LOOK WITHIN

TRADE MARK

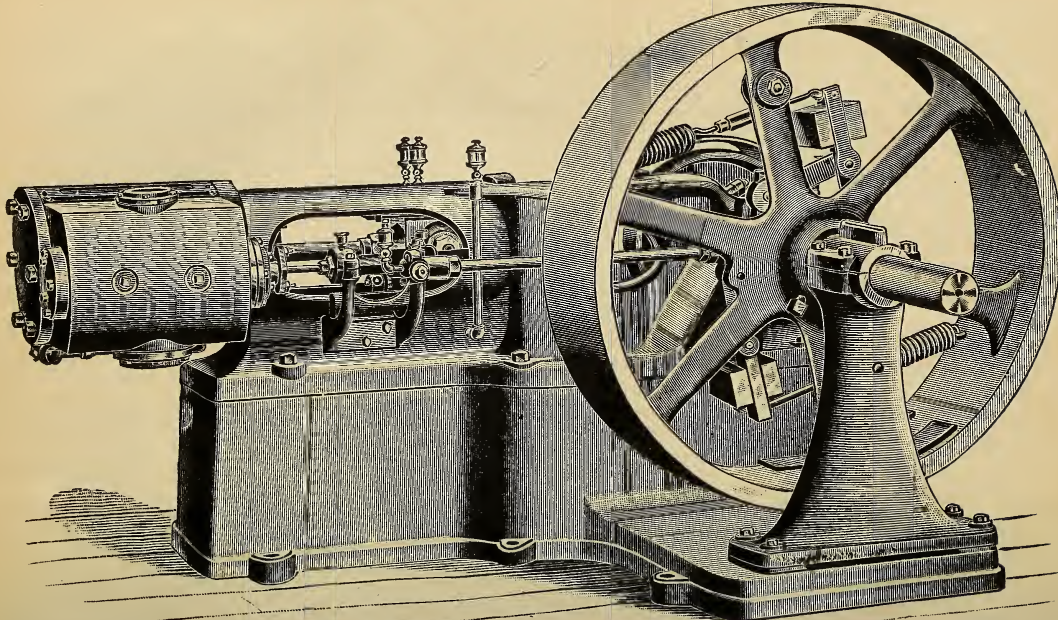

FIG. 1.—The Racine high speed "automatic" steam engine. High speed is here applied in the sense of quick revolution. The term automatic designates that class of engine in which the speed is controlled by varying the cut off by means of a shaft governor. The cut off is varied by the action of the governor upon a *shifting eccentric:* it shifts the eccentric so as to change the *throw*, and *angular advance*, thus changing the cut off.

The thought is in the question; the information is in the answer.

AUDELS ANSWERS

ON

PRACTICAL ENGINEERING

FOR

ENGINEERS, FIREMEN, MACHINISTS,

AND THOSE DESIRING TO ACQUIRE A WORKING KNOWLEDGE OF THE THEORY AND PRACTICE OF STEAM ENGINEERING

A PRACTICAL TREATISE

with ILUSTRATIONS

By GIDEON HARRIS *and Associates*

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PREFACE

This book is written for the special information of engineers, machinists, firemen and electricians who must, sooner or later, procure an engineers' license by going before a board of practical engineers and answering questions relating to the care of boilers, pumps, injectors, engines, indicator, safety valve and the dynamo, etc.

The author in the preparation of the work has had two objects constantly in view; first to cause the student to become familiarly acquainted with the leading principles of his profession as they are mentioned, and secondly, to furnish him with as much advice and information as possible within the reasonable limits of the work.

The question and answer form of presenting information appeals strongly to the practical man who wants a simple answer to a plain question without a display of technical terms or higher mathematics.

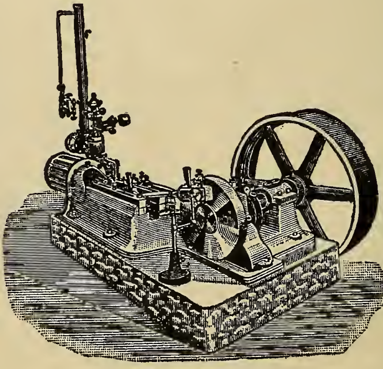
When technical terms are used they are either explained or made clear by the wording of the answer. In order not *to divert the mind and confuse the reader, the answer is always made short and direct, giving simply the information demanded by the question.*

Detailed explanations, or items of seeondary importance, are printed in small type in separate paragraphs.

This is not a book of theories—it is practical, the aim of the author being to present the different subjects treated in as simple a form as possible so anyone can understand it.

With this in view, the author has been careful to omit all unnecessary mathematics, and to present only such information as will be needed to prepare the reader for all emergencies, and for questions of the examining inspector or prospective employer.

THE AUTHOR.



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AIR

Ques. What is air?

Ans. Air is a mechanical mixture of two gases, nitrogen and oxygen, with traces of carbonic acid gas. The relative volumes are: Nitrogen, 4 parts; oxygen, 1 part.

Ques. Does air have weight?

Ans. Yes; all the air surrounding the earth has sufficient weight to cause a pressure of 14.7 pounds per square inch at sea level.

Ques. What is the volume of a pound of air?

Ans. At a temperature of 62 degrees F. at sea level, 13.14 cubic feet weigh one pound.

Ques. What effect has heat on air?

Ans. Like almost all other gases, fluids and solids, air expands as heat is applied.

Ques. Is the expansion of a gas proportional to the amount of heat applied?

Ans. Yes; the volume of a *perfect* gas increases $\frac{1}{273}$ of its volume at 0° Centigrade for every increase of temperature of 1° C.

Ques. What may be said of oxygen, one of the gases that compose air?

Ans. Oxygen is often spoken of as the supporter of combustion, and animal life.

Ques. What is a vacuum?

Ans. A space devoid of all matter.

Ques. What is the object of an air pump on a condenser?

Ans. To abstract the water condensed, and the air which was originally contained in the water when it entered the boiler.

WATER

Ques. What is water?

Ans. Water is a chemical composition of two gases: oxygen and hydrogen.

Ques. What do the characters H_2O signify when written after the word "water"?

Ans. They mean that water is composed of two atoms hydrogen to one atom oxygen.

Ques. What is the pressure at the base of a column of pure water, at a temperature of 62° F., one foot high?

Ans. .434 of a pound per square inch.

Ques. What are the relative weights of water and mercury?

Ans. Water is about 13.6 times lighter than mercury.

Ques. What proof have we that this is the case?

Ans. At the sea level the pressure of the atmosphere (14.7 pounds) will balance a column of water

34 feet high; this same pressure will balance a column of mercury only 30 inches high, so the formula $\frac{34 \times 12}{30} = 13.6$ must give the number of times mercury is heavier than water.

Ques. At what temperature is water at its maximum density?

Ans. At 39 degrees Fahrenheit.

Ques. What is the most remarkable characteristic of water?

Ans. Water at its maximum density (39.1 degrees F.) will expand as heat is added, and it will also expand slightly as the temperature falls from this point.

Ques. How much will pure water expand?

Ans. As the temperature of water is raised from 39.1° F. (point of maximum density) to 212° F. (boiling point) it will expand $4\frac{3}{10}$ per cent.

Ques. What is the weight of one gallon of pure water?

Ans. One gallon of pure water (U. S. standard gallon) will weight about $8\frac{1}{3}$ pounds and contains 231 cubic inches.

The weight here given is correct when the water is at a temperature of 65° F.

Ques. At what temperature does water freeze and boil?

Ans. Water at atmospheric pressure at the sea level will freeze at 32 degrees F. and will boil at 212 degrees F.

Ques. Is the boiling point of water the same in all places?

Ans. No; the boiling point of water will lower as the altitude increases; at an altitude of 5,000 feet water will boil at a temperature of 202 degrees F.

Ques. How does pressure affect the boiling point of water?

Ans. An increase of pressure will elevate the boiling point.

Ques. What is the weight of a cubic foot of water?

Ans. It varies with the temperature; at the freezing point, 32° F., 1 cu. ft. of water weighs 62.42 lbs., and at the boiling point, 212° F., it weighs 59.76 lbs. For ordinary calculations it is taken at 62.4 or roughly 62 lbs.

Ques. Is a cubic foot of ice lighter or heavier than a cubic foot of water?

Ans. A cubic foot of ice at 32° F. weighs 57.5 lbs.; the relative volume of ice to water at 32° F. is 1.0855, the expansion in passing into the solid state being 8.55 per cent. Specific gravity of ice = .922.

Ques. Can water be compressed?

Ans. Yes, but very little indeed; it is said that under a pressure of 130,000 pounds per square inch 16 volumes may be compressed to occupy the space of 15 volumes, under atmospheric pressure.

Ques. What is meant by pure water?

Ans. Water free from impurities held either in suspension or solution.

Ques. Is absolutely pure water ever found?

Ans. Pure water, strictly speaking, is rarely if ever found. The principal impurities are salt, lime, magnesia, etc. One thousand gallons of ordinary fresh water will contain about twelve pounds of solid matter.

Ques. Can water be purified wholly by filtration?

Ans. Water can only be partially purified by filtration, as none of the impurities of water contained in solution will separate until about 325 degrees of heat are applied.

Ques. What is meant by the latent heat of fusion of ice?

Ans. The amount of heat necessary to convert a pound of ice into water at the same temperature.

Ques. What is the latent heat of fusion of ice?

Ans. 143 heat units; that is, it takes 143 heat units to convert one pound of pure ice into water at the same temperature.

Ques. Is there any substance known that has a greater latent heat than water?

Ans. No.

Ques. What is a heat unit?

Ans. The amount of heat necessary to raise the temperature of one pound of water one degree F.

Ques. What other qualities does water contain?

Ans. Water contains the greatest absorbing qualities of any known substance.

Ques. At what temperature does water evaporate?

Ans. At any temperature above 32 degrees F.

STEAM

Ques. What is steam?

Ans. The vapor of water; the hot invisible vapor given off by water at its boiling point, the latter depending upon the pressure.

The visible white vapor popularly known as steam is not steam, but a collection of fine watery particles, formed by the condensation of steam.

Ques. Define the different kinds of steam?

Ans. Steam is said to be: 1,—*saturated* when its temperature corresponds to its pressure; 2,—*superheated* when its temperature is above that due to its pressure; 3,—*gaseous steam* or *steam gas* when it is highly *superheated*; 4,—*dry* when it contains no moisture. It may be either saturated or superheated; 5,—*wet* when it contains intermingled mist or spray, its temperature corresponding to its pressure.

Ques. Has steam weight, and if so, is it lighter or heavier than air?

Ans. Yes; steam has weight and it is about one-half the weight of air at atmospheric pressure; one pound of steam at atmospheric pressure will have a volume of 26.79 cubic feet.

Ques. What will be the volume of a pound of steam at 100 pounds gauge pressure?

Ans. 3.91 cubic feet.

Ques. In what way does the pressure affect the temperature of steam?

Ans. The temperature of steam will rise as the pressure increases; at atmospheric pressure steam will have a temperature of 212 degrees F. At 50 pounds pressure above vacuum a temperature of 281 degrees F., and at 100 pounds pressure above vacuum the temperature will be 327.8 degrees.

Ques. If you were required to find the temperature of steam corresponding to a certain pressure, how would you find it?

Ans. By referring to the steam table, given on page 71.

Ques. What is meant by the latent heat of steam?

Ans. It is the amount of heat required to change one pound of water into steam of the same temperature.

The latent heat varies with the boiling point, that is, it decreases as the pressure rises.

Ques. Explain more fully the meaning of latent heat of steam.

Ans. If heat be applied to a pound of pure water having a temperature of 212 degrees F., steam will be formed and in a short time all the water will be evaporated; now if the temperature of the steam so formed be taken, the thermometer will register the same as the boiling water, 212 degrees. It has been accurately determined by experiment that 970.4 degrees of heat, or heat units, must be applied to a pound of boiling water to change it into steam of the same temperature, and this heat is called the latent heat of steam.

Ques. What is the relative volume of steam and water at atmospheric pressure?

Ans. Water evaporated into steam will increase in volume or bulk 1646 times.

Ques. What are the usual working pressures employed for different purposes?

Ans. For steam heating from one to ten pounds. For power purposes from 20 to 200 pounds. In large mills and factories from 80 to 200 pounds; on locomotives from 150 to 225 pounds; on board ocean liners and war ships from 150 to 300 pounds.

Ques. What is the object of superheating steam?

Ans. To raise the temperature of the steam, without perceptibly raising the pressure; the excess heat is desirable in order to diminish or prevent *condensation* in an engine cylinder.

Ques. Does superheated steam follow the laws of saturated steam?

Ans. No.

Ques. Is superheated steam extensively used?

Ans. Yes; it is used extensively in power plants and much attention is being given to the design of engines for superheated steam, as the economy by its use is an established fact.

The saving in feed water due to superheating the steam is a little over 1 per cent. for each 10° of superheat.

Ques. Name a common type of boiler in which the steam is slightly superheated.

Ans. In the vertical or upright boiler the steam is slightly superheated by reason of its being in contact with the upper part of boiler tubes, which are above the water line.

FUEL AND HEAT

Ques. What fuels are used for making steam?

Ans. Anthracite coal (hard), bituminous coal (soft), wood, petroleum and other liquid fuels.

Ques. Of what value is wood compared to coal for steam making?

Ans. One ton of good average coal is equal to about 1½ cords (192 cubic feet) of wood.

Ques. How much water can be evaporated by one pound of the best coal?

Ans. Under favorable conditions we can evaporate about 11 pounds of water with one pound of good coal; this high average is only realized in very efficient modern plants. The general average will be about from 7 to 9 pounds of water evaporated per pound of coal, on account of lack of attention on the part of those in charge of the boiler or badly proportioned boiler.

Ques. Is all the heat extracted from the coal while on the grate?

Ans. No; the gaseous part of the coal burns in the space above and back of the grate.

Ques. How much coal is used per horse-power per hour in ordinary plants?

Ans. About 3 to 4 pounds of coal per hour for every horse power developed.

Ques. How much coal is used per horse power in large modern power houses?

Ans. Large power houses having modern triple expansion engines use as little as 1½ pounds of coal per hour for every horse power developed.

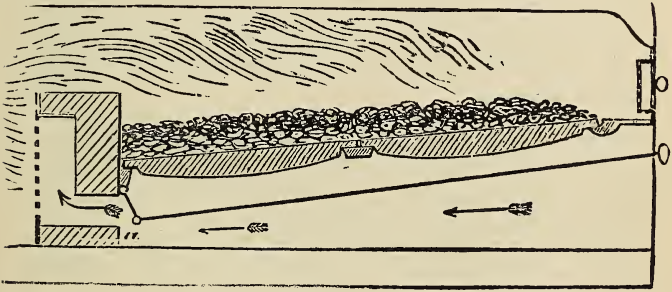


FIG. 2.—Firing with even depth of fuel on the grate, resulting in a uniform generation of gas throughout the charge.

Ques. How much coal may be burned per square foot of grate surface?

Ans. About 14 pounds is as much as can be burned per square foot of grate surface, although this may be greatly increased by forced draught.

Ques. Describe how you would fire with hard coal?

Ans. When firing with hard coal, the fire should be carried as level as possible, and just thick enough to allow the draught to pass through the fire freely. A hard coal fire must not be raked or poked on top. If necessary to slice the fire, a bar should be run under the bed of fire next to the grates and the lower ashes worked through the grate openings.

Ques. How thick would you carry a hard coal fire?

Ans. This depends altogether on the draught. With a poor draught a thin fire must be carried; with a strong draught, the fire bed may be quite thick; but no hard coal fire should be allowed to get thicker than nine inches.

Ques. How would you fire with soft coal?

Ans. When firing with soft coal the fire should be carried as level as possible and as thick as the draught will allow. In order to get the best results out of a soft coal fire, it requires frequent breaking up. This is done by running a bar in fire next to grates and lifting it up and breaking up the large lumps; soft coal is most inclined to cake up when wet, and for this reason it should be used dry if possible.

Ques. How would you clean a fire?

Ans. When a fire becomes so thick that the draught does not readily go through, it must be cleaned, and this is best done by pushing the top of good fire back to the bridge wall; the clinkers and ashes may now be hauled out and the good fire pulled forward; after which the ashes from back part of grate may be pulled over the fire and out of furnace doors. The remaining fire is now spread evenly over the entire grate, carefully leveled and covered thinly with coal.

Ques. How would you clean a fire if the boiler were fitted with dumping grates?

Ans. By pushing all the good fire back on the second section; the first section may now be dumped in ash pit, and fire pulled forward and the second section dumped. The fire is now evenly spread as before and covered with coal.

Ques. How would you bank a fire?

Ans. By shoving the fire back to bridge wall and covering thickly with coal, leaving about one-half the grate surface exposed.

Ques. How much carbon does hard coal contain?

Ans. From 80 to 90 per cent.

Ques. How much carbon does soft coal contain?

Ans. Only from 45 to 72 per cent.

Ques. What do you understand by carbon?

Ans. Carbon is the solid part of coal which burns on the grate.

Ques. How many heat units does one pound of average coal contain?

Ans. From 10,000 to 15,000 heat units.

Ques. What other substances are contained in coal?

Ans. Coal tar, sulphur, iron and slate; usually these only form a small percentage.

Ques. How many cubic feet will a ton of hard coal contain?

Ans. Per ton of 2,240 lbs., it varies according to quality and size from 36 to 41 cu. ft.

Ques. What causes draught?

Ans. Draught is caused and maintained by the difference in *weight* of the hot gases in the stack and the cold air surrounding the stack.

Ques. Describe more fully the theory of draught?

Ans. The air inside of a chimney will always be somewhat hotter than the outer air, and it will expand and rise to the top and flow out of the chimney. Now as this air flows out, other air must take its place, and in a boiler furnace this air can only come from under the grates, and it must pass through the fire under the boiler and through the tubes into the smoke connection. This circulation of air is maintained constant as long as there is a difference of temperature in and outside the chimney; the greater the difference of temperature, other conditions remaining the same, the stronger will be the draught.

Ques. Is it possible to build and maintain a fire without air?

Ans. No. A large amount of air is necessary in order to maintain a fire. About 14 pounds of air are required for every pound of coal burned.

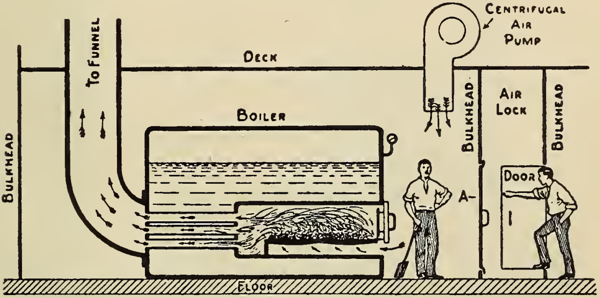


Fig. 3.—Illustrating the usual method of obtaining forced draught on steamboats. The boilers are placed in an air tight room and air under pressure is supplied by a centrifugal fan. In some cases the ash pan of the boiler is made air tight and connected direct to the outlet of the fan.

Ques. What is the mechanical equivalent of heat?

Ans. The amount of heat necessary to raise the temperature of a pound of water one degree F. is equivalent to the mechanical power that will raise a weight of 778 pounds one foot.

Ques. How are the temperatures of different substances ascertained?

Ans. By the thermometer. There are three thermometers in general use, but as the Fahrenheit ther-

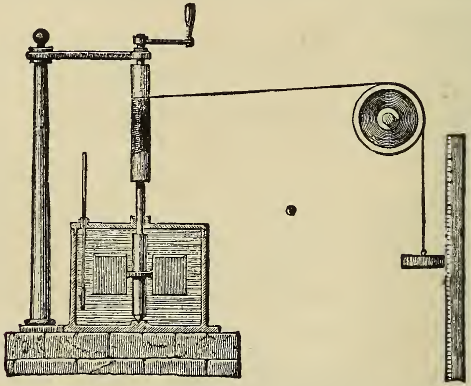


FIG. 4.—The mechanical equivalent of heat. In 1843, Dr. Joule of Manchester, England, performed his classic experiment, which revealed to the world the mechanical equivalent of heat. As shown in the figure, a paddle was made to revolve with as little friction as possible in a vessel containing a pound of water whose temperature was known. The paddle was actuated by a known weight falling through a known distance. A pound falling through a distance of one foot gives a foot pound of energy. At the beginning of the experiment a thermometer was placed in the water, and the temperature noted. The paddle was made to revolve by the falling weight. When 772 foot pounds of energy had been expended on the pound of water, the temperature of the latter had risen one degree, and the relationship between heat and mechanical work was found. Later determinations made with more refined apparatus have shown that the correct figure is 778 foot pounds.

mometer is the standard in this country, this instrument only will be described. The Fahrenheit thermometer consists of a glass tube having a very small bore; the lower end of which opens into a bulb or small reservoir, the upper end of the tube is sealed after all the air has been exhausted. The bulb of this instrument is filled with mercury, such a quantity being used that when the bulb of the instrument is immersed in boiling water the expanding mercury will be forced to a point near the top of the tube. This point is marked 212 degrees and is the boiling point of water.

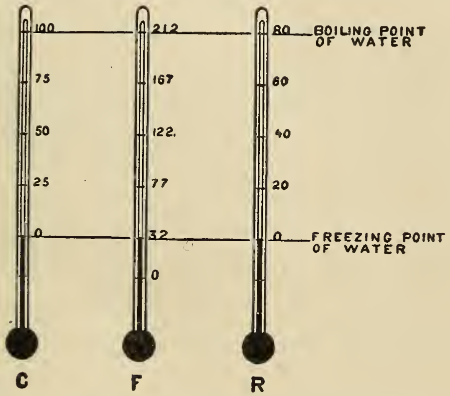


Fig. 5.—Comparison of thermometer scales. The figure shows the freezing and boiling points respectively of the Centigrade, Fahrenheit and Reaumur thermometer scales.

The bulb of the instrument is now plunged into cracked ice and the contracting mercury will rapidly fall in the tube; when it gets as low as it will go, that point is marked 32 degrees, and is the freezing point of water. The space between the boiling and freezing points is graduated into 180 parts or degrees. The space under the freezing point is graduated to 0, which is called zero in this instrument, the scale being continued as far as necessary below zero.

Ques. What is the meaning of absolute zero?

Ans. Absolute zero is the point where all heat action ends and is said to be 459.2 degrees below the zero on the Fahrenheit thermometer.

Ques. Give the relative heating values of some of the various fuels.

Ans. They are as follows:

1 lb.	turf and peat	will	raise	28	lbs.	of	water	from	32°	to	212° F.
" "	undried wood	"	"	27	"	"	"	"	"	"	"
" "	dried "	"	"	36	"	"	"	"	"	"	"
" "	soft coal	"	"	60	"	"	"	"	"	"	"
" "	alcohol	"	"	67½	"	"	"	"	"	"	"
" "	charcoal	"	"	75	"	"	"	"	"	"	"

STEAM BOILERS

Ques. What is a steam boiler?

Ans. A steam boiler is a very strongly built vessel in which steam is generated.

Ques. What are the chief functions of a steam boiler?

Ans. To hold the water we wish to turn into steam and to transfer the heat to the water.

Ques. Name some types of boiler in common use.

Ans. The horizontal return tubular, the water tube, the vertical or upright, locomotive boilers and marine boilers.

Ques. Give some of the good features of the horizontal return tubular boiler, also a brief description.

Ans. The horizontal tubular boiler consists of a cylindrical shell having a head or tube sheet riveted into each end. These tube sheets or heads are provided with numerous holes into which tubes are expanded, to provide more heating surface and also to prevent the head bulging out from the effect of the pressure. In this type of boiler the only parts requiring to be braced is a small segment above the tubes, and also below the tubes if the boiler be more than 72 inches in diameter. The good features of this boiler are that it is cheap at first cost, requires few repairs, and as all parts are fairly accessible, repairs may be easily made when necessary. This type of boiler has ample water and steam space and is therefore not liable to prime.

Ques. What are the bad features of this boiler?

Ans. Internal strains due to unequal expansion. When the boiler is started the shell plates, back head and tubes will become hot rapidly, while the upper parts of boiler will remain cold until steam begins to form; this causes unequal expansion, which causes severe strains; in fact greater strains than that due to regular service. It is not to be recommended for high pressures, especially in the larger sizes, on account of the thick plates and riveted joints exposed to the intense heat of the furnace.

Ques. What else may be said against this boiler?

Ans. This boiler is set up and supported by brickwork which must be kept in repair. If the brickwork in furnace be neglected the whole boiler might settle and break off the main steam pipe. Also this boiler, being built in one piece, the larger sizes are very heavy and hard to transport; another objection to this type of boiler is that its diameter is restricted because of the objection to thick shell plates exposed to the intense heat of the furnace.

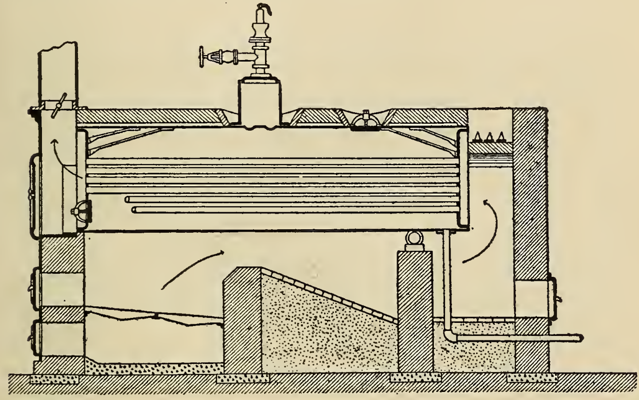


FIG. 6.—Horizontal return tubular boiler and setting; this type of boiler is suitable for low and moderate steam pressures.

Ques. What may be said of steam domes on boilers of this type?

Ans. Steam domes are supposed to furnish dry steam, but most boilers of this type are now built without domes.

In the absence of a dome, *a dry pipe* (see fig. 9) *should be provided*, because the ordinary horizontal boiler delivers steam containing about 2 per cent. of moisture.

BOILER CONSTRUCTION

Ques. What materials are used in the construction of horizontal tubular boilers?

Ans. The shell, heads, tubes and rivets are made of steel; all stays and braces of best double refined iron; the front, nozzles and other fixtures are usually made of cast iron.

Ques. How is this boiler held in position?

Ans. Heavy cast iron lugs are riveted to the sides of boiler so that the bottom of lug will be about 3 inches above the center of boiler; these lugs should be about 10 inches wide and project about 12 inches into the walls of the setting. With an iron plate 1 inch thick under the lug the bottom of brick under plate will form the fire line, which should be just at the extreme diameter or center of boiler.

Ques. How many lugs should a boiler have?

Ans. Small boilers usually have four lugs, two on each side; boilers over 60 inches in diameter should have three or four lugs on each side.

Ques. Define the term tensile strength?

Ans. Tensile strength is the amount of force (pulling) which when slowly and steadily applied to a bar or plate of iron or steel will pull it apart. Tensile strength is always expressed in pounds per square inch, hence, the statement that a boiler plate has a tensile strength of 60,000 pounds per square

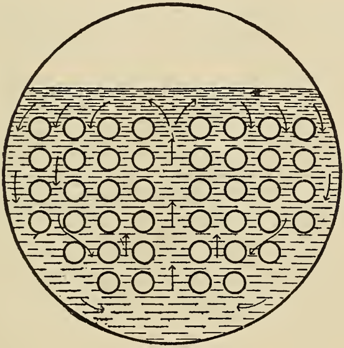


FIG. 7.—Cross section of a horizontal return tubular boiler showing *circulation of the water.*

inch, means that a section of the plate having an area of one square inch will break under a pull of 60,000 pounds.

Ques. What should be the tensile strength of good boiler plate?

Ans. From 55,000 to 60,000 pounds per square inch.

Ques. Can steel be made with a higher tensile strength than 60,000 pounds?

Ans. Yes; steel may be procured having a tensile strength of 100,000 pounds per square inch or more, but this steel cannot be flanged; it is hard and has other qualities which make it undesirable to use as boiler plate.

Ques. What should be the tensile strength of rivets used in boiler construction?

Ans. From 55,000 to 60,000 pounds per square inch.

Ques. Is a boiler stronger when generating steam than when cold?

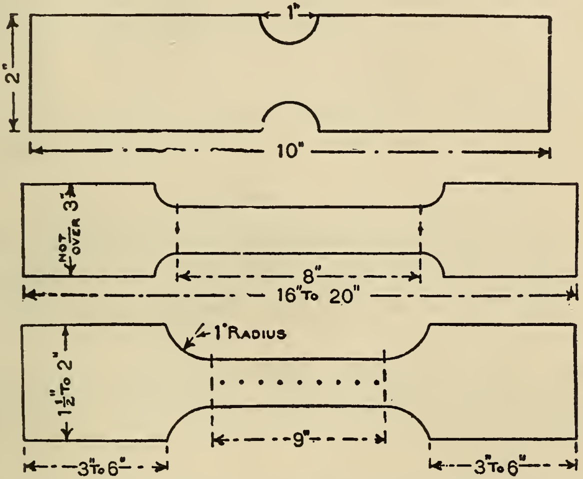
Ans. Yes; the tensile strength of iron and steel increase slightly up to a temperature of about 600 degrees F., but above 600 degrees it becomes weaker very rapidly. No part of a clean boiler, when in service, can ever attain so high a temperature, so a boiler is about 2 per cent. stronger when hot than cold.

Ques. What do you understand by the elongation of a boiler plate?

Ans. It is the amount that a plate will stretch before breaking. A good boiler plate should have an elongation of about 22 per cent.

Ques. Define the term elastic limit?

Ans. The elastic limit of a substance is the greatest strain it will endure and still completely spring back when released.



FIGS. 8 to 10.—Test specimens for boiler construction. FIG. 8.—Specimen for iron plate; figs. 9 and 10, specimen for steel.

Ques. Give principal dimension of a 70″ x 16′ horizontal boiler?

Ans. The shell plates in a boiler of this size should be 3/8 inch thick, the heads should be 1/2 inch thick and made of the best flange steel, the tubes would be about 1/8 inch thick. There will be about seventy 3-inch tubes.

Ques. This being the case, why are the heads of boilers built of heavier steel than the shell?

Ans. The heads are made heavier because they are flat and the pressure tends to bulge them out; the shell being round, is self supporting; that is, the pressure does not tend to change the shape of shell.

Ques. What is flange steel?

Ans. Steel that will stand flanging without weakening.

Ques. Why is it possible to make boiler tubes so much thinner than shell plates and heads, though they are exposed to the same pressure?

Ans. As the surface exposed to the pressure is very much less they are sufficiently strong although much thinner.

Ques. Describe fully the method of securing boiler tubes in the tube sheets or heads.

Ans. The holes are drilled in the tube sheets to receive the tubes loosely; the diameter of the tube ends is now increased by the roller expander, which is a frame carrying three steel rollers which may be forced against the inside of tube by driving a tapered mandril into frame. No particular skill is necessary to use an expander, but great care must be taken not to roll the tube too much, as that will expand the hole in tube sheet as well as the tube, and will cause leakage and no end of trouble.

Ques. What is the difference between boiler tubes and wrought iron pipe?

Ans. Boiler tubes lap welded, or drawn are measured from the outside. Pipe, as a general thing, is rolled and has a seam; pipe is always meas-

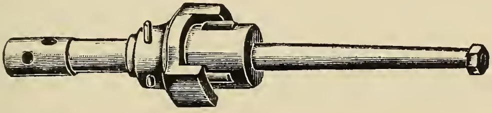


FIG. 11.—Roller tube expander for expanding boiler tubes.

ured from the inside. The sizes as listed do not correspond exactly to the actual sizes, especially for the smaller pipes.

Ques. How strong are riveted joints in modern boilers as compared to the strength of boiler plates?

Ans. A single riveted seam is 56 per cent. as strong as the solid plate; a double riveted, 70 per cent., and a triple riveted seam will have 85 per cent. the strength of the solid plate. This only holds true if the rivets are of proper size and properly pitched.

Ques. What is meant by the shearing strength of the rivets?

Ans. It is the amount of strain in pounds applied to the rivet at right angles to its length that causes it to shear in half.

Ques. What should be the tensile strength of rivets?

Ans. From 50,000 pounds to 60,000 per square inch.

Ques. What is meant by the pitch of rivets?

Ans. The distance from the center of one rivet to the center of the next.

Ques. What should be the pitch of a single riveted seam?

