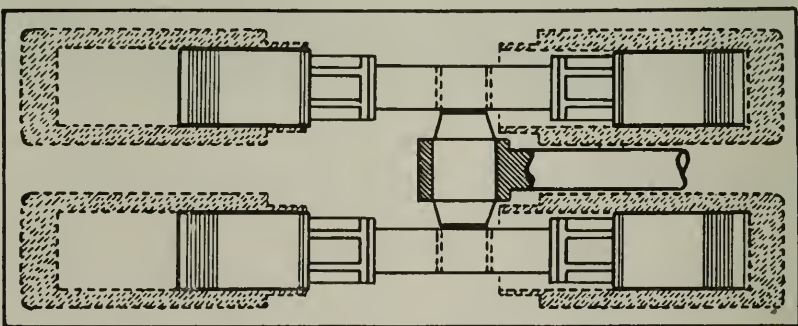
Heavy Rain Indirect Cause of Condenser Failure

An accident to a New York City cold storage system led to the loss of 6,000 lb of ammonia, and necessitated replacement of 16 tubes in the condenser tank. The condenser water circulating pump had been shut off from the system in order to permit its use for pumping out a cellar after a heavy rain. For some reason or other the operator neglected to stop the compressors, and when he sought to rectify matters by switching the circulating pump back into the system, the contact of the cold water with the over-heated condenser cracked two tube headers.

Insulation Resistance Tests Prove Helpful

INSULATION resistance testing continues to play a prominent part in the discovery of defects and consequently in the prevention of accidents, according to a report of 1938 inspection activities issued by the electrical division of the engineering department. Of particular note were tests on the rotors of 19 turbo-generators ranging in size from 30,000 kva to 500 kva in which adverse conditions were determined by this means. None of these rotors had shown signs of distress while in operation under load. When the end rings were removed, the insulation was found to be in such condition that each rotor had to be reinsulated or rewound. It is very evident that had not the insulation resistance readings provided the warning that led to the uncovering of the windings, these machines probably would have sustained severe burn-outs.

Four Pistons Drive Single Connecting Rod in New Diesel Design



The accompanying sketch shows a new design of 2-cycle double acting Diesel as presented by Industrial Power. *As indicated in the sketch, the fundamental unit is a group of four cylinders arranged in pairs with the open ends facing each other. Operating in these four cylinders are four pistons connected by a U-shaped structure or cross-head; a single connecting rod is attached to the center member of the "H" by means of a wrist pin. In this way all four pistons move in unison, and since operation is two-cycle, the expansion stroke occurs in two of the cylinders at the same time as the compression stroke in the other two.*

Inspiration is getting yourself into the mood of working up a little perspiration.
—*F. O. Klakring.*

Examine All Valves before Entering Idle Boiler in Battery

A RECENT report of injury to a boiler manufacturer's erector illustrates the necessity of examining all boiler valves before entering any idle boiler that is connected in battery to others which are under steam pressure.

After a new vertical bent-tube type boiler had been erected in an existing battery and connected to its piping system, some of the tube ends at the bottom drum leaked while under hydrostatic test. The boiler was drained and the following morning an employe of the manufacturer entered the drum and started re-rolling the tubes.

A fireman decided to blow down one of the operating boilers, but before opening the valves he asked whether it was all right to do so and obtained consent. After he had opened the blow-off valve, he noticed steam coming out of the mud drum manhole of the idle boiler and immediately closed the valve. The man in the mud drum shouted and got out of the drum as quickly as possible, but he was seriously burned about the head, shoulders and sides and had to be taken to a hospital.

The blow-off valve for the boiler being erected had been left open after the boiler had been drained and the hot water and steam backed up through the blow-off line.

Air-Conditioning in Florida 80 Years Ago

Dr John Gorrie (1803-1855), of Apalachicola, Fla., on May 6, 1851, was granted the first U. S. patent, No. 8080, on an apparatus for the mechanical production of ice, according to an article in the *Scientific Monthly*. In the practice of medicine at Apalachicola. Dr. Gorrie became convinced that excessive heat was the greatest obstacle in his fight against fever, and devoted his attention to the air-cooling of rooms in hospitals.

Gorrie wrote: "My whole process consists in first suspending an ornamental mantel vase, urn, or basin, in which the ice is placed, by chains like a lamp or chandelier, from the center of, and close to the ceiling of a room. Next, over this vessel an opening is made in the ceiling from which a pipe is extended, between the ceiling and the floor above, to the chimney of the house. In such an arrangement the external and fresh air is attracted to the upper part of the room, in consequence of the partial vacuum formed around the ice, and hence, after being cooled, it is dismissed in a diffused shower to the floor to be discharged by the lower pipe."

The necessity for large amounts of ice in a country where none was available led Doctor Gorrie to the invention of the ice machine, which he patented. The working substance was air, compressed and expanded in suitable cylinders. A model of the machine is on display at the Smithsonian Institution of Washington.

Hydro-Pneumatic Tank Explosion in School

Above is a room at an Alabama school after the bursting of a hydro-pneumatic tank. Air pressure higher than the tank could withstand caused the explosion after the automatic control of the compressor failed to work. The tank went through the floor, ceiling and roof and fell to the ground outside the building. Fortunately the accident occurred at 8:00 P.M. when the room was empty. During school hours it accommodated 37 sixth grade pupils.

It's too bad some people don't make work their hobby.

Taps From the Old Chief's Hammer

THE OLD CHIEF and his assistant Tom Preble, were driving home in heavy football traffic one Saturday evening in the early autumn. As they rode, they discussed the game they had seen.

"Both teams played well," commented Tom, "but that backfield of theirs was a bit too much for us."

"The backfield did well," answered the older man, "but I concede the victory to Fred Perley, if any one man is to be singled out."

"How is that, Chief? Perley played left tackle and he didn't touch the ball all afternoon."

"True enough; but did you watch him?"

"Not particularly."

"You should, if you see him again. It is uncanny the way he seems to be at just the right place for his backfield men on the offense and at the wrong place for the opponents on the defense. Any play on his side of the line found him in the middle of things, but he never seemed to get on the bottom of the pile. He tackled hard, and seemed to stop his man easily. On offense he seemed to drift into the man or men in the way and delay them just long enough, but somehow to break loose again to be of further service to his backs."

"He sounds like a one-man show."

"In a way, he is, but he co-operates too well for that. It's a knack he has—instinct, brains, luck. You find men like that, some of them brainy and some dumb as they make them, and they flash or blunder along with no fuss or bother. In fact they seem to be having a good time all the while.

"Did I ever tell you Inspector Tim Croat's pet story about a fireman named Orrie down at a little mill in Pottsville?"

"I don't think so, Chief," answered Preble.

"No? Its about as dumb a fireman as ever handled a shovel, and he's still working—never had an accident, Tim tells me.

"Tim went down to the plant one afternoon and found Orrie in difficulties. Orrie had neglected to blow down the boiler regularly since the last inspection and the blow-off pipe had plugged up so solidly he couldn't drain the boiler.

"He had tried to get some water out of the water column blow-off, but it was plugged, too.

"So Orrie worked out a plan. He opened the blow-off valve a little and pushed a rod as far up the pipe as he could.

"Fortunately nothing happened . . . . all this was done, you understand, with 40 pounds pressure on the boiler.

"But Orrie wanted to open up that blow-off pipe, so next he took the blow-off valve off entirely and straddled the pipe. Then he went to work with a 'plumber's friend,' one of those rubber suction cups used for opening up sinks and other drains.

"Orrie was pumping away full speed ahead when Tim arrived.

"Tim took in the whole scene in a moment and called to Orrie.

" 'Hey, young man, what's the trouble?'

" 'Blow-off pipe's plugged.'

" 'So I see,' said Tim, still standing by the door ready to move elsewhere, 'but you can't fix it that way. Put the valve back on and I'll show you what to do.'

"So Orrie screwed on the valve.

"When it was tight, Tim sauntered around to the front of the boiler.

" 'Hm'm,' he said, 'only 40 lbs pressure.'

" 'That's what we always carry,' said Orrie.

"Tim was angry, but he didn't let Orrie know. He just said 'Orrie, don't you know it's unlucky to fool with a blow-off pipe on a boiler that is under pressure?'

" 'No, is it?'

" 'Very unlucky, Orrie. Now I'm going to stay here and show you how to fix that blow-off pipe. It's almost quitting time so you'd better draw the fire. At 5 o'clock we'll blow her down. You start the whistle and keep it blowing until no more steam will come out.'

"Orrie liked that, so at 5 o'clock he blew the whistle. It blew and blew and after a while the owner came down. Tim explained the situation and emphasized the need of regular blow-offs.

"The owner shrugged his shoulders. 'I'll watch it personally,' he said. 'I ought to fire Orrie, but what would he do? Look at him.'

"Orrie was standing with the whistle chain in his hand and grinning from ear to ear.

" 'How about the plugged up blow-off pipe?' the owner asked.

" 'We'll have to drain the boiler. Probably the best way will be to unfasten a manhole cover and poke it into the shell. Most of the water will run out and down the floor drain. Then the blow-off pipe can be disconnected and a new one installed, without loss of much time.'

"Orrie helped with everything. The owner told Tim later that from then on Orrie blew off the boiler every day, and had asked several times whether the inspector thought everything was all right.

"Tim used to drop into the plant every time he was in Pottsville, would chat a few minutes with Orrie if it wasn't time for an inspection, and would give things the once-over."

"Chief, I'd think a plant would get rid of a fellow like Orrie in a hurry," said Preble.

"No, Tom. There are plenty of Orries among us . . . and they seem to keep their jobs. You see there are a lot of folks in this world like that Pottsville mill owner and good-natured Tim to look after them . . . . and besides, Orrie never had an accident."

Computing the Cost of a Steam Leak

An easy method of computing losses from steam leaks is offered by the *Petroleum Engineer.*

Let d = the diameter of the leak in inches
a = absolute steam pressure in pounds per square inch
\$ = cost of fuel in dollars per ton
x = loss in dollars per day

$$d^2 \times a \times \$ \times (0.08) = x$$

For example
d = ¼″
a = 320 lb
\$ = 6.00

$$.25^2 \times 320 \times \$6.00 \times 0.08 = \$9.60$$

Thus in a year of continuous operation the leak would cost \$3,504.

The magazine explains that the rule is based on Napier's well known formula, which states that to find the weight of steam flowing through a given orifice into the atmosphere per second it is necessary merely to multiply the area of the orifice in square inches by the absolute steam pressure in pounds per square inch and then to divide by 70.

In developing the above formula, it was assumed that one pound of fuel will evaporate 6 pounds of water.

Of course, ordinary steam leaks are not usually from round orifices, but the formula is helpful in estimating losses.

Chief Instructor: "Now remember, men, statistics don't lie. Now, for an example, if twelve men could build a house in one day, one man could build the same house in twelve days. Do you understand what I mean? Jeep, you give me an example."

Jeep: "You mean that if one boat could cross the ocean in six days, six boats could cross the ocean in one day." —*Whatyoumay.*

Second: Go in and finish him this time.
Fighter: But I can't see him.
Second: Then hit him from memory. —*Telephone Review.*

He who stops being better stops being good. —*Think.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

June 30, 1939 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,195,338.86
Premiums in course of collection (since April 1, 1939)		798,786.99
Interest accrued on bonds and mortgages		77,235.63
Mortgage loans		154,462.10
Home Office real estate		537,331.05
Other real estate		416,449.60
Bonds on an amortized basis and stocks at market value		16,343,214.44
Total		$19,522,818.67

LIABILITIES

Unearned premium reserve		$7,663,040.40
Losses in process of adjustment		284,113.64
Commissions reserve		158,163.00
Taxes reserve		299,686.68
Other liabilities		158,741.63
Dividends declared and unpaid		120,000.00
Liabilities other than capital		$8,683,745.35
Capital stock	$3,000,000.00	
Surplus over all liabilities	7,839,073.32	
Surplus to Policyholders		**10,839,073.32**
Total		$19,522,818.67

WILLIAM R. C. CORSON, President and Treasurer

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Incorporated 1866 *Charter Perpetual*

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HARTFORD STEAM BOILER

Boiler Feedwater Service

Whenever troublesome feedwater problems involving boiler safety or affecting operating costs are encountered by any of our policyholders, the Company stands ready to aid them through the service of its engineering and feedwater laboratory. During the nearly 60 years that this service has been available, thousands of boiler feedwater samples have been analyzed for policyholders who reported trouble and asked our help. As a result boilers menaced by troublesome feedwater conditions are fewer and much money has been saved policyholders by the recommendation of the proper kind and quantity of inexpensive basic chemicals for treatment.

Hartford Steam Boiler analyses bring to us letters which demonstrate the value of the service. For example, a large chemical plant writes, "These analyses have revealed very important facts which we did not know before." A prominent oil refiner says, "We appreciate your usual good service . . . our operating department, through such service, are giving better attention to operation and maintenance of boiler equipment."

Because an adequate consideration of each boiler feedwater problem calls for attention by our experts in the field as well as by the home office engineering department and feedwater laboratory, it is suggested that policyholders who desire the Company's advice on this subject communicate first with the chief inspector of the department in which the plant is located (see names and addresses on the inside back cover). He will see that the entire facilities of the company are enlisted, if need be, for the solution of your boiler feedwater problem.

Note: Please originate all inquiries with the chief inspector in your district and do not send in samples of feed water without consulting him. Time will be saved and accuracy enhanced thereby.

The Locomotive

OF

THE HARTFORD STEAM BOILER
INSPECTION AND INSURANCE CO.

INDEX
to
VOL. 43

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THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE CO.

HARTFORD, CONN.

1940-1941

INDEX TO VOL. 43 — 1940-1941

THE LOCOMOTIVE

REFERENCES MARKED WITH A STAR (*) ARE TO ILLUSTRATED ARTICLES.

"Combustion Explosions in Pressure Vessels"

Vol. 43 No. 1

JANUARY, 1940

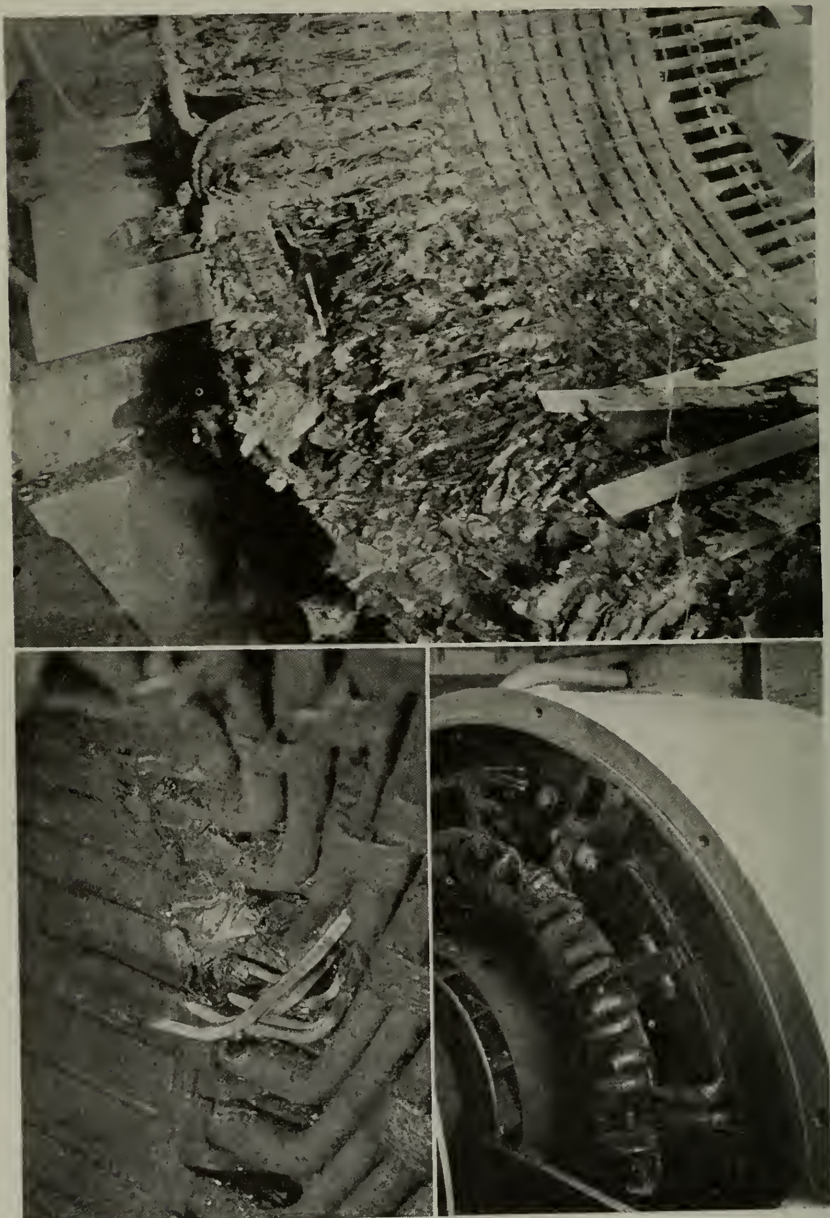
The Locomotive

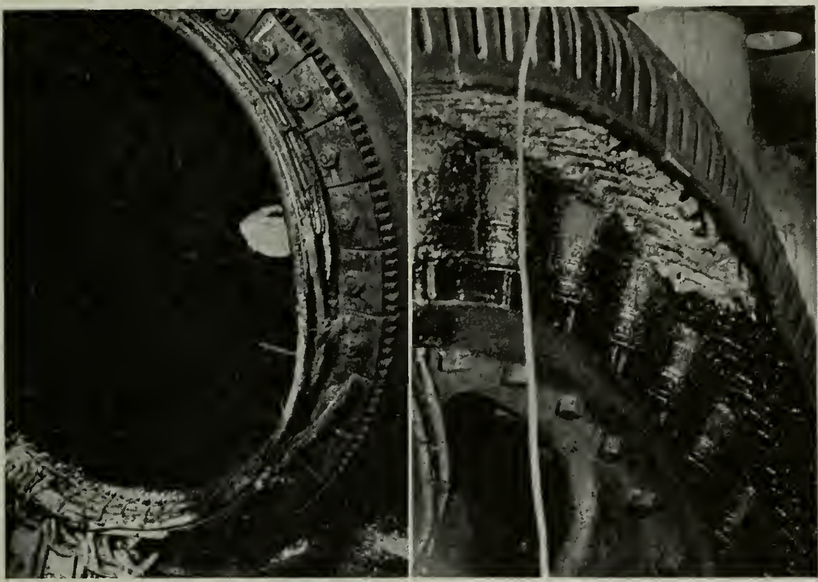
THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE CO.

Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Generator Accidents





Top, Page 2—Stator burnout on starting. The machine is a 2500 kva AC generator, part of a frequency-changer set, at a county utility. Bottom, Page 2—Two failures of turbo-generators because of lightning. The picture at the left shows a 3,000 kw machine at an oil refinery and that at the right a 750 kw generator at a municipal utility. Above—Left—A high frequency 1125 kw motor-driven alternator used at a boiler factory. Half of the coils were damaged when insulation failed on end turns. Right—Short circuiting of turns in one coil brought damage to about 60 other coils of a 168 kw generator driven by a steam engine at a manufacturing plant.

$39,000 Damages Awarded After Explosion

Liability damages totalling more than $39.000 were recently awarded as a result of a butane tank explosion in Texas, which killed four persons and injured eleven others. Property loss because of the accident amounted to about $12,000. One of the heads of the tank, which was buried, blew out as the tank was being filled from a truck tank. An explosion and fire followed.

Pitting, attributed to electrolytic action, in less than a year pierced 3/8" metal in a new hot water tank at an Iowa residence. It was necessary to remove the tank and install a new vessel.

The Protection of Miscellaneous Electrical Equipment

For insurance company purposes the term "miscellaneous electrical equipment" is used to describe a large variety of non-rotating electrical objects such as switchboards and equipment mounted on them, bus structures, rheostats, rectifiers, condensers, capacitators, choke coils, reactors, instrument transformers, oil switches, and circuit breakers.

A recent list of 182 accidents to such equipment during the 26 months ending in September, 1939, involved losses estimated at more than $135,000 and ranging from a $35,000 oil circuit-breaker explosion to an $8 burnout of a thermocouple on an antenna tuning unit.

Approximately 16 per cent of the accidents were directly attributable to lightning, and equipment not mounted on switchboards was apparently more vulnerable to accidents from this cause. With respect to equipment not so mounted lightning accidents were most prevalent in oil switches.

In numerous instances in which insulation failure was blamed for the accident it was believed that lightning or line surges, perhaps months before, had so weakened the insulation that eventual failure occurred under normal operating conditions.

Some of the other accidents were readily traceable to definite causes such as:

Mistakes in repairing windings.

The use of equipment which was not adequate to the load requirements of the plant, although it may have been when it was installed.

Physical abuse such as repeatedly pushing a waste can against leads.

Vibration.

Breakdown of insulation between turns.

Accumulations of dust and dirt.

However, tracing down the causes of electrical accidents is many times a theoretical problem at best. It has been found that experience as the result of numerous cases is often of more value in understanding any given accident than are the facts which any one accident will reveal.

Accidents as respects actual damage usually were confined to an individual switch, breaker, instrument transformer, rectifier, rheostat, lead, meter, relay or other apparatus or its connections, but they caused inconvenience and interruption of service because the functioning of other equipment was interrupted by the electrical disturbance as the result of the failure. Entire plants have been put out of service because lightning, surge or overload caused the failure and perhaps the explosion of an oil switch, or some other important device.

Such accidents in the list under consideration included one in which explosion of an oil switch killed two workmen, set a powerhouse on fire and shut off the power to a city. An accident at another utility originated with the explosion of a voltage feeder regulator which demolished the switch room and injured three employes. Electric power was shut off in a downtown area. A third accident to an oil circuit breaker resulted in serious damage to two generators and to the distributing system, with cessation of power for two hours. Each of these accidents caused thousands of dollars loss and much inconvenience.

Such explosions usually are the result of unusual electrical overloads on the switch. The resulting over-heating vaporizes the oil, permitting it to mix with air and to be exploded by an arc such as might occur because of the opening of the switch.

As a general thing the reports of electrical burnouts to miscellaneous electrical equipment are of a routine sort, but through them there are repeated a number of principles, the heeding of which may prevent serious accident. Let the owner of miscellaneous electrical equipment ask himself the following questions and answer them truthfully. If his answers obviously indicate an incorrect condition remedial measures are necessary. The questions are as follows:

1. Is the equipment clean? Free from dust? Free from unnecessary oil and grease?
2. Is the equipment dry? Continuously so?
3. Is the equipment operated in the presence of acids? Caustics? Deleterious fumes of any kind? Is the equipment checked for injury from such influences?
4. Are contacts misaligned, pitted or worn so as to foster over-heating?
5. Is the equipment over-loaded?
6. Are conductors in place and tightly fastened? Are connections tight?
7. Do protecting covers or boxes around the equipment lead to over-heating?
8. Do temperature comparisons show any abnormal rise?
9. Is there any evidence of vaporization of oil?
10. Are conductors and instruments exposed to unusual heat from a boiler or process?
11. Are insulation resistance test readings relatively high?
12. Are the lightning arrester ground resistances low?

13. Is the oil in switches and transformers of proper dielectric strength? Has excessive sludge accumulated? Is the oil at the proper level?
14. Are phase currents balanced within safe limits?
15. Are conductors exposed to physical damage from movable objects?

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16. If the plant contains equipment which has been idle for a long time, is it in condition to function as it should when it is called upon for use?
17. Are the operators sufficiently familiar with the purpose of the equipment? Its maintenance? Its control? Its relation to other equipment? Its construction?

These questions might well be asked of every power plant operator. Furthermore, conditions that are correct today will not prevent accidents tomorrow if changes have taken place. Wind, rain, temperature changes, lightning, line surges, mistakes by operators—a multitude of things subject to no law except the laws of averages and inevitability—can quickly change an electrical equipment picture.

The best assurance of safety comes through constant watchfulness by operators and expert inspections throughout the life of the equipment. Such a program will not prevent all accidents but it will prevent many of them.

Locomotive Boiler Explosion Kills Two, Injures Eight

Two trainmen were killed and eight persons, including four passengers, were injured when a passenger train locomotive boiler exploded and the train became derailed on September 26, 1939, near Preble, Texas. In his report, John M. Hall, Chief Inspector of the Bureau of Locomotive Inspection, Interstate Commerce Commission, attributed the accident to over-heating and failure of the crown sheet caused by low water.

Another failure which brought death to the engineer and injury to three of the crew occurred on a freight locomotive near South Bend, Indiana, October 23, 1939. The main steam pipe to the steam chests burst, releasing steam which scalded the engineer and forced the other three crewmen to the top of the coal tender. The train continued on its way until the steam pressure dropped, but no further damage occurred.

Diesel Engine Insurance and Experience

In a recent address before the Municipal Electric Utilities Association of New York State, H. J. Vander Eb, Assistant Chief Engineer, Turbine and Engine Division, discussed the most recent developments in Diesel engine insurance as reflected in the rate changes announced in the October, 1939, *Locomotive,* Page 245. His studies reveal highlights of Diesel engine experience which should be of interest to all owners of internal combustion engines. —Editor.

By H. J. Vander Eb

Diesel breakdown experience during the last 18 years has shown very clearly the superiority of the dual circuit type of closed cooling system with a heat exchanger as compared with the usual type of open cooling system. For this reason the most recent plan of Diesel engine rating retains the differentiation between the open and the closed cooling systems.

Obviously, one major advantage of the closed cooling system lies in the practically complete freedom of scale and mud accumulation in the water jackets. This results in much longer life of cylinder heads and liners. There is, however, another advantage that has been frequently overlooked, namely, the fact that with the dual-flow type of cooling system it is almost impossible to cause an abrupt lowering of the temperature of the inlet water to the cylinder jackets. Such changes of inlet water temperature are rather common where the open type of cooling system is used. They cause sudden shrinkage and distortion of cylinder liners, an unduly large number of piston seizures, and crank bearing troubles.

Hence, a very much lower insurance rate, about 40 per cent less, is available for Diesel engines having closed type cooling systems. This point may well be considered when new Diesel installations are planned. The saving in insurance in one or two years often equals the difference in cost between an open and a closed cooling system.

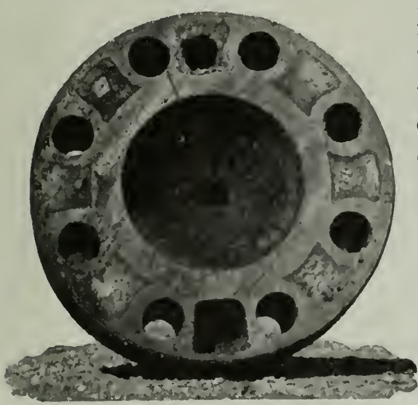


Figure 1—Diesel cylinder-head completely choked with scale. The faulty water condition in connection with an open cooling system caused repeated failure of the cylinder-heads on this engine.

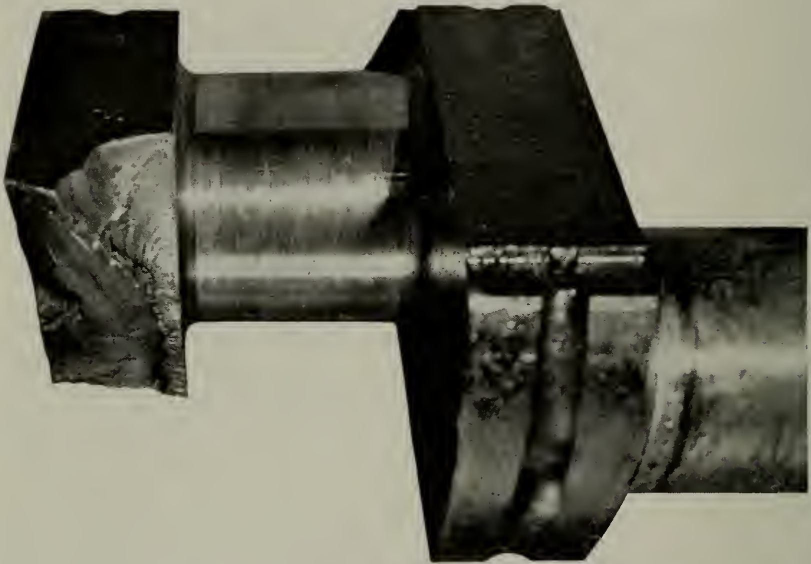


Figure 2—Crank distortion caused by bearing misalignment resulted in the breaking of this crankshaft. The fatigue cracks started in the fillet on the journal side of the crankweb.

The latest analysis made of the principal origins of failure in accidents to insured Diesel engines shows the following relationship:

Bearings	30.0%
Cylinders (including heads and liners)	24.3%
Pistons and Piston Rings	15.3%
Valves	7.3%
Crankshafts	4.5%
Connecting Rods and Crankbolts	4.5%
Gears	4.5%
Fuel Pumps and Piping	2.8%
Governor Parts	2.8%
Exhaust Manifolds	2.3%
Accidents Not Otherwise Classified	1.7%

These percentages vary slightly from year to year, but there has been a noticeable trend of improvement in the experience with crankshaft, connecting rod, and crankbolt breakage. This has been due to the breakdown-preventing inspections given insured equipment, and has, of course, been a factor in the most recent compilation of rates.

The highest percentage quoted is that of bearing failures. From an analysis of the loss history of bearings it seems quite significant that this high percentage of bearing failures is definitely connected with piston scuffing and piston seizure troubles, a fact which correlates bearing troubles and cooling practices.

The percentage of cylinder head, cylinder, and liner losses is next in line and could be appreciably lowered by the installation of closed cooling systems and by the systematic practice of after-cooling every time the engine is stopped. The necessity of safeguarding the cylinder wall against undue localization of heat from the hot piston tops at the time

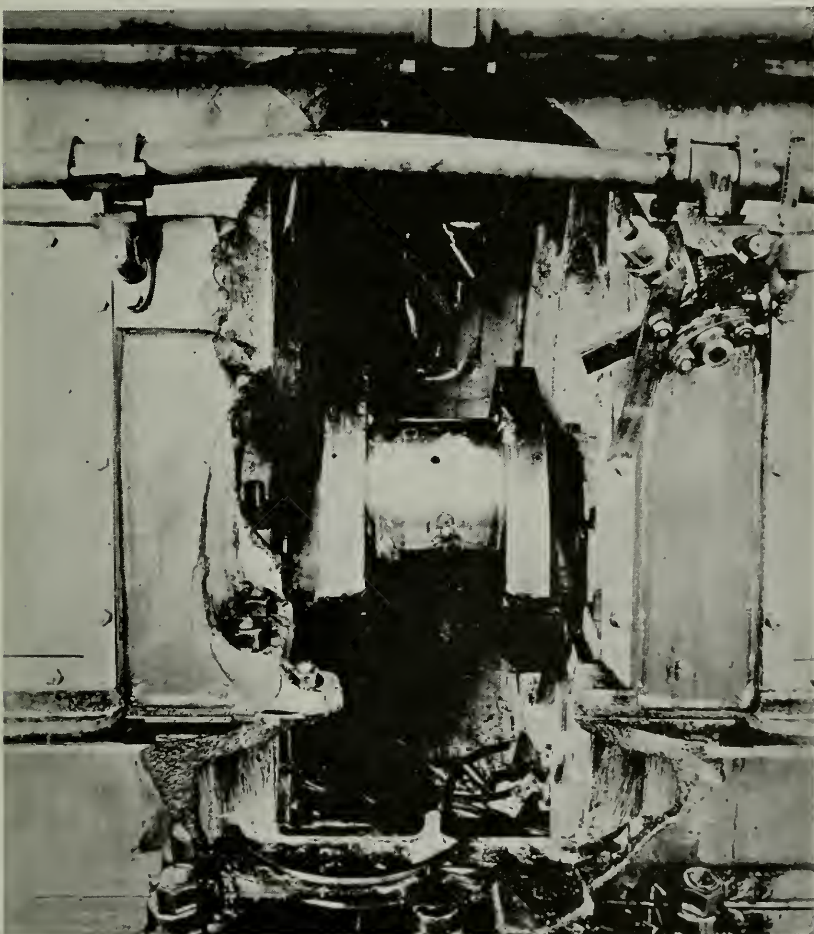


Figure 3—A wreck brought about by a crankbolt failure in a 2,000 hp engine. This accident resulted in a lost estimated at $45,000. Vertically the picture shows about 5 feet of the engine.

a Diesel engine is stopped is not sufficiently appreciated. Many engines always stop in approximately the same position. This may cause the formation of circumferential cracks in the cylinder wall at the point where a hot piston top has repeatedly come to rest. Numerous cases of circumferential cracks in cylinder liners could be directly traced to this cause, particularly where no after-cooling has been used.

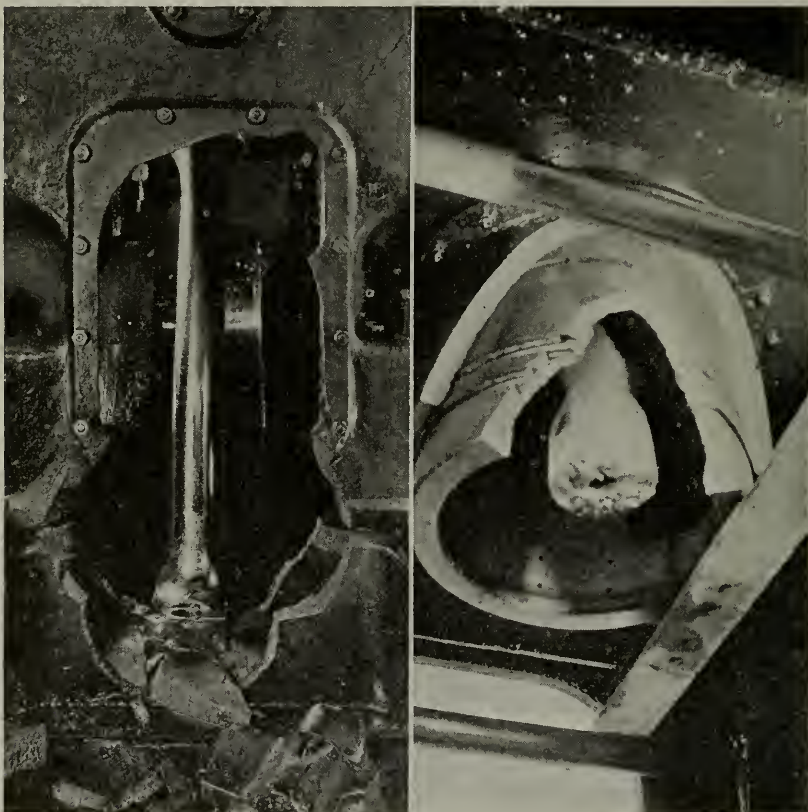


Figure 4—Left—Crankbolt breakage in a 260 hp Diesel engine. Figure 5—Right—Broken connecting rod and other damage on a 600 hp engine. This accident was caused by failure of a crankbolt, which had been in use for approximately 30,000 operating hours.

As already mentioned, crankshaft breakage is being more effectively prevented nowadays by an improved crack-finding technique and a somewhat better cooperation of owners in the necessary periodical dismantling of shafts. Whitewash tests give good results in most of this work, and the magnetic method of crack finding is employed in any case where it may give some advantage over the whitewash test. (See THE LOCOMOTIVE, April, 1939, Page 162.)

A very important factor in the improved crankshaft experience has been the use of the Hartford straingage developed by the Company (See: THE LOCOMOTIVE, April, 1934, Page 34). This highly useful instrument is placed between the crankwebs and gives a reading of the distortion of the cranks due to: Misalignment of bearings, the improper foundation support of the engine base, the influence of overhung flywheels, or excessive belt tension. From such distortion readings the apparent fibre stress from the bending strains in the cranks can be determined.

Likewise the very serious engine wrecks resulting from crankbolt breakage are being prevented better by the periodic testing of the bolts by means of the whitewash and magnetic methods.

Experience has taught that whenever a piston seizure has resulted in the engine being brought to a more or less abrupt stop, it is always advisable to replace the crankbolts of the affected cylinder because of the heavy over-stresses in the bolts caused when all the power in the engine is attempting vainly to continue the seizing piston in motion.

It seems appropriate in discussing Diesel accident prevention to mention the Company's experience with the repairing of broken shafts and the building up of shaft surfaces by fusion welding. Such repairs have not come up to expectations.

Shafts that have been welded should receive dismantled inspections at frequent intervals.

The building up of shaft journals and flywheel seats on shafts has been particularly disappointing in that in so many cases cracks form in such built-up shafts and eventually lead to complete breakage. Such repairs have stood up only from a few months to two or three years.

The economic advantages of power plant insurance by a specialist insurance company have been well recognized for nearly three quarters of a century. In the Diesel field the inspections and engineering advice have been of inestimable value to policyholders during the last 20 years in the prevention of costly accidents and in safeguarding the invested capital.

Armour Institute of Technology and Lewis Institute have entered into an agreement to consolidate into a new technology center for Chicago, to be called Illinois Institute of Technology. The actual consolidation of the educational program will be complete by September, 1940. For the time being, it will be necessary to operate both the Armour and Lewis plants, but the complete development of the new center of technology contemplates the acquisition of a well-planned campus, conveniently located.

Explosions of Condensate Receiving Tanks

Damage estimated at $8,000 occurred because of the explosion of a condensate receiving tank on October 28, 1939, at a paper mill. The tank was installed with a vent pipe to atmosphere, but as the vent pipe connected to the vent from the blow-off tank, a stop valve was installed in the condensate tank vent pipe in order to prevent the entrance of steam when the boilers were being blown down.

It was reported that the failure of a trap had permitted boiler pressure of approximately 118 lb to reach the tank at a time when the stop valve was closed. Under this pressure, the comparatively light tank failed, one of the heads bursting out and the rest of the tank tearing from its foundation.

The parts of the tank and the force of the explosion knocked down a 12″ wall as shown in the accompanying photograph, moved pumps from their bases, and damaged fire doors, walls, floors and windows on two floors.

Another condensate receiving tank on the roof of a laundry ex-

Part of the damage caused by the recent explosion of a condensate receiving tank.

ploded on October 12, 1939, with such force that a wooden structure housing it was demolished and the tank was catapulted at least 200′ upward and 300′ horizontally. It landed near a neighboring house.

The installation was one in which traps on the exhaust line from ironers and pressers discharged to a header from which the condensate was either forced to the receiving tank by steam passing through the traps or was conducted to a Moorehead trap, the operation of which permitted steam from the boiler to force the condensate to the tank.

This tank was vented to an open tank above it and connected to another Moorehead trap below it in the feed line to the boiler. All of this equipment was reported to be functioning in its usual manner on the day of the accident.

The arrangement of pipes to and from the receiver and the operation of the trap was such that fluctuating pressures built up in it. These stresses led to the tearing open of a head seam and the simultaneous explosion of the contents which was at a pressure considerably higher than atmospheric.

The vessel was not insured.

Steam Compressor Suffers Accidents

Two accidents involving the breaking of piston rings in a belt-driven steam compressor at a rubber plant recently caused use and occupancy losses of more than $2,500. Although the property damage was small and the accident of a common sort, the machine itself is somewhat unusual. The compressor takes steam at 100 lb gage and increases it to 175 lb, the pressure needed for certain vulcanizing processes.

Fired Radiator Bursts in Restaurant

A fired hot water radiator used in a McKeesport restaurant exploded on October 14 scattering fragments of one of its sections and spraying the room with rusty water. Two persons sustained injuries because of flying debris and were taken to a hospital. In the wall behind the radiator was an imprint of each section, showing that the heater had kicked back. The accident was attributed to over-pressure.

THE COVER

The photograph on the front of this issue of THE LOCOMOTIVE shows an inspector examining the spider of a synchronous motor field. Rotors such as this are subject to large centrifugal stresses. In addition loose rotor parts may rub against the stator with subsequent serious damage.

Combustion Explosions in Pressure Vessels

By W. D. Halsey, Assistant Chief Engineer, Boiler Division

Pressure vessels commonly fail either because some inoperative regulating or safety device permits an excessive increase in the pressure of such contents as water, steam, air, or other kinds of vapors, gases, or liquids, or because the vessel has become weakened from corrosion or other trouble. But vessels containing flammable gases or liquids are subject to an additional hazard—a combustion explosion resulting in a sudden and abnormal rise of pressure to a greater degree than the metal can withstand. Vessels also may fail following the breakdown of contents that are chemically unstable, the contents undergoing a sudden and violent chemical change, not necessarily a combustion, which produces an extremely high pressure.

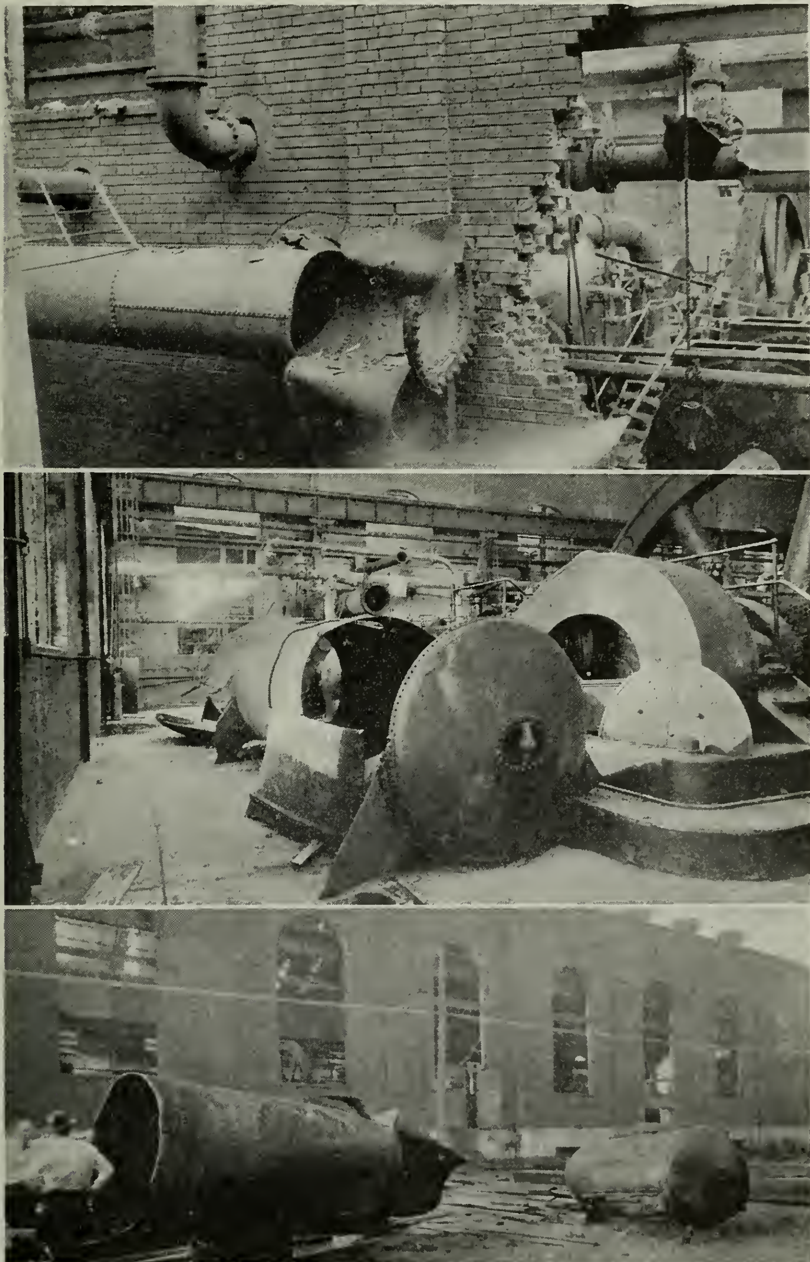
It is the purpose of this article to discuss the second form of explosion—in vessels which may contain flammable* substances.

Many new chemical compounds are now being manufactured and though relatively few are chemically unstable, a great many of them are flammable. However, combustion explosions cannot occur even with a combustible substance, unless there be a sufficient amount of air to permit combustion, and a source of heat of sufficiently high temperature to ignite the mixture.

A combustion explosion is not to be feared in a vessel which contains a flammable substance, but no oxygen or air. Whereas hydrogen is considered to be a highly flammable gas, there is no chance of a combustion explosion in a vessel containing pure hydrogen under a pressure higher than atmospheric. There is, however, the possibility of a combustion explosion in a vessel containing pure oxygen because, while oxygen itself is not looked upon as a flammable gas, it unites very easily with combustible substances. Pure oxygen in the presence of readily oxidizable substances such as oil will sometimes produce a combustion explosion even without the addition of heat from any other source.

There are many vessels that contain a mixture of a flammable substance and air which may operate indefinitely with no trouble whatsoever. On the other hand, there have been some violent explosions of such vessels and in many of them the source of ignition has been a mystery.

* It must be borne in mind that any substance which is flammable may, under certain circumstances, be explosive. A combustion explosion is merely a very rapid type of burning. The most rapid or sudden types of combustion explosion are commonly referred to as "detonations," although this term is often applied to the violent disturbance that takes place in an unstable compound that "flies to pieces."



Results of a combustion explosion in an air line and two large air receivers.

Vessels which contain a mixture of air and those substances which may be generally classed as hydo-carbons, of which oils are a notable example, can, under some circumstances, be very bad offenders.

The phenomenon of spontaneous combustion has unquestionably been the source of ignition in many of the combustion explosions in vessels containing air and a hydro-carbon. Spontaneous combustion begins with a very slow oxidation of the hydro-carbon. As this oxidation progresses, it produces heat. This heat is at first very slight and it might be said that "warmth" is produced rather than "heat," but of course, the difference is only one of degree. However, as the slight warming takes place the oxidizing action is accelerated and a higher temperature is reached. A vicious cycle is soon developed, for with the accelerated oxidation there comes an even more rapid increase in the temperature. This temperature finally reaches such a point that visible burning or rapid oxidation takes place. In other words, combustion occurs.

Spontaneous combustion ordinarily occurs only when the hydro-carbon is exposed to the air in thin films such as in the case of oily rags and waste. This form of spontaneous combustion is well known by all as a fire hazard.

Carbon in a finely divided porous mass and in the presence of a vapor of a hydro-carbon may also give rise to the spontaneous and rapid oxidation of that hydro-carbon. This is particularly true when the carbon is subjected to a relatively high temperature.

The progress of a combustion explosion leading to the development of a pressure which causes a vessel to fail is an interesting phenomenon. The steps involved in such an explosion have been the subject of considerable study by several investigators. It has been noted that, although a high pressure is developed, frequently only the heads are blown out of the vessel, even though the head seams are usually about twice as strong as the longitudinal seams. In fact, this type of failure is typical of a combustion explosion. In progressing through a pipe line a combustion explosion may blow out a section of pipe and proceed on to another section a considerable distance away, without disturbing the intervening portion. Sometimes, in a long pressure vessel, cylindrical portions near each end may be violently torn apart with the central section appearing to have suffered no damage whatsoever.

The progress of a typical combustion explosion, starting from a spontaneous source of ignition, may conceivably be about as follows:

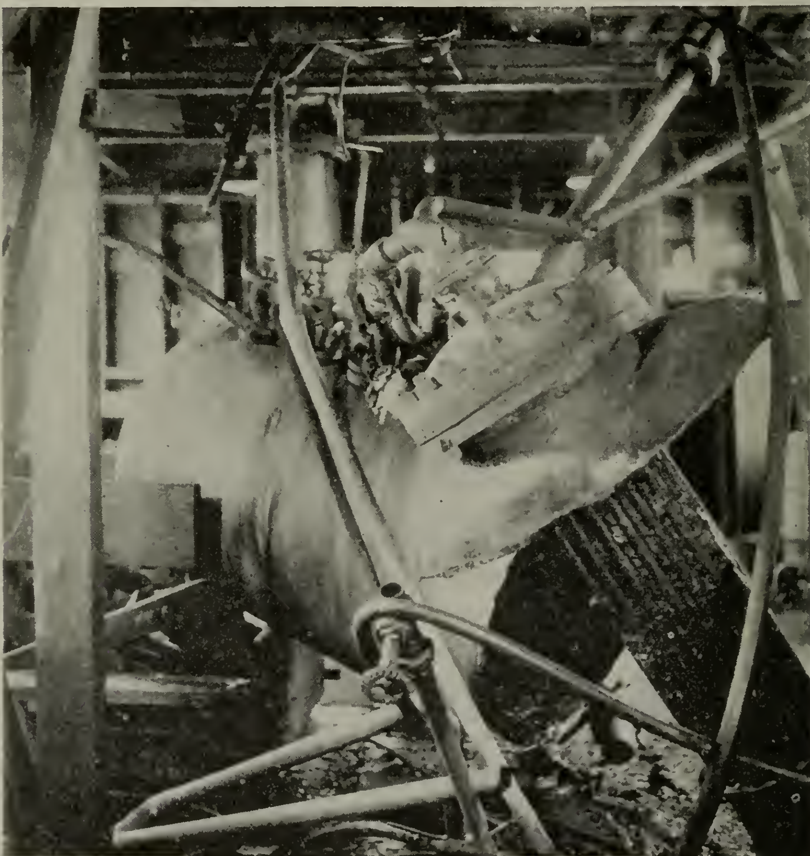
Assume that, about the middle of the vessel, there is a mass of porous carbon subjected to a relatively high temperature, such as from a steam heating coil, and that the vessel contains a mixture of air and a hydro-carbon in the form of a vapor. Slow oxidation begins in the carbon mass and progresses to the point where the mass becomes so hot that the air and hydro-carbon mixture is ignited. Assume that this mixture of air and hydro-carbon is in such proportion that a comparatively slow burning takes place. The burning of the mixture progresses toward each end of the vessel but as it does so the temperature produces an expansion of the contents, and the unignited mixture in each end of the vessel is forced to a higher and higher temperature merely by compression. Finally the mixture at the ends of the vessel reaches such a temperature, due almost entirely to the effect of compression, that ignition of the entire remaining mass takes place just as it does in the cylinder of a Diesel engine. When this sudden ignition occurs it is so rapid that it would be designated as a detonation.

Actually, of course, after the first ignition of the air and hydro-carbon mixture, this process progresses with extreme rapidity—so rapidly, in fact, that an ordinary pressure gage would not register its development.

In a long pipe line, when the flame travels through the pipe, the rapidity of its travel may be so great that the inertia of the mixture in the pipe causes the development of highly localized areas of very high pressure and consequently high temperature, giving rise to local explosions which rupture the pipe in the vicinity of the explosion and relieve the pressure momentarily, permitting the flame to travel on through the pipe and to give rise to successive localized explosions at various points along the line.

It is obvious from the above that the use of air pressure to move hydro-carbon liquids from one vessel to another may be hazardous and particularly so if masses of carbon are permitted to accumulate in locations where they may be subjected to high temperature. Such action is undoubtedly the explanation of combustion explosions in compressed air systems which are not kept free of carbon deposits and oil residue. In such systems the point of ignition is probably located close to the compressor where there are masses of carbon deposits being bathed by hot oily air. Ignition takes place at these carbon deposits and may cause a rupture of the pipe in their vicinity, or the flame may travel along the pipe and cause a violent combustion explosion in the air receiver.

An interesting case of a combustion explosion occurred about six months ago in a vessel which contained a liquid hydro-carbon which vaporized at relatively low temperatures. The vessel was equipped with steam heating tubes and, in the process, considerable carbon accumulated on these tubes. Air was used to force the liquid from the vessel. This method of operation had been followed for a considerable period of time and no trouble had resulted. Finally, just the right conditions occurred and an explosion took place, blowing one head out almost completely and distorting the other head.



Damage after a combustion explosion in a chemical process tank.

Last December it was reported that a thirty-two mile length of an oil pipe line in Texas was disrupted by an explosion. The report stated that "sections of the line gave way every thirty to fifty feet, leaving other sections in the ground."

It appears that the pipe line was being cleaned by a scraper which was pushed through the pipe by compressed air. Undoubtedly there was a gas or vapor in the line which became mixed with a sufficient amount of air to form a combustible mixture and this mixture may have been ignited from a spark struck by the scraper against the pipe wall. The occurrence is an excellent illustration of the manner in which a combustion or explosion wave travels through a pipe line.

Hot Water Tank Blast Kills Three

This pleasant spot on the shore of Lake Champlain witnessed the deaths of two men and a young girl one evening last summer. A hot water tank exploded in a small building at the location marked "3," struck the two men who were about 15 feet away, caromed into the garage "2," struck the girl at "1" and finally came to rest at "X" after traveling 750 feet. The accident illustrates the tremendous force inherent in hot water under pressure and above the atmospheric boiling point. In some way the building housing the tank had caught fire. The heat from this was believed to have brought about the explosion as it rapidly raised the pressure in the tank to a point which it could not withstand.

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

SIDNEY B. COATES, *Editor*

HARTFORD, CONN., January, 1940

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SIDNEY B. COATES

This issue of THE LOCOMOTIVE, prepared by Mr. Coates, its Editor, was in the hands of the printer December 12th. It is my sad duty now to add to its contents word of Mr. Coates' passing late that evening. During the day he had been at his desk carrying on his usual duties in apparent good health. In the evening he played his part in a community entertainment in his home town of Wethersfield and had just left the stage when some heart failure brought about a sudden collapse and his death.

Mr. Coates was born thirty-nine years ago, the son of a veteran in our organization and our present Detroit Manager, Mr. L. L. Coates and Mrs. Coates. He was thus, so to speak, born into our Hartford Steam Boiler Family and brought up in its traditions. After graduation from the University of Michigan he engaged in journalistic and advertising work for several years and in it acquired an experience and a facility of expression which especially fitted him for the position he was to have in the publicity department of our Company.

We were happy when in 1932 he joined its organization and that happiness continued throughout the intervening years as we noted his thorough and devoted performance of every duty and his growing ability to tell in simple and interesting language of the Company's activities in the several publications it issues. Among them the most important is The Locomotive, a magazine in which for seventy-two years our Company has endeavored to inform the public of the hazards of power producing machinery for which it affords protection. Some two years ago Mr. Coates was given editorial charge of this magazine and we have been most gratified to feel, from many favorable comments by its readers, that under his charge it has continued to provide interesting and understandable discussions of the often highly technical engineering matters involved.

However, the editing of The Locomotive was but one of several functions Mr. Coates had in our Company. Perhaps he has been better known throughout its organization as the source from which information concerning the Company's developments and new activities has been disseminated to its members and to the public. To friends and associates his death has brought a keen sense of personal loss. To those of us who know of his work and of the importance and value of the service he rendered in its performance now comes a realization of the loss our Company also has suffered.

W. R. C. C.

PERCY C. STEVENS

Percy C. Stevens, office engineer in the Boston department, died suddenly in his office December 1, 1939.

Born in Brockton, Massachusetts, in 1895, Mr. Stevens was graduated from the Massachusetts Nautical School as a marine and electrical engineer, and attended the school of turbine engineering at Carnegie Institute of Technology. After seven years' experience as a marine engineer, including a term in the United States Navy, he joined the Company on February 14, 1921, as an inspector in the Fall River and Boston districts.

News of his untimely death will be received with regret by the many who knew him in the Boston territory. His loss is keenly felt by his associates in the Company.

Machinery Insurance — 1940

(An Editorial)

It has been my experience, covering more than 20 years of operating Diesel plants ranging from 100 to 3,500 horsepower that, despite careful maintenance and constant inspection of engines and equipment, accidents or breakdowns of vital parts may occur. While it is true that Diesel insurance is not a definite assurance that such accidents, or breakdowns, will not occur, it is equally true that a plant carrying breakdown insurance, is protected against financial loss resulting from heavy costs of repairs, or loss of service. Such insurance should be invaluable to the small-plant operator who, through lack of adequate standby, might ill-afford the experience of a protracted shut-down.

There is little doubt in my mind as to the value of periodic inspections of plant equipment by men who, by reason of constant association with all types of Diesel installations, are in a far better position to detect flaws or irregularities in operating conditions, than the plant engineer. Many times, and again I speak from experience, timely suggestions on the part of trained inspectors are the means of saving a Diesel operator as much in repairs as would be the cost of the premium of a Diesel insurance policy.

A plant engineer in a middle western city recently contributed the above statements to the magazine *Diesel Power and Transportation.* His remarks reflect the modern viewpoint with respect to Diesel insurance in particular and machinery insurance in general.

For more than 70 years there have been explosions of boilers and tanks, each such accident adding its weight to the preponderance of evidence supporting the soundness of boiler and pressure vessel insurance and emphasizing the benefits to be secured from inspections of insured equipment.

The early conception of machinery insurance on the part of both the operator and the insurance company naturally followed in the footsteps of boiler insurance. It was sought to protect against catastrophe losses. First to be insured were flywheels which could *explode.* Next came other wheels which could *explode.* Next came turbines, the rotor of which could *explode* from centrifugal force and the casing of which could *explode* because of the pressure of steam. These explosions still occur all too frequently. Through them machinery insurance got its start and became well established.

In more recent years, however, a change has taken place in the reception given the subject of machinery insurance—a change brought about by the attitude of the persons who were either responsible for, or had in their charge, the maintenance and operation of machinery.

Led by some of the most important utility and manufacturing plant engineers in the country, the power plant field as a whole has been steadily adopting an attitude toward machinery insurance which indicates plain dollars and cents reasoning. One prominent engineer said, "The more Hartford inspectors I can get into my plant the better I like it." His company reflects his attitude by insuring virtually all important equipment. The plant runs like an expensive watch. It is clean as a hospital. It welcomes the inspector and gladly adopts his recommendations for greater safety. This company and others like to tell us that their program is financially sound in the one conclusive way that such things are told—by renewing their machinery insurance term after term.

They consider machinery insurance and the accompanying breakdown-preventing inspections actually in the light of a financial protection against the cost of failure, both of machines and their operators. The development of any machine today is the result of co-operative thinking by hundreds of men whose finished creation is in most cases complex. Few operating engineers can hope to understand thoroughly all of the factors that can lead to accidents to the equipment in their charge. The average man must content himself, even if he is unusually conscientious, with a thorough understanding of his local operating problems. How can he do much more? So, with respect to complicated machinery, he follows the directions of those in whom he has confidence—(1) the reliable manufacturers who created the equipment and the instructions for operating it, and (2) the inspectors who are assisted by the collective experience of hundreds of their fellows and who are guided by engineers who have spent their lives in accident prevention work. To these the operator adds the essentials of experience in power plant operation, the skillful guidance of men and a fundamental knowledge of the forms of power used by his own plant.

Insurance and inspections of machinery have proved their worth in many an important power plant for the past two decades. As 1940 begins, further increased demand for machinery insurance is noticeable as more owners of steam engines, Diesel engines, turbines, generators, motors, pumps, compressors and other important apparatus enlist the "safety-trained" ability of the insurance company engineer in order to achieve more reliably the complex goal of safer and less costly plant operation.

So many of us know what we are against, but not what we are for—what we disbelieve, not what we believe. A negative life easily becomes neutral and futile.—Rev. Joseph F. Newton, D.D., Rector of Episcopal Church of St. Luke and Epiphany, Philadelphia, in *Think*.

The Combustion Turbine

Increasing attention is being given in power plant circles to the so-called continuous-combustion gas turbine or combustion turbine, which is now being profitably applied for utilizing hot gases from process or from blast furnaces. Its principal application is for peak load generation, and for more specialized uses calling for large amounts of power for a short time such as in wind-tunnel blowers.

The cycle is interesting for its simplicity. A turbine-driven air compressor is started by means of a motor; compressed air at from 20 to 30 lb pressure is conducted to a combustion space where gas, oil, natural gas, blast furnace gas or pulverized coal is burned; the resulting gases of combustion are conducted to the gas turbine which takes over the job of driving the air compressor and furnishing, in addition, power to drive a generator or some mechanical device.

Because the gases of combustion are too high in temperature for immediate injection into the turbine, they are cooled by surplus air which passes around and cools the burner jacket and then mixes with the gases of combustion to reduce them to the desired temperature, usually about 1000°F. Net output efficiencies of from 15 to 18 per cent are possible in such a unit, which, while lower than for modern steam and Diesel plants, have offsetting features of low initial cost and low fuel cost. From the construction standpoint outstanding differences, in comparison with conventional cycles, are the elimination of boiler, condenser, water supply system and cooling towers.

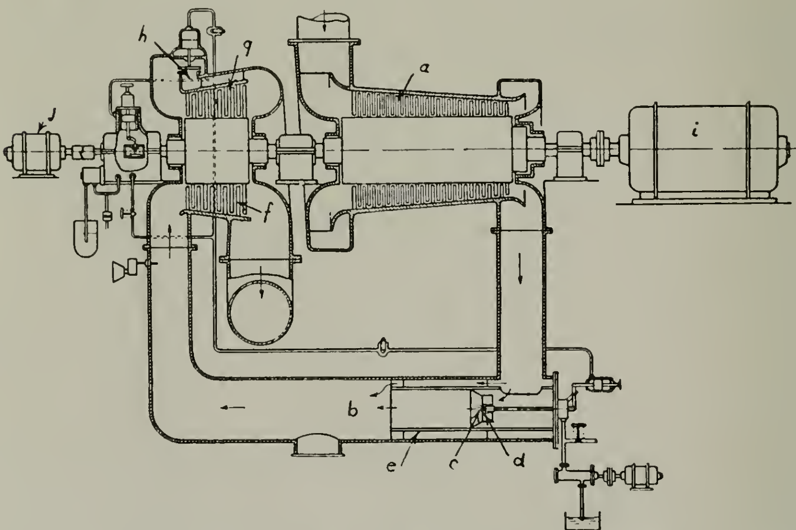
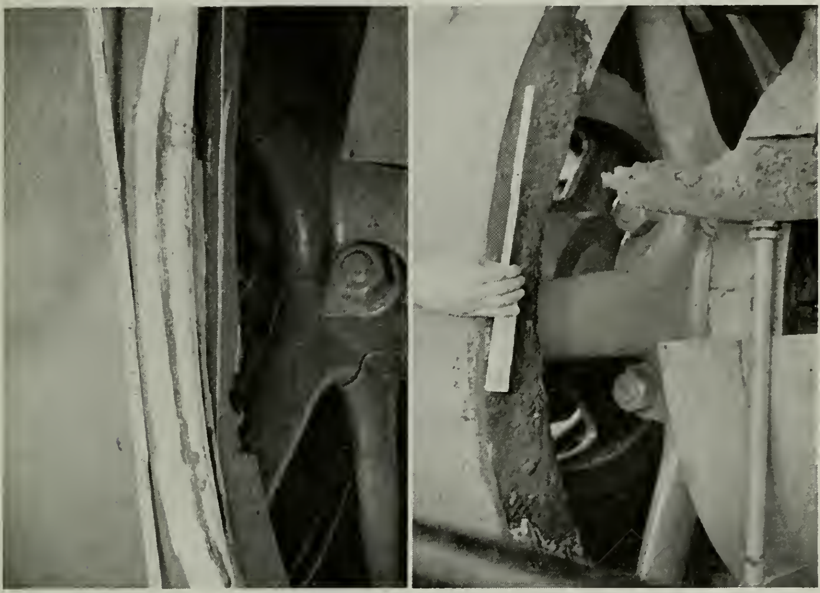


Diagram of the simplest form of combustion turbine plant as presented in Mechanical Engineering *by Adolphe Meyer. Parts are: a, axial compressor; b, combustion chamber; c, ignition point; d, burner; e, burner jacket; f, gas turbine blading; g, reaction type gas turbine; h, by-pass safety valve; i, electric generator; j, starting motor.*

Patient: "Why does so small a cavity feel so large to the tongue, doctor?"
Dentist: "Just the natural tendency of the tongue to exaggerate, I suppose."
—*Trumbull Cheer.*

Unusual Flywheel Defect



The illustrations show a casting defect in a 40-year-old flywheel. The engine on which this wheel was used had not been in operation for two years as it was kept as a stand-by for emergency service. It was given a test run each week.

The presence of the circumferential crack was suspected, and a whitewash test applied with the results shown in the photographs. By means of a few well-directed hammer blows large slabs of cast iron came off the wheel rim. Apparently, the defect was attributable to faulty casting practice at the time the wheel was poured.

It was fortunate that the heavy slab of metal never became detached sufficiently to be thrown off by centrifugal force when the engine was in operation.

The hydraulic principle of transmission has been adapted for use on Diesel powered locomotives. In a recent test reported by *Diesel Power* magazine, a hydraulic-drive Diesel locomotive pulled 300 gross tons (not including locomotive weight) up a 5% grade coal chute, stopped in the middle of the grade and continued to the top with the load.

Explosions of New Hot Water Heating Boilers

Left—Damage caused by the bursting of a hot water heating boiler from excess pressure. An investigation brought the conclusion that the system had been expected to operate with no expansion tank outlet and no relief valve. This accident occurred in Detroit.

Right—Outside and inside an Alabama residence after explosion of a hot water heating boiler because of excess pressure. Exactly what occurred was not determined, but it is evident that as the boiler continued to operate, the pressure of expanding water was not relieved. In each of the above cases the boiler had been in service only a few hours.

A 16-cylinder, 100 ton, air conditioning compressor of new design has been introduced in the American market. Since the unit is hermetically sealed and the in-built 100 hp driving motor is cooled by refrigerating gas on its way back from the evaporator to the compressor, it can be tucked into 21 sq. ft. of floor space, without regard for cross-ventilation normally required to dissipate motor heat.

Taps From the Old Chief's Hammer

THE Old Chief and Tom Preble, his assistant, were at lunch one day shortly before Thanksgiving. Preble had purchased some additional life insurance the day before and the subject was still fresh in his mind.

"Chief," he said, "some one ought to give a medal to certain of these life insurance men. Such quiet patience should be rewarded. Old Barnes has been in to see me a half dozen times lately with the recommendation that I purchase more life insurance. I kept putting him off, but some way he always found a mighty plausible reason for coming back.

"I didn't tell him, but I was sold on the idea from the start, and I suppose he must have suspected it. Even at that, I only reluctantly told him to go ahead. Saving money or at any rate saving more money isn't easy."

"You're right, Tom," replied the older man, "but quiet patience like Barnes has is a habit. We've men just like that and it's a good thing, too. Did I ever tell you about Inspector Dave Franklin and how he brought us the Potter line?"

"I don't think so, Chief," said Preble, knowing full well that a story was on the way.

"Good," chuckled the veteran boiler man. "It was about 30 years ago at a distillery down state. The company had changed ownership and we had been called on to approve the battery of eight boilers for insurance.

"As an internal inspection of every boiler was required before it could be accepted, we had been asked to take the boilers two at a time when they could be spared.

"Dave was detailed to make the inspections. He examined the first two boilers and reported the need for a few minor repairs. At the end of his report he said the boilers were extremely dirty and that there was heavy scale in them.

"Dave's next visit to the plant was a few weeks later. When he arrived, he found the chief engineer, a man named Walter Campbell, waiting for him, and on the table before him was the inspection report on the first two boilers.

" 'Franklin,' the chief engineer said angrily, 'this is an outrage. Those boilers can't be in as bad condition as you say they are.'

"You never met Dave, but he was as unruffled under fire as your man Barnes.

"He just replied, 'So—I hadn't thought to exaggerate. I can't show you, because the boilers are under steam, but in my desk at the office are a number of pieces of scale from different parts of the boilers. These are properly stamped and labeled and I can bring them down the next time I come.'

"There didn't seem to be an immediate answer so the engineer took a new tack.

" 'We'll see, young man. I don't like to be kept waiting. Suppose you get on with the next two boilers.'

"Dave just picked up his bag and went down to the boiler aisle. There he found two boiler cleaners doing nothing and complaining that they had been waiting for nearly three hours.

"Still calm and methodical, Dave climbed up on one of the boilers and turned his light into the open manhole, but he never even bothered to climb in. He just retraced his steps to the office.

" 'Mr. Campbell,' he said, 'instead of your waiting for me, it's a case of my waiting for you and I am not going to do it. It will take your men at least six hours to clean those boilers. They are worse than the first two.'

"Naturally Mr. Campbell was taken aback. I guess he lost his temper. Finally Dave said, 'Mr. Campbell, we are strangers, but you appear to be a good sort of a chap. Suppose you take my boiler suit and see for yourself.'

" 'I don't need your —— suit,' the engineer said, and stamped off toward the empty boilers.

"Dave went on dressing and was ready to leave the plant when the engineer returned.

"Instead of his former abuse, he now was friendliness itself. He held out his hand and said, 'Young man, I want to apologize to you. You were right. Those are the dirtiest boilers I ever saw and from now on I don't care how strong you make your reports.

" 'Some one is going to get called on the carpet and I'm that one. The only excuse I can offer is that I have a great deal to look after and have placed too much confidence in those boiler cleaners. They've been with me for several years, and I've paid little attention to them for the past year or two on the assumption that I could trust them. When you come tomorrow, I assure you, those boilers will be clean.'

"Mr. Campbell was as good as his word and before long Inspector Franklin and Chief Engineer Campbell were just plain Dave and Walt.

"Sometime later Campbell changed jobs and went with the Potter Corporation as assistant chief engineer. The plant superintendent wanted a check by a disinterested third party on the inspections they were receiving and Campbell at once thought of Franklin, but Dave said he couldn't make such inspections without instructions from his chief inspector and that such instructions, according to Company rule, would have to be preceded by an application for insurance.

"The upshot of the whole thing was that an application for insurance eventually came through for a few objects. Franklin was assigned to the inspections and he, of course, did his best. We never learned what the Potter Company thought of his reports, but we all know that we insure this company today," concluded the Old Chief.

"Good stuff," commented Preble, "but I should think Dave might have stretched things a bit and complied with that first request of the Potter engineer."

"What!" barked the Old Chief. "You young whippersnapper, don't you ever make a comment like that again."

Then in a kindlier tone he added, "Tom, occasionally we may hear some fault found with a Company rule and there may be some justification for the complaint; but the solution is not to break the rule When quality is at stake, rules are made only after days and perhaps months of consideration, and business men everywhere have a respect for and a confidence in employes who know their Company rules, know the reasons for them and can explain those reasons accurately and logically. If a rule is faulty, it can be amended, but the granting of exceptions leads only to eventual trouble."

Parson: "Zekiel, that's a fine garden you have there."
Zekiel: "Yas suh, Mis' Pahson."
Parson: "You must thank the Almighty for that."
Zekiel: "Pahson, did you evah see dis piece of ground when de Lawd had it all to Hisself?"—*Lanphar Counselor.*

Bricklayer: "Hello, Bert. Where's that helper you took on—the chap that used to be an artist?"
Second Bricklayer: "Haven't you heard? Soon as he laid a couple of bricks, he stepped back off the scaffolding to admire his work."—*Typo Graphic.*

In the test flight of a new plane, the pilot ordinarily writes the data on a pad of paper fastened to his leg. A Los Angeles airplane company is using a movie camera to record changes on the instrument board dials, and the pilot dictates his observations into a microphone.—*Business Week.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONN.

June 30, 1939 — *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks	$1,195,338.86
Premiums in course of collection (since April 1, 1939)	798,786.99
Interest accrued on bonds and mortgages	77,235.63
Mortgage loans	154,462.10
Home Office real estate	537,331.05
Other real estate	416,449.60
Bonds on an amortized basis and stocks at market value	16,343,214.44
Total	$19,522,818.67

LIABILITIES

Unearned premium reserve		$7,663,040.40
Losses in process of adjustment		284,113.64
Commissions reserve		158,163.00
Taxes reserve		299,686.68
Other liabilities		158,741.63
Dividends declared and unpaid		120,000.00
Liabilities other than capital		$8,683,745.35
Capital stock	$3,000,000.00	
Surplus over all liabilities	7,839,073.32	
Surplus to Policyholders		10,839,073.32
Total		$19,522,818.67

WILLIAM R. C. CORSON, President and Treasurer

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Incorporated 1866 *Charter Perpetual*

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"IS IT SAFE?"

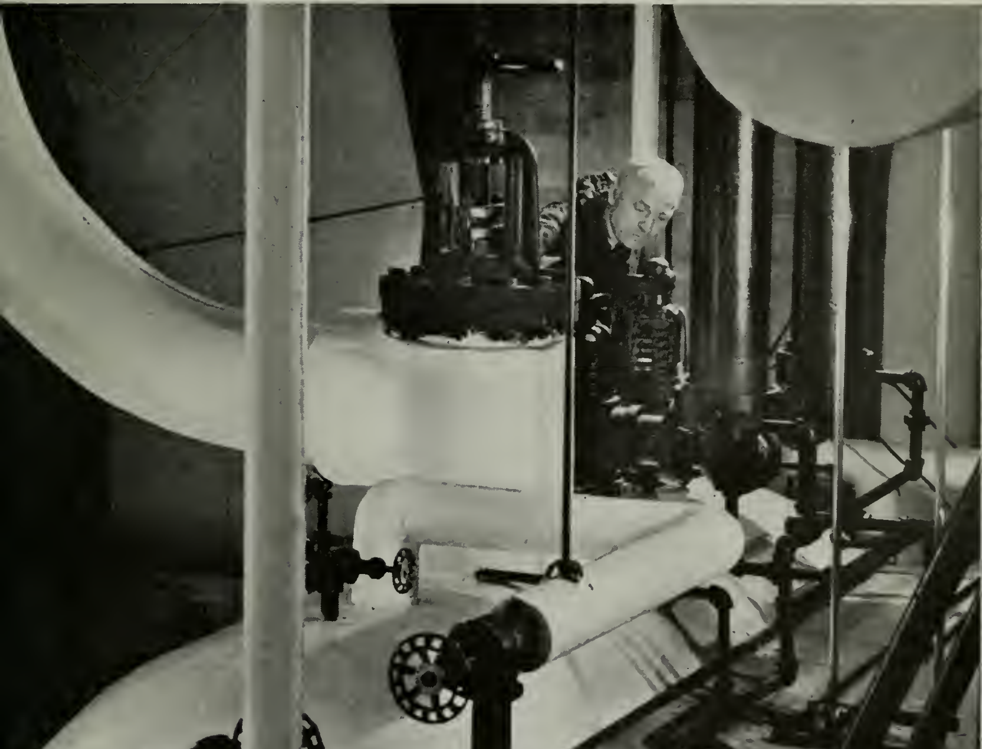
"Certainly, it's safe - - - now."

No Hartford Steam Boiler electrical inspector will tell you that an electrical machine or apparatus will be safe. He knows too much about the effects of dust, oil, grease, moisture, wear, vibration, cracks, looseness, heat, abuse, carelessness, lightning, ice and wind for that. He knows that accidents will happen sometimes, despite all his efforts and those of plant engineers. When they occur, insurance on electrical equipment furnishes needful protection against financial loss under the policy . . . . A request to any Hartford Steam Boiler office or representative will bring you additional information about electrical insurance and inspections.

"*Care of Heating Plants Idle During Summer Months*"

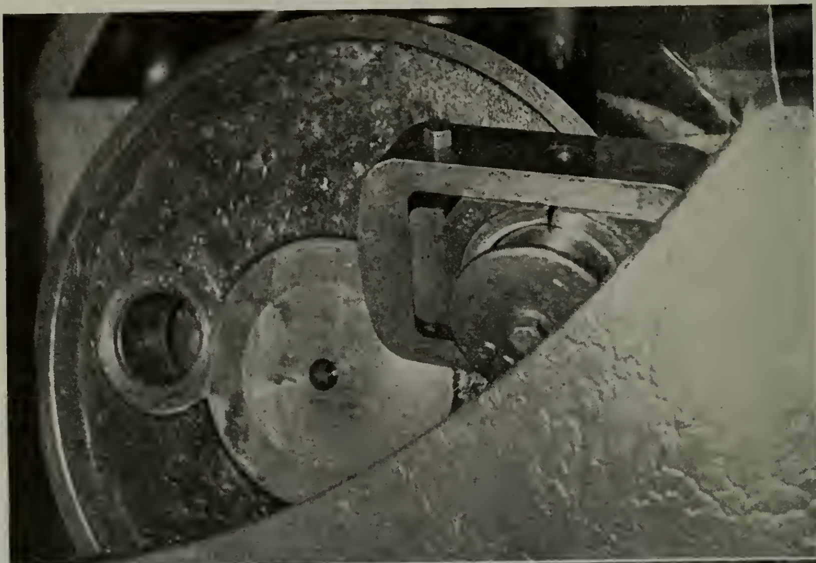
Vol. 43 No. 2 APRIL, 1940

The Locomotive



Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer



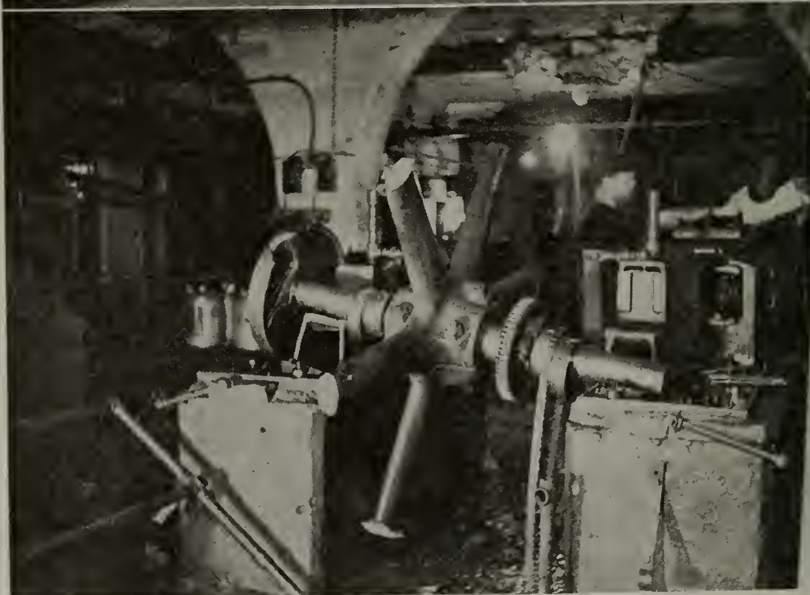


Figure 1 (above)—View of Engine No. 1 showing the loosened crank-pin and the connecting rod jammed between the disc and the frame.

Figure 2 (below)—This is what remained of Engine No. 2 after the flywheel exploded.

Three Steam Engines Involved in One Accident

A CRANKPIN that came out of its disc on one of the steam engines in a Western paper mill recently caused an accident which not only badly damaged the engine and injured an attendant, but led to circumstances that brought about the wrecking of another engine and damage to a third in the same engine room. Figure 1 on Page 34 shows the disc from which the pin worked loose, and Figure 2 shows the wreckage of one of the other engines.

After the crankpin worked out of the disc, the piston knocked out the cylinder head and the loose connecting rod jammed between the disc and the frame. The connecting rod was bent, and the oil-splash plate and stuffing box were broken. Steam escaping from the cylinder then set off two sprinkler heads that were located over a second engine. Almost immediately its flywheel burst from over-speed, completely wrecking this engine. Parts of the heavy wheel, traveling a distance of about 50 feet, went through two open dorways which were in a direct line with its plane of rotation. An employe standing beyond the second doorway was struck by pieces of flying metal and another employe nearby was knocked down.

Fortunately the third steam engine involved in this unusual accident was not in operation. The damage to it was not as extensive as on the other two engines but a cover plate and a connecting rod were hit and slightly bent by flying fragments. Repairs were necessary before the engine could be put in use.

In determining the cause of the over-speeding of the second engine it is reasonable to assume that the water released from the sprinklers wet both the governor and flywheel belts, causing them to slip and the engine to race as the load was lost. There was an independent automatic speed control which had a trigger arm extending three-quarters of an inch beyond the rim of the flywheel but it is thought that the speed control mechanism was damaged by the flywheel belt working to one side of the rim of the wheel and jamming this trigger arm, thereby making the control ineffective.

The damage to two of these engines may be directly attributed to the location of the sprinkler heads.

Scale can usually be removed from the water jackets of Diesel engines by boiling it out with a 10 to 20 per cent solution of muriatic acid, although in some cases a stronger solution may be required. In order to protect steel parts, such as the cooling pipes, from acid corrosion, the jackets should be thoroughly flushed out after the boiling process.

Suggestions for the Care of Heating Plants Idle During Summer Months

The inclination to forget about the heating plant when warm weather rolls around and the boilers are shut down is a natural one. The owner may say to himself that there is no need to worry about heat when it isn't being used, that there will be time enough before next fall to clean the boilers and make whatever repairs may be necessary. But there are two very good reasons why postponing the work of cleaning and repairing is inadvisable. Extensive and rapid deterioration by corrosion, while boilers are idle, may take place because of an accumulation of moist ashes and soot. Secondly, repairs which may be necessary may be put off or forgotten until cold weather arrives and heat is needed. Then it will be too late to make them conveniently.

The impairment and shortening of the life of a heating boiler may be, and often is, greater during periods of idleness than when the boiler is in use. Corrosion, one of the most troublesome causes of impairment, can be greatly reduced by thorough cleaning of the boiler. A complete examination of both the boiler and the heating system will show whether or not there are leaks and whether or not piping, valves, fittings and controls are in need of repairs. Elimination of these defects will help to prevent breakdowns when the heating plant is in operation—with consequent inconvenience, extra cost of temporary or hurry-up repairs and possible suffering by those who are dependent on the boiler for heat. And last, but not least, prevention of accidents as a safeguard against losses involving personal injuries, deaths and property damage is a very definite reason for a thorough cleaning and checking of the heating plant while the boiler is idle.

Steel Boilers

Draining of a steel boiler immediately after it is shut down for the summer is important. All surfaces to which soot and ashes adhere should be thoroughly cleaned by wire brushing. When coal or other solid fuel is used, ashes should be removed from the firebox, furnace, or ashpit where this waste collects. Soot and ashes will absorb moisture and this moisture when combined with the sulphur in soot and ashes forms sulphurous acid—an acid highly corrosive to steel. For the same reason the smoke pipe should be cleaned as well as any other passages through which the gases of the products of combustion travel. Even though the boiler is apparently clean and dry, there will be times during the summer when the surrounding air will contain moisture and some corrosion from this is almost inevitable. But if the boiler has not been thoroughly cleaned, this corrosion will be greatly aggravated by the action of the sulphurous acid.

The boiler should be completely drained at the time it is taken out of service. If it is left partly filled with water, internal pitting and corrosion of the sheets and tubes may take place, particularly at the water line. Also, if the atmosphere is humid, the difference between the temperature of the water in the boiler and the air will cause "sweating" on the outside of the metal and this moisture, combined with the deposits of the wastes from combustion, will form an acid which, in turn, will cause corrosion of the external surfaces. With the boiler left completely filled with water, the internal corrosion might not be as extensive as with the boiler filled only to its normal level, but the deterioration of the metal on the outside will be the same or greater. Hence, it is recommended that the water be drawn off, all manhole plates, handhole plates, and washout plugs removed, and the boiler flushed to wash out loose sediment and scale. When the boiler has been drained, care should be taken to close tightly the stop valve in the feed-water line so that it will not permit a slow leakage of water into the boiler. In an excessively damp location, in order to keep the boiler as dry as possible, a salamander, a coke-jack, or some other similar heating device may be used in the furnace to minimize moisture. However, when this method of drying is used, the temperature of the boiler surfaces exposed to the heat should not be too great to be uncomfortable to the hand.

Cast Iron Boilers

Although a cast iron boiler is less susceptible to, and less affected by, corrosion than a steel boiler, it should be cleaned of all soot, ashes, scale and rust on the external surfaces of the sections and gas passages when it is shut down for the summer. Ashes should be removed and kept away from the foundation, headers or other parts of the boiler. Wet ashes or moist soot will corrode cast iron as well as steel, and occasionally this corrosion will be of sufficient severity to eat through the metal foundation or the cast iron sections and headers. The smoke pipe should not be neglected for there again, if it is not cleaned, the combination of moisture with soot and dust will corrode through the metal in a comparatively short time. If the basement is damp, it may be advisable not to replace the pipe after cleaning but to keep it in a dry place until the boiler is again put in service. A smoke pipe rusted through or choked with soot will interfere with the draft, causing loss of boiler capacity and efficiency. Under certain conditions, the lack of a suitable draft may produce within the furnace a combination of gas and air which may explode violently.

At the end of the heating season a cast iron steam boiler should not be drained and left dry but filled with water to the top of the water-gage. External corrosion probably would be less on a dry boiler than one full of water. However, changing the water by draining at the start of the shut down period and refilling the next fall would increase to some extent the sediment, scale and rust in the sections. As a large amount of these deposits may cause the sections to overheat and crack, it is desirable to prevent accumulation of such matter as much as possible. There is also danger that the boiler may be fired inadvertently while it is dry, thereby cracking or warping the sections.

When heat is obtained by means of a cast iron hot water heater the complete system should be filled with water, for both the open and closed type systems. Any air that has been trapped in radiators or the piping system should be released by the valves provided for that purpose on the radiators. In both types of systems, the altitude or pressure gage will indicate when there is a proper amount of water as then the black hand will be at the same point as the red hand.

Other Points for Maintenance

When a boiler is being cleaned and leakage is discovered the insurance company inspector should be notified, providing insurance is carried, so that he can make an examination. To assure that repairs will be adequately and economically made, the owner should have the advice of the inspector and the benefit of his knowledge and experience. For example, the boiler may not be worth repairing because of its age and condition. Boiler tubes that have been plugged as a temporary repair measure because of leakage during the previous heating period should be replaced, and if the remaining tubes are of about the same age and are likely to give out in another year or two, retubing of the entire boiler may be advisable. Safety valves may stick to their seats when out of operation for a number of months, and it is a good precaution, therefore, to prop them open by inserting a block of wood between the try lever and the valve body. The water-level gage-glass may need cleaning. This is important in order that the operator may readily determine the actual height of the water in the boiler. The gage cocks and the gage-glass drain-cock should operate easily and water should flow through them freely when they are open.

Poor efficiency in many heating plants is caused by excess air being admitted to the combustion spaces and hot gas passages through warped or cracked furnace doors and frames, between sections or through other openings. These should be sealed up or defective parts replaced and insulation repaired. For a boiler with brick walls or bricked-in ashpit, cracked brickwork should be repaired, particularly where the cracks permit leakage of air into the furnace.

Heating Boilers are Not Intended For Use as Incinerators

The practice of using a heating boiler for the disposal of waste paper, rubbish, waste oil or any highly inflammable material, either during the heating season or when the boiler is idle, is contrary to accepted standards for good operating care and maintenance. Reasons have been given previously in this article to show the importance of keeping idle boilers clean and the advantages thereby obtained would be nullified if those boilers were used to burn refuse during the summer months. Moreover, a steel boiler that had been drained would be badly damaged by over-heating if any quantity of waste were burned in its furnace, and with cast iron boilers the rapid rate of combustion, which usually takes place when refuse is burnt, would cause large differences in temperature between parts of the sections. This might result in cracking, as cast iron is not a ductile metal and does not readily accommodate itself to severe or sudden expansion and contraction strains.

Attention to Piping and Auxiliary Equipment

While the boiler itself is the main part of the heating plant, the auxiliaries, controls, safety devices and piping, as well as other parts are important for the efficient and safe operation of the complete system. They should not be neglected. Leaks in return piping may cause low water, and subsequent cracking of sections in a cast iron boiler, or overheating and distortion of a steel boiler. Each control device has a definite function, which may be the feeding of water to the boiler, the cutting off of the fuel supply when the water is too low, the regulating of operation by pressure or temperature, or some other essential role. In order that these devices may do their work successfully they should be checked and, if necessary, repaired or replaced.

Steam, return and feedwater piping should be examined for leaks, cracks and corrosion. Installation of new piping is essential where there is evidence of leakage or where corrosion has thinned the piping to the point that it is no longer reliable. In some cases the piping may be in damp locations and should be coated with a rust-preventing paint.

Coal, ashes, rubbish or articles in storage should not be piled on or against the piping nor should the piping be used as a hanger or support, but should be kept free at all times. Piping and radiator shut-off valves that do not open and close freely should be repaired or replaced.

A rather frequent cause of heating plant failure during cold weather is the breakdown of automatic fuel burning equipment, such as oil burners and stokers or their controls. They may need overhauling and should be checked to see that they are in good working condition and dependable. Parts may need to be replaced as they wear out after a number of years of service. Even though the burner or stoker has been running smoothly, it will not last indefinitely and the longer it has been in use, the greater the need for a thorough examination. Preferably, that work should be done by the manufacturer's representative or by a concern qualified and familiar with the burner or stoker and its control equipment.

Summary

The principal points that have been discussed in this article for the care of heating plants while they are idle may be summarized as follows:

1. Thoroughly clean the boilers, furnaces, fireboxes, ashpits, and smoke pipes at the end of the heating season.
2. Drain and flush out steel boilers, remove manhole or handhole plates and washout plugs and keep the boiler as dry as possible.
3. On cast iron boilers, for steam heating systems, fill the boiler with water to the top of the gage-glass; and with hot water systems fill the boiler and system completely.
4. Repair or stop air leaks and replace cracked or broken brickwork.
5. Examine piping, joints and fittings for corrosion and leaks and make whatever repairs are necessary.
6. Do not burn rubbish in cast iron boilers nor in empty steel boilers.
7. Have the oil burners or stoker equipment examined and worn parts replaced.
8. For insured boilers on which extensive repairs may be necessary, consult with the insurance company inspector.

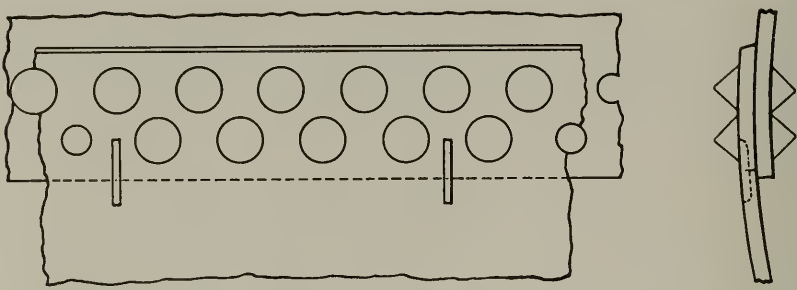
In the interests of both economy of operation and of safety, the boiler room should be kept properly lighted, clean and inhabitable. Breakdowns of many heating plants would undoubtedly have been prevented had the operator realized the importance of good housekeeping and of having repairs made when needed. Unseasonable weather or some other reason may necessitate the use of the heating plant earlier than anticipated and, therefore, it is to the real interests of the owner to know, as the heating season approaches, that it is safe and that it can be put in service promptly when required.

Slotting of Seams Reveals Cracks

An explosion of a large air tank was undoubtedly prevented when longitudinal cracks were discovered recently by cutting slots in one of the seams. As this tank was of lap riveted construction the inspector suspected a crack when he found leakage, although slight, along the caulking edge of a seam that showed signs of repeated caulking. On his recommendation, the seam was slotted at several points and leakage through these slots with the vessel under hydrostatic pressure showed definitely that a crack had developed in the plate forming the outside lap of the seam. As is usual with this type of crack, it started from the hidden side of the plate and could not be seen. The slots, made at right angles to the direction of the probable cracks, are shown in the accompanying photograph of the tank.

The method of detecting cracks, referred to above, was devised by the Company several years ago for the purpose of investigating the

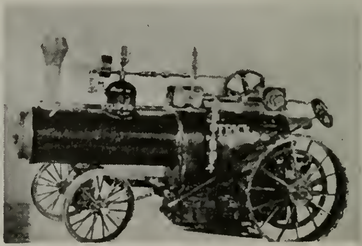
Possible explosion of this air tank was averted when hidden cracks were found by slotting the seams.



Drawing of a lap-riveted joint showing method of testing the outside plate for hidden cracks.

seams of lap-riveted boilers. Although it has not been used generally for unfired pressure vessels of similar riveted construction, there are cases, as in this one, where it is applicable and effective. Previous articles in THE LOCOMOTIVE have given accounts of explosions resulting from lap seam cracks and have also described the procedure for making the investigation. Briefly, the method consists of chiseling or milling a series of slots (about 1½″ long and ¼″ wide) two-thirds or more through the plate and spaced about 1′ apart along the line of rivets. The drawing on this page illustrates the relation of the slots to the seam. Such slots will not appreciably weaken the strength of the joint but will reveal whether a lap-seam crack exists, either by leakage during a hydrostatic test or by the crack being visible in the bottom of the slot.

A miniature steam traction engine about one-eighth the size of a similarly designed engine from which it was modeled, has been built by the teachers and students of the Washington, Pa., high school. This little machine, about two feet in length, is a duplicate of one named the "Eclipse" built in 1889 by the Frick Manufacturing Company, Waynesboro, Pa. The accompanying picture shows how well the model was proportioned.



The engine is a working model and the boiler was constructed in accordance with a special ruling by the Pennsylvania Industrial Board. The shell was made of three-sixteenths inch steel plate with the joints electrically welded and it has a normal operating pressure between 125 and 150 lb per sq in. The valves, fittings, gages, and other parts were made and installed in conformity with the A.S.M.E. Code.

Furnace Explosion Doors

By: E. R. Fish, Chief Engineer, Boiler Division.

Explosions, within boiler furnaces, of mixtures of air with volatile fuel vapors or with other combustibles, often cause heavy damage not only to the structure enclosing the boiler but also to the building or power house. Accidents of this type are known as furnace explosions and, on the theory that their destructive effects may thereby be somewhat lessened, some furnace settings are equipped with "explosion doors"—devices designed to open quickly and dissipate the pressure created by the detonations. However, as there is a question as to the effectiveness of these doors, an analysis of what takes place when there is an accident of this sort may interest many readers.

An explosive mixture is formed by various combinations of combustibles, such as gases or pulverized coal, and air. There is a considerable range in the percentages of the two substances within which an explosion may occur. Outside of that range, when there is either too much fuel or too much air, no explosion can take place. As the range is entered from either end the violence of a detonation increases to a maximum and then decreases. Near the ends of the range the effects may be insignificant, often only a "puff," but in the middle of the range the effects can be, and often are, very serious.

This type of an explosion is in reality only an extremely high rate of flame propagation or burning, and its intensity depends upon the quantity of combustible and the size of the combustion space. When the mixture is at or near the middle of the range the explosion causes a tremendous and instantaneous increase in volume which immediately produces a pressure on all the bounding surfaces of the furnace—sides, top and bottom. Rarely does the explosion damage the parts of the boiler subject to steam or water pressure, as the force against those parts from the detonation is not usually sufficient to be injurious nor great enough to displace the heavy boiler proper, although occasionally boilers have fallen when the severity of the blast was sufficiently great to displace the supports. In the majority of cases, the damage is confined to the setting, gas baffles and furnace. However, in some instances the building has been damaged, particularly windows and doors; and even foundations and floors have been pushed out or cracked.

As an example, a few years ago there was an explosion in the furnace of a large boiler fired with natural gas. The sides of the setting were bulged out, the top lifted off and the bottom pushed down, bending the 8″ I-beams supporting the floor. Repairs cost over $20,000.

Every furnace-inclosing structure, whether it be made of brickwork or insulated sheet iron, should be braced to withstand some internal pressure. However, as it is impossible to estimate accurately the amount of that force, it is not feasible or possible to provide sufficient strength to resist a major furnace explosion. In an effort to minimize the destructive action of such an explosion many furnaces have been provided with explosion doors in varying number and size, and explosions have occurred where these doors operated and the settings were strong enough to resist the pressure without damage. However, in these instances the explosions undoubtedly took place near one end of the explosive mixture range; that is, at a point where there was either a relatively high or low percentage of combustible. There might not have been any damage even though the doors had not been present.

An explosion door must have some weight to stay closed. Overcoming the inertia and starting it to open introduces an appreciable time factor. In the meantime the actuating pressure has been impressed with a destructive shock on every square foot of the furnace boundaries. Whether the severity of the shock is much lessened by explosion doors is questionable. Moreover, the volume of gas that can be relieved through the door or doors is relatively small compared to the total volume generated by the explosion, so that it does not seem logical to expect any appreciable reduction in pressure by reason of these openings.

It must be considered that although the flue gas passages to the breeching and stack are always open, and offer an avenue of escape, the increase in volume of gas is so sudden that the velocity of flow through even these large passages cannot be increased with sufficient rapidity to keep the furnace pressure below the danger point. Here again the time factor enters to prevent the needed prompt relief, just as it does in the case of the smaller openings represented by explosion doors. To be effective, doors would have to be of very large dimensions and of exceedingly light design.

Intelligent care in operating, firing and maintenance is the best way to avoid or minimize furnace explosions and to achieve this end the boiler operators should be guided by regulations and instructions based upon the kind of fuel used and the operating conditions. Observance of such rules and practice should be compulsory and should greatly reduce the number of accidents of this kind.

If so-called explosion doors are used, they should either be equipped with deflectors or located high enough so that no one will be injured by a blast.

Many Killed and Injured by Steamboat Boiler Explosion

SEVERAL newspapers during the early part of last December carried accounts of a disastrous steamboat boiler explosion on the Ohio river at Huntington, W. Va. Three members of the crew were killed, five others injured and the boat was damaged to an extent estimated at $35,000. The picture below shows how completely the forward part of the boat was wrecked.

The power plant for the steamboat consisted of three marine-type fire-tube boilers, lap-seam construction, with maximum approved pressure of 240 lb per sq in. According to the reports, two of the boilers exploded while the pressure was only 150 lb. The boat had been tied to the dock for washing out the boilers and steam was being raised again when the accident occurred.

The exact cause of the explosion was not stated. According to the news accounts, new shell sheets had been installed on the boilers within three years—some in 1937 and the remainder in 1939.

View of the wreckage following a boiler explosion in an Ohio river steamboat.

THE COVER

The picture shows an inspector making an examination of the safety valves on a water tube boiler. The satisfactory operation of protective devices on boilers and pressure vessels is of vital concern in the safeguarding of lives and property. Checking these devices is one of the many important duties of an inspector's work.

Cracking of Diesel Cylinder Liners

By H. J. Vander Eb, Assistant Chief Engineer, Turbine and Engine Division.

The view is held by many operators of Diesel engines that there is not much possibility of a cylinder liner failure and that the only reason for replacing a liner is excessive wear or deep scoring caused by a piston seizure. However, accident investigations by the Company have revealed a surprisingly large number of failures in which slow cracks have developed through the liner walls, permitting water to leak into the cylinder. Serious piston seizures are likely to result from such water leakage.

Cracks of this sort seldom run longitudinally but almost always circumferentially and are found at a distance of a few inches from the top of the liner—as at "C" in Figure 1. This drawing shows a typical design of removable cylinder liner and the usual method of liner support in the cylinder block.

There are a number of different causes for the formation of these slow-forming cracks. One of them is the uneven bolting down of the cylinder heads. It is well understood by erectors and operating engineers of Diesel engines that this bolting down must be done with care and that the bolts must be set up uniformly. However, the mistake is occasionally made of tightening all the bolts on one side before tightening any of those on the opposite side. This imposes a bending strain on the top of the cylinder block, which strain is transmitted to the liner, tending to distort and bend it out of shape.

Injury to the threads of the cylinder head bolts may cause similar strain and distortion. For instance, if there is thread dam-

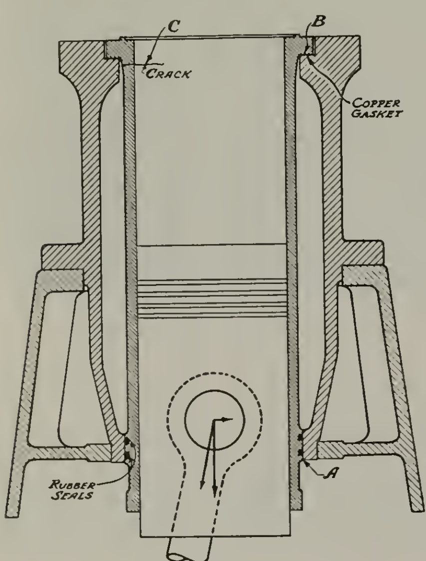


Figure 1—Typical design of removable cylinder liner showing the usual method of liner support in the cylinder block.

age to the bolts on one side of the head only, while the bolts on the other side are free from such damage the nuts that turn more easily will be set closer, causing severe uneven strain on the liner flange.

Another cause of crack formation is insufficient or total absence of "after-cooling" after the engine is shut down. When a Diesel engine is stopped there is a large amount of heat in the top of the pistons. In order to avoid local distortion of the liners from this heat, the circulating pump for the cooling water should be continued for 15 to 30 minutes after the shutdown. In many cases, the pistons come to rest repeatedly in the same places, so that the local overheating of the liners is nearly always in the same spots. Cracks that may eventually result from this will originate on the wearing side of the liner and may be observed without pulling the liner out of the cylinder.

In many installations, after-cooling is impossible because the circulating pump is driven either by the engine, or by an electric motor which in turn is supplied by power from a generator driven by the engine. In these cases it is desirable to run the engine for a period of 15 minutes without any load before it is shut down.

Even in cases where it is possible to operate the circulating pump when the engine is stopped, it is good practice to run the engine without load for a 15 minute period before shutting down, and then afford after-cooling for a further period of about 15 minutes.

Circumferential cracks may develop in the cylinder liners from a third cause; namely, a slight looseness where the lower end of the liner fits the cylinder block—as shown at point "A" in Figure 1. The fit of the lower end of the liner and the cylinder block should be solid and dependent upon a metallic contact between the liner and the block or frame and not upon rubber seals. Otherwise the side thrust of the piston will cause the lower end of the liner to move or "wiggle." A very small amount of movement at this point may result in excessive stress at the top and this may lead eventually to cracking at point "C."

Still another source of bending strain at the neck of the liner flange is an appreciable unevenness of the contact surface at "B." Originally this is a carefully ground surface and the liner is fitted by using Prussian blue and scraping to a complete contact with the supporting flange in the cylinder block. A copper gasket of about 1/32″ thickness is then used to insure tightness. However, after a cylinder liner has been in use for many years the cylinder block may become warped to such an extent that there will not be an even contact over the entire surface of the flange.

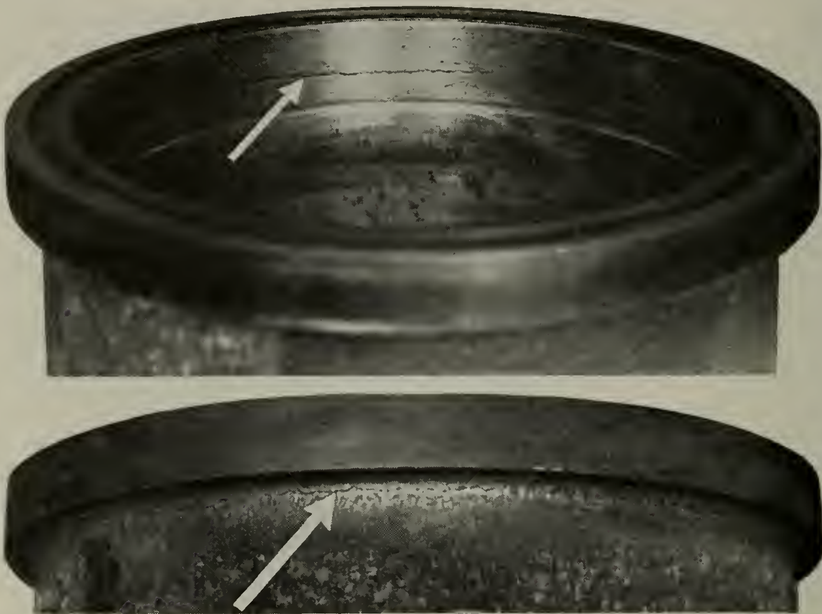


Figure 2 and 2A—Views showing a circumferential crack near the top of a 15″ cylinder liner. This crack permitted leakage of water into the cylinder.

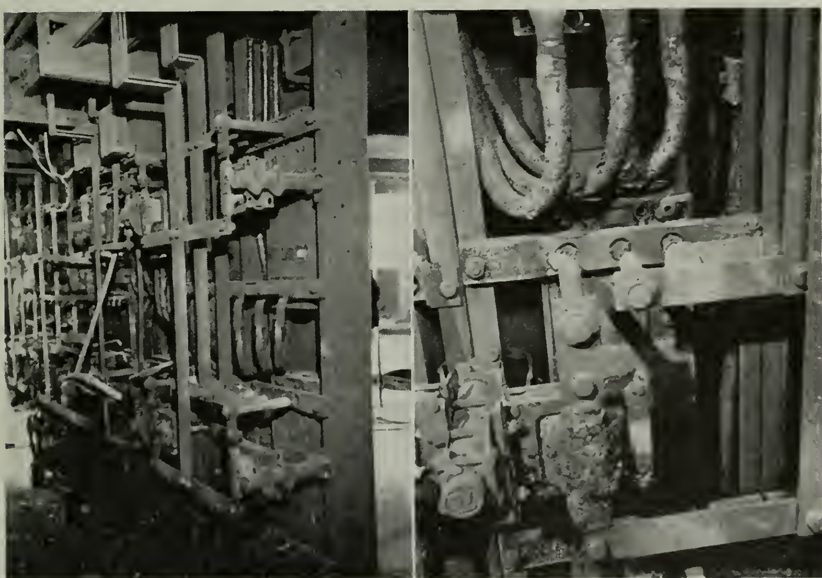
In a number of cases that have been investigated recently, cracks had progressed until water began to leak through from the jackets into the cylinder. Further investigation revealed that there was considerable clearance between the cylinder blocks and the liners (point "A") in several of the other cylinders in these same engines. In one case, after a liner had cracked a distance of 12″ circumferentially—See Figures 2 and 2A—a clearance of 23 mils was found between the block and liner of another cylinder. On pulling this liner two cracks 5″ to 6″ long were discovered, although neither crack extended through the liner.

Cracks that arise from bending or flexing of the liner will, as a rule, start on the outside and cannot be found unless the liner is removed from the cylinder block. When a failure has occurred to one liner in a multiple-cylinder engine, the others in that same engine are very likely to have similar cracks. It is particularly advisable that in such cases all the cylinder liners in the engine be removed for inspection. By this procedure other forced shutdowns can be prevented.

Short Circuit Destroys New Switchboard

NEARLY all the electrical equipment on a seven-panel switchboard in a textile mill was badly damaged recently by what appeared to be a phase to phase short circuit. The ensuing fire destroyed cable insulation, wiring and instrument transformers, and only the copper bus bars escaped damage. In use only a few months, the switchboard had cost about $7,000. The total cost of repairs and replacement of parts was approximately $5,000.

Examination of the electrical equipment after the accident showed that there had been arcing across the studs of circuit breakers on four of the seven panels. The remainder of the damage appeared to have been caused by the ensuing fire and intense heat from the short circuits. One of the two pictures on this page shows some of the burned insulation and damage to the back of the switchboard, while the other is a close-up view of one section showing the studs burned through at one



Left—Back of a seven-panel switchboard badly damaged by phase to phase short circuit and by ensuing fire.

Right—The connecting studs burned through at one circuit breaker, and damage to a current transformer and to cables is clearly shown in this close-up view of one section of the same switchboard.

circuit breaker, and charred insulation on cables and an instrument transformer.

Constructed of sheet steel ⅛″ thick, the switchboard was 7′8″ high and 10′8″ long. Air circuit breakers and meters with their transformers were mounted on each of the seven panels. In addition there were copper buses, cables, copper strap conductors and control wiring—all attached to the back of the board. As all the control wiring, circuit breaker casings and supports, meters, and instruments transformers were damaged by the short circuits and the ensuing fire, it was necessary to ship the board to the manufacturer's shop for rebuilding.

Although a careful investigation was made after the accident the actual cause of the short circuit has not been determined. As repairs required over two months' time a temporary bus was installed to which the plant feeder lines were connected, so that the owner was thereby able to maintain normal production.

The Whistle Blew Too Soon

At the sound of the noon whistle a workman in a Western packing plant left off fastening the cover on a steam retort with the expectation that tightening of the nuts could be finished after lunch. However, another workman took over at the end of the lunch hour and, in the belief that the retort was ready for the "cook," turned live steam into it. Pressure caused the cover to fly open and escaping steam scalded several employes who were working nearby.

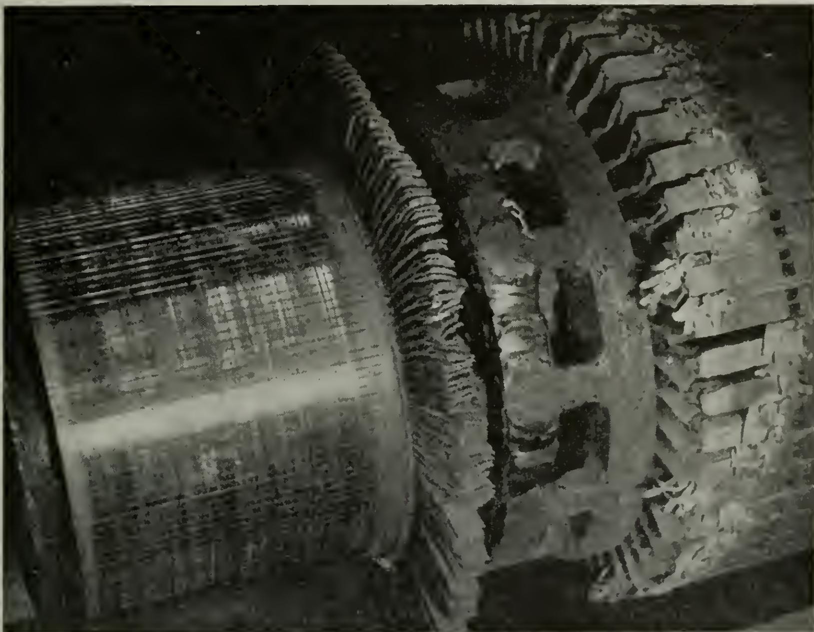
The cover was held in place by wing nuts which were fastened into lugs attached to the side of the retort. Only two of the nuts had been set when the operator stopped work. When the normal operating steam pressure was reached, these two lugs broke, as alone they did not have sufficient strength to hold the cover in place.

Steam Drying Drum Explodes, Killing Workman

One man was killed and the lives of fifteen other employees endangered when a rotary drying drum 6′ in diameter and 4′ long exploded in a California gum tape plant. The explosion lifted the drum from its trunnions and hurled it against the factory wall. Parts of the drum and a dyeing machine to which it was attached went as far as 100′. The vessel was constructed of a cylindrical sheet attached to two cast iron heads. These heads contained integral shaft trunnions stiffened by six cast iron ribs. Failure started at a crack near a manhole located between two of these ribs.

Steinmetz, the electrical wizard, defined a highbrow as "any person educated beyond his intelligence."—*The Valve World.*

Generator Accident



Breaking of the band wires on the commutator end was found to have caused the damage to this exciter armature of a 30,000 kw turbo-generator set. The winding between the armature core and the commutator risers was completely destroyed. The resultant arcing burned the iron and laminations of the core and also set fire to the insulation. Estimated cost of repairs, which consisted of rewinding the armature and the field, rebuilding of the commutator and replacing the burned iron and laminations in the core, was $3,000.

Symbolic of the burning of coal, the exterior of the Board of Water and Electric Light Commissioners' power plant at Lansing, Machigan, is black brick at the base, shading through red and orange hues to an almost white brick at the top. The structure is 12 stories in height and no stacks are visible.

A party of tourists came upon an Indian brave riding a pony. A heavily burdened squaw walked beside him.

"Why doesn't the squaw ride?" asked the tourist.

"Ugh," said the Indian, "she's got no pony." —*The Line.*

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

HARTFORD, CONN., April, 1940

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Bound volumes one dollar each.

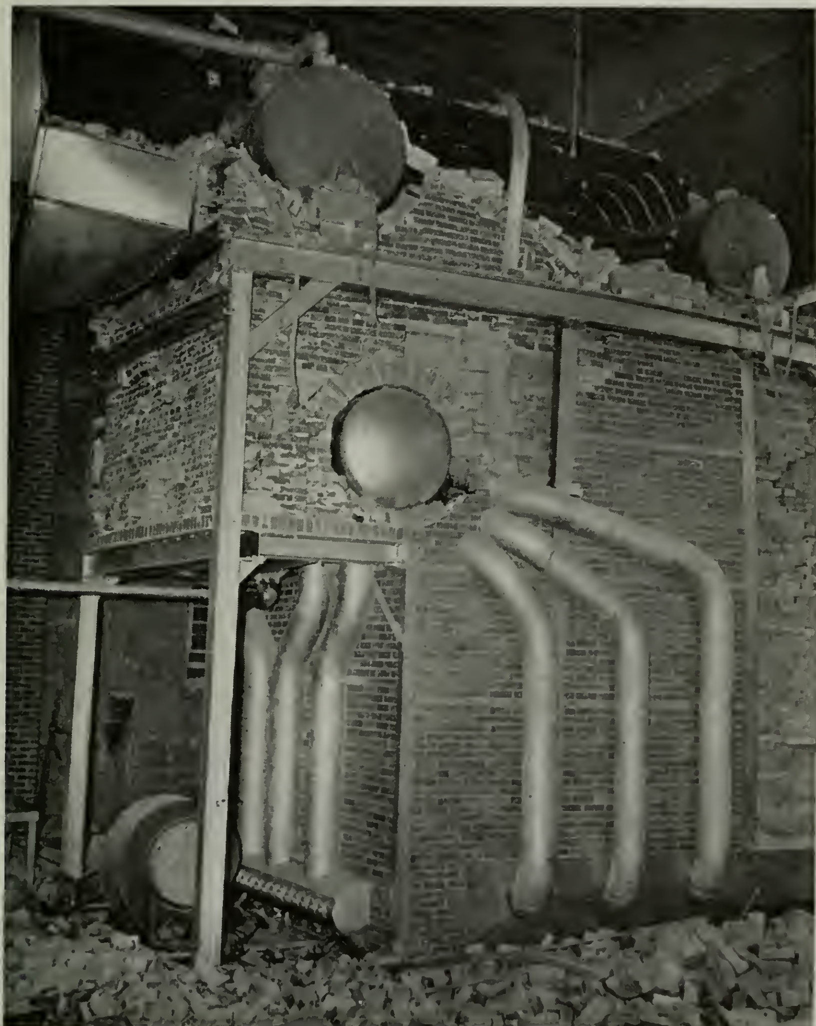
H. C. Freeman Appointed Financial Secretary

In recognition of the nature of the work he has been handling, Mr. H. Crowell Freeman has been appointed to the post of Financial Secretary. Mr. Freeman joined the Company in its investment department in 1936, after having served in a similar capacity with the Third National Bank and Trust Company of Springfield, Mass. A graduate of Yale University, he was for several years associated with a New York firm of investment bankers.

A Few Recent Furnace Explosions

DAMAGE estimated at $20,000 was caused recently by the explosion of accumulated gas in the furnace of a large water tube boiler in a Western hospital power house. Of the four men working near the boiler at the time of the accident, one was killed and the others injured—one seriously. As shown by the accompanying picture on Page 53, the brick setting was blown out, although the boiler itself was not harmed. The windows and doors of the boiler house were shattered and there was considerable damage to other parts of the building, as well as to the breeching and controls.

The fuel used was natural gas. While all the facts are not available, it is believed that the fire had been extinguished in some way as the burners had been operating with a low flame. The engineer, who was



The damage to this large water tube boiler fired with natural gas was caused by a furnace explosion.

the man killed, had apparently been attempting to relight the burners without first taking the precaution of venting the furnace to eliminate the unburned gas accumulated in the combustion chamber and other passages. The boiler was new, having been in operation only ten days.