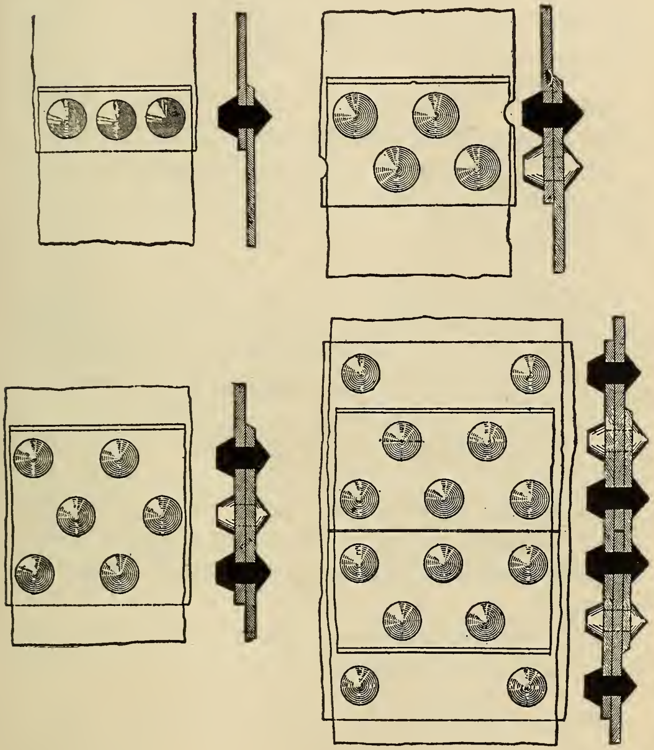
Ans. For single riveted work the pitch should be about 2¼ times the diameter of rivet hole.

Ques. What should be the pitch for double riveted work?

Ans. About 3 times the diameter of rivet hole.

Ques. How much larger should rivet hole be than rivet?

Ans. The rivet hole should be about $\frac{1}{16}$ inch larger than rivet, because all rivets are driven hot, and if they would fit the holes snugly when cold they would not enter at all when red hot, as heat expands them.



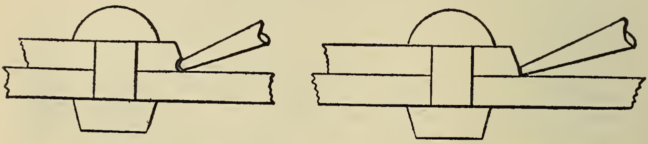
FIGS. 12 to 15.—Various forms of riveted joint: fig. 12, single riveted lap joint; fig. 13, double riveted lap joint; fig. 14, triple riveted lap joint; fig. 15, triple riveted butt joint with double butt straps.

Ques. Does riveting alone make a tight joint?

Ans. No; all riveted joints must be calked, which is done with a round nosed tool with which the edge of upper lap of point is driven close against lower lap.

Ques. What seams on a horizontal return tubular boiler are double riveted?

Ans. The seams running lengthwise are double riveted, while the seams running around the boiler are single riveted.



FIGS. 16 and 17.—Square and round nosed caulking tools; the latter is usually employed in modern practice.

Ques. If the seams running in the direction of the length of boiler be triple riveted, would the seams running around the boiler be double riveted?

Ans. No; the seams running around the boiler are always single riveted.

Ques. Why?

Ans. Because the strain on the seams running lengthwise is always much greater than on seams running around boiler.

Ques. How do we find the load on a girth seam (seam running around boiler) of a horizontal tubular boiler?

Ans. By multiplying the area of one head less the area of the tube ends in square inches by the pressure.

Ques. How do we find the strain on each rivet in the girth seam?

Ans. By dividing the strain on the seam by the number of rivets in the seam.

Ques. How do we find the load on the longitudinal seam (the seam running lengthwise) of a horizontal tubular boiler?

Ans. By multiplying the circumference of the boiler by the length of the boiler in inches and by the pressure; this last product is divided by two and the answer is the strain on the longitudinal seam.

Ques. How do we find the load on each rivet in the longitudinal seam?

Ans. By dividing the strain on the seam by the number of rivets in the seam.

Ques. Explain fully a lap joint and a butt strap joint?

Ans. A lap joint on a boiler is one where one part of the shell plate laps over the other, hence the name. Lap joints are always used in single riveted work. A butt joint is a joint where the end of plates butt together and is made by riveting a strip of iron over the joint. Butt joints are used in double and triple riveted work. Some butt joints are made with a strip on both inside and outside of boiler; this makes a stronger job, because the rivets on a joint of this kind are in double shear.

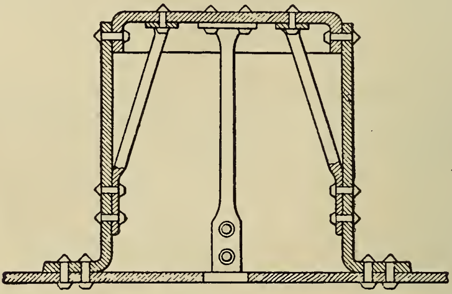


FIG. 18.—Steam dome of a horizontal boiler; its object is to secure steam with as little moisture as possible. The dome is cylindrical, having usually a flat plate top securely braced as shown. In the absence of a steam dome the boiler should be provided with a so called *dry pipe*, as shown in fig. 19.

Ques. If a horizontal boiler have a dome, what seams of dome should be double riveted?

Ans. The seam which secures dome to boiler shell.

Ques. In an upright or vertical boiler, which seams should be double riveted?

Ans. The vertical seams.

Ques. In a horizontal tubular boiler, what part of boiler requires to be braced or stayed?

Ans. The space above the tubes on front and rear head.

Ques. How much of this space must be supported?

Ans. To find the space that requires bracing, draw a line three inches above the top row of tubes

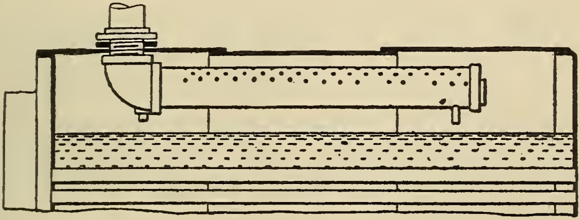


FIG. 19.—"Dry pipe" for horizontal boiler; it is connected to the main outlet and its upper surface is perforated with small holes, the far end being closed. With this arrangement steam is taken from the boiler over a large area, so that it will contain very little moisture. *All horizontal boilers without a dome should be fitted with a dry pipe;* most engineers do not realize the importance of obtaining dry steam for engine operation.

across the boiler head and a line three inches below the curve of the flange all around upper part of head. This will give the space to be braced, its shape being a segment.

Ques. How do we find the load on this segment?

Ans. By multiplying its area in square inches by the pressure.

Ques. How do we find the area of this space, approximately?

Ans. Multiply the distance from the upper row of tubes to top of boiler in inches by the distance across head of boiler three inches above the upper row of tubes; multiply the product by .7854 and the answer will be the area of segment very nearly.

Ques. How would you find the number of one inch braces required in a certain boiler?

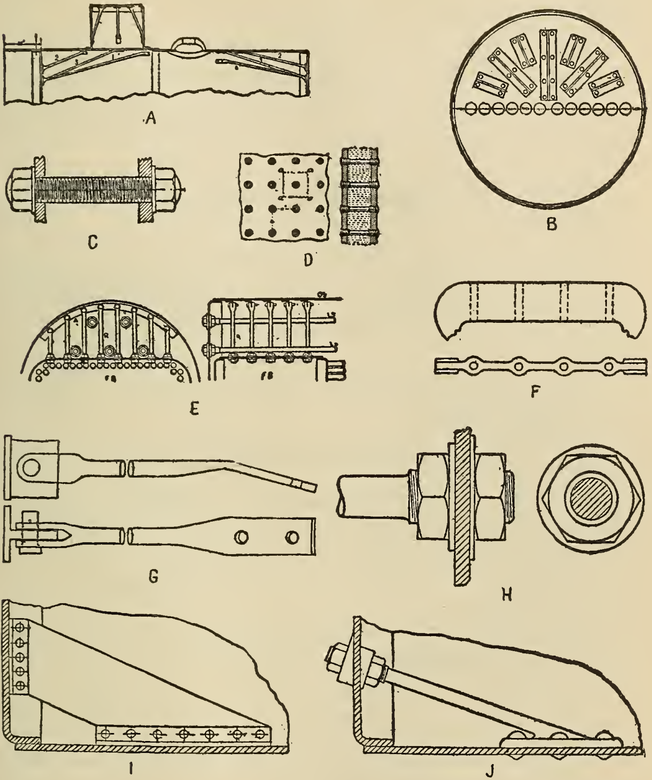
Ans. By multiplying the area of the segment above the tubes in square inches, by the pressure in pounds, and dividing the product by 7,000. Answer will be the number of braces required.

Ques. Do horizontal boilers ever require bracing below the tubes?

Ans. Only large boilers. Where the distance between the lower tubes and bottom of boiler is considerable, these boilers are generally provided with two through stays running parallel to tubes from front head to rear head.

Ques. What is the safe allowable stress on braces or stays?

Ans. 7,000 pounds per square inch of area for iron braces.



Figs. 20 to 29.—Various braces and stays. A, head brace; B, angle iron stays; C, screw stay; D, riveted stays for fire box; E, vertical bar stays secured by nuts and washers to the crown sheet, and by pins to the boiler shell; F, roof stay; G, end braces; H, screwed longitudinal brace; I, gusset stay; J, palm stay.

Ques. Does the cutting of a manhole in head or shell of boiler weaken it?

Ans. Yes, and this weakness is remedied by riveting a heavy iron ring around hole on the inside; this ring should have a strength equal to the metal cut away to form the hole.

Ques. How should large pipes be attached to boilers?

Ans. For pipes above 1½ inches a plate should be riveted to shell at the hole; for pipes above 2½ inches a cast iron flange nozzle should be riveted on boiler.

Ques. What do you understand by a factor of safety of 6?

Ans. The term factor of safety signifies the ratio between a working stress and a breaking stress. Thus, a boiler is said to have a factor of safety of six when the bursting pressure is six times the working pressure.

Ques. How do we find the bursting pressure of a horizontal tubular boiler?

Ans. By multiplying the tensile strength of the weakest plate by its thickness in inches, and multiplying the product by .56, for single riveted seams, by .70 for double riveted seams, or by .85 for triple riveted seams; divide this last product by one-half the diameter of boiler in inches, and the answer will be the bursting pressure.

Ques. A boiler is 60 inches in diameter; plates are 3/8 inches thick, and have a tensile strength of 60,000 pounds per square inch; efficiency of longitudinal seam, 70% What is its bursting pressure?

Ans. $$\frac{60000 \times 3 \times .70}{8 \times 30} = 525 \text{ lbs.}$$

Solution:

1st Step.

$$\begin{array}{r} 60000 \\ \times 3 \\ \hline 180000 \\ \times .70 \\ \hline 126000 \end{array}$$

2nd Step.

$$8 \,)\, 126000 \quad = 15750$$

3rd Step.

30) 15750 (525 lbs. bursting pressure

$$\begin{array}{r} 150 \\ \hline 75 \\ 60 \\ \hline 150 \\ 150 \\ \hline \end{array}$$

A boiler of the above dimensions would burst under a pressure of 525 pounds per square inch.

Ques. When the steam gauge registers 80 pounds, what do you understand?

Ans. That a pressure of 80 pounds is exerted on every square inch of surface inside the boiler on head, shell and tubes.

Ques. How do we find the safe working pressure of a horizontal tubular boiler?

Ans. Multiply one-sixth of the lowest tensile strength found stamped on any pate in the cylindrical shell by the thickness (expressed in inches or parts of an inch) of the thinnest plate in the same cylindrical shell and divide by the radius or half diameter (also expressed in inches), the quotient will be the pressure allowable per square inch of surface for single riveting, to which add twenty per centum for double riveting when all the rivet holes in the shell of such boiler have been "fairly drilled" and no part of such hole has been punched (*U. S. rule*).

Ques. Do boiler inspectors depend entirely on this rule?

Ans. No; they have what they call a hammer test and a hydrostatic test.

Ques. How is a hammer test made?

Ans. By striking all parts of the boiler inside and without, which are liable to fracture, crack or burn, a sharp blow with a light hammer; any loose rivets, cracked plates, etc., are at once found by an experienced inspector, being betrayed by the sound of hammer.

Ques. What is one boiler horse power?

Ans. One boiler horse power is equal to 34½ pounds of water evaporated per hour from a feed-water temperature of 212 degrees Fahr. into dry steam of the same temperature. The standard is equivalent to 33,317 British thermal units per hour. It is also practically equivalent to an evaporation of 30 pounds of water from a feed-water temperature of 100 degrees Fahr. into steam at 70 pounds gauge-pressure.

A boiler rated at any stated capacity should develop that capacity when using the best coal ordinarily sold in the market where the boiler is located, when fired by an ordinary fireman, without forcing the fires, while exhibiting good economy; and further, the boiler should develop at least one-third more than the stated capacity when using the same fuel and operated by the same firemen, the full draft being employed and the fires being crowded; the available draft at the damper, unless otherwise understood, being not less than one-half inch water column.

Ques. Give a rule that is much used, although it is only approximate?

Ans. To find the horsepower of horizontal tubular boiler we find the heating surface in shell tubes and both heads and divide by 15. That is, 15 square feet of heating surface are necessary for each horse power. Now only two-thirds of the shell is exposed to the heat, so we find the area of the shell and multiply by two thirds; two thirds of the back head is

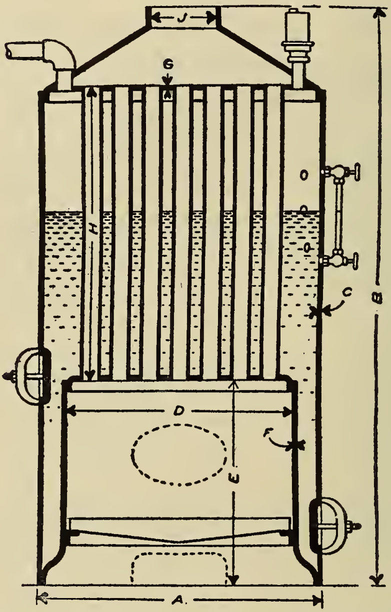


FIG. 30.—Dimensions of standard vertical boilers; the letters refer to dimensions given in the table on page 43. Where sufficient head room is available, the vertical boiler makes a cheap construction and one which gives good economy when properly proportioned. The furnace is within the shell as in the case of the locomotive boiler, and a door is opened through the furnace wall and the boiler shell, which are joined together at this point. One advantage of this type of boiler is that it gives slightly superheated steam instead of slightly wet steam, as in the case of the horizontal boiler. If engineers were careful to always carry the water at the proper level, there would be no danger of burning the tubes; submerged tubes in vertical boilers are not necessary for long life when the boiler is properly proportioned and properly handled.

exposed to the heat, so we find the area of that part of head, and the full area of the front head; from each subtract the area of the tube ends; all the tube surface is heating surface, and we now add these three quantities together for the total heating surface in boiler and divide by 15 for the horse power.

DIMENSIONS OF STANDARD VERTICAL BOILERS.

Horsepower	Shell.			Furnace.			Heads Thick.	2-in. Tubes.		Heating Surface.	Diameter Stack.
	Diam. A	Height. B	Thick. C	Diam. D	Height. E	Thick. F	G	Length. H	No.		J
	Ins.	Ft.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.		S. Ft.	Ins.
4	24	4	¼	20	24	¼	⅜	24	31	44	12
5	24	5	¼	20	24	9/32	"	36	31	60	12
6	24	6	¼	20	24	"	"	48	31	75	12
8	30	5	¼	25	27	"	"	33	55	92	14
10	30	6	¼	25	27	5/16	"	45	55	121	14
12	30	7	¼	25	27	"	"	57	55	150	14
15	36	6½	¼	31	28	"	"	51	77	189	15
18	36	7	¼	31	28	"	"	57	77	210	15
20	36	8	¼	31	28	"	"	69	77	250	15
25	42	7¼	9/32	37	30	"	"	60	109	307	18
30	42	8¼	"	37	30	"	"	72	109	364	18
35	42	9¼	"	37	30	"	7/16	84	109	422	20
40	48	8½	5/16	43	32	"	"	72	149	496	24
45	48	9	"	43	32	"	"	78	149	535	24
50	48	10	"	43	30	"	"	90	149	613	24
60	54	9	"	48	30	"	"	78	201	716	28

Ques. Can the horse power of a boiler be calculated by the grate surface?

Ans. Yes, and this rule is about as accurate as the previous one just given and much simpler. Divide the grate surface in sq. ft. by the particular value of grate per horse power corresponding to the conditions of operation as given in the table below.

	Lbs. of water from and at 212° F. per lb. coal.	Pounds of coal burned per sq. ft. of grate per hour.					
		15	20	25	30	35	40
		Sq. ft. grate per horse power.					
Good coal and boiler	10	.23	.17	.14	.11	.10	.09
	9	.25	.19	.15	.13	.11	.10
Fair coal and boiler	8	.29	.22	.17	.14	.13	.11
	7	.33	.24	.20	.17	.14	.12
Poor coal and boiler	6	.38	.29	.23	.19	.17	.14
	5	.46	.35	.28	.23	.22	.17

In general allow ⅓ sq. ft. of grate per horse power.

Ques. How much water will the average boiler evaporate per hour?

Ans. About 30 pounds, or about 3½ gallons for every horse power per hour.

Ques. Which has the most surface, shell or head?

Ans. The shell.

Ques. How many times as much heating surface as grate surface will the average boiler have?

Ans. The average boiler will have about 35 times as much heating surface as grate surface.

Ques. How many pounds of coal can be burned per hour per square foot of grate surface?

Ans. With natural draught about 14 pounds.

Ques. How much coal will the average boiler burn per horse power?

Ans. The average boiler will burn about four pounds of coal per hour per horse power.

Ques. Define " heating surface."

Ans. That surface exposed to the fire and hot gases; with respect to the tubes of a boiler *it consists of the inner surface in a fire tube boiler and the outer surface in a water tube boiler.*

It is the common practice of boiler makers to use the external instead of the internal diameter of fire tubes, for greater convenience in calculation, the external diameter of boiler tubes usually being made in even or half inches. This is an error and gives more than the true amount of heating surface. The purchaser should therefore note this fact where the builder agrees to furnish a given area of heating surface.

WATER TUBE BOILERS

Ques. What is a water tube boiler?

Ans. A type of boiler in which the water is inside the tubes instead of around the tubes, as in the horizontal boiler. The latter is sometimes spoken of as a fire tube boiler.

Ques. Are many water tube boilers in use?

Ans. Yes; next to the horizontal tubular, there are more horizontal water tube boilers in use to-day than all other types put together, for stationary work.

Ques. What advantages are claimed for the water tube boiler?

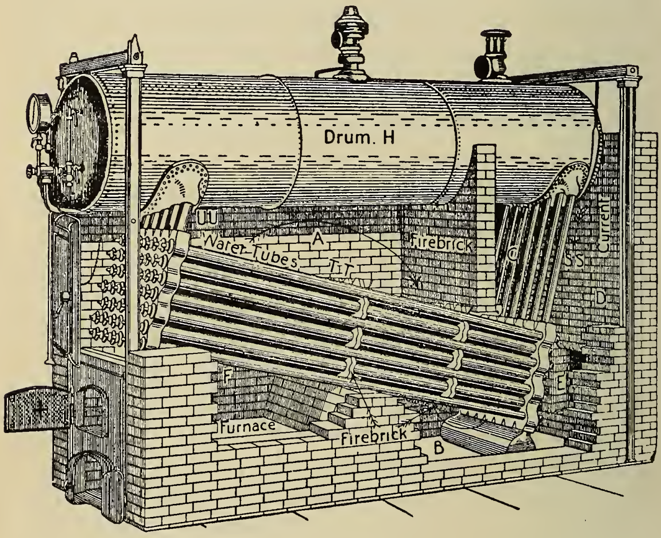
Ans. They are quick steamers, and may be built in units of 500 horse power and over; they are easily transported, when built in sections. They are supported independent of any brickwork, and have no riveted joints over the fire; the bulk of the heating surface is composed of thin tubes right in the fire; water tube boilers are also free from disastrous explosions. They are suited to very high steam pressures.

Ques. What are the disadvantages of the water tube boiler?

Ans. They contain less steam and water space, and while they steam quickly, they require a steady fire to keep the steam pressure constant, on account of the small water space; the water level falls very rapidly when boiler is worked up to its capacity, and feed is interrupted.

Ques. Give a brief description of one make of water tube boiler?

Ans. The Babcock & Wilcox boiler is composed of lap welded wrought iron tubes, placed in an inclined position and connected with each other, and with a horizontal steam and water drum, by vertical passages at each end, while a mud drum is connected to the rear and lowest point in the boiler. The end connections are in one piece for each vertical row of tubes, and are of such form that the tubes are "staggered" (or so placed that each row comes over the spaces in the previous row). The holes are accurately bored out to size, and the tubes fixed therein by an expander. The sections thus formed are connected with the drum, and with the mud-drum also by short tubes expanded into bored holes, doing away with all bolts, and leaving a clear passage way between the several parts. The openings for cleaning opposite the end of each tube are closed by hand hole plates, the joints of which are made in the most thorough manner, by milling the surfaces to



Fig, 31.—The Babcock and Wilcox water tube boiler. One side of the brick seating has been removed to show the arrangement of the water tubes and furnace. TT, inclined tubes; SS, down flow tubes; UU, up flow tubes; F, furnace; B, mud drum; A, side wall; D, end wall; E, cleaning door.

accurate metallic contact, and are held in place by wrought iron forged clamps and bolts. They are tested and made tight under a hydrostatic pressure

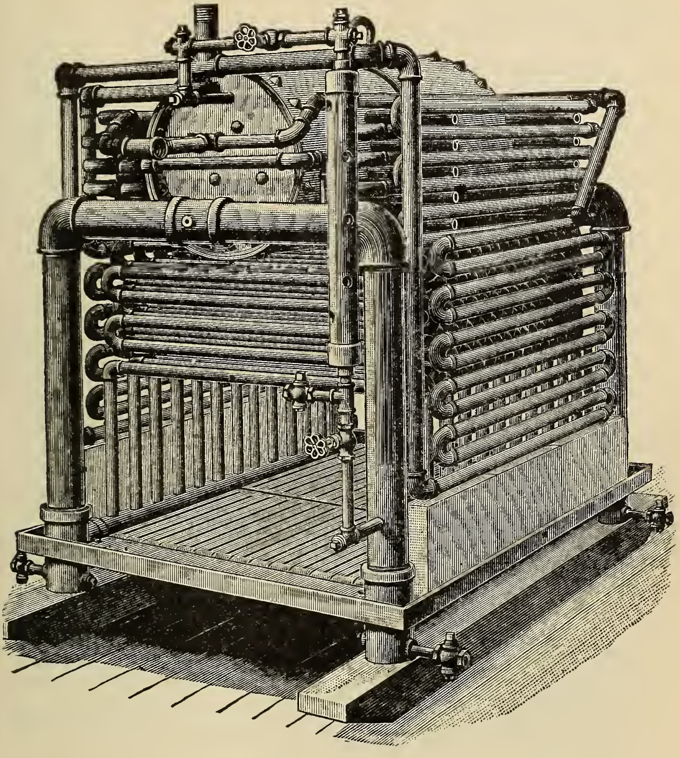


FIG. 32.—The Roberts marine water tube boiler with casing removed to show construction. This boiler consists of the following essential parts: 1, the steam and water drum; 2, lower drums (large horizontal pipes); 3, up flow coils made up with return bends; 4, large down flow pipes; 5, feed water heating coils (on each side of steam drum); 6, superheating coils running down on each side of the furnace. There are no special pipe fittings used in this boiler. It is tested to 500 or 600 lbs., and is good for a working pressure of 300 lbs. of steam.

of 300 pounds per square inch, iron to iron, and without rubber packing, or other perishable substances.

The steam and water drums are made of flange iron or steel, of extra thickness, and double riveted. They can be made for any desired pressure, and are

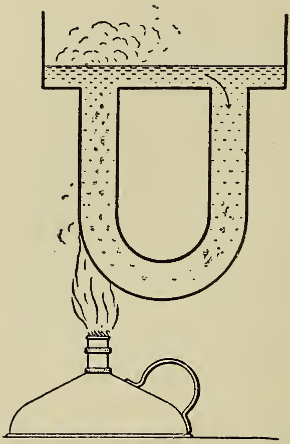


FIG. 33.—Principle of circulation in water tube boilers. The water in the tube directly above the fire is heated in excess of that in the other tube; it expands and becomes lighter than the water in the tube to the right, resulting in a movement of the water as indicated by the arrow. The tube at the left, directly exposed to the fire, is called the *up flow* tube, as distinguished from the one (to the right) more remote from the fire, which is called the *down flow* tube. In the actual boiler, there is a large number of up flow tubes of small diameter and a few down flow tubes, usually of larger diameter.

always tested at 50 per cent. above the pressure for which they are constructed. The mud drums are of cast iron, as the best material to withstand corrosion, and are provided with ample means for cleaning.

THE STEAM GAUGE

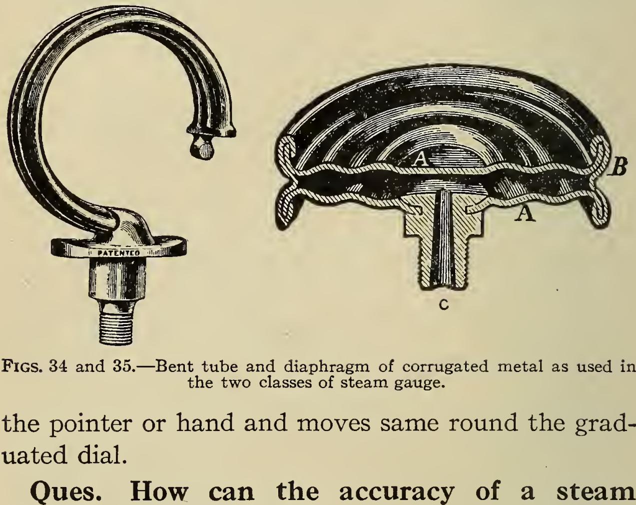
Ques. How can we tell what pressure is on a boiler?

Ans. By the steam gauge.

Ques. How does a steam gauge work?

Ans. A steam gauge works on one of two principles as shown in figs. 34 and 35. In the one class, the pressure of the steam acts upon diaphragms or plates of some kind, shown in fig. 35, which represents a section of a pair of metal plates, *A A*, of this kind. These are made with circular corrugations, as shown in section and also by the shading. The steam enters by the pipe, *c*, and fills the chamber between the metal plates or diaphragms. The corrugations of the latter give them sufficient elasticity, so that when the pressure is exerted between them they will be pressed apart by the steam. If they were flat, it is plain that they would not yield, or only to a very slight degree, to the pressure of the steam.

In the other class of gauge, the steam acts upon a bent metal tube of a flattened or elliptical section, such as shown in fig. 34. The pressure has a tendency to straighten this tube, and this straightening tendency is directly proportioned to the pressure; the free end of this tube is connected through suitable gearing to



FIGS. 34 and 35.—Bent tube and diaphragm of corrugated metal as used in the two classes of steam gauge.

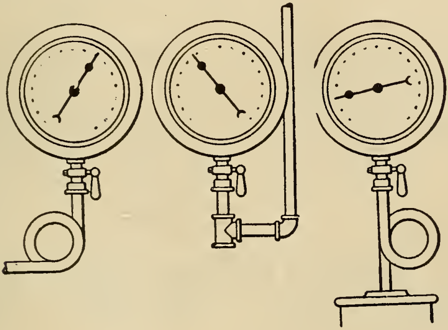
the pointer or hand and moves same round the graduated dial.

Ques. How can the accuracy of a steam gauge be tested?

Ans. When the gauge is in good working order, the index or pointer moves easily with every change of pressure in the boiler, and if the steam be shut off from the gauge, the index should always go back to 0. In order to determine the accuracy of its indications, however, it should be tested with a column of mercury.

Ques. What precaution is taken to prevent the steam taking the temper out of the discs or tubes of steam gauges?

Ans. They are put on with a turn or two of pipe between the boiler and the disc; the bend of the pipe gradually filling with condensed steam, which prevents the live steam touching the elastic discs or tubes.



FIGS. 36 to 38.—Various forms of connection for steam gauge. The pocket formed by the connection becomes filled with water of condensation which protects the spring from the heat of the steam.

Ques. What kind of pressure does a steam gauge indicate?

Ans. It shows, what is called the *gauge pressure*, as distinguished from absolute pressure; that is, pressure measured above the atmospheric pressure, instead of above a perfect vacuum, as in the case of absolute pressure.

Ques. To what should the hand of the steam gauge point when there is no pressure in the boiler?

Ans. To 0, or zero.

Ques. Does this indicate that the gauge is correct?

Ans. No; if it point to a figure above 0, it is certainly out of order; but the fact of its pointing to 0 when there is no pressure does not prove its correctness even at low pressures; it might continue pointing to 0 when there was pressure on it; or it might point to 90 when there was 100 pounds pressure on it, and to 160 when there was 170 pounds. Gauges may be "fast" at some steam pressures, and "slow" at others.

Ques. Which it the more dangerous gauge: one that is "fast" or one that is "slow."

Ans. One that is slow.

THE SAFETY VALVE

Ques. What is the most important valve on any type of boiler?

Ans. The safety valve.

Ques. What is the object of the safety valve?

Ans. To prevent the steam raising above the safe working pressure or above the pressure at which it is set.

Ques. What care should a safety valve receive?

Ans. It should be kept clean and should be raised by hand every morning.

Ques. Why should it be raised so often?

Ans. So that it cannot stick in its seat through the accumulation of dirt and scale.

Ques. Can you give a rule to find the approximate size of safety valve for a given size boiler?

Ans. Yes; allow one square inch of area of valve to every two square feet of grate surface.

Ques. What may be said of the above rule?

Ans. It gives about the right area for low pressure boilers (25 to 50 lbs., working pressure), but too much for medium, or high pressure boilers. The rule has been enforced by law in some districts, for convenience of calculation and to clearly define the requirements.

For calculations of precision, it should be noted that the grate area alone is no criterion in determining the *correct* size of safety valve. The proper area of opening depends on *the weight of steam to be blown off per minute and the working pressure.* The grate area is simply one of many factors which enter into the calculation of total capacity. Thus, to determine the weight of steam generated per minute, it is necessary to consider in addition to the grate area, the kind and quality of fuel, rate of combustion, efficiency of the heating surface, pressure, etc.

Ques. Give a better rule for proportioning the safety valve.

Ans. The area of opening should be such, that when the boiler is worked at its maximum capacity the steam may escape, as fast as it is generated, at a velocity of not over 6,000 feet per minute *at the working pressure*, and *before expansion.*

Ques. What types of safety valve are in general use?

Ans. The lever safety valve, and the spring safety valve.

Ques. How should a safety valve be attached to boiler?

Ans. It should be attached to a separate outlet, but if only one outlet be on boiler it may be attached to a tee on main steam pipe, as close to boiler as possible without any kind of valve between it and boiler.

Ques. How is the pressure regulated on the weight and lever safety valve?

Ans. By moving the weight on lever; the farther it is from valve the greater the blowing off pressure.

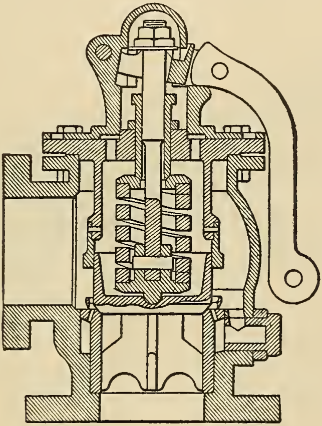


FIG. 39.—A pop safety valve. To insure proper working, the valve should be attached directly to the boiler, otherwise the discs are likely to give trouble by chattering. Pop valves should be operated at least once a day, which will overcome any tendency of sticking. For superheated steam, a valve with outside spring should be used.

Ques. How is the blowing off pressure regulated on a spring loaded valve?

Ans. By increasing or decreasing the tension of the spring. This style of valve always has an adjusting spindle, and by compressing the spring we increase the blowing off pressure, by slacking up on spring we decrease it.

Ques. Why does a pop safety valve "pop"?

Ans. In this type of spring valve, the construction is such that as soon as the valve begins to open an

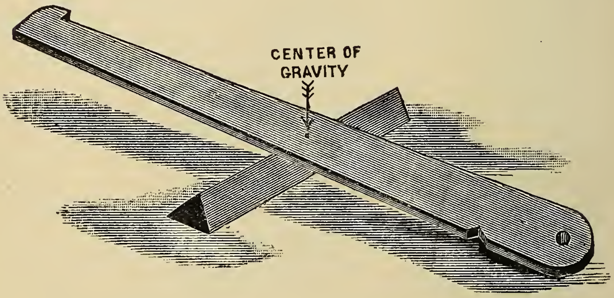


Fig. 40.—Method of finding the center of gravity of the lever. The center of gravity of the lever is the point where the bar would be in equilibrium if balanced over a knife edge or any other support with a sharp corner, as shown in the figure.

excess area of the disc is presented to the escaping steam, hence it suddenly opens widely.

Ques. What is the peculiar feature in the operation of a pop valve?

Ans. It will continue to blow until the pressure is reduced somewhat below that at which it opens.

Ques. Why is this?

Ans. It is due to the increased area of disc presented when the valve opens.

Ques. What type of spring valve should be used with superheated steam?

Ans. *One with an outside spring.*

SAFETY VALVE RULES

Rule for finding the weight necessary to put on a safety valve at a given distance from the fulcrum, so that the valve will blow at a given pressure.

1.—Find the area of the valve, in inches, by squaring the diameter of the opening and multiplying the product by .7854.

2.—Multiply the area thus found by the steam pressure on the boiler.

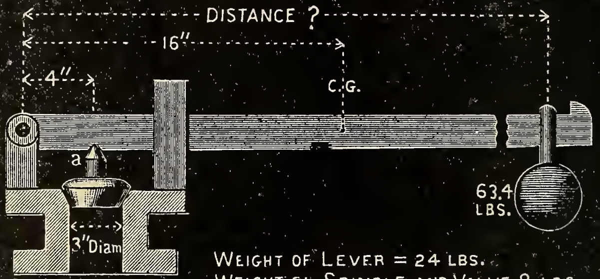
3.—Deduct from the product the weight of the valve and stem.

4.—Multiply the weight of the lever, in pounds, by the distance of its center of gravity, in inches, from the fulcrum, and divide this by the distance from the valve center to the fulcrum, and deduct the quotient from the remainder found according to Section 3.

5.—Multiply the last result by the distance of the valve (a) from the fulcrum and divide the product by the length of the lever.

The answer is the weight of the ball to be placed at the end of the lever to balance the required pressure of steam.

PROBLEM. SUPPOSE WE WISH TO FIND AT WHAT POINT THE BALL WILL HAVE TO BE PLACED FOR STEAM TO BLOW OFF AT 60 POUNDS.



WEIGHT OF LEVER = 24 LBS.
WEIGHT OF SPINDLE AND VALVE 8 LBS.
STEAM PRESSURE 60 LBS.

AREA OF VALVE = 7.07″

7.07
60
424.20 LBS. = TOTAL STEAM PRESSURE UPON VALVE.
8 WEIGHT OF VALVE.
416.2 = EFFECTIVE PRESSURE UPON LEVER.

THIS MUST BE BALANCED PARTLY BY WEIGHT OF LEVER.

24 = WEIGHT OF LEVER
16 = DISTANCE.
144
24
4) 384
96 LBS. = EFFECT OF LEVER AT a.

416.2
96
320.2 NUMBER OF LBS. THAT MUST BE BALANCED BY THE BALL.

320.2 : 63.4 :: D : 4

320.2
4
63.4) 1280.8 (20.2
1268
1280

DISTANCE = 20.2″ ANSWER.

Rule for finding the steam pressure at which a valve will blow for given position and weight of ball.

1.—Multiply the weight of the ball in pounds, by its distance in inches from the fulcrum, and divide the product by the distance in inches, between the fulcrum and the center of the valve (a).

2.—Multiply the weight of the lever in pounds, by the distance in inches, of its center of gravity from the fulcrum and divide the product by the distance in inches of the fulcrum, from the center of the safety valve (a).

3.—Add to the two results already obtained (Sections 1 and 2) the actual weight of the valve and spindle; the sum of the three numbers will equal the downward pressure on the valve.

4.—Now, obtain the area of the valve by squaring its diameter and multiplying by the decimal .7854.

5.—Divide the total downward pressure (Section 3) by the area of the valve (Section 4) and the answer will be the total steam pressure per square inch on the boiler.

Rule for finding the distance from the fulcrum at which the ball should be placed so that the valve will blow at a given pressure.

1.—Multiply the area of the valve in square inches, by the pressure in pounds per square inch, at which it is required to blow; deduct from the product the weight in pounds of the spindle and valve. (Call this Section 1.)

2.—Multiply the weight of the lever, in pounds, by the distance, in inches, of its center of gravity from the fulcrum; divide this product by the distance in inches from the center of the valve to the fulcrum. (Call this Section 2.)

3.—Deduct amount obtained by calculations in Section 2 from that obtained in Section 1; this remainder is the pounds pressure on the valve which must be balanced by the ball.

4.—Multiply this last "remainder" by the distance in inches between the valve center and the fulcrum, and divide the product by the known weight of the ball in pounds. The result will be the required distance, in inches, of the weight (or ball) from the fulcrum.

There are two methods by which the applicant for an engineer's license can prepare to answer questions on the safety valve problem: 1, by *learning several rules* parrot fashion, or 2, *by reasoning out the matter* and writing an equation from which the answer to any question the examiner may ask is easily obtained.

The man who adopts the first method, spends considerable time in memorizing the several rules, which have absolutely no meaning to him, and consequently, he does not know any more about the problem than he did at first, although he may be able to recite these rules and pass the examination.

Again, the man who can solve the problem by the second method *understands* what he is talking about; he knows *why* a given weight must be placed at a certain point for the valve to blow at a given pressure. Moreover, he commands *respect* rather than *tolerance* from the examiner.

Unfortunately, those with very limited knowledge of mathematics are unable to learn how to construct and solve an equation without considerable study, but the author believes, in most cases, that the time spent in committing to memory meaningless rules, could be far better utilized in studying the principles of the problem and thus acquire some *real knowledge* rather than *artificial knowledge.*

Principle of the Safety Valve.—When a boiler is in operation there are four forces acting on a lever safety valve, of which, one *tends to raise the valve off its seat* and the other three *tend to keep it closed;* when the first force slightly exceeds the sum of the other three forces, the valve will open and allow the steam to escape. The four forces just mentioned may be described as follows:

1. The force due to the steam, *which tends to raise the valve;* it is equal to the area of the valve in square inches multiplied by the steam pressure as indicated by the steam guage;

2. The force due to the weight of the valve and spindle, *which tends to close the valve;*

3. The force due to the weight of the lever, *which tends to close the valve;*

4. The force due to the weight of the ball, *which tends to close the valve.*

These forces act at different distances from a point called the *fulcrum*, which corresponds to the point F in fig. 42, about which the lever turns. As indicated in the figure, the four forces are as follows:

S = *total* pressure due to the steam tending to raise the valve;

> This is equal to the steam pressure indicated by the steam gauge multiplied by the area of the valve. The area of the valve is equal to its diameter squared, multiplied by .7854.

V = weight of valve and spindle;
G = " " lever;
B = " " ball.

The distances at which these forces act are:
v = distance from fulcrum to center of the valve;
g = " " " " center of gravity of the lever;
b = distance from fulcrum to the ball.

The weights are measured in pounds and the distances in inches.

The weight of the lever is considered as acting at its center of gravity, *g* distance from the fulcrum.

The center of gravity of the lever is that point where it would be in equilibrium if balanced over a knife edge or any other support with an edge, as in fig. 40.

Now, since all of these forces do not act along the axis or central point of the valve (fig. 42), it is necessary to determine the *tendency of the several forces to produce rotation of the lever about the fulcrum F.*

In order to determine this, the *moments* of the several forces with respect to the fulcrum F must be determined.

In mechanics the *moment of a force* is a measure of its effect *in producing rotation about a fixed point.*

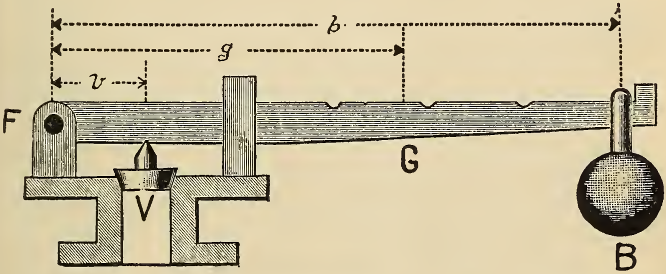


FIG. 42.—Lever safety valve with dimensions, etc., necessary in making calculations. *b*, Distance from fulcrum to ball; *g*, distance fulcrum to center of gravity of lever; *v*, distance fulcrum to spindle; F, fulcrum; V, weight of valve and spindle; G, weight of lever; B, weight of ball.

The moment of a force, with respect to a point, is the product of the force multiplied by the perpendicular distance from the point to the direction of the force.

The fixed point (corresponding to the fulcrum F) is called the *center of moments*, and the perpendicular distance, *the lever arm* or *leverage* of the force.

The moment of the ball B in fig. 42 with respect to the fulcrum F, for instance, is equal to the weight of the ball multiplied by its distance from F, that is, moment of the ball $= B \times b$ or simply B*b*.

The four moments to be considered in solving the safety valve problem are as follows:

1. Moment due to the steam;

   It is equal to the *total* pressure of the steam acting on the valve multiplied by the distance from fulcrum to center of valve; that is, in fig. 42, *steam moment* = S*v*.

2. Moment due to the *weight* of the valve and spindle;

   It is equal to the weight of the valve and spindle multiplied by the distance from fulcrum to center of valve; that is, *valve and spindle moment* = V*v*.

3. Moment due to the weight of the lever;

   It is equal to the weight of the lever multiplied by the distance from the fulcrum to the center of gravity of the lever; that is, *lever moment* = G*g*.

4. Moment due to the weight of the ball.

   It is equal to the weight of the ball multiplied by the distance from the fulcrum to the ball; that is, *ball moment* = B*b*.

Now, when the valve is at the point of blowing off, the first moment *which tends to raise the valve* will equal the sum of the other three moments *which tend to keep the valve closed;* that is:

$$\left\{\begin{matrix}\text{steam}\\ \text{moment}\\ S \times v\end{matrix}\right\} = \left\{\begin{matrix}\text{valve and}\\ \text{spindle moment}\\ V \times v\end{matrix}\right\} + \left\{\begin{matrix}\text{lever}\\ \text{moment}\\ G \times g\end{matrix}\right\} + \left\{\begin{matrix}\text{ball}\\ \text{moment}\\ B \times b\end{matrix}\right\}$$

or simply:

$$Sv = Vv + Gg + Bb.$$

This is the safety valve equation with which any problem is easily solved. In working out an example, the given values are substituted for the letters and the equation solved for the unknown letter.

EXAMPLE:—What weight ball must be put on a 3″ safety valve so that it will blow at 100 lbs., if the weight of valve and spindle be 8 lbs., lever, 24 lbs., distance of valve from fulcrum 4″; distance of center of gravity from fulcrum 16″; distance from fulcrum to ball 38″.

First write out the equation and substitute the values given in the example under the proper letters, thus:

$$\begin{aligned} Sv &= Vv + Gg + Bb \\ S\times 4 &= 8\times 4 + 24\times 16 + B\times 38 \end{aligned}$$

multiplying

$$4S = 32 + 384 + 38B$$

and adding

$$4S = 416 + 38B$$

S, the total pressure tending to raise the valve is equal to the steam pressure multiplied by the area of the valve in square inches = 100 × diam. × diam. × .7854 = 100 × 3 × 3 × .7854 = 706.9 lbs., say 707 lbs.

Substituting this for S in the equation: $4S = 420 + 38B$ thus:

$$4 \times 707 = 416 + 38B$$

multiplying

$$2828 = 416 + 38B$$

The equation must be "solved for B," which means that everything must be transferred to the left hand side of the equality sign except the B. The first step then is to get the 416 on the left hand side; to do this, subtract 416 from both sidcs, thus:

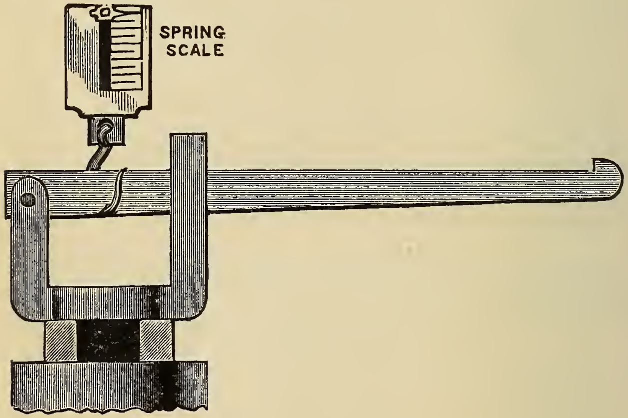


FIG. 43.—Weighing the force exerted by the lever; by thus obtaining the downward thrust due to the lever, the calculation is simplified as explained on page 69.

$$
\begin{array}{rcl}
2828 & = & 416 + 38B \\
416 & & 416 \\
\hline
2412 & = & 38B
\end{array}
$$

As it now stands, 2412 = 38B, or in other words, 38 B = 2412 hence;

$$B = \frac{2412}{38} = 63.4 \text{ lbs., weight of ball.}$$

When the engineer has to solve a safety valve problem in actual practice, he may do so without finding the center of gravity of the lever, if he use a spring balance as in fig. 43.

The balance should be hooked under the point at which the valve spindle acts and then by pulling up on the balance, the actual downward pressure of the

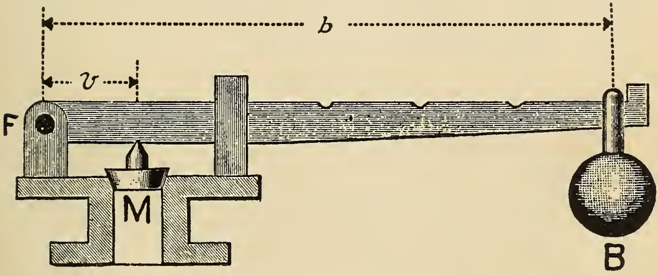


FIG. 44.—Lever safety valve with dimensions, etc., necessary in making calculations where the thrust due to the lever is determined by a spring balance as in fig. 43. *b*, distance fulcrum to ball; *v*, distance fulcrum to valve; M=S—L, that is, the total pressure due to the steam tending to raise the valve, less the downward thrust due to the lever as measured in fig. 43; F, fulcrum; B, weight of ball.

lever *at this point* can be determined. To this weight should be added the weight of the valve and spindle.

The forces then will be as in fig. 44, from which the equation is:

$$Sv = Mv + Bb$$

here M is equal to the sum of the pressure of the lever as indicated on the scale and spring fig. 43, plus the weight of the valve and spindle; the other letters are as before.

If the weight of the ball, or its distance from the fulcrum be required, the equation can be still further simplified by letting M, in fig. 44, represent the *sum* of the pressure of the lever as indicated on the spring scale plus the weight of the valve and spindle, subtracted from the *total* pressure of the steam on the valve. The equation then becomes

$$Mv = Bb$$

TABLE
OF THE
PROPERTIES OF SATURATED STEAM.
FROM PEABODY'S TABLES.

Gauge pressure in lbs. per sq. in.	Temperature in degrees Fahr...	Total heat in heat units from water at 32 degrees Fahr....	Heat units in liquid from 32 degrees Fahr...	Heat of vaporization in heat units........	Density of weight of 1 cu. ft. in lbs..........	Volume of 1 lb. in cubic feet..	Weight of 1 cubic foot of water........
0	212.00	1146.6	180.8	965.8	.03760	26.60	59.76
..	......	......	.....	.....	.....,	.....	59.64
10	239.36	1154.9	208.4	946.5	.06128	16.32	59.04
20	258.68	1160.8	227.9	932.9	.08439	11.85	58.50
30	273.87	1165.5	243.2	922.3	.1070	9.347	58.07
40	286.54	1169.3	255.9	913.4	.1292	7.736	57.69
50	297.46	1172.6	266.9	905.7	.1512	6.612	57.32
55	302.42	1174.2	271.9	902.3	.1621	6.169	57.22
60	307.10	1175.6	276.6	899.0	.1729	5.784	57.08
65	311.54	1176.9	281.1	895.8	.1837	5.443	56.95
70	315.77	1178.2	285.6	892.7	.1945	5.142	56.82
75	319.80	1179.5	289.8	889.8	.2052	4.873	56.69
80	323.66	1180.6	293.8	886.9	.2159	4.633	56.59
85	327.36	1181.8	297.7	884.2	.2265	4.415	56.47
90	330.92	1182.8	301.5	881.5	.2371	4.218	56.36
95	334.35	1183.9	305.0	879.0	.2477	4.037	56.25
100	337.66	1184.9	308.5	876.5	.2583	3.872	56.18
105	340.86	1185.9	311.8	874.1	.2689	3.720	56.07
110	343.95	1186.8	315.0	871.8	.2794	3.580	55.97
115	346.94	1187.7	318.2	869.6	.2898	3.452	55.87
120	349.85	1188.6	321.2	867.4	.3003	3.330	55.77
125	352.68	1189.5	324.2	865.3	.3107	3.219	55.69
130	355.43	1190.3	327.0	863.3	.3212	3.113	55.58
135	358.10	1191.1	329.8	861.3	.3315	3.017	55.52
140	360.70	1191.9	332.5	859.4	.3420	2.924	55.44
145	363.25	1192.8	335.2	857.5	.3524	2.838	55.36
150	365.73	1193.5	337.8	855.7	.3629	2.756	55.29

INSTALLATION OF BOILERS

Ques. How should a horizontal tubular boiler be set?

Ans. On a good unyielding foundation. The side walls for a medium sized boiler should be about 16

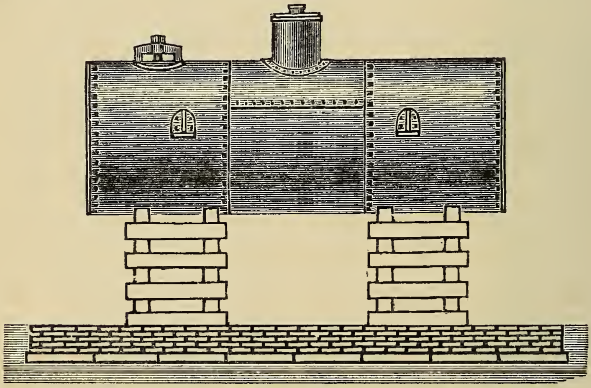


FIG. 45.—Boiler blocked up ready for setting.

to 20 inches thick and should have an air space of about 2 inches the entire length, except that part of walls under the lugs, which should be built solid, like a pillar. The furnace should be lined with first quality fire brick, and it is well to extend the fire brick lining one or two feet back of bridge wall. All fire brick should be laid in fire clay, and the rest of setting should be built of hard, red brick, laid in lime or Portland cement. The rear wall should be about 16 inches thick, built entirely of red brick, except the arch over cleaning out door, which should be of fire brick. The front wall, for a flush front boiler, need only be about 12 inches thick. The jambs, and arch over furnace doors, should be most carefully built, as this part of furnace and furnace wall require frequent renewing. The bridge wall may be from 16 to 24 inches thick, and should come to within about 9 or 10 inches of the lowest part of boiler.

Ques. Should a horizontal tubular boiler be set exactly level?

Ans. No. The back end should be from 1 inch to 1½ inches lower than the front end, so that when we open up boiler for inspection or cleaning all the water will drain back to blow off outlet.

Ques. Why should we provide for expansion in a boiler setting?

Ans. A boiler when hot will be slightly longer than when cold, and provision must be made for this expansion or the setting will crack.

Ques. What is a "dead plate"?

Ans. A heavy cast iron plate placed in front of grates.

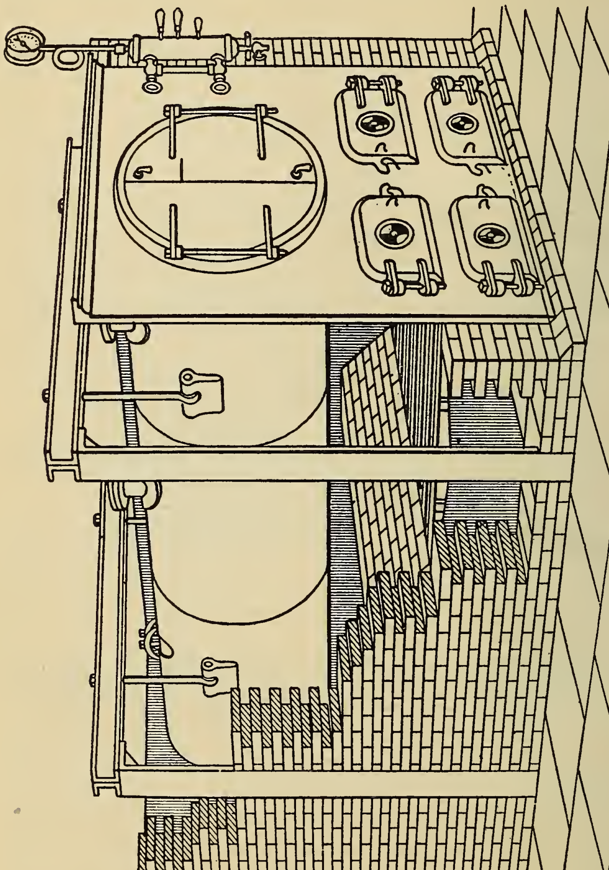


Fig. 46.—A modern setting for a horizontal return tubular boiler, with support by steel frame work.

Ques. What is an arch plate?

Ans. It is a heavy cast iron plate reaching across front of boiler from jamb to jamb above the furnace door. Its object is to protect the brick work above the furnace door from the heat.

Ques. What is the best kind of an arch to use above the furnace doors?

Ans. A water arch, which consists of a hollow steel or cast iron chamber of such shape that it will fit between front and boiler all the way across furnace. The feed water is made to flow through this arch, and the arch is also connected with top and bottom of boiler to keep up the circulation when feed pump is closed down; this arch saves the cost of frequent repairs and also adds a little heating surface to the boiler.

Ques. How are grate bars installed in boilers?

Ans. Heavy cast iron bars are run across the furnace near the dead plate and one near the bridge wall, on which the grates are laid. If the grates be over 4 feet long a center bearing bar should also be used.

Ques. At what distance should the grates be from the lowest part of boiler?

Ans. The grate bars should be about 24 inches below the lowest part of boiler for hard coal; for soft coal, they should be placed about 28 inches below the lowest part of boiler.

Ques. What is a mud drum?

Ans. Horizontal boilers were formerly fitted with mud drums; a mud drum is a small pot or chamber riveted to bottom of back of boiler, into which the sediment and mud settled. Few horizontal boilers are built with mud drums, although several types of water tube boiler are fitted with them.

Ques. What is a surface blow off?

Ans. A pipe passing through front or rear head into the boiler at the water line fitted with a valve which may be opened daily, and through which the impurities in water floating on the surface may be expelled.

Ques. How would you attach a blow off pipe to a boiler?

Ans. I would attach blow off pipe to bottom of shell, near the back end of boiler and run pipe through the setting of boiler, as near the boiler as possible; I would attach a good, reliable cock and continue blow off pipe to tank or sewer.

Ques. Should the blow off pipe between the boiler and setting be protected?

Ans. Yes; it should be protected by a metal sleeve or wrapped with asbestos. A good plan is to connect the blow off pipe with both top and bottom of the boiler; in this case there is always a circulation in pipe, and it is less liable to burn out.

Ques. Are you allowed to blow directly into sewers in New York City?

Ans. No. The blow off should lead into a closed tank to break the force of the steam and water, and this tank may be connected with the sewer.

Ques. How would you connect up the water column?

Ans. I would put the column at such a height so that the bottom of glass gauge would be two inches above the tops of the upper row of tubes on a small boiler and about six inches above the upper row of tubes on a very large boiler.

Ques. How would you connect a feed pipe to a boiler?

Ans. I would have the pipe enter boiler through the front head, about two inches above the upper row of tubes. Just outside of boiler I would put on a globe valve; then a short nipple and a check valve, and continue pipe to pump, where I would place another globe valve with which to regulate the water supply.

Ques. What is a fusible plug?

Ans. A fusible plug is a brass plug having a hole drilled all the way through. This hole is filled with pure tin or other soft metal which melts at a temperature of about 600 degrees F. This plug is screwed into the back head on a horizontal tubular boiler as close to the top of the upper row of tubes as possible. Now, when the water is at its proper level, the temperature of plug cannot rise much above the water in boiler and the soft metal cannot melt, because the water will absorb the heat too fast; however, if the water in boiler should fall below the plug, it would immediately melt out, and the escaping steam and water would put out the fire.

Ques. How should the main stop valve be attached to boiler?

Ans. In such a way that the pressure will come under the valve; a valve attached in this manner may be packed under pressure by closing the valve.

Ques. How should large steam pipes be secured?

Ans. Large steam pipes should be secured to overhead beams or suspended from the roof in a most thorough manner. Violent vibration of large pipes will soon lead to leaks at the joints.

Ques. Why do we put a check valve near boiler?

Ans. So that no water can flow from boiler back to pump when pump is stopped.

Ques. Why do we put a globe valve between check valve and boiler?

Ans. So we can open up check valve for the purpose of inspection or repair while a pressure is on boiler by simply closing the globe valve between check valve and the boiler.

Ques. Is a damper regulator a useful appliance?

Ans. Yes, it assists in keeping the steam pressure constant.

Ques. What should be the area of a chimney or stack?

Ans. The area of a chimney should be about 30 per cent. more than the combined area of all the tubes.

MANAGEMENT OF BOILERS

Ques. What is the first duty of the engineer or fireman on entering the boiler room in the morning?

Ans. To make sure that the water in boiler is at a proper level.

Ques. If on entering the boiler room you would find the water out of glass, safety valve blowing off strong, and a good, hot fire under boiler, what should be done?

Ans. First, the fire should be smothered as quickly as possible with wet ashes, earth or coal, closing ash pit doors and leaving furnace doors and damper open. If now it be found that the water has not fallen below the level of either the crown sheet of any other extended area of heating surface, the feed pump may be started with perfect safety, but if this certainty cannot be assured, the boiler must be cooled down completely, carefully inspected, and repaired if necessary. If no part of the exposed metal be heated to redness, there is no danger except from a rise in the water level sufficient to flood the overheated metal. Hence, care should be taken that the safety valve be not raised so as to produce a priming that might throw the water over the overheated metal, and *that no change be made in the working of either engine and boiler that shall produce priming or an increased pressure.*

If any portion of the boiler plate be red hot, an additional danger is due to the steam pressure, which should be reduced by continuing the engine in steady operation while extinguishing the fire. If the safety valve be touched at such a time it should he handled very cautiously, allowing the steam to issue steadily and in such quantity that the steam gauge does not show any sudden fluctuations while falling. The damping of the fire with wet ashes will reduce the steam pressure very promptly and safely.

Ques. How should a boiler be fed?

Ans. The pump should run constantly, supplying just enough water to keep the water line in boiler at a constant level.

Ques. What is meant by priming?

Ans. We say a boiler primes when it lifts the water level and delivers steam full of spray or water to engine.

Ques. What is the cause of priming or foaming, as it is sometimes called?

Ans. Priming is usually caused by forcing a boiler too hard or by too high a water level. Foaming is caused by dirty or impure water; in either case the remedy is to check the draught. When a boiler primes violently it may be necessary to close the main steam valve for a few seconds to find the true water line.

Ques. Would you fire a water tube boiler the same as a fire tube boiler?

Ans. Yes. Strictly speaking, the work would be about the same.

Ques. Why do we often see the fronts of boilers cracked and broken?

Ans. When the brickwork over the furnace door becomes bad and is not quickly repaired, the front will become overheated and in a short time will crack.

Ques. How are the hand holes and man holes cut in boilers?

Ans. Crossways and oval in shape.

Ques. How are the tubes of a horizontal boiler cleaned?

Ans. The soot and ashes may be blown out with a steam blower or swept with an iron or steel wire brush. When a blower is used the steam should be dry, so as not to leave moisture on inside of tube, which will form a scale and, in some cases, will corrode the tube; all tubes should be swept at frequent intervals; the oftener the better.

Ques. How is a crack between two tube holes in a boiler head repaired?

Ans. By fitting an iron or steel patch over crack, which may be fastened with two tap bolts; a layer of cement made of red lead and iron filings should be spread under the patch.

Ques. If a tube should split or leak, how would we replace it?

Ans. When boiler tubes have to be cut out, it is done by cutting a long slot in tube from front end; this slot should be cut with a ripping chisel and should extend back about 3 inches; the tube may now be contracted and by cutting the back end loose, can easily be pulled out. A new tube is now inserted and secured into both heads with an expander and the ends of tube riveted over.

Ques. What care do the various appliances of a boiler require?

Ans. The safety valve should be kept clean and working freely by lifting by hand at least three times a week. The water column should be blown out every day and kept free from scale, when blowing down; the water should come up in glass rapidly, and if it do not, the lower connection is partly stopped up; the gauge should not be entirely relied upon, the gauge cocks should be tried frequently, and in all cases the glass and cocks should agree, if they do not agree the cause should be found and removed. The steam gauge should agree with safety valve at the blowing off pressure, and should be connected to boiler through a trap or syphon, so that the water in tube of gauge will be comparatively cold; when steam is allowed to enter gauge directly it will draw temper out of tube and the gauge will not record correctly. The feed pump or injector should be kept in perfect condition, and all globe valves and the check valve in feed pipe should be carefully kept in repair. The blow off should be opened once every day, preferably at the time of day when pressure is lowest, as this assists greatly in keeping a boiler clean and in prolonging life of boiler; the blow off valve should be kept tight and pipe kept covered inside of setting to protect it from the intense heat. If a fusible plug be used it must be kept clean within and without the boiler, otherwise it may not act when needed.

Ques. What care do fusible plugs require?

Ans. They must be kept clean on the outside, otherwise they will not melt out if water in boiler fall below the plug, and they must not be allowed to become covered with scale on the inside, or they may melt out, even when covered with water, through the inability of the water to absorb the heat through the scale.

Ques. In case one of the fire plates of a boiler bagged or bulged over the fire, how would you repair it?

Ans. If the plate was not burned, and not drawn thin, I would heat it red hot by rigging up a gas furnace under the bulge and drive it up into its original position. If the plate was burned or too large to drive back, the burned part must be cut out and a patch put on. A slightly bulged plate may be prevented from getting worse by putting a stay through the center of bulge and attaching the other end of stay to some part of boiler diametrically opposite. If a bulge, bag or blister be very large, or if the metal be wasted thin, a new fire sheet should be put in.

Ques. In case of fire in building where you are employed, what would you do?

Ans. I would haul the fire from under boiler, and, if a tank were on roof to supply fire lines, I would start the tank pump full speed and abandon the boiler room

Ques. Suppose the fire had gained such headway before discovery that you would not have time to haul fires, what would you do?

Ans. I would open furnace doors, start feed pump and tank pump full speed and abandon boiler room.

Ques. If the burning building had its own electric light plant, would you stop dynamo engine before abandoning boiler room?

Ans. No; I would leave engine running so as to keep up the lights, which may be of assistance to the tenants in leaving the burning building quickly.

Ques. What about the elevator machinery?

Ans. I would not stop the elevator machinery for same reason.

Ques. How often should a boiler be cleaned?

Ans. This depends on the quality of the feed water, the kind of fuel, and conditions of operation. This cleaning should be done thoroughly, and, when opened up for cleaning, the engineer has an opportunity to make a thorough inspection also. If any hard scale be present on the fire plates, heads or tubes, it should be removed with a scaling hammer, and all mud in bottom of boiler washed out. The braces should all be sounded to see if they be tight, for they are useless if slack. The tube ends on front and rear heads should be examined for leaks and all accessible seams should be carefully looked over. The brickwork should also be inspected.

Ques. What causes scales to accumulate on the heating surface of boilers?

Ans. As all water contains more or less solid matter, scale will form in all boilers; this solid matter forms a scum on the surface of the water, but finally becomes heavy enough to sink and is deposited and baked on the heating surface of boiler in the form of scale.

Ques. Is a thick layer of scale in a boiler dangerous?

Ans. Yes. Many boilers are ruined by the scale accumulating in sufficient quantities to burn or bag the fire plates.