In another case the explosion of oil vapor resulted in damage approximating $4,500 and injury to both the engineer and fireman. This accident occurred last January in the furnace of a water tube boiler at an Eastern forging plant. One brick side wall of the boiler setting was cracked and forced outward about an inch. The brickwork covering one steam drum, the rear wall under the headers, and a refractory baffle were pushed out of place and required rebuilding. The breeching was bulged out of shape and torn at the end next to the smokestack. The power house was damaged more extensively than the boiler unit. The roof was constructed of reinforced concrete slabs laid on a supporting steel framework and nearly all of these slabs were hurled out of place—a large number of them falling into the boiler room. The roof on a small lean-to building at one end of the power house was caved in. Steam pipes were broken and a portable hoist, a sand drying machine, a tractor and some auxiliary equipment for operating the boiler were damaged by the falling slabs. Most of the glass in the boiler room was shattered.

As nearly as could be determined, the flame went out while the oil-burners were operating so that the furnace became filled with unburned fuel gases. An attendant attempted to relight the burners without first venting the setting.

This loss was covered by furnace explosion insurance under a boiler policy.

Failure to shut off completely the fuel supply of an oil-fired water tube boiler when it was taken out of service was believed to have been the cause of a furnace explosion a few months ago in a California manufacturing plant. Slowly leaking into the hot furnace, the oil vaporized over a period of about four hours after the boiler was shut down and combined with air to form a combustible gas, which was ignited by the hot brickwork. The force of the explosion cracked and partly pushed out one brick sidewall of the setting, shattered the brickwork and other covering on the top of the steam drum and damaged the bridge wall and baffling. The photograph on Page 55 shows a portion of the damage—that to the top of the boiler and part of the sidewall.

View of another watertube boiler—oil fired—showing damage from a furnace explosion.

An explosion of gas from semi-bituminous coal last November in a vertical cast iron hot water heater located in a Pennsylvania residence cracked and bulged two brick walls of the house, shattered the front and side windows, lifted the heater from the foundation, broke its return lines and blew off its doors. The owner of the residence had filled the fire box with coal, closed all the drafts and left the heater for the night. The explosion followed about half an hour later. Fortunately the occupants of the house were not hurt.

Ignition of vapor in an oil-fired cast iron heating boiler resulted in damage to the boiler, the building in which it was located and injuries to the owner and his son. This accident took place last January in a Connecticut manufacturing plant. The stack switch had been giving trouble and was being repaired. When the owner thought he had it fixed he turned on the burner and did not notice that the oil fuel failed to ignite. The furnace filled with gas and shortly afterward the explosion occurred. Probably the ignition failed temporarily but finally it did function and fired the accumulated gas mixture. The detonation blew off the doors of the boiler, knocked down the flue pipe, broke the feedwater pipe and shattered panes of glass in the building.

In the causes of all these explosions there was what might be termed a common denominator; namely, operating errors. Either the operator was careless or did not understand the correct methods of firing. Possibly, too, he did not appreciate the explosive hazards of mixtures of air and fuel gases. All these accidents were preventable. In the case of the residence heater explosion, for example, the heavy banking and the closed drafts caused the accumulation of coal gas which was ignited and exploded when the fire burned through the coal. If the fuel bed had been properly arranged and proper draft adjustment made to introduce air over the top of the coal to carry off the unburned gases, a violently explosive mixture would not have resulted.

In two cases the operators forgot, or did not know, that settings of boilers should be ventilated before burners are relighted. If a fan had been available, air should have been blown through the combustion chambers, gas passages and breeching to purge them of the accumulated vapors, or air should have been circulated by natural draft through the settings for a period of not less than five minutes by opening the dampers and furnace access doors.

The accident to the oil-fired cast iron boiler illustrates the danger from repairs being made to control apparatus by a person not fully acquainted with the construction or operation of the control. Frequently, furnace explosions have been brought about by faulty adjustments of automatic controls or by attempts to operate the burner with a control disconnected. The operator may think a particular control is defective when actualy the trouble is elsewhere—in many instances in the ignition.

Hot Water Tank Explosion Wrecks School

When a hot water supply tank exploded on February 26, in the Ripon Union High School, Modesto, California, it not only blew out a corner of that building, but also ripped holes 10′ in diameter through the two side walls of another school building nearly 100 yards away. Even then, all the destructive force of the vessel had not been spent as it continued another 35 yards to land on and damage playground apparatus. The blast occurred shortly before 7 A.M. Fortunately, there was no one in the building at the time, although an employe who had been in the second building a few minutes before, narrowly missed being hit. Had the accident happened later in the day, many students would have been exposed to serious injury. The severity of the explosion can be judged from the wreckage of the school as shown in the accompanying photograph. A local newspaper estimated the damage as $10,000.

The damage to this school was caused by an explosion of a hot water tank.

The tank, 3′ in diameter by 6′ long, was constructed with ⅜″ saucer heads welded to the shell, without any skirt or flange, and with the longitudinal lap seam of the ¼″ shell tack-riveted and fillet-welded. Both the tank and the cast iron hot water supply boiler to which it was connected normally operated under a pressure of 55 lb per sq in. A thermostat, set for a maximum temperature of 160°F, and a pressure relief valve were provided to control the temperature and guard against over-pressure.

After the accident it was found that the tank had failed at the welded joint of one head and that there was very poor fusion of the metal in this joint. While the poor quality of the welding and the design of the vessel affected its strength, the violence of the explosion indicates the probability that failure of the thermostat control permitted the temperature of the water in the tank to reach the boiling point corresponding to the service pressure. The water relief valve either was inoperative or unable to discharge all the steam generated and consequently the tank was subjected to excess pressure.

Low Water—High Dive

This locomotive fire box type boiler soared to the above location 250 feet from its setting in a California oil field when the crown sheet dropped because of low water and over-heating. A boiler attendant was scalded.

"Rastus, I see your mule has 'U. S.' branded on his hindquarters. Was he in the army?"

"No, boss, dat 'U. S.' don't stand for Uncle Sam, it means Un-Safe."—*Think.*

Taps From the Old Chief's Hammer

THE Chief and Tom Preble, his assistant, had returned from lunch and were sitting in the Chief's office relaxing for a few minutes. They had been discussing heating boiler controls.

"Yes," said Tom, "the new heating plant in my house runs as smoothly as a clock; no trouble with it at all. You know, there have been a lot of changes in heating in the last fifteen or twenty years."

"In what way do you mean?" asked the older man.

"Well, for one thing, nowadays the boiler takes care of itself. There is a device to cut off the burner if the ignition fails; another to shut it down because of low water, and a safety valve to release excess pressure so that I don't have to worry about it blowing up. But the main point I have in mind is the convenience. No furnace to tend—a thermostat keeps the temperature at the right point—all in all, it requires very little attention."

"Did I ever tell you about the boilers in the Miller plant down in Cheston, Tom?"

"I can't recall it, Chief."

"We had an application a few years ago," the Chief went on, "to insure three water tube boilers, 150 lb pressure, at this plant. I don't recall the exact year just now and it isn't importnat anyway. This was a new installation and had various controls for regulating the fuel and feedwater. In fact, one of the arguments given by the salesman in selling the automatic devices was the reduction in labor costs that would be obtained. In other words, he stressed the idea that the boiler operator could be doing other work and visit the boiler room only every three or four hours.

"About a year later we had a call from Tim Wright, the plant superintendent. He wanted our inspector to come down right away, so I asked him what was wrong."

"'Plenty,' he replied. 'There wasn't enough water in one of the boilers; it overheated and it's in pretty bad shape. I'd like to have an inspector make an examination and advise us about repairs.'

"I told him I would come down myself. As Inspector McAlear was in town, and as he had been making the inspections of these boilers, I phoned him to go along with me."

"I suppose," Tom interrupted, "the automatic controls didn't work, but it doesn't seem possible all of them would have been out of order at the same time."

"Yes," replied the Chief, "that's just about what did happen. There were three different devices to guard against this kind of trouble. Water was supplied to the boiler by an automatically controlled pump. There was also a low-water feeder and a cut-out device to shut off the fuel supply in the event the water dropped below a safe level. The man who looked after the boilers had checked them about 8:00 o'clock in the morning. He said that after finding everything operating satisfactorily he had gone to work in a building located at a considerable distance from the boiler house. In accordance with his usual procedure he didn't check the boilers again until noon and that was when he discovered the trouble."

"Lucky for them and for us, too, there wasn't a serious explosion," commented Tom.

"You're right," answered the Chief. "I asked the operator when he had checked the controls last. He didn't give me a very definite answer. It's quite likely that one, and perhaps two, of them had not been working for some time.

"Tim Wright wasn't in too good humor, and I couldn't blame him for that. You can't make money when the power plant is shut down. The $3,000 bill for repairing the boiler wasn't figured on either. He started to lay into Mac and myself, blaming us for the boiler burning up. As diplomatically as I could, I told him that while we make inspections of the controls, they can get out of order between visits and that the plant engineer, fireman or some one competent should be in the boiler room when the plant was running."

"Our inspectors are cautioned to check the operating program of each power plant we insure," put in Tom. "I was wondering what Mac had found on his previous inspections?"

"I was coming to that, Tom. Another inspection was about due. When Mac had been there last—about four months previously—the operator was with him or in the boiler room all the time. Mac had had him check the automatic controls to see that they worked. It was after that, as I recall the case, that Tim Wright gave the operator the other job, probably figuring that the safety devices had proven their reliability sufficiently to be depended on.

"But there is one thing we are sure of, Tom—that plant hasn't depended upon automatic devices alone since then. Whenever there is a power or process load on the boilers you will always find the operator in the power house and what's more, he checks those automatic controls and protective devices systematically and regularly."

Damage to this water tube boiler was reported to have been caused by overheating when the feedwater was shut off and the automatically controlled stoker continued in operation. Installed about 7 months previously at a cost of $12,000, the boiler was so badly burned that replacement was necessary.

Judge—"Guilty, or not guilty?"
Rastus—"Not guilty, suh."
Judge—"Have you ever been in jail?"
Rastus—"No, suh; ah nevah stole nothin' befo'."—*Commerce.*

Customer: "Heavens, man! Do you want to burn me? That towel is scalding hot!"

Barber—"Beg your pardon, sir. I couldn't hold it any longer."—*Commerce.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONNECTICUT

December 31, 1939 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,131,575.00
Premiums in course of collection (since Oct. 1, 1939)		1,404,532.70
Interest accrued on bonds and mortgages		75,051.67
Mortgage loans		147,287.10
Home Office and Philadelphia branch office real estate		642,331.05
Other real estate		305,499.60
Other admitted assets		8,862.20
Bonds on an amortized basis	$8,587,809.88	
Stocks at market value	8,460,040.00	
		17,047,849.88
Total		$20,762,989.20

LIABILITIES

Unearned premium reserve		$8,097,450.81
Losses in process of adjustment		266,219.31
Commissions reserve		280,906.54
Taxes reserve		335,000.00
Other liabilities		307,937.43
Liabilities other than capital		$9,287,514.09
Capital stock	$3,000,000.00	
Surplus over all liabilities	8,475,475.11	
Surplus to Policyholders		**11,475,475.11**
Total		$20,762,989.20

WILLIAM R. C. CORSON, President and Treasurer

Incorporated 1866 *Charter Perpetual*

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BOSTON, Mass., ... 87 Kilby Street	THOMAS F. RICE, Manager. W. A. BAYLISS, Chief Inspector.
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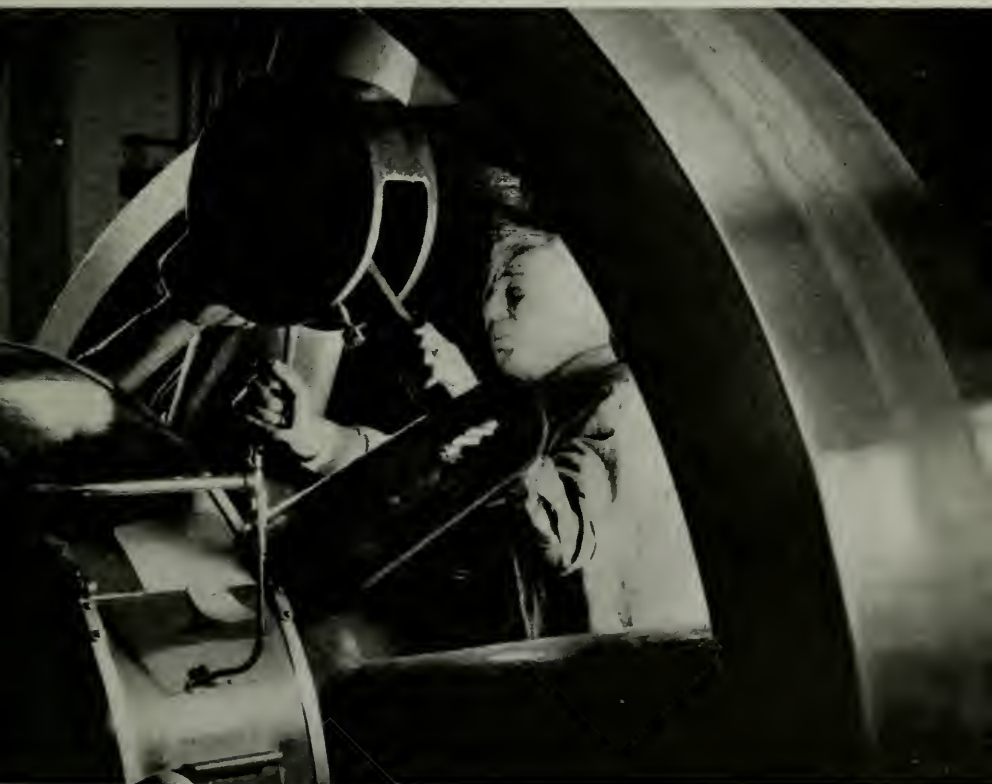
"Why Concealed Parts of Boilers Should be Inspected"

Vol. 43 No. 3 July, 1940

The Locomotive

The Hartford Steam Boiler Inspection and Insurance Co.



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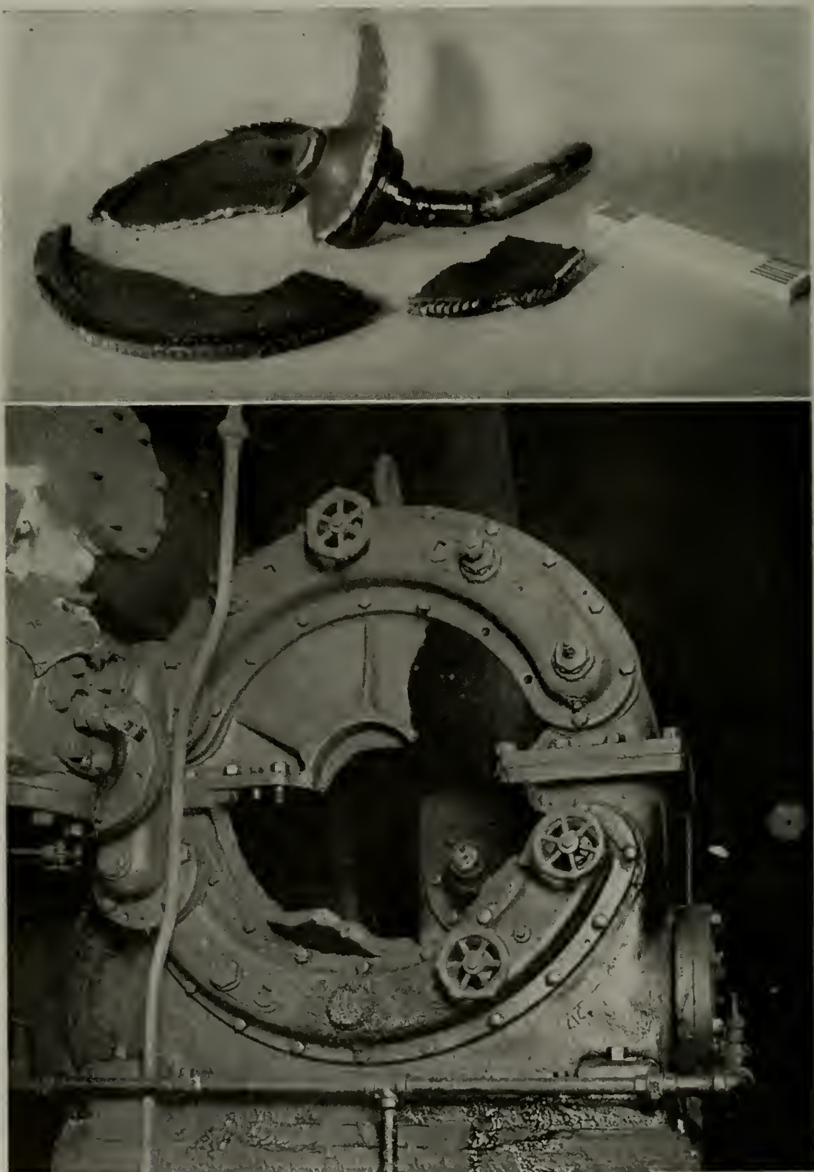

Top—Two men were injured when the rotor—pictured above—of a small steam-turbine burst from excessive speed.

Bottom—Explosion of this steam-turbine draft-fan unit was attributed to overspeed after the load was lost.

Failures of Auxiliary Steam Turbines

SMALL steam turbines driving utility or industrial power plant auxiliaries such as feed and condenser pumps, fans, blowers and coal pulverizers, require a system of maintenance and periodic dismantled inspections similar to those customarily afforded on larger turbines. Experience has shown that many of the failures of small turbines could have been prevented if these machines had been given proper attention. Relief valves may become inoperative, parts may be worn or cracked and safety devices designed to guard against overspeed may not function properly. In order to eliminate these and other causes of failure and to reduce both accident frequency and repair expense, much can be accomplished by a systematic program of maintenance supplemented with inspections by specialists who have an extensive knowledge of steam turbine troubles.

In many instances a breakdown of an auxiliary turbine unit may not interfere with the handling or carrying of the plant load because duplicate equipment or other means of performing the work are available. However, aside from the turbine's importance for continuous and efficient plant operation, the expense of repairing or replacing the unit itself when a breakdown occurs should be considered. In addition, there is danger of personal injuries or loss of life from an explosion caused by excessive steam pressure or excessive speed.

As auxiliary turbines frequently are located so that they are not readily accessible for attention, there is a tendency for operators to give them less care than is afforded larger units. Often the steam is of poor quality because the auxiliaries usually are supplied from the lowest ends of the steam lines where the amount of moisture is higher. This is one of the many reasons why these machines should be dismantled at least once a year for examination.

Some small turbines, even though they have a single rotor of relatively small diameter, are capable of producing a surprising amount of destruction if the energy is suddenly released. This was well illustrated recently by the explosion at a Connecticut manufacturing plant of a small, single-stage turbine designed for driving a draft fan. The rotor was 14″ in diameter and the rated capacity for the machine, running at 4,000 rpm, was 3.65 hp. The turbine was set up in the yard and was being tried out at 125 lb steam pressure but with the fan removed. Not being equipped with a governor and because the operators overlooked the fact that there was no load, the turbine burst from overspeed. Two men nearby were injured by the flying parts of the casing and rotor. One of the men lost a finger and suffered a compound fracture of one knee while the other received several cuts. A photograph of the shaft and broken parts of the turbine rotor are shown (top) on Page 66.

Several explosions of auxiliary turbines have been described in THE LOCOMOTIVE in previous issues. Among them was one which, last fall, caused the instantaneous death of the operator. This turbine drove a condenser pump. Through oversight, the exhaust valve was not opened when the unit was being started, and the steam pressure burst the casing. A sentinel valve, provided to warn against an accident of this type, failed to function.

In another case a turbo-blower exploded in a laundry, destroying the unit and seriously injuring one of the plant engineers.

In the majority of accidents to auxiliary turbines the property damage is confined to the unit itself; that is, to the driving steam motor and the driven fan, pump or other machine. The following are typical examples of failures of this type.

1. The breakdown in a paper mill of a 275 hp steam turbine driving a fan through a reduction-gear set was caused by a broken gear tooth wedging between the gears, thereby damaging the pinion gear and springing the turbine shaft. Repairs, consisting of a new gear set and new bearings for the turbine end of the unit, cost over $500.
2. In another turbine failure in a paper mill involving a 110 hp machine which also operated a fan through reduction gears, a group of thirty buckets broke away from the turbine rotor and lodged between the stationary and rotating elements. In addition to a broken shaft, the turbine and reduction gears, except their casings, were wrecked. The total cost of repairs exceeded $1,700, not including extra expense of more than $230 for a temporary motor drive for the fan.
3. When the impeller blade tore out of a fan driven by a 320 hp steam turbine in a chemical manufacturing plant, the resultant damage required repairs totaling nearly $1,600. Three holes were broken in the fan casing and the rotating parts of the fan were completely destroyed. Fortunately the steam driving end of the unit was not damaged.

   In investigating the cause of this breakdown a heavy accumulation of dirt mixed with oil and water was found in the air intake pipe to the fan. Dirt, lodging between the fan rotor and the casing in a gradually increasing amount, acted as a drag and thus imposed an excessive strain on the rotor. This caused some rivets to tear out or shear off, until finally the shroud ring broke and allowed the rotor to fly apart from centrifugal force. Had a dismantled inspection been permitted, undoubtedly the presence of dirt in the intake pipe would have been found and changes made to assure that only clean air would be drawn into the fan.

4. When a fan blade broke in a 21 hp steam-turbine driven fan located in a utility plant, the resultant damage amounted to $500. Not only was the fan destroyed, except for its casing, but also the turbine shaft was distorted and the bearings and their housings were cracked. The definite cause of the failure was not determined.
5. A steam turbine driving a pump through reduction gears overspeeded, completely wrecked the turbine and badly damaged the gears. The capacity of the machine was 104 hp. Although there was an emergency mechanism to shut off the steam supply in case normal speed was exceeded by more than ten percent, a lever which formed an essential part of this safety device did not function properly. As a result the turbine ran away. The cost of repairs was approximately $2,200.

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*Carbon Dioxide Cylinder on Rampage**

After the safety disc ruptured on a portable carbon-dioxide cylinder standing on the platform of a California warehouse, the cylinder fell over and broke off a special discharge valve in which the safety disc was contained. This released the contents through a ½″ opening, and the reaction from the discharge of the gas caused the cylinder to soar away like a rocket. Traveling at a terrific speed, the tank hit another building about 90 feet away, turned and came back toward the warehouse, struck the end of the platform, made a right-angle turn and about 100 feet further on crashed into a third building. Even then all the energy had not been exhausted as the cylinder scooted along the ground in another direction and finally was stopped by a wooden post. Altogether the tank traveled a distance of over 375′. Two men, close to the path of its flight, narrowly escaped being hit.

The usual pressure at normal temperatures for this and other similar cylinders is 1000 lb per sq in, each cylinder being equipped with a safety disc calibrated to rupture at 2500 to 2800 pounds per sq in. When exposed to the direct rays of the sun the gas expands and the pressure increases. As this cylinder had been in the sun for more than 4 hours undoubtedly the pressure had been increased sufficiently to fracture the disc.

On portable carbon-dioxide containers the discharge valves should be covered with protective caps in order to eliminate the hazard of the valves being hit and broken off.

* Condensed from the *California Safety News.*

The oxy-acetylene flame, in universal use today for severing and joining metals, develops a temperature of approximately 6,000° F.

Why Concealed Parts of Boilers Should be Inspected

More catastrophic boiler explosions have resulted from weaknesses brought about through corrosion, grooving or cracking of concealed parts than from any other cause. Explosions of water tube boilers from this cause have resulted in death or injury to a large number of people in the majority of cases, and property damage of $50,000 to $100,000 or more in almost every case. Explosions of other types of boilers from similar causes have been so frequent that we feel compelled to emphasize the need for a complete and thorough examination periodically of all concealed parts, particularly those that are likely to have been weakened in any way.

While all boiler failures do not cause extensive destruction, it is nevertheless true that, potentially, even a small boiler contains sufficient energy to cause loss of life and extensive property damage under certain conditions of failure. From the standpoint of economy as well as safety it is to the owner's advantage to know the true condition of his boiler. The wasting away of metal from corrosion is often so rapid that costly repairs become necessary to avoid the need for replacing the boiler long before it has completed its normal period of usefulness.

Causes of Defects

External corrosion from moisture in contact with metal surfaces exposed to products of combustion is the most prevalent cause of failure of concealed parts. Covered to some degree with soot and ashes which form an acid when combined with moisture, these surfaces will corrode more or less rapidly from the action of that acid. The moisture may come from leakage through handhole or manhole gaskets, leaks at tube ends, from atmospheric conditions when the boiler is idle but filled with water (so-called sweating), from water used to wash out the setting, from a soot blower, and from leaks outside the boiler itself such as through the roof, overhead pipe connections or defective valves.

Another type of defect that results in failure is the incipient crack which develops from the breathing or flexing action of comparatively flat surfaces with short-radii knuckles— a type of construction formerly used for the heads of water-tube boiler drums. This also applies to the heads in some types of fire tube boilers. Cracks are also likely to occur in plates or heads near a seam, where the stress in the material is the greatest.

There have been instances in which the boiler structural supports were weakened by oxidation from high temperatures or by corrosive action from moisture. In some of these cases the steel columns or other structural supports were enclosed in brickwork and located in the intermediate walls of a battery of boilers. Moisture seeping down through the walls from the top caused extensive corrosion, especially during periods when the boilers were idle. In other cases supports, such as those in the center and front, have been overheated by the gases of combustion which caused gradual wasting away of the metal. A good illustration of this type of damage is shown in Figure 1. When structural supports fail, the weight of the boiler is transferred to the pipe connections and brickwork with consequent distortion and stresses in the pressure parts of the boiler and its connecting piping. Ruptures at

Figure 1—Boiler supporting columns, encased in intermediate brick-walls of a battery of boilers, almost entirely wasted away by oxidation from the high temperatures in the combustion chambers.

pipe fittings and valves, or leakage in seams, tube ends or other parts have occurred from stresses so caused.

Inspections Reveal Defects

Periodic visual examinations, both internal and external, disclose many defects such as external corrosion and cracking of joints, flanges or knuckles in the parts of boilers that are readily accessible for examination. These examinations are supplemented by hydrostatic and hammer tests to determine the soundness of other sections that are not readily accessible for such visual examinations. However, experience has shown that such tests will not always reveal weak spots. For example, concealed mud-drum heads, seriously corroded externally, may satisfactorily withstand hydrostatic tests and even hammer tests from the inside of the boiler and still may be found unsafe when later uncovered or test holes are drilled.

The Company's experience over a period of years in the inspections of concealed parts of mud-drum heads, both the blank heads and those with manholes, has disclosed that about 10% have been affected—the defects ranging from slight weakening to damage so serious that the heads were unsafe and the boilers had to be retired from service until repaired or replaced. About 1% were in a dangerous condition, while the other 9%, after changes had been made to eliminate the cause of corrosion and to permit proper cleaning and inspections in the future, were considered safe for further periods of service. Had not the corrosion-causing conditions been eliminated, it would have been only a matter of time before the deterioration reached the point of causing failure or of requiring expensive repairs or replacement. Boiler manufacturers, recognizing the hazards in installations having buried mud-drum heads or other concealed parts, have changed their designs during the past few years so that parts most susceptible to corrosion and grooving may be thoroughly inspected externally as well as internally.

The Company's experience also discloses that concealed parts subject to rapid deterioration are not confined to the bottom drum-heads of water tube boilers, as any metallic surface will undergo more or less corrosive action unless it is kept clean and dry. The tops of boilers, shells, drums and circulating tubes that are completely covered with brickwork, cement or other material may be seriously impaired by corrosion from moisture from various sources. The circulating tubes and sheets on box-header type water-tube boilers may corrode where they are covered. The upper tube sheet of a vertical tubular boiler is subject to corrosion as it will accumulate some soot and moisture. In vertical

Figure 2—Weakened by corrosion, the blind head in the mud drum of this water tube boiler in a utility plant tore loose and caused the death of four people, injuries to six others and $100,000 property loss.

tubular and locomotive type boilers, wet ashes around the edges of and under the grates in contact with the firebox sheets, and hand-hole gasket leakage, will cause corrosion. Economic-type boilers occasionally have the grates and the rear ash-pit wall installed in such a manner that the parts of the boiler, where leakage is likely to occur, are difficult to clean and examine and, therefore, may become unsafe from corrosion.

Examples of Explosions and Weaknesses from Hidden Defects

External corrosion of the top shell-plate of a horizontal tubular boiler 72″ in diameter, caused an explosion early in 1937 at a West Virginia coal mine. As the top of the boiler was enclosed in brickwork, the deteriorated plate was not accessible for examination. Four men were killed and the property damage, both from the explosion and from the fire that followed, amounted to $50,000.

An explosion of another horizontal tubular boiler in a lumber company plant in Arkansas in August, 1937, resulted in property damage approximating $20,000. In this case, also, the failure was caused by external corrosion of the shell plate which had been reduced to paper thickness for a distance of 2½′ from the front head.

In October, 1936, a vertical bent-tube type water-tube boiler in a small utility plant in Missouri exploded with property loss of about $100,000. Four people were killed and six others injured. The initial point of failure, which occurred in the blind head of the mud-drum—shown in Figure 2—was caused by external corrosion where the head was completely covered with brickwork.

When the concealed head of the bottom drum of a water tube boiler failed in a municipal power plant in Mississippi in April, 1931, three persons were killed, three others were injured and the property loss amounted to $26,000. From the appearance of the head after the accident it was believed that external corrosion underneath the brickwork weakened the metal to the point where a crack occurred. Subsequently the head tore away from the drum and this rupture loosened the tubes in two of the three steam drums. The energy, thus suddenly released, blew these two drums from the boiler, one of them traveling a distance of more than 500′.

The damage caused by another water tube boiler explosion that occurred in Illinois in 1938 was the result of corrosion on the outside of the lower drum-head which had been covered by the brick setting.

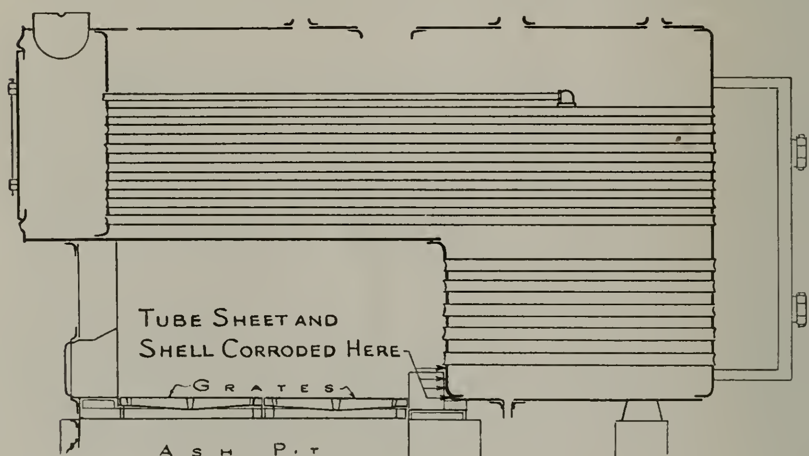


Figure 3—Drawing of an economic-type boiler indicating areas concealed by grates or brickwork where external corrosion is likely to occur.

Figure 4—Wreckage at a steel mill following an explosion of a water tube boiler. Caused by external corrosion of one head of the lower drum which had been concealed in brickwork, the explosion killed two people and injured five others. Property loss was about $75,000.

The boiler, rated at 300 hp and of the vertical bent-tube type, was operating at a pressure of 155 lb per sq in when the failure took place. Amounting to $50,000, the property loss included destruction of the boiler house and two adjacent shops, and the lifting of three other boilers from their settings. Fortunately no one was killed although one person was injured.

Figure 3 illustrates the importance of uncovering parts of boilers concealed by the ash-pit brickwork and grates. In this case the lower part of the tube sheet in the furnace of an economic-type boiler ruptured after it had been weakened by external corrosion which had been caused by accumulations of ashes and soot, together with moisture. The cost of repairs amounted to more than $1,200. As moisture, even though slight, may be present around the joint of the tube sheet and the lower shell plate from leakage at tube ends, need for having this area periodically accessible for complete examination becomes apparent.

When the top head of a small vertical tubular boiler tore open along the flange three men were badly scalded. Examination of this head, following the failure, disclosed that a previous crack in the head at the point of failure had been poorly repaired by welding. Ten braces supporting the head either had been broken or the rivets had sheared off. Probably some of these braces had been broken prior to the original cracking as the breathing or bending action of the unsupported plate would tend to crack the metal along a line where the rupture occurred. Figure 5 shows that an internal inspection of the upper section of the boiler could not be made unless the tubes were removed as there were no openings in the head or shell. This sketch also illustrates the importance of removing the smoke hood periodically unless there is an opening through the hood sufficiently large to permit access for external inspection in this area.

A tube rupture in a water tube boiler, which occurred last November in an Ohio manufacturing plant, illustrates the danger from corrosion of those sections of tubes where soot and fly ash accumulate. The tube had wasted away externally at a point a short distance above the mud drum directly behind a baffle, until it became so thin that it suddenly failed. While the damage to the boiler itself was small, as only the ruptured tube and a few baffle blocks were damaged, two men working on an adjacent boiler were killed and another worker seriously injured by the steam and fire which were blown out of the setting of the damaged boiler.

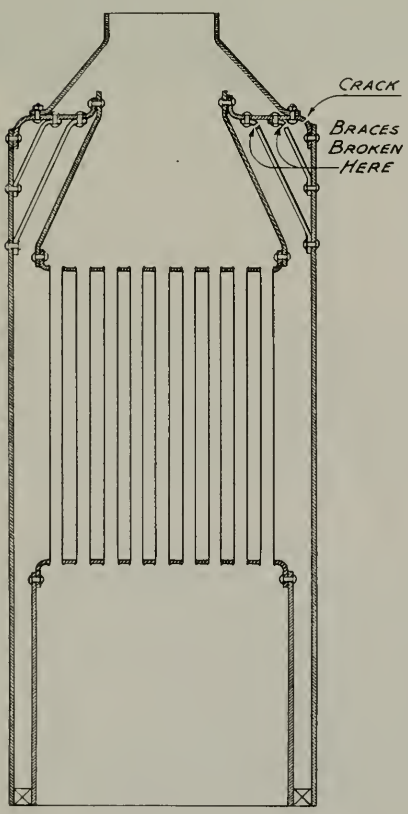


Figure 5—Three men were badly scalded when the top head of a small vertical tubular boiler, similar to the one drawn here, tore open at the flange along the line of a previous crack.

Leakage, over a considerable period of time, around the manhole plate of the mud drum of a water tube boiler corroded the head so badly that in some places it was only one-sixteenth of an inch thick. The discovery of the weakened condition was brought about by a hydrostatic test following almost complete retubing of the boiler. Considerable leakage resulted from the test, and in an effort to disclose the exact source, the brickwork around the manhole was removed. Then it was found that the outside surface of the head was seriously corroded away. Undoubtedly a disastrous explosion would have occurred if the true condition of the head had not been discovered.

Frequency of Complete Examinations

Modern high pressure steam boilers are usually constructed according to accepted safety standards and in such a way as to permit cleaning internally and externally as far as practicable. Furthermore, experience has shown the points where cracking, grooving, corrosion or some similar weakening action is likely to occur and designs have been revised to reduce or eliminate these conditions to a great extent. However, in spite of this experience, boilers are frequently installed so that proper cleaning and inspection of many of the parts is difficult or even impossible. In some plants maintenance is carried on by employees who do not understand the significance of nascent deterioration, so when leaks occur they are not eliminated promptly; and, of course, such disability increases with age. Various other conditions also have a bearing in determining the frequency at which concealed parts should be exposed for examination.

While some states and cities have laws specifying periods when boilers should be completely stripped for inspection of concealed parts, the majority do not have any such requirements. What the frequency of complete exposure should be, is a matter of judgment in each individual case. Wherever there is a suspicion that weaknesses exist, those parts in doubt should be exposed. As a general rule it is recommended that where there are conditions tending to promote corrosion, the boilers should have the insulation, brickwork or other covering removed at least every 5 years. This applies especially to boilers exposed to the weather, to boilers installed in poorly constructed buildings, to boilers on which water leaks on the brickwork or where the brickwork is frequently subjected to moisture from the blow-down discharge or from some other source, to boilers in damp locations, or to those operated intermittently.

When extensive furnace wall repairs are made or similar maintenance work is performed, an excellent opportunity is afforded for an

Figure 6—Parts of the lower drum of a water tube boiler showing the manner external corrosion wastes away the metal and weakens the head.

examination of hidden parts and such repairs should be planned with that thought in mind. Before the boiler surfaces are re-covered, following an examination, a valuable protection can be given them by applying a suitable coating of moisture-absorbing material next to the surfaces, beneath the usual insulation of masonry or magnesia blocks.

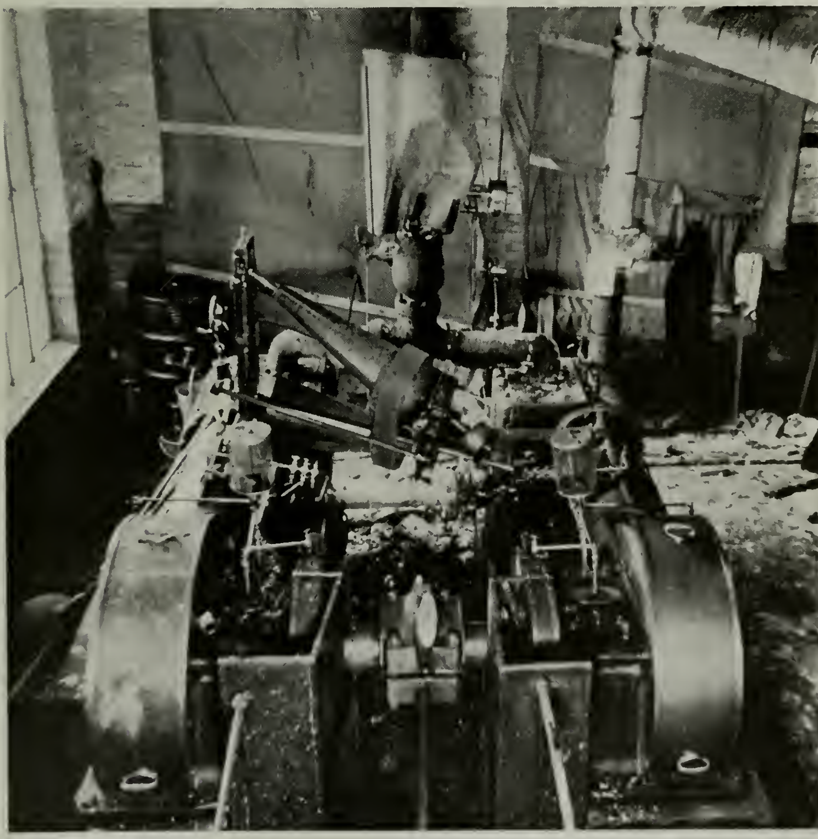
A program of permanently rearranging the design and application of brickwork or insulation, so that hidden surfaces can be readily examined during a normal shutdown period, should be given serious consideration. Where such a program is not possible the uncovering of hidden parts remains of utmost importance as many defects do not make their presence known in advance of failure.

Without any warning boilers have suddenly sky-rocketed, even though there was nothing visibly wrong, as the defective part was not accessible for examination. Accordingly, those responsible should not be lulled into a false sense of security or feel that the expense of preparation for inspection has been needlessly incurred whether or not the examination leads to discovery of a dangerous condition.

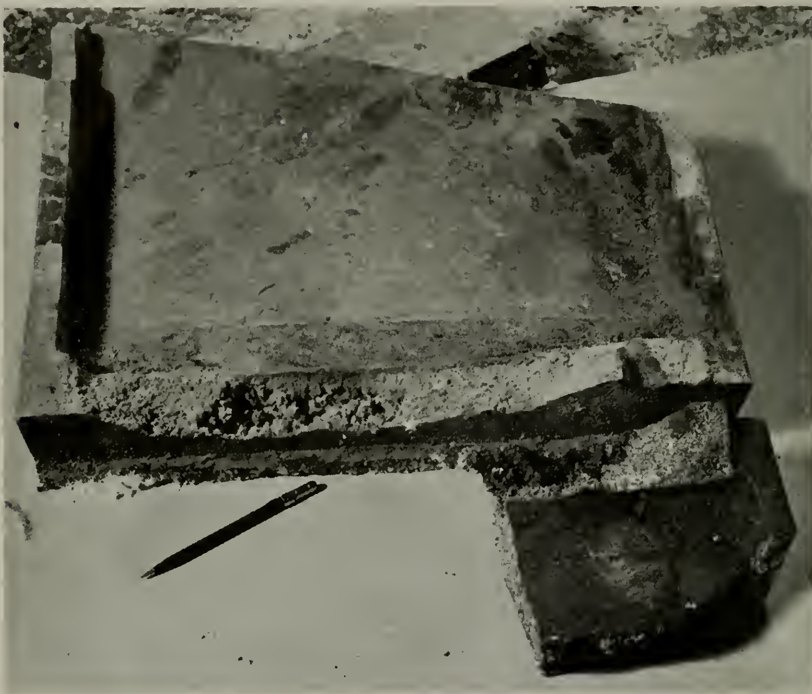
Two Steam Engine Flywheel Explosions

Overspeed was believed to have been the principal reason for the recent bursting of a 72″ engine flywheel at a Connecticut paper board manufacturing plant, although porosity of the wheel casting was probably a contributing factor.

In addition to breaking the engine, as shown in one of the accompanying photographs, parts of the wheel damaged the felts on two paper machines, the driven line shaft pulley, electrical wiring, sprinkler



View of the steam engine showing the wreckage following the explosion.



These two broken parts of the wheel, placed together as they were located in the rim, show slag and gas pockets in the casting.

piping, the drive-belt, the walls and roof of the engine and paper-machine rooms, a concrete floor, and other parts of the building. One piece traveled a distance of about 40′ and tore a small hole in the roof of another building. The total loss was about $5,500.

According to a newspaper account the explosion of a flywheel a few months ago in a Southern laundry was caused by a broken engine governor. The accident not only wrecked the engine and damaged additional property of the owner, but also damaged property of others located a considerable distance from the laundry. One part of the wheel tore a hole through the roof and a wall of a warehouse two blocks away. In reaching that point it had to pass over a number of buildings, including one three stories high.

A long face and a broad mind are rarely found under the same hat.—*Cilco News.*

Unusual Generator Accident

An unusual accident was recently caused in a Texas paper mill by a loose air-filter section falling into a d-c generator while it was in operation. Instantly, ninety of the two hundred and seventy outside copper conductors in the armature end-coils were nicked and cut from one-third to one-half way through near the armature core and in close proximity to a banding wire. Ninety other conductors were slightly damaged. At the same time arcing between the filter section and the conductors melted the copper in some places and burned several strands of the band wire.

Rated at 750 kw, the generator, which was part of a motor-generator set, was installed close to, and parallel with, an outside building wall. The air filter, 6½′ wide by 8′ high, and consisting of twenty removable sections, was installed in the wall with the top part of the filter extending inward so that it nearly overhung the generator. It was one of the top sections, which had not been securely fastened, that caused the accident.

As there was available no other source of direct current, which was essential if production was to be maintained, a temporary repair was made by soldering copper sleeves around the weakened sections of the conductors. Although the distance between coils was small after the sleeves were installed, there remained about one-eighth inch clearance—enough, it was believed, to permit installation of sufficient insulating material for temporary operation.

Two methods for permanently repairing the generator were feasible: either the armature could be completely rewound or a new one installed. Nearly a month would be required to obtain new coils and five days more to rewind, during which latter period plant production would be stopped. At least three months time would be required to build a new armature and the cost would be more than twice as much as rewinding, but replacement could be made when the generator was normally out of use without interfering with production. The decision was made to order a new armature as a cost comparison of the two methods showed that the financial loss from shutdown of the paper mill for rewinding would greatly exceed the extra cost of a new armature.

At this writing, permanent repairs have not been made but the estimated total cost of the accident, including the expense for the temporary repairs, is $5,000.

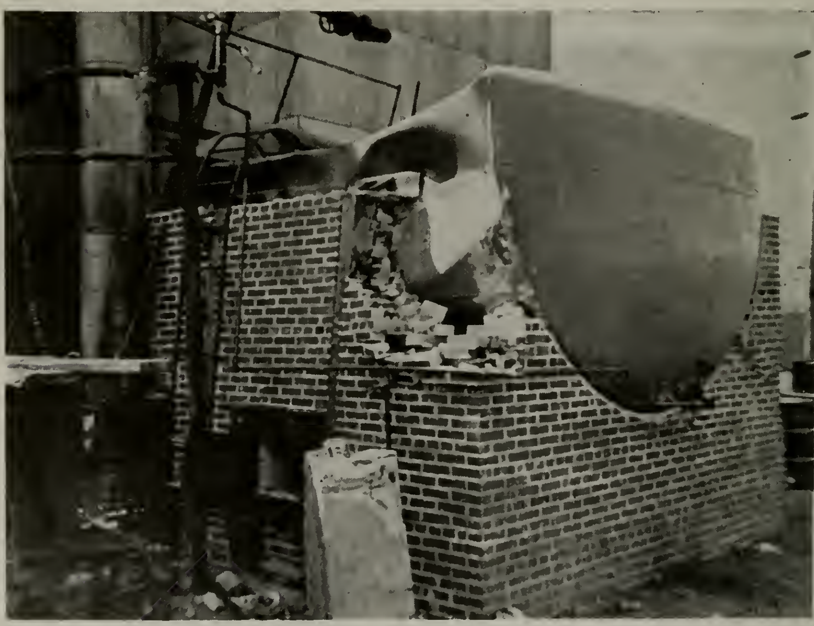
That thought should be given in the installation of motors, generators or other electrical equipment to those hazards outside the machine itself that may cause an accident, is well illustrated by this case.

New Vessel Collapses Under Vacuum Test

Intended for process work requiring direct firing for distilling pitch and the use of 30″ vacuum for drawing off the distillate, a new vessel called a pot still collapsed under a 22″ vacuum while being tested. The top section of the shell fell in, as shown in the accompanying picture, and then ruptured in the center of the collapsed area.

Constructed with welded seams, the vessel was 10′ in diameter by 12′ long and made of tank steel ¼″ thick in the upper half and ⅜″ thick in the lower half. According to accepted engineering standards, the structure was adequate for a maximum safe vacuum of only 6″.

This case illustrates the importance to both purchasers and manufacturers of pressure vessels, of the use of designs conforming with



View of a large tank after it had collapsed while being given a vacuum test.

accepted standards of construction. Many states and cities have laws governing the construction of several classes of pressure vessels, and the purchaser should determine whether or not the vessel he requires will come within such laws. If it does, he should specify that the vessel be constructed in accordance with those requirements. Otherwise, in order to assure proper construction and workmanship, it is recommended that the vessel be built in accordance with the A.S.M.E. Code.

Points for the Operator

The safety valve on a superheater should be set to release before the safety valves on the boiler, so that in case of a sudden drop in the demand for steam, the superheater safety valve will relieve the excess pressure first, thus continuing the flow of steam through the superheater and preventing its overheating.

The steam supply line to the auxiliary oil pump for a steam turbine should be connected to the steam header on the boiler side of the stop valve which shuts off the steam to the main throttle valve for the turbine. Then if something happened to prevent closing the throttle valve, the turbine can be removed from service by closing the stop valve without shutting down the auxiliary oil pump. This would permit the turbine to come to rest with ample lubrication of its main bearings.

When a foundation bolt of a horizontal steam engine works loose, a very careful investigation should be made to determine the cause of the trouble. Frequently, local softening of the grouting under the engine base or frame by oil-soaking causes the looseness. Possibly the foundation has cracked or settled, so that it does not support the engine frame uniformly. Hence, the tightening of loose foundation bolts is inadvisable until the cause of the looseness has been determined and corrected; otherwise, it is very likely that such tightening will subject the frame to dangerous stresses which may cause it to crack.

THE COVER

An inspector is checking the governor on a large steam engine. Speed regulation and safety against overspeed are largely dependent upon the proper functioning of the governor. By periodic inspections defective parts or incorrect adjustments are discovered, thereby permitting repairs and preventing costly accidents.

Many a man thinks he has an open mind when it is merely vacant.—*Cilco News.*

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

WALLACE H. HENSHAW, *Editor*

HARTFORD, CONN., July, 1940

Single copies may be obtained free by calling at any of the Company's offices.
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Bound volumes one dollar each.

When, last December, the sudden death of Mr. Sidney B. Coates made vacant the editorship of this magazine, we anticipated some difficulty in finding a man to succeed him of the technical and literary qualifications which that position requires. We were very happy, accordingly, when a canvass of our own organization disclosed that in Mr. Wallace H. Henshaw, of our field agency staff, we had one who, by education and years of experience in the business of boiler and machinery insurance, was equipped with a thorough knowledge of its engineering features and who also had shown an ability to write simply and clearly of technical and other matters pertaining to our very specialized branch of underwriting. Though he had no experience in editorial work, Mr. Henshaw willingly took over at our request the preparation of the April number of THE LOCOMOTIVE. His capable handling of that issue was such that we have now given him editorial charge of the magazine, with full confidence that under his guidance it will continue the purpose with which it started over seventy years ago, of furnishing to our assured and to power users generally interesting articles and discussions on power plant protection.

WM. R. C. CORSON, President.

Recent Refrigerating Equipment Accidents

SEVERAL accidents to refrigerating equipment during recent months have come to the attention of THE LOCOMOTIVE. These cases illustrate the need for insurance and inspection of the vessels and piping of the systems as well as the compressors. Many of the losses were preventable but occurred either because the equipment was not properly maintained or because it was not properly operated. In one instance five persons were killed or injured while working on equipment under pressure. Other accidents were caused by failure of worn parts, fatigue of metal or by defective material. Too much emphasis cannot be placed on the importance of competent operation of all refrigerating equipment, and on thorough inspection and careful maintenance.

Following are brief descriptions of a few recent accidents involving vessels and piping in refrigerating systems in which ammonia was used as the refrigerant.

Refrigerating Systems

An ammonia receiver explosion last March in an Iowa cold storage plant resulted in the death of three men and injury to two others. At the time of the accident, these men were making changes in the refrigerating system. According to the newspaper accounts, and from other information that could be obtained, the ammonia was supposed

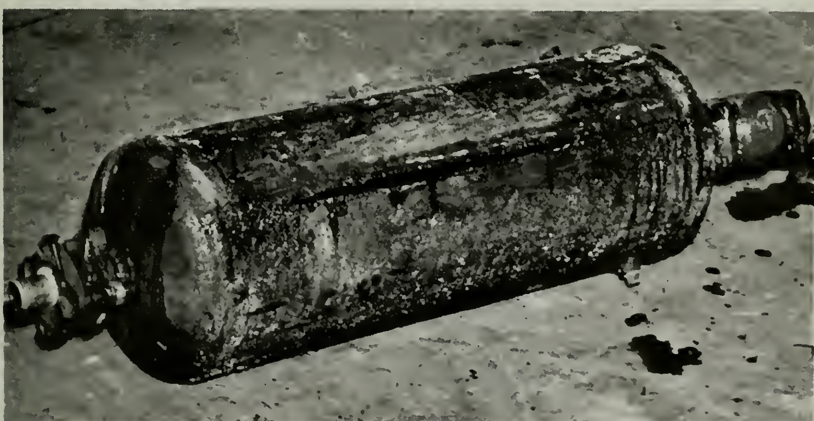

Figure 1—Five men were injured (three of them fatally) by the rupture of this ammonia receiver along a welded seam. Overpressure from expansion of the ammonia when an acetylene torch was used to cut a connected pipe was the probable cause of the failure.

to have been pumped out of the receiver before the work was started. One of the men was cutting a connected pipe line with an acetylene torch while the others were unbolting the receiver supports when the vessel suddenly burst along a welded longitudinal seam as shown in Figure 1.

In attempting to determine the cause of the accident, it was found that all pipe lines connected to the tank were equipped with stop valves which had been closed. As there was no safety valve on the receiver and as the ammonia probably had not been pumped from it, heat from the acetylene torch vaporized the liquid ammonia and increased the pressure in the vessel to an amount greater than it could withstand.

A vessel that can be entirely isolated from other parts of the system by stop valves should be equipped with a relief valve, and care should be taken in changing or repairing refrigerating systems to make sure that the vessels or pipes on which the work is to be done do not contain refrigerant.

Another accident to an ammonia refrigerating system occurred last August in the cold-storage room of an ice manufacturing plant located in Minnesota. The storage building, 50′ wide, 64′ long and 50′ high, was badly damaged, the roof being wrecked and one wall pushed out. Five thousand feet of 2″ direct-expansion cooling coils fell from the ceiling, most of them being broken as they struck the floor or as they were hit by sections of the roof. Other parts of the refrigerating equipment, located in separate buildings, were not damaged, but approximately 1500 lb of ammonia was lost when it was released through the broken expansion coils. Figure 2 gives some indication of the extent of the wreckage.

Respecting the cause of the accident, one theory was that the roof collapsed and forced out the front wall. Another explanation was that leaking ammonia vapor may have created an explosive mixture which was ignited in some way. An eye witness stated that there was a detonation, after which the roof lifted up and then caved in—indicating that an explosion had been the real cause of the damage rather than collapse of the roof.

The disastrous consequences of an explosion of mixtures of ammonia gas and air were demonstrated by an accident last September to a large refrigerating system supplying cold storage for a Mid-Western packing plant. As nearly as the facts could be determined, it appears that a 6-inch elbow ruptured in the discharge pipe line from one of the

Figure 2—Some of the broken ammonia cooling coils and a section of the collapsed roof following an accident to a refrigerating system in an ice storage building.

compressors, thereby allowing hot ammonia gas to escape and fill the compressor room. About 20 minutes later there was an explosion, immediately followed by fire. Undoubtedly the mixture of ammonia gas and air was ignited by a spark in electrical equipment nearby. Most of the damage resulted from the fire as it burned so fiercely and with such intense heat that the overhead girders buckled, permitting the collapse of the roof and one wall. The system was a large one and as the plant operators were unable to close the valves on the ammonia suction lines, approximately 53,000 lb of ammonia was lost. This ammonia mixing with air, was the main fuel supply for the fire. The damage to the compressors was not great although many of their fittings and attachments required replacement. A switchboard and all the ammonia, steam, brine and water piping were ruined. A view of the wrecked building and two of the shell-and-tube type condensers, which had been located on the roof, are shown in Figure 3. The total property loss was estimated at more than $75,000.

In making an investigation to determine the cause of the elbow rupturing, the plant operator stated that when he heard a clicking noise in the ammonia cylinders of one of the steam-driven compressors and observed some vibration in the connected piping, he partly closed the throttle valve. But as the noise stopped when the compressor slowed down, he reopened the throttle thinking the trouble had been eliminated. Shortly afterward there was a strong odor of ammonia; in fact, so strong that the operator was forced to leave the building after hastily shutting off the steam supply to the compressor. Probably the clicking noise came from liquid ammonia in the compressor which withstood

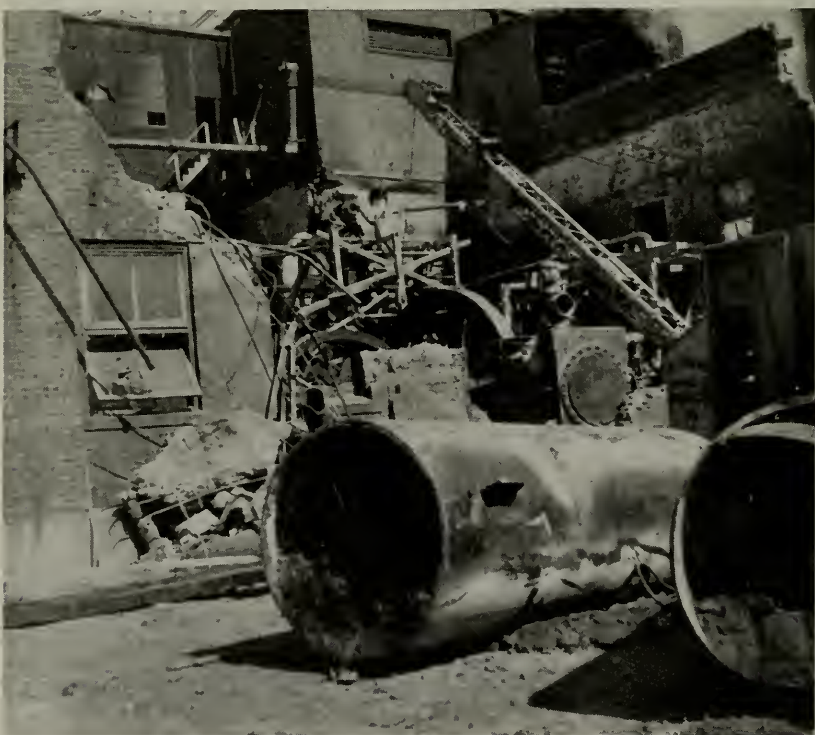

Figure 3—Power plant for a packing company wrecked by an explosion and fire after a fitting ruptured in an ammonia discharge line of a large refrigerating system.

Figure 4—Lack of fusion in this welded seam in a fitting for an ammonia by-pass line brought about circumstances which resulted in damages estimated at $20,000 to a refrigerating plant.

the strain but caused the discharge line to vibrate and rupture at an elbow.

As it was essential for plant operation that the refrigerating system be reconditioned as soon as possible, temporary welded piping was installed and a temporary building erected to house the equipment. Two and a half months later there was a second accident which, in many ways, was very similar to the first one. A section of four-inch by-pass piping, connecting the suction line to the discharge line in one of the compressors, ruptured at a welded joint. Ensuing fire severely damaged the building and much of the contents although, as in the previous accident, the compressors were not greatly harmed. The probable amount of the damages was given as $20,000.