Ques. How does scale affect a boiler when not enough is present to be dangerous?

Ans. It makes a boiler steam hard; scale, being a poor conductor of heat, will not transmit heat as readily as iron.

Ques. Of what nature is scale?

Ans. Scale in boilers may be of hard, rock like nature; or of soft, greasy, or powdery nature, according to its chemical and mechanical composition or formation.

Ques. How does the scale get into the boiler water?

Ans. The scale, or the ingredients that form the scale, get into the boiler by the feed water.

Ques. How does the feed water receive the scale ingredients?

Ans. The feed water for jet condensing plants is obtained from a different source from that of surface condensing plants, therefore the scale formation is of a different nature for these two classes.

Ques. From what does scale formation originate in jet condesning plants?

Ans. Scale formation in boilers of jet condensing plants results from salts, which were contained in the hard feed water, as obtained from the hot well, when drawn in by the vacuum of the condenser.

Ques. What salts are most frequently found in the scale of the boiler?

Ans. The salts found in the scale of boilers and deposited from the hard, fresh feed water are generally various combinations of lime or magnesia.

Ques. From what does scale formation originate in surface condensing plants?

Ans. Scale formation in boilers or surface condensing plants results mainly from the sea water that enters the boiler, as feed make up, or through leakage of the condenser. Some of the salts are from sea water, at boiling, thrown down upon the heating surfaces, where they adhere very firmly. Cylinder oil produces scale, it being carried by the feed water into the boiler.

Ques. How can the accumulation of scale in a boiler be reduced?

Ans. By providing boiler with a surface blow off, as well as bottom blow off, and using both every day.

ANALYSIS OF AVERAGE BOILER SCALE

	Parts per 100 parts of deposit.	
Silica	.042	parts.
Oxides of iron and aluminum	.044	"
Carbonate of lime	30.780	"
Carbonate of magnesia	51.733	"
Sulphate of soda	Trace	"
Chloride of sodium	Trace	"
Carbonate of soda	9.341	"
Organic matter	8.060	"
Total solids	100.	parts.

Ques. What other means are taken to keep a boiler free from scale?

Ans. Chemicals to dissolve or neutralize the impurities contained in the water are extensively used to prevent the formation of scale.

Ques. Name some alkalis that are good to use in boilers in many localities for the prevention of scale?

Ans. Sal soda, or soda ash. It may be put into boiler dry when it is opened up for cleaning, or it may be dissolved and fed into boiler by pump; being an alkali, it will not injure pump, pipes or the boiler. About 10 pounds of soda ash weekly will keep an ordinary sized boiler clean in New York City.

Ques. Is kerosene sometimes used in boilers to prevent scale forming?

Ans. Yes; although some engineers claim it will injure boiler if used a long time. When used, kerosene is best fed into boiler through a sight feed lubricator, and it may be regulated to feed any desired quantity; the lubricator is piped up exactly as we would attach a lubricator to an engine.

Ques. How are boilers tested?

Ans. The boiler inspectors use the hydrostatic test.

Ques. How is a hydrostatic test applied?

Ans. By closing all pipe openings in boiler and filling boiler with water to safety valve; the safety valve is now blocked and enough more water is pumped into boiler until the steam gauge registers the desired amount of pressure. Boilers so tested are allowed to carry two-thirds the test pressure.

Ques. How would you prepare for a test?

Ans. I would clean the boiler thoroughly inside and outside, remove all ashes from ash pit and brush or blow out the tubes; the grate bars should be removed if boilers be internally fired, and safety valve and all stop valves should be made tight. The boiler may now be filled with water to safety valve, and we are now ready for the inspector to apply the pressure, which is done by connecting a force pump to some outlet in feed pipe and forcing water into boiler until the pressure is 50 per cent. in excess of the working pressure. All parts of the boiler are now carefully examined for leaks, and if none appear and the boiler be all right in other respects, a certificate allowing the boiler to be put in service will be granted by the inspector.

Ques. What else do boiler inspectors examine?

Ans. The safety valve and steam gauge. After applying pressure they see that the safety valve and gauge agree.

Ques. If, in inspecting a boiler, you found one or more defective braces, what course would you follow?

Ans. I would repair same, or have same repaired, before putting boiler in service again.

Ques. If a boiler was to be put out of service for a year or more, how would you lay boiler up?

Ans. Clean the boiler thoroughly inside and outside. By putting about 10 pounds of rock lime in a pan inside of boiler and closing all hand holes and pipe holes, boiler will remain perfectly dry for a very long period; the outside of boiler should be kept dry, damper should remain open, furnace doors closed and ash pit doors should remain open so that a draught of air is constantly passing through boiler. If the boiler is to be out of service only a short time, a good plan is to fill boiler entirely full of water and close all openings tight.

Ques. Should the exposed parts of a boiler be covered?

Ans. Yes; all exposed parts of a boiler should be carefully covered with asbestos or other good insulators.

ENGINEERS' LAW

Law under which all engineers are licensed in the City of New York.

LAWS OF NEW YORK.—*By Authority.*

CHAP. 635.

AN ACT to amend chapter four hundred and ten of the laws of eighteen hundred and eighty-two, entitled "An act to consolidate into one act and to declare the special and local laws affecting public interests in the City of New York," relative to engineers.

Accepted by the city.

Became a law May 22, 1897, with the approval of the Governor.

Passed, three-fifths being present.

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. Section three hundred and twelve of chapter four hundred and ten of the laws of eighteen hundred and eighty-two is hereby amenced so as to read as follows:

Section 312. The board of police shall preserve in proper form a correct record of all Inspections of steam boilers made under its direction, and of the amount of steam or pressure allowed in each case, and in cases where any steam boiler or the apparatus or appliances connected therewith shall be deemed by the board after inspection, to be insecure or dangerous, the board shall prescribe such changes and alterations as may render such boilers, apparatus and appliances secure and devoid of danger. And in the meantime, and until such changes and alterations are made, and such appliances attached, such boiler, apparatus, and appliances may be taken under the control of the board of police, and all persons prevented from using the same, and in cases deemed necessary, the appliances, apparatus, or attachments for the limitation of pressure may be taken under the control of the said board of police. And no owner, or agent of such owner, or lessee of any steam boiler to generate steam, shall employ any person as engineer or to operate such boiler unless such person shall first obtain a certificate as to qualification therefor from a board of practical engineers detailed as such by the police department, such certificate to be countersigned by the officer in command of the sanitary company of the police department of the city of New York. In order to be qualified to be examined for and to receive such certificate of qualification as an engineer, a person must comply, to the satisfaction of said board, with the following requirements:

1. He must be a citizen of the United States and over twenty-one years of age.

2. He must, on his first application for examination, fill out, in his own handwriting, a blank application to be prepared and supplied by the said board of examiners, and which shall contain the name, age, and place of residence of the applicant, the place or places where employed and the nature of his employment for five years prior to the date of his application, and a statement

that he is a citizen of the United States. The application shall be verified by him, and shall, after the verification, contain a certificate signed by three engineers, employed in New York City, and registered on the books of said board of examiners as engineers working at their trade, certifying that the statements contained in such application are true. Such application shall be filed with said board.

3. The following persons, who have first complied with the provisions of subdivisions one and two of this section, and no other persons, may make application to be examined for a license to act as engineer.

a. Any person who has been employed as a fireman, as an oiler, or as a general assistant under the instructions of a licensed engineer in any building or buildings in the city of New York, for a period of not less than five years.

b. Any person who has served as a fireman, oiler or general assistant to the engineer on any steamship, steamboat, or any locomotive engineer for the period of five years and shall have been employed for two years under a licensed engineer in a building in the city of New York.

c. Any person who has learned the trade of machinist, or boilermaker or steamfitter and worked at such trade for three years exclusive of time served as apprentice, or while learning such trade, and also any person who has graduated as a mechanical engineer from a duly established school of technology, after such person has had two years experience in the engineering department in any building or buildings in charge of a licensed engineer, in the city of New York.

d. Any person who holds a certificate as engineer issued to him by any duly qualified board of examining engineers existing pursuant to law in any state or territory of the United States and who shall file with his application a copy of such certificate and an affidavit that he is the identical person to whom said certificate was issued. If the board of examiners of engineers shall determine that the applicant has complied with the requirements of this section he shall be examined as to his qualifications to take charge of and operate steam boilers and steam engines in the city of New York, and if found qualified said board shall issue to him a certificate of the third class. After the applicant has worked for a period of two years under his certificate of the third class, he may be again examined by said board for a certificate of the second class, and if found worthy the said board may issue to him such certificate of the second class, and after he has worked for a period of one year under said certificate of the second class he may be examined for a certificate of the first class, and when it shall be made to appear to the satisfaction of said board of examiners that the applicant for either of said grades lacks mechanical skill, is a person of bad habits or is addicted to the use of intoxicating beverages he shall not be entitled to receive such grade of license and shall not be re-examined for the same until the expiration of one year. Every owner or lessee, or the agent of the owner or lessee, of any steam boiler, steam generator, or steam engine aforesaid, an every person acting for such owner or agent is hereby forbidden to delegate or transfer to any person or persons other than the licensed engineer the responsibility and liability of keeping and maintaining in good order and condition any such steam boiler, steam generator or steam engine, nor shall any such owner, lessee or agent enter into a contract for the operation or management of a steam boiler, steam generator or steam engine, whereby said owner, lessee or agent shall be relieved of the responsibility or liability for injury which may be caused to person or property by such steam boiler, steam generator or steam engine. Every engineer holding a certificate of qualification from said board of examiners shall be responsible to the owner, lessee or agent employing him for the good care, repair, good order and management of the steam boiler, steam generator or steam engine in charge of or run or operated by such engineer.

Sec. 2. This act shall take effect immediately.

FIREMEN'S LAW

To provide for the licensing of firemen operating steam stationary boiler or boilers in the City of New York.

Accepted by the City.

Became a law May 13, 1901, with the approval of the Governor.

Passed, three-fifths being present.

The people of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. It shall be unlawful for any fireman or firemen to operate steam stationary boilers in the City of New York, unless the fireman or firemen to operating such boiler or boilers are duly licensed as hereinafter provided. Such fireman or firemen to be under the supervision and direction of a duly licensed engineer or engineers.

Section 2. Should any boiler or boilers be found at any time operated by any person who is not a duly licensed fireman or engineer as provided by this act, the owner or lessee thereof shall be notified, and if after one week from such notification the same boiler or boilers is again found to be operated by a person or persons not duly licensed under this act, it shall be deemed prima facie evidence of a violation of this act.

Section 3. Any person desiring to act as a fireman shall make application for a license to so act, to the steam boiler bureau of the police department as now exists for licensing engineers, who shall furnish to each applicant blank forms of application, which application when filled out shall be signed by a licensed engineer engaged in working as an engineer in the City of New York, who shall therein certify that the applicant is of good character, and has been employed as oiler, coal passer or general assistant under the instructions of a licensed engineer on a building or buildings in the City of New York, or on any steamboat, steamship or locomotive for a period of not less than two years. The applicant shall be given a practical examination by the board of examiners detailed as such by the police commission and if found competent as to his ability to operate a steam boiler or steam boilers as specified in Section 1 of this Act, shall receive within six days after such examination a license as provided by this Act. Such license may be revoked or suspended at any time by the police commissioner upon the proof of deficiency. Every license issued under this Act shall continue in force for one year from the date of issue unless sooner revoked as above provided. Every license issued under this act unless revoked as herein provided, shall at the end of one year from date of issue thereof, be renewed by the board of examiners upon application and without further examination. Every application for renewal of license must be made within thirty days of the expiration of such license.

With every license granted under this Act there shall be issued to every person obtaining such license a certificate, certified by the officers in charge of the boiler inspection bureau. Such certificate shall be placed in the boiler room of the plant operated by the holder of such license, so as to be easily read.

Section 4. No person shall be eligible to procure a license under this Act unless the said person be a citizen of the United States.

Section 5. All persons operating boilers in use upon locomotives or in government buildings, and those used for heating purposes carrying a pressure not exceeding ten pounds to the square inch, shall be exempt from the provisions of this Act.

Such license will not permit any person, other than a duly licensed engineer to take charge of any boiler or boilers in the City of New York.

Section 6. This act shall take effect immediately.

STEAM ENGINES

Ques. Name the different classes of engine.

Ans. Engines may be divided into three great classes: Stationary, marine and locomotive.

Ques. What are the principal types of stationary engine?

Ans. Stationary engines may be divided into three classes: Common slide valve, automatic and Corliss engines.

Ques. How is a common slide valve engine constructed?

Ans. The common slide valve engine is the simplest form of engine, having one slide valve moved by an eccentric and rod.

Ques. What is an automatic engine?

Ans. In this type of engine the speed is kept constant by a governor mounted on crank shaft and usually placed in one of the band wheels. Most automatic engines have double ported balanced slide valves, and are usually run at a high speed.

Ques. What is a Corliss engine?

Ans. A steam engine fitted with Corliss valves. These are four in number for each cylinder, a separate steam and exhaust valve being provided at each end. The valves are shaped as a sector of a cylinder and vibrate within a cylindrical seat over ports in line therewith. The admission valves are not in positive connection with the valve gear, but are tripped or disengaged at a point in the stroke determined by the governor or by hand, the closing being

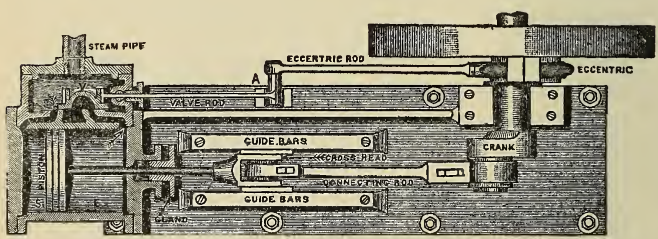


FIG. 47.—Plain horizontal slide valve engine; view showing parts.

effected by the action of the dash pot thus giving a quick cut off, variable according to the load. The Corliss engine has a very small percentage of clearance.

Ques. What may be said in favor of the slide-valve engine?

Ans. It is cheap, simple and easily kept in repair, and little skill is necessary to operate one successfully. It is used in small plants where the economical production of power is not of first importance.

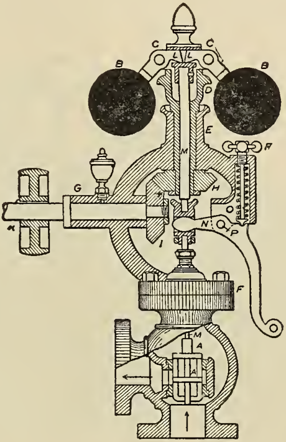


FIG. 48.—A throttling governor. In operation, as the engine speeds up, the centrifugal force acting on the balls causes them to swing outward, which in turn, through suitable connections, closes the steam valve, resulting in maintaining a nearly constant speed at all loads.

Ques. How is the speed regulated on a slide valve engine?

Ans. By a throttling governor, which is placed on valve chest, and driven by a small belt from crank shaft. This governor controls the amount of steam admitted to engine and keeps the speed fairly constant.

Ques. Are automatic engines in extensive use?

Ans. Yes; this type of engine is very much used, principally for electric lighting, and for power in mills, factories, hotels, etc. It occupies little space,

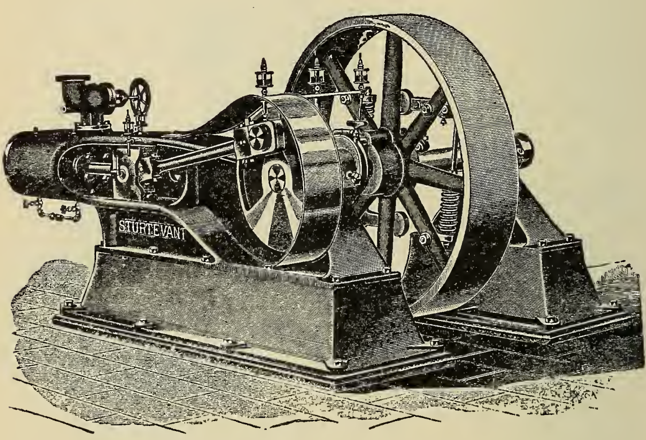


FIG. 49.—The Sturtevant automatic high speed engine. The term *high speed* is here used in the sense of "quick revolution" rather than high piston speed. A shaft governor is used with this type of engine. It operates by shifting the eccentric so as to vary the *throw;* this changes the travel of the valve, thus altering the *cut off* to suit the load.

has a very sensitive governor, is fairly economical in the use of steam, but requires much attention to be kept in repair. Automatic engines are short stroke engines and are operated at a high rotative speed.

Ques. Of what material are the principal wearing parts of an engine made?

Ans. The crosshead pin is usually made of tool steel ground true, the crosshead shoes are made of brass on small engines and are babbitted on large engines. The crosshead boxes are usually made of phosphor bronze or brass. The crank pin is made of tool steel ground true, and turns in brass boxes lined with babbitt metal. The crank shaft is made of machine steel and runs in cast iron boxes lined with babbitt metal; the eccentric is usually made of cast iron throughout.

Ques. What is a crosshead?

Ans. The crosshead is that part of an engine which fits loosely in the guides, and to which the piston rod and connecting rod are attached.

Ques. What is the connecting rod?

Ans. The connecting rod forms the link between crank and crosshead of an engine; the crosshead, connecting rod and crank convert a straight back and forward motion into a rotary motion.

Ques. What is the nature of the strain on the piston rod?

Ans. It is alternately tensile and compression.

Ques. What is the nature of the strain on connecting rod?

Ans. Tensile, compression and bending.

Ques. Why is an engine crank shaft usually provided with only two bearings?

Ans. Because two bearings are much more easily kept in line than a greater number.

Ques. What is the nature of the strain on crank shaft?

Ans. The strain on shafts is torsional (twisting), and for that reason they must be made much stronger than piston and connecting rods.

Ques. Why are the crank pin boxes and crank shaft bearings lined with babbitt metal?

Ans. So that the boxes will wear faster than the crank pin and shaft. When the boxes are worn large they may be re-babbitted.

Ques. What is a fly wheel on an engine for?

Ans. To smooth out any slight irregularity of speed; fly wheels on some engines are made very heavy, with most of the weight placed in the rim of wheel, where it will do the most good; on other engines the fly wheel is also used as a band or driving wheel.

THE VALVE AND VALVE GEAR

Ques. Describe a slide valve.

Ans. A slide valve is a cup shaped piece of metal arranged to slide over and alternately cover and uncover the openings or ports through which steam

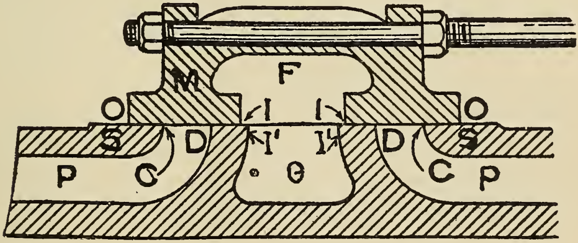


FIG. 50.—A plain unbalanced slide valve. The parts are: M, valve; S. seat; O, steam edges; I, exhaust edges; CD, steam ports; P, steam passages; I'I', exhaust port; DI', bridge; F, cavity; G, exhaust cavity; OC, *outside lap:* DI, *inside lap.*

is distributed to the cylinder; called also, *D valve* and *D slide.* It is situated in the steam chest, and is moved by the valve gear.

Ques. What are the good points of the slide valve gear?

Ans. Its simplicity, and the little attention required to keep it in order.

Ques. What are the principal objections to the slide valve?

Ans. As the full pressure of the steam presses valve to its seat, much power is necessary to move valve, and if not liberally lubricated both valve and seat will wear rapidly; with this style of valve, cut off cannot take place earlier than ½ stroke.

Ques. What is a balanced slide valve?

Ans. A balanced valve has its back ground true and slides between valve seat and a pressure plate; this type of valve is used on automatic engines.

Ques. What is lap?

Ans. That amount of the valve that is more than necessary to cover the ports; in other words, the amount the valve laps over the ports, when the valve is in its central or *neutral position.*

Ques. Name two kinds of lap.

Ans. Inside lap and outside lap.

Ques. What is outside lap?

Ans. The distance from the steam edge of the steam port to the steam edge of the valve when the valve is in its neutral or central position.

Ques. What is inside lap?

Ans. The distance from the exhaust edge of the steam port to the exhaust edge of the valve when the valve is in its neutral position.

Ques. What is the object of outside lap?

Ans. To close the steam port before the piston reaches the end of stroke. When the valve is closed (when cut off begins) the steam in cylinder must expand to finish stroke.

Ques. What regulates the cut off?

Ans. The amount of lap; the more lap the earlier the cut off.

Ques. At what part of stroke does the cut off take place in slide valve engines?

Ans. At from $\frac{6}{10}$ to $\frac{7}{8}$ stroke.

Ques. What is the object of inside lap?

Ans. To secure later *release* of the steam and more *compression*.

Ques. When the exhaust edge of valve closes the exhaust port what takes place?

Ans. Compression; that is, the remaining exhaust is compressed, and assists in bringing the piston to a stop.

Ques. What is meant by lead?

Ans. Lead is the amount of opening of valve as the engine begins the stroke; engineers give their engines lead so that the clearance space in cylinder is full of steam at boiler pressure when the engine begins its stroke.

Ques. Should more lead be given an engine on the crank end than head end?

Ans. Many engineers give the valve a trifle more lead on the crank end because the piston is somewhat smaller in area, due to the piston rod being attached to piston, also any lost motion in the eccentric rods tends to decrease the lead on crank end and increase the lead on head end.

Ques. How much lead would you give a small engine, say about 10 horse power?

Ans. About $\frac{1}{16}$ inch, or a little less.

Ques. What is negative lead?

Ans. The amount by which the steam edge of the valve overlaps the steam edge of the port when the engine is on the dead center.

Used sometimes on locomotives having link motion to prevent excessive positive lead when cutting off short.

Ques. If an engine valve had neither lap nor lead, how much in advance of the crank would you place the eccentric?

Ans. When an engine has neither lead nor lap the eccentric would be placed exactly 90 degrees or ¼ turn in advance of the crank, that is, the *angular advance* would be zero.

Ques. What is the angular advance of the eccentric?

Ans. The angular advance is the amount that the eccentric is more than 90 degrees in advance of the crank. The greater the lap the greater will be the angular advance.

Ques. In a slide valve engine how much is the eccentric placed in advance of the crank?

Ans. The eccentric is placed in advance about 115 degrees more or less. No rule can be given that will apply in general; in all engines the eccentric is placed enough more than 90 degrees in advance of the crank to give sufficient lead.

Ques. What is the travel of a slide valve?

Ans. The extent of the movement of the valve in either direction; *for full gear*, it is equal to *twice the outside lap plus twice the port opening.*

Ques. What part of the cylinder volume is clearance space.

Ans. The clearance space is the space between the piston and cylinder head when engine is on dead center, plus the volume of the steam passage leading from valve to cylinder; it amounts to from 2 to 10 per cent. of the total cylinder volume.

Ques. Is the steam that fills the clearances altogether wasted?

Ans. No; when cut off takes place it expands and does some work.

Ques. Should this clearance space be kept as small as possible?

Ans. Yes; as the steam that fills the clearance performs little work, it should be kept as small as possible.

Ques. How do we set the valve on a common slide valve engine?

Ans. Turn the eccentric on the shaft so that the high part of the eccentric, will be about one-quarter of a revolution in advance of the crank (by advance is meant in the direction the engine is to run) when the engine is on dead center. Now square the valve over ports by adjusting the locknuts that hold it on valve rod. This done, turn the eccentric on shaft until valve has the proper amount of lead (if engine run "over" eccentric will have to be turned in the direction of rotation; if engine run "under" the eccentric must be moved back). Make the eccentric fast on shaft when the lead is right, and turn the engine on the opposite dead center, and if the lead be the same as on the other end the valve is properly set. If the lead be unequal it must be equalized by adjusting the valve stem.

By placing the engine on the dead center and turning the eccentric in the reverse direction of rotation

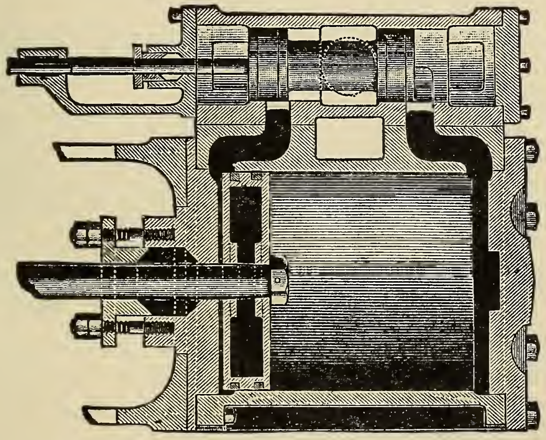


FIG. 51.—Section of cylinder showing the construction of a piston valve. This type of valve is cylindrical in form, the seat consisting of a cylindrical ring containing the ports. As shown in the figures, the valve is arranged for *inside admission.*

until the valve again comes into the lead position; this may be done without taking off the steam chest cover, by means of a scriber and a reference mark on the valve stem.

Ques. How is the cut off arranged in an automatic engine?

Ans. In the automatic engine the cut off is adjustable and is effected by the shaft governor varying the throw of eccentric, which varies the valve travel and cut off to suit the boiler pressure and load of engine.

Ques. How do we set the valve, on an automatic engine fitted with a double ported balanced valve and pressure plate?

Ans. To set the valve the governor weights are propped out sufficiently to cause the valve to cut off at about $\frac{1}{4}$ stroke, and the locknuts on valve rod are adjusted to give the same amount of lead on both ends of cylinder when the engine is on dead centers.

THE CORLISS ENGINE

Ques. What may be said of the Corliss engine?

Ans. This engine is complicated, but very economical; it occupies much more space than an automatic engine of the same power, is high at first cost, and requires a skillful engineer.

Ques. How much lap have the Corliss engine valves?

Ans. The amount of lap depends upon the size of engine and is always small in all Corliss engines, because, unlike the slide valve engine cut off, does not depend upon the amount of lap when engine is up to speed.

Ques. Is the clearance smaller in Corliss engines than in most of the other types?

Ans. Yes; the clearance is always small in Corliss engines; in large engines it is usually about 3 per cent. of the total cylinder volume.

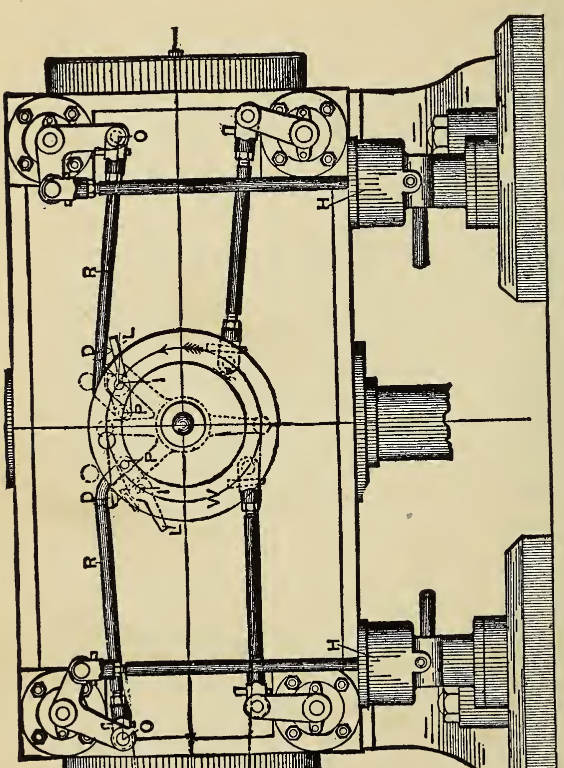


FIG. 52.—View of Corliss engine cylinder showing the valve gear. W is wrist plate which gives motion to both steam and exhaust valves. R R are valve rods which operate the steam valves. L L are connecting links and are supported by steel pins II securely fastened in wrist plate. P P are small steel wrist pins connecting valve rods R R with links L L. D D are tripping arms moving to and from each other, varying the point of cut off to suit load. They are actuated by governor through rods G G. H H are dash pots which quickly close the steam valves as soon as released at wrist plate.

Ques. Why do we require so little compression in the Corliss engine?

Ans. Because its rotative speed is low.

Ques. How do we set the valves on a Corliss engine?

Ans. The following will be found sufficiently general to apply to all Corliss engines:

TO SET THE CORLISS VALVES

Remove the back valve chest bonnets and upon the bore of the seats will be found a mark indicating the closing edge of port. On the end of valve is a mark representing the closing edge of valve; note that in the case of the exhaust valve, the valve controls the port leading into the exhaust chest and not the opening from the cylinder downward, the outer edge of port in exhaust valve is the closing edge and the outer edges of the steam valves are the closing edges.

The wrist plate should now be looked over. On the back of wrist plate will be found a center line, and a line will also be found on the hub of stand supporting wrist plate, also on either side of central mark will be lines which show the vibration of wrist plate, and when the line on wrist plate coincides with either of these lines it will be in its extreme position. The wrist plate should be located exactly central between the four valves, and is so placed in the shop in building the engine, and all adjustments are made

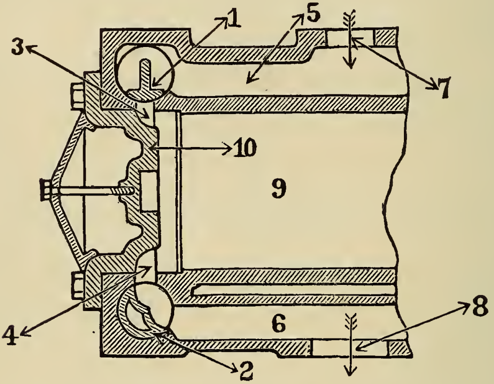


Fig. 53.—One end of Corliss cylinder showing operation. Steam enters the cylinder casing by the opening for the steam pipe flange 7, and flows around the cylinder barrel in the annular passage 5. It gains admission past the steam valve 1, through the admission port 3, into the bore of the cylinder 9. After peforming its work upon the piston the steam passes through the exhaust port 4 and exhaust valve 2, into the exhaust passage 6, finally escaping to the atmosphere or condenser through the exhaust outlet 8; the cylinder cover 10 is not jacketed in this instance.

and valves properly set, but in taking apart for adjustment, it may be possible that the adjustments may be disturbed, and need careful going over before attempting to start the engine for the first time.

To test the marks on wrist plate and stand, connect the eccentric rod and hook rod, then rotate the eccentric on the shaft the full throw each way, and observe if the mark on the wrist plate at full throw agree with marks on stand; if not, to set the valves

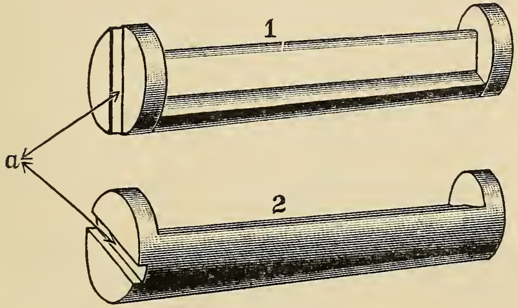


Fig. 54.—Corliss valves: 1, steam valve; 2, exhaust valve. The recesses *a*, cut across the face of the circular end of the valves, are to receive a T shaped head of the valve stems, which transfers the rotary motion of the latter to the valves, and still allows the valves to be withdrawn from their respective chambers by removing the covers on the front side of the engine. It also enables the valves to leave their seats, if forced by water or over pressure, and to follow up near without bending the valve stem.

adjust the nuts on eccentric rod (or stub end, as the rod may be constructed), and by lengthening or shortening (as required) until the marks agree on both extremes of vibration of wrist plate. Place the wrist plate in a vertical position at the central mark, turn the valves until the "steam valves" show by the marks on valve and seat that the closing edges lap as per table below, and the marks on exhaust valve and seat show opening as per table below:

Cyl. 10 to 14 ins. diam.,	$\frac{1}{4}$-in. steam lap,	$\frac{1}{16}$-in. exh. open.
Cyl. 16 to 20 ins. diam.,	$\frac{3}{8}$-in. steam lap,	$\frac{3}{32}$-in. exh. open.
Cyl. 22 to 30 ins. diam.,	$\frac{7}{16}$ in. steam lap,	$\frac{1}{8}$-in. exh. open.