Failure in this second loss was attributed to a defective weld, as the by-pass fitting which is shown in Figure 4, contained a comparatively small amount of fused metal in the welded seam where the rupture occurred.

Compressors

The accidents so far described in this article have been those involving refrigerating systems; that is, the vessels and piping containing the refrigerant. The following paragraphs are accounts of a few typical compressor breakdowns. While the average loss is much larger for refrigerating systems than for compressors, accident frequency is much greater for the latter.

Thrown out of line by a worn outboard bearing, the crankshaft of a vertical ammonia compressor broke in the web adjacent to the flywheel. Resultant damage to the compressor consisted of bent connecting rods, broken piston and bearings and a hole in the crank case. The compressor supplied refrigeration for a dairy products plant and contained two cylinders each 6″ in diameter. It was belt-driven by a 20 hp motor. Rather than make repairs, which would have cost nearly $700 and taken considerable time, the owners decided to install a new compressor.

On investigating the cause of this accident, it was found that a centrifugal pump, mounted on the wall behind the compressor, had been leaking badly and probably had thrown water into the oil well of the outboard bearing. Without proper lubrication the bearing wore rapidly and allowed the shaft to drop about one-sixteenth of an inch. Subjected to excessive stresses because of this condition, the shaft broke at a point where, it is believed, a small crack had existed previously.

Another refrigerating compressor accident involved a single cylinder carbon-dioxide compressor in a hotel. Jamming against a small piece of a valve spring which had worked its way between the piston and cylinder, the piston rings broke and scored the piston and cylinder surfaces. The cylinder was scored so deeply that a new cylinder was necessary. Because replacement was less costly and more satisfactory than attempting to recondition the old parts, a new piston and rings were installed. Figure 5 shows the damaged piston and broken rings.

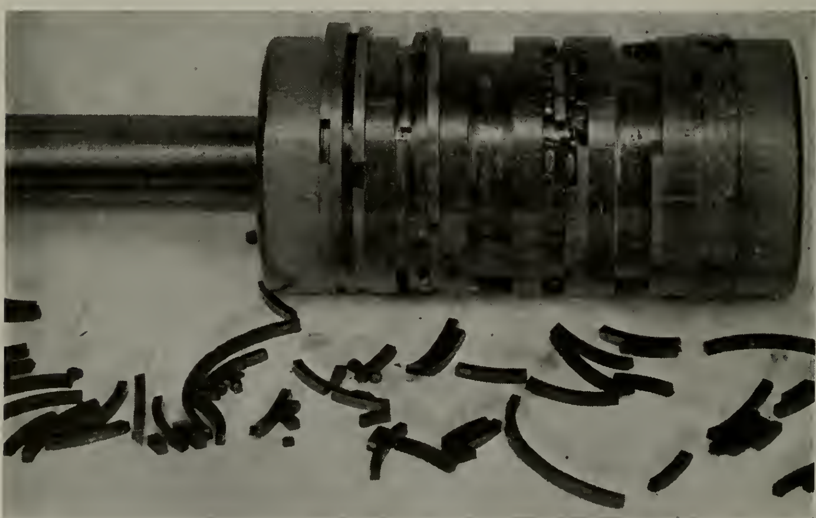

Figure 5—Carbon-dioxide compressor piston and rings damaged by a piece of valve spring which worked its way between the piston and cylinder wall.

Taps From the Old Chief's Hammer

AFTER reviewing the morning mail the Old Chief, as was his custom, called his assistant, Tom Preble, into his office. Matters requiring attention were discussed and how they should be handled decided upon. Having disposed of these routine affairs the conversation turned to other subjects.

"Yesterday I had lunch with Joe Adams, a friend of mine," said Tom. "We were swapping yarns and he told me a story I thought was pretty good, especially as he works for a concern that makes heating boilers."

"Sounds interesting—I'd like to hear it, Tom. In fact, that reminds me,"—began the older man, when Preble interrupted, for he knew from past experience that unless he related his story then, he probably would not be able to tell it—at least not that day.

"This is a short one Chief. It will only take a minute.

"Since last winter," Tom hurried on, "Joe has been traveling and frequently he's away from home several days at a time. Before, he was seldom away over night.

"On one of his first trips his wife forgot to look after the fire and it went out. She thought she remembered the instructions her husband had given her for rebuilding it, so she cleaned out the ash pit, put in some paper and kindling wood, lighted the fire and after she thought it was burning satisfactorily threw on some coal, but the fire went out. She knew the drafts were open and couldn't understand what was wrong. After two or three attempts with no better results, she called on a neighbor for help. The neighbor showed her why her methods had not been successful. She had been building the fire in the ash pit."

"That is a good one, Tom," chuckled the Chief, "but I doubt that your friend's wife saw any humor in the situation at the time. However, your story reminds me of a generator that an inspector was told was all right but had just 'run out of electricity'."

"Is this the same one you were going to tell before?" put in Tom.

"No, that's another story—I'll tell you that one some other day. This concerns a plant in which we insured, along with some other machinery, a d-c generator, rated at 150 kw and 275 volts. Bill Lampson related the facts to me. He is one of our inspectors for electrical machinery in that territory. Perhaps you are acquainted with him?"

"I don't know him," answered Tom, "but I do recall seeing copies of a number of letters plant owners had written the Company commending his work during the 1936 flood."

"Correct, Tom," agreed the Chief. "He is a good man on electrical troubles. But to get on with the story—the generator went dead and the plant engineer, not being able to find the trouble, called in a local electrician. The electrician spent two days checking over the machine and its connections without finding anything wrong and finally gave it up as a bad job.

"The owner then sent for Lampson. On questioning the plant engineer Bill found out that the generator had been operating normally and that both the switch and the circuit breaker in the feeder line to the switchboard were closed when the electricity went off. Neither the plant engineer nor the local electrician could account for the trouble; their only explanation was it just seemed to have 'run out of electricity'.

"Well, Lampson went to work and made insulation and short circuit tests of the field and armature circuits and across the commutator bars but all the readings were satisfactory. Neither could he find any indication of defective insulation in the exposed parts of the windings nor in any of the connections."

"I imagine he was about ready to agree with the electrician and plant engineer, wasn't he, Chief?" asked Tom.

"He was beginning to get worried," the Chief went on. "But there was another method of testing for a short circuit he hadn't tried—using a head receiver and battery and checking each coil in the armature with every other coil with which it might be shorted. You can figure the number of tests that would require—over 5,000, as I recall the case—provided he checked the entire armature.

"However, Lampson was fortunate as he found the trouble after he had tested comparatively few coils, although that had taken him about two hours. Even then he couldn't see where the coils were short circuited, but by digging out the padding in one end of the slot common to the two coils that he knew were affected, he found them welded together directly under the band wires on the commutator end. After breaking them apart and putting in some temporary insulation, he had the operator start the generator. It ran without a bit of trouble."

Tom didn't say anything for a moment as he thought about Lampson's experience. "I guess the owner of that plant was pleased to have the generator running again. Was there much time and expense required to make permanent repairs?"

"Oh, I forgot to tell you about that, Tom. Lampson didn't want to leave a makeshift repair, so he and the electrician cut off the band wires around the end of the armature where the short occurred. It was comparatively easy then to move the ends of the coils sufficiently to permanently reinsulate them, put on new band wires and place the generator in service."

"That sounds like a good method for finding a short circuit," commented Tom. "Had Lampson used it before?"

"I asked him about that," replied the Chief. "He said that when he was a boy working as an oiler in a power house the same kind of a short circuit occurred in one of the generators and it wasn't located until all of the top coils had been lifted out of their slots. Afterward the electrician in charge figured out that, by using a battery and buzzer, he could have saved a lot of time and avoided the possibility of damaging the insulation when the coils were taken out. Lampson remembered what the electrician had said, applied the method and it worked. Instead of a buzzer Lampson used a receiver as he could tell by the sound when he had located the short circuit."

He Just Walked Away

An inspector recently investigated an explosion in a store building in the New York metropolitan area. On questioning the janitor about the safety valve on the boiler the following astounding conversation took place.

Inspector: "Did the boiler have a safety valve?"

Janitor: "Yes, just like that one" (pointing to the valve on a new boiler taking the place of the one that exploded).

Inspector: "Did you ever work it by hand?"

Janitor: "No, sir."

Inspector: "Did you ever hear it blow?"

Janitor: "No, sir. I never touch those valves no time on any boiler. I was told once that's what makes a boiler explode, and if any one of those valves starts to shoot steam, I just walks away and comes back later. I don't mess with them."

The man had been firing boilers for nine years, and was taking care of the boilers in six different buildings.

The three bears were walking on the desert.

Papa Bear sat on a cactus and said, "Ouch!".

Mama Bear did likewise and said, "Oh!".

Baby Bear sat on a cactus and said nothing. Just sat.

Mama Bear turned to Papa Bear and said, "Gosh, I hope we're not raising one of those Dead End Kids."

Trumbull Cheer.

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONNECTICUT

December 31, 1939 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,131,575.00
Premiums in course of collection (since Oct. 1, 1939)		1,404,532.70
Interest accrued on bonds and mortgages		75,051.67
Mortgage loans		147,287.10
Home Office and Philadelphia branch office real estate		642,331.05
Other real estate		305,499.60
Other admitted assets		8,862.20
Bonds on an amortized basis	$8,587,809.88	
Stocks at market value	8,460,040.00	
		17,047,849.88
Total		$20,762,989.20

LIABILITIES

Unearned premium reserve		$8,097,450.81
Losses in process of adjustment		266,219.31
Commissions reserve		280,906.54
Taxes reserve		335,000.00
Other liabilities		307,937.43
Liabilities other than capital		$9,287,514.09
Capital stock	$3,000,000.00	
Surplus over all liabilities	8,475,475.11	
Surplus to Policyholders		**11,475,475.11**
Total		$20,762,989.20

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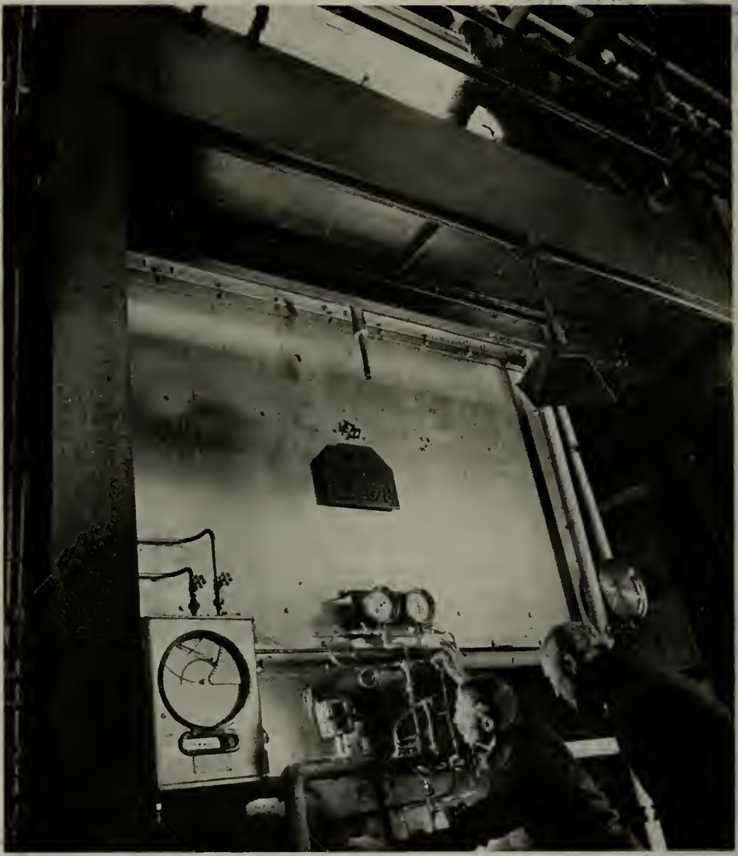


IN a single year, Hartford Steam Boiler unearths about 20,000 serious threats to boiler safety! The inspectors responsible are no casual amateurs, content with a "once-over," but experienced professionals . . . specialists at a specialized job. Numbering over 400 and located strategically throughout the country, these men are seeking to lessen the possibilities of ruin to Hartford-insured power-plants . . . to lengthen the life of expensive installations.

The organization of which they are a part includes a full-time staff of engineers whose efforts are devoted to the study of power-plant accident causes and means of prevention; to the analysis and interpretation of field inspectors' findings; to the furtherance of power-plant safety.

The protection of power equipment is a job warranting the attention that only a specialist can give it.

"Steam Turbines—Comments on Maintenance and Safety"

Vol. 43 No. 4

October, 1940

The Locomotive

THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE CO.

Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

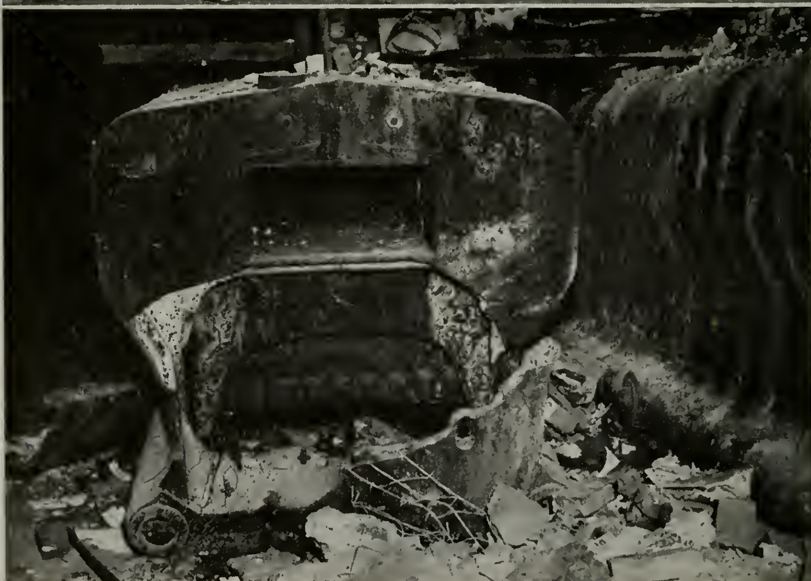


Figure 1—Top—Section of a brick wall in a large apartment house demolished by an explosion in a cast iron steam heating boiler.

Figure 2—Bottom—Front view of the boiler in which occurred the explosion that resulted in the damage shown in the top photograph.

Cast Iron Heating Boilers Do Explode

Almost all owners and operators of heating boiler plants recognize the danger of boiler explosions. Many intend to give their boilers the attention necessary to prevent accidents but often delay doing so until shortly before the start of the heating season. This past summer, abnormally low temperatures in some parts of the country resulted in many heating boilers being returned to service several weeks earlier than usual. Nevertheless, for both these boilers and others which have not yet been placed in operation, it seems timely to call attention to the need for the thorough examination and reconditioning of both boilers and appliances, before the need for continuous use makes this maintenance work more difficult and expensive.

A large number of heating boilers in commercial properties and a great majority of those in residences are of cast iron construction. In ever increasing numbers these boilers are being equipped with automatic pressure and temperature control devices in an effort to give the attendant more time for other duties away from the boiler room and at the same time without increasing the probability of accidents. There is no doubt that the dependability of automatic controls has been improved but the fact should not be overlooked that any automatic device is an added source of danger unless given the attention necessary to assure its satisfactory operation.

Numerous heating boiler accidents are recorded in the daily press. Some of those accidents are attributable to failure of the "human element" and others to automatic equipment which did not function properly. That the latter is likely to be the cause of accidents is confirmed from the frequent finding by inspectors of undependable safety appliances. Apparently, some accidents have been the result of a combination of conditions which might or might not have been discovered prior to the accident.

The operation of cast iron boilers at excessive pressures is a common cause for rejecting them for insurance. A safe working pressure of 15 lb for a cast iron boiler used with a steam heating system and 30 lb for one used with a hot water heating system has been generally adopted as standard by insurance companies, boiler manufacturers, the American Society of Mechanical Engineers, and by all states and cities having boiler laws. Higher operating pressures are undesirable even though a boiler successfully withstands a hydrostatic test greatly in excess of these pressures.

Figure 1 on Page 98 shows the havoc done last March to a sixteen-story apartment-building in Philadelphia by an explosion of the cast iron steam heating boiler shown in Figure 2. About three hundred tenants were in the building at the time of the accident but fortunately no one was injured. Local papers carried the story of the blast as front page news and although an estimate of the property damage was not given it undoubtedly amounted to several thousand dollars.

In the basement of the apartment there were four cast iron boilers, each of which was entirely enclosed with brickwork except in front. They were oil fired and equipped with low pressure safety valves and automatic low-water fuel cut-outs. Steam for heating the building was supplied by three of the boilers while the fourth—the one that exploded —furnished steam to a coil hot-water heater. A flat piece of the casting about 2′ x 4′ in size was blown out of the rear section. Another large hole was made in the top of the section next to the rear one by the violence of the explosion as it moved the boiler forward and tore it loose from the pipe connections. The brick walls on the sides and top of the boiler were demolished as was also a large part of the brickwork surrounding the boiler next to it. In addition to blowing out a 15′ by 40′ section of the building wall, as shown in the top photograph on page 98, many windows were broken, the sound-proof ceiling over the boiler room was shattered and partitioning walls around the boiler room were demolished.

Examination of the broken parts of the rear section revealed that the cast stays which supported the flat surfaces had been broken previously as there was a thin hard scale on the broken ends of the stays. Because of the weakened condition of this part of the section, the explosion may have been caused by steam and water pressure even though that pressure was comparatively low. It is also possible that the accident resulted from an explosion of accumulated fuel gases in the firebox and in the gas passages of the boiler. However, neither from the facts that were obtained nor by careful consideration of the nature and extent of the damage, could it be determined definitely whether internal pressure or ignition of accumulated fuel gases caused the explosion.

Last December an explosion of a round cast iron hot water heating boiler in a Watertown, New York, garage killed one man and caused property damage amounting to more than $1,000. Built for 100 lb water pressure to heat water for supply purposes, the boiler operated at 70 lb —the usual pressure in the city water main to which the boiler was directly connected. In this case, adequate provision had not been made for expansion as the water in the system was heated. Installed only a few days previous to the explosion, the boiler had not been provided with an expansion tank nor a relief valve. for it was expected that any excess pressure would be released by backing into the city main as there was no obstruction in the feedwater pipe except a stop valve which was supposed to be open at all times. It is not known what the operator may have done, if anything, to cause the explosion, for he was killed. However, it is probable that either the stop valve in the feedwater line had been closed or connection with the city main stopped in some other way.

Evidence of the terrific force of the concussion, of which some indication may be seen in Figure 3, was the fact that the outer shell was broken into many small pieces while the remainder of the boiler and its base were hurled in different directions several feet away. In addition, a large area of the cement-block wall adjacent to the boiler was blown out, several holes were made in the roof by small pieces of cast iron, doors were broken and windows shattered both in the garage and in another building a considerable distance away.

An explosion of a round cast iron hot water heating boiler a few months ago at a foundry in Brooklyn, New York, is a good illustration of accidents caused by failure of the "human element." Because the safety valve in the expansion tank leaked, some one removed it and inserted a pipe plug in the opening. Evidently the boiler was operated afterward at a temperature higher than normal so that the pressure in the system increased. Without a safety valve or other means to provide

Figure 3—After an explosion of a cast iron hot water heating boiler in a garage. Originally located adjacent to the hole in the rear wall, the base of the boiler was hurled several feet to the right.

Figure 4—Failure of a pressure control device plus an inoperative safety valve caused the explosion of this cast iron steam heating boiler in a Kansas residence.

for expansion the boiler burst when the pressure exceeded the amount it could withstand. From the extent of the damage the pressure must have been several times greater than the safe maximum of 30 lb per sq in. The top part of the boiler was so badly shattered and scattered over such a wide area that identification of the make, size number or other data, usually obtainable from the castings, was impossible. Parts of the grates and doors were found all over the large room housing the boiler although the base and lower section were not broken or moved from the foundation. The building which was one story high with brick walls and a wooden roof, was extensively damaged. One wall was bulged outward, a small hole was blown in another wall, windows were broken, the chimney knocked down, block partition walls around one office were demolished and a section of the roof about 10′ x 8′ was blown out. One employe was injured, although not seriously, by falling debris.

Figure 4 is an example of what may happen to a heating boiler when automatic controls and safety devices fail. Located in a Kansas residence, this gas-fired cast iron steam heating boiler exploded last November from excess pressure when the automatic pressure control designed to shut off the fuel supply did not function and a safety valve stuck. Tearing loose from the steam and return lines, the boiler was blown off its base and hurled completely across the basement. So great was the force of the concussion that a number of bricks were knocked out of a wall, the thermostat motor-control apparatus was blown through another wall and a piece of a cast iron section pierced the jacket and damaged the insulating material on a storage water heater. An interesting side light regarding this accident is that the boiler was reported to have been checked and pronounced satisfactory by a local concern only three days previously.

Last March an inoperative safety valve prevented release of excess pressure in a cast iron steam heating boiler and as a result the rear section burst. Located at a Texas college, the boiler was gas fired and supplied steam for heating purposes. According to the report of the investigation, a diaphragm was broken in the valve which automatically controlled the gas fuel, so that regulation of the fuel was dependent upon manual operation. The attendant said that he had looked at the steam gage about an hour after lighting the fire in the furnace and the gage did not register any pressure. A few minutes later there was an explosion. As the steam gage was tested subsequently and registered satisfactorily, it is probable that the pointer had made a complete revolution, leading the operator to believe there was no pressure in the boiler. On this assumption, the pressure was undoubtedly considerably higher than 30 lb, as the gage was graduated to that amount.

Damage to the boiler itself was not extensive as only the rear section was broken, although the remainder of the boiler was pushed from its base about 18″, part of the insulation was blown off and the steam and

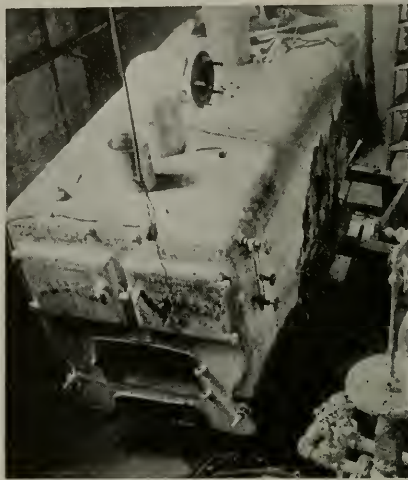


Figure 5—Cast iron steam heating boiler partly pushed off its foundation by an explosion in the rear section. Over-pressure and a defective safety valve caused this accident.

return lines were broken. Figure 5 shows some of this damage. In addition window glass was broken, door and window frames were bent or thrown out of place in the boiler room and in other parts of the building, and repairs were required to a feedwater pump, gas piping and burner, and to several other items. The total amount of the property damage was about $525.

Three people were injured—one of them seriously—and property was damaged to an amount estimated at $2,000 by an explosion last April of a four-section cast iron steam heating boiler in a Michigan greenhouse. Pieces of the boiler were found over a radius of 80′. Excessive steam pressure was believed to have been the cause of the explosion. Whether or not there was a safety valve on the boiler was not determined but none was found afterward. As indicated by Figure 6, the boiler room was completely wrecked.

Figure 6—Some of the wreckage caused in a greenhouse boiler-room by the explosion of a round cast iron sectional steam heating boiler.

Steam Turbines

Comments on Maintenance and Safety

By T. B. Richardson, *Chief Engineer, Turbine and Engine Division.*

Operators of steam turbines or others who are responsible for their care and maintenance should be well informed about the detailed construction of each unit. They should possess a complete understanding of the design and operation of the controls, such knowledge being of assistance in anticipating and forestalling trouble. For instance, one side of one of the older type turbines has a vertical steam chest in which a nest of control valves are arranged one above the other. A ring gasket is placed between each valve seat and the chest with all of the seats held against their gaskets by one set of bolts in the top flange of the chest. When this flange is bolted down it presses the seats against their respective gaskets. If there are any irregularities in machining or spacing of the valves, or in the thickness of the gaskets, some of them will be steam-tight while others will permit leakage. Knowing this feature of design, the operator is better able to appreciate the need for thorough examination of the valve mechanism by periodic dismantling of the turbine as well as understand the importance of proper maintenance, not only in order to avoid subsequent replacement of expensive parts but also to avoid the possibility of serious overspeed in the event of a sudden loss of load.

Obviously, better and safer operation of steam turbines and their auxiliaries is obtained when those in charge know both the functions for which the controls are intended and the limits of adjustment of those controls. As an example, on bleeder condensing-turbines which have the speed and pressure controls automatically interlocked, there must be proper adjustment so that neither control will prevent the operation of the other within certain limits. In illustration of this point, the speed governor should limit the speed to about 8% above operating speed when there is a loss of load and the pressure governor, at the lowest limit of its travel, is endeavoring to increase the bleeder pressure by opening the steam inlet valve.

Relief and Sentinel Valves

Arrangement of piping and the location of stop valves in that piping are important items that should be considered in the interests of safe operation. There should be an atmospheric relief valve between the turbine casing and any stop valve in the exhaust line or in any bleeder line which has automatic pressure control. Such a relief valve should be of adequate size to prevent overpressure in the turbine casing. Usually, the larger valves are equipped with hand-wheels or with hydraulic cylinders for moving the valves between their limits of travel. Good maintenance practice requires that these valves be moved several times each year.

Spring-loaded atmospheric relief valves on bleeder lines should be tested regularly. They can be opened usually with a bar lever but, if not, the spring compression should be reduced until the valves can be so moved. However, before turning the nuts which compress the springs, the position of the nuts should be recorded so that the original compression on the springs may be restored. When the turbines are dismantled, it is well to take advantage of the opportunity to examine and clean atmospheric relief valves. If the valve is provided with a water seal, use of clean water is essential in order to avoid mud or scale deposits which would prevent the valve from moving within the desired pressure.

If a small mechanical-drive turbine is equipped with a casing sentinel-valve, its steam discharge should be located where the operator can easily observe it both from the throttle valve and from the stop valve in the exhaust line. Sentinel valves should be removed regularly for cleaning and testing when the turbine can be spared from service. In any event, the interval between complete examinations should not be longer than a year. As the turbine should be dismantled annually for inspection, a good opportunity for such work is afforded at that time.

Non-Return Valves and Drains

A non-return valve is essential in a turbine extraction or bleeder line if live steam from a reducing valve feeds into the line; if large receiver-capacity is connected to it, or if two or more turbines bleed into the same line. However, when steam at a pressure varying with the load is extracted from the turbine for heating feedwater, a non-return valve is not essential unless steam from some other source feeds into the same heater. These valves should be examined and cleaned when the main turbine is opened for complete inspection.

At the lowest point in any loop of the main-steam inlet-piping, drains are necessary. The same requirement applies to extraction lines. The loops should be connected to a steam trap or receiver of sufficient capacity to handle any water that may accumulate in the loop under any condition of pressure or vacuum. Likewise, a vacuum trap should be connected to the lowest point in a loop in an exhaust line; for instance, on an exhaust pipe line leading to a barometric condenser.

Oil-drain piping running from the bottom of the turbine lubricating-oil tank to the oil filters must be directed upward through a vented overflow which should be at the same height as the oil operating-level in the tank. All valves that are used for draining oil must be padlocked in a closed position or else the discharge ends of the valves must be plugged while the turbine is operating or held ready for operation.

Auxiliary Oil Pumps

The steam supply line for the auxiliary oil-pump should be connected to the main steam line for the turbine on the boiler side of the stop valve which precedes the main throttle-valve or emergency trip-valve. Then if the emergency trip-valve should stick, the turbine can be shut down by closing the stop valve at the steam header without cutting off the steam supply to the oil pump while the turbine is coming to rest.

In many installations the regulator for the auxiliary oil-pump is placed below the operating-floor level where it is very inaccessible for adjustment and inspection. In such cases it is recommended that the steam line in which the regulator is located be piped above the floor in an upward loop beside the turbine or near a wall, so that the regulator will be above the floor level. To permit its removal for maintenance when necessary, a steam by-pass line around it is desirable.

There should be a means for testing the oil-pump regulator. An orifice 1/8″ or 3/16″ in diameter located in the oil-pressure line to the regulator and near it, will suffice for this purpose. A drain line to the oil tank should be connected between the orifice and the regulator with a stop cock or valve placed in the line near the orifice. By opening this valve, the oil pressure will be reduced between the orifice and the regulator, thereby operating the regulator which in turn will start the oil pump. In order to know whether or not the pump has started, a small oil-gage can be located near the regulator and connected to the pump discharge line on the pump side of the discharge check-valve. When the drain valve is closed again, full pressure from the main oil-pump will be restored to the regulator which then will stop the auxiliary oil-pump. This regulator should never be cut out of service so that it cannot automatically start the auxiliary oil-pump during any time the main turbine is in operation. It is a good precaution to padlock the auxiliary oil-pump steam-valves in an open position. Should it become necessary to disconnect the regulator to grind its steam valve whenever the main turbine is in service, an operator should be stationed near the valve in the by-pass line, so that he may start the auxiliary oil-pump by hand if it is required.

Station Log

A station log showing operating conditions should be maintained at all times, thereby providing a means for comparison of present and past performances. To those in charge of the turbines, an analysis of the log will frequently reveal particularly valuable information. The following are a few examples:

1. If the log shows that the first-stage pressure at a definite load has increased above previous pressures for the same load, it is an indication that the buckets or blading have been plugged with deposit or that rubbing has closed them at the edges.
2. If the log shows an increase in the temperature of the discharge oil from the thrust bearings, either the area of the steam passages through the turbine has been reduced or care and maintenance of the oil has been neglected.
3. From the log it can be determined whether or not there has been an increase in the discharge-oil temperatures from the main bearings. These temperatures usually should be between 140° F. to 160° F. It is desirable to maintain the oil temperature in the tank at 130° F. to 135° F. in order to reduce water in the oil and consequent sludging. This can be obtained by adjustment of the oil cooler. Centrifuging or filtering the oil and proper washing with hot condensate to reduce acidity and deposits is a necessity. Further elimination of impurities can be obtained by application of a coating of corrosion-resistant material inside the oil tank and in the bearing pedestals.
4. Log readings should show how frequently the emergency governor has been tested and the speed at which it functions.

Emergency Governor

The emergency governor should be tested once each week provided operating conditions permit, or at periods not exceeding three months operation. Daily moving of the emergency trip-valve stem in its packing is advisable in order that the valve will be more likely to operate freely when called upon to function.

The emergency governor should function at a speed at or near 10% above normal operating speed. When the governor can be tested with oil, testing by increasing its speed above the operating speed is not regularly required. If, in making a test after all load and field excitation has been removed, the control valves leak enough steam to cause overspeeding, these valves should be repaired immediately. When these tests are made or when any repair parts are installed on the unit, the dates of the tests and a list of such repairs should be recorded on the station log.

Vibration

Any appreciable increase in a turbine's vibration, as compared to previous vibration at the same load, is an ominous sign. It may indicate that inside the turbine there is a condition which will lead to serious failure if not corrected immediately. When the operator notices an increase in vibration, any unusual sound, a change in the amount of load the unit will carry, or a change in the amount of steam required for a specific load, he should shut down the unit at once and have the cause determined. In many cases increased vibration has been caused by broken blading, and in a few cases by serious cracks in wheel discs or in reaction-turbine spindles. Such defects have been found after shutting down and opening up the turbine as soon as the increased vibration was noticed but if that had not been done, undoubtedly damage many times greater would have followed.

Dismantled Inspections

Many of the vital parts of a steam engine, such as the piston rod, crosshead, connecting rod, side crank, main shaft and flywheel are accessible for inspection without dismantling the complete engine, but the vital parts of a steam turbine cannot be seen so easily. Except when certain operating changes indicate trouble inside the unit, the true condition of the really vital parts of the turbine can be judged only by a complete dismantled inspection. In no other way than by such an inspection can wear be found through measurement of clearances, alignment checked for its effect on smoothness of operation, and parts examined for erosion or corrosion to determine whether or not their renewal is necessary. Frequently, the search for cracks or for deterioration of parts has revealed conditions which would have led to very extensive and serious failures if they had not been discovered in time.

A steam turbine should be dismantled for complete inspection once a year, and in this connection it is well to note that the manufacturer's erector is better equipped for supervising the work of dismantling and reassembling than any one else. Supplementing the examinations of the turbine that are made by the erector and the owner's own staff, however, it is very desirable to have an independent search made for defects by another engineer who has no direct connection with the operation or maintenance of the machine. Preferably, this inspection should be made by an insurance company inspector, for his experience in detecting conditions which may lead to accidents and outages well fits him for this specialized phase of the work. Furthermore, his primary interest is the finding of such accident-causing conditions. He is kept well informed of the causes of accidents, particularly of every major one irrespective of where it occurs, and he is also advised of the best methods by which similar accidents to other turbines can be prevented.

Power Boiler Accident

An explosion of a locomotive type boiler, one of a battery of four, caused this wreckage. Located a few miles from New Orleans, La., these boilers furnished power for oil-well drilling operations. In addition to extensive damage to the boilers, piping and other equipment used for the operation of this drilling rig, a fireman was killed and his helper injured.

As can be seen in the picture, the failure occurred in the firebox section of the boiler. Although no reason for the accident was given in the news account, it is probable that the cause was low water, or scale and sediment, which resulted in over-heating of either the crown sheet or side sheets. Investigations of other similar oil-well drilling boiler explosions have borne out this assumption as in a large number of such cases, inferior feedwater or inadequate attention to the maintenance of a safe water level have caused overheating and the subsequent explosion.

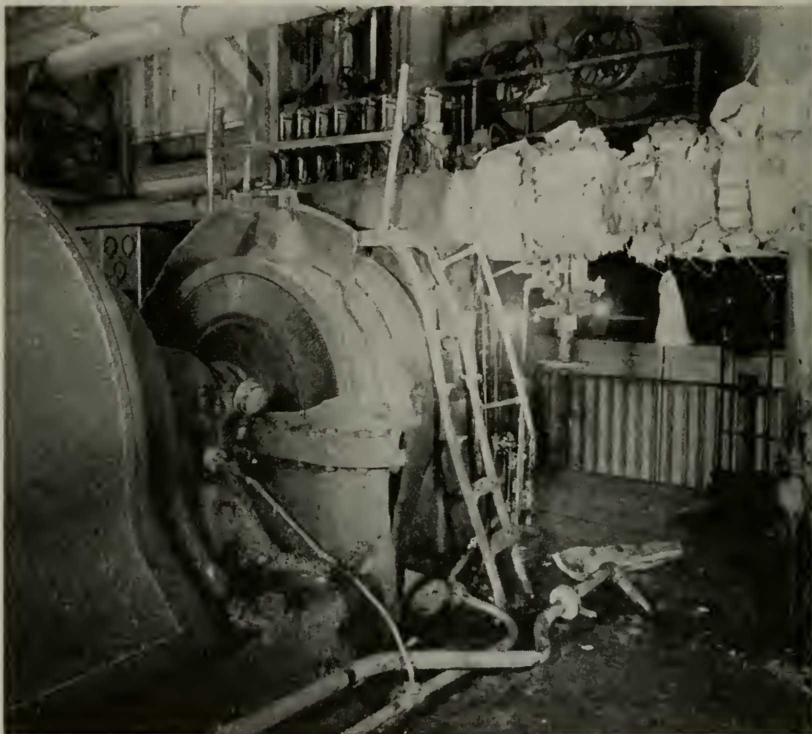
Atmospheric Relief Valve Sticks—Turbine Explodes

About 7:00 o'clock at night, during a severe electrical storm, the load was suddenly lost at an Eastern power plant. Immediately there occurred a series of events which culminated in an explosion of the exhaust casing of a 4800 kw steam turbine. This explosion resulted in the entire district served by the plant being without power for several hours. One man who was standing near the throttle of the turbine in which the explosion occurred was killed, parts of the turbine exhaust casing injured three others, and caused damage to the turbine, auxiliary equipment, and power house amounting to more than $20,000.

Apparently lightning caused arcing across the buses of a large power transformer and this damage resulted in the loss of the entire plant load. There were six main turbo-generator units in the plant, all of which were in service at the time. Three tripped out automatically and the other three were shut down by hand. In order to place the plant in operation again, it was necessary to start an auxiliary steam-driven exciter and to bring one of the main units up to speed non-condensing as the pumps for the condensors were motor driven and could not be operated until a source of current was established. According to the facts obtainable, while the one main unit was being started, an attempt was made also, in the confusion, to operate another main turbine. When the steam was admitted to the latter unit, it started to operate but evidently the pressure in the casing soon became higher than normal as witnesses stated they saw steam blowing out around the seals on the main shaft. The explosion came shortly thereafter.

On subsequent investigation it was found that a 16″ atmospheric relief valve on the condenser was inoperative. With the condenser not functioning and the relief valve stuck, pressure built up within the turbine casing and condenser within a comparatively short time. However, as neither the exhaust casing nor the condenser were designed to withstand a pressure much higher than 15 lb the unit failed at its weakest point.

Damage to the turbine from the explosion, in addition to the casing, consisted of a broken generator frame and the bending and grooving of a large part of the blading on the low pressure wheel. One part of the casing struck and damaged the throttle valve on another turbine. A signal equipment panel was knocked over and various parts of the power house such as railings, windows and roof were damaged. Another large section of the casing, weighing about 500 lb, was thrown up onto a gallery where it hit the exciter-bus switchboard. Because of the extensive damage to this switchboard it was impossible to operate the plant



Steam turbine wrecked by an explosion when its exhaust casing burst from excessive steam pressure.

again for several hours. From the accompanying picture some idea of the tremendous force of the explosion can be obtained.

When the atmospheric relief valve was examined, it would open only 1/16″ and could not be moved more with an 80 lb water test. The valve contained two cylinders having pistons with lead guide rings and this mechanism guided the movement of the valve disc. On dismantling the mechanism, it was found that hard scale and dirt had caused one of the pistons to stick in its cylinder. Also, some corrosion and scoring of cylinder walls was discovered. Impurities in river water which had been used to seal the valves was undoubtedly the reason for the scale, dirt and corrosion in the cylinders.

In another article entitled "Steam Turbines—Comments on Maintenance and Safety" in this issue of The Locomotive, one section discusses relief and sentinel valves with reference to their location and maintenance, and the importance of testing them regularly and frequently. This case well illustrates the value of compliance with those recommendations.

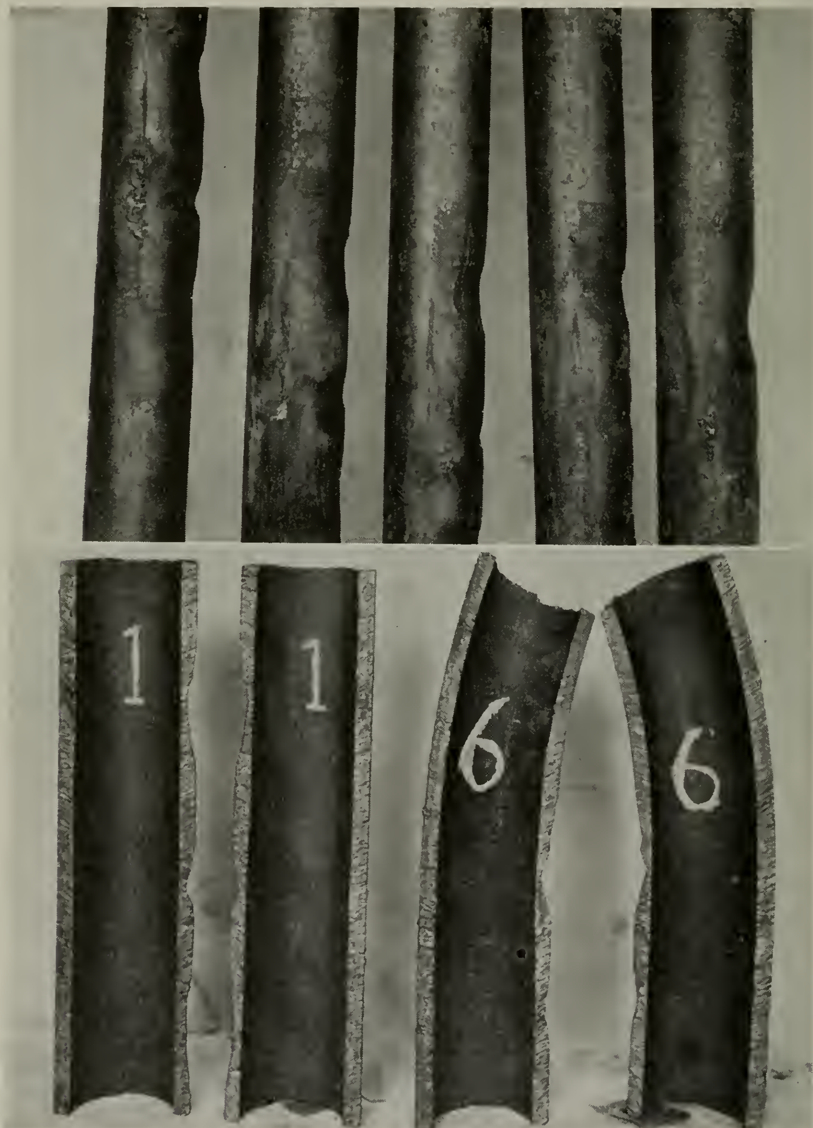
Boiler Tube Erosion Attributed to Steam From Soot Blower

A GOOD example of the extreme erosion that can be caused by soot blowers was encountered recently when it became necessary to replace several tubes in a large water tube boiler. The blower was of the revolving and retractable type and steam from it striking certain tubes intermittently at the same points, cut the metal badly.

In the top photograph on Page 114 sections of five of the affected tubes are shown, while the lower view shows two tubes which were cut in half longitudinally in order that the tube-wall thicknesses could be measured at the deepest points of the erosion. These tubes had an outside diameter of 4″ with an original wall thickness of .417″. At one point in tube "1" the wall thickness had been reduced to .175″ and at one point in tube "6," it had been thinned to .137″. All told, 19 water tubes were worn away sufficiently to require replacement. Several others were eroded also but were considered satisfactory for further service. In addition, it was necessary to cut out parts of eleven superheater tubes and weld in new sections.

While, in this case, erosion by steam from the operation of the soot blower was believed to have been the reason for the excessive wearing away of the tubes, it is possible that corrosion was a contributing factor. Occasionally, leakage of steam into a blower when it is not in use, causes an intermittent discharge of steam and water against the tubes or other boiler parts, either because the steam shut-off valve is defective or has not been closed tightly. This moisture, combining with the waste products of combustion, produces corrosive acid. Then when the boiler is placed in operation, metal in those parts of the boilers that have been corroded by the acid will wear away more rapidly than the uncorroded metal.

If the steam valve for a soot blower does not close properly it should be repaired, and each time the blower has been used the operator should be sure that the steam valve has been closed completely. Warping or the wear and tear of service may sometimes prevent telescopic blowers from being retracted. With this condition, should leakage occur, water and steam may strike the tubes, drums or headers, causing corrosion of those parts.



Top—Tubes in a water tube boiler eroded by steam from a soot blower. Previously, shields had been welded to these tubes to stop the erosion but they proved ineffective.

Bottom—Sections of two of the tubes in the same boiler showing the extent of the erosion. The wall thickness was reduced 60% in tube "1" at one point while tube "6" was reduced 66% at one point.

In some installations, consisting of two or more boilers in a battery, the steam supply of the soot blowers may be taken from the main steam header or some other source, so that even though a boiler is idle, the piping up to the blower is under pressure. Every precaution should be taken in such cases to make sure that the stop valves are tight in order to prevent leakage of steam and water through them.

From the possibilities cited above it is clear that the question of whether or not a blower fulfills its functions in removing soot from the heating surfaces of the boiler is not the only one that should be considered by the operator. There have been many costly replacements of tubes and other parts directly attributable to improperly operated and defective soot blowers. Furthermore, there have been cases in which erosion or corrosion progressed to the point that the affected tube or other part burst while under pressure, causing overheating of the boiler and necessitating the renewal of a large number of tubes. Hence, the need for care in the operation and maintenance of soot blowers is not only for the sake of fuel economy but also for prevention of expensive repairs and accidents.

Defective Safety Device Kills Operator

An operator in a lumber manufacturing plant in Tennessee was killed last February when he was struck on the head by a governor spring which became detached from a steam-engine balance wheel. Failure was caused by the working loose of a threaded connection which held the spring in place at one end. The other end then unfastened where is was attached by a "J" hook, and the centrifugal force of the revolving wheel threw the spring clear of the engine. Seated about twenty feet away, the victim was directly in the wheel's plane of rotation and in the path of the flying spring. There was no other damage as the engine stopped after the governor failed.

According to *Industrial Power,* when the boiler in a New York plant was disabled during the 1880's, two teams of two men each, working in relays, became the "Prime Movers" and turned manually two 15-inch cranks attached to the ends of the steam engine shaft. Operating on the basis of three minutes of work followed by three minutes of rest, each team turned the cranks at the rate of 100 revolutions a minute and developed an average of 3 hp. This system of power generation was kept up for twelve hours a day for twelve days.

THE COVER

View of a power-plant switchboard on which the operating conditions and settings of the electrical equipment are being ascertained. The proper maintenance of this equipment is essential, for it controls the operation and concerns the safety of the generators and other machinery in the power plant.

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

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Change of Managers at Detroit

Mr. L. L. Coates, manager of the Detroit department of the Company for the past 12 years, was retired from active service, at his own request, on September 1, 1940. Coming to the Company as a special agent in the Chicago department in 1907, after considerable teaching and administrative experience in Michigan schools, Mr. Coates was made resident agent in charge of the Detroit office in 1917 and was appointed manager when the Detroit department was established in 1928. During his 33 years of service, Mr. Coates' successful administration of the Company's affairs gained for him the respect and friendship of all agents and clients with whom he dealt.

Mr. William H. Kerrigan, who has been closely associated with Mr. Coates, has been selected to succeed to the position of manager. His broad knowledge of the business and his competent handling of responsible work thoroughly equip him for the new duties. Joining the Company in the Philadelphia department in 1922, Manager Kerrigan has been a special agent in the Detroit department since October 1930 and was appointed assistant manager of that department March 1, 1939.

WILLIAM H. KERRIGAN L. L COATES

The department which Mr. Kerrigan will have in charge serves policyholders in Michigan and parts of Indiana and Ohio.

Points for the Operator

The governor support on a Corliss releasing-type engine should be of the automatic type unless there is a reliable independent stop. Safety against overspeed of a steam engine requires that there be at least one automatic device for holding the speed in check under all load conditions.

The Hartford Loop is suitable for boilers subjected to pressures in excess of 15 lb per sq in as well as for low pressure boilers. This loop stops the water in the boiler from falling below the safe operating level by preventing the pressure in the boiler from forcing the water out through the return line.

Efficiency of belt drives is not increased appreciably by excessive belt tension. Shortened life of bearings and misalignment often are caused by too much belt tension. The higher the tension, the greater the load and the resultant wear on the bearings. This will tend to produce misalignment which sometimes causes the shaft to break.

Thousands of Dollars in Damages From Hot Water Tank Explosions

Hot water tanks are familiar objects to nearly every one, but not every one appreciates the potential destructive energy they contain. Under certain conditions these tanks explode violently.

As water is heated it expands and unless there is an outlet to absorb the expansion the pressure is increased. If the internal force sets up stresses greater than the vessel can withstand, something is bound to break. When that occurs, the higher the temperature the greater the amount of water that flashes into steam and the greater the destructive force of the explosion. A 30-gallon hot water tank, for example, may contain sufficient energy—if suddenly released—to wreck the average residence. Too many tanks either do not have provision for release of excess pressure or else have protective equipment which is inoperative. Often, too much dependence is placed on automatic control devices. Like any other mechanical contrivance a relief valve or automatic control may get out of order. Pipes and tanks may corrode and not infrequently an explosion is caused by an accumulation of solid matter from scale, sediment and corrosion choking the connecting pipes.

The following are a few representative examples of recent hot water tank explosions.

When a plug one inch in diameter was blown out of a small hot water tank in a storage building the resultant water damage to woolen yarn amounted to about $6,600. Other damage, amounting to $200, included repairs to an oil burner and replacement of the insulation on a heating boiler, both damaged by the water. An interesting fact in connection with this case is that only $15 was required to repair the tank while the remainder was necessitated by the water damage.

The tank was made of copper with one head containing two threaded iron plugs that closed pipe openings which were not in use. Because of corrosion in the threads of one of the plugs that had been inserted a distance of only two threads, the strength of the joint was insufficient to withstand the normal water pressure of 45 lb per sq in. By the time the trouble was discovered and the water supply shut off, the basement had been flooded to a depth of several inches.

Adjacent to the boiler room where the tank was located, there was a large section of the basement used for the storage of bales of woolen yarn. Almost half of these were water soaked, greatly reducing their value.

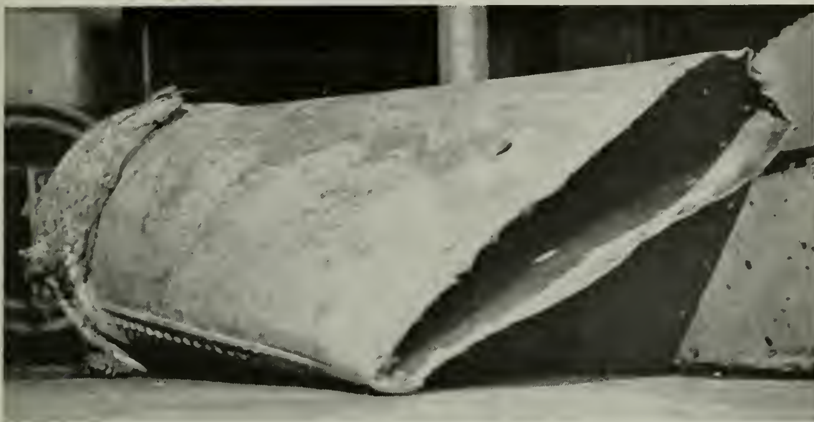


Figure 1—Over-pressure caused explosion of this hot water tank in a laundry. The property loss was over $5,800.

Figure 1 shows a picture of a new hot water tank after it had exploded from over-pressure. This failure occurred in a cleaning plant and resulted in damage amounting to more than $5,800.

The small tank was suspended from the basement ceiling in a horizontal position. When the minus head was blown out the remainder of the tank was hurled through the basement in the opposite direction against a concrete foundation wall, where the plus-head end was telescoped as though the tank had been crushed by a huge press. The force of the concussion raised the reinforced concrete floor over the boiler room, pushed out of place two partition walls—one wooden and the other concrete—broke several plate-glass windows, damaged the roof and cracked plaster in many parts of the building. In addition doors, conduits, wiring, piping, boiler auxiliaries, steam presses, furnishings, the hot water tank itself and many other fixtures and contents of the building required repair or replacement.

The water was heated by circulating through a coil in the furnace of one of the boilers. There was a relief valve on the incoming service line and a check valve between it and the city main. While the actual cause of over-pressure developing in the tank is not known, the evidence indicates clearly that the relief valve did not operate. The setting of the relief valve prior to the accident could not be determined; afterward, it released at 260 lb per sq in. The tank was constructed for operation at 125 lb.

An explosion last November in a residence in Georgia killed two people, injured several others and demolished the house. According to the newspaper accounts, tanks in a hot water system burst from over-pressure. The owner stated that the system was only two months old. and that it had been installed by a competent heating contractor who had provided a safety valve. Why the safety valve did not operate to prevent this explosion was not explained.

A vertical 30-gallon hot water tank blew up in a Kansas City, Missouri, residence last January. The vessel was torn from its setting in the basement and went through two floors and stuck in the roof. The weather had been exceptionally cold and as there was only a small amount of heat in the cellar, both the city service line and the hot water line froze. Water was heated as needed by a gas-fired coil connected to the tank, and when the gas was lighted, with the pipes plugged by ice, the pressure soon became great enough to burst the vessel which had no relief valve.

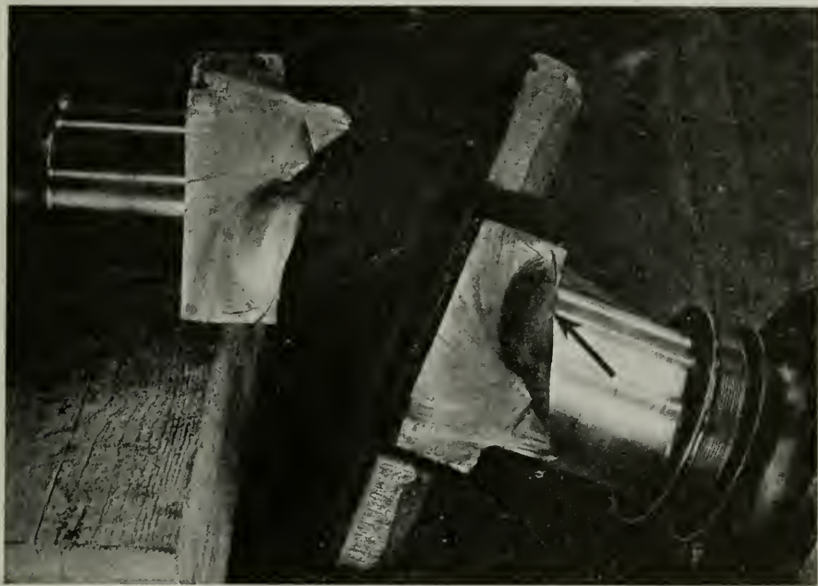
Eight people were in the house at the time but, fortunately, none was injured.

Although five people in a Virginia residence escaped injury when a hot water tank in that residence exploded last November, property damage, estimated between $2.000 and $3,000, resulted from the blast. According to news accounts the chief of the local fire department stated that over-pressure caused the explosion and indicated that the tank was not equipped with a relief valve.

Heard for blocks around, the explosion scattered debris over the yard and in the street. A part of the damage to the first floor, which was wrecked almost com-

Figure 2—Part of the damage to the first floor of a residence from an explosion of a hot water tank.

pletely, is shown in Figure 2. Plaster was knocked down, flooring torn apart and furniture upset and broken. Brick foundation walls and the sills were jarred out of place and the outside walls were blown apart at one corner. In fact, the damages were so extensive, it was reported that the house might have to be dismantled and rebuilt.



Broken crankshaft on an 180 hp Diesel engine which had been operated only 1000 hours. The failure lines in the surfaces of the break show that it started with a small crack on the main-bearing side of the web (see arrow) and also clearly indicate the progress of the crack through the web. Evidently caused by high local stress produced by misalignment, this failure illustrates the value of timely and thorough inspections of Diesel engines. Many similar failures have been prevented by such inspections.

Press reports refer to the development of a new type of copper. Characterized by greater conductivity, ductility, fatigue resistance and surface quality than the ordinary metal, it is asserted that this new type possesses a malleability approaching that of gold, thus permitting sharper bends and easier forming and drawing. According to the producer, slivers and other surface imperfections are eliminated, thereby reducing the hazards of short circuits in electrical equipment by the penetration of such irregularities through the insulation. Under a special patented process involving tremendous pressures, the metal is made into smooth, dense bars, rods, strips and other commercial shapes.

Taps From the Old Chief's Hammer

"DID you drive today, Tom?" asked the Old Chief as he came out of his office and stopped for a moment's chat with his assistant before leaving for the day. "Glad to give you a ride home if you didn't."

"Thanks, Chief. If it won't put you out I'll take you up on that offer. Mrs. Preble wanted the car today, so I came in on the bus. I have a couple of letters to sign and then I'll be ready."

A few minutes later they started down the street to the garage where the Chief parked his car. "Great weather we're having," the older man commented, "just the right amount of zip in the air—time of the year I like to take a trip to the mountains . . . rather cold nights. And that reminds me—what did that trouble at the Newton School amount to? The superintendent called yesterday morning and said he thought one of the boilers had exploded, so I had Mac go up there right away."

"Mac phoned me shortly after he arrived that there wasn't anything serious," replied Tom, "and his report came in this morning. When he reached the plant he found two boilers in service and the boiler room full of smoke. It was coming out through the fire doors instead of going up the chimney because some one had closed the dampers. After they were opened the fires burned freely and Mac reported everything as operating satisfactorily before he left."

"Some of these calls we receive for hurry-up service, Tom, are like that but most of the troubles aren't so easily remedied," remarked the Chief. "I recall a case that Bob Rushton went out on a few years ago—took him all night to remedy the trouble."

"What was it, a Diesel engine breakdown?" encouraged Tom, for Rushton made many of the inspections of Diesels in that territory.

"Yes, Tom, it was. This Diesel was a small two-cylinder engine. We insured it for Use and Occupancy as well as for direct damage. Late one afternoon the plant manager telephoned that the engine wouldn't run but he'd be darned if he could discover what the trouble was. The plant was located in a small town about 75 miles from the office and as there wasn't any shop in the territory on which we could rely for immediate repairs, Bob decided to take along an experienced machinist and some small tools which might be needed.

"They arrived at the plant about 9:30 that evening and found it locked up, although Bob had phoned the manager that he was coming and had asked him to have a couple of his men at the plant to assist with the work. Bob phoned from a drugstore nearby to find out why there wasn't some one at the plant. I don't remember now all the details but after some discussion the manager said he would have the man who had charge of the engine and a helper there as soon as possible. All this took considerable time so that it was nearly eleven that night before the men arrived and they were able to get in and start to work."

"I should have thought the manager would have told his men to do all they could to fix the engine, even though Bob wasn't there," Tom put in.

"They had been working on it," the Chief went on. "As a matter of fact, these same men had dismantled the governor and a number of other parts which, it turned out, didn't need to be dismantled. However, they had found the trouble—a broken link in the governor mechanism. But, not being mechanics and not being very familiar with the engine, they had decided that they would wait for Bob before proceeding further. When he hadn't shown up by 9:00 o'clock, they went home, thinking he wouldn't be there that night.

"Well, Bob went to work. First he went over the engine thoroughly, asking questions as he did so, to find out what had happened when the Diesel failed and whether it had been running smoothly or there had been any previous indication of trouble. He didn't find anything wrong except the broken governor link. The problem was, however, how to repair it as there were no spare parts which could be used. The quickest way, Bob figured, was to weld the broken link but the question was—how to have that done at that time of night. One of the Assured's men said there was a welding shop in town and perhaps they could find the owner and see if he would help them out. This procedure was agreed upon and fortunately they didn't encounter any difficulty in locating the owner and in getting him to open his shop and weld the broken link."

"All of them must have been ready to quit about that time, weren't they?" questioned Tom. "How late was it?"

"About two o'clock in the morning," continued the Chief. "I don't know how tired they were but Bob wasn't the kind to stop before the job was completed. Reassembling of the governor and the other parts which had been dismantled was started and while everything went along smoothly, nearly an hour was required to complete the work. On attempting to start the engine, it wouldn't run. They went over all the connections and tried again but with no better results. After a few more trials so much compressed air had been used that the supply was about exhausted."

"Evidently the power for driving the air compressor was dependent on the engine," Tom commented. "What did they do, pump up the air tanks by hand?"

"No, they didn't have to do that," the Chief said with a smile. "Fortunately there was an auxiliary compressor driven by a gasoline engine, so that's one difficulty they didn't have to contend with. However, something else happened to add to their troubles. Just about that time a severe electrical storm broke. It rained 'cats and dogs' as the saying goes, and there was plenty of lightning. This plant made its own power but purchased current from the local utility for its lights. After a particularly severe flash of lightning all of the lights went out."

"I can imagine what they said when that happened," remarked Tom, as the Chief paused, for congested traffic at that point required all of the older man's attention. He was soon out of it, however, and continuing his story.

"Between them, Tom, they had a couple of flashlights and Bob, of course, had his carbide lamp. These certainly did not furnish the most satisfactory of lighting arrangements but it was the best they could do under the circumstances. The plant men wanted to stop work, for they couldn't see any use in trying to do any more that night but Bob insisted that they stick to it.

"Before making any more attempts to run the engine, Bob had them disconnect and clean the oil-fuel lines while he checked over other parts as well as he could with the limited light. Apparently cleaning the fuel lines did the trick, for then the engine started on the first try. It did not run at normal speed, however, as one cylinder failed to fire regularly, but by adjustments of the governor mechanism and a number of trials, the speed was within three or four revolutions of its name plate rating."

"Chief, they must have been about tired out by that time, but they did have the satisfaction of knowing that their work had been successful," commented Tom. "Were the repairs completed before the time for the plant to open?"

"Yes, repairs were completed by 7:00 A. M. which was an hour before the plant normally began operating. Consequently, there was very little loss of production. It might have been much more but—thanks to

Bob's persistence—the only production loss was for a short period the previous afternoon. It was a darned good night's work. The manager was so pleased that he wrote the Company a letter in which he commended Bob very highly. You might say 'it's all in a day's work,' and so it is, but a good many plant owners aren't entirely convinced that they need insurance until something like this happens. Then they appreciate its value."

"Say, Chief, you haven't forgotten where I live?" asked Tom, as the older man drove by his street.

"What's that? . . . Um, does look as though I am a little off my course. I'll go down this next street and around the block—had my mind on that yarn and forgot where I was going."

"Jimmy, I wish you'd learn better table manners; you're a regular little pig at the table."

Deep silence. So father added, "I say, Jimmy, do you know what a pig is?"

"Yes, sir," replied Jimmy, meekly. "It's a hog's little boy."

"Hey, Bill, what you doin' nowadays?"
"Got a job as an engineer."
"Like it?"
"It's a bit tedious. Gotta make things to a thousandth of an inch."
"My goo'ness. How many thousandths to an inch?"
"Gosh, millions of 'em." *Trumbull Cheer.*

Grocer: "You want a pound of ochre? Is it the red ochre for painting bricks?"
Small boy: "Naw, it's tappy ochre wot Ma makes puddin' with."
Trumbull Cheer.

The business card of an early insurance agent ran like this: "Office in my hat. Wherever my hindquarters are there you will find my headquarters. I am the preferred Michigan perambulating prognosticator, probing the agents and the people with pernicious persistency until prudent people provide preferred protection."
The Casualty and Surety Journal.

Businessman: "What do you do with all these pictures you paint?"
Artist: "I sell them, sir."
Businessman: "Name your figure and report Monday. I've been looking for a salesman like you for years." *Powerfax.*

The mill overseer had sent one of his bobbin setters down to the sink for a pail of water. About ten minutes later he noticed the boy meandering around the other end of the room talking with the yarn boys.

"Hey," yelled the boss. "What are you doing down there?"

"I'm looking for a pail," came back the ready response.

"To H——— with the pail," commanded the overseer, "bring me the water."
Overseers' Magazine

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONNECTICUT

June 30, 1940 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,920,020.07
Premiums in course of collection (since April 1, 1940)		1,210,076.59
Interest accrued on bonds and mortgages		73,381.34
Mortgage loans		114,815.00
Home Office and Philadelphia branch office real estate		642,331.05
Other real estate		304,196.70
Other admitted assets		16,193.44
Bonds on an amortized basis	$8,527,621.65	
Stocks at market value	7,706,881.50	
		16,234,503.15
Total		$20,515,517.34

LIABILITIES

Unearned premium reserve		$8,859,895.83
Losses in process of adjustment		368,349.63
Commissions reserve		242,015.32
Taxes reserve		316,483.01
Other liabilities		305,053.79
Liabilities other than capital		$10,091,797.58
Capital stock	$3,000,000.00	
Surplus over all liabilities	7,423,719.76	
Surplus to Policyholders		**10,423,719.76**
Total		$20,515,517.34

WILLIAM R. C. CORSON, President and Treasurer

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Incorporated 1866 — *Charter Perpetual*

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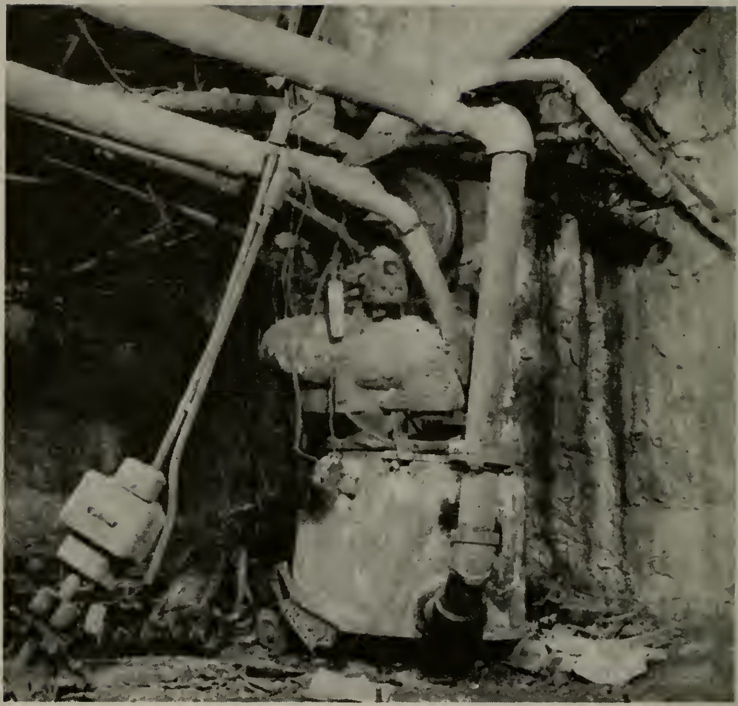


THIS cast iron boiler—uninsured—exploded from overpressure. Connected to a closed type hot water heating system, the boiler was not equipped with a dependable means to provide for expansion of the water. Electric wiring for an aquastat short circuited, the oil burner continued in operation, and as the water expanded the pressure increased. A closed valve between the boiler and a safety valve prevented release of excessive pressure.

Here was a preventable accident. To the trained inspector the danger in such an installation would have been apparent. Hartford's inspectors have found similar and other accident-causing conditions in many heating plants, proving again the wisdom of the saying "An ounce of prevention is worth a pound of cure."

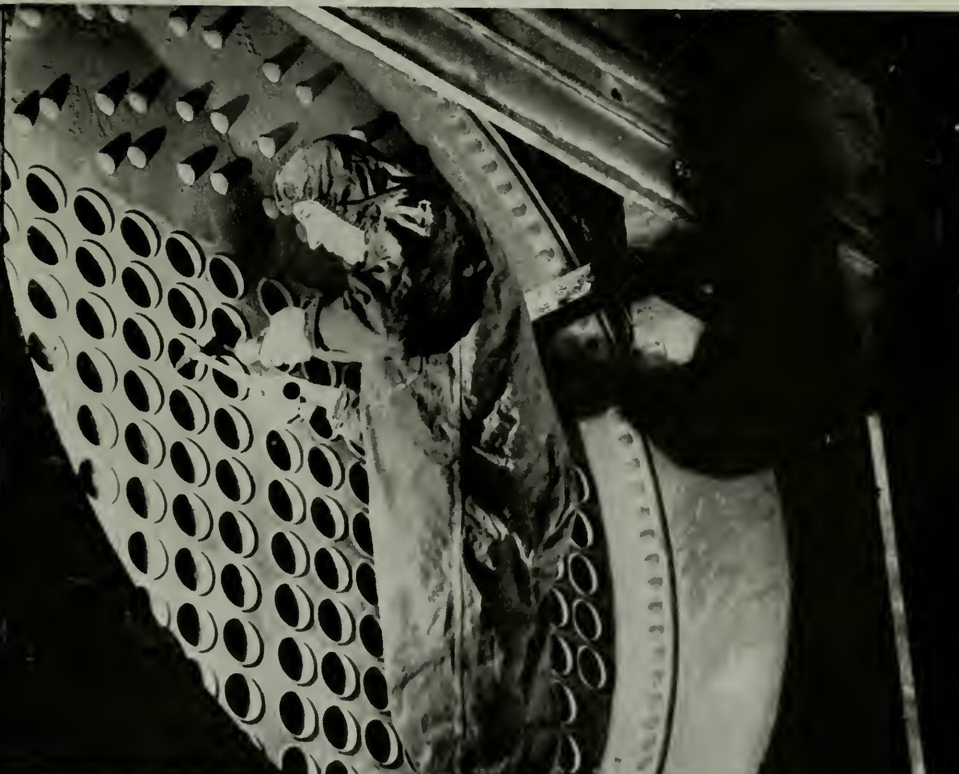
Included in Hartford Steam Boiler's field staff are over 400 trained inspectors. Insured heating boilers and pressure tanks, whether in residences, apartments, stores or in other buildings are inspected by men who are specialists in their work—by the same men who inspect the large power plants of industry.

"Modern Water Tube Boilers"
"Air Compressor Accidents"

Vol. 43 No. 5 January, 1941

The Hartford Steam Boiler Inspection and Insurance Co.

The Locomotive



Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

Two views of a utility sub-station after an explosion, caused by a direct stroke of lightning, blew out the end-walls.

Vaporized Transformer Oil Source of Two Recent Explosions

In the operation of oil insulated transformers there is a potential hazard of explosion from mixtures of volatilized oil and air. Often the amount of destruction which may result from an accident of this kind is not fully appreciated. Last October such an explosion occurred in a utility sub-station in Salt Lake City, Utah, causing damage estimated at $15,000. In another recent case the loss to a hotel in Ontario both from the explosion and the ensuing fire was given as $50,000. In the latter accident one person was killed and nearly a score were injured, two of them seriously.

The photographs on Page 130 show two views of the damaged Salt Lake City sub-station, both ends of which collapsed from the force of the blast. The night operator, who luckily escaped injury, was the only person in the building at the time of the accident. A residence, located near one end of the power plant, was damaged by large chunks of masonry falling against it. These partly caved in the roof and cracked a wall. Most of the damage to electrical equipment was caused by fire which followed immediately after the explosion, and although the flames were quickly controlled, connections and wiring for several induction feeder regulators were considerably damaged. A hand-hole plate and about 30 gallons of insulating oil were blown out of one power transformer and a few gallons of oil lost from each of the regulators.

While it was difficult to establish exactly what happened, there is but little doubt that a stroke of lightning which hit a 22,000 volt incoming power line close to the sub-station was the primary cause of the trouble.

Considered as the most plausible explanation for the explosion was the theory that the high voltage surge of electricity, following along the power line and into the building, passed through a bus structure and into a bank of oil-insulated, 500 kva transformers. This caused an electrical failure in one of the transformers. Intense heat from the failure volatilized part of the oil and created sufficient pressure to blow out the plate, and at the same time, eject some of the liquid oil. Escaping from the transformer, the vaporized oil mixed with air and formed a combustible gas which in some way was ignited, causing the explosion. In making an investigation after the accident it was found that oil from both the transformer and the feeder regulators had been sprayed over a switchboard, the walls, floor and other equipment. Whether the oil lost from the regulators resulted from the explosion or from a disturbance set up by the lightning was not determined.

The source of the Ontario hotel explosion was a combustible gas which escaped from an oil-insulated transformer of only 37½ kva capacity. Nine transformers were located in a separate room in the hotel basement. According to the information obtained, failure of the windings in one of these transformers overheated and volatilized the insulating oil. This oil vapor not only permeated the transformer room, but also escaped into an adjacent service hallway and then into a grill room. From the extent and the nature of the damage, this room was believed to have been the center of the concussion.

About 11:30 on the night of the accident smoke and vapor were noticed coming from under the transformer room door. All of the transformers were maintained by the local power company who kept the door locked and retained the keys. A representative of the power company was notified and after some delay he arrived at the hotel, but the fumes were so dense that he was unable to enter the room and open the switches on the income power lines. It was decided then to shut off all the current to the hotel by disconnecting the lines on the outside of the building. Before doing this the management advised the patrons that there might be a power interruption for a short time and candles were placed on the tables in preparation for the period when the lights would be out. In the meantime, as the door into the transformer room had been left open, vapor was flowing into the hallway and grill room. About six or seven minutes after the door had first been opened there was a terrific explosion. One man was killed in the hallway while in the grill room several people were injured and one wall was blown out completely. A freight elevator shaft and the doors opening into it at the various floors were badly damaged, although undoubtedly this shaft relieved much of the pressure from the concussion. Part of the ruins in the grill room are shown in the picture on Page 133.

Exactly in what way the gas was ignited is not known. Immediately after the explosion fire broke out and damaged the switches and transformers but none of this equipment was shattered, indicating that the main force of the blast had not occurred in the transformer room. Neither was the source of heat which vaporized the oil determined, although the transformer windings had not been examined when an investigation was made shortly after the accident and the information for this article was obtained. The possibility of arcing at the transformer terminals was remote, as they were found intact, and from traces of oil in the casing it appeared fairly certain that the overheating had not been caused by an insufficient amount of oil.

There are several ways in which an explosive gas may be generated

These ruins in a hotel grill-room resulted from an explosion of gas which had been generated in an oil-insulated transformer.

in oil-insulated transformers. One of these is overloading. As the amount of heat to be absorbed by the cooling medium varies approximately with the square of the current, an overload, particularly for a long period, is likely to result in volatilization of the oil. Similarly, oil may be vaporized from overheating of the transformer because of insufficient oil. Loose terminal connections or accumulation of dirt or other matter at these connections may cause arcing and provide the source of heat for generating oil vapors. In an endeavor to prevent explosions from lightning surges as well as to avoid breakdowns of transformer windings and other electrical equipment, it is advisable that adequate lightning arrestor protection be afforded and that the arrestors be kept clean and properly grounded. In many installations in which transformers are located within buildings or confined places and there is danger of a large amount of damage from explosion and fire, other than to the transformers themselves, a non-flammable fluid may be used for insulating and cooling medium.

If the time to make friends is before you need them, if the time to prepare for war is in time of peace; then certainly the time to prevent accidents is before they happen.—W. E. Mitchell, Vice-President and General Manager, Georgia Power Co. in *Edison Electric Bulletin.*

Modern Water Tube Boilers

Problems Encountered in the Operation of Large Installations

By E. R. Fish, Chief Engineer, Boiler Division.

During the last two decades exceptional progress has been made in the development of steam generation, particularly by increased size of water tube boilers having high rates of evaporation and high steam pressures and temperatures, by more extensive use of heat recovery equipment, such as economizers and air preheaters, and by improved methods of firing.

Not only has the maximum steam pressure and temperature, and size of water tube boilers been greatly increased, but these same characteristics for the average installation have also advanced. Pressures of 1400 lb and steam temperatures of more than 900° F. are now widely employed in central stations and in a few large industrial power plants. In the newer medium-size industrial installations pressures of 400 lb to 600 lb are common. In marked contrast, twenty years ago 275 lb in central stations and 150 lb to 175 lb for industrial plants represented current practice.

Accompanying this transition there have necessarily been changes in designs which have been made possible by research and experience, and by advances in metallurgy, in fusion welding and in operating practice. Among others, two outstanding developments are (1) improvement in methods of burning coal both in the pulverized condition and on stokers and (2) the adoption of furnace water walls. Without these the present high-capacity boilers would have been impossible. Today, in a large modern steam generating unit, more than fifty per cent of the total heat liberated in the furnace may be absorbed by the water walls and as little as eight to twelve per cent by the heating surface of the boiler proper. A large part of the remaining heat is utilized by the superheater, economizer and air preheater.

In order to obtain the high capacities, temperatures and pressures characteristic of these modern boilers, large quantities of fuel are burned under conditions which result in very high furnace temperatures. These are as high as 2500° F. or even 3000° F. and, as a result, the greater danger of overheating intensifies the problem of preventing boiler-tube ruptures and damage to other parts.

With these large installations most of the troubles with pressure parts, which bring about shutdown or interruption of the operation of power plants, are caused by overheating of the water-wall and superheater tubes. There are three principal causes for this overheating. One is scale on the inside of the tube, another is poor circulation, and the third is flame impingement. Of these three causes the first two are the most common. Not even an "egg shell" thickness of scale is permissible, as even so slight an amount will interfere with the rapid transfer of heat through the metal of the tube and result in practically instantaneous overheating. With poor circulation, often called "starvation," the velocity of steam flow through the tubes, as steam is generated, is not sufficiently rapid to absorb the heat and keep the tube temperature below a safe limit. Steam is a relatively poor absorber of heat, and hence it is essential that as the steam is generated it should move rapidly. Fundamentally, the reason for the slowness of the steam flow is the fact that as the boiler pressure increases the steam density increases and approaches the density of water. Consequently, in very high pressure boilers, without forced circulation, the height must be sufficient to provide a difference in weight, or hydrostatic head, that will assure proper circulation.

In some cases impingement of the flame against the tubes has caused overheating. In one instance, an investigation of tube trouble which had been experienced in the side-wall area disclosed that the "swirl" from the oil burners had impinged against the affected tubes while those in a corresponding area on the opposite side had not been damaged. The trouble was overcome by rearrangement of the burners.

Water-Wall Tubes

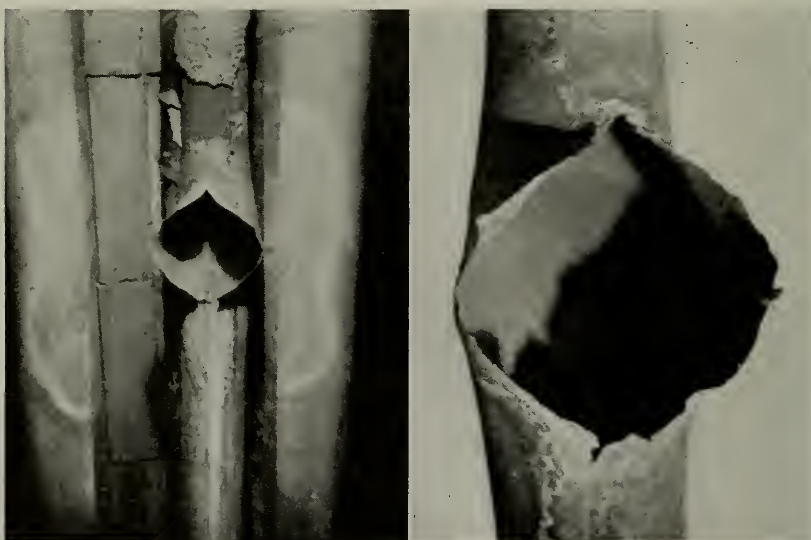
Water-wall tubes are particularly susceptible to damage from overheating because of their proximity to the points where combustion takes place and the intense heat to which they are subjected. They as well as their headers must be so designed that they will be supplied at all times with a continuous and equally-distributed quantity of water. In illustration of this point, there may be cited a recent failure of some horizontally-inclined slag tubes at the top of a water-cooled furnace. The lower water-wall tubes entered a large 36″ drum-header from which other tubes led across the top of the furnace to headers on the opposite side. Apparently, the large drum-header so interfered with the circulation that the cross-over tubes contained too much steam and therefore overheated. To effect a cure, a thin shell was installed inside the drum-header. The purpose of this shell, which was about 6″ less in diameter than the header, was to increase the velocity of the flow of steam and water into the upper tubes by eliminating the trapping or pocketing effect of the large header.

Frequently, water-wall tubes are protected by refractory or metal blocks. These coverings should be maintained in good condition, for if they are broken small areas of the tubes will be exposed to excessive heat. There have been instances of tube failures from this cause.

Superheater Tubes

Overheating is the most common cause of superheater tube failures. In some cases a very thin coating of scale has resulted in burning or rupturing of such tubes. Thus it is important that the steam entering the superheater be dry or, at least, not contain an appreciable amount of moisture. Water in moist steam will be evaporated in the superheater and any impurities in the carry-over will be deposited in the tubes.

Oxidation of superheater tubes is another possible cause of tube failures. With high steam temperatures, some breakdown of the steam into hydrogen and oxygen is likely to occur, particularly if the velocity of the steam flow through the superheater is comparatively slow and



Two views of a ruptured tube for a water tube boiler reported to have been operated at a higher rating than that for which it was designed. Steam pocketed in the tubes, causing one of them to overheat and rupture. Because of the resultant loss of water and the high furnace temperature, 100 additional tubes were distorted and had to be replaced.

the temperature of the gas stream is high. If this breakdown occurs, the oxygen in contact with the hot steel forms magnetic oxide of iron, a very dense and exceedingly brittle substance. Through this action the original thickness of the metal is reduced and if the deterioration of the metal in this way continues long enough the strength of the tube may be weakened until finally it ruptures. Occasionally such oxidation takes place in boiler tubes but more often only the superheater tubes are so affected.

In some installations radiant heat from the furnace supplies the superheaters while in others the superheaters are protected by baffles and heated by convection. Primarily, baffles are arranged to direct the flow of the gases of combustion in order that proper and economical utilization of the heat will be obtained. There may be locations, however, where the baffles have been broken or have been arranged in such a way that hot gases impinge on the superheater tubes or on other parts of the boiler which should not be heated so highly.

Recently a superheater tube ruptured in each of two large water tube boilers which generated steam at 1250 lb pressure and 900° temperature. These boilers had been in operation only a few months, and in each case the rupture occurred at the same point—a few inches above the first baffle. As no evidence of scale or defects in the tubes was found, it is probable that the failures resulted from overheating caused by insufficient baffle protection. The top sections of the superheater elements, where the tubes ruptured, were located in such a way that they were struck by the hot gases while the other sections were protected by baffles. This example demonstrates that the importance of proper maintenance and location of baffles has another significance in addition to that of directing the flow of hot gases.

Other Possible Sources of Trouble

Of course there are other possible sources of trouble which may be encountered in the operation of modern installations. Effects of expansion and contraction is one of them. Many boilers are of very large dimensions and some are so tall that the change in height from a cold condition to the height at operating temperature may amount to several inches. Unless adequate provision is made to care for the expansion, unduly high stresses may be created. This is particularly applicable to the downcomer and interior water-wall tubes.

Extremely important is the treatment of the feedwater. Not only should it be free from impurities which may adhere to the heating surfaces and cause overheating, but also it should not contain chemical elements which may cause pitting or corrosion. Free oxygen in the feedwater may bring about serious pitting of the tubes or other parts, especially those in the upper parts of the boiler. Presence of oxygen results from air entrained in the boiler water and this can best be eliminated by deaeration of the feedwater.

In operation, the water level of large high-pressure and high-capacity boilers behave about the same as for an ordinary boiler. However, as the amount of water in one of these large boilers is relatively small in comparison with the rate of evaporation, the feedwater supply must be absolutely dependable. If the supply is cut off, it takes but a few minutes for the level to reach a dangerously low point. Fortunately, in most cases the fuel supply can be shut off instantly although, even so, the furnace temperature may remain high for sometime afterward because of the residual heat in the refractories. In many large plants stokers are used, and with those installations it is practically impossible to stop the source of heat so quickly.

For boilers operating at low or medium pressures, it is customary to test a safety valve by increasing the pressure until it opens automatically or by manually operating the valve with its hand try-lever. For high pressure boilers daily or frequent testing in this manner is not advisable. Determination of the dependability of a valve in some other way can be accomplished when a boiler is taken from service. At that time the pressure can be controlled over a wide range and the safety valves made to blow automatically without affecting other boilers in the plant. It is also desirable that the valve be dismantled annually for a complete checking. One objection to the blowing of the valve when a boiler is in operation, and one of a battery, is the probability that the pressure on the entire system will be considerably reduced, because of the blow-down range, before the valve can close. In addition, if the pressure is maintained by the other boilers, the valve might continue to blow indefinitely. Furthermore, at high pressures, cutting of the valve discs and seats by the action of the steam is quite likely, even though those parts are made of specially hard materials.

Prevention of Plant Outage

Basically, the kinds of hazards which may cause explosions, ruptures or other failures of these large boilers are about the same as for the older types of steam generators. However, what might be only an undesirable condition in an average plant may constitute a very dangerous one in a modern installation, for the chances of an accident from such conditions are multiplied many times with the newer and more sensitive equipment. For example, where a moderate amount of scale

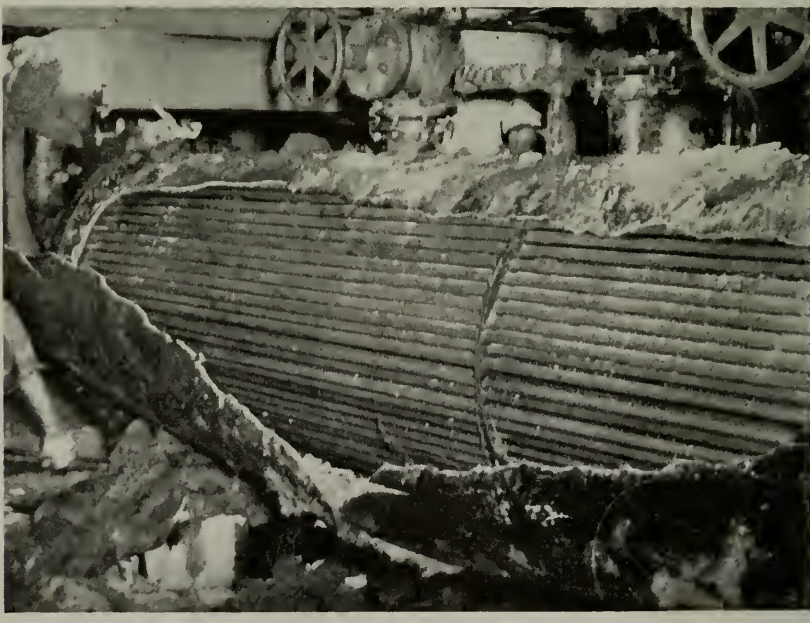
Scale resulted in overheating and bulging of a number of water-wall tubes in this boiler. Change in the feedwater supply without proper adjustment of the feedwater treatment caused the scale accumulation. Two of the damaged tubes are marked. Cost of repairs was not large but several hours of production were lost before steam could be supplied by spare boilers.

in older types of boilers might not be hazardous, a small amount in a modern steam generator can have disastrous consequences. It might well be said that to a certain extent the importance of the prevention of scale, pitting and corrosion as well as the need for intelligent and carefull operating practices are in direct proportion to the size, pressure and generating capacity of the boiler.

The most frequent cause of plant outages from water tube boiler troubles is failure of the tubes although these failures in themselves are not, as a rule, serious accidents. With older types of boilers a tube that burned out, pitted or corroded through could be replaced at a comparatively small expenditure. Because there were usually a number of boilers in the plant, the shut down of one boiler did not seriously interfere with operations. The situation is different, however, when a tube fails in a large modern boiler. Often such a boiler represents a large portion of the whole steam-generating capacity, so that all the production, or the main part of it, is stopped when a failure occurs. Considerable time is required, too, for the boiler to cool sufficiently so that repairs can be made, and there also must be some lapse of time after the repairs before it can be brought up to full pressure again.

In general, the advantages obtained from the use of modern steam generators are increased efficiency and less capital outlay in building and in auxiliary equipment—in brief, less costly power. Much of the gain from these advantages, however, may be lost by interruptions of production unless utmost care is taken in feedwater treatment; in operation of the boiler at high ratings; and in the strict observance of rules for plant operation and maintenance practices.

Brine Cooler Bursts



When this brine cooler exploded violently last August four men were seriously injured, one of them being burned so severely by ammonia that he died three days later. Estimated at more than $40,000, damage to the building and contents was caused principally by escaping water and ammonia.

The brine cooler was 43" in diameter by 16' long. It contained ammonia in the shell and brine in the tubes. Apparently a pressure greater than normal caused the explosion although the reason for the excessive pressure is not known as the piping arrangements, location and condition of valves, method of operation and the events preceding the accident were not obtained.

Air Compressor Accidents

This discussion of explosions and mechanical breakdowns in air compressors has been taken in part from a paper written a few months ago by H. J. Vander Eb, Assistant Chief Engineer, Turbine and Engine Division, for presentation before the Casualty Engineers Association of Chicago, Illinois. Several precautionary measures for prevention of accidents are also mentioned. In the interests of safety, lower accident frequency and elimination of plant interruptions, it is believed that this discussion should be of value to the owners and operators of air compressors. —*Editor.*

By H. J. Vander Eb

In general, accidents to air compressors are of two types; those caused by explosions and those caused by mechanical breakdowns. The former are the more costly but the latter more frequent.

Explosions in air compressors, or in connected pipes and receivers, usually result from ignition of a combustible mixture of air and a carbonaceous substance. Lubricating oil may become vaporized through overheating of the compressor and these vapors, combining with the oxygen in the air, form an explosive mixture. Then if the air in the compressor becomes hot enough, the mixture burns or there occurs what is called a combustion explosion. Often the resultant concussion is so great that the compressor is wrecked, other property is damaged and personal injuries are sustained.

For such explosions to occur there must be a source of ignition irrespective of the flammability of the mixture. Excessive heat is the usual source and the principal ways in which this heat may be generated are as follows:

1. Improper lubrication.
2. Lack of cooling water.
3. Excessive coating of scale or mud in the water jackets.
4. Throttling of the air inlet thereby causing a high ratio of compression.
5. Leaky discharge valves which allow hot air from the receiver to return to the cylinder where the air is recompressed.

Insufficient lubrication of the cylinder may cause overheating and thus any carbonaceous matter, already present in the system, might become ignited. But as a rule, there is greater danger of the use of too much oil rather than of too little. The problem of lubrication of an air compressor cylinder is one of supplying the minimum quantity of the right kind of oil. Only a high grade mineral oil should be used and a compounded oil should always be avoided.

Not only should the source of the cooling water for a compressor be dependable but the water should be reasonably clean and free from scale-forming ingredients, as an ample and active water circulation through the cylinder jackets is important in the prevention of overheating. Having the cooling water discharge visible to the operator is also very desirable so that any interruption in the flow may be noticed readily. An even better safeguard is an alarm actuated by loss of water pressure in the jackets. While the water temperature at the outlet should not exceed 100° to 110° F., the temperature at that point is not necessarily a reliable indication of the effectiveness of the cooling. If there is scale in the jackets, exit-water temperature may be quite low and yet there may be danger of overheating. Hence the water jackets should be inspected, and cleaned of mud and scale at regular intervals.

Figure 1 shows a high pressure cylinder of a two-stage motor-driven machine which was damaged by an explosion. The lower half of the cylinder and discharge piping near the compressor were blown off, and the water jacket broken on both sides of the cylinder. In an attempt to analyze the cause, the thought was expressed that the stop valve in the discharge piping had been closed by vibration, and as there was no safety valve between the compressor and the stop valve, over-pressure caused the accident. However, it is possible that overheating caused a combustion explosion or, at least, was a contributing factor. As shown in the picture, a large amount of scale had accumulated on the inside surface of the water jacket. Unfortunately, the engineer was struck by flying parts and fatally injured.

Impurities in the intake air are another cause of air compressor explosions. This air should be clean and free from dust, sand, flammable vapors or carbonaceous materials. Filters will remove many of these impurities and intake piping should be provided with filters where-ever the air supply contains injurious substances or combustible solid matter. To prevent throttling action of the air supply to the compressor, filters should be cleaned regularly.

Leakage of the compressor discharge valves is the most frequent cause of overheating and of subsequent combustion explosions in air piping and tanks. When the valves do not close completely, the compressed air returns to the cylinder where it is recompressed and its temperature increased. After some time, as this recompression continues, high-temperature air, coming in contact with carbon deposits on the inside of the discharge piping, may produce spontaneous ignition of these deposits. Or if the valves become red hot, there is also the possibility that small particles of overheated metal may become separated

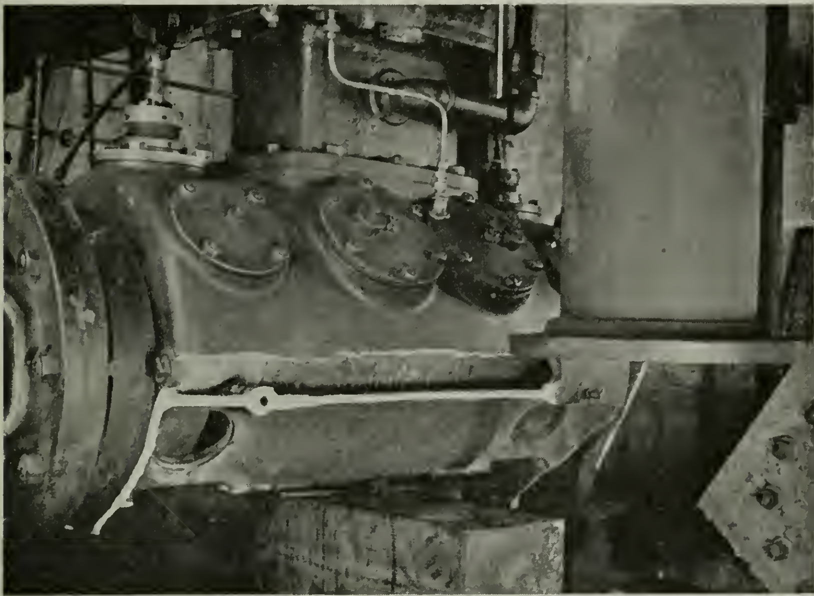


Figure 1—High pressure cylinder on a two-stage motor-driven air compressor damaged by an explosion. Excessive air pressure or a combustion explosion may have been the cause. The operating engineer was killed.

from these valves and propelled into the air piping. Then if there is a combustible mixture of oil vapors and air in the piping, the ignition of the deposits causes a combustion explosion.

A recent accident at a steel mill was a typical occurrence of this kind. The plant engineer heard a sudden dull roar. At almost the same instant the safety valve opened on one compressor and emitted smoke and soot. The compressor was shut down immediately and on investigation it was found that a 12″ discharge pipe leading from the compressor to an aftercooler was very hot for a distance of about 8 feet. Also, it was found that one of the discharge valves was red hot and that the internal fire had even extended into the aftercooler. The compressor was connected to a system for supplying air to helmets for sand-blast operators. Immediately after the occurrence one of the operators was overcome and could not be revived. The cause of his death was diagnosed as asphyxiation by monoxide gas. Undoubtedly the presence of this gas in the system resulted from burning of combustible matter in the discharge piping.

In this case what took place might be described as a comparatively slow internal combustion, for neither the compressor nor the piping was broken. In many instances, however, the concussion has been so violent that the compressor, the piping or tanks were wrecked and broken parts scattered over a wide area.

From this discussion of causes and examples of air compressor explosions, the advisability of regular examinations of both intake and discharge valves is apparent. These valves should be checked for tightness at regular intervals of 400 to 500 hours of operation. It is recommended also that compressor cylinders, discharge piping, and air receivers and tanks located near the compressor, be cleaned periodically with soapy water. Under no circumstances should flammable solvents be used for this purpose.

An excellent safeguard against overheating can be obtained by installing a fusible plug with a whistle alarm in the discharge piping close

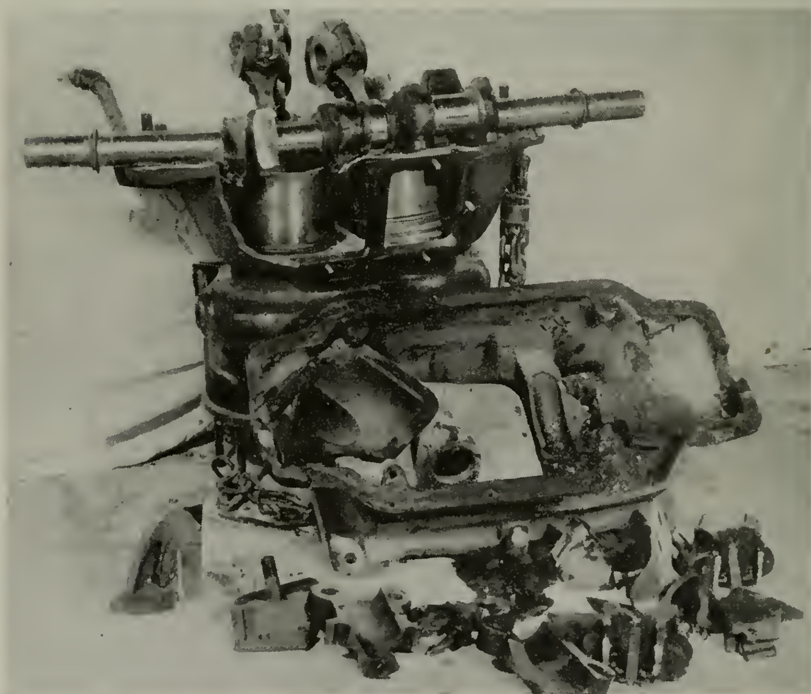


Figure 2—Vertical two-cylinder air compressor so completely wrecked when the crankshaft broke that repairs were impracticable.

to the compressor. For a two-stage compressor, the melting point of the fusible plug should be 350°F. and for a single-stage compressor a melting point of 500°F. is recommended.

Another type of accident which occurs more frequently than do explosions is breakdown caused by failure of some part. There are many conditions which may lead to breakdowns, and while these occurrences are not so spectacular as explosions nor do they frequently cause personal injuries, nevertheless they are costly and may seriously interfere with production or cause property loss by spoilage. Breaking of pistons, crankshafts, cylinders, bearings, connecting rods and other parts, come within this classification.

Many of these breakdowns result from wear, misalignment, small cracks or other defects. Figure 2 illustrates a case of this kind. Having two cylinders, 7″ in diameter, and designed for 125 lb pressure at 630 rpm, this air compressor was completely wrecked by the breaking of its crankshaft. The accident resulted from a progressive crack in one of the crankwebs. The crack developed through misalignment which, in turn, had been caused by worn bearings.

By periodic dismantled inspections of the various compressor parts, possible sources of trouble can be discovered and breakdowns prevented.

Two Killed When Valve Breaks

An illustration of the serious consequences which may be caused by a rupture of a valve or fitting in high pressure steam piping was given by an accident that occurred last April on a Great Lakes freighter when two men were killed as a result of an explosion of a throttle valve. Five others required hospitalization for grave burns while several more crew members were treated for minor injuries. According to a news account, three boilers were in operation at the time of the accident and a large volume of steam, pouring into the engine room through the broken valve, caused the injuries.

Wind Turbine to be Tried in Vermont

A new wind turbine using vanes designed rather like airplane wings with a "wing-spread" approximating that of the largest modern bombing planes, will soon be located at the top of the Green Mountain ridge near Rutland, Vermont. Called a vento-electric station, this initial experimental plant has been designed to produce 1000 kw. The site was selected after elaborate investigations and it is expected to provide wind sufficiently steady for an availability factor greater than that for most reservoir-fed hydroelectric stations. By connecting together a number of the two types of plants through a power line, dependable power would be afforded and the value of each thereby greatly enhanced. The manufacturers of this wind turbine expect vento-electric stations to provide a competitively cheap electric power.

Industrial Bulletin of Arthur D. Little, Inc.

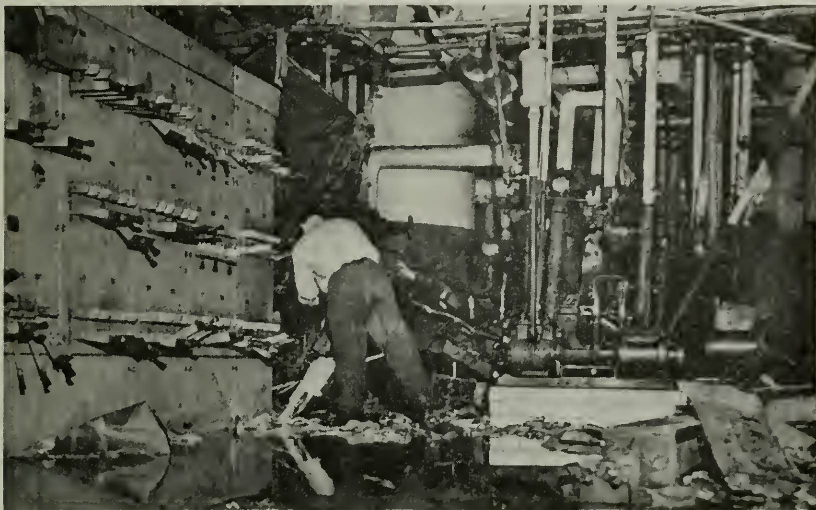
Three Die From Injuries Caused by Feedwater Heater Explosion

One of the most serious accidents in recent years to an open-type cast iron feedwater heater occurred last September in a large office building in a mid-western city. The heater was located in the power plant in the sub-basement of the building, and it exploded when a control valve stuck, permitting exhaust steam to build up a pressure in the vessel greater than it could withstand. The power plant engineer and two of his assistants, all of whom were standing near the heater when the accident occurred, were scalded severely, causing almost immediate death to two of them while the third died a few days later from his injuries.

This cast iron heater was approximately 8′ long and 5′ in diameter. Large sections of it were hurled several feet, some of the pieces breaking a number of small high pressure steam pipes as well as damaging water piping and other equipment. All the windows were shattered in the engineer's office on the first basement level and considerable other damage was caused by the escaping steam and water. An estimate of $4,000 was given as the total cost of repairs.

There was another loss, however, in addition to the fatal injuries and the property damage. Elevators, lights, water and other services were cut off by the blast as all of these services were dependent on the building's own power plant. According to reports, 4,000 workers in the twenty-story structure were forced to evacuate. The explosion occurred about 9:15 A.M. on a Friday and the building was not made habitable again until the following Monday morning.

Steam for both power and heating was obtained from a battery of water tube boilers, and engine-generator sets furnished electric power. The exhaust from the engines was discharged to the feedwater heater through a 20″ line to which other steam piping was connected for supplying heat to a separate building. In order to maintain an even pressure for the heating system as well as limit the pressure in the heater, a control valve was installed in one of two pipe lines which ran from the heater to the atmosphere. In the other line there was a stop valve which was opened only slightly. When the pressure exceeded 2 lb, the control valve was intended to relieve the excess steam to the atmosphere. A by-pass line, having a stop valve and an atmospheric relief valve, was connected around the section of piping containing the control valve but during normal operation this stop valve was closed and the relief valve loaded down. Since the heater itself did not have a safety valve, there was no way of preventing excess pressure if the control valve failed.



Some of the damage caused by an explosion of an open-type cast iron feedwater heater. Originally the heater was installed near the place where the man is standing and parts of it can be seen to the man's right and over his head. The explosion caused the death of 3 men and property damage of approximately $4,000.

That something was wrong in the power plant was first indicated by fading of the lights. Apparently the engineer and his assistants had realized that back pressure in the exhaust line was slowing down the engines and causing the trouble, for they were near the heater when the explosion occurred, and evidently were attempting to fix the control valve or make other changes which would relieve the back pressure. Confirming this belief is the fact that immediately after the explosion the lights were normal again and remained so until the engines were shut down.

Because of the low pressure at which open-type feedwater heaters are operated, owners and engineers may not think of them as a possible source of serious accidents. But occasionally these vessels are so installed that no safeguard against excess pressure is afforded. Through oversight valves may be shut off or may be closed by vibration, with the heater in service. On any installation having a stop valve between the heater and the atmospheric relief valve, the stop valve should either be removed or locked in a fully open position. It is also important that relief valves be examined and tested regularly in order to be sure that they will function properly when required.

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

WALLACE H. HENSHAW, *Editor*

HARTFORD, CONN., January, 1941

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THE LOCOMOTIVE *of* THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE CO.

Albert E. Bonnet

Albert E. Bonnet, Chief Inspector of the Hartford department for seventeen years, died October 6, 1940, at his home in Wethersfield, Connecticut. He had been active in the administration of Company affairs until a few days before his death.

Born January 31, 1874, in Brooklyn, New York, Mr. Bonnet was educated at Greenwich Academy and Stevens Institute. After three years employment in stationary engineering practice he entered the merchant marine with which he stayed in an engineering capacity for five years. Following this he entered the U. S. Revenue Cutter Service as lieutenant of engineering, serving much of the time in Alaskan waters.

Only a few days before he died, Mr. Bonnet had observed his thirty-fifth anniversary with the Hartford Steam Boiler. Joining the Company in 1905 as an inspector in its New Orleans department, he was transferred to the New York office in 1913 and in 1915 was made

Assistant Chief Inspector there. In 1923 he was promoted to the post of Chief Inspector at Hartford.

Well known by many of the owners and engineers in the industrial plants in Connecticut and Western Massachusetts, Mr. Bonnet accomplished much in the furtherance of the Company's friendly relations with its many clients in this territory.

Department Changes at Hartford, Baltimore and Pittsburgh

R. P. GUY

W. C. NICOL

JOHN TODD

Three inspection staff changes of interest to policyholders and friends of the Company in many of the eastern states were announced during November.

In the Hartford department Mr. R. P. Guy, has been selected to succeed the late A. E. Bonnet as Chief Inspector. For the past six years Mr. Guy held a similar position in the Baltimore department. Entering the employ of the Company in 1910, he first worked in the Hartford department as an inspector in Bridgeport, Connecticut, and later in Worcester, Massachusetts. In 1920 he was transferred to New York where he served as a directing inspector until 1923 when he was made an assistant chief inspector, a position which he held for 10 years. From there he was promoted to Chief Inspector at Baltimore in 1934. Mr. Guy's broad experience during his thirty years with the

Company and his previous work in the territory served by the Hartford department well fit him for his new duties.

The new Chief Inspector at Baltimore is Mr. W. C. Nicol who formerly held the same post in the Pittsburgh department, having been appointed Chief Inspector there in September, 1937. Mr. Nicol joined the Company as an inspector in the Pittsburgh territory in 1922 and served there until 1930 when he was transferred to the Chicago office as a directing inspector. He was stationed in Chicago until his promotion at Pittsburgh in 1937.

Succeeding Mr. Nicol, Mr. John Todd, formerly office engineer in the New York department, has been appointed Chief Inspector at Pittsburgh. Mr. Todd joined the Company in August, 1930, after having been employed with a number of industrial concerns, including the Babcock and Wilcox Co. and the Allis-Chalmers Manufacturing Co. He worked for five years as an inspector in the Philadelphia and New York departments and in 1935 was made an assistant to the Chief Inspector of the latter department. His extensive experience and training both with the various manufacturing companies and with the Hartford Steam Boiler ably qualify him for the responsibilities of his new positon.

Points for the Operator

The source of ammonia leaks in refrigerating apparatus can be detected by using a swab saturated with hydrochloric (or muriatic) acid. When this acid is brought into contact with ammonia gas a white cloud of ammonium chloride is produced.

In electrical apparatus, heating does not vary directly with an increase in load. As the load increases, the current increases but the heating increases as the square of the current. Therefore, when electrical equipment is overloaded, the rate of increase in the heating is much greater than the rate of increase in the current. This explains why the insulation may be so seriously affected by drying out, becoming brittle and deteriorating even though the amount of overload is comparatively small.

THE COVER

An inspector examining the tube ends of a horizontal tubular boiler. Through detection of weaknesses in tubes as well as in other parts, the inspector seeks not only to prevent costly accidents and improve the boiler's efficiency but also to prevent power plant interruptions, and troublesome and inconvenient repairs.

Damage Estimated at $50,000 From Boiler Explosion in School

SMASHED as though hit by a bomb, the study hall of a Cleveland high school was wrecked last November by an explosion of a heating boiler. Virtually every part of the new $300,000 building was damaged. During school hours this study hall was occupied by 125

Pictured above are the ruins of a high-school study hall. An explosion of a hot water heating boiler caused this damage.

pupils but fortunately the accident occurred on a holiday. Although workmen and some of the faculty members were in the school, they were in other parts of the building and were not injured.

The floor of the study hall was directly over the boiler room. It was demolished, and chairs and desks were shattered and twisted, some of them being blown through the roof. Great pieces of the reinforced concrete floor were hurled through the study hall ceiling, corridor walls were cracked in many places, and windows and doors broken. The picture on Page 151 well illustrates the damage to the study hall and also gives some indication of the large amount of energy that must have been released when the boiler exploded. According to the reports there was no boiler insurance carried.

The heating system was of the closed hot-water type with expansion tanks in the basement. Forced circulation was used with a provision in certain sections for automatic recirculation by means of thermostatically operated three-way valves. Heat was supplied by two steel firebox-type boilers, 54″ in diameter by 8′ long. These boilers were of welded construction and were built in 1940. Soft coal, stoker fired, was used for fuel. The normal operating pressure on the system was 18 lb, this pressure being maintained automatically by a pressure-reducing valve in an open connection to the city-water service-main. According to the information obtained each boiler had a 1″ water relief valve set at 29 lb and equipped with a test lever.

Only one of the boilers was in service at the time of the explosion. Its shell tore open from end to end in the solid plate through or adjacent to the openings in the top, ripped apart at the welded head seams and unwrapped itself almost completely from the boiler. Also blown apart were the welded legs, the outside sheets pulling loose from the welded-in staybolts and the plate tearing away at the edges. Apparently lifted bodily, the boiler struck a heavy steel beam in the boiler room ceiling and dropped to the floor several feet from its original location. This beam was bent considerably, indicating that it had been hit with tremendous force. Although the idle boiler did not appear to have been seriously damaged, it was torn from its setting and hurled across the boiler room against a basement wall.

Piping, controls and appliances as well as the boiler itself were so badly wrecked that it was impossible from the remaining evidence to determine definitely the cause of the explosion. So far as it is known, the boiler relief valve was not found but it was reported to have been in good working order previously. As respects the system, it was designed entirely for automatic operation. Control of the stokers was said to have been governed by an aquastat set to limit the water temperature in the boiler to 190° F. However, it was reported that the day before the accident the location of the aquastat control had been changed and a time control installed to govern operation of the stoker. It was not learned where the controls were placed nor how they were connected.

In the absence of evidence to the contrary, one theory that seems plausible is that the water circulation in the boiler was greatly reduced or stopped entirely in some way. Then failure of the stoker control to limit the water temperature resulted in the pressure increasing until the boiler burst. Following this line of reasoning, the relief valve, if it functioned at all, must have been of inadequate discharging capacity and unable to relieve the pressure at the high temperature which undoubtedly had been reached when the boiler exploded.

Unfired Pressure Vessel Accident

Part of the wreckage caused by an explosion of a soda leaching tank in a paper pulp manufacturing plant is shown in the picture on Page 154. The total loss amounted to $12,200—about $8,800 for loss to the building and equipment and $3,400 for indirect loss or extra expense incurred in maintaining production and expediting repairs.

Used in a process for reclaiming soda from black ash, this riveted tank was 5′ in diameter and 9′ in overall height. It had cone shaped ends and was made of steel with the exception of the bottom cone which was cast iron. It was the bottom cone that failed. Blown upwards, the shell and top cone first hit a black ash charging hopper on one side, bending the hopper badly. Continuing upward, it then struck the roof beams and fell back to the floor.

Five of these tanks, all of similar size and construction, were used in the leaching process. In the cycle of operations one tank at a time was filled with dry ash, the cover of the charging opening closed and leaching water or liquor added. By means of interconnecting piping, the liquor was passed through all five tanks before it was drawn off for use in the digesters. About half an hour previous to the accident the vessel that exploded had been charged with hot ash, and the leaching process started in the usual manner. In flowing through the hot ash, the temperature of the liquor was raised and some steam generated. Although there was a 1½″ relief valve which was supposed to guard against over-pressure, in some undetermined way pressure gradually increased until the tank burst. To prevent a recurrence it was decided that thereafter the leaching liquor would be added and the hot ash thoroughly quenched before the coverplate was closed.

Scene in a soda recovery room at a paper pulp manufacturing plant after an explosion of a soda leaching tank.

The violence of the accident dislodged the four other tanks from their foundations and broke fittings and piping to such an extent that operations in that department of the plant had to be suspended. However, it was possible to maintain normal plant output by purchasing extra soda ash from an outside source while repairs were being made—the extra expense for this and for rushing through repairs amounting to about $3,400.

Pressure Valve Bursts

Two repairmen were scalded to death while doing fitout work on boilers. A defective valve broke, allowing steam to escape, killing two repairmen and injuring six other employes.

Maintain regular inspections of boilers, gages and valves; make promptly such repairs and installations as are deemed necessary by these inspections.

Safety Engineering.

When ignition is lost on a gas, oil or pulverized coal burner, the fuel should be cut off immediately and the furnace thoroughly purged before lighting up. A drop in steam pressure is preferable to a prolonged visit from the coroner.

Power Plant Engineering.

Taps From the Old Chief's Hammer

"WHERE were you, Tom?" questioned the Old Chief good-naturedly as his assistant, looking out-of-sorts with the world, hurried into his office a half hour later than usual. "Did you over-sleep?"

"No," answered Tom, somewhat wryly. "Had some trouble with my car. This morning was just one of those times when it had to be contrary."

Tom did not volunteer any more information and as it was apparent that he wasn't in the mood for further discussion about the matter then, the Chief changed the subject.

"Here's a stack of reports for you to wade into. For those first two cases, after you have obtained the files, bring them into my office and we will decide on the recommendations we should make."

At noon the two men went out for lunch together. The Old Chief was still curious about what had happened to Tom to disrupt his usual even disposition but he didn't mention the matter. However, as they finished eating, Tom spoke of it himself. "You know, Chief, it was certainly cold and raw this morning. I found that out when I was fixing my car. First one of the tires was flat and in changing to the spare, my clothes became considerably mussed, and my temper upset—especially the latter. Then, after I had cleaned up a bit and was ready to start for the office the motor wouldn't run. Well, I fussed around for quite a few minutes—cleaned the distributor points, and looked for loose connections and broken wires, but I couldn't find anything wrong and finally called a service garage. The distributor points were worn, so the mechanic said, and he put in a new set. Then just to cap the climax, I discovered some dirt and oil on my clothes which didn't improve my disposition any."

The Chief laughed. "So that's what happened. I can appreciate your state of mind, Tom. As the saying goes, 'It never rains but it pours.' Your experience reminds me of a story Bill Scott told me last summer when he stopped in the office during his vacation. There was a jinx, as he called it, that was after a municipal power plant in his territory. You remember Bill, don't you?"

"Yes," Tom answered. "He's an inspector in the Chicago department now, isn't he?"

"That's right," the Chief replied. "It seems this plant had an endless amount of trouble over a period of two or three weeks. It started with a fire. A new water tube boiler and steam turbine had been installed but before the work was completed some temporary woodwork overheated and caught fire at a point where it was set too close to a section of steam piping from the superheater. Bill was called at 2:00 o'clock in the morning and asked to make an inspection. The engineer wanted to know how badly the boiler had been damaged by the fire. So far as the boiler itself was concerned, Bill found that it hadn't been damaged. However, a few fittings, such as the safety valve springs, had been overheated and required replacement.

"Not long afterward trouble developed at the municipal water works in the same city. In order to maintain an adequate water supply, two fire engines had to be used to pump water directly from a lake into the city mains. Unfortunately, these emergency pumps sucked up a considerable quantity of mud which went through the mains and eventually accumulated in the new boiler, making it necessary to shut it down for a thorough cleaning."

"What was the trouble at the water works?" asked Tom. "A breakdown of the pumps?"

The Chief shook his head. "No. Bill said it was caused by the shortage of power resulting from the fire at the municipal power plant. The latter wasn't able to generate enough current to meet the demands of the pumping plant.

"Two or three days later—that is, after the boiler had been cleaned—the plant engineer noticed that the new turbine sounded differently than usual. In spite of the fact that it would be difficult to carry the load with two older generators (the only other ones in the plant) there was nothing else to do but shut down the turbine and open it up to find out what was wrong. When the turbine was dismantled they found that the revolving and stationary blades were rubbing and two or three rows were so badly damaged they had to be replaced."

As the Chief paused a moment to light his pipe, Tom remarked: "They certainly were having their troubles. If one of the older units had failed then, they would have been in hot water for fair."

"That's almost what did happen, Tom," the older man continued. "With the new turbine out of service they were dependent on another steam turbine and an old engine-generator set. The two together generated less than half as much as the new unit, so there wasn't any spare power. Although there were some other boilers the new one was continued in service. As it supplied superheated steam, it was necessary to reduce the temperature of the steam for the engine. There was a desuperheater for that purpose but its regulators didn't work and the steam temperature had to be controlled manually.