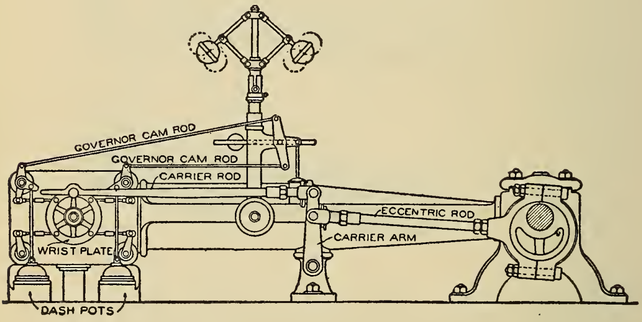


FIG. 55.—Reynolds-Corliss engine; view showing valve gear.

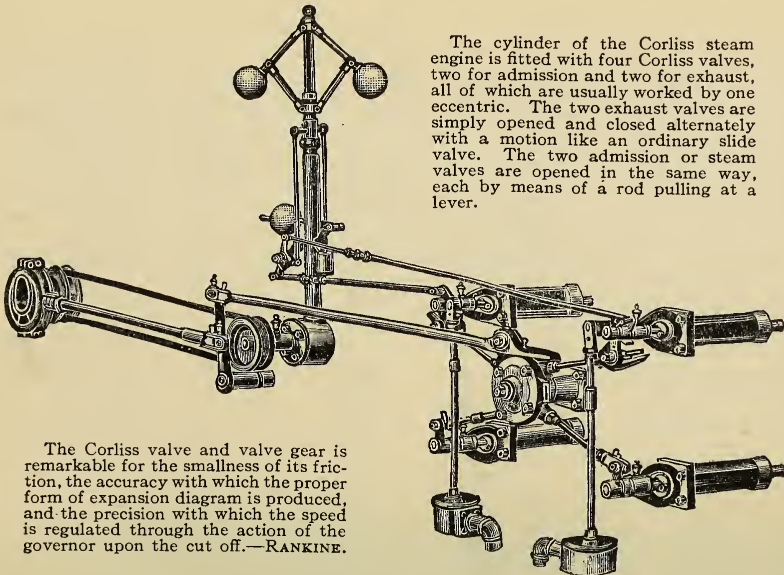
The valves at both ends of cylinder should be alike, and can be adjusted by means of the right and left hand screws in connecting links, so that the lap and opening stand exactly the same in both ends of the cylinder.

With the valves and connections properly adjusted, drop the hook on wrist plate pin, place the engine on either center (if engine is to run over, it will be more convenient to place it on inner center), turn the eccentric upon the shaft in the same direction in which the shaft is to run, a little more than at right angles ahead of the crank or until the steam valve on the same end as the piston has the proper amount of lead; in this position secure the eccentric on shaft (see in all cases that the steam valves are hooked up or engaged by the cut off mechanism), then turn the engine on the opposite center and see if the steam valve on that end has the same opening; if not, make the adjustment by shortening or lengthening, as may be required, the connection between the valve and wrist plate.

TO ADJUST THE CUT OFF

See that the governor and connections are properly put together, block the governor up half-way of its rise when resting on safety collar, then fasten cam rod lever so that it stands about right angles to a line drawn midway between the cam rods, then adjust the cam rods so that the cam lever stands vertical, the governor and connections now occupy the proper relative positions. Now lower the governor on safety collar, and see that the cut off mechanism does not unhook, but allows steam to be taken full stroke; now throw the safety collar around so that governor can drop the extra travel, and see that the

The cylinder of the Corliss steam engine is fitted with four Corliss valves, two for admission and two for exhaust, all of which are usually worked by one eccentric. The two exhaust valves are simply opened and closed alternately with a motion like an ordinary slide valve. The two admission or steam valves are opened in the same way, each by means of a rod pulling at a lever.



The Corliss valve and valve gear is remarkable for the smallness of its friction, the accuracy with which the proper form of expansion diagram is produced, and the precision with which the speed is regulated through the action of the governor upon the cut off.—RANKINE.

FIG. 56.—View showing Corliss valves, and valve gear complete; the governor and governor connections are here clearly seen.

catch block is disengaged so that valve will not open. This safety catch is to prevent engine running away in case governor belt breaks, and should be thrown back when engine is in motion, but should be put in place before stopping engine.

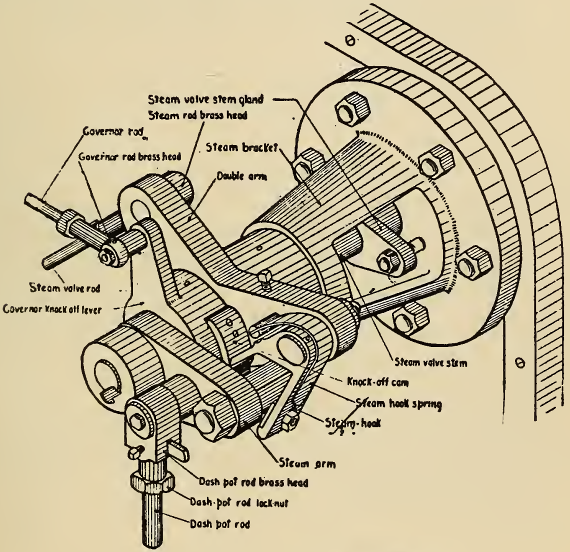


FIG. 57.—The Murray-Corliss releasing gear.

To equalize the cut off at each end of stroke, place the engine at, say, ¼ stroke, which can be done by measuring upon the slides from each end and turning the engine until crosshead is in line with the mark; then raise the governor until the cut off on the end taking steam, trips or unhooks; now block the governor in this position and try the cut off on the other stroke, same distance from end, and adjust length of cam rods so that cut off unhooks at same point of stroke. The dash pot rod should be adjusted so that the latch is sure to hook under the latch stud on steam valve stem arm when the plunger is at bottom of dash pot.

GOVERNOR DASH POT

The dash pot attached to governor is used to prevent over sensitiveness and too sudden response to trivial changes. Do not allow it to become gummed with oil, but keep it clean, and use only coal or kerosene oil in the pot. Adjust the screw in piston which acts as a valve to allow the oil to pass from one side of piston to the other to give freedom of motion.

See that all parts of the governor move freely; a little kerosene oil run through all its parts occasionally will prevent gumming.

ARITHMETIC
OF THE
STEAM ENGINE

Ques. How do we find the piston speed of any engine?

Ans. By multiplying twice the number of revolutions per minute by the stroke of engine in inches, and dividing the product by 12, to reduce to feet.

Ques. What are the usual piston speeds for stationary work?

Ans. From 350 to 800 feet per minute.

Ques. How can we find the length of stroke of any engine without disturbing cylinder?

Ans. By finding the distance between center of shaft and center of crank and multiplying by 2.

Ques. How do we find the area of piston?

Ans. By squaring the diameter and multiplying the product by .7854.

Ques. What is the mean effective pressure?

Ans. The mean effective pressure is the average pressure exerted on piston throughout one stroke.

To find the mean effective pressure exactly we must use an indicator; if no indicator be at hand we estimate it roughly from the boiler pressure by multiplying the latter by from .40 to .70, according to how early cut off takes place, or more accurately by the use of hyperbolic logarithms.

Ques. What is a horse power?

Ans. 33,000 foot pounds of work done in one minute is a horse-power; in other words, a horse-power is equivalent to the work of raising a weight of 33,000 pounds one foot in one minute.

Ques. How do we find the horse power that a certain engine will develop?

Ans. Multiply the mean effective pressure by the area of piston in square inches and multiply the product by the length of stroke in feet, and by the number of strokes per minute (twice the number of revolutions); divide this last product by 33,000 and the answer will be the horse power. The formula for finding the horse power of a double acting engine is usually written:

$$\frac{2\ PLAN}{33000}$$

P = Mean effective pressure per square inch;
L = Length of stroke in feet;
A = Area of piston in square inches;
N = Number of revolutions per minute.

The following example shows method of computing the power of a 16 x 42 engine, with 84 revolutions per minute and mean effective pressure 40 pounds; cylinder diameter 16 ins.; stroke 42 ins.; revolutions 84; mean effective pressure 40 lbs.

1st Step

```
         16
         16
        ---
         96
        16
       ----
        256
      .7854
      -----
       1024
      1280
     2048
    1792
   --------
   201.0624 piston area in sq. ins.
```

2nd Step

```
 201.06   piston area
     40   mean effective pressure
 -------
8042.40   lbs., total pressure
          upon the piston
```

3rd Step

42 ins = 3.5 stroke

3.5×2 = 7 ft. per rev.

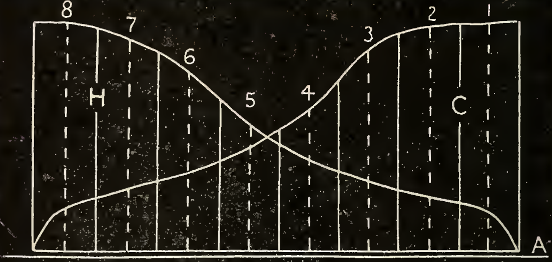
```
 84 rev. per min.
  7 ft. per rev.
---
588 ft., piston speed
```

4th Step

```
  8042.4 lbs., total pressure
     588 ft. piston speed
  ------
  643392
 643392
402120
---------
4728931.2 foot pounds
          per minute
```

5th Step

4728931.2 ÷ 33000 = 143.3 horse power.



SCALE OF SPRING, 1" = 50 LBS.

SUM OF "C" ORDINATES = 8.75 IN.
SCALE OF SPRING 50

8)437.50

M.E.P. OF "C" CARD. 54.69

8.2 IN. = SUM OF "H" ORDINATES.
50 SCALE OF SPRING.

8)410

51.25 M.E.P. OF "H" CARD.

AVERAGE LBS M.E.P.

$(54.69 + 51.25) \div 2 = 52.97$ LBS.

PISTON TRAVEL.

$3 \times 112 \times 2 = 672$ FEET PER MINUTE

AREA OF PISTON.

$12 \times 12 \times .7854 = 113.1$ SQ. IN. OF PISTON

$$\text{I.H.P.} = \frac{672 \times 113.1 \times 52.97}{33000} = 122.$$

Ques. What is an indicator card?

Ans. An indicator card or diagram is the diagram penciled, by the indicator, on a sheet of paper from which we figure horse power, pressure, volume, etc.

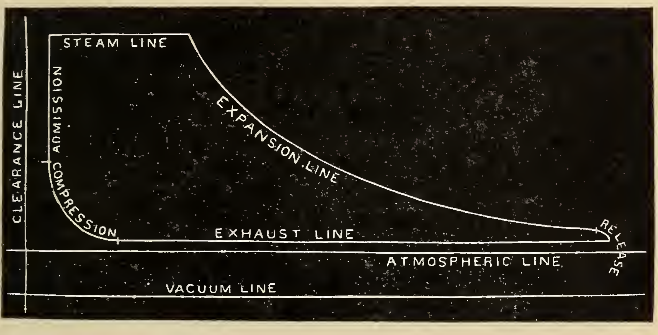


FIG. 59.—Ideal indicator card, with pre-release and compression; the card represents ideal action; however *this does not occur in practice.* It takes time for the valve to open for admission and to close for cut off, hence the corners of the diagram taken from an angle will not be so sharp as in the figure; the expansion line is usually distorted on account of the cylinder condensation and re-evaporation. The curve at the toe of the diagram shows the effect of the gradual opening of the valve at pre-release.

Ques. How do we find the area of an indicator card and the mean effective pressure?

Ans. We can find the area directly and accurately by the planimeter, which is an instrument for finding the area of bodies of irregular shape; if no planimeter be at hand, a method much used and fairly accurate is to find the average height of the diagram by drawing ten lines or ordinates through the diagram from

top to bottom, at equal distances apart; by addir
the lengths of these lines together and dividing tl
sum by 10, the average height of diagram is foun
and this multiplied by the length of diagram and b
the scale of spring will be the mean effective pressur

Ques. How do we find the mean effecti pressure from an indicator diagram?

Ans. By multiplying the area of card by the sca of spring.

Ques. What data should be noted in takin an indicator card?

Ans. The data that should be recorded *on the ca* are:

1. Diameter and end of cylinder to which tl card belongs;

2. The scale of the spring that has been used;

3. The number of revolutions per minute;

4. The pressure from the steam and receiver gaug and the vacuum;

5. Degree of opening of throttle;

6. Time, date, cut off of cylinder and other detail as desired.

Ques. What is an indicator?

Ans. An instrument for finding the pressure within the cylinder at any part of the stroke; in fact, by the indicator we find exactly what is going on inside the cylinder.

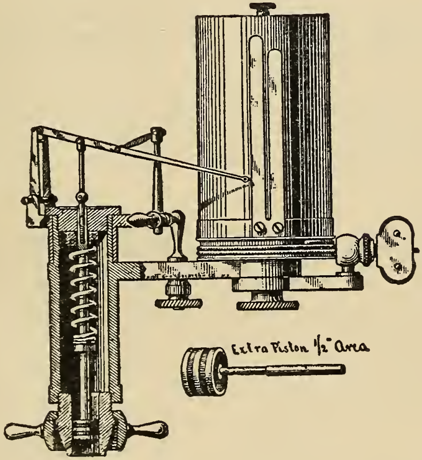


FIG. 60.—The indicator. It consists of a small cylinder communicating by a cock with the cylinder of the engine, and fitted with a piston, to which a pencil is attached. The roller upon which a card is fastened, is oscillated forward and backward by a cord attached to the piston rod of the engine as the pencil rises by the steam pressure, and is brought back by a graduated spring when that pressure is reduced. This traces a closed figure upon the card, which represents the pressure at each point in the stroke of the engine.

In all cases where it is possible and an indicator can be obtained, it should be applied to test the correctness of valve setting.

The connection between the indicator and the steam cylinder of the engine must be as direct as possible, so that the same pressure that is acting upon the piston in the engine may at the same instant act upon the piston in the indicator.

Almost all modern engines are tapped for the indicator; but if no provision be made, the holes should be drilled into the counterbore of the cylinder, and tapped for a half inch pipe thread.

Care should be taken that none of the drill chips drop into the engine cylinder, and that the holes thus drilled are not obstructed by the piston.

When the connections are all up, allow the steam to blow through them freely some time before attaching the instrument, to remove any scale or dirt that is liable to become detached.

LUBRICATORS

Ques. What is a lubricator?

Ans. A device to hold oil and supply it in regular amounts to a bearing or cylinder.

The term lubricator is applied more especially to an oiling device intended for *internal lubrication*, that is for cylinder lubrication. A few examples of lubricator are shown in figs. 64, 65, 66 and 67.

Ques. Describe the different methods of feed for external lubrication.

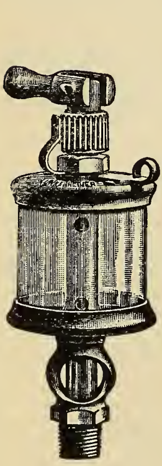
Ans. The supply is fed either by worsted syphons, by gauged drips, or by a needle, placed in the oil passage through the neck of the lubricator, and which induces feeding by capillary attraction and the shaking of the needle.

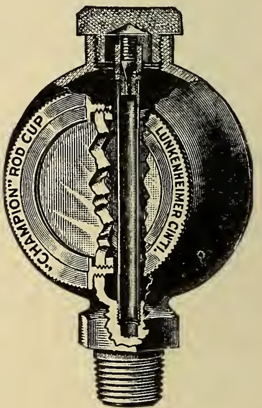
Ques. What is a sight feed lubricator?

Ans. One that passes the oil visibly, drop by drop, through a section of glass tube so that its rate of supply may be observed. The term is usually applied to those types designed for feeding oil into the engine cylinder, that is, those intended for *internal lubrication*.

Ques. What is the principle of operation of a sight feed lubricator?

Ans. The condensation of steam displaces oil from a vessel under pressure, the weight of the column of water plus the steam pressure forcing the drops of oil along pipes to the desired spot.



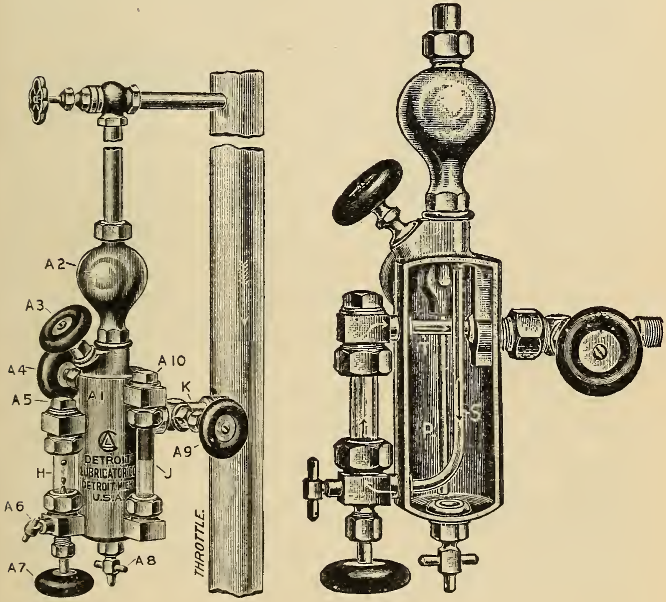


Figs. 61 and 62.—Sentinel sight feed oil cup; fig. 61, lever down feed shut off; fig. 62, lever up, cup feeding. To adjust feed raise the lever and turn the milled thumb nut until the desired feed is obtained. When the lever is set at an angle of 45 degrees it raises the feed stem clear off its seat and cup flushes.

Fig. 63.—Oiler for movable bearings. The feeding arrangement consists of a tube, screwed into the base of the cup and communicating with the oil hole in the shank. Secured to the top of this tube is a regulating valve, by means of which any quantity of oil can be fed through the tube.

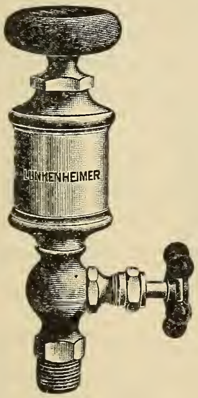
Ques. Describe the construction and operation of a sight feed lubricator.

Ans. Figs. 64 and 65 show external and sectional views of a sight feed lubricator. The pipe P shown in sectional cut on the right, connects with a passage



FIGS. 64 and 65.—Detroit sight feed lubricator. The parts are A1, body of oil reservoir; A2, condenser; A3, filler plug; A4, water feed valve stem; A5, plug for inserting sight feed glass; A6, sight feed glass drain stem; A7, sight feed regulating valve stem; A8, drain valve; A9, globe valve in support arm; A10, plug for inserting gauge glass; H, sight feed glass; J, gauge glass; K, connection to steam pipe.

from condenser A-2, so that as soon as the water feed valve A-4 is opened, the water in the condenser will pass down the pipe P, to the bottom of the body of the lubricator, and being heavier than oil, will stay at the bottom, the oil floating above it. The pipe S, leads to the lower sight-feed arm from the upper part of the body of the lubricator. The body A-1 is filled with oil. Steam from the main steam pipe passes in the connecting pipes above the lubricator, and condenses, filling the condenser A-2 and part of the pipe above it with water. The steam also passes into the support arm and through the internal tube T into the sight feed glass, where it condenses, filling the glass with water. As soon as the valve A-4 is opened, the oil in the body of the lubricator is subjected to the pressure of the column of water extending through the pipe P, the condenser and part of the pipe above it, amounting to about 2 lbs. to the square inch, and in addition to the pressure of the steam above the water, amounting to say 100 lbs. to the square inch, or a total pressure of about 102 lbs. to the square inch. This we may call the positive pressure. Liquids communicate pressure equally in all directions, so the oil in the body of the lubricator will press in every direction with a force of about 102 lbs. to the square inch. It will therefore press down through the tube S with this force of 102 lbs. to the square inch. Then, if the valve A-7 be opened, a force acting in the opposite direction is encountered, which we may call the back pressure. When the lubricator is connected as shown, this back pressure will consist of the column of water in the sight feed glass, and in addition, the steam pressure back of this column entering through the support arm, and amounting to 100 lbs. to the square inch. The positive steam pressure being just



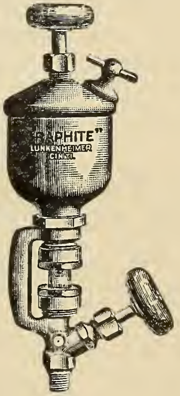


FIG. 66.—Plain cylinder lubricator without sight feed.

FIG. 67.—Graphite sight feed lubricator. To operate close steam valve and open drain plug to allow steam to escape from cup; then close regulating valve, remove filling plug and fill cup with graphite. After replacing filling plug, close drain plug, open steam valve (wide) and regulate the feed of graphite by regulating valve. The sight feed glass can be cleaned by opening drain plug. If necessary to replace the sight feed glass, take cup apart by means of lock nut, and slide the new glass down through the opening.

the same as the back steam pressure, these two forces will neutralize each other, and we have left, the positive pressure of the column of water extending through the pipe P, the condenser and part of the pipe above it, and the back pressure of the column of water in the sight feed glass. As the latter is much less than the positive pressure, the drop of oil is forced through the nozzle. As soon as it leaves the nozzle it is no longer acted upon by the positive pressure, and it rises through the water in the glass from the force of gravity, it being lighter than the water. After rising through the sight feed glass it floats through the tube T and through the support arm into the main steam-pipe and goes with the current of steam to the steam chest and cylinder.

Ques. What is necessary for the operation of the lubricator?

Ans. The positive pressure must always be greater than the back pressure.

For instance, if a lubricator be connected to a horizontal steam pipe by being suspended below it, the back pressure would be greatly increased, and in order to get sufficient positive pressure the condensing pipe should rise 18 in. to 24 in. above the horizontal steam pipe and then descend to the condenser. This will give a column of water for positive pressure higher than the column of water which acts as back pressure.

Ques. How should a lubricator be attached to the steam pipe?

Ans. First drill and tap the steam pipe above the throttle, with ½-inch or ¾-inch gas tap as may be required to receive support arm of the lubricator;

insert the part containing the globe valve, after which couple the lubricator to it. Then tap the steam pipe about 18 inches or more above the top of the condensing chamber, using $\frac{1}{4}$-inch gas pipe for steam connecting tube which attaches to the top of the condenser.

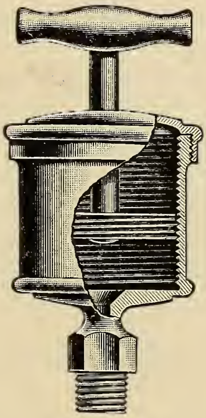


Fig. 68.—Screw feed marine grease cup. This cup is designed for the main bearings of marine engines, but will also be found suitable for other purposes where a screw feed is desired, such as for forcing grease some distance to the parts to be lubricated.

If, for any reason, the steam pipe cannot be tapped 18 inches or more above the condensing chamber, it may be tapped lower down, and the tube of required length be bent into a horizontal coil. The action of the steam pipe which is tapped to receive the lubricator connections, should be extra heavy unless of large size, in order to secure proper thickness of metal to, form good joints.

Ques. How is the lubricator figs. 64 and 65 refilled?

Ans. Close valves A4 and A7. Open drain valve A8, then remove filler plug A3 and the water will drain out rapidly. When water is all out, close valve A8, fill with oil, and replace filler plug A3. Then open

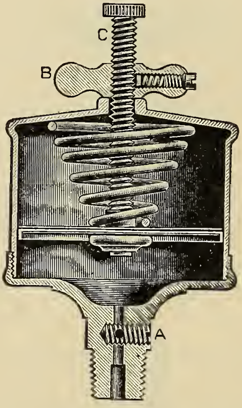


Fig. 69.—Nathan automatic grease cup. Directions for operating: When cup is empty, screw the plunger to top of reservoir, by means of the thumb nut C, unscrew and take off the reservoir and fill with grease, and, after screwing it back on the base, screw the jamb nut B up to the top so as to put the pressure of the spring on the grease. The base of the cup is provided with a simple feed regulating screw A, adjustable to suit any kind of grease.

valve A4, and regulate the flow of oil with valve A7. The valve A9 is to be closed only when desiring to shut off steam from the lubricator in case of accidental breakage of the glass or when there is danger from freezing. Before starting the lubricator, time should be allowed for the sight feed glass and condensing chamber to fill with water from condensation. When there is danger from freezing when lubricator is not in use, empty the lubricator, and leave open valves A4, A8 and A6. Then close valve A9 and the small angle valve in condensing pipe above the lubricator.

Ques. How is the feed started and regulated?

Ans. By valve A-7 (fig. 64).

POINTS RELATING TO SIGHT FEED LUBRICATORS.

1.—Before starting the lubricator, time should be allowed for the sight feed glass and condenser to fill with water.

2.—When the sight feed glass fills with oil, the trouble is usually due to the condition of the nozzle below the glass. Sometimes the upper part of this nozzle on the outside becomes covered with dirt or sediment from the oil. This makes the surface rough, and the drop will adhere to the nozzle much longer than if its surface was smooth. In consequence the drop becomes too large, and it is very liable to strike the side of the glass when rising and break, filling the glass with oil. To overcome this trouble take out the glass, clean off the dirt from the upper part of the nozzle, and rub it smooth. Then only drops of moderate size will form, and there will be no danger of them striking the side of the glass while rising.

3.—Do not use common rubber gaskets or cut glasses in sight feed lubricators. Both the gaskets and glasses in a lubricator have to withstand the action of heat and steam. The steam soon rots the common rubber gasket, causing it to leak, and cut glasses are very liable to crack and split from the ends as the result of the expansion and contraction due to the heat. A gasket made of alternate layers of linen and rubber is suitable.

4.—Sometimes a lubricator cannot work because some of its small passages have become choked up with dirt from the oil. It is a good practice to occasionally empty the lubricator and blow steam through it so as to thoroughly clean out any dirt or sediment that may be lodging in the small tubes or passages.

5.—When the engine is shut down, as during the noon hour, and the oil regulating valve closed, the water feed valve should be left open. If the water feed valve be left open it acts as a vent, and some of the water in the bottom of the body of the lubricator will be forced up into the condenser. If the oil regulating valve and the water feed valve be both shut there will be no outlet for the expanding oil, and it will soon exert such a pressure on the body as may cause it to bulge and even to burst. By attaching a pressure gauge to a lubricator, which had both water feed and oil regulating valves shut off while being acted upon by steam, a pressure of nearly 1,000 lbs. to the square inch was shown to be acting on the body of the lubricator.

INSTALLATION AND OPERATION

OF

ENGINES

Ques. How should an engine foundation be built?

Ans. The foundation should be built large and heavy enough to effectively prevent vibration, and should be independent of the building walls. It should be at least 25 per cent. larger in area at bottom than the area of engine bed plate. It should be built of stone or hard brick laid in the best Portland cement. The foundation bolts should go to within a foot of bottom of foundation and should have large plates or washers. The foundation should be amply seasoned before placing engine in position.

Ques. How would you line up an engine?

Ans. The cylinder is first bolted to the frame of engine, and if dowels be provided, it is easily lined up true with frame; if no dowels be provided, cylinder must be so adjusted to frame that a line passing through center of cylinder will be exactly midway

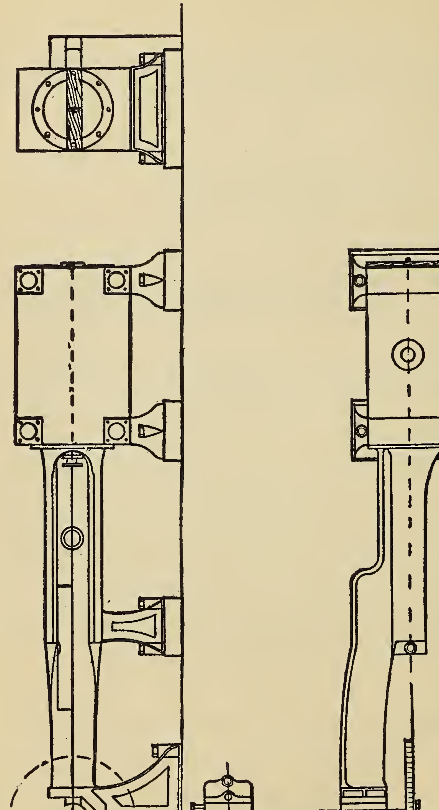


FIG. 70 to 72.—Lining up a horizontal engine; views showing method of locating the center lines. In this work the engine and shaft must be level, and the shaft at right angles to the center line of the engine. Lining up an engine requires precision and the exercise of common sense. If the work be not properly done there will be considerable trouble in the operation of the engine.

between the two guide bearings on frame. The piston and rod and crosshead are now put in place, and the crosshead is adjusted on its shoes so that the piston rod will be exactly level at all parts of stroke. The crank shaft is now put in position and connecting rod put in place. When the engine is on either dead center the centers of piston rod, connecting rod and crank should be exactly in line, also the center of cylinder should be exactly in line with center of shaft. We now level the crank shaft carefully and install it exactly at right angles to the connecting rod, and the engine is properly lined up.

Ques. How do we make a steam tight joint between cylinder and piston?

Ans. All pistons are fitted with a cast iron or steel spring ring, which lays up tight against inside of cylinder; if sufficiently lubricated, both inside of cylinder and piston rings will wear as smooth as glass, and a steam tight joint is easily maintained. If engine be run long periods without oil, cylinder walls will become rough and cut, and will leak steam. Usually too much oil is used.

Ques. How does lubrication reduce friction?

Ans. Lubrication reduces friction by keeping the bodies separated by a film of the lubricant, thus preventing their direct contact, and in substituting the fluid friction of the particles of the lubricant for the friction of the solid bodies.

Ques. What are the important qualities that a lubricant should possess?

Ans. 1, Body; 2, fluidity; 3, freedom from gumming ingredients; 4, freedom from acidity; 5, stability under temperature changes; 6, freedom from foreign matter.

Ques. What is understood by the term "body of a lubricant?"

Ans. The "body of a lubricant" indicates a certain consistency, or substance, that prevents it being squeezed out easily from between the moving bodies.

Ques. What is understood by the term "fluidity of the lubricant?"

Ans. The fluidity of a lubricant refers to a certain lack of cohesion between the different particles of the substance, that reduces the fluid friction to a minimum.

Ques. Why should lubricants be free from gumming ingredients?

Ans. A lubricant that gums loses its fluidity easily, collects dust and grit, and thus increases friction and wear and tear generally.

Ques. Why should lubricants be free from acidity?

Ans. A lubricant that holds free acid would attack the bearing surface, destroy its smoothness, increase friction and lead to frequent and costly repairs.

Ques. Why should lubricants possess stability under temperature changes?

Ans. Lubricants should retain their good qualities, even when used under high temperatures, as in steam cylinders or valve chests, or when used under low temperatures, as in ice machines or exposed winches and windlasses. They should not evaporate nor be decomposed by the heat, nor congeal by the cold, and should retain their normal body and fluidity as much as possible.

Ques. Why should the lubricant be free from all foreign matter?

Ans. Foreign matter will increase the friction, and clog the feeding tubes, thus leading to dangerous accidents.

Ques. What determines mainly the choice of a lubricant for a given purpose?

Ans. 1, Price; 2, pressure; velocity; 3, temperature.

For heavy pressures the lubricant should have a good deal of body, while for light pressures this is not so important.

For high speed the lubricant should possess good fluidity; for low speeds, less fluidity.

For low temperatures light mineral oils are used, while heavy mineral oils are employed for high temperatures.

Ques. Name some good lubricants for cylinders and valves.

Ans. For cylinders and valves a good grade of cylinder oil having a high cold test should be used. Graphite or plumbago in powdered form is also largely used in cylinders.

Ques. How do we lay up an engine, say for a year or more?

Ans. The inside of cylinder and valve chest should be carefully drained and covered thickly with oil or grease; the piston should be worked back and forth after grease is applied to cylinder, so that the piston ring may become oiled and the grease spread all over the cylinder walls. The valve and the seat should be carefully oiled; all packing should be removed and piston rod and all moving and bright parts of engine should be thickly covered with grease to protect them from rust.

Ques. What is a gasket?

Ans. A gasket is the packing placed between the boiler and handhole or manhole plate, or between the cylinder flanges of the engines so as to obtain a tight joint.

Ques. Of what materials are packings made?

Ans. Steam packing, for piston rods, etc., is usually made of rubber interwoven with some strong cloth fabric; water or hydraulic packing is made of braided flax or hemp for low pressures and from hemp and rubber for high pressure work. Metallic packing, made of babbitt metal, is used on the piston and valve rods of some engines.

Ques. How do we find the necessary speed of a throttling governor to give the best results?