"Bill was at the plant a lot during all this time; in fact, I guess he practically lived there. One night while he and the engineer were in the basement and the only ones in the plant, Bill said he noticed all of a sudden that the tone of the machinery on the main floor had changed. He listened a moment and then it came to him what happened. The engine was running at excessive speed. Bill ran for the stairs and raced up them like 'greased lightning' as he expressed it. He shut down that engine in a hurry and I guess it was none too soon. Once the speed of a flywheel is out of control, it doesn't take long for it to skyrocket. In this case, if I remember correctly, the wheel was about 10′ in diameter —large enough to wreck the plant if it had burst."

Tom grinned. "I can think of a number of other places where I would prefer to be than near a wheel that was about to explode." Then, in a more serious tone, he added: "Usually when an engine flywheel overspeeds, something has gone wrong with the governor, but in this case I imagine the trouble resulted from a steam temperature that was too high. Was that the cause?"

"A good deduction, Tom," answered the Chief. "The engineer had been especially busy with all the repairs and other work going on and he hadn't given as much attention to the regulation of the steam temperature in the engine supply line as he should have. Consequently at times the engine was operated with superheated steam. As the valves were not designed for high temperature they became warped and would not shut off the steam sufficiently with light loads."

"I guess when Bill said that the plant was jinxed," commented Tom, "he wasn't far wrong."

The older man looked at his watch. "Say, it's late. Time we were getting back to the office.

"Perhaps Bill's name for it was as good as any," he added, as he put on his coat, "but most troubles, Tom, as well as a good many accidents, don't just happen. A lot of them could have been prevented by good planning and by taking proper precautions. Some things we attribute to luck are really caused by lack of practical judgment and good common sense."

Customer: "Have you that book called 'Man, the Ruler'?"
Salesgirl: "Fiction department is on the first floor, sir."—*Trumbull Cheer.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONNECTICUT

June 30, 1940 — *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,920,020.07
Premiums in course of collection (since April 1, 1940)		1,210,076.59
Interest accrued on bonds and mortgages		73,381.34
Mortgage loans		114,815.00
Home Office and Philadelphia branch office real estate		642,331.05
Other real estate		304,196.70
Other admitted assets		16,193.44
Bonds on an amortized basis	$8,527,621.65	
Stocks at market value	7,706,881.50	
		16,234,503.15
Total		$20,515,517.34

LIABILITIES

Unearned premium reserve		$8,859,895.83
Losses in process of adjustment		368,349.63
Commissions reserve		242,015.32
Taxes reserve		316,483.01
Other liabilities		305,053.79
Liabilities other than capital		$10,091,797.58
Capital stock	$3,000,000.00	
Surplus over all liabilities	7,423,719.76	
Surplus to Policyholders		**10,423,719.76**
Total		$20,515,517.34

WILLIAM R. C. CORSON, President and Treasurer

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NEW YORK, N. Y., . . 90 John Street . . .	C. C. GARDINER, Vice President. J. F. HUNT, Chief Inspector.
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TORONTO, Ont., Canada, . Federal Building . . .	H. N. ROBERTS, President The Boiler Inspection and Insurance Company of Canada.

When Production Loss DWARFS Direct Damage

Water tube boiler in a steel mill—water-wall tube burst.
Direct Damage $600; Use and Occupancy loss $8,469.

Transformer in a foundry—coils burned out.
Direct Damage $950; Use and Occupancy loss $18,455.

Diesel engine in a rubber goods factory—piston ring broke.
Direct Damage $7; Use and Occupancy loss $1,800.

Steam turbine in a paper mill—a few buckets stripped.
Direct Damage $115; Use and Occupancy loss $4,166.

Steam engine in a refinery—governor damaged.
Direct Damage $80; Use and Occupancy loss $2,200.

Horizontal tubular boiler in cannery—shell plate ruptured.
Direct Damage $223; Use and Occupancy loss $1,278.

Generator in a fibreboard plant—collector-ring leads burned.
Direct Damage $49; Use and Occupancy $5,354.

THESE are a few typical instances in which the payment for loss resulting from curtailment or complete suspension of manufacturing operations because of a power plant accident was much larger than the payment for direct property damage. Relatively minor accidents can cause expensive interruptions of production.

Today, industrial demands for power have increased, loads are larger, operating hours are longer—and there is less reserve equipment. Many contracts contain clauses exacting heavy penalties for delayed fulfillment of orders.

A manufacturing plant is but partly protected if it insures only against direct loss and not against loss of production. On power plant equipment and on other machines and pressure vessels, Use and Occupancy coverage afforded by boiler and machinery policies is an essential protection and a worth while investment.

"Inspection of Fusion Welded Vessels During Construction"

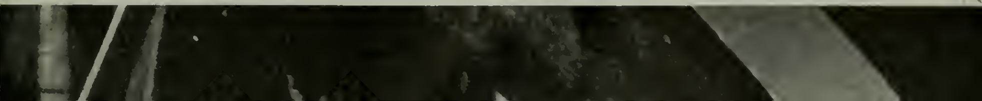
Vol. 43 No. 6 April, 1941

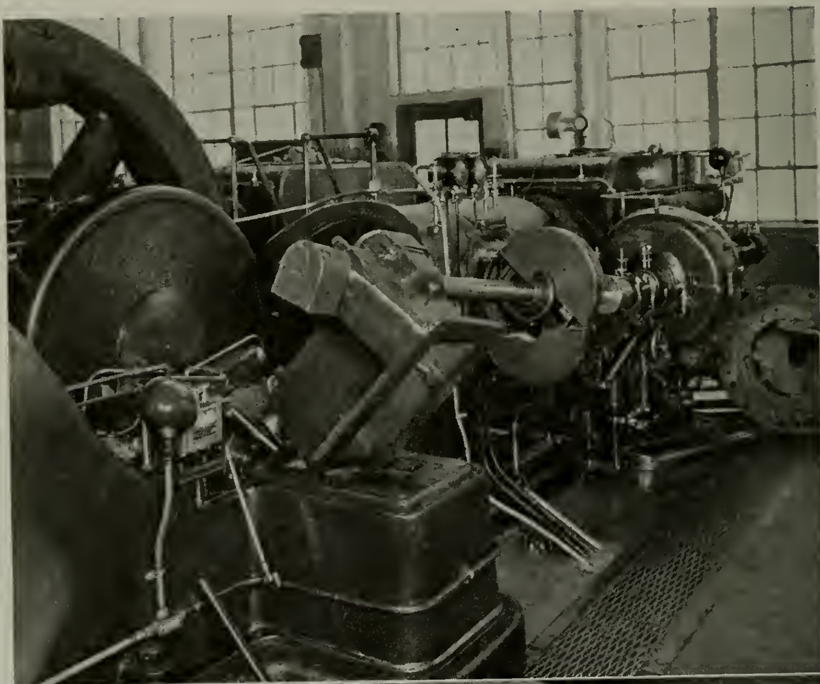
The Locomotive

The Hartford Steam Boiler Inspection and Insurance Co.

Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer





Ammonia Compressor Accident

THE top picture on Page 162 shows some of the damage to a large two-stage steam-driven ammonia compressor after the crankshaft broke. This view was taken from the low-pressure ammonia side looking toward the steam end. As shown in the photograph, the accident resulted in bending of the governor shaft, breaking of the governor gear-drive and housing, and damage to the overspeed tripping wheel which shut down the compressor when it was raised out of position. In addition, other parts not visible in the photograph were broken or damaged. Although the compressor was not insured, from information obtained it was estimated that the total cost of repairs would amount to $5,000.

Evidence obtained from an examination of the broken ends of the shaft indicated that the break had developed from a small crack starting in one side of the keyway. Progressing gradually during a considerable period of time, possibly as long as several years, the crack extended eventually nearly through the shaft and so weakened it that failure occurred while the compressor was in normal operation. As shown in the lower photograph by the rough section opposite the keyway, only a comparatively small amount of sound metal remained when the shaft broke. The dark area to the right and above the key-way shows where oil seeped into the crack and also indicates the extent of the fracture in its early development. The shaded area adjacent and above the dark section is the part of the shaft through which the crack progressed before the final separation.

Although just what caused the original crack could not be determined, it might have been due to some such abnormal operating condition as a sudden jolt or blow from water or liquid ammonia in the compressor cylinders. In this case the usual methods of detecting cracks in crankshafts (visual examination, whitewash tests or Magnaflux tests) could not have been applied without removing the crankdisc, as the crack was located inside of the disc.

An accumulation of water in the exhaust pipe loops of steam engines has resulted in several accidents through this water entering the engine cylinders. An accident of this kind is caused by the flywheel momentum continuing the engine in motion for several seconds after the throttle valve has been closed, thus creating in the cylinder a vacuum which draws the water into it. To avoid such accidents, a trap that will remove the water under all conditions of pressure or vacuum should be connected to the lowest point of the loop.

Inspection of Fusion Welded Vessels During Construction

By Inspector Carl Tyler

The use of fusion welding in the construction of pressure vessels has increased tremendously within the last few years. Today, steel boilers and tanks of all types, sizes and pressures are fabricated with welded joints. Improvement in the results obtained has increased rapidly through constant study of the engineering problems involved and through the use of standards established to overcome the faults disclosed by experience and research. The greater the care taken in following these standards the better the quality of the finished weld. However, materials, methods, designs and technique are constantly changing, thereby creating new problems for which the solutions are not always fully known. Consequently, over-confidence should be guarded against as stresses of unknown magnitude and distribution will be set up under even the most favorable conditions, and these stresses can, and often do, cause cracks which may eventually lead to a serious explosion.

Causes of Cracking

Cracks in fusion welding are caused by the weld not being free to shrink when it cools. If there were unlimited ductility in the welded joint, or if there were perfect freedom for movement when shrinkage takes place, no cracking would occur. However, in any weld the ductility is limited and there is never complete freedom of the parts being welded, so there are created stresses which may be sufficiently severe to cause cracking. Any defect in the weld or in the adjacent metal, where shrinking takes place, will increase the chances of cracking because of the highly localized stresses existing in that area. Hence, a welded seam in order to be sound and dependable must be free from defects such as excessive porosity, lack of fusion or absence of penetration of the weld into the base of the joint, and slag or dirt in either the parent or weld metal.

Occasionally cracking is caused by mishandling of material or from the methods used in construction. The manufacturer may not be equipped with the tools and means for forming plates properly. A considerable amount of stress may be set up in the rolling of a plate or in the shaping of a head flange when the metal is cold. For example, longitudinal seams in the shell of a vessel may be welded, X-rayed and found satisfactory before the heads are attached; later it may be necessary to round the shell by means of a hydraulic press and dies so that the heads will fit. This treatment produces stresses which alone or together with those created in welding, may cause cracking.

Crack Prevention

In order to overcome stresses set up by expansion and contraction there are two main precautions that may be taken—the procedure depending upon the size of the vessel, and the use and pressure for which it is being constructed. One precaution is preheating—a method used to increase the ductility of the base material and to reduce the expansion and contraction differential when the material is heated to a molten state in the welding process and then cooled. Preheating reduces the intensity of stress. With some materials preheating has an additional advantage in that it permits the avoidance of dangerous metallurgical changes which might result from a more sudden cooling of the metal from a high temperature. The other precaution is stress relieving which performs a similar function after the welding. By this method the vessel is slowly and uniformly heated to a temperature at which the metal becomes ductile, is kept at that temperature for a considerable time and then gradually cooled, thereby relieving the major portion of the localized stresses. Improvements in weld metal, whereby its ductility has been increased, also tend to reduce the hazard of cracking from localized stresses. Nevertheless, the possibility of cracking is always present, particularly with the ever growing demand for vessels constructed for higher pressures and temperatures which require both thicker metals and metals containing alloys capable of producing higher tensile strengths.

The thicker the material being welded the greater is the hazard of cracking as the rigidity and resistance to bending or distortion increases proportionately. A thick material does not distort and relieve the tremendous stresses which are set up during the process of cooling by the contraction of the metal in the welded joint. The thicker material will cool on the outside first while the thinner part will remain relatively hot, so that stresses which may cause cracking are created from this uneven contraction. For that reason stress relieving is more essential the thicker the metal being fabricated, as it provides more uniform and gradual reduction in the rate of cooling.

In order to increase the strength of vessels without using proportionally thicker metals, the trend is toward use of materials of higher tensile strength. Many of these materials contain alloying elements that may undergo severe metallurgical changes when welded. Such changes may result in brittleness or hardening of the metal in the weld or adjacent thereto, subsequently leading to the formation of cracks.

To overcome this, many vessels are preheated, the amount of preheating varying with the metallurgical composition of the metal and the mass of the object.

Methods of Testing

Fusion welded construction under the A.S.M.E. Code requires an X-ray examination of the welded seams of power boilers and unfired vessels subjected to certain classes of service, pressures or temperatures.

This means of exploring the seams for defects is very helpful but should not be considered as a guarantee that cracks are not present as the success of X-ray examinations is dependent on a number of factors. Some of these factors are the technique used in the operation of the X-ray machine, the manner of exposure, the angle the crack makes to the direction of the X-ray, the possibility of faulty practice in developing the film, or the inability to interpret correctly the condition of the weld as shown on the film.

Application of a hydrostatic test is another method of testing generally used and, in fact, is required for boilers or vessels constructed in accordance with the A.S.M.E. Code. When such a test is applied, even though no leakage is found, the seams may not be sound and free from cracks. There may be cracks which do not extend through the weld or which may be so fine that leakage cannot be detected unless the water pressure is maintained for two or three hours.

Probably the most important procedure in the prevention of explosions and failures of welded vessels are the inspections made both during construction and afterward. Knowledge of the problems of welding, the ability to find flaws or weaknesses, and experience gained from many inspections are essential requisites in finding the defects, many of which may be minute but nevertheless constitute weaknesses that might eventually bring about a serious explosion.

Illustrating detection of cracks by inspection and their probable causes, the cases in the following paragraphs of this article are from actual experiences in the examination of fusion welded vessels during construction.

Crack in Weld of 300 lb Pressure Tank

When an inspector found a crack 24″ long and about ½″ deep in a welded seam of a large tank constructed for operation at a pressure of 300 lb per sq in he undoubtedly prevented a serious explosion. Inspected while in the builder's shop, the tank was first subjected to a hydrostatic test of 450 lb and while under that pressure the seams were hammer-tested. As there was no evidence of defects or leakage, another test at 600 lb pressure was made with the same favorable results. Later, when making an internal examination the inspector found what appeared to be a notch or slight undercutting in the shell plate at the base of the fillet weld around the manhole saddle. Closer study revealed that the undercutting was considerably deeper than usual and by probing along this seam a crack extending about half-way through the 1-1/32″ plate was discovered. In all probability the defect was caused by stresses set up by the contraction of the metal when the vessel was cooling.

Defective Weld in Boiler Drum

Even though a boiler drum constructed for an operating pressure of 800 lb per sq in had been pronounced as satisfactory by the purchaser's representative after he had witnessed a hydrostatic test and made an inspection, subsequent investigation revealed a crack in the welded joint for the feedwater connection. The purchaser's inspector made his examination before the drum was dry but afterward a wet area was noted around the feedwater nozzle. This area was wiped dry but became wet again after a short time. On investigation a crack about 4½″ long and 2″ deep was discovered. By chipping out the surrounding metal the cause was found to have been slag inclusions and incomplete fusion of the metal in the welded joint together with stresses created in cooling.

Shell Seams Cracked by Mishandling

Two large shells with fusion welded longitudinal seams had been stress relieved, the welds X-rayed, completely inspected and pronounced satisfactory. No evidence of cracks or defects had been found. However, the shells were constructed with thick end flanges and it was necessary to machine these flanges with a further inspection required after the machining. Several die marks were then found in the shell plate near the longitudinal seams and further investigation of the welds revealed cracks large enough to insert the tip of a pen-knife blade. When the end flanges were machined, the shells had been found slightly out-of-round and had been forced into the proper shape by a bull-riveter. This had caused cracks to develop.

Other Cases of Cracks in Fusion Welding

One head flange of a fusion-welded grain-cooker 8′6″ in diameter, cracked when hammer-tested although it had been struck only one blow. The crack, 13′6″ long, apparently was caused by a combination of stresses created in the cold-forming of the flange when the vessel was fabricated and by the welding of the head seam.

On making inspection following completion of the welding, cracks have been found in the heads of a large number of small air tanks ranging from 10″ to 16″ in diameter. As the heads had been cold-pressed, the cracking was attributed to a combination of stresses, part from the welding and part from the punishment of the metal in the cold-forming of the heads.

Driving Motor Wrecked When Draft Fan Bursts

When a section of the shrouding broke in a 450 hp induced-draft fan for a large water tube boiler in an Ohio plant last December, the resultant unbalance in the fan set up such a terrific vibration that not only was the fan damaged beyond repair but the driving motor which was connected to the fan through a coupling was likewise wrecked. Several pieces of the fan were blown out through the stack and scattered over a wide area. One of them, weighing about 100 lb, was found on the boiler-house roof, while another somewhat smaller piece was hurled onto an adjacent railroad track. So severe was the vibration during the time the fan was wrecking itself that the concrete foundation of the unit was cracked in several places, the hold-down bolts were almost pulled out of the foundation and the cast iron pedestals and bases were broken.

Shortly before the accident an operator, in making his usual periodic inspection of the fan, had found the bearing temperatures and speed normal and had detected no unusual vibration. Fifteen minutes later, when he was in the control room, he heard a loud noise in the fan-room, four floors above, but before he could reach the control panel for the fan motors, a circuit breaker on one of them opened and cut off power to both the forced and induced draft fans for one boiler. By then, however, the damage had been done.

Normally operated at 585 rpm, the complete unit consisted of a 450 hp, 2300 volt wound-rotor induction motor coupled to an 8′7″ diameter fan, having a shaft 20′ long. The shaft was 13″ in diameter in the middle with the ends tapered down to 8″ at the bearings. The fan contained two identical blowers with a partition between them forming a part of the housing. Each blower had ten blades riveted to a cast steel spider. The arms of the spider were cast integrally with split hubs which were bolted onto the shaft. Circular shrouds reinforced by riveted steel straps, were fastened by riveted angle-irons to the edges of the blades on both sides. Constructed of 1/8″ steel plates bolted together, the housing was provided with manhole openings for cleaning and inspection purposes.

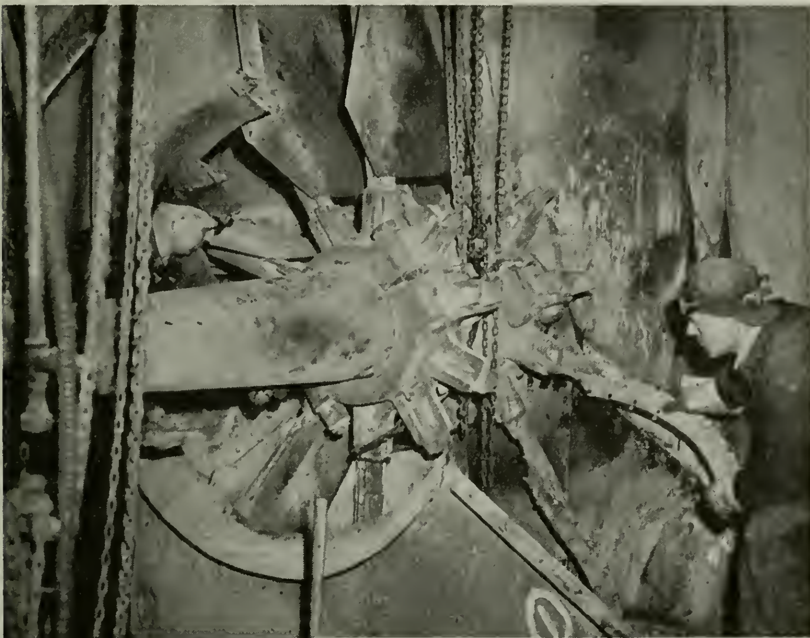


Figure 1—Part of the damage to one-half of a duplex-type induced draft fan, 450 hp capacity. Erosion of the shrouding and excessive temperature of the stack gases caused the accident.

An examination of the unit after the accident revealed that four of the ten blades in one-half of the fan had torn loose near the hubs. Taking parts of the blades and arms with it, the inside shrouding had ripped completely away from the spider. A circular gash in the center partition indicated that the center ring of shrouding had failed and torn loose from the blades before the fan disrupted completely. The breaking of this part of the fan was believed to have been the initial failure.

The principal damage to the motor consisted of breaking of both end-bells, distortion and wearing away of the iron at both ends of the rotor, and bending of the shaft. It was thought that the stator might have been thrown out of alignment by the vibration, but there was no serious impairment visible. Several wedges were charred by the friction from the rubbing of the rotor against the stator and there was damage of a minor nature to the collector rings, brush rigging and one of the band wires. Although no evidence of an electrical breakdown was found in either the stator or rotor windings, new coils would have been necessary in any event if the motor was to be repaired. As the cost would have equalled the price of a new motor, replacement was decided on rather than repairs.

All told, the expense incurred for removing the old unit, repairing the foundation and installing a new motor and fan was approximately $7500. Although the fan was not insured by a machinery insurance policy, part of this amount was recoverable under insurance on the motor.

From the findings obtained by an examination of the broken fan parts and from an investigation of operating conditions at the time of the failure, there were conclusive indications that the accident had been caused by internal erosion of the fan, together with high stack temperatures. Many of the rivet heads had been eroded extensively and the cross-section area of some of the angle-irons at the joints attaching the shrouding to the fan blades likewise had been so reduced by erosion that less than 20% of the original area remained. Normally the average stack temperature was about 550°F. but the boiler room charts indicated that these temperatures had been considerably higher prior to the failure. Further evidence of abnormally hot stack gases was obtained

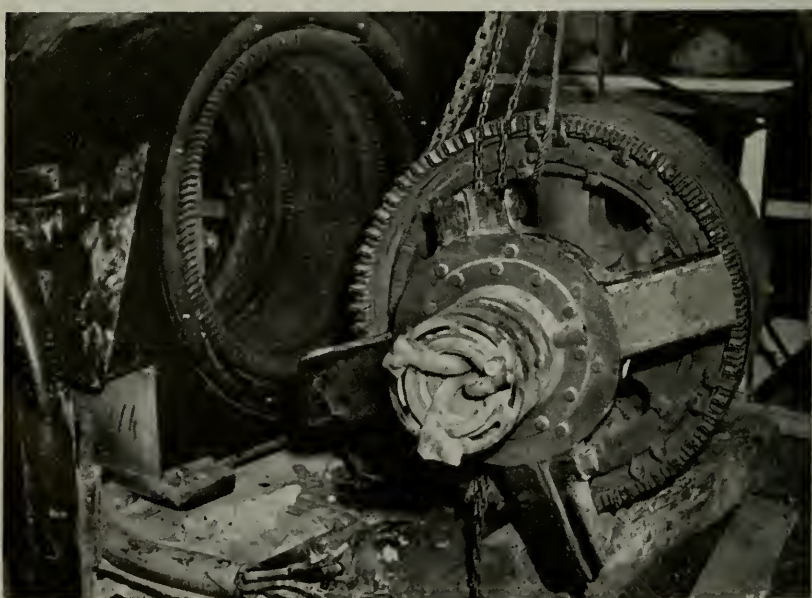


Figure 2—Connected through a coupling to the draft fan shown in Figure 1, this 450 hp wound-rotor induction motor was wrecked by the severe vibration which resulted from the disruption of the fan.

from a report that the section of the fan on the railroad track was still glowing when it was found a few minutes after the accident. In addition, the roof was burned slightly by the large section that fell on it. Undoubtedly, the eroded shrouding was further weakened by these hot gases.

In order to guard against such accidents to large fan units not only should the condition of the units be checked frequently while in operation but they should be examined internally at regular intervals. The following are some of the more important precautions which should be taken:

1. The fan unit should be examined internally at regular periods for erosion and corrosion, and for cracks, particularly in the hubs and shrouding.
2. When an internal examination is made, all parts of the fan should be looked over for an accumulation of foreign matter which might unbalance the rotor.
3. If there is excessive vibration, the cause should be definitely determined.
4. The condition of the coupling and the alignment of the unit should be checked.
5. The stack temperatures should be ascertained in order to determine whether or not they are kept within reasonable limits.
6. If the unit can overspeed, the driving machine should be equipped with overspeed protective devices and it should be determined that these devices function within safe limits of speed.
7. A check should be made of the operation of all control apparatus for the unit.
8. It should be determined that the bearings both for the driving machine and for the fan are properly lubricated and that bearing temperatures are not excessive.
9. Foundations, pedestals, bases, frames and other parts of the unit should be examined for loose bolts, cracks or any unusual conditions or defects which might cause a breakdown.

Mobile Substation

The latest means for quickly restoring power to customers in an emergency is a 1000 kva mobile substation, recently acquired by the Central New York Power Corporation. Having a total weight of almost 10 tons, including the chassis on which it is mounted, this substation can be hauled at speeds as high as 40 miles per hour. Compact size and weight were obtained by use of a forced oil cooling system. The substation consists of one 3-phase 1000 kva transformer, primary and secondary switching equipment, and lightning arrestors. One of the outstanding features of the unit is its flexibility, as it is designed for transforming power at various voltages from 11000 to 44000, to amounts varying from 230 to 4600 volts.

Edison Electric Institute Bulletin.

Several similar portable substations are now being constructed for other utility companies.—Editor.

Stalled Motor Causes Large Loss

When a 250 hp motor driving a Weiner stalled in a Southern paper mill, there followed in rapid succession a series of failures resulting in a shut down of the entire plant. In addition to the motor, three cubicle-type switchboards and a dozen sets of cables were involved. Before the plant was again back to normal production, nearly a week's output had been lost. The total cost of this accident was more than $51,000—about $45,000 for loss of production and the remainder for temporary and permanent repairs.

The first object to fail was an oil circuit breaker controlling the motor. Then the motor itself burned out. This caused a phase-to-phase short circuit across the buses on a 16 cubicle distribution switchboard on which the breaker was located. Because of the heavy flow of current through the cables supplying this switchboard, the contacts fused on an oil switch located on the main switchboard in the power plant. When the turbine operator noticed the disturbance, he opened the generator oil-circuit breakers cutting off all power and lights. Only 3 minutes elapsed between the first trouble with the motor and the time the generator breakers were opened.

Meanwhile, several sets of cables had failed and the circuit supplying current to the motor had burned out. Feeder cables from the power house to the 16 cubicle board had burned and charred for a distance of several feet starting from the short circuited buses. In addition, these same feeder cables had burned and grounded in a junction box in which there were 9 other sets of cables—four 2300 volt, four 440 volt, and a 125 volt dc circuit. All of them had burned not only in the junction box but also for a foot or two back into the conduits.

Originally the trouble was caused by the Weiner (pulp refining machine) being jammed with pulp so that the motor would not run. Instead of freeing the Weiner by using a bar or some other similar method to "back off" the rotor and loosen the pulp, an operator tried to clear the machine by manipulating the push button starter for the motor. After a short time the motor began to smoke and almost immediately an explosion occurred on the 16 cubicle switchboard. With the motor stalled, the heavy load overheated and damaged the stator windings, damaged several bars in the squirrel cage rotor, and burned and grounded the leads and cables near the motor where the insulation had been weakened by black liquor used in the paper manufacturing process. Probably initial failure in the controlling breaker was caused by the attempts to start the motor, the breaker's contacts fusing together from the heavy flow of current. Similarly the short circuit across the buses caused the accident to the oil switch on the main switchboard and the overheating and breakdown of the feeder cables.

As all production in the mill was stopped, repairing the damage as soon as possible was of primary importance. Another motor of the same size and type was available for the Weiner. Buses, circuit breakers, instrument transformers, relays and other switchboard parts either could be repaired, or replaced with equipment obtained from other switchboards or spare parts in the plant, within a comparatively short time. Although 440 volt and 125 volt cables were available, new cables for the 2300 volt circuits could not be obtained for several days. About 3000 feet of the latter size was required. New sections could be spliced in the 2300 volt circuit cables but it was agreed that making a permanent repair in that manner would not be advisable. Therefore, as an emergency measure in order to hasten resumption of production, it was decided to repair these circuits, construct overhead supports and reinstall the cables temporarily in these supports.

Approximately four days and four hours after the accident, permanent or temporary repairs had been completed. Current was turned on to the feeder lines for the 16 cubicle switchboard and immediately there was a short circuit across the buses at one point where they were supported. As with the original breakdown, the oil switch on the main switchboard did not function, the breaker opening only half way as part of the stationary and movable contacts had fused together. For this second breakdown the cause was attributed to insufficient insulation of the buses at their supports and absorption of moisture by the bus supports and insulators during the period the switchboard had not been in use.

The next day before the repairs required by this accident had been completed, there was an explosion in a cubicle of a second switchboard in the power house. This cubicle contained control equipment for a motor driving a Jordan pump. On investigation it was found that there had been a short circuit in the cable supplying current to the motor, and that the contacts on the oil circuit breaker had fused the same way the contacts had failed on the breakers involved in the two previous breakdowns. In this instance the point of failure of the cable was near the junction box in which all the cables had been damaged in the first accident. Although not running through the box, but in conduit close to it, this cable had been damaged by the tremendous heat generated by the previous cable failures.

Before all repairs were completed and the paper machines were in operation again, more than five and one-half days had elapsed. There remained, then, only the work of installing the new 2300 volt cables and of replacing parts of the switchboards which previously had not been permanently repaired. In order to complete this work it was necessary to stop production for another day and a quarter and about three weeks later, over a week-end, these repairs were finished. In the meantime, the new cables had been obtained, pulled into the conduits, and preparations made for changing over the connections at the terminals as quickly as possible.

This accident illustrated several points that are important to concerns dependent on electrical apparatus for production.

1. The widespread damage and costly delay which may result from a breakdown of even a small piece of electrical apparatus.
2. The importance of circuit breakers having ample interrupting capacity to open in case severe faults should occur in the circuits which they control.
3. The danger in an installation consisting of several circuits of different voltages in one junction box where the failure of one may seriously damage the others.
4. The importance of special attention to bus insulation in damp locations.

Crack in Turbine Disc Causes Accident

A few months ago a 23,000 kw steam turbine in a Texas utility plant was damaged when a section, about 12″ long and containing 18 blades, broke from the rim of the disc of the nineteenth stage wheel. Having a rated speed of 1800 rpm, the turbine contained twenty-three stages and was operating at a pressure of about 185 lb at the time of the accident. Figure 1, which is a view of the top-half of thirteen of the lower pressure stages, shows where the break occurred. Although the broken parts, in striking the diaphragms and blading in the remaining stages, nicked and bent some of the nozzles and blades, the defects were not sufficiently serious to require replacement of these parts. Some additional damage, however, was sustained by the turbine through the diaphragm packings becoming badly worn by the whipping action of the shaft.

When the accident occurred the turbine did not trip out automatically nor was it shut down immediately by the plant operators as they did not interpret outward evidences as indicative of such a serious internal condition. Just how long the unit was operated afterward is not known. The accident was not discovered until an operator, preparing to place

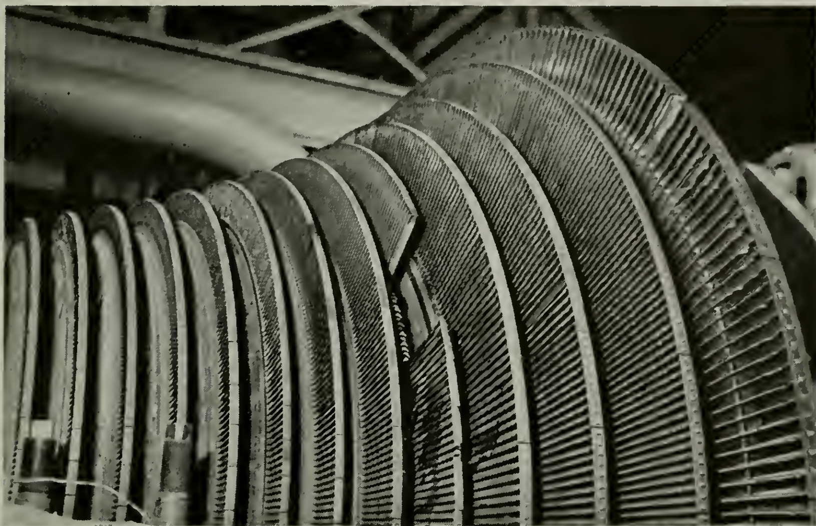


Figure 1—Part of the upper half of a 23,000 kw steam turbine showing damage to the nineteenth stage wheel when a 12″ section of the disc broke near the rim. The cause was attributed to a progressive crack.

the turbine in service after a brief shut-down, encountered difficulty in draining the hot well and found two holes in one of the condenser tubes. As the appearance of the holes led to the belief that they might have resulted from broken blading, an examination was made of the last stage wheel through the exhaust connection to the condenser. Several nicks were visible on the inlet side of the last stage blading, so it was decided to remove the casing for a complete inspection in order to determine fully the internal condition of the machine.

From the first examination, it appeared that the only repairs needed to recondition the turbine were replacement of the broken wheel and its blading, and the straightening of the damaged blades and nozzles. However, there was reason to suspect that other wheels or some of the blades, particularly in the final stages, might have been cracked by the broken parts or by the vibration which was created through operation of the turbine with an unbalanced rotor. In order to check these parts for cracks, Magnaflux tests were made of the wheels in the last thirteen stages and of the blades in the eighteenth and the last four stages. With the exception of a few small cracks in the edges of the blades no serious defects were found in any of these parts. The shaft, coupling and bearings, also inspected carefully, were found in an equally satisfactory condition.

The original point of failure occurred at the rim of the wheel in the shoulder of the groove in which the blades were fastened. Figure 2, which was taken with the aid of a mirror, gives both a top and side view of the fracture. The appearance of the broken metal indicated that part of the crack had existed for some time. Just what caused the crack originally could not be determined but as a burr was found on the dove-tail of one of the broken blades, the thought was expressed that when this blade was installed the tight fit produced sufficient wedging action to start a small crack on the inside of the shoulder. Then, progressing gradually along the rim of the wheel and through the shoulder, the crack finally so weakened the disc that it broke from centrifugal force.

This accident is a good illustration of the importance of careful observation of a turbine's vibration. When an appreciable increase is noted, the unit should be shut down immediately. In this case, through discovery of the damaged condenser tubes and the subsequent investigation, it is quite likely that a much more costly accident was avoided, for if the turbine had been operated for an appreciable time with the broken wheel, the continual vibration created by the unbalanced rotor might have caused further damage to the unit.

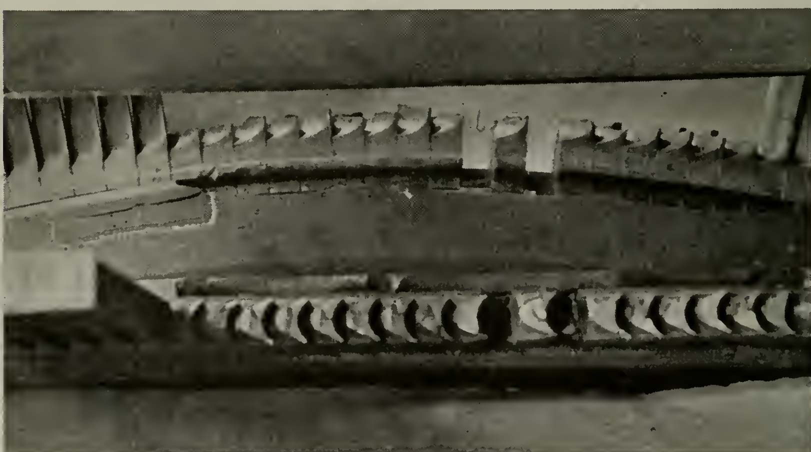


Figure 2—Taken with the aid of a mirror, this picture gives a close-up view of both the top and one side of the broken section in the turbine rotor shown in Figure 1.

An optimist is a man who can walk to work just as cheerfully as if he were chasing a golf ball on the links. *Valve World.*

Twenty Explosions During Recent Months Cause 77 Casualties—23 Killed and 54 Injured

Although there is no way of knowing of all explosions which have occurred during recent months to fire tube boilers operated at steam pressures over 15 lb per sq in, information about several such explosions has been obtained from various sources. Few, if any, of the boilers were insured and the majority of them did not receive the benefits of regular inspections.

As owners and operators have become enlightened about the potential hazards in the operation of high pressure boilers and have taken precautions to prevent accidents, disastrous explosions have become less frequent. The number of spectacular accidents in which the boilers have skyrocketed and have caused several casualties as well as large property damage losses, seem to be fewer each year. Undoubtedly much of this improvement can be credited both to more intelligent care and operation, and to a greater realization by a larger number of owners of the value of frequent and thorough examinations of their boilers by qualified inspectors.

There are some owners and operators, however, who are inclined to believe that as long as a boiler looks all right, has a safety valve, and generates steam at the required pressure, it is safe. But sometimes safety valves stick, are of too small capacity, or are ineffective for some other reason. Moreover, even though a safety valve is satisfactory, serious structural weaknesses in a boiler can cause it to explode while under a pressure well below that at which the valve is set.

Some of the information about the explosions described in the following paragraphs was obtained from reports of investigations made by our inspectors, while other material was taken from statements given in news accounts. In all but four of the explosions, personal injuries were involved.

Disastrous Accident from Hidden Crack

An explosion of a locomotive fire box boiler last July in a Missouri mill was the most disastrous of these accidents. Occurring during the noon hour while the mill operators were eating their lunch near-by, the explosion killed three men and injured twelve others, eight of them seriously. One news report stated that parts of the boiler were hurled 1000′ and that the blast was felt five miles away. Estimated as thirty-five years old, the boiler was 36″ in diameter and constructed of 3/8″ plate with double-riveted lap-seams. The safety valve was reported to have

Figure 1—A crack in a longitudinal lap-seam caused the explosion of this boiler. Three men were killed and twelve others injured, eight of them seriously.

been set at 140 lb. From an examination of the wreckage the cause was definitely established as a crack in a longitudinal lap-seam, the crack extending for a distance of several feet along the hidden surface of the outside plate. Figure 1 shows a part of the boiler 400′ from its original setting. The sheet in the left foreground is the one in which the initial failure occurred.

A method of finding cracks in double-riveted lap-seams has been in use for more than twenty-five years. By this method a few slots are cut about two-thirds through the outside plate of the lap at right angles and opposite to the edge of the inside lap. If leakage develops through these slots when a hydrostatic test is applied, it is an indication that a dangerous condition exists. This accident is a good example of the value of this type of inspection, for the defect had extended nearly through the plate and if slots had been cut, the seriousness of the defect would have been readily apparent. This case shows also the fallacy in considering an old boiler safe even though no serious defects are visible. In general, an old boiler should not be considered as dependable as a new one.

Another mill boiler explosion, occurring last October in North Carolina, resulted in the death of three people. Information on the cause was not obtained but it was reported that the boiler was an old one.

In two other boiler explosions, one in a Mississippi factory and the other in an Alabama mill, four persons were killed and nine injured.

Low Water Cause of Several Explosions

Five of the boilers that exploded were locomotive fire box boilers operating oil-well drilling rigs. Four persons were killed and eight others

(Continued on Page 182)

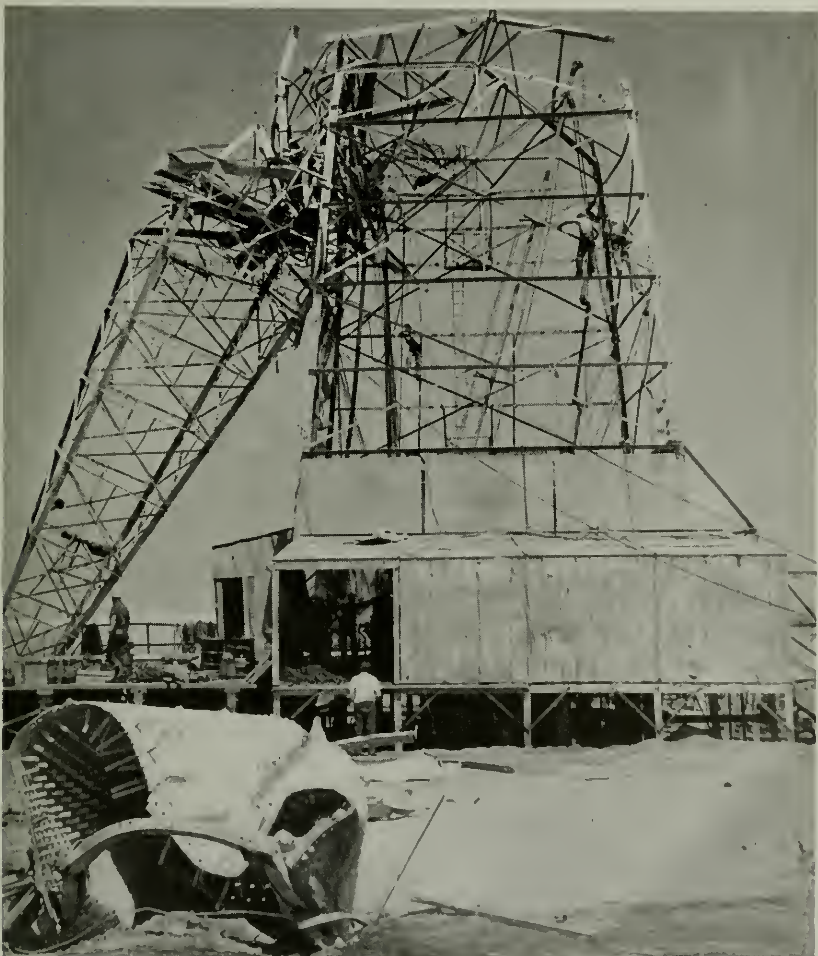


Figure 2—Derrick in an oil field wrecked by an explosion of an oil-well drilling boiler which was located a quarter of a mile away. The boiler's fire box that crashed into the derrick is shown in the foreground.

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

WALLACE H. HENSHAW, *Editor*

HARTFORD, CONN., April, 1941

Single copies may be obtained free by calling at any of the Company's offices.
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each.

William R. Lewis

William R. Lewis, a veteran inspector in the Atlanta department, died suddenly in Knoxville, Tennessee, February 26, 1941. He had been located in Knoxville during most of his 34 years of continuous service with the Company which he joined in September 1906, at St. Louis. Previously Mr. Lewis had been a marine engineer and Chief Engineer of a U. S. Quartermaster's Depot in Indiana. He was born in Louisville, Kentucky, November 29, 1875.

Possessing a congenial personality, Bill Lewis was widely known throughout the southern territory. His friendship and wise counsel were valued highly by his associates and by the many others with whom he was acquainted and with whom his work brought him in contact.

THE COVER

This photograph shows an inspector checking the connecting rod and crosshead in a vertical steam engine. Many engine accidents have been prevented through discovery of cracks or other weaknesses in these parts.

Agency Department Changes

LYMAN B. BRAINERD

GEORGE H. PRALL

On March 18 the Company was pleased to announce the appointments of Mr. George H. Prall as Agency Secretary and of Mr. Lyman B. Brainerd as Superintendent of Agencies. Having served capably in the agency department for several years, both men have demonstrated that they possess the ability to undertake successfully increased responsibilities in the supervision of the Company's branch offices and in the handling of agency and business production problems.

Following his graduation from Rutgers College in 1919, Mr. Prall was engaged in engineering and newspaper work before he joined the Company in January, 1928 as Editor of The Locomotive. He was made Assistant Superintendent of Agencies in July, 1935 and Superintendent of Agencies in March, 1937.

Mr. Brainerd has been associated with the Company since he was graduated from Trinity College in 1930. Working first in the underwriting and claim departments, he then became a Special Agent in the territory of the Hartford department and was appointed Assistant Superintendent of Agencies in March, 1937.

Addendum

In the last issue there was described a severe accident resulting from failure of a boiler in what was referred to as a high school in Cleveland. The school was privately controlled and not under the jurisdiction of the city's Board of Education.

(Continued from Page 179)

were injured by these accidents. Only limited data was obtained but for each of the explosions the opinion was expressed that low water had caused overheating and failure of the crown sheets. Scale may have been a contributing factor, however, for in oil fields, a poor quality feedwater is often used; in fact, in many districts a poor quality water is the rule rather than the exception. In many oil-well drilling boilers, especially those operated at more than 300 lb pressure, water is evaporated at a high rate. Consequently, both the water level and the gage-glass connections should be checked and tested frequently, a duty which attendants often neglect under the press of other work.

In most cases the property damage caused by explosions of oil-well drilling boilers is limited to the boiler itself, or to other boilers and equipment used in that drilling operation, as the power plant is in the open and usually located a considerable distance from other property. An explosion a few months ago, however, in a California oil field was unique in this respect in that the boiler was blown through the air a quarter of a mile where it crashed through a derrick of another drilling contractor. The wrecked derrick and the fire box section of the boiler which did the damage are shown in Figure 2 on Page 179.

Fire tube boilers on track locomotives were also the source of five other explosions. Four of the locomotives were hauling freight trains and the fifth a passenger train which, fortunately, was empty at the time of the accident and was barely moving as it was entering the railroad

Figure 3—Weighing more than 40 tons, this track locomotive boiler was hurled 500′ when low water caused failure of the crown sheet.

yards at Denver. A news account of this latter explosion stated that the boiler and cab were lifted from the undercarriage, hurled 60′ in the air and thrown upside down on an empty railway express car over 200′ away. It was reported also that at least twenty-two persons were injured, some of them seriously. In the four freight train explosions, eight trainmen were killed and two injured. News reports on most of these accidents indicated that they involved failure of the crown sheets because of low water. Figure 3, showing one of the freight train locomotives, was taken after the heavy boiler had been torn from the running gear and hurled 500′ by the force of the explosion. As shown in the picture the failure occurred in the fire box.

A Welding Failure

A Missouri plant was damaged in an amount approximating $2,000 by an explosion of a 48″ horizontal tubular boiler which was hurled 20′ from its setting, the explosion destroying completely the concrete block room where it was installed. The failure was caused by corrosion of one of the tube sheets over a large area, especially around the manhole opening. At some previous time an attempt had been made to restore the sheet to its original thickness by fusion welding but the work was poorly done. Furthermore, in this instance, welding was contrary to good engineering practice because of the extent and depth of the corrosion.

Last June a Spokane, Washington, newspaper contained a story about a boiler explosion in a mill located in a near-by town. According to the account, the three-story building was wrecked and the boiler was blown several feet into the air and into an adjacent street. Damage to the plant was estimated at $3,000.

Using Hot Water Heater as a Steam Boiler Proves Costly

An explosion last January in a South Carolina cleaning establishment resulted from operating a boiler at a pressure and in a service for which it was not designed. Causing property damage estimated at $500, the explosion broke several plate glass windows, tore a hole through a concrete floor and started a fire. The boiler was constructed originally as a hot water heater for 60 lb pressure but subsequently it was acquired by a second hand dealer who installed a gage glass and then sold it to the cleaning company as a steam boiler. About a year previous to the accident, the boiler had been offered for insurance and declined.

Another Explosion from a Hidden Crack

A small vertical flueless boiler only 20″ in diameter and 57″ high, blew up early this year in a Virginia laundry. The boiler went through

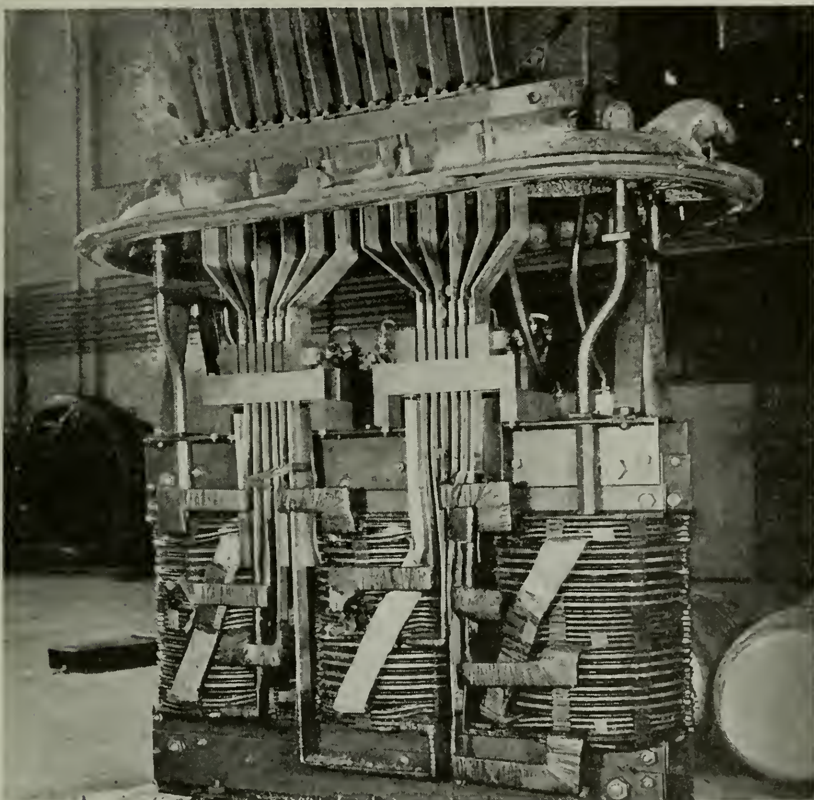
Figure 4—Part of the damage to a laundry building caused by an explosion of a small vertical flueless boiler.

the roof of the laundry building, sailed over an alley and an adjacent two-story building, and landed in a yard a half block away. Part of the wreckage is shown in Figure 4.

Although the boiler was not insured, an investigation was made by an inspector who was in the vicinity when the accident occurred. He found that the entire cone in the top of the furnace had collapsed and that the initial failure took place along the longitudinal lap-seam in the cone, this seam having been weakened by a crack about 2′ long. In addition, he found that a crack had extended around the entire circumference of the cone head-seam and that the furnace sheet had cracked for a short distance at the edge of the mud ring opposite the fire door. In several places the furnace sheet and the cone had been pitted and corroded half way through the metal. Even with all these defects, however, at no point in the boiler had they made themselves evident through leakage.

Small boilers also were involved in two other accidents. In one a boy was fatally burned by steam when a miniature boiler, operated without a safety valve, exploded in a tailor shop. In the other a small gasoline fired steamer, used for removing wall paper, exploded and severely burned the operator.

Transformer Burnout



View of a three-phase, 800 kv-a transformer, removed from its casing for an examination after it had failed to operate. The source of trouble was readily determined, for as shown in the photograph the short-circuited coils in the center phase were plainly visible. Further investigation revealed that several high-tension windings had burned through completely and a number of secondary coils had been damaged as well. Intermittent excessive overloads which produced both severe mechanical stresses between the windings and excessive heating were believed to have been the cause. The cost of repairs to the transformer was about $1,900 although production loss and extra expense incurred for a temporary transformer while repairs were being made exceeded $12,000.

Taps From the Old Chief's Hammer

"TOM, I'd like you to review this application for Use and Occupancy coverage on the Chester Manufacturing Company plant and let me know whether you think we should take it," said the Old Chief.

"I've already studied it and I think we should," Tom replied. "We've insured their boilers and turbines for direct damage for several years and our experience has been good. They have a capable chief engineer who has been there a long time, and our recommendations have always been complied with promptly. The main hazard from a U. & O. standpoint, it seems to me, is the lack of spare equipment. If either turbine should break down or if a tube should rupture in one of the water tube boilers, production would likely be reduced fifty per cent. In Mac's report, he says the power plant is being pushed pretty hard at present but that plans have already been made to install an additional boiler and turbine during the next year."

"I agree with what you say, Tom," countered the Chief, "but we should consider the risk from all angles, especially with a U. & O. exposure as large as $5,000 a day. Here's a plant that has orders ahead for several months and very probably will continue at capacity production for a long time. They are operating twenty-four hours a day and six days a week, which doesn't give them the time they had formerly during low-load periods, nights and long weekends for cleaning, repairs and maintenance work. With the added power plant capacity they are planning, plus the other favorable points, I'd say the risk could be considered an average one, but at present the exposure is somewhat more than average."

"Why do you think they have ordered U. & O. coverage now?" asked Tom. "A year ago they decided not to buy it."

"One reason, and probably the main one, is their increased production. A serious breakdown in their power plant might mean a total shut-down, while an accident to any one of their main units would certainly cause a substantial reduction in output as well as delay in fulfilling orders. Another reason is the difficulty likely to be encountered in obtaining parts in the event of an accident."

"According to Mac's report, Chief, the local power company has a substation only a block from the plant. He says power could be obtained from that source, if necessary. The substation has sufficient reserve capacity at present to carry fifty per cent of the load."

"Undoubtedly by purchasing outside power, if it was available, the plant could continue part, if not all, of its production," continued the older man. "Nevertheless, the extra expense of a temporary hook-up plus the cost of the purchased power, can be considerable. Did you hear about that case up in Boston a few months ago, when a transformer burned out in a foundry and practically stopped the plant?"

"I heard some of the story but not all the details," answered Tom. "Wasn't that the case where a spare transformer was found somewhere out West and special arrangements were made for shipping it to Boston?"

"That's right, Tom, but this wasn't an ordinary transformer. It was one of a special type, of 800 kw capacity and used to supply current for an electric furnace. When it failed, the foundry was operating two shifts a day with plenty of orders ahead. These orders were for valued customers so naturally the owner wanted to make deliveries on time to retain their good will and obtain their future business. Although our policy covered U. & O. in an amount of $1,000 a day for a total shut-down, that wouldn't have reimbursed the owner for loss of future business because of dissatisfied customers, if he had failed on these orders."

"Wasn't there another transformer near-by that could have been rented?" interrupted Tom.

"Unfortunately, there was none available. To remove the transformer, have the manufacturer make new coils, and then rewind and reinstall it would have taken at least three weeks. In discussing the situation with the owner and the furnace manufacturer, we learned of three transformers that might be suitable. Two were in Pittsburgh and the other one was in Toledo.

"Immediately through our local inspection departments for those cities the condition and characteristics of the transformers were determined and the owners interviewed with reference to renting them. As the one in Toledo was the most suitable, our Detroit office was instructed to make the necessary arrangements with the owner and the railroad for shipping it as soon as possible. This required careful planning because the transformer weighed about 18 tons and was so high that a special car was required in order to clear tunnels and bridges. In fact, a route had to be laid out that would assure its getting through without delay.

"But that wasn't all the planning necessary. Dimensions and sketches of the transformer and diagrams of the electrical connections were needed in Boston so that everything would be prepared for the installation and hook-up as soon as the transformer arrived. By having our staff out there obtain that data before it was shipped, our people in Boston received the information in ample time to complete that part of the work before the transformer reached the plant."

"It sounds simple enough," put in Tom, as the Chief paused, "but I'll bet there were plenty of headaches before the job was completed."

"You're right about that, Tom. All along the route we had our men located at railroad junction points to see that the car was not side-tracked nor delayed unnecessarily. And it was fortunate we planned to follow the shipment so closely, for shortly after the car left Toledo it developed a defective air-hose and had to be cut from the train. Through the insistence of our man who was following its progress, repairs were made so quickly that the car was picked up by the next train.

"No further delays were encountered, except a short one at one junction in New York State, until the car reached Fitchburg. It arrived at 1:00 A.M. and normally it would have stayed there until late evening of the same day. But this delay of a day's time would have prolonged the shut-down of the plant at least one day and possibly longer, as the power company had a requirement that the transformer would have to be put on the line shortly after a midnight when their load was light and when the circuit could be isolated and fed from one generator. When our men in Boston heard this, they immediately chartered a special locomotive and crew and were able to have the transformer in place, connected up and on the line shortly after midnight of that same day."

"How long after the accident, Chief, before the plant was back to normal production?" questioned Tom.

"About four days," the older man answered. "By the way, there was another interesting incident about this case I almost forgot to mention. In order to make the proper adjustments to the furnace controls so as to adapt the transformer to its new requirements, we needed an installation engineer from the furnace manufacturer. The nearest man available was working on an installation in the eastern part of the province of Quebec and as soon as he could arrange to leave there, he drove to a town in the upper part of Vermont where he was met by a plane and flown to Boston."

"All this extra expense must have been costly," commented Tom, "but I presume the saving in the amount of the production loss was substantial considering there was a difference of approximately two weeks between the time required to put in the temporary transformer and the probable time for repairs."

"Yes, it was," added the Chief. "The total loss was about $12,000. If we hadn't arranged for the temporary transformer, our payment probably would have been twice that amount to say nothing of the future loss the owner might have sustained because of the delay.

"So you see, Tom, there are a number of points to be considered when we review an application for U. & O. While a plant may believe it is adequately prepared to avoid a shut-down if a breakdown should occur, it isn't always possible to obtain spare equipment, new parts, other power or have repairs made as quickly as planned, especially today when production in so many concerns is continually increasing."

Points for the Operator

Operating temperatures in steam turbines having cast iron casings should not exceed 450°F. as cast iron is not suitable for higher temperatures.

When a water tube boiler, having water walls, is under load it should not be blown down through a water-wall header. If this is done, some of the water-wall tubes, and possibly other tubes as well, are likely to be damaged by overheating through disturbance of the water circulation in the boiler.

As the temperature and pressure cut-outs on a compression type refrigerating system are intended to protect the compressor cylinder, they should be located in the discharge line between the compressor and the shut-off valve.

Something More to Worry About

A Russian physicist calculates that the sun will give off increasing light until after 10,000,000,000 A.D., at which time it will be 100 times as great as at present, and then it will rapidly contract and give off less light.

Freshman: "Mr. Brown, is water-works all one word, or do you spell it with a hydrant in the middle?" *Powerfax.*

No need to wonder why they call a locomotive "she." "She" wears a jacket with yoke, pins, hangers, straps, and stays. "She" has an apron, also a lap; and not only pumps and hose but even shoes. "She" surmounts great obstacles but sometimes jumps the track at the slightest provocation. *U. S. Steel News.*

Patron: "May I have some stationery?"
Hotel Clerk (haughtily): "Are you a guest of the house?"
Patron: "Heck, no! I'm paying $20 a day!" *Trumbull Cheer.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONNECTICUT

December 31, 1940 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,246,498.78
Premiums in course of collection (since October 1, 1940)		906,526.27
Interest accrued on bonds and mortgages		76,117.15
Mortgage loans		108,781.50
Home Office and Philadelphia branch office real estate		642,331.05
Other real estate		292,114.84
Other admitted assets		13,715.92
Bonds on an amortized basis	$9,201,193.59	
Stocks at market value	8,342,441.50	
		17,543,635.09
Total		$20,829,720.60

LIABILITIES

Unearned premium reserve		$8,738,617.66
Losses in process of adjustment		317,499.96
Commissions reserve		181,305.25
Taxes reserve		250,000.00
Other liabilities		313,596.90
Liabilities other than capital		$9,801,019.77
Capital stock	$3,000,000.00	
Surplus over all liabilities	8,028,700.83	
Surplus to Policyholders		**11,028,700.83**
Total		$20,829,720.60

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Incorporated 1866 *Charter Perpetual*

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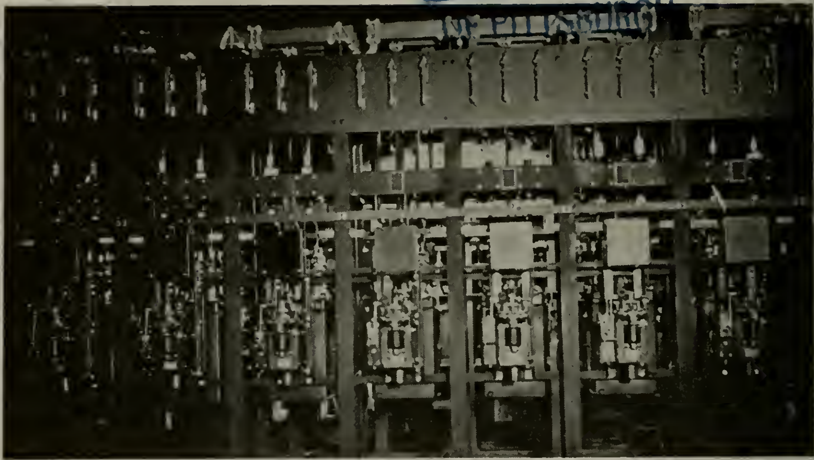


Production Stops When Switchboards Fail

BELOW are a few actual losses indicating some of the many accidents that can happen to switchboards. In all these cases, production was curtailed for a number of hours or for several days. Through failure of only a small part, buses may be short-circuited and a plant's entire output stopped.

Switchboards are the nerve centers for power control and distribution—vital links in the systems for delivering electric energy to machines on which production depends.

A machinery insurance policy affording Direct and Use and Occupancy coverages on switchboards and other electrical machinery, provides essential protection against production "bottlenecks" caused by accidents to such equipment.

Burnout of a circuit breaker in a paper mill.
Direct Damage $494; Use and Occupancy loss $1,432.

Short circuit across 2,300 volt buses in a chemical plant.
Direct Damage $620; Use and Occupancy loss $2,241.

New switchboard destroyed by arcing—textile plant.
Direct Damage $4,967; Use and Occupancy loss $492.

Circuit breaker tripping device failed in paper bag factory.
Direct Damage $23; Use and Occupancy loss $3,992.

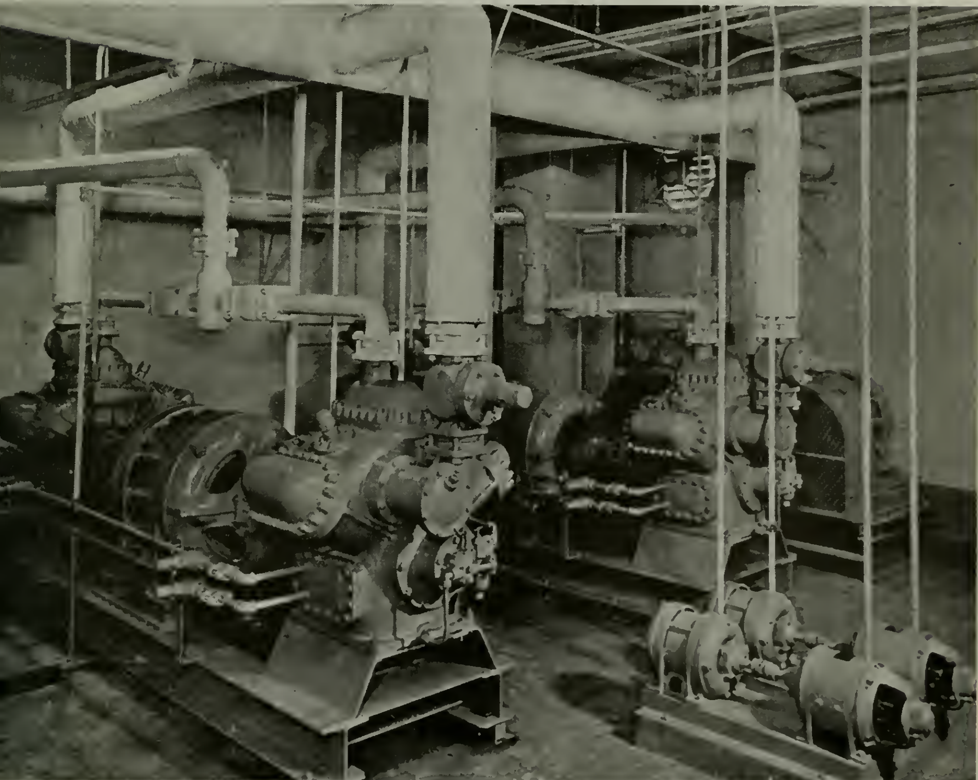
Accident to a disconnect switch in a cotton mill.
Direct Damage $300; Use and Occupancy loss $1,000.

"Power Equipment Accidents and Their Relation To National Defense"

Vol. 43 No. 7 July, 1941

The Locomotive

THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE CO.



Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

A Boiler Explosion Caused this Wreckage

Two Boiler Catastrophes

Last February an explosion of a stationary locomotive-type boiler at a roundhouse in Minnesota killed three railroad employes and injured a fourth seriously. All four men were in a boiler house adjacent to one end of the roundhouse building when the accident occurred. An eight-stall section of the roundhouse and the boiler house, both of brick and wooden frame construction, were demolished. The pictures on the opposite page, taken at the scene of the disaster, indicate graphically some of the havoc which resulted from this explosion.

The photograph in Figure 1, giving a general view of the wreckage, was made as a search of the debris for the missing workmen was being started. Of the several parts of the disrupted boiler and stack shown in Figure 2, the flat sheet in the center is the manhole course in which the initial point of failure is believed to have occurred. The tubes, steam dome and the wrapper sheet are shown in Figures 3, 4 and 5, respectively. All these and other parts of the boiler were scattered over a wide area. Figure 6 shows another boiler of the same size and type, which was also in operation, where it was thrown by the concussion, 60′ from its setting. Several automobiles in the roundhouse were damaged, a wooden coal bin was wrecked, and various other pieces of equipment such as a feed-water heater, an air receiver, two feed pumps, piping and wiring were destroyed. In addition, stained glass windows were broken in two churches, as also were a number of windows in residences, all several blocks away.

Although a complete investigation was made in an attempt to determine the exact sequence of events which brought about the explosion, the definite cause remains largely a mystery. The boiler had been shut down a few days previously for cleaning, inspection and repairs, and apparently it had not been fired again until about two and one-half hours before it blew up. Information could not be obtained from the operators who may have known what happened, as unfortunately they were killed, but from an examination of the shattered parts of the boiler, the conclusion was reached that over pressure was the probable cause.

Approved pressure for the boiler was 110 lb and the safety valve was stated to have been set at about 100 lb. However, when the safety valve was tested after the accident, it did not open until a pressure of 250 lb had been reached. Moreover, the main-steam stop-valve for the boiler was reported as having been closed, indicating that there had been no outlet for the steam as it was generated. In this type of boiler a common cause of explosions is overheating and failure of the crown sheet from low water, but in this case no evidence was revealed by the investigation to support an opinion that the accident was brought about by a low-water condition, nor was there any evidence to indicate that the boiler contained any weakness which might have led to its failure.

The entire property damage loss was estimated at $30,000, including the damage to property of others.

Another boiler explosion last April at a California creamery and cold storage plant was also violent and spectacular but fortunately no one was injured and the resultant property damage was not as large as in the Minnesota disaster. The accompanying picture shows the wrecked boiler room which was in a small building attached to the main plant. Also erected at the side of the main building and demolished was a cooling tower for a refrigerating system and part of the wreckage shown came from the collapse of this tower. It was located to the left and in back of the car which is visible in the lower right-hand corner.

Installed parallel to the side of the main plant, the boiler was blown backward about 40′, the stack falling forward and crushing the cooling

Damage at a creamery and cold storage plant caused by a boiler explosion as a result of low water which, in turn, was attributed to failure of automatic controls. The furnace in the boiler overheated, collapsed and ruptured. Property loss was nearly $5,900.

tower. Three automobiles in the yard or nearby were also damaged by the accident. Some of the fire bricks of a Dutch-oven extension to the boiler furnace were blown through the walls of the owner's office, located in a separate building 200′ away. Amounting to nearly $5,900, the loss included approximately $4,300 for damage to property of the owners while the remainder was the extent of the damage to other property.

The boiler in which this disaster occurred was of the Scotch-marine type, 78″ in diameter, with its safety valve set at 92 lb. At the time of the accident gas fuel was being used although the boiler was equipped to burn either gas or oil fuel. Operation was entirely automatic, as controls were provided for regulating the feed-water supply, the damper and the burner. Furthermore, it was reported that the boiler was checked about once an hour when the plant was in operation.

In this case the cause of the explosion was definitely determined, for as a result of low water the furnace had overheated, collapsed and ruptured. The exact cause of failure in the automatic controls was not established as all fittings, attachments and other equipment connected to the boiler, except the safety valve, were so badly damaged that any conclusions reached, even after a careful examination had been made of these parts, would not have been reliable. Actually lack of proper testing and servicing of the controls might more appropriately have been stated as the real cause.

This accident illustrates that automatic controls are fallible and need to be tested regularly. This should be done even though an attendant is on duty to check the boiler at frequent intervals.

Sabotage Claimed Reason For Breakdown

Gravel or emery dust mysteriously dumped into the main bearings of a large steam engine-generator set caused a shutdown of the power plant for a large manufacturing plant in Ohio last April, according to a local news report. The president of the factory expressed the belief that the breakdown was due to sabotage. All production was stopped for one day while repairs were being completed. The estimated loss was given as $3,600.

New Transformer-Core Steel

The developers of a new type of transformer-core steel, known as Hipersil, state that it has one-third greater flux-carrying capacity than the best silicon steel; and that it requires no more magnetizing force for carrying the increased flux—nor is the flux loss greater—than for ordinary transformer steel. In the distribution transformers in which Hipersil has been used, size and weight are reported to have been reduced as much as 25% and copper losses by 10%.

Metals and Alloys.

Power Equipment Accidents and Their Relation to National Defense

At the present time industry is producing goods at a rate which probably exceeds all past production records in this country, and even now it is unlikely that the peak has as yet been reached. Not only has there been a greatly accelerated output in plants making war materials, and in those engaged in other national defense work, but there has also been a big increase in output in other industries. Nearly all industrial plants, large and small, and in almost every line of business, are being affected either directly or indirectly by the present activity in the manufacturing and operating fields.

For these concerns to fulfill successfully the demands placed on them, both for materials and goods relating to national defense and for other products for which consumption is constantly increasing, adequate supplies of materials, labor and power are essential. Much has been written in magazines and in the daily press on the problem of obtaining sufficient materials and labor, particularly skilled labor, but perhaps not so much thought has been given nor concern felt about the third essential —namely, that of sufficient power to meet all requirements in an emergency arising from failure of important power equipment. The reliable performance of equipment used for generating, distributing, converting and utilizing power is of vital importance to all manufacturing plants, for every one of them requires power in one form or another, whether it be steam, water, electric power or power in some other form.

The purpose of this article is to point out and discuss some of the problems confronting manufacturers by reason of their generation and use of power rather than to discuss the adequacy of the power available in public and privately owned central stations. Owners appreciate that if a boiler explodes and wrecks a plant, production stops—probably for a long time. This is also true of an explosion of other power units such as turbines and engine flywheels. But there are many other types of power equipment which are subject to a wide variety of accidents that might badly cripple a plant's production if they failed. Various unfired pressure vessels, air and other types of compressors, large motors or those having special characteristics, motor-generator sets, switchboards and bus structures, transformers, power plant auxiliary units such as steam and motor driven pumps and fans and, in fact, any key machines come within this classification.

Doubtless most owners and plant engineers have considered what could be done to restore production as quickly as possible if an accident occurred. Every plant should consider these probabilities, for it is better to prepare for any eventuality before an accident occurs rather than afterward. In every plant a study should be made to determine what the effect would be on plant production if a boiler, pressure vessel, machine or other piece of equipment should fail. This study should start with the boilers, turbines, engines, or transformers from which the power for a plant originates, and go right down through the machines that utilize the power. Under present conditions, it is quite likely that any previous analysis or survey along this line may need revising, as extra or reserve equipment, formerly satisfactory for use in an emergency, may not now be suitable or available. Furthermore, while it might have been possible before to obtain a new part, or a new vessel or machine within a short time, the same prompt delivery today is in most cases impossible. Neither can a plant depend upon obtaining readily suitable secondhand equipment, for much of it has already been returned to service, due to the inability of owners to obtain new.

The longer operating hours under which plants are now running will undoubtedly in time bring about a higher accident frequency and, as respects interruption of production, there will be even larger losses or longer outages than before because of difficulty encountered in securing repairs or replacements promptly and because of a shortage of skilled labor which many repair jobs require. The operation of a plant for twenty-four hours per day instead of eight hours per day and six or seven days per week instead of five days per week, is not necessarily in itself a condition that will cause more accidents, although depreciation from normal wear and tear will be faster because of greater use. Rather, the principal cause for a greater number of accidents with longer operating hours, will come from the fact that under those conditions the operators do not have the time to carry out a proper maintenance program. A defect or weakness which previously might have been discovered and corrected during shut-down periods is not detected, with the result that the condition becomes more serious, eventually leading to an explosion or breakdown. Therefore, plant managers, plant engineers, plant operators and others responsible for production should give thought to ways and means of providing their equipment with the essential maintenance that it needs. Moreover. particular attention should be given to any unusual operating noise, vibration or other sub-standard condition, and arrangements should be made to investigate the cause and eliminate the trouble promptly even though it may occasion some temporary inconvenience and possibly some relatively slight delay in plant output. Otherwise, there may be an accident for which the cost measured in terms of lost production will exceed by far any loss resulting from the delay needed to correct the trouble.

With a scarcity of trained men and with a greater demand for them because so many plants are now running two and three shifts per day, many factories are compelled to employ operators who are not experienced and who are not immediately competent to take the responsibility which the work requires. Each new operator should receive a painstaking training and his work should be carefully supervised until he has obtained a thorough instruction and knowledge of his duties. With the present activity in many plants, this may seem to be a difficult task, but such training will pay worth while dividends, for experience has shown that many accidents have been caused by operating mistakes, carelessness, and neglect—accidents that need not have happened if operators had been properly trained and capable of recognizing signs of trouble in time to take the necessary steps to prevent a breakdown. As a matter of fact, operating errors are among the principal causes of accidents. In a recent example, an attempt was made to start a stalled motor by repeatedly manipulating the push-button control. The result was not only the overheating and burning out of the motor but also a series of short circuits on a main switchboard and on two distribution switchboards, and the destruction of several cables. The total cost of this mistake was about $51,000, including the value of approximately a week's loss of production. The motor had stalled when material jammed in a machine it was driving, and the operator should have looked for and found this jam when his first attempt failed to start the motor.

Although no automatic protective device or control can be considered a definite guarantee against an accident, many of these devices would be particularly valuable today as additional safeguards. Plants that heretofore may have thought of some of them as unnecessary, may now favor their installation, first as a means of offsetting increased hazards because of longer operating hours and because of insufficient time for the operators to give the equipment as close attention as before, and secondly as a precautionary measure to guard against mistakes of inexperienced operators.

Plants having old boilers, turbines, engines, generators and other spare machinery for standby or emergency use should make certain that it is in satisfactory and dependable condition. Many of the machines should be given a dismantled inspection and quite likely much of this equipment needs a thorough overhauling. Any worn or defective parts should be replaced. For electrical apparatus on which tests of the windings show low insulation resistance, the dielectric strength of the insulation should be built up to accepted standards. Some machines having old windings on which the insulation is brittle and unreliable may require complete rewinding to be made dependable for reserve use. Expense of rewinding probably would be small compared to the production loss that might result if an old generator, motor or transformer failed when placed in service.

Another precaution which should be taken to reduce lost time from boiler and machinery outages is that of keeping on hand an adequate supply of spare parts. Both a larger number of parts and a greater variety should be readily available as they might be difficult to obtain quickly when needed. This applies especially to parts that have failed most frequently in the past and other parts that are known to be likely to fail from normal wear, fatigue or any other reason. Some of these are tubes for boilers and condensers; coils for tanks; gears; parts of governor and valve mechanisms for turbines, engines and compressors; coils for generators, motors and other electrical machines; and bearings for all types of machinery.

Whenever a sub-standard condition is found it should be corrected promptly; otherwise, it may be the cause of an accident or it may lead to the scrapping of equipment before its useful life should have been completed. Even though a plant may have a priority rating, if parts, materials and machinery requiring replacement are not available, production will be curtailed. In other plants engaged in manufacturing articles not essential to national defense, several months may be required to obtain new equipment. What might happen if such a factory were crippled by an accident was illustrated a few months ago when a small plant was badly damaged by fire. As its operation was dependent on certain machine tools which were destroyed, new equipment was ordered but it could not be obtained in less than a year, with no guarantee of delivery then. Under the circumstances the owner was forced to go out of business. A serious accident to power plant equipment could likewise stop production for a long period—one very impelling reason why non-defense industries should take extra precautions for accident prevention.

When production is of paramount importance, there is a natural tendency to reduce maintenance, overload equipment and, if more suitable equipment is not available, to operate vessels and machines on work for which they were not intended. Generally such practices or misapplications in the use of equipment will not turn out to the owners' advantage, as accident frequency is bound to increase and while many of the accidents may be minor ones with respect to the damage to the objects themselves, the resultant loss of production may be much more costly.

As it has been pointed out, a well-planned and properly-executed system of care and maintenance is the best way of avoiding breakdowns and resultant production troubles. In addition, an independent check for accident-causing conditions is desirable—checks such as those afforded by the inspections that are provided by an insurance company on the equipment which it insures. Under the present heavy production schedules, the application of this inspection service to various pressure vessels, turbines, engines, electrical equipment and other machinery, as well as to boilers, can be especially helpful to plant operating personnel as a further precautionary means of preventing accidents and as an additional safeguard to offset the increased hazards arising from longer operating hours, shortage of skilled labor, and the more severe service under which the majority of the equipment is today operating.

Ammonia Compressor Accidents

Although less frequent than other kinds of ammonia compressor accidents, those involving explosion are the more costly and the more likely to cause personal injuries and extensive property damage. Some explosions have resulted from the breaking of compressor crankcases or from the rupture of compressor manifolds. Then too, there have been instances in which cylinder heads have been blown out violently when the compressors were placed in operation, this type of accident being caused by starting the machines with the stop valves closed in the discharge lines and without proper protection for the cylinders against excessive pressure. On direct-connected steam-driven compressors, large losses have resulted from explosions of their flywheels, usually from overspeeding.

In general, other accidents are from the breaking of reciprocating parts and crankshafts. In the majority of these cases the direct damage is limited to the compressors themselves and to loss of ammonia, although contact of the released ammonia with products in storage may cause their spoilage and may damage other property in a similar manner. Furthermore, indirect loss may be brought about by lack of refrigeration as the result of a compressor accident.

Probably the most disastrous explosions in connection with refrigerating installations using ammonia for the refrigerant are those in which combustible mixtures of air and ammonia become ignited. When a part breaks in a compressor and permits ammonia to escape, such a combustible mixture may be formed. Then if this mixture is ignited, there is likely to be a violent explosion and heavy damage. An accident of this kind occurred a few years ago in an ice manufacturing and cold storage plant. A by-pass valve broke on an ammonia compressor, the escaping ammonia mixed with air and a few minutes later there was a terrific detonation. The source of ignition was not known, although it was thought to have been an arc produced by the opening of a circuit breaker. Four people were injured and the property damage exceeded $37,000. Taken after a new by-pass and valve had been installed, Figure 1 shows part of the compressor and indicates where the break occurred. The broken valve is shown in Figure 2 on Page 204.

Flywheel explosions on steam-driven ammonia compressors have occurred in several cases as the result of operating compressors with

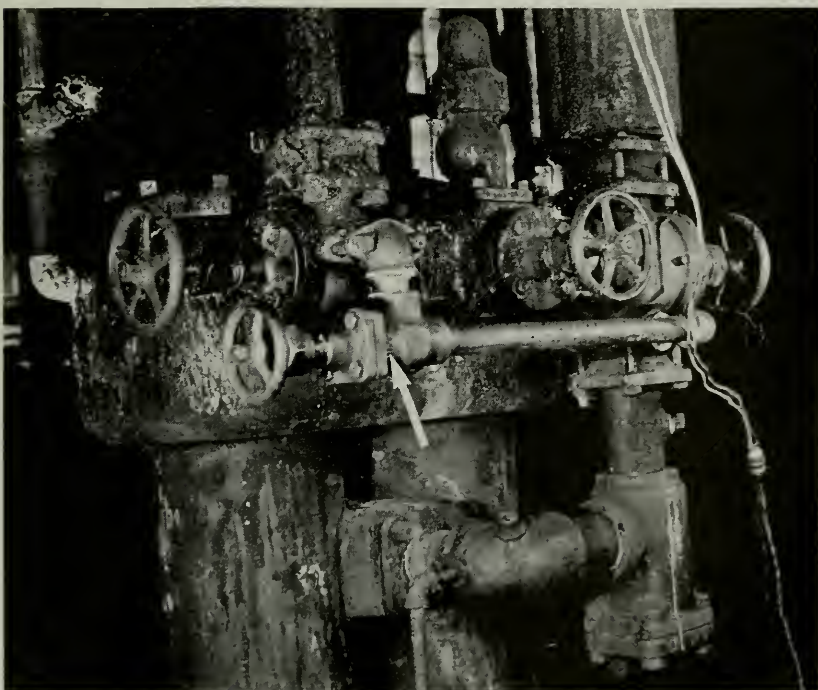


Figure 1—Four people were injured and a $37,000 property damage loss was caused by the breaking of a by-pass valve on this ammonia compressor. Arrow indicates the point where the break occurred although a new valve had been installed when this picture was taken.

Figure 2—View of the broken by-pass valve which led to the violent explosion described on Page 203.

the suction stop-valves closed and with the governors or valve gears on the driving engines deranged. In some of these cases the suction stop-valves had become detached from their stems and had acted as check-valves so that the loads on the engines were lost at a time when the governors were not in a condition to hold the speed in check.

Figure 3 shows part of the damage from an explosion of a 12′ flywheel on a steam-driven ammonia compressor. Running normally at only 58 rpm, the wheel overspeeded when the governor belt became oil-soaked and slipped off its pulley. A contributing cause was improper adjustment of the engine valve-gear. Not only was the compressor wrecked but, in addition, parts of the broken wheel extensively damaged the building, an engine-generator set and a large ammonia storage tank. The latter was punctured by flying parts and lost all its ammonia. The total damage amounted to more than $40,000.

For safe operation of any ammonia compressor there should be a relief valve between the compressor and the first stop valve in the discharge line. Occasionally an installation is not provided with this relief valve or with some other device to act as a safeguard against dangerous over-pressure. Fortunately this latter type of installation is becoming rare. Many cities have a law requiring that each ammonia compressor have some kind of a safety device. In one state there is a similar law which not only is strict in its requirements but also unique in that it specifies that the ammonia discharge from the relief valve shall be piped to the atmosphere through a diffuser or ventilating stack. In the usual arrangement the discharge is piped back to the low pressure side of the system.

Occasionally with an installation having the discharge returned to the system, the operator may inadvertently forget to open the stop valve in the discharge line when starting the compressor. If the machine is run for several hours in this manner, the ammonia gas is churned around continuously through the relief valve and its discharge piping to the suction side of the system. This causes an excessive increase in the temperature which affects the lubrication and operation of the wristpin and pistons, and may lead to the seizure of the bearings or sticking of the pistons in the cylinders. On motor-driven compressors, in order to prevent an accident of this kind, a pressure-actuated automatic cut-out should be provided for the motor, with the cut-out set to operate at a pressure not higher than 90 per cent of the pressure at which the relief valve functions. This recommendation is contained in the safety code of the American Society of Refrigerating Engineers.

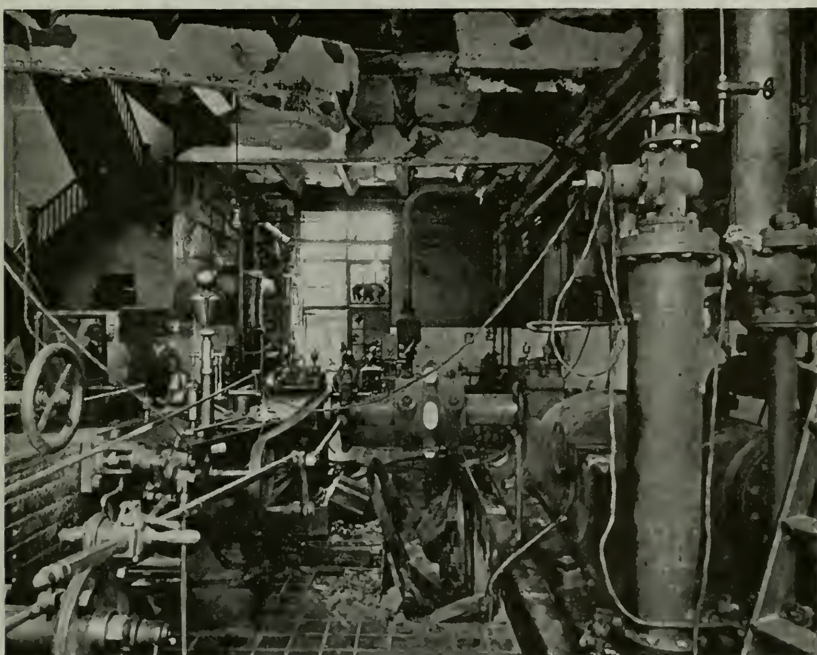


Figure 3—When a 12′ flywheel on this steam-driven ammonia compressor ran away, the resultant property damage amounted to more than $40,000.

There have been ammonia compressor accidents that have been attributed to explosions of the closed crankcases for these machines. The theory was that a combustion explosion of lubricating oil vapor or of ammonia gas had occurred, but it is unlikely that an amount of oxygen sufficient for combustion could have been present in the systems. Furthermore, a source of ignition would have been necessary, and while excessive temperatures within the compressors could have been that source, no evidence of excessive temperatures was found. A more likely theory is that the crankcases were broken by shocks, thereby permitting the forming of explosive mixtures which were ignited in some way.

The following account of an explosion shows the danger in running a motor-driven compressor with the stop valve closed in the discharge line and also shows the value of an overpressure-actuated cut-out for the driving motor. According to the statement of the operator who barely escaped being killed, the explosion was accompanied by a blinding flash of fire. It was found that he had started the compressor with the discharge-line stop valve closed and had operated the machine in that manner for nearly four hours. As a result, the ammonia gas temperature increased greatly and the compressor overheated. What actually happened then isn't known but the conjecture is that a piston seized and caused a shock which broke the crankcase. The hot oil vapor or

Figure 4—Only the bottom of the crankcase, the shaft and the wheel remained after this vertical twin-cylinder belt-driven ammonia compressor exploded. The cause was attributed to a combustion explosion in the crankcase. $7,500 was the estimated damage.

ammonia gas thus released mixed with the air and was ignited almost instantly as evidenced by the sudden flash of fire.

In approximately one out of every three accidents to ammonia compressors of the vertical single-acting closed-crankcase type, a suction or discharge valve is the initial part broken. Frequently the resultant damage is quite large, sometimes necessitating replacement of a cylinder.

The valves in vertical single-acting compressors are spring loaded and provided with a dash-pot to prevent them from slamming. Both the spring and the dash-pot are of great importance in obtaining shockless seating of the valve and in avoiding, thereby, the development of fatigue cracks which lead ultimately to valve breakage. Likewise, slamming of the valves may cause loosening of the nut that secures the dash-pot piston to the suction valve stem. When either of these failures occurs, the suction valve may be drawn into the cylinder and jammed between the piston and cylinder head. Cylinders, cylinder heads and pistons are broken frequently in this way, or at least the cylinders or pistons are badly scored.

Even though the cost of repairing or replacing a valve may be thought of as a comparatively small expenditure, the resultant indirect loss is often large. Recently the breaking of a suction valve in an ammonia compressor in an ice cream manufacturing plant resulted in the temperature in the hardening room rising sufficiently to affect the quality of the ice cream. Cost of repairs to the compressor was only $75 but the spoilage of ice cream caused by the lack of proper refrigeration amounted to $2,500.

Accidents attributable to fatigue or wear of valve parts can best be held to a minimum by dismantling and thoroughly inspecting the valves at regular intervals. This should be done annually and a good opportunity is afforded for such work during the winter months when most compressors are not operated regularly. In addition to accident prevention, annual dismantled inspection is desirable from the standpoint of economy. Leaky valves mean wasted power, so when leakage occurs the valves should be ground and made to fit properly.

Two other main causes for the breaking of valves are operating a compressor above the designed speed and improper operating practices whereby slugs of liquid ammonia are permitted to enter the compressor. Liquid ammonia may cause a large amount of damage, not only to the valves but also to the cylinder heads, piston rods, connecting rods, or other parts which receive the brunt of the shock as the piston strikes the incompressible liquid. A liquid trap installed in the suction line is an excellent precaution for preventing breakdowns from this cause.

Burned out or broken bearings generally come from dirty oil; from sludge or some obstruction in the oil lines or in the passage ways in the shafts or other parts through which oil is fed to the bearings; from a broken oil pump; and from lack of oil. There have been cases in which, through operating errors, liquid ammonia accumulated in the crankcase while a compressor was shut down and when it was placed in service again the bearings were damaged by the contamination of the lubricating oil.

Probably more crankshaft failures result from misalignment than from any other one cause. Frequently this type of accident is brought about by worn bearings. On belt-driven compressors having a pulley wheel adjacent to an outboard bearing, both rapid wear of the bearings and misalignment are often caused by too much belt tension. In a recent accident of this kind a 5″ crankshaft broke at the web adjacent to the belt wheel. A crack had progressed through the shaft until the remaining metal at the time of the accident was only about 1½″ thick. The repair cost for installing a new shaft, connecting rod and bearings, all of which were damaged by the accident, amounted to approximately $330.

Causes of breakdowns of other parts are varied but often the source of trouble is the breaking or loosening of some small part such as the breaking of a bolt, the working loose of a nut, or the excessive stressing of some part through wear or misalignment. For the prevention of these and other breakdowns, not only are correct operating practices and proper maintenance particularly essential, but periodic dismantled inspections are likewise important for detecting possible sources of trouble, thus enabling the owners to apply preventive measures before an accident occurs.

VARY SPEED WITH MAGNETIC DRIVE ON CONSTANT SPEED MOTOR

Using electromagnetic principles for torque transmission, a novel drive method provides variable speed with a constant speed driving motor, *Industrial Power* reports. The magnetic drive is made up of two compact rotating parts—a flux linkage ring and a magnetic flux producer. The ring is driven by the motor, and the magnet—which is connected to the load shaft—revolves within the ring. Torque is transmitted by electromagnetic forces only—there being no mechanical connection between motor and shaft—and the speed of the load shaft is dependent upon the magnetic flux in the air gap between the ring and the magnet. This flux is varied by adjusting the control current to the magnet by means of a rheostat. The drive can be applied to new or existing installations, is available in a wide range of speeds and horse powers, and as accessory equipment requires only a small source of d-c control current and a rheostat.

The American output of steel last year of nearly 67,000,000 tons represented 42% of the world production—greater than the combined output of Germany, U. S. S. R., and England. *Metals and Alloys.*

Experience in Finding Cracks by Visual Inspections

By Inspector W. W. Mattson

There are several procedures followed by an inspector in looking for defects or weaknesses in the various types of machines which the Company insures. All aim at finding these accident-producing conditions before they have progressed to the point of causing breakdowns. Several examples are cited in this article, together with some observations on inspection procedure, to illustrate the value of one phase of this work; namely, that of careful visual examinations for cracks in machinery parts, such as shafts, wheels, crossheads, crankpins and connecting rods. Owners and engineers will recognize herein the value of periodic dismantled inspections as a means of preventing breakdowns that are costly not only because of the damage to the machine itself but because of the resultant loss from interruption of plant production. ***Editor.***

During a dismantled inspection of a 10 hp, single-cylinder, 720 rpm Diesel engine, a crack was found in the 3″ crankshaft. The crack was located at the pulley end of the engine shaft in the fillet adjacent to the crankweb.

The first step of the procedure followed in this case in the search for cracks was a visual inspection of the fillets between the center crankpin and the crankwebs, after which these fillets were given a coating of whitewash. This part of the inspection of the engine was given precedence in order to allow the oil to work out of any cracks that might exist through the flexing of the webs when the shaft was being turned and the wheels hammer-tested during other inspection work.

The next step was an inspection of the fillets between the main shaft journals and the crankwebs. Although on first consideration, a satisfactory examination of these fillets seemed impossible, as one of them was concealed by the cam-shaft drive-gear and the other was located between the web and the roller bearing in a space only an inch wide, a close scrutiny of this space disclosed a streak resembling a piece of embedded thread in the latter fillet. As the streak was characteristic of a small crack, the shaft was cleaned and a whitewash test applied. This test confirmed the opinion formed by the visual inspection as it revealed that the shaft was cracked.

From the standpoint of preventing a costly accident, the finding of this crack might be considered as insignificant, for had the shaft broken and resulted in the wrecking of the engine, the amount of damage probably would not have exceeded $750. Nevertheless, this case is a good illustration of the effectiveness and value of careful visual examinations.

Although it might be argued that either a whitewash or a Magnaflux test would have disclosed the crack, there are two important reasons why vulnerable parts should be scrutinized closely even though specific tests are to be undertaken later. For one reason, the cracks may be so located or be of such a nature that although they would not be disclosed effectively by whitewash or Magnaflux tests they could be seen, once the ability to recognize their various characteristics and disguises had been acquired. Often a close-lipped crack in a dry steel shaft will not absorb kerosene, thus making a whitewash test unsuccessful. The same comment applies to a Magnaflux test at sharp fillets or at other places where magnetization is difficult and the strength of the field is uncertain.

The finding of cracks in oily or dirty parts presents a different problem from that of crack detection in dry, clean parts. With a progressive crack or one that extends gradually through the affected part, there is a continuous flexing or "working" of the metal. Consequently, cracks in oily engine parts such as those that occur in crossheads, center-cranks, shafting or pulleys, will alternately draw in and eject the surface oil. If this oil is scanty, a ridge of grease will be formed on each side of the crack; and if there is a thick coating of sludge or grease, a thread will seem to be embedded in the grease. On the other hand, if the part is dry, a tiny ridge of iron oxide may cover the crack.

A visual examination is most successful when a part has not been cleaned before it is inspected. In one case involving a 10′ twin-pulley wheel with its hubs about 8″ apart, the shaft between the hubs was coated with dirt and grease approximately 1/4″ thick. Near one hub, there was the peculiar earmark or manifestation of a crack—twin ridges of grease and a valley between. At that particular inspection, a whitewash test of this section of the shaft had not been planned, but under the circumstances it was applied and a crack extending one-third of the way around the shaft was disclosed.

In some instances, whitewash or Magnaflux tests may not be effective or conditions may be such that their application would not be advisable—a second reason which emphasizes the importance of visual examinations. In one instance during an inspection of a paper-machine engine shaft which had been built up by welding because of a loose wheel, tiny, rusty, grease ridges were noticed extending around the shaft about 1/2″ from the hub of the engine wheel. These ridges were not continuous but were in one or two inch lengths with unequal spaces between them. Several attempts were made by whitewash tests to determine whether the shaft was cracked, but none of the tests produced significant results nor did a subsequent test, made three weeks later when the same suspicious signs were found, give a different result. At a third inspection, as similar ridges were again in evidence, a hole was drilled at the location of the suspected crack, confirming the opinion formed previously, for a definite crack was found. None of the whitewash tests had been successful because the kerosene had spread out from under the hub and covered the area where the ridges had been found faster than it had worked out of the cracks.

The effectiveness of careful and experienced visual scrutiny was proven again by the discovery of a crack in a large shaft of a rolling-mill engine. This defect was located in a section of the shaft between the governor drive pulley and a 10′ gear wheel, both being mounted so closely together that a small paint brush could barely be inserted between them; hence, it was a space difficult to clean and in which to apply a satisfactory whitewash test. The telltale signs of a crack, however, were clearly outlined in the layer of dry dirt covering this section of the shaft and on subsequent investigation and test, a crack about 5″ long was found.

During an inspection of a 1500 hp engine which had been painted just previously, a wrinkle was observed in the paint on one of the crossheads, indicating the probability that it was cracked. When the paint had been scraped off, a whitewash test applied and the crosshead drilled, it was shown definitely that a crack did exist.

Cracks are quite common in some types of pulley wheels and probably they are even more common in various engine and turbine parts. Not all of them are indicative of serious conditions but each one should be fully investigated to determine its nature and extent. If possible, the source of the excessive stresses which caused the cracks should also be determined, both in order that the condition may be eliminated and to avoid cracks or failures of other parts of the same machine. Even though a crack is small and not one that could be classified as immediately dangerous, nevertheless its existence should be considered sufficient justification for a dismantled inspection of other parts that cannot be seen and which may contain much more serious defects.

THE COVER

View of a motor-driven freon-compressor installation for an air-conditioning system in a store. As with refrigerating machinery for cold storage and ice making plants, air-conditioning systems are subject to costly breakdowns. Periodic inspections afforded with insurance provide a valuable service for preventing such accidents.

This picture was furnished through courtesy of the York Ice Machinery Corporation, York, Pa.

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

WALLACE H. HENSHAW, *Editor*

HARTFORD, CONN., July, 1941

Single copies may be obtained free by calling at any of the Company's offices.
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each.

Lucius F. Robinson

Lucius F. Robinson, the oldest in length of service on the Company's present Board of Directors, died after a short illness on June 11, 1941. Elected a director in March, 1900, he served the Company continuously in that capacity and took an active interest in its affairs until the time of his death.

An eminent lawyer, Mr. Robinson was an outstanding and highly regarded member of his profession and one of Connecticut's leading citizens. In addition to his law practice, he held a prominent place in civic life and was also closely associated, as a director, with many financial and industrial corporations.

Graduating from Yale in 1885, Mr. Robinson was presented with an honorary degree of LL.D. by that university in 1926. In the citation, he was praised, among other things, for his championship of state rights and for his achievements both in his own profession and in promoting the general welfare of the people in his state and community.

Seventy-Five Years

On June 30, 1866, the Connecticut Legislature, acting on a petition by a group of engineers and business leaders in Hartford, granted a charter to The Hartford Steam Boiler Inspection and Insurance Company to inspect steam boilers and to insure against loss arising from explosions or other accidents attendant on their use—in short, to engage in boiler insurance. The granting of that charter marked the origin in this country of a form of insurance which has so expanded in scope that today it is more aptly described as power plant protection. At the same time, it gave birth to the first organized industrial safety movement in America.

The need for an insurance protection against boiler explosions became evident not long after the beginning of our present era of industrial expansion. By the middle of the last century, most boilers were being operated at considerably higher pressures than had previously been used. With this increase in pressures there was an accompanying increase in disastrous boiler explosions until these losses became so severe and frequent that many realized that some steps should be taken to prevent them. That was the primary purpose of the founders of the Company, for they were convinced that many explosions were due to faults and weaknesses in the boilers, and to lack of knowledge about proper care and use by those who were responsible for their operation. They felt that if boilers were inspected regularly by men who were trained to know where to look and what to look for, defects and dangerous conditions could be discovered and many explosions prevented. They also felt that much could be accomplished at the same time through education to bring about an appreciation of the hazards created by carelessness, neglect and ignorance in boiler operation—underlying causes of many of the disastrous losses during those times.

Accordingly an inspection and engineering service was provided as an accompaniment of this new form of insurance—an insurance which in effect guaranteed up to the limits of the policy to indemnify for losses that were not prevented. While in the early years of the Company's development many difficulties were encountered in convincing owners of the worth of the new undertaking, the soundness of the principle of accident prevention on which boiler insurance was based gradually became recognized. Industrial management has long accepted this protection as an economic necessity.

About thirty years after the beginning of boiler insurance, a very similar protection against explosions of engine flywheels was undertaken, for although less frequent than boiler explosions, they were occurring occasionally with devastating results. This was the forerunner of insurance protection against breakdown accidents as well as explosions to a great variety of industrial power machinery. In the insuring of flywheels it was soon found that many costly accidents that were not flywheel explosions were occurring to the engines on which the wheels were mounted. Thus a demand for a more complete coverage arose and there grew out of it a form of protection to pay for such accidental breakdowns. First this broader coverage was extended to engines, compressors and pumps, then to electrical machines, and shortly afterward to steam and water turbines and turbine-generator units. Throughout all this expansion the original basic principle was rigidly adhered to; namely, that of accident prevention through inspection service.

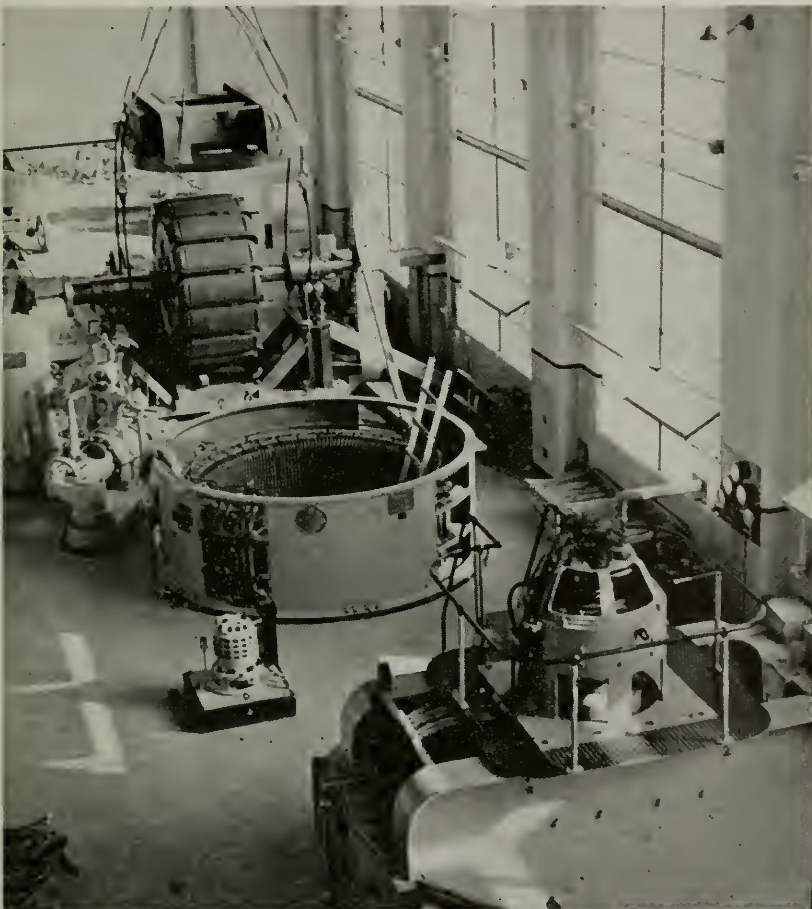
The trend during the past seventy-five years has been, and still is, toward an ever greater use of mechanical power. In what ways it will be generated and utilized in the future cannot be foreseen but undoubtedly civilization's use of power and dependence upon it will constantly increase and the coverages afforded by boiler and machinery policies will continue to change and expand as required by new conditions and by the needs of industry.

Faced today with the tremendous task of fulfilling the production requirements of National Defense, industry in meeting these requirements must be able to count on the reliable performance of power equipment. As an organization whose facilities and energies are devoted to just this one job, the Company finds itself in its seventy-fifth anniversary year sharing with industry the greatest responsibility that has ever faced our nation.

$37,000 Generator Loss

A STROKE of lightning which apparently hit a 66,000 volt high tension line close to where the line entered a California utility hydro-power plant, was the principal cause of a stator coil burnout in a 7,500 kw generator last March. Designed for operation at 6,900 volts and a speed of 450 rpm, the machine formed a part of a vertical water-turbine generator unit built in 1930. The total loss including that from curtailment of electrical power output while the generator was being repaired amounted to approximately $37,000.

On the day of the accident severe electrical storms in the vicinity had caused a number of disturbances in the utility company's distribution system and had tripped out the 66,000 volt circuit breakers at the plant several times. In the late afternoon, after a blinding flash of lightning that struck very close to the station, the differential relays



Scene in a California power plant showing the generator ends of two vertical water turbine-generator units, each of 7,500 kw capacity. One generator has been dismantled for complete rewinding of its stator, necessitated by failure during a severe electrical storm. The total loss, direct and indirect, was $37,000.

operated and tripped the main circuit and field breakers, caused the governor control for the water turbine to operate, and tripped the carbon-dioxide fire-extinguishing apparatus. The accompanying picture shows the generator with the rotor and direct-connected exciter removed and also shows in the foreground another water-turbine generator unit of the same size and type which was not in operation when the failure occurred.

In order to determine the source of the trouble, insulation resistance tests of the generator were made and these revealed that the stator winding was grounded. When the generator had been dismantled, four coils in the stator were found to have been damaged and the stator iron slightly fused.

To effect replacement of the damaged coils, it was necessary to remove other coils in adjacent slots but when this was done the outside layer of insulation on all of them was found to be so brittle and affected by corona that an entirely new set of coils was necessary.

Nearly fifty-three days were required to complete the repairs to the machine. Of the total loss, about one-third was chargeable to the rewinding and to extra expense incurred in expediting the repair, while the remainder was the loss from reduction in power output while the generator was shut down.

Although a high voltage surge from lightning was the immediate cause of this loss, the majority of the expense for repairs and the main part of the loss from outage was due to the poor condition of the insulation, brought about by the effects of corona which had resulted in considerable grooving of the insulation at the stator-core ventilating-ducts.

Two Air Conditioning System Accidents Attributed to Failure of Automatic Controls

Control of the operation of air conditioning systems is dependent to a considerable extent upon automatic pressure and temperature cut-outs. Two accidents which occurred a few months ago illustrate the importance of checking these devices frequently. As with any mechanical and electrical controls or safety devices that are installed to protect machinery and pressure equipment, they will not be effective unless they are set to function at the proper pressures and temperatures, and maintained in good working order. While in neither of these accidents was the damage to the systems themselves extensive, the repairs were nevertheless costly and required several days before they were completed and the systems returned to service.

One of the accidents occurred to a large system in a hotel. Usually the system was operated from about the first of May to the first of November each year and it had been running only a few days after the start of the season when the surging action of the cooling-water circulating pumps indicated to the operating engineer that something was wrong. A test of the cooling-water revealed that it contained a high percentage of freon, so the compressors were shut down immediately.

To determine the source of the leakage the water coolers were drained and tested. In one of them 23 small copper fin-tubes out of a total of 367 had ruptured.

Two motor-driven compressors having a total capacity of 160 hp supplied the refrigeration for the system. Equipped with a combination high and low pressure cut-out, each compressor was also controlled by a temperature cut-off in the outlet water piping from the coolers. The low pressure cut-outs were set to shut down the compressors at a minimum suction pressure of 32 lb while the temperature controls were adjusted to shut them down at a minimum cooling-water temperature of 39°F. It was believed that the accident was caused by these safety devices failing to shut off the compressors. As a result, the temperature in the coolers dropped below 32° F., thereby freezing the water in some of the tubes and rupturing them. Water then entered the cooler, mixed with the freon and was circulated through the entire system. All the freon, amounting to about 1500 lb, was spoiled.

Before the system could be operated again, it was necessary to repair the cooler, remove all moisture from the compressors, condensers, coolers, piping and other parts, repair or replace the controls, and put in a new supply of freon. As replacement of the ruptured tubes was impracticable because of the cooler's construction, the tube ends were plugged. Thus the cost for this part of the repairs was relatively small, the principal expense being incurred in removal of the moisture. Drying out the equipment was particularly important, for if any moisture remained in the system it might freeze, thus interfering with the equipment's operation and possibly causing a breakdown. Furthermore. moisture in the presence of freon would cause rapid oxidation of iron or steel parts.

In order to purge the equipment properly, it was necessary to dismantle the compressors, disconnect the system at several points, drill holes in low piping sections or pockets that could not be drained otherwise, and use various other means for getting out the water. After the system was again in service it was necessary, over a period of several weeks, to use about 300 water absorbing cartridges in the liquid side of the refrigerating cycle to remove the final traces of moisture. Although the system was out of service only for about two weeks, nearly three months elapsed before the work was entirely completed. The total cost of the accident was more than $5,200, including $800 for a new supply of freon.

In the second accident, which was very similar, a 225 hp air condi-

(Continued on Page 221)

Taps From the Old Chief's Hammer

"WHAT are you doing over the holiday week-end, Tom?" asked the Old Chief, as his assistant was about to leave the office late one afternoon. "Are your plans all made?"

"Yes, just about. We're going up home to stay with the old folks. The boys want to be in the country where they can have some fire crackers and celebrate the Fourth with more freedom than they can here. They say it's too quiet around home. Then too, as you can probably imagine, they find several other interesting things to amuse them up there."

The older man smiled. "Don't know as I blame them, Tom. You haven't, by any chance, encouraged the idea; that is, about the fire-works?"

"Possibly I have a bit," replied Tom, grinning. Then, defensively, he went on: "When I was their age, the Fourth of July was always a big day and one we looked forward to. There was plenty of noise and excitement from the time we got up at 5:00 in the morning until the last Roman candle had been shot off that night. Some of the cannon crackers, as I remember them, were as large as a stick of dynamite. although actually they were probably much smaller. Under present standards, the things we did could hardly be called 'safe and sane' but I guess I have too many fond memories not to be sympathetic to the kids' pleas for a few fire crackers; at least, the small ones. Fortunately, none of us was ever hurt seriously so probably the dangers were never sufficiently impressed on my mind."

"I can appreciate how you feel, Tom. But," the older man added in a more serious tone, "you'll agree there are several other safer ways to celebrate the holiday. Most of us are inclined to belittle or ignore some hazards and we do not really acknowledge their seriousness until we get hurt. Often it is difficult to learn the same lesson from what happens to some one else. Jim White from the Home Office was here the other day and he told me of a recent case which, in a way, shows how an accident may prove costly even though usually it might be thought of as a minor one."

"What was that?" asked Tom, sitting down, as he knew the Chief was about to tell a story which might take some time.

"Ordinarily, Tom, in our line of business we wouldn't consider this case as unusual. In the course of a year we hear of several accidents to power plant equipment where something went wrong that wasn't expected. But that's beside the point for the moment.

"The accident Jim described to me occurred last January in a large paper mill. The cause of the trouble was the bursting of a water-wall tube in one of three large water tube boilers which furnished steam at 130 lb pressure for process work, heating and for driving turbines. In addition, there was a smaller boiler, not in operation, that was used occasionally in the summer to help carry the load when it was necessary to shut down one of the larger boilers for cleaning and repairs.

"When the accident occurred the water tender noticed almost immediately that something was wrong from the drop in pressure and steam load, and it wasn't but a minute or two before he discovered the cause and shut off the coal pulverizer which supplied the fuel. However, combustion continued for another two minutes until the coal already pulverized had been burned."

"I should imagine the other tubes in the boiler, both those in the water-walls and in the boiler proper would have been ruined." interjected Tom, "unless the feed pump was able to maintain a safe water level. Incidentally, isn't it unusual to find a boiler with water-walls and burning pulverized fuel, operating at only 130 lb?"

"Yes, it is," answered the older man. "In fact, I do not recall another case like it. But to get back to the story, the pump had been shut down at the same time as the pulverizer. However, as it turned out it didn't make any difference as the pump could not have maintained enough water in the boiler to prevent overheating. The next morning when the boiler had cooled sufficiently so that it could be entered and examined, the source of the failure was located. A rectangular shaped piece of metal, approximately 3″ wide and 8″ long, had been completely blown out of one of the side water-wall tubes. The failure occurred at a point about 15′ above the bottom of the furnace on a line with the lower boiler drum and as a result nearly all the water in the boiler was drained out within a very short time.

"Consequently, with the fire continuing, even though for only a couple of minutes, and with the setting and lining retaining a large amount of heat for several hours afterward—the lining being white hot at the time of the accident—it is not surprising that the boiler was damaged extensively.

"As you know, Tom, a tube failure of a water tube boiler is caused by overheating which has been brought about by scale, low water or poor circulation, and the resultant hole looks like a large punch had been driven through the tube from the inside outward. In this case a very thorough examination was made of the entire boiler, but no evidence of overheating previous to the accident could be found. Evidently the composition of the steel was such that it had cracked like a piece of cast iron and the section of the tube had blown out under normal operating conditions.

"So as you imagined, Tom, a lot of the other tubes were badly distorted and, of course, they had to be replaced before the boiler could be operated again. The five lower rows of generating tubes in the boiler proper and all of the water-wall tubes except those in the rear wall had to be cut out and new ones installed."

"What was the effect on production with this boiler shut down?" asked Tom, as the Chief paused for a moment. "Could the other boilers carry the load?"

"Unfortunately, Tom, sufficient steam could not be generated to maintain the usual production, even with the small boiler in operation. The plant had five paper machines and one of them had to be shut down, but by expediting the repairs with overtime work and by being fortunate enough to obtain immediate delivery of new tubes and other necessary materials, the boiler was back on the line in about five days' time. The production loss during this period was about twenty-five per cent of the normal output."

"That certainly was quick work," commented Tom. "It seems to me they were lucky to obtain the new tubes so promptly, considering the demand and rush of business in boiler manufacturing plants. How much did the loss amount to; that is, both for repairing the boiler and for the production loss?"

"I don't recall the exact figures," replied the Chief, "but the cost of repairs was about $4,000 and the loss from decrease in production was around $5,000. That's more than pocket-money even for a large plant.

"There are several interesting points about this loss, Tom. The one that I had in mind when I started this yarn is the amount of loss that may result from what some people might consider a minor failure. When a tube bursts, the tube itself might be replaced at a comparatively small cost but as happened in this case that expense may be but a small fraction of the total resultant loss. This accident also shows that even though a plant may have several boilers, an accident involving only one of them and only partly curtailing output may mean a costly loss from interruption of production. Thus plant owners need protection against an indirect loss, or Use & Occupancy coverage, as well as insurance to pay for personal injuries and for direct property damage."

Tom looked at his watch: "Say, Chief, it's late. If we want any dinner tonight, we'd better be getting home. While that story is fresh in my mind I'm going to talk to the boys about celebrating the Fourth in other ways which would be safer and just as entertaining."

(Continued from Page 217)

tioning system in a store and office building failed. In this case also the cause of the breakdown was attributed to failure of the pressure and temperature controls, although it was possible that the low pressure cut-off was set too low. Eighteen tubes were ruptured by water freezing in the cooler and the entire supply of freon for the system was lost. The labor cost for purging the equipment, however, was very much less than for the first accident as the total repair expense was $2,450 of which amount $1,200 was the cost of a new supply of freon.

Engineer, to new assistant: "What's the idea of this loafing? Didn't you tell me you never get tired?"

Assistant: "That's right, chief, I always stop and rest before I get tired."

Powerfax.

Sergeant: "Did you shave this morning, Jones?"

Jones: "Yes, sergeant."

Sergeant: "Well, next time stand a bit closer to the razor." *Trumbull Cheer.*

"Uncle Joe," said Albert Edward Wiggam, the author, meeting an old darky who was always cheerful in spite of having had more than his share of life's troubles, "how have you managed to remain so cheerful and calm?"

"Well, I'll tell yo'," replied Uncle Joe. "I'se jus' learned to cooperate wid de inevitable." *Ediphone—Hidden Treasure.*

A young woman reporter who did not know what it was all about was trying to interview a golf champion. She asked a great number of faulty questions, and finally asked to what the golf champion attributed his success. The golfer yawned and said: "I'm too lazy to take as many strokes as other people." *Toledo Blade.*

"Say, pa."

"Well, my son?"

"I took a walk through the cemetery today and I read the inscriptions on the tombstones."

"Well, what about it?"