Ans. The speed of a throttling governor depends altogether on the make, size and weight of the balls, no general rule can be given; the proper speed is always stamped on the governor.

Ques. How do we re-babbitt a bearing?

Ans. The shaft is placed in journal box after all the old babbitt metal has been chipped out and placed in its true running position and secured by blocks or hangers. Melted babbitt metal is now poured into the space between the journal box and the shaft; the shaft is now removed and the rough surface of the babbitt metal scraped off with a scraper or an old knife, and shaft may be put back in its place. Great care is necessary when heating babbitt metal so as not to overheat or burn it; when it will char a dry, soft wooden stick it is at about the proper temperature for pouring.

Ques. What is a speed indicator?

Ans. A speed indicator is a small instrument used to find the number of revolutions a certain machine or shaft is making per minute; all speed indicators have a bayonet pointed shaft which may be inserted into the center hole in end of shaft and the speed that shaft runs is recorded on a graduated dial.

Ques. What is a condenser?

Ans. A condenser is an apparatus used on engines to reduce the back pressure due to the exhaust and atmospheric pressure.

STEAM PUMPS

Ques. What is a steam pump?

Ans. A steam pump is a machine for pumping water against any desired pressure.

Ques. How high will a pump lift water?

Ans. When in perfect condition and if the suction pipe is tight a pump will lift water almost 34 feet.

Ques. Why do you say if the suction pipe be tight?

Ans. Because a very small leak in the suction pipe would reduce the vacuum, and the pump would not lift the water so high.

Ques. Is it practical to install a pump in such a manner that the suction lift will be 34 feet?

Ans. No; no pump should be made to lift water more than about 24 feet.

Ques. Will a duplex pump lift water higher than a simple pump?

Ans. No.

Ques. Against what pressure will a pump work?

Ans. There is practically no limit of the pressure against which a pump will deliver water; we are only limited by the strength of the water end of pump; some hydraulic presses require pumps that will pump against a pressure of 30,000 pounds per square inch.

Ques. Why will a pump not lift hot water as well as cold water?

Ans. When the lift is considerable and the water hotter than about 140 degrees, vapor will fill the water cylinders of pump and this vapor is simply compressed and not expelled by the action of the plungers. When a pump must handle hot water it should get the water under a head; that is, the water should flow into the pump by gravity.

Ques. Which cylinder should be the larger in a boiler feed pump?

Ans. The steam cylinder should have considerably more area than the water cylinder on any boiler feed pump.

Ques. Why must the steam cylinder be so much larger?

Ans. Because if the pistons were of the same size the resistance offered by the water in discharge pipe would be equal to the total force on the steam piston; to overcome this resistance and the internal friction in pump, which is considerable, and the friction of water in suction and delivery pipe, it is necessary for steam pistons to be considerably larger than the water pistons.

Ques. What may be said of single or simple pumps?

Ans. All single cylinder pumps have a somewhat complicated valve gear; all have two and some makes have three steam valves for each cylinder, while in the duplex pump we have but one simple slide valve for each cylinder.

Ques. What is a compound pump?

Ans. A compound pump may be either simple or duplex and has two sets of steam cylinders placed one back of the other. The larger cylinder is driven from the exhaust of the smaller cylinder.

Ques. Are any pumps made which have larger water cylinders than steam cylinders?

Ans. Yes; pumps used for light service; where a large quantity of water is to be pumped against a very light pressure the water piston may have more area than the steam piston.

Ques. What is an elevator pump?

Ans. A pump designed to pump against a heavy pressure used chiefly for hydraulic elevator service.

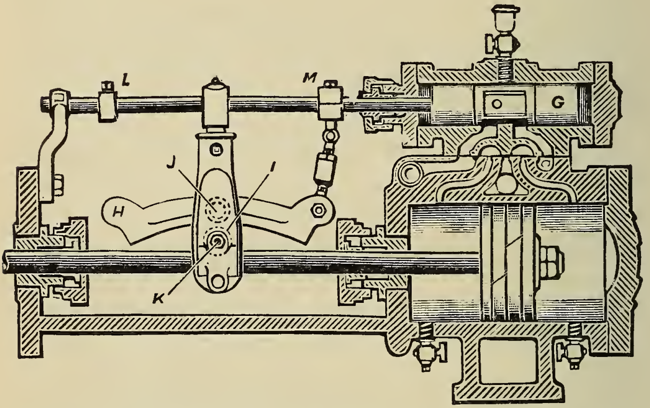


FIG. 73.—The Knowles pump. A piston valve G in the steam chest moves the main valve. This valve piston is driven alternately backward and forward by the pressure of steam, carrying with it the main valve, which admits steam to the main steam piston that operates the pump. The main valve is a plain slide whose section is of B form, working on a flat seat. The valve piston is slightly rotated back and forth by the rocker bar, H; this rotative movement places the small steam ports D E F, fig. 74., which are located in the under side of the valve piston in proper position with reference to the corresponding ports, A B, cut in the steam chest. Steam enters through the port at one end and fills the space between the valve piston and the head, drives the valve piston to the end of its stroke and carries the main slide valve with it. When the valve piston has traveled a certain distance, a corresponding port in the opposite end is uncovered and steam enters, stopping its progress by giving it the necessary cushion. The piston rod with its tappet arm, J, fig. 73, moves backward and forward with the piston. At the lower part of this tappet arm is attached a stud or bolt, K, on which is a friction roller, I. This friction roller, lowered or raised, adjusts the pump for a longer or shorter stroke. This roller coming in contact with the rocker bar at the end of each stroke, and this motion is transmitted to the valve stem, causing the valve to roll slightly. This action opens the ports, admits steam and moves the valve piston, which carries with it the main slide valve which admits steam to the main piston. The upper end of the tappet arm does not come in contact with the tappets, L M, on the valve rod, unless the steam pressure from any cause should fail to move the valve piston, in which case the tappet arm moves it mechanically.

Ques. What is an underwriters' or fire pump?

Ans. A pump installed in large factories and high buildings to supply fire lines and stand pipes in case of fire.

Ques. What is a centrifugal pump?

Ans. A rotary pump somewhat resembling a blower in appearance; no valves being required in this pump, it is valuable in pumping sewerage and other liquids containing sand, gravel or mud.

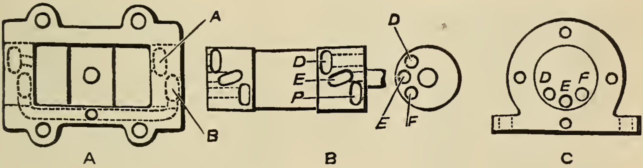


FIG. 74.—Valve details of Knowles single pump as described in fig. 73.

Ques. What is a "high duty" pump?

Ans. A pump having a fly wheel or equivalent in connection with a valve gear designed to secure an early cut off, so as to work the steam expansively and thus obtain greater economy than that of the ordinary type of pump which takes steam at full stroke.

Ques. What economy will a compound pump have over a simple pump?

Ans. About 20 per cent, more or less depending upon operating conditions.

Ques. How do we set the steam valves of a duplex steam pump?

Ans. Place both piston rods of pump in mid position; when this is done both levers which engage the

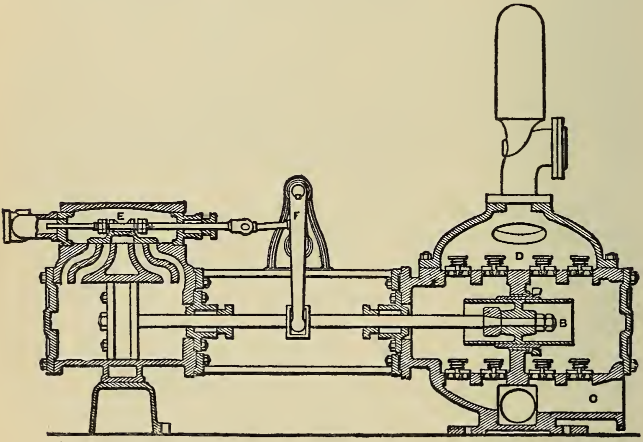


FIG. 75.—Duplex pump with inside packed plungers. In construction, two steam pumps are placed side by side and so combined that one piston acts to give steam to the other, after which it finishes its own stroke and waits for its valve to be acted upon by the other pump before it can renew its position. This pause allows the water valves to seat quickly, and removes any harshness of motion. As one or the other of the steam valves is always open, there is no dead point, and therefore the pump is always ready to start when the steam is admitted.

spools on piston rod will be in exactly a vertical position. Now place the valves in mid-position, that is, place them so that they will just cover both steam ports. Now connect the valve rods and links in such a way that the lost motion will be exactly divided and the valves are properly set.

How to Set the Valves of a Duplex Pump.

Rule.—I. *Locate the steam piston in the center of the cylinder,* as in fig. 75. This is accomplished by pushing the piston to one end of its stroke against the cylinder head and marking the rod with a scriber at the face of the stuffing box, and then bringing the piston in contact with the opposite head;

II. *Divide exactly the length of this contact stroke.* Shove the piston back to this half mark, which brings the piston directly in the center of the steam cylinder;

III. *Perform the same operation with the other side*;

IV. *Place the slide valves*, which have no lap, *to cover all the ports*;

V. *Pass the valve stem through the stuffing box and gland.* The operation of placing the pistons in the center of their cylinders brings the levers and rock shafts in a vertical position;

VI. *Screw the valve stem through the nuts* until the hole in the the eye of the valve stem head comes in a line with the hole in the links, connecting the rocker shaft; then put the pins in their places;

VII. *Adjust the nuts on both sides of the lugs* of the valves to leave about ¼″ or ⅛″ loss motion on each side.

This process of adjustment being performed with both cylinders, the steam valves are set. In short the travel of the two valves is simply *equalized.*

Ques. Why do we give the valves lost motion in a pump of this type?

Ans. The lost motion has very much to do with the popularity of this style of pump. When the piston reaches the end of stroke this lost motion must be taken up, which causes the pump to pause slightly before beginning the return stroke; this slight pause allows the water valves to seat properly and noiselessly and gives the pump a smooth action throughout the entire stroke.

Ques. Where is this lost motion placed?

Ans. On most pumps inside the steam chests; on some pumps it is outside where it may be adjusted while pump is running.

Ques. Does this lost motion ever have to be reduced to make the pump work properly?

Ans. Yes; when the links and motion pins become worn they have the same effect on the pump as though the lost motion in valve was increased, and the remedy is either new links and pins or reducing the lost motion in valve gear, which may be done by fitting a washer between the valve nut and the lugs on valve.

Ques. When the levers that engage the spools on piston rod become worn, how may they be made as good as new?

Ans. They should be taken out, heated and spread with a hammer; they may now be filed and carefully rounded to fit between the shoulders of spool and put back.

Ques. When the slide valves of duplex pumps leak badly, what should be done?

Ans. They should be taken out, ground or filed true; the valve seats will also have to be filed and scraped true.

Ques. If new rings were put on steam piston and we found that it still leaked steam badly, where would you look for the trouble?

Ans. We would find that the piston body and follower had become worn at the face where they touch the rings and that steam passed over piston under the ring and over follower; the proper remedy would be to file the distance piece cast on piston body so that the ring will fit snugly between piston and follower.

Ques. How many ports has a duplex pump?

Ans. Five; the steam and exhaust ports are separate in this style of pump; the exhaust ports are those placed nearest the center of the cylinder and are covered or closed by the piston just before the end of the stroke, whereby a portion of the exhaust steam is

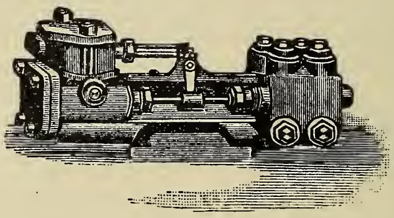


Fig. 76.—A very small Worthington duplex pump. Its dimensions are as follows: 2-inch diam. steam cylinder; 1⅛-inch water cylinder; 2⅔-inch stroke. Its capacity is .044 gallons per revolution; rev. per minute, 80; gallons per minute, 3.5. Steam pipe, ⅜-inch; exhaust pipe, ½-inch; suction pipe, 1-inch; discharge, ¾-inch. Floor space occupied, 1′ 9″ x 7″ wide.

trapped and made to act as a cushion between the piston and cylinder head. This assists materially in the smooth operation of the pump.

Ques. How many water valves has a duplex pump?

Ans. Eight; four suction and four discharge valves.

Ques. Of what material are the water valves made?

Ans. For low pressure of hard rubber; for hot water and high pressure they are preferably made of brass.

Ques. What is the difference between a plunger and a piston?

Ans. A plunger is a solid cylindrical body which fits accurately or approximately the chamber within which it reciprocates. It differs from a piston in that *it is longer than its stroke.* A plunger is guided by a stuffing box, either internal or external, while a piston is guided by the cylinder walls.

The term plunger is aften erroneously used for piston; the distinction should be carefully noted.

Ques. Why is a duplex pump not as economical in the use of steam as a power pump?

Ans. Because all duplex pumps take steam full stroke, therefore there is no expansive benefits derived.

Ques. How are the water cylinders of steam pumps lined?

Ans. The water cylinders are bored out somewhat larger than the size of plunger; a brass or composition sleeve is forced into the cylinder by a pulling screw or by a hydraulic ram.

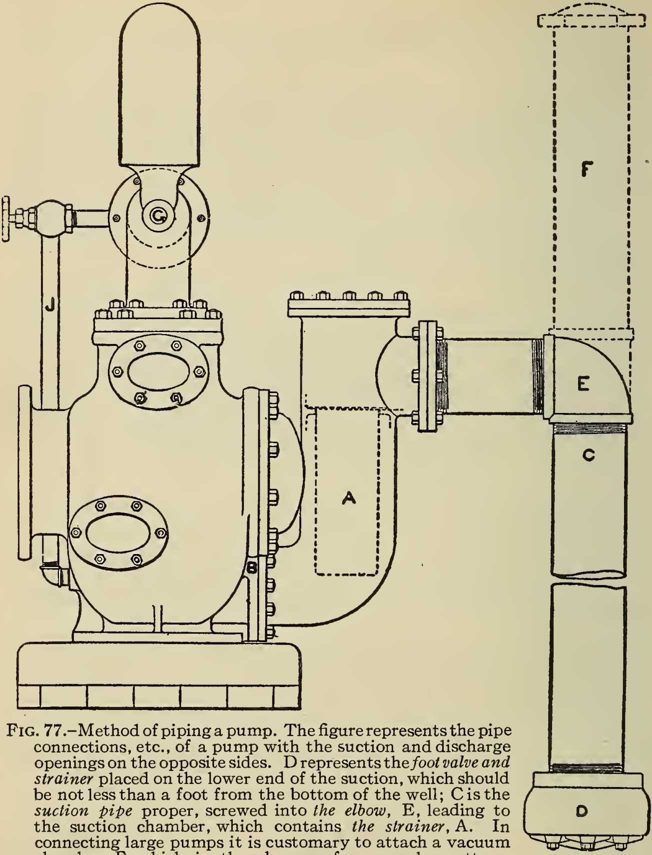


FIG. 77.–Method of piping a pump. The figure represents the pipe connections, etc., of a pump with the suction and discharge openings on the opposite sides. D represents the *foot valve and strainer* placed on the lower end of the suction, which should be not less than a foot from the bottom of the well; C is the *suction pipe* proper, screwed into *the elbow,* E, leading to the suction chamber, which contains *the strainer,* A. In connecting large pumps it is customary to attach a vacuum chamber, F, which in the absence of any regular pattern, may be made of a piece of pipe of the same diameter as the suction and screwed into a T, instead of the elbow, E, with a regulation screwed cap on top as shown in the dotted lines. A *priming pipe* is shown by the letter J, often used to fill the pump on starting. The *discharge pipe* connection is shown at G with the *air chamber attached.*

Ques. What type of pump has all the advantages of the duplex pump and is more economical to use?

Ans. A power pump which is driven by a belt from the engine, we naturally get some expansive benefits of the extra steam used in engine to drive pump; the speed of a power pump, of course, cannot be regulated, so we keep the water in boilers at the desired level by connecting a bypass between suction and delivery pipe provided with a valve with which we can send as much water as is not needed back into suction pipe of pump.

Ques. Of what use is an air chamber on a pump?

Ans. It causes the pump to deliver the water in a steady stream; when pumps are obliged to lift the water more than 8 feet, an air chamber should also be placed on suction pipe.

Ques. How should the pipes be arranged on pumps?

Ans. They should have as few bends and sharp turns as possible; elbows and tees in a pipe line greatly increase the friction.

Ques. How do we find the pressure of a column of water of any height?

Ans. By multiplying the height in feet by the constant .434.

Ques. How do we find the number of gallons of water a pump will supply per hour?

Ans. From the following formula:

$$\frac{\text{diameter}^2 \times .7854 \times \text{strokes per minute} \times 60}{231} = \text{gals. per hour.}$$

The diameter and stroke is taken in inches.
The numerator is divided by 231 because 1 gal. = 231 cu. ins.

Ques. In selecting a pump for a certain sized boiler, how large a pump would you select?

Ans. I would select a pump capable of supplying about 60 pounds or about 7 gallons of water per hour, for every horse power developed by boiler; this would be just twice as much water as the boiler would need, but boiler feed pumps should be plenty large, as much water is wasted through leaks in pipes, packing, etc. The pump should be capable of supplying the above amount of water when running at a moderate speed.

Ques. How do we find the horse power a pump is developing in pumping a certain amount of water a certain height?

Ans. By multiplying the weight of water pumped in pounds by the perpendicular height it is raised, in feet per minute, and dividing the product by 33,000.

INJECTORS

Ques. What is an injector?

Ans. An injector is an instrument for forcing water into a boiler against the boiler pressure. Some boilers depend altogether on one or more injectors for feeding; others have and use an injector as an auxiliary feed.

Ques. Describe briefly how an injector works.

Ans. Dry steam from the upper part of the boiler is led into the injector and made to flow through a contracted tube; at a short distance from the end of this contracted tube is placed another tube which gradually increases in diameter. The space around and between the two tubes forms a chamber which is in communication with the suction pipe. Steam coming from the boiler at a great velocity will shoot across the small gap between the two tubes and create a partial vacuum in the suction chamber and cause the water to flow into the injector and mix with the steam; when first started this water and steam will escape through the overflow pipe, and when we get a steady stream we close the overflow valve and the water and steam are forced into the boiler. In

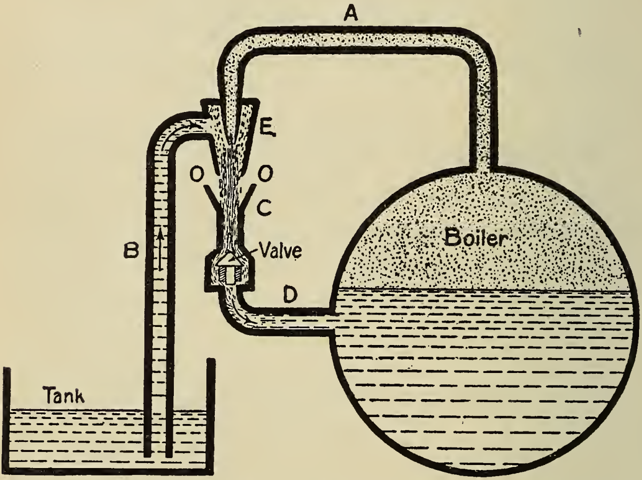


FIG. 78.—Principle of the injector. Steam is led from the boiler through pipe A, which terminates in a nozzle surrounded by a cone E, connected by the pipe B with the water tank. When steam is turned on it rushes with great velocity from the nozzle, and creates a partial vacuum in cone, E, which soon fills with water. On meeting the water the steam condenses, but not before it has imparted some of its *velocity* to the water, which thus gains sufficient momentum to force open the check valve and flow through pipe D to the boiler. The overflow space O O between E and C allows steam and water to escape until the water has gathered the requisite momentum. An important condition which must be fulfilled, in order that the injector will work, is that the supply of water be sufficient to condense the steam. The efficiency of the injector as a boiler feeder is 100% less the trifling loss due to radiation; however, the injector is not the most economical boiler feeder because it can draw only cold or moderately warm water, while a pump can draw water heated by exhaust steam, which otherwise would be wasted.

any of the automatic types of injector the overflow valve is closed automatically and to start an injector of this type all that is necessary is to open steam and water valves.

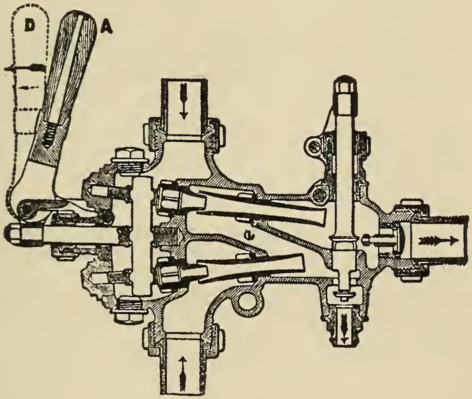


FIG. 79.—Sectional view of the Korting double tube injector. The lower tube is for lifting the water to the injector, and the upper tube for forcing the water in the boiler. A is the closed position of the operating handle. To start the injector, the handle is moved slowly in the direction D.

Ques. State the principle of the injector?

Ans. An injector forces water into the boiler because the kinetic energy of a jet of steam is much greater than that of a jet of water escaping under the same conditions.

Ques. Will an injector handle hot water?

Ans. Yes, if not too hot, the average injector will handle water up to about 140 degrees F., but its capacity will be somewhat reduced. The best results are obtained when the temperature of the water is about 50 degrees F.

Ques. What advantage is there in feeding boilers with an injector?

Ans. There are practically no heat losses; all the steam used to operate the injector is returned to the boiler and the only heat loss is from radiation, which is very small.

Ques. What is the best way to connect up an injector?

Ans. Injectors should preferably take water from a tank instead of the city mains and should be placed directly over the tank so that the overflow may be watched when starting the instrument. This tank should be supplied from the city mains and should be fitted with a float valve so that the tank will always remain full. Satisfactory results, however, may be obtained by direct connection with city main by regulating the supply with a valve.

Ques. If an injector fail to work, what is usually the cause?

Ans. The strainer on suction pipe may be clogged, or there may be a bad leak in the suction pipe; sometimes a small chip or a piece of scale will pass the strainer and will lodge in the contracted opening of the forcing tube, or some foreign matter may have lodged between the overflow valve and seat, preventing its closing.

Ques. At how low a pressure will an injector work?

Ans. About 30 pounds, although some injectors will work well on 20 pounds of steam or less.

The author, by very careful adjustment of the steam and water valves, has succeeded in operating a single tube injector with only 5 lbs. steam pressure.

Ques. How high will an injector ordinarily lift water?

Ans. A well constructed injector will lift water at least 15 feet.

FEED WATER HEATERS

Ques. What is a feed water heater?

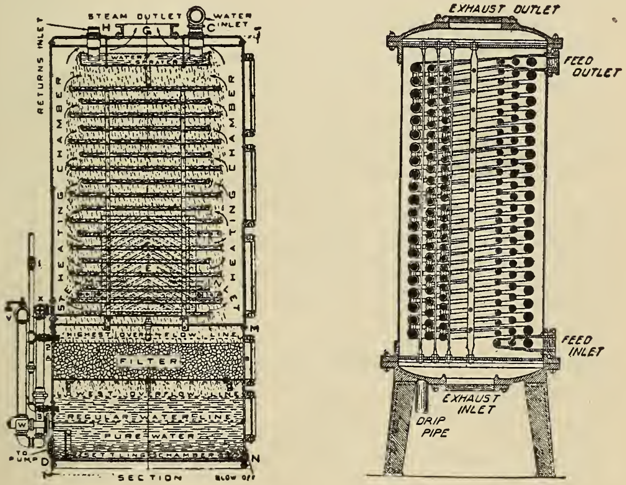
Ans. A contrivance by which the feed water is heated before it enters the boiler.

Ques. How many types of heater are there?

Ans. Two types: the open and closed feed water heater.

Ques. How is an open heater constructed?

Ans. An open heater is simply a tank kept about half full of water by a float valve on a water pipe from city mains; the exhaust steam from the engine blows into this tank and heats the water very hot; the boiler feed pump takes its suction from this tank, which should be placed above the pump so that the pump will get the water under a head. This form of heater has the advantage of imparting somewhat more heat to the water than does the closed type because the feed water and the exhaust steam come in direct contact. With this form of heater the feed pump will have to pump hot water, which is undesirable; also, more or less oil passes through the filter with the water and is deposited in the boiler forming a hard scale.



FIGS. 80 and 81.—Open and closed feed water heaters. In the open heater, fig. 80, the steam raises the temperature of the water by mingling with it, that is, by direct contact. The closed type of heater resembles a surface condenser; the exhaust steam surrounds copper or brass tubes which contain water, or the water circulates about tubes through which steam passes. Fig. 81 shows a feed water heater, of the closed type, the exhaust steam heating the feed water within the tubes.

Ques. How is a closed feed water heater built?

Ans. The closed feed water heater consists of a closed tank provided with a coil, or a great number of small tubes; the exhaust steam passes through the tank and heats the feed water, which is contained in the coil or tubes. In this style of heater the steam and water do not mix, and the pump only has to pump cold water, as this style of heater is always placed between pump and the boiler.

Ques. How should the piping be arranged on a closed heater?

Ans. A valve should be placed on the pipe entering heater and a valve should be on pipe leaving heater; a by pass pipe should be connected between the supply and delivery pipe so that heater may be opened for inspection or repair without interrupting the service.

Ques. What economy is due to heating the feed water?

Ans. There is a saving of about 1 per cent. for each 11° F. increase in the temperature of the feed water.

STEAM HEATING

Ques. What systems of steam heating are in general use?

Ans. There are two systems of steam heating in general use, the one pipe system and the two pipe system.

Ques. How does the single pipe system work?

Ans. In this system of steam heating, only one pipe is necessary and the return end of radiator is permanently plugged up. Great care must be taken in the design and installation of a system of this kind to have all the horizontal pipes throughout the building drain towards the boiler. Another requisite is that all risers must have large drip pipes connected to bottom of them, which lead into the pump governor or receiver; as all the condensed water from radiators must fall to bottom of riser in this system all horizontal pipes above the boiler room floor should be as short as possible, which means that a greater number of risers are necessary. The principle on which this system works is as follows. Steam is turned on from the boiler and in a short time the pipes are filled with steam at the desired pressure.

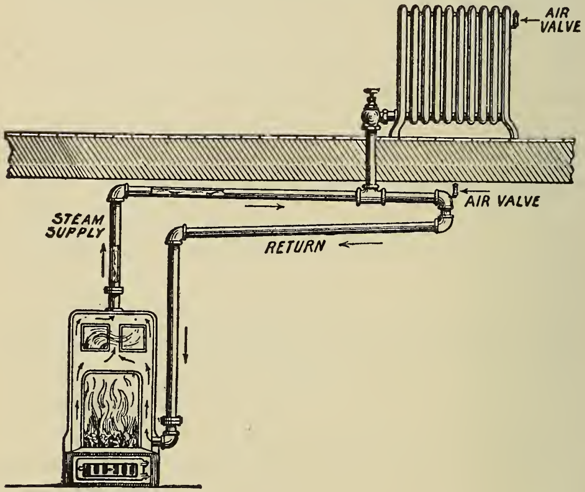


FIG. 82.—One pipe system of steam heating. The steam rising from the boiling water passes through the top opening of the boiler into the feed pipe, travels to the radiators, where it gives up its heat, is condensed by being turned back to water, and returns to the boiler through the return pipe, entering it at the side near the bottom.

The arrangement of the piping permits the condensed water to drop back and down the riser and to be carried through the drip pipe to pump governor or back to boiler, although the steam is flowing in the opposite direction to replace the steam condensed. As in the two pipe system, an air pipe is frequently added, but if an automatic air valve be used, the air pipe may be dispensed with.

Ques. How does the two pipe system work?

Ans. Steam from the boilers is led up through the building to be heated through a riser having outlets on each floor for connecting the radiators. The returns from the radiators are piped back to the boiler or pump governor by a separate pipe; sometimes a small air pipe is added to keep the radiator from becoming air bound.

Ques. What system is the better, the single or two pipe system?

Ans. The single pipe system, if properly installed, will give as good results as the two pipe system, and only one-half the number of valves and pipes though larger sizes are required.

Ques. What is a gravity heating system?

Ans. In the gravity heating system no pump or pump governor is used. The returns from the radiators are returned to boiler by gravity, hence its name; this system is suitable only for small heating plants.

Ques. Explain why radiators become air bound?

Ans. Radiators become air bound because when turned off and full of steam, the steam will rapidly condense and a vacuum will be created in the radiator; this vacuum will be broken by numerous small leaks in piping and through packing of valves, etc. If the radiator remain turned off for a long time it will fill with air and this air must be expelled so that steam may take its place. Air also is contained in the water.

Ques. How does an automatic air valve work?

Ans. Automatic air valves have long composition stems which when cold, contract and open valve and let out the air; as soon as steam reaches the valve stem, it will expand and close valve.

Ques. Is it more economical to heat a building with low or high pressure steam?

Ans. Low pressure is more economical; very few buildings require more than ten pounds pressure for heating; some of the largest buildings are heated with three pounds of steam in extreme cold weather.

Ques. How do we know what pressure is on radiators?

Ans. Every heating system should have a steam gauge connected to main heating pipe as near the reducing valve as possible.

Ques. When a building is heated by steam from a high pressure boiler, how do we maintain a constant pressure on the radiators?

Ans. By the use of a reducing valve, which is a double seated valve of such construction that any desired pressure may be carried on the low side of valve.

Ques. How much space will a square foot of radiating surface heat?

Ans. About 70 cu. ft. in outer or front rooms and 100 cu. ft. in inner rooms.

Ques. How many square feet of radiating surface will a square foot of boiler heating surface supply?

Ans. From 7 to 10 square feet.

Ques. Should a pump governor be fitted with a blow off?

Ans. Yes, as the oils from engine and pumps will float on the top of water in receiver and by closing the main return valve this oil may be blown into sewer; otherwise it would eventually find its way into the boiler and cause trouble.

Ques. How much space will one horse power heat in ordinary city buildings?

Ans. From 10,000 to 20,000 cubic feet, depending on the amount of glass surface exposed to the open air.

Ques. Is it proper to heat a building with exhaust steam from engines and pumps?

Ans. Yes, it is, and a very large amount can be saved by so doing.

Ques. What is the chief objection made to using exhaust steam for heating?

Ans. The chief objection is that the whole system will become coated with oil on inside, and that a large quantity of oil will be returned to the boilers with the returns. Plants using exhaust steam for heating should be provided with a water purifier or grease extractor.

Ques. How do we force the exhaust steam through the radiators?

Ans. By putting a back pressure valve on or near the top of exhaust pipe and tapping the exhaust pipe on every floor for radiator or coil connections.

Ques. May not this back pressure valve be connected to exhaust pipe near the engine instead of just under or on roof?

Ans. Yes, but in this case a separate riser is necessary; when installed on or just under the roof of building the exhaust pipe may also be used as a riser by providing outlets at each floor.

Ques. How should a building be piped for exhaust heating?

Ans. The piping throughout should be about 30 per cent. larger in area.

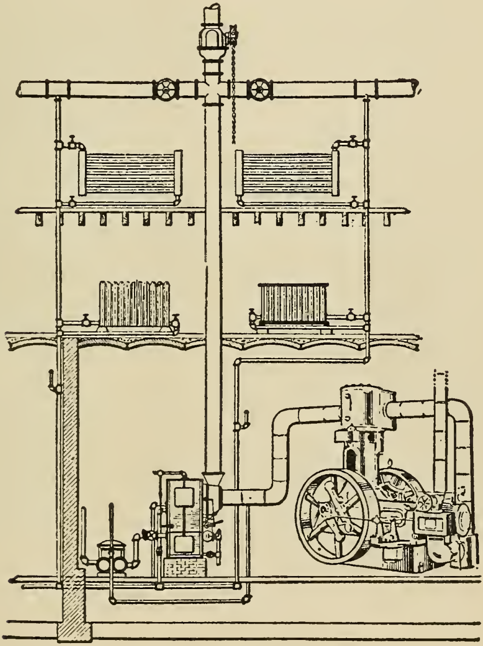


FIG. 83.—American Ball angle compound engine connected to an exhaust steam heating system. The exhaust pipe is extended to the roof, and a relief valve attached which prevents the back pressure exceeding that for which the valve is set. Small pipes lead from the large horizontal distribution pipe to the receiver into which the condensation drains: these pipes are connected with the radiators at intermediate points are shown. A pump, shown at the left, returns the condensation to the boiler.

Ques. How does a pump governor work?

Ans. A pump governor or receiver, as it is sometimes called, is simply a closed tank and should set below the lowest radiator or heating coil and enough above the pump so that the water will flow freely from receiver into pump. The returns from the entire heating system flow into the bottom of the receiver, which is fitted with a float valve controlling the steam to pump. When the receiver is nearly full of water the float will raise and open valve, admitting high pressure steam from boiler to pump, and it will keep the pump running at such a speed to just keep the water in the pump governor or receiver at a certain level. In order that the pump governor may not become air or steam bound they are usually fitted at the top with a pipe leading to the low pressure side of main steam pipe. The extra water necessary to maintain a constant water line in the boilers is provided by tapping a small pipe into governor from the city mains and the water line in boilers is maintained constant by regulating this valve and not by manipulating throttle valve on pump.

STEAM TRAPS

Ques. What is a steam trap?

Ans. A steam trap is a device in which the water of condensation is drained out of a radiator hot water tank or other steam appliance without permitting any live steam to escape.

Ques. Is a steam trap ever connected to a steam engine?

Ans. Yes; steam traps are sometimes placed under the cylinders of engines and the cylinder drips are connected to trap to keep cylinder free of water; when this is done the drip valves may remain open when engine is running.

Ques. How may traps be divided?

Ans. There are two kinds of trap, float traps and expansion traps; the float trap depends upon a float to open and close a valve to expel the accumulated water, while in the expansion trap the valve is opened and closed by a rod which expands and contracts.

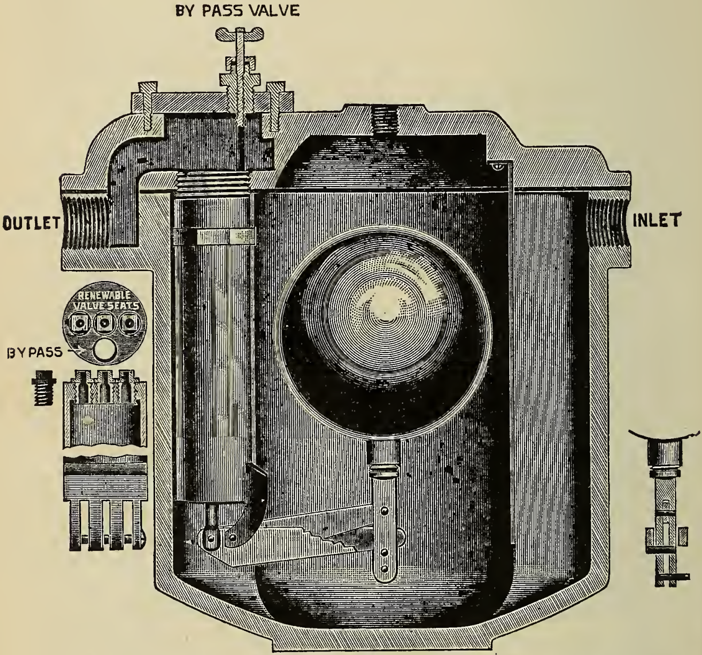


Fig. 84.—Steam trap in operation. As water of condensation collects in the receiver, the float rises and opens the valve at the left, thus allowing the water to escape. As the water level recedes the float closes the valve, hence there is no escape of steam.

Ques. Will a common trap return the condensed water back into the boiler?

Ans. No; a common trap will only work against about one-quarter the boiler pressure.

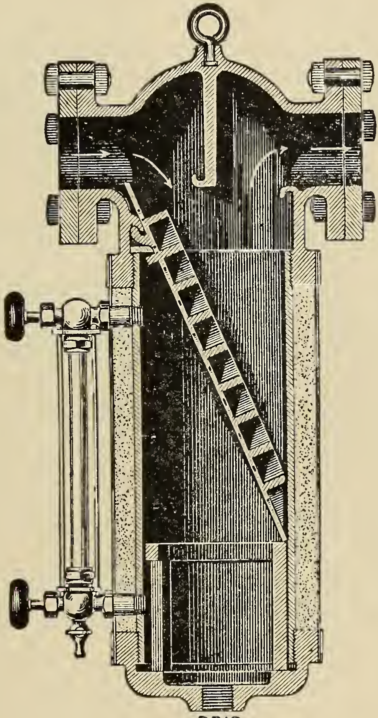


FIG. 85.—Separator with receiver and water gauge glass for showing the height of the separated water in the receiver. In operation, the entrained water carried along with the steam is separated from the steam by *centrifugal force;* that is, the separator is arranged to suddenly change the direction of the steam, thus throwing out the entrained water and delivering to the engine almost dry steam.

Ques. What is a by pass on a trap?

Ans. A small valve which we may open to start the trap or which may be opened when a very large amount of water is to be discharged; this valve allows the water to flow directly into the waste or sewer pipe without passing through the float valve; the by pass should always be closed as soon as trap becomes hot.

Ques. Should a trap be placed near a coil or radiator?

Ans. Yes, a trap should be placed as close as possible to the tank or coil that it drains.

BELTS, GEARS, AND PULLEYS

Ques. How should belts be run?

Ans. Whenever possible belts should be run with the tight side on the bottom, the upper or loose side will then form a concave arc, which increases the arc of contact on both pulleys; a belt put on in this manner may be kept much slacker than a belt put on the reverse way.

Ques. What is a quarter turn belt?

Ans. A quarter turn belt is used to drive a shaft that is at right angles to the driving shaft; as, for example, a vertical shaft driving a horizontal shaft.

Ques. What is a cross belt?

Ans. A cross belt is used to drive a shaft in the reverse direction of the driver.

Ques. Which will pull more: an open belt or a cross belt?

Ans. A cross belt will pull more, as by crossing we increase the arc of contact (belt surface on pulley).

Ques. How do we find the diameter of pulley required on engine to run a dynamo at a speed of 1,450 revolutions per minute the dynamo pulley being 10 inches in diameter and the speed of engine is 275 revolutions per minute?

Ans. The diameter of pulley required on engine will be

$$10 \times \frac{1,450}{275} = 53 \text{ inches, nearly.}$$

To find the diameter of the driving pulley, multiply the speed of the driven pulley by its diameter, divide the product by the speed of the drive and the answer will be the size of the driver required.

Ques. If the speed of engine be 325 revolutions per minute, diameter of engine wheel 42 inches, and the speed of the dynamo 1,400 revolutions per minute, how large a pulley is required on dynamo?

Ans. The size of the dynamo pulley will be

$$42 \times \frac{325}{1,400} = 9\tfrac{3}{4} \text{ inches.}$$

If the size of dynamo pulley is to be found, multiply the speed of engine by the diameter of engine wheel and divide the product by the speed of the dynamo.

Ques. If a steam engine, running 300 revolutions per minute, have a belt wheel 48 inches in diameter, and be belted to a dynamo having a pulley 12 inches in diameter, how many revolutions per minute will the dynamo make?

Ans. The speed of dynamo will be

$$300 \times \frac{48}{12} = 1{,}200 \text{ rev. per min.}$$

When the speed of the driving pulley and its diameter are known, and the diameter of the driven pulley is known, we find the speed of the driven pulley by multiplying the speed of the driver by its diameter in inches and dividing the product by the diameter of the driven pulley.

Ques. What will be the required speed of an engine having a belt wheel 46 inches in diameter to run a dynamo 1,500 revolutions per minute, the dynamo pulley is 11 inches in diameter?

Ans. The speed of engine will be

$$1{,}500 \times \frac{11}{46} = 359 \text{ r. p. m., nearly.}$$

To find the speed of engine multiply the dynamo speed by the diameter of its pulley and divide by the diameter of engine pulley.

Ques. How much horse power will a belt transmit?

Ans. The capacity of a belt depends on, its width, speed, and thickness. *A single belt one inch wide and travelling 1,000 feet per minute will transmit one horse power; a double belt under the same conditions will transmit two horse power.*

This corresponds to a working pull of 33 and 66 lbs. per inch of width respectively.

Ques. At what velocity should a belt be run?

Ans. At from 3,000 to 5,000 feet per minute.

Ques. How are the diameters and speeds of gear wheels figured?

Ans. The same as belted wheels, only we use the number of teeth in gear instead of the diameter in inches.

STEAM TURBINES

A turbine is a machine in which a rotary motion is obtained by transference of the *momentum* of a fluid or gas. In general the fluid is guided by fixed blades, attached to a casing, and, impinging on other blades mounted on a drum or shaft, causing the latter to revolve.

Turbines are classed various ways: They are classed as: 1, *radial flow*, when the steam enters near the center and escapes toward the circumference; and 2, *parallel flow*, when the steam travels *axially* or parallel to the length of the turning body.

Turbines are commonly, yet erroneously classed as:

1. Impulse;
2. Reaction.

Ques. What is the distinction between these two types?

Ans. In the so called impulse type, *steam enters and leaves the passages between the vanes at the same* *pressure.* In the so called reaction type, *the pressure is less on the exit side of the vanes than on the entrance side.*

Fig. 86 is a sectional view of the Parsons-Westinghouse parallel flow turbine. Steam from the boiler enters first a receiver in which are the governor controlled admission valves. These valves are actuated by a centrifugal governor.

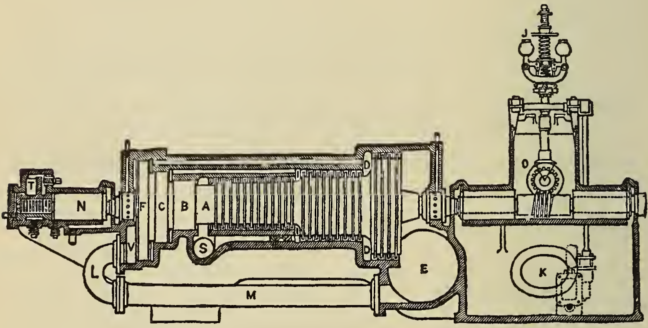


Fig. 86.—The Parsons-Westinghouse turbine.

Steam does not enter the turbine in a continuous blast, but intermittently, or in puffs. The speed regulation is therefore accomplished by proportioning the duration of these puffs to the load of the engine, this being effected by the governor, fig. 87.

The governor of the turbine has only to move a small pilot valve, or slide, E, which admits steam under the piston F, and lifts the throttle valve proper off its seat.

As soon as the pilot valve closes, the spring shuts the main throttle valve. Thus, at light loads, the main throttle or admission valve is continually opening and shutting at uniform intervals, the length of time during which it remains open depending upon the load.

As the load increases, the duration of the valve opening also increases, until at full load the valve does not reach its seat at all and the steam flows steadily through the turbine. The steam thus admitted flows into the annular passage A, fig. 86, by the opening S, and then past the blades, revolving the rotor.

When the load increases above the normal rated amount, a secondary pilot valve is moved by the same means, this in turn admitting steam to a piston, similar to F, which lifts another

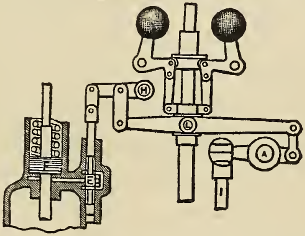


FIG. 87.—Governor of the Parsons-Westinghouse turbine.

throttle valve. This admits steam into the annular space I, so that it acts upon the larger diameter of the drum or rotor, giving largely increased power for the time being.

The levers or arms of the governor are mounted upon knife edges instead of pins, making it extremely sensitive. The tension spring may be adjusted by hand while the turbine is running.

The governor does not actually move the pilot valve, but shifts the point L in fig. 87. A reciprocating motion is given to the rod I by a small eccentric on the governor shaft; this is driven by worm gearing shown near O in fig. 86, so that the eccentric makes one revolution to about eight of the turbine. Thus, with a turbine running 1,200 revolutions, the rod I would be moved up and down 150 times per minute. As the points A and H are fixed, the motion is conveyed to the small pilot valve E, thus giving 150 puffs a minute. The governor in shifting the point L brings the edge of the pilot valve nearer the port and so cuts off the steam earlier.

The annular diameter or space between the rotor and the stator is gradually increased from inlet to exhaust, the blades being made longer in each ring. When the mechanical limit is reached, the diameter of the rotor is increased as at I and D so as to keep the length of blade within bounds.

Balance pistons as at B, C, F are attached to the rotor, their office being to oppose end thrust upon those blades in corresponding diameter of the rotor. Communication is established through the passage V and pipe M between the eduction pipe and the back of these pistons, thus increasing the efficiency of their balancing and also taking care of any leakage past them.

A small thrust bearing T prevents end play of the rotor, and is adjustable to maintain the proper clearance between the rings of blades; this varies from ⅛″ at the admission to 1″ at the exhaust. This bearing also takes up any extra unbalanced thrust. A turbine should operate with a high vacuum because without this it does not compare favorably with ordinary reciprocating engine from the point of economy. A usual method of securing the desired result is by forming a well in the lower part of the surface condenser, from which the water is drawn and delivered to the hot well by an independent pump.

Separate pumps are provided to create the vacuum, these really being reversed air compressors, sometimes in two stages, which deal with the air alone.

Where the ordinary type of vertical air pump is employed a booster or *vacuum increaser* is added, as nothing below 26″ is admissible, 28″ and 29″ being always striven for. It is also preferable to use a certain amount of *superheat* with steam turbines, wet steam placing them at a disadvantage.

To assist in producing the high vacuum, exhaust passages are made large, the eduction passage E in fig. 86 being nearly twenty-three times the area of the steam pipe.

Among other details, a noteworthy feature is a small oil pump K, which circulates oil through bearings of the machinery, the oil being drawn from the tank under the governor shaft and gravitating there after use. No pressure of oil is employed. Stuffing rings prevent leakage; these consist of alternate grooves and collars in shaft and bearing, like the grooves in an indicator piston.

Ques. Why is a high vacuum desirable?

Ans. Because the turbine is capable of expanding the steam to a very low terminal pressure, and this is necessary for economy.

Ques. What may be said of the working pressures for turbines?

Ans. To meet the varied conditions of service, turbines are designed to operate with: 1, high pressure, 2, low pressure, or 3, mixed pressure.

High pressure turbines operate at about the same initial pressure as triple expansion engines.

Low pressure, as here applied, means the exhaust pressure of the reciprocating engine from which the exhaust steam passes through the turbine before entering the condenser.

Mixed pressure implies that the exhaust steam is supplemented, for heavy loads, by the admission of live steam.

Ques. What determines the working pressure?

Ans. When all the power is furnished by the turbine, it is designed for high pressure; when operated in combination with a reciprocating engine, low pressure is used for constant load, and mixed pressure for variable load.

The De Laval steam turbine is termed by its builders a high speed rotary steam engine. It has but a single wheel, fitted with vanes or buckets of such curvature as has been found to be best adapted for receiving the impulse of the steam-jet. There are no stationary or guide blades, the angular position of the nozzles giving direction to the jet. The nozzles are placed at an angle of 20 degrees to the plane of motion of the buckets. The best energy in the steam is practically devoted to the production of velocity in the expanding or divergent nozzle, and the velocity thus attained by the issuing jet of steam is about 4,000 feet per second. To attain the maximum of efficiency, the buckets attached to the periphery of the wheel against which this jet impinges should have a speed of about 1,900 feet per second, but, owing to the difficulty of producing a material for the wheel strong enough to withstand the strains induced by such a high speed, it has been found necessary to limit the peripheral speed to 1,200 or 1,300 feet per second.

It is well known that in a correctly designed nozzle the adiabatic expansion of the steam from maximum to minimum pressure will convert the entire static energy of the steam into kinetic energy. Theoretically this is what occurs in the De Laval nozzle. The expanding steam acquires great velocity, and the energy of the jet of steam issuing from the nozzle is equal to the amount of energy that would be developed if an equal volume of steam were allowed to adiabatically expand behind the piston of a reciprocating engine, a condition, however, which for obvious reasons has never yet been attained in practice with the reciprocating engine. But with the divergent nozzle the conditions are different.

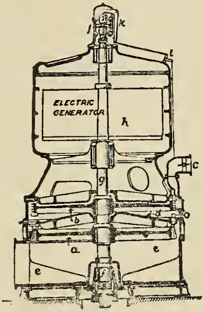


FIG. 88.—The Curtis turbine.

The Curtis turbine is built by the General Electric Company at their works in Schenectady, N. Y., and Lynn, Mass. The larger sizes are of the vertical type, and those of small capacity are horizontal. In the vertical type the revolving parts are set upon a vertical shaft, the diameter of the shaft corresponding to the size of the machine. The shaft is supported by and runs upon a step bearing at the bottom. This step bearing consists of two cylindrical cast iron plates bearing upon each other and having a central recess between them into which lubricating oil is forced uuder pressure by a steam or electrically driven pump, the oil passing up from beneath. A weighted accumulator is sometimes installed in connection with the oil pipe as a convenient device for governing the step bearing pumps, and also as a safety device in case the pumps should fail, but it is seldom required for the latter purpose, as the step bearing pumps have proven after a long service in a number of cases, to be reliable. The vertical shaft is also held in place and kept steady by three sleeve bearings, one just above the step, one between the turbine and generator, and the other near the top. These guide bearings are lubricated by a standard gravity feed system. It is apparent that the amount of friction in the machine is very small, and as there is no end thrust caused by the action of the steam, the relation between the revolving and stationary blades may be maintained accurately. As a consequence, therefore, the clearances are reduced to the minimum. The Curtis turbine is divided into two or more stages, and each stage has one, two or more sets of revolving blades bolted upon the peripheries of wheels keyed to the shaft. There are also the corresponding sets of stationary blades, bolted to the inner walls of the cylinder or casing.

The governing of speed is accomplished in the first set of nozzles, and the control of the admission valves here is effected by means of a centrifugal governor attached to the top end of the shaft. This governor, by a very slight movement, imparts motion to levers, which in turn work the valve mechanism. The admission of steam to the nozzles is controlled by piston valves which are actuated by steam from small pilot valves which are in turn under the control of the governor. Speed regulation is effected by varying the number of nozzles in flow, that is, for light loads fewer nozzles are open and a smaller volume of steam is admitted to the turbine wheel, but the steam that is admitted impinges against the moving blades with the same velocity always, no matter whether the volume be large or small. With a full load and all the nozzle sections in flow, the steam passes to the wheel in a broad belt and steady flow.

OUTLINE OF REFRIGERATION

Refrigeration may be defined as the process of lowering the temperature of a body or of keeping the temperature below that of the atmosphere. Low temperature may be produced by:

1. A transfer of heat from a warm to a cold body;

2. By expansion of a gas;

   If work be done by the gas, as in pushing a piston, this work must be performed at the expense of the energy contained in the gas; the temperature of the gas will therefore fall.

3. Evaporation of liquids having low boiling points.

   When a liquid is changed to a vapor, a certain quantity of heat, called the *latent heat of evaporation*, must be added to the liquid to effect the change. When evaporation of a liquid takes place in the presence of other bodies, the heat required for it is drawn from these bodies, and they are thereby cooled.

Ques. What may be said of mechanical refrigeration?

Ans. Mechanical refrigeration is produced by expanding a heat medium from an ordinary temperature to a low temperature.

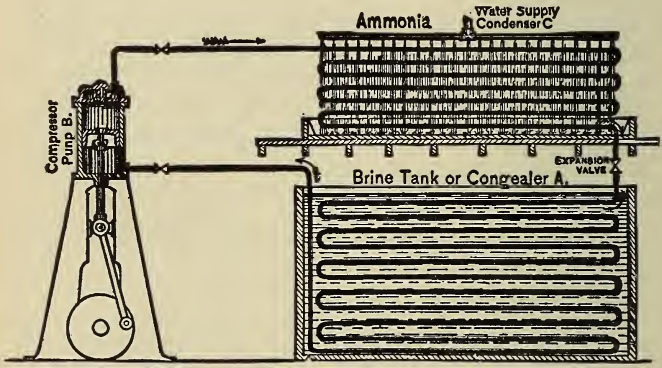


FIG. 89.—Diagram showing the essentials of a mechanical compression system with vertical compressor. The condenser shown is of the atmospheric type, and the brine circulating system is used, the brine being cooled by the expansion coils in a tank and then circulated through pipes in the refrigerating rooms.

Ques. What determines the choice of the heat medium?

Ans. Its willingness to surrender its heat energy to surrounding objects; vapors are best employed.

Ques. How is the vapor treated?

Ans. It is compressed and then relieved of its heat in order to diminish its volume. It is then expanded so as to do mechanical work and its temperature is lowered. The absorption of heat at this stage by the vapor in resuming its original condition constitutes the refrigerating effect.

Ques. What substances are used for refrigeration?

Ans. The most commonly employed agents are ammonia, carbonic acid, sulphur dioxide, and compressed air, the first named being the most generally used and approved, while the others have advantages for use on shipboard and in other places where the fumes of ammonia would prove objectionable.

Ques. What are the advantages of ammonia?

Ans. It liquefies at low pressure, it is not explosive or inflammable, and possesses great heat absorbing power.

Ques. Name two methods of refrigeration extensively used?

Ans. The ammonia compression system, and the ammonia absorption system.

Ques. Describe the ammonia compression system?

Ans. The ammonia vapor is compressed to about

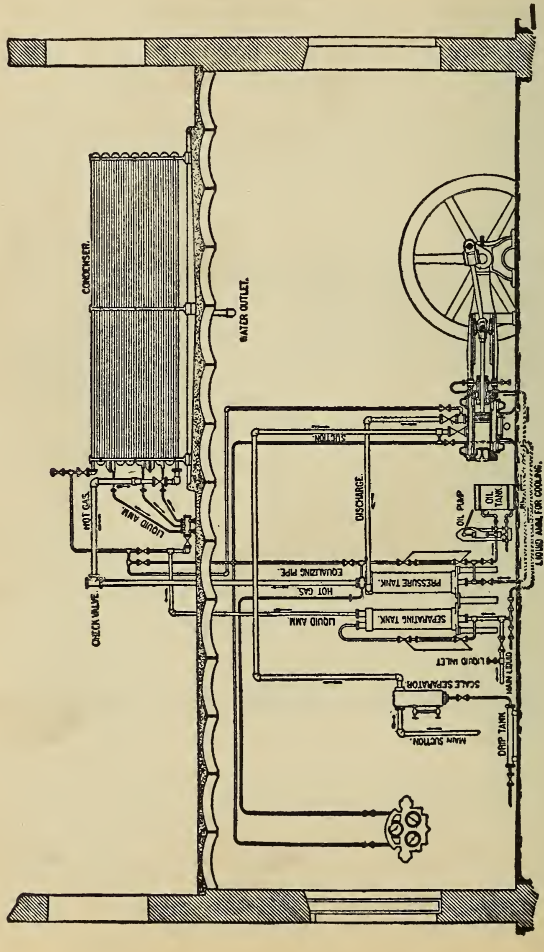


FIG. 90.—View of a compression refrigerating plant with horizontal double acting engine driven compressor, showing all the principal piping and apparatus.

150 lbs. pressure, and is then allowed to flow into a cooler or surface condenser, where the heat due to the work of compression is withdrawn by the circulating water and the vapor is condensed to a liquid. It is then allowed to pass through an expansion cock and to expand in the piping, thereby withdrawing heat from the "brine" with which the pipes are surrounded. This brine

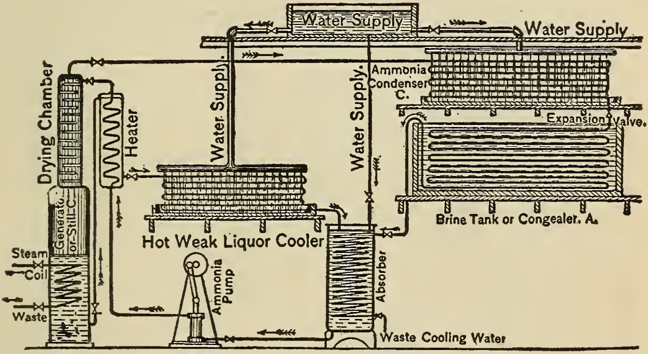


FIG. 91.—Diagram of absorption system with vertical generator, weak liquor cooler, and brine tank.

is then circulated by pumps through coils of piping and produces the refrigerating effect. The expanded ammonia gas is then drawn into the compressor under a suction of from 5 to 20 lbs., thus completing the cycle of operations. The brine consists of a solution of salt in water. Liverpool salt solution weighing 73 lbs. per cu. ft. (sp. g. = 1.17) will not congeal at 0° F.

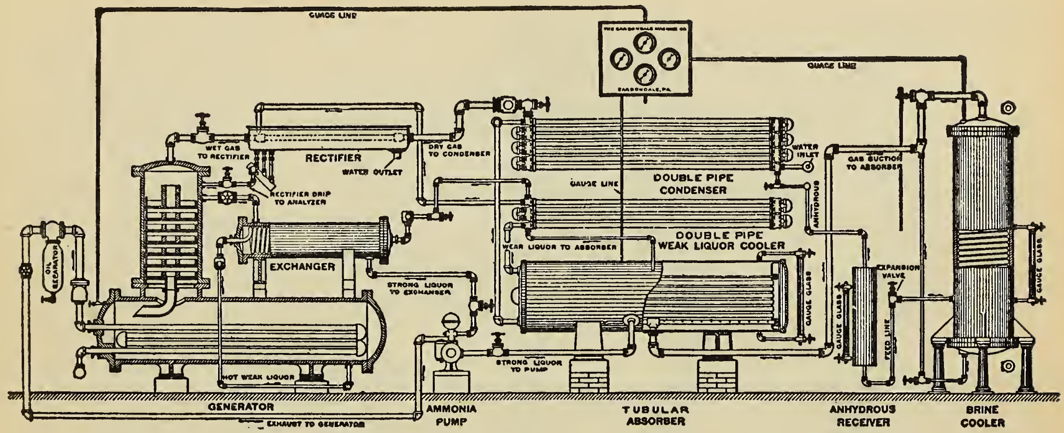


FIG. 92.—Elevation of an absorption plant. The ammonia is evaporated out of the rich liquor in the generator and analyzer, and passes off into the rectifier; from the rectifier the gas passes to the condenser. The anhydrous ammonia passes from the condenser to the liquid receiver which is simply a reservoir. The receiver is connected to the expansion valve by a pipe of comparatively small size. The expansion valve is regulated so as to allow enough ammonia to enter the cooler to keep the latter at the required temperature From the cooler the ammonia vapor is led to the absorber into which the poor liquor is sprayed, coming from the exchanger and passing through the weak liquor cooler. The rich liquor is taken from the absorber by the pump and discharged through the exchanger into the analyzer from whence it flows into the generator. The poor liquor is forced by pressure from the generator through the exchanger. In the exchanger the outgoing poor liquor gives up part of its heat to the incoming strong liquor. The brine from the cooler is circulated through the refrigerating coils.

American salt brines of the same proportions congeal at 20° F. Ammonia required = 0.3 lb. per foot of piping. Leakage and waste amount to about 2 lb. per year per daily ice capacity of one ton. The brine should be about 6° colder than the space it cools.

Ques. Describe the ammonia absorption system?

Ans. In this system the compressor is replaced by a vessel, called the absorber, where the expanded vapor takes advantage of the property of water or a weak ammoniacal liquor to dissolve ammonia gas. (At 59° F. water absorbs 727 times its own volume of ammonia vapor.) The liquor in the absorber is then pumped into a still heated by steam pipes, where the ammonia gas is vaporized, the remainder of the process being then the same as in the compression system. The absorption system is less expensive to install, and commercial ammonia hydrate (62% water, sp. g. = 0.88) may be used in the absorber.

Ques. Name two methods of compressing?

Ans. Dry compression and wet compression.

Ques. What is dry compression?

Ans. Compression in a cylinder cooled by a water jacket.

Ques. What is wet compression?

Ans. In this method, the cylinder is not jacketed, but a certain amount of liquid anhydrous ammonia is allowed to enter the cylinder with each stroke, the cylinder walls being cooled by its evaporation.

The wet system is harder on packing, as there are few soft packings that will stand the freezing action of the liquid air-hydrous ammonia without becoming hard and causing leaky stuffing boxes.

PRACTICAL ELECTRICITY

Introductory.—Usually when a power plant includes both steam engines and electrical generators, all are under the charge of one head. Such installations being very numerous, the stationary engineer can no longer afford to be deficient in a knowledge of electricity, and especially so, since the examination for the higher grades of steam engineer's license includes questions on this subject.

Electricity.—The name electricity is applied to an invisible agent known only by the effects which it produces, and the various ways in which it manifests itself.

Electrical *currents* are said to flow through *conductors*. These offer more or less *resistance* to the flow, depending on the material. Copper wire is generally used as it offers little resistance. It is now thought that the flow takes place along the surface and not through the metal.

The current must have pressure to overcome the resistance of the conductor and flow along its surface. This pressure is called *voltage* caused by what is known as *difference of potential* between the source and terminal.

An electric current has often been compared to water flowing through a pipe. The pressure uuder which the current flows is measured in *volts* and the quantity that passes in *amperes.* The resistance with which the current meets in flowing along the conductor is measured in *ohms.*

The flow of the current is proportional to the voltage and inversely proportional to the resistance. The latter depends upon the material, length and diameter of the conductor.

Since the current will always flow along the path of least resistance it must be so guarded that there will be no leakage. Hence to prevent leakage, wires are *insulated*, that is, covered by wrapping them with cotton, silk thread, or other insulating material. If the insulation be not effective, the current may leak, and so return to the source without doing its work. This is known as a *short circuit.*

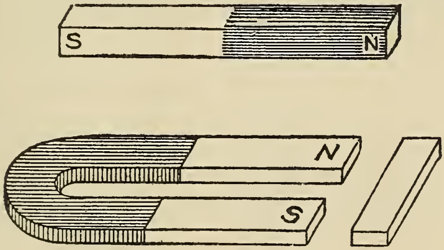
The conductor which receives the current from the source is called the *lead*, and the one by which it flows back, the *return.* When wires are used for both lead and return, it is called a *metallic circuit;* when the ground is used for the return, it is called a *grounded circuit.*

An electric current is said to be:

1. *Direct*, when it is of unvarying direction;
2. *Alternating*, when it flows rapidly to and fro in opposite directions;
3. *Primary*, when it comes direcrly from the source;
4. *Secondary*, when the voltage and amperage of a primary current have been changed by a transformer, or *induction coil.*

A current is spoken of as *low tension*, or *high tension*, according as the voltage is low or high. A high tension current is capable of forcing its way against considerable resistance, whereas, a low tension current must have its path made easy. A continuous metal path is an easy one, but an interruption in the metal, is difficult to *bridge*, because air is a very poor conductor.

Air is such a poor conductor that it is usually, *though erroneously*, spoken of as a "non-conductor;" it is properly called an *insulator*.



FIGS. 93 and 94.—Simple *bar magnet* and *horse shoe magnet* with *keeper*. These are known as permanent magnets as distinguished from electro magnets. The horse shoe magnet will attract more than the bar magnet because both poles act together. A piece of soft iron, or keeper, is placed across the ends of a horse shoe magnet to assist in preventing the loss of magnetism.

Magnetism.—The ancients applied the word "magnet," *magnes lapes*, to certain hard black stones which possess the property of attracting small pieces of iron, and as discovered later, to have the still more remarkable property of pointing north and south when hung up by a string; at this time the magnet received the name *lodestone*.

Magnets have two opposite kinds of magnetism or magnetic poles, which attract or repel each other in much the same way as would two opposite kinds of electrification.

One of these kinds of magnetism has a tendency to move toward the north and the other, toward the south. The two

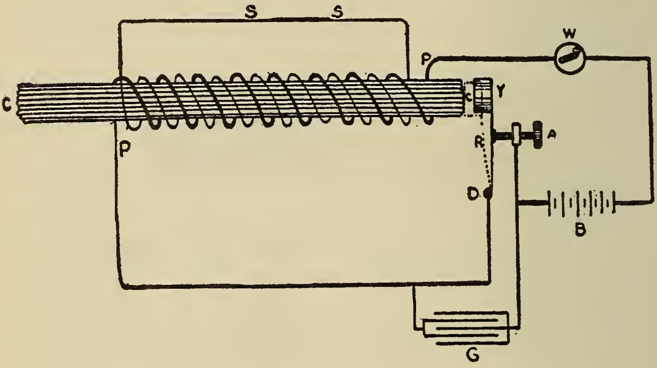


FIG. 95.—Diagram of a vibrator coil. The parts are as follows: A, contact screw; B, battery; C, core; D, vibrator terminal; G, condenser; P, primary winding; S, secondary winding; W, switch; Y, vibrator. When the switch is closed, the following cycle of actions takes place: *a*, the primary current flows and magnetizes core; *b*, magnetized core attracts the vibrator and breaks primary circuit; *c*, the magnetism vanishes, inducing a momentary high tension current in the secondary winding; *d*, magnetic attraction of the core having ceased, vibrator spring re-establishes contact; *e*, primary circuit is again completed and the cycle begins anew.

regions, in which the magnetic property is strongest, are called the *poles*. In a long shaped magnet it resides in the ends, while all around the magnet half way between the poles there is no attraction at all.