"Where are all the wicked people buried?" *Ediphone—Hidden Treasure.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONNECTICUT

December 31, 1940 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,246,498.78
Premiums in course of collection (since October 1, 1940)		906,526.27
Interest accrued on bonds and mortgages		76,117.15
Mortgage loans		108,781.50
Home Office and Philadelphia branch office real estate		642,331.05
Other real estate		292,114.84
Other admitted assets		13,715.92
Bonds on an amortized basis	$9,201,193.59	
Stocks at market value	8,342,441.50	
		17,543,635.09
Total		$20,829,720.60

LIABILITIES

Unearned premium reserve		$8,738,617.66
Losses in process of adjustment		317,499.96
Commissions reserve		181,305.25
Taxes reserve		250,000.00
Other liabilities		313,596.90
Liabilities other than capital		$9,801,019.77
Capital stock	$3,000,000.00	
Surplus over all liabilities	8,028,700.83	
Surplus to Policyholders		**11,028,700.83**
Total		$20,829,720.60

WILLIAM R. C. CORSON, President and Treasurer

Incorporated 1866 *Charter Perpetual*

Department	*Representatives*
ATLANTA, Ga., ... Citizens & So. Nat. Bk. Bldg.	W. M. Francis, Manager. N. F. Bailey, Chief Inspector.
BALTIMORE, Md., ... 704-9 Garrett Building . .	D. W. Little, Manager. W. C. Nicol, Chief Inspector.
BOSTON, Mass., ... 87 Kilby Street	Thomas F. Rice, Manager. W. A. Bayliss, Chief Inspector.
BRIDGEPORT, Conn., . . City Savings Bank Building .	W. G. Lineburgh & Son, General Agents. R. P. Guy, Chief Inspector.
CHICAGO, Ill., ... 175 West Jackson Boulevard .	P. M. Murray, Manager. C. W. Zimmer, Chief Inspector.
CINCINNATI, Ohio, . . . 1904-12 Carew Tower . .	James P. Kerrigan, Manager. W. E. Glennon, Chief Inspector.
CLEVELAND, Ohio . . . 1040 Leader Building . .	Arthur F. Graham, Manager. F. E. Le Gates, Chief Inspector.
DENVER, Colo., ... Gas & Electric Building . .	J. H. Chesnutt, Manager. Jesse L. Fry, Chief Inspector.
DETROIT, Mich., ... National Bank Building . .	W. H. Kerrigan, Manager. Thomas P. Hetu, Chief Inspector.
HARTFORD, Conn., ... 56 Prospect Street . . .	F. H. Kenyon, Manager. R. P. Guy, Chief Inspector.
NEW ORLEANS, La., . . 519-24 Hibernia Building . .	R. T. Burwell, Manager. Arthur R. Keiler, Chief Inspector.
NEW YORK, N. Y., . . . 90 John Street	C. C. Gardiner, Vice President. J. F. Hunt, Chief Inspector.
PHILADELPHIA, Pa., . . 429 Walnut Street . . .	A. S. Wickham, Manager. John L. Scott, Chief Inspector.
PITTSBURGH, Pa., . . . Arrott Building . . .	William P. Wallace, Manager. John Todd, Chief Inspector.
ST. LOUIS, Mo., ... 319 North Fourth Street . .	Chas. D. Ashcroft, Manager. Eugene Webb, Chief Inspector.
SAN FRANCISCO, Calif., . 114 Sansome Street . . .	C. B. Paddock, Manager. L. E. Grundell, Chief Inspector.
SEATTLE, Wash., ... Arctic Building	E. G. Watson, Manager. William J. Smith, Chief Inspector.
TORONTO, Ont., Canada, . . Federal Building . . .	H. N. Roberts, President The Boiler Inspection and Insurance Company of Canada.

Power Equipment Protection

Boiler and Machinery insurance provides essential protection against loss from explosions, disruptions and breakdowns of equipment used for generating, distributing and utilizing power. Not only is such protection invaluable on power boilers and prime movers, but it is also very important on other machinery and pressure equipment.

Listed below are several objects insurable under Boiler and Machinery policies. Accidental failures of these objects can cause large property damage losses, personal injuries, costly delays in production and troublesome interruptions in plant operating schedules.

Through inspections the insurance company seeks to discover accident-causing conditions and defects, and the effectiveness of this activity greatly reduces the probability of accidents occurring to interfere with plant output. On its staff The Hartford Steam Boiler has more than 400 trained inspectors. Back of its engineering service is an organization which, in 75 years, has gained its specialized experience from over 20,000,000 inspections.

Power Boilers	Steam Turbines
Heating Boilers	Water Turbines
Hot Water Supply Boilers	Steam Engines
Water Tanks	Diesel Engines
Air Tanks	Gas Engines
Refrigerating Systems	Compressors
Air Conditioning Systems	Pumps
Piping	Wheels
Digesters	Shafting
Kettles	Generators
Kiers	Motors
Economizers	Transformers
Vulcanizers	Switchboards
Feed Water Heaters	Bus Structures
Rendering Tanks	Blowers and Fans
Laundry Presses	Gears and Gear Sets

"Boiler and Pressure Vessel Failures"

Vol. 43 No. 8 October, 1941

The Locomotive

Quarterly Magazine Devoted to Power Plant Protection

Please Show to Your Engineer

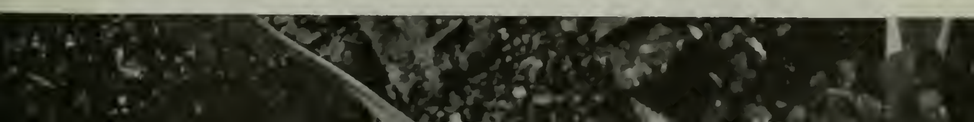


Figure 1 (Top)—An explosion of a cast iron sectional heating boiler caused this damage. A new boiler, it had been placed in service for the first time only a short while previously.

Figure 2 (Bottom)—View in a hotel office showing havoc caused by an explosion of a small hot water supply boiler. The damage was estimated at $2,000.

21 Persons Injured and $50,000 Property Damage

During recent months there have been several explosions of heating boilers and hot water tanks that have not been mentioned in this publication. Twenty of these cases have been reviewed, and athough the information available about a number of them is limited to data obtained from news reports, brief descriptions of what happened will show the kinds of failures that can and do occur to such equipment. These cases show, too, that so-called low-pressure heating boilers and tanks need to be intelligently operated and given proper care; otherwise, such objects may not only fail but do so violently, causing injuries and even loss of life as well as costly property damage. This review does not profess to include all similar accidents that have occurred recently. Undoubtedly there have been others which have not been brought to our attention.

In these twenty cases, twenty-one persons were injured, four of them fatally. While the property damage for each of about half of the explosions was less than $1,000, the aggregate for all of them was approximately $50,000, including in several instances damage to property of others in addition to that of the owners. In only two cases was Boiler Insurance carried and few, if any, of the other boilers and tanks involved were inspected by qualified inspection agencies.

Most of the explosions resulted from excessive pressures, although in two cases the accounts indicated that they were believed to have been explosions of accumulated fuel gases within the boiler fire boxes—accidents commonly called furnace explosions. Information as to the underlying causes or the primary reasons for the excessive pressures was lacking or not definitely determinable for several of the accidents. Seven of the explosions occurred to steam heating boilers, five to boilers for hot water heating systems, and eight to boilers or tanks for hot water supply systems.

The top picture on Page 226 is a view taken in the basement of a Pennsylvania store following an explosion of an oil-fired cast iron hot water heating boiler. A new heater, it had been placed in operation for the first time only a short while previously. The damage amounted to approximately $1,700 and extended to the fixtures and considerable of the merchandise on the first floor. The cause was not determined nor could it be learned whether the accident was a pressure or a furnace explosion.

Wreckage in a Nevada hotel from an explosion of a round cast iron sectional hot water supply boiler is pictured in Figure 2 on Page 226. The boiler shot up through the floor close to the clerk's desk but fortunately he was elsewhere at that time. The main section of the boiler, supported by the floor joists where it landed, is shown in the center foreground of the picture. No explanation was given to indicate the reason for the excessive pressure which caused the accident. The damage was estimated at $2,000.

The most disastrous of these cases was an explosion of a large coal-fired cast iron steam heating boiler in a Virginia apartment house. It caused fatal injuries to three persons and a fire that ruined half the building. The initial point of failure appeared to have been in the rear section as all of it, except its inner wall, which was found attached to the next to the rear section, had been blown out while the remainder of the boiler had been moved forward two or three feet. In falling, the rear section broke a gas pipe and the escaping gas became ignited, resulting in a fire which spread rapidly throughout the building. Two tenants and a janitor were so badly injured from burns and smoke that they later died. The cause of the failure was not determined definitely. After the accident the safety valve was reported to have been tested and found in good operating condition. Possibly poor circulation through the nipples connecting the rear section to the remainder of the boiler, together with a weakness in that section, might have caused it to burst violently even though the safety valve functioned properly at 15 lb. Furthermore, as the condensate returns and the feedwater were reported as fed to the boiler through the rear section, sudden admission of cold water at a time when the boiler was under some pressure and the water level low, could have caused the section to crack and disrupt with sufficient violence to throw the remainder of the boiler from its foundation.

Another explosion which resulted in severe personal injuries occurred in an Illinois residence when a cast iron laundry heater blew up. Struck by flying parts, a girl sustained fractures of both legs, one of them being so badly shattered that amputation was necessary. The girl's mother was also seriously injured as one of her legs was broken in three places. Two other members of the household suffered from burns and cuts as they were hit by flying parts of the exploded boiler. While the cause was not stated in the news account, the information given indicated that undoubtedly the explosion resulted from excessive pressure.

Last February a horizontal cast iron sectional boiler connected to a closed-type hot water heating system exploded in a Michigan machine shop. Figure 3 shows the damaged building, part of the boiler where it landed after crashing through a window, and an automobile partly crushed by falling brickwork. The cost of repairs was estimated at

Figure 3—A check valve between a hot water heating boiler and its relief valve was reported as the cause of the explosion which wrecked this building.

$6,000. In the feedwater line to the boiler was a reducing valve set at 30 lb and a diaphragm-type relief valve set at 35 lb with a check valve between it and the boiler. A thermostatically controlled stoker was used to fire the boiler, and an aquastat, set to limit the water temperature to 180°F, was clamped to the hot water riser pipe. Apparently this aquastat failed to stop the stoker when the water temperature reached 180°F and the check valve prevented release of excess pressure through the relief valve.

This case illustrates the importance of installing safety valves for heating equipment directly on the boilers or tanks themselves, or without any obstructions between the valves and the objects which they are intended to protect.

Another case, caused by an obstruction between a boiler and a relief valve, was an explosion of a small cast iron hot water supply boiler in a New York City apartment house. Mud and scale accumulated in the circulating piping between the boiler and the hot water tank. As the relief valve was installed on the tank and as the mud and scale had stopped the water circulation almost completely, there was no outlet for the increased pressure produced by expansion of the water as it was heated. Furthermore, at the time of the accident, the boiler was being forced in an attempt to obtain hot water. Not only did the explosion demolish the boiler itself, but it blew a large hole in the foundation of the building, lifted the floor directly about 1½-in. and shattered a number of windows.

Three of the explosions were caused by water freezing in the safety valves or in piping connected to the boilers, thereby preventing release of excessive pressure. Two occurred to cast iron boilers for hot water heating systems, one in a North Carolina church and the other in a building at a Missouri airport, while the third accident involved a round cast iron steam heating boiler in a store and apartment building in St. Louis. In each case, the boiler had been idle during cold weather and the explosion occurred shortly after it had again been placed in service. In two cases no provisions had been made to prevent freezing while in the third, the boiler had been drained previously as a precaution against that probability. As respects the latter accident, however, it is believed that some water had been trapped in a short section of horizontal piping at the end of which the relief valve for the boiler was

Figure 4—Through an operating mistake, a small hot water supply boiler was changed to a steam boiler. As its water relief valve did not afford suitable protection, the boiler exploded from overpressure.

located. Freezing of the water in this section of piping would have made the valve ineffective. Although the system was of the open type, a stop valve was located in the line to the expansion tank and for some reason this valve had been closed at the time the boiler was fired. In all three of these explosions the violence was such that not only were the boilers wrecked but there was also damage amounting to several hundred dollars to surrounding property.

The picture in Figure 4 was taken in the basement of a utility company's shop and warehouse building and shows part of the damage caused by an explosion of an oil-fired cast iron boiler. In the summer time, the boiler was used for hot water supply purposes and connected directly to a storage tank. During the cold months it was operated with an open-type hot water heating system for supplying heat to a sprinkler tank located on the roof. While it was being operated as a hot water supply boiler, the sprinkler tank overflowed, indicating that the stop valves in the circulating lines to that tank were not closed tightly. Thinking that scale might have lodged in the valve seats, the operator opened the switch to the oil burner motor, closed the stop valves to the hot water tank, opened those to the sprinkler tank and finally opened the boiler blow-off valve in order to drain water from the sprinkler tank with the hope that thereby the valve seats would be cleaned. When the water had been withdrawn so that the boiler was only partly full, he closed the blow-off valve and the stop valves in the lines to the sprinkler tank but forgot to open those in the hot water supply lines. At that time he was called away from the boiler room but before leaving he closed the switch to the oil burner motor, thus placing the burner in operation. Shortly afterward the explosion occurred. Investigation revealed that although a water relief valve, set at 125 lb, was installed on the boiler, it was not suitable for relieving excess pressure while the heater was being operated as a steam boiler. Consequently the pressure continued to increase until the boiler burst.

The accident causing the largest amount of property damage, excluding those accidents from which fire ensued, was an explosion of a large cast iron steam heating boiler in a three-story building in New York City. Most of the damage, which was estimated in a news account as $15,000, occurred to merchandise and fixtures in two stores on the first floor of the building. The account also stated that 100 guests at a wedding party on the second floor were thrown into a panic and three of them were cut by flying pieces of glass from broken windows. Both the front and rear sections of the boiler were completely demolished and other parts, including the base, were broken. Although the exact cause was not learned, the evidence led to the conclusion the accident had resulted from overpressure.

In two cases the boilers that exploded were located in automobile service stations, one in Ohio and the other in Pennsylvania. In the Ohio accident, a steam heating boiler exploded and resulted in property damage estimated at $3,000 and minor injuries to the attendant. Parts of the boiler were blown through the roof and into an adjacent street. What caused the explosion wasn't determined, but it was believed that the safety valve had been stuck. In the other accident, the boiler involved was a cast iron hot water heater connected to a closed-type system with a reducing valve and relief valve in the feedwater line. In this case, also, the relief valve was believed to have been inoperative. One person was reported to have been blown through an open doorway without serious injuries. Damage to the station and fixtures, including the boiler, was about $500.

After making an investigation, local authorities released a report stating that an explosion of a round cast iron steam heating boiler in a Wisconsin store and restaurant building had been caused by failure of a pressure control together with an inoperative safety valve. The boiler was stoker-fired and the control device was intended to shut off the stoker when the pressure reached 5 lb. The explosion blew off the top section of the boiler, ripped plaster from the walls, shattered window glass and damaged fixtures and merchandise in the store. In addition, it injured three people. According to a news account, property damage was more than $2,000.

In three cases involving failure of hot water supply equipment the hot water storage tanks were the weakest points in the supply systems rather than the boilers or coil heaters in which the water was heated. One explosion occurred in a nurses' home in Tennessee, another in a residence in Connecticut and the third in a store and apartment building in Illinois. Damage to the buildings was extensive as the total for the three explosions, according to the reports, was approximately $10,000. The news accounts for the first two of these accidents stated that the blasts resulted from the safety valves having been stuck. Although an inspector made an investigation of the Illinois accident, piping, valves and fittings were so badly twisted and broken that he found it impossible to reach a definite conclusion as to the cause. The exploded tank, which was 2-ft. in diameter by 5-ft. long and constructed of galvanized steel, is shown in Figure 5.

Two other explosions, one at a military camp in New York State and the other in an Ohio residence, were attributed to furnace explo-

Figure 5—The damage resulting from the explosion of this hot water tank was estimated at $4,000. The cause was not determined.

sions, although the violence of the blasts and other information about them as given in the news accounts, leads to the belief that they were pressure explosions. Both were small units using coal fuel, one being a round cast iron sectional boiler and the other a steel boiler of the horizontal tubular type.

In one other accident, also occurring to a boiler in a military camp, the explosion injured seven men, one of them fatally. Information released by an official board of inquiry stated that it had been caused by non-functioning of a relief valve which contained a definite obstructive defect.

THE COVER

An inspector discussing a performance chart for a power boiler. Not only are such charts indicative of operating efficiency but they are also useful in warning of possible trouble. Sudden or widely fluctuating changes, for example, on a feed-water flow chart may indicate a faulty valve or regulator—a condition which, if not corrected, can lead to an accident from low water and overheating.

The Department of Interior reports that at the end of 1940, the installed water-wheel capacity in the United States was 19 million hp. This is more than 27% of the amount installed in the entire world. —*Power.*

Boiler and Pressure Vessel Failures

One inescapable conclusion drawn from a study of a large number of boiler and pressure vessel failures is that, for the greater part, such failures are caused primarily by operating errors, neglect, lack of proper maintenance, and failure to follow accepted safety precautions—all causes which might be characterized generally as effects of carelessness and poor housekeeping. With today's shortages of new equipment and with uninterrupted production of paramount importance in many plants, owners, engineers and operators can appreciate why this condition creates a problem of particular significance to them at the present time.

In this article the primary or fundamental reasons underlying the several main causes of boiler and pressure vessel failures will be discussed and, for the purpose of illustration, several explosions or other failures will also be described. In addition, percentages will be given to indicate the proportion of failures from certain causes to the total for all causes. While these percentages are approximate, they do give a rough indication of the relative frequency with which failures occur from various causes. Likewise, they suggest wherein the greatest opportunities lie for avoidance of boiler and pressure vessel accidents through improvement in care and maintenance.

Overpressure

Roughly 3% of all failures are from overpressure. While they do not occur as frequently as those from other causes, usually the resultant property damage and personal injuries are far greater from this type of accident. Actually, overpressure is an immediate or proximate cause which may be brought about in several ways or which may arise from a number of primary or fundamental causes. Generally, boilers and pressure vessels are installed with suitable provisions for protection against excessive pressures but occasionally safety valves or other devices either fail to function, or, for one reason or another, are incapable of affording the desired protection.

Overpressure accidents have resulted from improper setting of a safety valve or from failure of a safety device to release at the intended pressure. In some cases, boilers or pressure vessels that had not been properly installed and inspected have exploded from a complete lack of a pressure-relieving device. Safety valves installed on inlet or outlet connections, rather than on independent connections to the vessels, have been made ineffective by obstruction of the connections with scale. In other similar installations, stop valves have been installed inadvertently between the boilers or vessels and their safety valves. Although the hazards in such installations would seem obvious, disastrous explosions have occurred as a consequence. Overpressure accidents have also resulted from the operation of vessels at pressures greater than they could safely withstand. Others have occurred in unfired pressure vessels as the result of the safety valve openings becoming obstructed by the materials being processed.

Part of the damage to an Ohio school from an explosion of a welded steel hot water heating boiler is shown in Figure 1. Although positive proof was lacking, the nature and extent of the damage indicated that overpressure was the probable cause. The boiler was stoker-fired and automatically controlled. The theory generally accepted for the explosion was that the water circulation in the system had been greatly reduced or stopped entirely and that a water temperature control for the stoker had failed, resulting in the pressure increasing until the boiler burst. If the water relief valve functioned at all, it must have been of inadequate discharging capacity to relieve the pressure at the high temperature which undoubtedly had been reached when the boiler exploded, as at that temperature a large amount of water would have

Figure 1—An explosion of a steel hot water heating boiler was responsible for the damage to this Ohio school. Excessive pressure was believed to have been the cause.

Figure 2—View of a North Carolina manufacturing plant wrecked by an explosion of a horizontal tubular boiler. Overheating from an accumulation of scale and sediment caused the accident.

flashed into steam when the valve opened. Fortunately, the accident occurred on a holiday, so no one was injured. But the property damage, which was estimated at $50,000, shows how costly a heating boiler explosion may be.

Overheating Cause of One-Third of the Failures

Approximately one-third of all boiler and pressure vessel failures can be attributed to overheating. There are several ways, however, in which a failure of this kind may be brought about, the most common one being from internal scale, mud or oil. Experience indicates that these conditions are responsible for about 19% of all failures, or for more than one-half of those in which overheating is given as a general cause. This emphasizes the importance of keeping boilers clean and free from internal deposits of foreign matter.

Accumulations of foreign substances on boiler heating surfaces in sufficient quantities to result in failures from overheating may arise from several sources. For example, during low water periods, feedwater obtained from wells may contain considerable sand and sediment. At certain times, feedwater taken from rivers or streams may contain abnormal amounts of suspended matter or scale-forming material. Improper use of a boiler compound has been responsible for overheating through its action in loosening scale and thereby causing it to fall and accumulate on the lower heating surfaces. An amount of scale-forming material which might not be harmful to a boiler operated at a low rating may cause a failure within a comparatively short time in a boiler operated at a high rating. Similarly, a normal concentration of such material which may not result in overheating of the boiler itself, may produce a carry-over into its superheater tubes and cause their failure.

Six persons were killed and nine injured in a North Carolina plant by an explosion of a horizontal tubular boiler that had been overheated as a result of a heavy deposit of foreign material. A large part of the property damage, which all together amounted to approximately $45,000, is shown in Figure 2. The overheating was brought about by an increase in the sediment and scale-forming content of the feedwater. Although the operators had followed a practice of opening the boiler for cleaning every week, this cleaning had consisted only of removing the lower manhole plate and of washing the loose scale and sediment to the rear of the boiler with a hose, the operators expecting that this foreign matter would be carried away through the blow-off piping when the boiler was blown down. However, because of the unexpectedly heavy accumulation of this foreign matter, this method of cleaning proved insufficient and the fire sheets overheated.

When oil gets into boilers, usually it is through contamination of condensate used for feedwater make-up. As an example of overheating from this source, defects in steam coils in creosote or oil tanks have permitted the creosote or oil to leak into the coils and be returned to the boilers with the condensate.

Two accidents have occurred in recent months to diphenyl boilers as a result of overheating. A diphenyl boiler has a very definite safe maximum rating based on its B.t.u. capacity. If that rating is exceeded, the temperature of the diphenyl may be raised above a safe limit of 750°F, thus causing its disintegration. This results in a deposit of solid material on the tube walls and leads to their overheating and eventually to their failure.

Other Overheating Causes

The cause of the greatest number of other overheating failures is from loss of steam, water or other contents. About 6% of the total of all failures occur in this way, most of them involving heating boilers.

Leaks in buried and corroded return lines for cast iron boilers are one of the principal sources of trouble under this classification. Water may be drained from a boiler by the operator failing to close the blow-off valve tightly, or by the lodging of scale particles within the valve, thus preventing it from closing completely. Other accidents are caused by operators forgetting to close blow-off valves after having opened them.

There have been cases in which pressure and low-water control devices on automatically fired boilers failed to operate, and as a consequence so much steam and water were lost through the blowing of the safety valves that the boilers were overheated.

With heating boilers, inoperative check valves and breakdowns or the non-functioning of return pumps and traps are two of the principal causes for overheating from low water. The result of these failures is stoppage of the condensate returns.

A reason frequently found for low water and for subsequent failure of heating boilers is the accumulation of enough sediment or scale in the float chambers of low-water fuel cut-outs or feedwater regulators to prevent them from operating. Failures are also caused by the connections between the floats and tripping mechanisms in these devices being packed so tightly—usually to stop leakage—that they are unable to function when required. Accidents from these causes are often traceable to oversight or negligence on the part of operators through their failure to maintain and test the devices properly and regularly.

Other causes of failures from overheating are defective check valves and defective water level indicators; non-operation of pumps or injectors, or of protective or control equipment such as low-water fuel cut-offs and feedwater controls; and the firing of boilers when dry or with the water dangerously low. Experience indicates that altogether these causes are responsible for about 4% of all failures. Although injectors may fail to function properly for several different reasons, accidents from low water because of such failures are infrequent. In some instances, improper lubrication of motor-driven pump units has resulted in their bearings "freezing" when they stopped. Then when the units attempted to start again the fuses blew. Accidents have also been caused by loss of water from boilers through feedwater or return pipes because the pipes were not provided with check valves or the check valves were defective. Stoppage of the connections to the water glass on a boiler level indicator, thereby leading an operator to believe a boiler had sufficient water when actually it was dangerously low, has been the primary reason for other overheating accidents.

Although there are a few other causes of failures under the general heading of overheating, the number of such cases is comparatively small. Some tube failures in water-tube boilers fall within this group since they are not brought about by low water or scale conditions but rather by steam pocketing in the tubes. This type of failure is more likely to occur in water-wall and roof tubes than in other boiler tubes. In some water-tube boilers, under certain conditions of operation, a surging action of the boiler water may cause a rapid covering and uncovering of the tube surfaces. This action, in turn, produces a rapid alternate heating and cooling of the tubes, causing them to fail. Tubes have also been overheated because the armor or protective coating, placed on the outside of the tubes, had been destroyed by slag accumulations.

Internal Corrosion

A source of trouble which occasionally results in disastrous explosions is internal corrosion. The number of failures, however, from this cause is not high, as their proportion to the total is about 3%. Pitting of tubes, grooving and general corrosion internally in all types of objects, come under this heading. Rendering tanks are one of the types of pressure vessels that are subject to rapid corrosion as are also sulphite digesters if their linings become defective and permit leakage of the contents through to their shells. Hydro-pneumatic tanks, and air tanks improperly installed or operated, are also likely to corrode internally. Several costly explosions of such objects have resulted from this type of corrosion.

Figure 3—Georgia sawmill extensively damaged by an explosion of a horizontal tubular boiler. The feedwater contained tannic acid which resulted in rapid internal corrosion.

Figure 4—When a badly corroded vulcanizer exploded in a Pennsylvania plant, two persons were injured and the property damage amounted to $6,000. This shows parts of the exploded vessel.

In chemical manufacturing plants, vessels containing chemicals used in process work have also failed from internal corrosion. This resulted from the processes getting out of control, although ordinarily the contents of the vessels were not corrosive. Similarly, Freon refrigerating systems may fail by the Freon becoming contaminated with moisture, and accidents to carbon-dioxide gas scrubbers have resulted from the dissolving of carbon dioxide gas in the water, thereby making it acid.

Figure 3 is an illustration of damage from a boiler explosion caused by internal corrosion. Two persons were injured and property damage amounted to $6,500. Feedwater for the boiler, a horizontal tubular, was obtained from a log pond, and as this water contained a considerable proportion of tannic acid, it was the reason attributed for the very rapid and extensive internal corrosion which caused the accident.

In another case involving a vulcanizer, corrosion affected all the interior surfaces of the vessel to such an extent that it exploded. Used in making rubber-base division plates for storage batteries, the vulcanizer was corroded by the condensate becoming acid, which condition, in turn, was produced by the sulphur compound used in the vulcanizing process. Figure 4 shows parts of the exploded vessel. This accident resulted in injuries to two persons and property damage of more than $6,000.

External Corrosion

Experience shows that the number of failures resulting from external corrosion is approximately twice those from internal corrosion. Often operators do not appreciate that under certain conditions external corrosion is very likely to occur on covered boiler surfaces. Hence this corrosion is not discovered or preventative measures taken before it has progressed to the point of causing a failure. It is well known that neglect to keep ash accumulations away from boiler surfaces results in rapid corrosion. Also, it is well recognized that leakage around manhole and handhole plates, or at riveted seams and staybolts, leads to similar trouble. Coal-fired boilers that are lagged and located on portable equipment, such as those on cranes in which the coal bins and water tanks are placed close to the boilers, have failed more frequently from this cause than have other types of fire-tube boilers.

Many disastrous explosions of water-tube boilers have resulted from external corrosion of the buried heads of the lower drums. However, through the determined efforts of boiler inspecting agencies, owners have been made to realize that these concealed heads should be uncovered periodically for inspection and, therefore, accidents from this source have largely been eliminated.

As an example of the costly consequences of external corrosion to covered boiler surfaces, an explosion of a horizontal fire-tube boiler at a West Virginia coal mine killed four people, and caused a property loss of $18,000. The boiler had been installed in a building with a leaky roof and rain water had penetrated the brickwork covering the top of the shell. As the boiler was used intermittently, ample opportunity was afforded for corrosion to take place under the brickwork.

Failures of cast iron boilers from rust growth between the sections also come within this classification. Leakage around connecting nipples or condensation during idle periods are the common causes of this rust growth.

Expansion Stresses

From a study of a large number of failures, it is found that more accidents result from expansion stresses than from any other main cause except overheating. About 20% are attributed to this cause, more than half of them occurring to cast iron boilers. Cracking of sections in cast iron boilers is probably the most frequent of all boiler failures. While overheating is usually thought of as the reason for sections cracking, often the evidence indicates that they fail from unequal expansion rather than from overheating. In some cases tie rods are set too tightly or the rods are not equipped with expansion washers. Sections also crack from the pipe connections to the boilers being too rigid to permit proper expansion, and from too rapid firing through the resultant local expansion creating excessive concentrated stresses.

Expansion stresses in steel boilers and in unfired vessels cause nearly as many failures as those occurring from the same cause in cast iron boilers. Vertical water-tube boilers have failed in installations in which the mud drums were not free to move because packing for stopping air leakage through the setting had hardened. Cast iron headers in steel boilers have cracked as a result of a combination of rust growth and packing between the headers preventing proper expansion. In a few instances, economic type boilers have failed from expansion stresses through these stresses weakening the cross braces, causing them to break from corrosion fatigue.

There have been several failures attributable to expansion stresses in unfired pressure vessels constructed of cast iron. The most common causes of these failures are operating errors. The sudden admission of a large amount of steam to a vessel that has been idle for some time is likely to produce uneven expansion with an accompanying stress of sufficient severity to cause it to crack. Last February an accident to a Yankee drier roll in a paper mill occurred in this way. Constructed of cast iron 1¾-in. thick, the roll was 10-ft. in diameter and 104-in. long and normally operated at 45 lb pressure. It was heated by exhaust steam from engines, supplemented by live steam as the latter was required for the temperatures and pressures needed at high speeds. On the day of the accident, the roll was started without any load at about 7:00 A. M. and operated in this manner until shortly before 8:00 A. M. Then, in order to warm the roll more rapidly so that the temperature would be increased to a point where production could be started, a considerable quantity of live steam was admitted, and the temperature raised quickly to the desired amount. A few minutes later there was a sharp report. On stopping the roll, the attendant found a crack about 5-in. long running horizontally at one end of the shell. After several attempts to repair the roll had failed (as steam and water continued to leak through the crack at high speeds) a new roll was ordered. Approximately three months were required to construct and install it. In the meantime the machine was continued in operation but at somewhat less than full capacity. The total loss was more than $33,000, including the extra expense for temporary repairs and for expediting construction of the new roll. The indirect loss, or the loss from reduction in production amounted to about two-thirds of this total.

Furnace Explosion

Experience shows that accidents from explosions of fuel gases in boiler furnaces, flues and fireboxes, or accidents called furnace explosions, are high in frequency compared to many of the other classes of boiler and pressure vessel failures. Approximately one out of every ten failures is a furnace explosion. In automatically operated oil and gas-fired boilers, furnace explosions have resulted from delayed or poor ignition; accidents which may occur, for example, from low voltage or from impurities in the fuel. Failures of safety devices, intended to prevent oil burners from operating when they were defective, have also contributed toward such accidents. Explosions in installations having

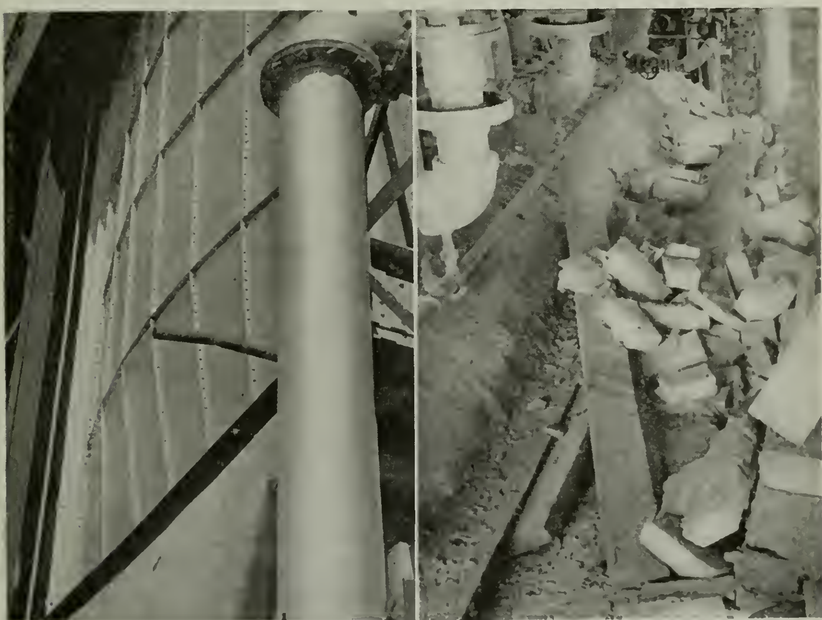


Figure 5—(Left) and 5A (Right)—Two pictures showing some of the damage caused by a furnace explosion to a large water-tube boiler in an Arizona utility power house. The one at the left shows one wall of the boiler's economizer bulged out several inches, while the other gives a view of damaged brickwork in the top of the setting.

manually controlled burners are usually traceable to operating errors, such as starting the fires with the stack dampers closed or with the drafts improperly adjusted. Furnace explosions have resulted from fuel leakage into the furnaces of idle boilers, the fuel gases later being ignited by hot brickwork or in some other way. Primarily poor maintenance is the usual reason for such losses.

A few months ago a furnace explosion in a large water-tube boiler in an Arizona utility plant seriously burned the operator and necessitated repairs costing approximately $39,000. Although the boiler was equipped to burn either gas or oil fuel, gas was being used at the time of the accident. The entire top of the setting and the rear arch were blown out of place. Both the front and rear walls of the setting were bulged outwardly, the front arch disrupted and other parts such as the breeching and baffling were also damaged. Each of two horizontal 14-in. I beams supporting the boiler were bent about 5-in. and several supporting columns, which were also 14-in. I beams, were twisted at the top of the setting. One side wall of the economizer was bulged outwardly several inches as shown in Figure 5. Other damage to the brickwork on top of the boiler is shown in Figure 5A. Although the exact sequence of events prior to the accident was not obtained, it is believed that the operator lighted the fire and started the forced-draft fans but with too much draft for the amount of fuel, thus extinguishing the flame. When later the operator discovered that the fire was out, he attempted to relight it. He should have shut off the fuel supply first and then thoroughly vented the furnace of the accumulated gas before again attempting to operate the boiler.

Other Causes

The percentage of failures from any one of several other causes is comparatively low. Some of these causes are defective welding or brazing, defective castings or other defective material, and improper design. On an average they are primarily responsible for about 7% of all failures. Lap-seam or caustic embrittlement cracks, improperly applied or unsuitable welding or brazing, and water hammer are other causes which all together account for about 4% of all boiler and pressure vessel failures. Although there are various other miscellaneous causes, usually the failures from them are of a minor nature in that they do not result in extensive damage. For any of these failures, however, the resultant loss to the owner from curtailment of production may be costly.

Causes such as defective welding or brazing, defective material and improper design, are self-explanatory and little can be added to explain them more fully. Failures resulting from improperly applied welding or brazing have occurred to boilers or vessels in which attempts had been made, contrary to approved engineering practice, to repair or rebuild defective or corroded parts. In some of them, even a new part would not have made a satisfactory repair. There have also been boiler explosions for which the cause has been traced to the application of welding at staybolt ends to stop leakage. As the staybolt threads and those in the sheet were defective or wasted away by corrosion, the welding only covered over a dangerous condition and did not make a suitable repair.

A few failures have occurred to large cast steel valve bodies through development of cracks in the castings. Blow holes in castings have also caused failures as likewise has the shifting of the cores for cast iron boiler sections when the sections were poured. Accidents for which the resultant damages are occasionally extensive and costly, are those caused by water hammer. These usually result from operating errors, from lack of drains in steam-mains or from improper location of the drains.

Forty or fifty years ago boiler explosions from lap-seam cracks were numerous, but today, through changes in design and through the use of better inspection methods for finding such cracks, few accidents of this kind occur. Similarly, a few years ago, boiler failures from caustic embrittlement cracks were sufficiently frequent as to cause considerable concern. No violent explosions from this source have been reported during recent months indicating undoubtedly that steps are now being taken more generally by power plants to treat boiler feedwater in a way that will prevent such cracks. In addition, as the symptoms of embrittlement are now well recognized, it is more readily detected and greater efforts are being taken for its control.

Source of Industrial Power

According to *Power*, a preliminary Census Bureau report shows that at the end of 1939 a total of 46 million hp in motors and approximately 7 million hp in mechanical drive prime movers was connected to the industrial production machinery in this country. More than half of this driving machinery was supplied by purchased energy. Prime movers in industrial plants totaled over 21 million hp, of which 53% was steam turbines, 31% steam engines, 7.5% hydro-turbines or water wheels and 8.5% internal combustion engines. Of this steam-turbine capacity, 85% drove generators while for steam engines, the proportion driving generators was only 31%. For the water-power units 75% of their capacity was converted to electric energy.

Reduces Belt Slippage on Pulleys

A new slip-proof pulley coating with a rubber base is claimed to increase the efficiency of belt drives as much as 50%. Suitable for metal, wood or composition pulleys (flat or V-type), the new coating may be applied to a pulley at the end of the day and the next morning the pulley will be ready for use. —*Forbes.*

The Locomotive

A QUARTERLY MAGAZINE
DEVOTED TO POWER PLANT PROTECTION

Published continuously since 1867

. WALLACE H. HENSHAW, *Editor*

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Observe Proper Precautions When Working in Boilers

From time to time we encounter newspaper items or reports describing deaths or serious injuries suffered by workmen while cleaning or repairing idle boilers. Most frequently the cases involve scalding of workmen.

When boilers are connected to a common steam header, or are interconnected through blow-off piping or tanks, and some of the boilers are in operation, a person planning on entering an idle boiler should make sure that the stop valves in the blow-off piping, and between the main header and the boiler, are closed. He should further assure himself that they will not be opened by some one through error or carelessness. And another important safety precaution he should observe is not to attempt making repairs to boilers or vessels while they are under pressure.

In an accident which involved workmen in an idle boiler, two convicts were fatally scalded while cleaning a boiler drum at the Missouri state prison. It was reported that another worker opened the stop valve in the steam line between the boiler and the main steam header, thereby permitting steam to enter the drum in which the men were working.

Use of gas pressure for short periods to operate equipment designed to be steam driven is more or less common practice in oil field installations. It recently led indirectly to the injury of two men who were removing tubes from a boiler. Ordinarily the boiler furnished steam for driving a pump and an engine. However, while it was being repaired, the pump and engine were temporarily being operated by gas pressure. Apparently a leaky stop valve in the steam line permitted the gas to enter the boiler and resulted in an explosion when the gas was ignited by an acetylene torch the men were using to cut the tubes.

Lucius F. Robinson, Jr., Elected a Director

At a meeting of the Company's Board of Directors on June 23, 1941, Lucius F. Robinson, Jr., of Hartford, Connecticut, was elected to the directorate to succeed his father, the late Lucius F. Robinson. In this capacity, the new director holds a position which had been filled by his father for 41 years and, previous to that, had been held by his grandfather, Henry C. Robinson, for 19 years.

Lucius F. Robinson, Jr.

A graudate of Yale in 1918, Mr. Robinson served as a lieutenant during the World War and afterward entered Harvard College of Law from which he received an LL.B. degree in 1921. Since 1924 he has been a partner in the law firm of Robinson, Robinson and Cole.

In addition to his law practice, Mr. Robinson has taken an active interest in civic affairs, both those in his home city and in his state, and he has served as chairman or as a member of several commissions. At the present time he is a member of the City of Hartford's Park Board, and he is also closely associated as a trustee and director with a number of institutions and prominent businesses.

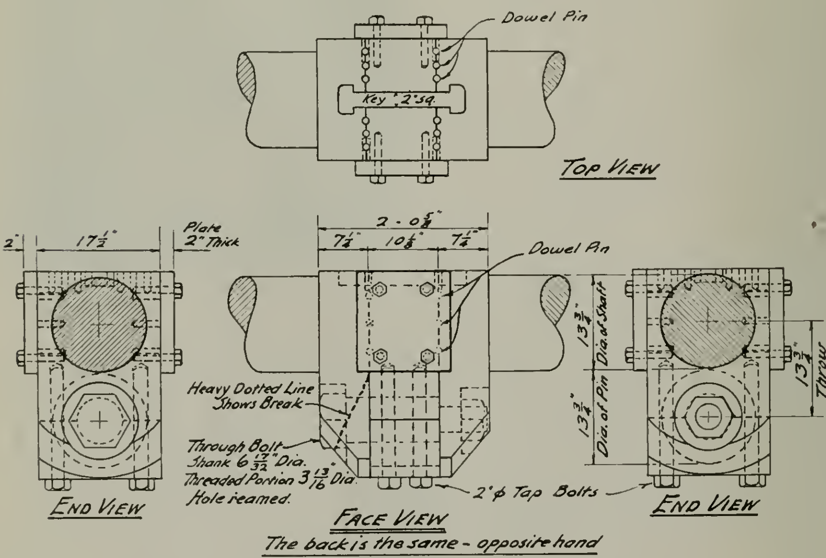
New York City—Reason why a certain apartment building was cold, was that the furnace had been stolen. Janitor had actually dismantled and sold it. It's warmer where he is now. —*The Casualty and Surety Journal.*

Crankshaft Breaks on 3,000 hp Diesel Engine

While operating at about seventy-five per cent of its customary load, a 10 cylinder, 3,000 hp Diesel engine, which had been installed for 8 years, developed excessive vibration. It was shut down as soon as possible and an investigation revealed that the bearing for the number six crankpin was seriously overheated. When the bearing had been removed, one web was found to have been broken, the failure having taken place through the chamfered portion of the web at the connecting pin. Although usually when a shaft breaks on a Diesel engine the accident results in the breaking or deforming of other parts, in this case, fortunately, there was no other damage.

Operated at a speed of 240 rpm, the engine had a one-piece shaft 22-ft. long and 13¾-in. in diameter. Each web was 7¼-in. thick and 17½-in. wide, except at the crankpin ends where the webs were chamfered. The pins, which were hollow, were 13¾-in. in diameter and 10⅛-in. long between the webs.

Although a new shaft was ordered promptly, at this writing it has not been obtained. The engine manufacturer did not have one of this size on hand and stated that probably six months would be required to furnish a replacement. In the meantime, the engine is being operated



Sketches showing method used in making a temporary repair to a large shaft for a 3,000 hp Diesel engine.

with the sixth cylinder cut out. A temporary repair was accomplished by removing the connecting rod, blocking the piston in such a position that the exhaust and scavenging ports were closed, and installing between the webs a solid steel block with a cap, both machined to fit around the pin and both securely held in place, thus firmly connecting the two ends of the shaft together. As shown in the accompanying sketches, this block and cap were fastened to the shaft by a steel link at the top, a through bolt at the bottom, and two steel plates bolted to the block, one on the front and the other on the back. Four 2-in. tap-bolts fastened the cap to the block.

The total cost of a new shaft, including shipping and installation expense, is estimated as $31,000.

1000 kw Steam Turbine Explodes

Last July a 1,000 kw steam turbine-generator unit exploded in a power plant at a Rhode Island mill. The unit was wrecked completely. The top part of the turbine casing was thrown off, all the blading was bent and flattened out, the generator shaft was broken between the end of the rotor and the collector rings, and the outboard bearing pedestal was torn from its foundation. After being hurled through a switchboard, the outboard end of the generator shaft struck a wall of the power house and a part of the pedestal knocked a large hole through the floor. A news account indicated that the mill would be closed for several days as a result.

The exact sequence of events which led to the crash was not learned but apparently the turbine overspeeded. At the time of the accident, the load was being changed from a larger turbine to two smaller units, one of which was the one that exploded. It was reported that an operator was at the switchboard working the controls for the larger unit when its speed increased. On noticing this condition, the operator was said to have increased the speed on the other two units but to have failed to shift the load to them. Presumably the governor and the emergency stop for the turbine that exploded either failed or did not react quickly enough to prevent excessive speed.

Explosive Rivets

A new type of rivet with a high explosive secreted in the shank has been developed and is now being manufactured in commercial quantities according to *Forbes* magazine. Heat applied to the rivet head by an electric gun sets off the charge, the explosion expanding the charged end, thus forming a "blind" head and setting the rivet. The manufacturer states the explosive charge has been controlled so finely that the expansion it effects may be held within twenty-thousandths of an inch. The strength of these rivets in both shear and tension is reported to be equivalent to that for rivets of the driven type.

Taps From the Old Chief's Hammer

"DID I hear you tell Bill you were in the dog house, Tom?" queried the Old Chief.

Tom grinned. "I was for a while but I'm not now. I was telling him about an incident that happened at home a couple of weeks ago."

"What was it, Tom?" asked the Chief, jocularly. "I can't imagine your upsetting Mrs. Preble to such an extent as to be placed in that predicament."

"Oh, there's not much to tell," answered Tom. "I guess I mentioned to you before that we had a couple of rooms redecorated last month. In one of the rooms the painters, in unscrewing the wall-type lighting fixtures, short-circuited a couple of them. I didn't know about it at the time but found it out the evening after the painters finished when I tried to turn on the lights.

"As we were having guests that evening we, of course, wanted to have the newly decorated rooms appear at their best, so I decided that being a capable 'handy man around the house' it wouldn't take me long to locate the trouble and make the necessary repairs. I was in luck, so I thought, for in the first fixture I took apart I found the wires had been twisted and broken. Making repairs didn't take long but when I put in a new fuse, it promptly burned out. That was a bit disconcerting, but having started, I didn't want to stop then, guests or no guests. By the time they arrived, I was still hard at work and rapidly getting more exasperated. Finally, after having checked all the outlet fixtures except one, I removed that and found another short circuit. The wires had been twisted and broken the same way as in the first one I had examined.

"When the second fixture had been repaired, I discovered I didn't have any more fuses, but by borrowing one from another circuit, I had the satisfaction of knowing that all the short circuits had been eliminated, for this time the fuse did not blow. All this had taken considerable time and as we weren't well acquainted with our guests, you can appreciate why my seeming indifference to the amenities expected of a proper host earned me a place in the dog house rather than a medal for my accomplishments as a 'handy man'."

The Chief chuckled. "I imagine your thoughts about the abilities of painters as electricians were hardly flattering, Tom. Reminds me of an experience Bill Scott had in a small plant up on the coast a couple of years ago. Bill was more fortunate than you, though, for he won the seat of honor, so to speak, before he left. But he certainly was in the dog house for a while."

"I don't remember hearing about that experience," put in Tom "What happened?"

"It wasn't so much what happened, Tom, but rather what didn't happen," replied the Chief, his eyes twinkling. "All the power for this plant was supplied by a direct current generator, one of about 50 or 60 kw capacity, if I remember correctly. Bill arrived there about 11 o'clock in the morning, planning to make an inspection during the noon shut-down, which usually ran from 11:30 to 12:30. On that particular day, however, the plant engineer insisted that power would be required until 12:15, so Bill had only 15 minutes to make tests and examine the windings while the machine was shut down."

"That certainly didn't give him much time," interrupted Tom. "Just about enough to get started when he had to stop."

"You're right about that, Tom," the Chief continued. "First he made a megger test which indicated that the generator was grounded. In looking around for the cause, Bill discovered that an equalizer lead, no longer in use but which had been connected to another generator that had been removed some months previously, had been chopped off at the floor rather than pulled from the conduit as it should have been. After this lead had been disconnected, the megger readings were satisfactory. By the time Bill had made a hasty examination of the windings, it was nearly 12:30. The generator was started but it wouldn't build up any voltage. Removal of the equalizer lead was the cause, according to the engineer, so it was reconnected. But still nothing registered on the voltmeter. The engineer grumbled something to the effect that the generator had never acted that way before, and hinted that the cause must have been something Bill had done in making the tests."

"Bill was on the spot, all right," commented Tom. "But I judge from what you said at first that he knew what was wrong."

"Oh, he knew where the trouble lay or, at least, he had a very good idea. The indications were, as you have probably guessed, that in some way the field had lost its residual magnetism and he tried to explain that to the engineer. Bill asked for batteries to energize the shunt field but he was told that there were none available. In the meantime quite a crowd, including the manager, had gathered in the engine room. All wanted to know why there wasn't any power. After hearing what happened it was apparent they figured Bill was to blame, so his plea for some storage batteries fell on ears that were decidedly unsympathetic. Plenty of advice of a kind was offered, along with other remarks which weren't flattering to Bill or to inspectors in general. He said they added to the confusion but contributed nothing of a constructive nature. Finally, in desperation, Bill removed the battery from his car and connected it to the generator field. Although he had hoped this might do the trick, it didn't work. The voltmeter pointer moved a little but there wasn't sufficient voltage to produce the required exciting current. As he had feared, one battery wasn't enough."

"Considering that the engineer seemed to be at a loss as to what to do," said Tom, as the Chief paused, "I should have thought some of the would-be assistants would have come to Bill's rescue and borrowed a couple of batteries from some other cars."

"Perhaps so, Tom, but as is often the case with a crowd of that kind, few show any initiative. However, the manager, beginning to see the light, sent a messenger to the wharf for a couple of storage batteries and in almost no time at all, he returned with them. With 18 volts connected to the field, Bill felt better. And he wasn't disappointed, for this time when he started the generator, the pointer on the voltmeter began to climb slowly but surely, finally coming to rest at the usual potential."

Tom smiled. "Bill did have quite an experience, at that. I suppose they were convinced then," he added, questioningly, "that Bill knew what he was doing?"

"Not entirely, Tom. At least, the engineer wasn't. As I mentioned previously the equalizer lead had been reconnected and left that way during all this time. So, as a 'daring' demonstration to show that whether or not the lead was connected wouldn't make any difference, Bill removed it while the generator was running. Much to everyone's surprise, nothing happened. Still somewhat skeptical, the engineer shut down the machine and then while everyone held his breath, according to Bill, started it again. It picked up the voltage and functioned without a hitch."

"As the saying goes," put in Tom, facetiously, " 'all's well that ends well'." Then speaking in a more serious tone, he continued: "How did Bill account for the loss of the residual magnetism? Did he know what caused it?"

"I asked him about that, Tom. He said he didn't know the reason but he thought that probably a short circuit on the line at the time the generator was shut down just before he made his inspection, had been the cause. With d. c. generators it happens occasionally. In this case, considering the engineer's inexperience with such occurrences, the owner was fortunate to have it happen when Bill was at the plant."

Cooling Oil Line Failure Causes Explosion in Diesel Engine

While a Diesel-electric locomotive was hauling a passenger train at a speed of about 75 miles per hour, an explosion occurred in the crankcase of one of its engines. The operator was badly burned, particularly on his face.

Power for the locomotive was supplied by two units, each having two 1,000 hp, 12 cylinder, 2 cycle Diesel engines driving generators. The operator had just checked one engine of one unit. Having found it running apparently satisfactorily, he was about to check the other engine when there was a heavy puff from the former, followed by considerable smoke. As he pushed the stop button to shut down the engine, a sheet of flame shot out from it.

An investigation revealed that a ¼-in. tube through which cooling oil was supplied to the number-one piston had broken. Normally the tube discharged the oil into a funnel attached to the inside of the piston, but through misalignment of these two parts the funnel had been striking the tube slightly on each down stroke of the piston. This eventually caused the tube to break at a point where it was rigidly fastened to the cylinder liner.

Without cooling oil the piston had overheated, and the temperature in the crankcase had been increased sufficiently to cause a combustion explosion of oil vapor. The resultant concussion blew off the cylinder head casings, and two of the crankcase cover-plates. So severe was the piston distortion from overheating that both it and the cylinder were badly scored and the cylinder liner cracked.

Boss: You should have been here at nine o'clock.
New Employee: Why? What happened? —*Mercury.*

She: "Did anyone ever tell you how wonderful you are?"
He: "Don't believe they ever did."
She: "Then where'd you get the idea?" —*Powerfax.*

A recent article mentions that a good poker player can successfully run any business. But what does a good poker player want with a business? —*Powerfax.*

Nervous Passenger: "Don't drive so fast around the corners. It frightens me."
Taxi Driver: "Do what I do—shut your eyes when we come to a corner."
—*Trumbull Cheer.*

The Hartford Steam Boiler Inspection and Insurance Company

OF HARTFORD, CONNECTICUT

June 30, 1941 *Capital Stock $3,000,000.00*

ASSETS

Cash on hand and in banks		$1,404,063.02
Premiums in course of collection (since April 1, 1941)		1,381,922.58
Interest accrued on bonds and mortgages		67,373.91
Mortgage loans		72,215.00
Home Office and Philadelphia branch office real estate		642,331.05
Other real estate		288,969.04
Other admitted assets		19,127.84
Bonds on an amortized basis	$9,076,961.17	
Stocks at market value	8,138,162.03	
		17,215,123.20
Total		$21,091,125.64

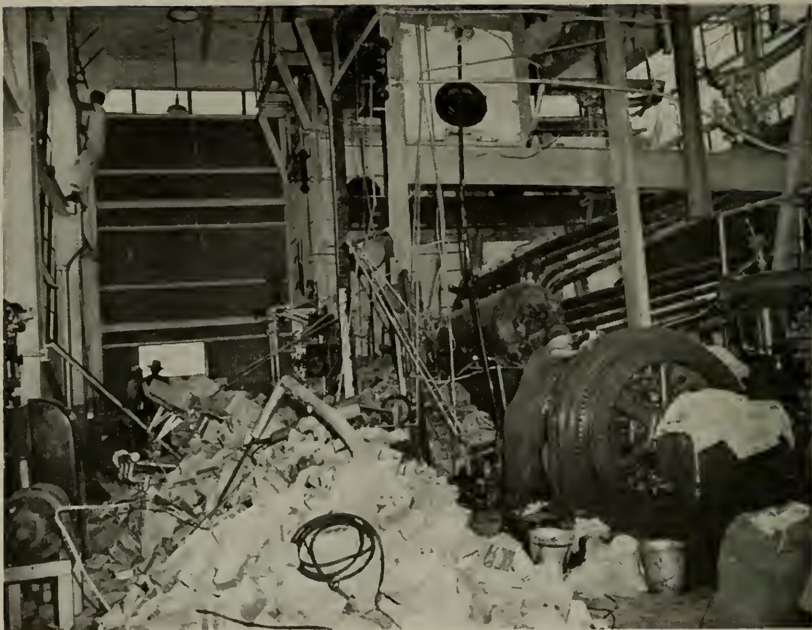
LIABILITIES

Unearned premium reserve		$9,159,937.22
Losses in process of adjustment		542,349.61
Commissions reserve		276,384.52
Taxes reserve		256,218.24
Other liabilities		344,765.46
Liabilities other than capital		$10,579,655.05
Capital stock	$3,000,000.00	
Surplus over all liabilities	7,511,470.59	
Surplus to Policyholders		**10,511,470.59**
Total		$21,091,125.64

WILLIAM R. C. CORSON, President and Treasurer

Incorporated 1866 *Charter Perpetual*

Department	*Representatives*
ATLANTA, Ga., ... Citizens & So. Nat. Bk. Bldg.	W. M. Francis, Manager. N. F. Bailey, Chief Inspector.
BALTIMORE, Md., . . . 704-9 Garrett Building . .	D. W. Little, Manager. W. C. Nicol, Chief Inspector.
BOSTON, Mass., . . . 87 Kilby Street	Thomas F. Rice, Manager. W. A. Bayliss, Chief Inspector.
BRIDGEPORT, Conn., . . City Savings Bank Building .	W. G. Lineburgh & Son, General Agents R. P. Guy, Chief Inspector.
CHICAGO, Ill., ... 120 South La Salle St. . .	P. M. Murray, Manager. C. W. Zimmer, Chief Inspector.
CINCINNATI, Ohio, . . . 1904-12 Carew Tower . .	James P. Kerrigan, Manager. W. E. Glennon, Chief Inspector.
CLEVELAND, Ohio, . . . 1040 Leader Building . .	Arthur F. Graham, Manager. F. E. Le Gates, Chief Inspector.
DENVER, Colo., ... Gas & Electric Building . .	J. H. Chesnutt, Manager. Jesse L. Fry, Chief Inspector.
DETROIT, Mich., . . . National Bank Building . .	W. H. Kerrigan, Manager. Thomas P. Hetu, Chief Inspector.
HARTFORD, Conn., . . . 56 Prospect Street . . .	F. H. Kenyon, Manager. R. P. Guy, Chief Inspector.
NEW ORLEANS, La., . . 519-24 Hibernia Building . .	R. T. Burwell, Manager. Arthur R. Keiler, Chief Inspector.
NEW YORK, N. Y., . . . 90 John Street	C. C. Gardiner, Vice President. J. F. Hunt, Chief Inspector.
PHILADELPHIA, Pa., . . 429 Walnut Street . . .	A. S. Wickham, Manager. John L. Scott, Chief Inspector.
PITTSBURGH, Pa., . . . Arrott Building	William P. Wallace, Manager. John Todd, Chief Inspector.
ST. LOUIS, Mo., ... 319 North Fourth Street . .	Chas. D. Ashcroft, Manager. Eugene Webb, Chief Inspector.
SAN FRANCISCO, Calif., . . 114 Sansome Street . . .	C. B. Paddock, Manager. L. E. Grundell, Chief Inspector.
SEATTLE, Wash., . . . Arctic Building	E. G. Watson, Manager. William J. Smith, Chief Inspector.
TORONTO, Ont., Canada, . Federal Building . . .	H. N. Roberts, President The Boiler Inspection and Insurance Company of Canada.



What Happens To Production?

Although many accidents in power plants may not be as damaging as the one that caused the wreckage shown above, they can happen wherever power equipment is operated. Often, the resultant indirect loss from curtailment of output is far greater than the direct loss from property damage.

An explosion of a boiler or pressure vessel, the disruption of a turbine or engine, the burnout of a generator or motor—these and other power equipment accidents mean idle hours and lost production. With industry facing a tremendous responsibility in successfully completing the defense program, its need is greater than ever for insurance and inspection on the boilers, pressure vessels and machines on which production depends.

A specialist for 75 years in the business of insuring and safeguarding power plant equipment, Hartford Steam Boiler has a nation-wide force of trained inspectors, who, under the guidance of a highly experienced engineering staff, seek to prevent production-crippling accidents through discovery of weaknesses, defects, and other substandard conditions.