The poles of a magnet are usually spoken of as *north pole* and *south pole*.

When a current of electricity passes through a wire, a certain change is produced in the surrounding space producing what is known as a magnetic field. If the wire be insulated with a covering and coiled around a soft iron rod, it becomes an electro-magnet having a north and south pole, *so long as the current continues to flow.* The magnetic strength increases with the number of turns of the coil, for each turn adds its magnetic field to that of the other turns.

Induction.—If a second coil of wire be wound around the coil of an electro-magnet, but not touching it, an *induced current* is produced in this second coil by what is known as *induction*, each time the current in the inside coil begins or ceases flowing. The inside coil is called the *primary winding* and the outside coil the *secondary winding.* Similarly, the current passing through the inside coil is called the *primary current* and that in the outside coil the *secondary* or *induced current.*

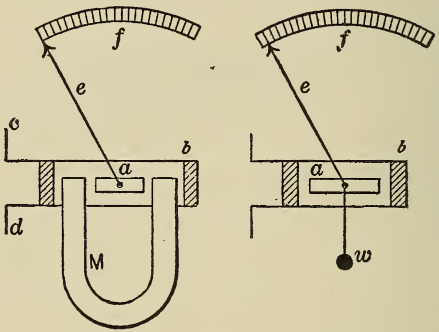
It has been found that by varying the ratio of the number of turns in the two coils the tension or voltage of the two currents is changed proportionately. That is, if the primary winding be composed of ten turns and the secondary of one hundred, the voltage of the secondary current is increased ten times that of the primary. This principle is employed in the construction of induction coils and transformers.

Ques. What is a volt?

Ans. An electromotive force or pressure which will produce a current of one ampere in a circuit having a resistance of one ohm.

Ques. What is an ohm?

Ans. The resistance offered to an electric current by a column of mercury one square millimeter in section and 106 centimeters long, at a temperature of 0° C.



FIGS. 96 and 97.—Illustrating the construction of volt and ammeters. The soft iron needle, *a*, is pivoted within a coil of very fine wire, *b*, and held normally out of line with the axis of the coil by means of a permanent magnet, *M*, or a weight, *w*. Passlng a current through the coil, *b*, causes magnetic lines to flow (vertically in the illustrations) through its center, and these tend to pull the needle around into line with them. The permanent magnet, *M*, or the weight, *w*, resists this pull, and the distance that the needle is deflected indicates the strength of the current in the coil. A pointer, *e*, is attached to the needle, *a*, and the scale, *f*, is marked in volts; the pointer, *e*, indicates on the scale the voltage at the terminals, *c*, *d*, of the coil, *b*.

Ques. What is an ampere?

Ans. The current produced by an electromotive force of one volt in a circuit having a resistance of one ohm.

An ampere is that quantity of current which will deposit .001118 gramme of silver per second.

Ques. State Ohm's Law, and the formulae derived from it?

Ans. Considering a steady flow of electricity in a given circuit, then according to Ohm's law: *the amount of current in amperes is equal to the electromotive force in volts divided by the resistance in ohms.*

The law may be expressed in three simple formulæ, when I is used as the symbol of the current strength in amperes, R, as that of the resistance in ohms, and E, the electromotive force in volts, as follows:

$$I = \frac{E}{R},$$

which reads: The current in amperes equals the electromotive force in volts divided by the resistance in ohms.

$$E = IR,$$

which reads: The electromotive force in volts equals the current in amperes multiplied by the resistance in ohms.

$$R = \frac{E}{I},$$

which reads: The resistance in ohms equals the electromotive force in volts divided by the current in amperes.

Ques. What is a watt?

Ans. The product of one ampere multiplied by one volt.

Ques. What is the electrical horse power?

Ans. The unit of electrical work, being the mechanical horse power expressed in watts. It is equal to 746 watts.

Ques. What is meant by the carrying capacity of a wire?

Ans. The amount of current it will carry without heating to such an extent as to cause danger of burning the insulation or wood work.

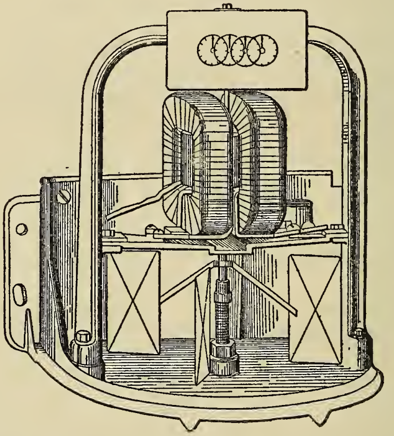


Fig. 98.—Recording watt hour meter. It consists of a very small motor which drives a delicate train of gears, the hands of which indicate on dials the number of watt hours supplied. The two coils of wire enclose the armature and furnish the field magnetism. The fan blades on the lower part of the shaft serve as a brake to steady the rotation of the shaft. There are several forms of motor meter, all based on the same principle—that of making the speed of the motor proportional to the watts supplied to the circuit.

Ques. What is meant by the "drop" in a circuit?

Ans. The drop in a circuit means the number of volts lost in overcoming the resistance of the circuit.

It corresponds to the drop in pressure along a steam pipe or water main.

TABLE OF CURRENT CAPACITY OF WIRES.

No. of wire, B. & S. gage.	Rubber covered Wire. Amperes.	Weather proof Wire. Amperes.
18	3	5
16	6	8
14	12	16
12	17	23
10	24	32
8	33	40
6	46	64
5	54	77
4	65	92
3	76	110
2	90	131
1	107	156
0	129	185
00	150	220
000	177	262
0000	210	312

Ques. Describe a dynamo.

Ans. A dynamo consists of three essential parts, a *field magnet*, an *armature*, and a *commutator*. The field magnet must be magnetized either by the dynamo itself or some outside source. The armature consists of coils of insulated copper wire wound upon a core of thin iron discs which is mounted on a shaft and caused to rotate between the poles of the field magnet in such a manner that the lines of magnetic force passing through the coils of the armature are constantly increasing or decreasing. This action causes *alternating* currents of electricity to be generated in the coils of the armature, which are collected by suitable brushes at the commutator and converted into *direct* current for the external circuit.

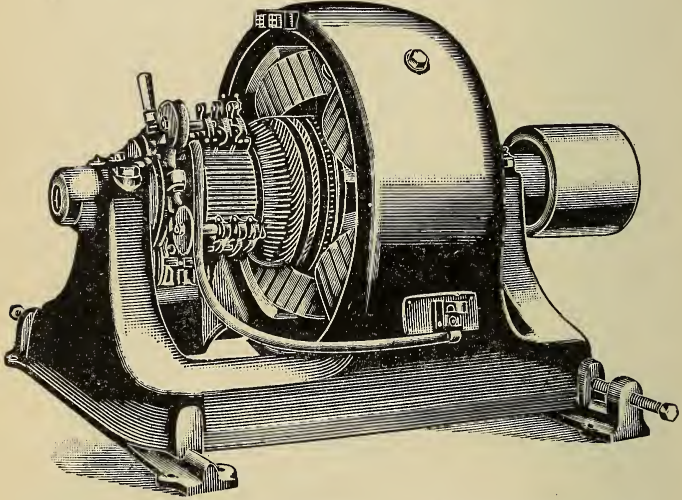


FIG. 99.—A four pole dynamo, mounted on V rails with adjustment for tightening the belt.

Ques. What is meant by the magnetic current?

Ans. The path through which the magnetic lines or force travel.

Ques. What is the object of making the armature core of thin discs rather than of solid metal?

Ans. To prevent *eddy currents* which convert energy into heat; this would not only produce a waste of energy, but would also injure and perhaps destroy the insulation of the armature coils.

Ques. How are dynamos classified according to the winding of their field magnets?

Ans. Into three classes: series, shunt, and compound dynamos.

Ques. What is a series dynamo?

Ans. A dynamo in which all the current produced by the machine flows through its field magnet coils.

This is accomplished by taking a wire from one brush, carrying it the required number of times around the field magnet and then connecting it to the external circuit; the other end of the external circuit is connected to the other brush.

Ques. What is a shunt dynamo?

Ans. One in which only a portion of the total current of the machine passes through the field magnet coils.

Ques. What is a compound dynamo?

Ans. A dynamo having two windings: a series winding, around which the main current flows; and a shunt winding, through which a fraction of the main current flows.

Ques. For what class of work is a shunt dynamo used?

Ans. For work requiring a constant pressure at all loads.

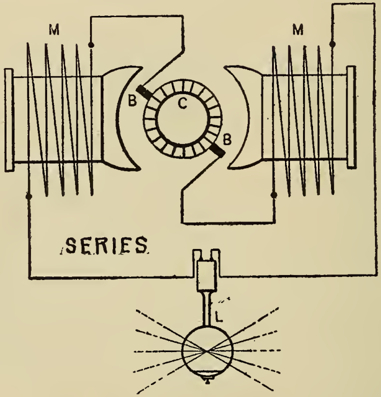


FIG. 100.—Series dynamo connections; also called constant current machine because the voltage rises with the load. This type of machine requires a regulator which is usually an electro-mechanical device for shifting the brushes to conform with the load. *M M*, field coils; *B B*, brushes; *C*, commutator; *L*, lamp. The field coils consist of a few turns of heavy wire joined in series with the armature so that the whole current passes through the coils to the external circuit, thus maintaining the field; the strength of field increases with the load.

Ques. Does a shunt machine maintain a constant pressure at all loads?

Ans. Nearly so; the pressure falls off a little as the load increases.

Ques. What system of distribution requires a constant pressure at all loads?

Ans. The ordinary parallel or multiple system used for the lighting of buildings.

Ques. Are shunt dynamos used in general for this class of work?

Ans. No; they have been superseded largely by the compound dynamo, which gives a closer regulation of pressure.

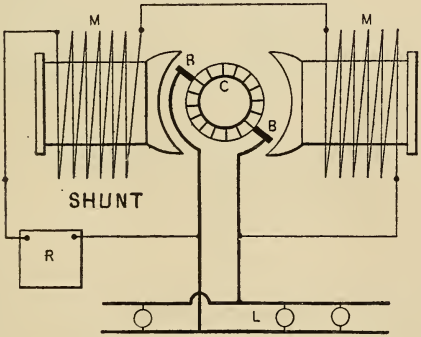


Fig. 101.—Shunt dynamo. Generally used for incandescent lamps and motors. M M, field coils; B B, brushes; C, commutator; L, lamp circuit; R, field rheostat. The field coils consist of many turns of fine wire connected in parallel to the external current, thus obtaining a small portion of the armature current for maintaining the field. The voltage is regulated by adding or cutting out resistance in the field by means of the rheostat R.

Ques. What is meant by an overcompounded dynamo?

Ans. One which automatically raises the pressure a little in proportion as the load increases, due to increasing the series winding.

Ques. What are its advantages over one that would maintain the pressure constant?

Ans. Such a dynamo would make up for a slight fall in the speed of an engine, which takes place as the load increases; it also makes up for a loss in pressure on the circuit wires, which loss is proportional to the load which they carry.

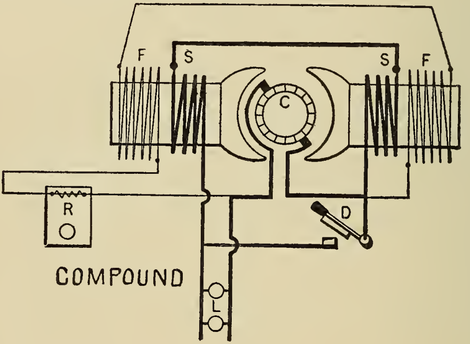


FIG. 102.—Compound wound dynamo. This has two windings on the field magnets, and is a combination of the series and the shunt dynamos. *S S*, series winding; *F F*, shunt winding; *R*, shunt rheostat; *C*, commutator; *L*, external circuit; *D*, series cut out switch, which permits dynamo to be used as simple shunt machine. The series coils strengthen the field as the load rises, and by varying the number of series turns, different results may be obtained. If the series coils be of many turns, the field magnets will be so strengthened as to cause the voltage to rise with increase of load. This is called *over compounding*.

Ques. How is overcompounding actually obtained?

Ans. By increasing the number of turns in the series coil of a compound dynamo above what would be necessary to give a constant pressure machine.

Ques. Can the pressure furnished by a shunt or compound dynamo be varied? and if so, how?

Ans. Yes; it could be varied by altering the speed of the engine, but the common method is to insert an adjustable resistance called a "rheostat" in series with the shunt field coils. When the arm of the rheostat is turned one way more resistance is thrown into the shunt circuit, which cuts down the current flowing around the coils. As this diminishes the strength of the field magnet the pressure furnished by the machine is lessened. Moving the rheostat arm in the other direction cuts out resistance and raises the pressure.

Ques. What care must be given to a dynamo in order to make it run properly?

Ans. It must be kept clean and dry. The bearings, of course, need no more nor no less attention than similar bearings in other machinery. The parts which require the most care are the commutator and brushes.

Ques. What causes "sparking" at the brushes?

Ans. The causes for "sparking" are varied and many; it may be due to the following among other causes: 1, The brushes may not be set at point of commutation; 2, brushes may be wedged in holders; 3, brushes may not be properly fitted to commutator;

4, brushes may not bear with sufficient pressure; 5, brushes may be burned on ends; 6, commutator may be rough; 7, commutator may have a loose or projecting bar; 8, commutator may be dirty, oily or worn; 9, machine may be badly designed or overloaded; 10, loose connection of coil to commutator, or open circuit.

Ques. State in a general way how a dynamo should be connected to switch board, how circuits should be run from same, and where circuit breakers and fuses should be placed, explaining why the latter are put in.

Ans The exact arrangement of the switch board varies with the judgment of the designer, and the requirements of the case. Dynamos are generally connected from the terminal board to the switch board by cables. Generally the positive lead is connected to one leg of the switch. The circuit switches are connected to the main switch by means of bus bars which take the entire current from the main switch and distribute it to the different circuit switches. Fuses and circuit breakers are used to protect the lines and machines from burning out, due to excessive current caused by short circuits or an overload, either momentary or sustained. They are generally placed between the dynamo and main switch; fuses are placed on all distributing circuits between the line and the switch.

Ques. What is an automatic circuit breaker? Upon what does its action depend, and what advantage has it over a fuse?

Ans. An automatic circuit breaker is an apparatus for opening the circuit when an excessive amount of current passes through it. A common form depends for its action upon the principle that a bar of iron will tend to balance itself in a solenoid. In this case

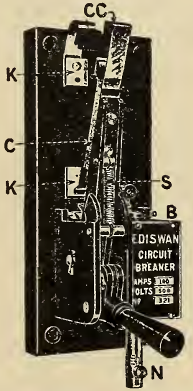


FIG. 103.—Single pole circuit breaker (shown in off position). The laminated switch contact bridge *C*, when on, interconnects the two fixed contact plates, *K*, *K:* and the auxiliary carbon contacts *CC* break the circuit after the metal contacts *C* and *K*, *K* have separated, thus lessening the spark wear at the latter. The "breaker" is closed by hand, and is opened electromagnetically when the current exceeds a predetermined strength. It may also be released by hand when necessary. Included in the main circuit between the terminals is a solenoid. When the breaker is put on, it is held in place by a catch, and if the current become too great, the solenoid acts with such force on its armature that the latter—through simple connecting mechanism—"trips" the catch, and allows the switch part to be pulled off by the helical spring *S*. The solenoid, etc., are contained in the box *B*, and the thumb nut at *N* enables the apparatus to be adjusted within certain limits.

the solenoid is composed of three or four turns of the entire current conductor; as the current increases the soft iron bar raises until it trips the spring actuated switch. Their advantage over a fuse is, that in case of a momentary overload they can be quickly thrown in again, whereas a fuse takes time to replace and, under certain conditions, is a dangerous operation.

Ques. What style winding is best adapted for a motor which is to run at a constant speed and carry a variable load?

Ans. The shunt winding is almost universally used for motors with variable load and using direct current. This type of motor gives a very nearly constant speed with a variable load, providing the voltage be kept constant.

Ques. What is a starting box, and why is one required in connection with a motor? Explain also the automatic cut out and the reasons for attaching same?

Ans. A starting box is necessary in order to insert a resistance in the circuit, so that the current may be turned on gradually, otherwise one or more coils would burn out, as the total current would pass through them before the armature had a chance to start revolving. An automatic cut out is so arranged that should the external circuit be broken, the box will automatically cut in its resistance and then open the armature circuit.

Ques. Should motors be run on independent circuits? Why?

Ans. Motors should be run on independent circuits, very often, however, they are cut in almost anywhere. The work of a motor with a variable load requires more or less current and if not on a separate circuit, unless the conductors are excessively large, will make the lights unsteady.

Ques. What general rules should be observed in making electrical connections?

Ans. The metallic surfaces should be perfectly clean and make good contact. They should also be mechanically strong enough to withstand any strain likely to be encountered.

Ques. What broad rule should be observed on the score of personal safety when handling electrical conductors?

Ans. Be careful not to interpose any portion of the body where such will become a conductor of current.

A good rule for personal safety when working around electrical machines is to wear rubber gloves; use one hand only, as much as possible, and always stand on a dry or insulated spot.

Ques. What is a simple primary cell?

Ans. A combination of two dissimilar metal plates in an exciting fluid or *electrolyte* contained in a glass jar.

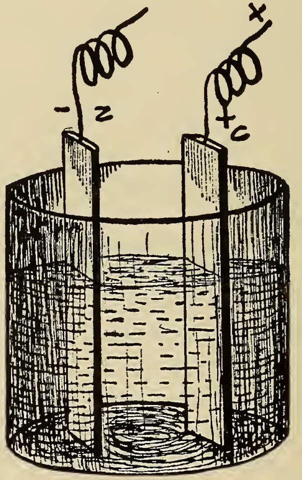


FIG. 104.—A primary cell. Volta discovered that an electromotive force may be created between two dissimilar substances through chemical action set up by a so.ution in which they are immersed. This discovery led to the construction of the primary cell, long known as the *voltaic* cell. The cell consists essentially of two plates of different substances standing apart in a jar containing a solution which attacks one and not the other. By joining the outside terminals of the plates by a conducting wire, a current will flow from one to the other so long as the chemical action or *electrolysis* continues through the solution. The solution is known as the *electrolyte*, and the two plates are called the *elements*. This type of cell is called *primary* to distinguish it from the *secondary* or storage cell.

Ques. What is a "battery?"

Ans. A word often used incorrectly for a *cell;* it is a combination of two or more cells joined together so as to form one unit.

Ques. What is a " secondary " or " storage " cell?

Ans. One in which electrical energy may be stored.

Ques. Describe a secondary cell?

Ans. As usually constructed, it consists of a positive and negative set of lead plates immersed in an electrolyte of dilute sulphuric acid. The proportion of acid to water is about one part acid to three and one-half parts of water.

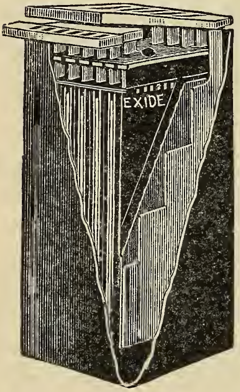
In making the electrolyte, the acid should be added to the water—*never the reverse.*

Ques. Explain how a storage cell works.

Ans. In passing an electric current through a cell the plates undergo a chemical change; when this is complete the cell is said to be *charged.* A quantity of electricity has been stored in the cell, hence the name, *storage* cell. The cell after being charged will deliver a current in a reverse direction because during the discharge a reverse chemical action takes place which causes the plates to resume their original condition When fully charged the positive plates are coated with peroxide of lead and are brown in color and the negative plates gray.

Ques. Describe the method of charging.

Ans. In charging, a direct current should be used—never an alternating one, care being taken to connect the positive wire to the positive terminal and the negative wire to the negative terminal. If connected in the reverse direction serious injury to the battery will result. The simplest method of charging is from an incandescent light circuit, using lamps



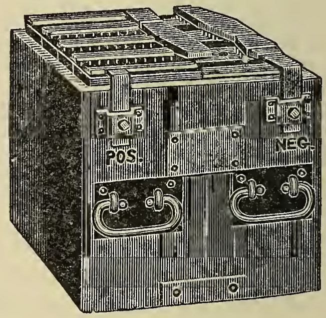


FIG. 105.—The Exide storage cell. The positive and negative plates are separated by thin sheets of perforated hard rubber, placed on both sides of each positive plate. The electrolyte and plates are contained in a hard rubber jar.

FIG. 106.—An Exide battery of five cells. The box which holds the cells is usually made of oak, properly reinforced, with the wood treated to render it acid proof. The terminals, as shown, consist of metal castings attached to the side of the box and plainly marked.

connected in parallel to reduce the voltage to that of the battery, the current being adjusted by varying the number of lamps in the circuit. A storage battery should be charged once every two months whether it be used or not.

Ques. What is sulphation?

Ans. The formation of *sulphate of lead* on the plates of a storage cell in the form of a very hard grayish coating. This sulphate of lead is practically an insulator, hence, plates so affected are rendered useless unless it be removed.

Ques. Name some causes of sulphation.

Ans. Too strong or too hot electrolyte, over discharging, etc. The most common cause of sulphation is over discharging. A battery that is discharged to a low point and then allowed to lie around unused for a considerable time will be destroyed by sulphation or rendered practically useless.

Ques. What may be said of local sulphation?

Ans. *Local sulphation* is caused by small particles of the active materials, which have become dislodged from the plates, catching in the separators. The latter are used to prevent the plates touching and forming a " bridge " between two plates and discharging them entirely.

Sediment, which gradually accumulates in the bottom of the jars, should be removed before it reaches the bottom of the plates.

Ques. How should sulphated plates be treated?

Ans. When the plates are sulphated the battery should be given a long slow charge at one-quarter the normal charging rate, till the electrolyte shows the proper specific gravity and the voltage has attained its maximum. The terminals and top of the cell should be kept free from acid, which will cause corrosion.

Ques. What is the proper specific gravity for the electrolyte?

Ans. The specific gravity of the electrolyte at the end of the charge should be 1.3. The specific gravity should not be altered when the battery is fully charged.

Ques. Describe the Edison three wire system.

Ans. The Edison three wire system is a peculiar combination of series and multiple systems. Two lamps are placed in series with each other and the sets of two are in multiple with each other. A conductor, called the neutral, connects the point of junction of the lamps which are placed in series with each other and runs to the point of junction of the two generators (in series with each other) which supply the system.

Ques. What is the advantage of the Edison system?

Ans. It secures economy in the size of wire, from the fact that it permits the distribution at a higher pressure without any very serious disadvantages; for example, the distribution on the feeders and mains is essentially at 220 volts, while the pressure on the branch circuits and the lamps is only 110 volts.

Ques. What is a dynamotor?

Ans. A combination of dynamo and motor on the same shaft, one receiving current and the other delivering current, usually of different voltage, the motor being employed to drive the dynamo with a pressure either higher or lower than that received at the motor terminals. In one form two armatures are mounted on one shaft in a single field or in separate fields; one is a motor armature driven by the original current; the other generates new current. This is a "motor-dynamo," and it can transform continuous current up or down. Another form of dynamotor is called the continuous alternating transformer. This is arranged so as to change a continuous into an alternating current or the reverse.

Ques. What is a fuse, and why and where is it used?

Ans. A fuse consists of a piece of metal, usually some alloy of lead which will melt at a fairly low temperature, soldered to copper terminals. It is intended to melt whenever the current passing through it exceeds the safe carrying capacity of the wire which the fuse is designed to protect. Fuses are placed at all points of a circuit where there is a change made in the size of the wires.

Ques. What is an alternating current?

Ans. A current which changes its direction many times each second.

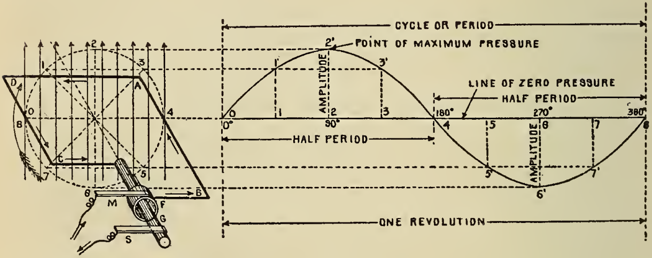


FIG. 107.—Application and construction of the sine curve. The sine curve is a wave like curve used to represent the changes in strength and direction of an alternating current. At the left of the figure, is shown an elementary alternator, consisting of a loop of wire A B C D, whose ends are attached to the ring and shaft F and G, being arranged to revolve in a uniform magnetic field indicated by the vertical arrows representing magnetic lines at equidistances. The alternating current induced in the loop is carried to the external circuit through the brushes M and S. The loop as shown, is in its horizontal position but at right angles to the magnetic field. The dotted circle indicates the circular path described by A B or C D during the revolution of the loop. Now, as the loop rotates the induced electromotive force will vary in such a manner that its *intensity at any point of the rotation is proportional to the sine of the angle corresponding to that point.* Hence, on the horizontal line which passes through the center of the dotted circle, take any length as 08, and divide into any number of equal parts representing fractions of a revolution, as 0°, 90°, 180°, etc. Erect perpendiculars at these points, and from the corresponding points on the dotted circle project lines parallel to 08; the intersection with the perpendicular give a point through 2 at the 90° point of its revolution, hence, projecting over to the corresponding perpendicular gives 2′2, whose length is proportional to the electromotive force at that point. In like manner other points are obtained, and the curved line through them will represent the variation in the electromotive force for all points of the revolution. At 90° the electromotive force is at a maximum, hence by using a pressure scale such that the length of the perpendicular 2′2 for 90° will measure the maximum electromotive force, the length of the perpendicular at any other point will represent the actual pressure at that point. The curve lies above the horizontal axis during the first half of the revolution and below it during the second half, which indicates that the current flows in one direction for a half revolution and in the opposite direction during the remainder of the revolution.

Ques. What is an alternation of the current?

Ans. A rise from zero potential to a maximum potential and fall back to zero potential.

Ques. Define the term "phase."

Ans. In wave, vibratory, and simple harmonic motion, the portion of one complete vibration, measured either in angle or in time that any moving point has executed.

Ques. What is a single phase alternating current?

Ans. A simple alternating current of uniform frequency as distinguished from polyphase currents.

Ques. Describe a two phase alternating current.

Ans. Two alternating currents of the same frequency, but having a difference in phase of a quarter of a period, a *diphase* or *quarter phase alternating current.*

If two identical simple alternators have their armature shafts couples in such a manner, that when a given armature coil on one is directly under a field pole, the corresponding coil on the other is midway between two plates of its field, the two currents generated will differ in phase by a half alternation, and will be two phased currents; similarly, three phased currents could be generated by coupling the armatures of three simple alternators so that the corresponding coils on each are equally "staggered" with respect to each other.

Two phase and three phase currents differ in this respect; the two phase system requires four wires to connect the generators with the motors, and their action is that of two distinct and separate circuits through which are passing simple alternating currents of electricity which act upon the revolving part of the motor like the two cranks on a cross connected engine at right angles to each other, or one 90 degrees in advance of the other.

Ques. What is a polyphase alternating current?

Ans. One having more than one phase; two or more alternating currents which differ in phase in a fixed proportion.

Ques. What is the advantage of the alternating current?

Ans. It can be transformed from a large current at low voltage to a small current at high voltage, or vice versa.

Ques. Of what advantage is this?

Ans. It permits the transmission of large power to a great distance economically. The higher the voltage the less the current for a given amount of power, consequently, the smaller the line wire may be for a given loss, or the smaller the loss with a given size of wire.

For example, 1,000 kilowatts at 2,000 volts demand a current of only 500 amperes; if the pressure were 500 volts, the current would be 2,000 amperes. Now, suppose there were a line that transmitted 500 amperes with a drop of 100 volts, or 5 per cent. The drop with 2,000 amperes would be 400 volts, or 80 per cent. of the available pressure of 500 volts. Hence, to transmit the 1,000 kilowatts at 500 amperes with a loss of 5 per cent., the line would have to be sixteen times as heavy as it would with a pressure of 2,000 volts.

Ques. How is the voltage of an alternating current raised or lowered?

Ans. By a transformer.

Ques. Describe a transformer,

Ans. It is an apparatus similar to an induction coil, and consists essentially, of two coils of insulated wire

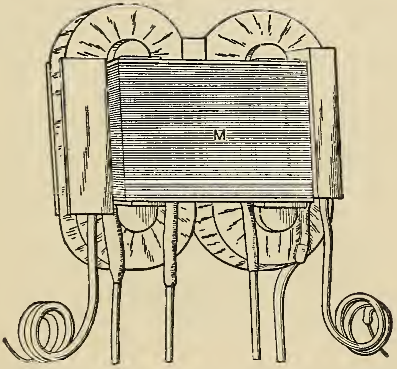


FIG. 108.—Transformer with case removed. It consists of an iron core of thin sheets, M, on which are wound two sets of coils called the primary and secondary windings.

wound adjacently upon a soft iron core; the *primary* coil of high resistance, consisting of many turns of fine wire, is connected to the high voltage circuit, and the *secondary* coil, consisting of fewer turns of coarse wire, furnishes the current at a reduced pressure.

This is a "step down" transformer; in a "step up" transformer the conditions are reversed, that is, primary winding is made up of a few turns of coarse wire and the secondary winding of many turns of fine wire.

Ques. Cannot direct current be generated at high voltage?

Ans. Yes, up to certain limits. Above 2,000 or 3,000 volts, however, the commutator becomes prohibitively expensive, and it is extremely difficult to obtain smooth commutation at such high potentials. Moreover, the voltage is too high to use at the lamps or motors, and to reduce it, the use of a combined motor and dynamo is required, the motor winding being designed for the high potential and the dynamo winding for the lower distribution voltage.

Ques. What is a rotary converter?

Ans. A dynamo for generating both direct and alternating current.

If conductors be led from the armature of a direct current machine to collector rings, alternating currents may be obtained; if the machine be run as a direct current motor alternating currents may be had at the collector rings; and if run as a synchronous alternating current motor, direct current may be obtained from the commutator.

Ques. What is an alternator?

Ans. A generator of alternating current; it is essentially a dynamo with *collector rings* instead of a *commutator.*

Ques. What else may be said of alternators?

Ans. Alternators are classified with respect to the current, as: 1, Single phase; 2, two phase; or 3, polyphase; with respect to construction as: *a*, those with stationary field magnet and rotating armature; *b*, those with rotating field magnet and stationary

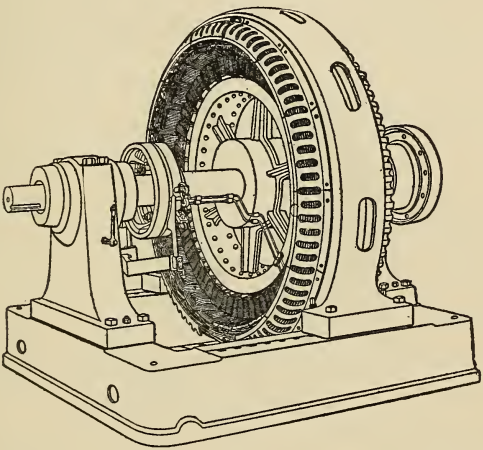


FIG. 109.—An alternator. The field revolves and the armature is stationary. Alternators are always multipolar because a high *frequency* is desirable. With stationary armature, the armature wires can be more securely fastened and more effectually insulated.

armature; *c*, those with both field magnet part and armature part stationary, but having revolving inductors made up of appropriate pieces of iron. Alternating current generators or *alternators* are usually multipolar, having north and south poles alternating around the field. The number of changes of direction of the current per revolution is the same as the number of coils in the armature or poles in the field, the armature coils in simple current machines being equal in number to the poles. The field magnets are often excited by a separate generator.

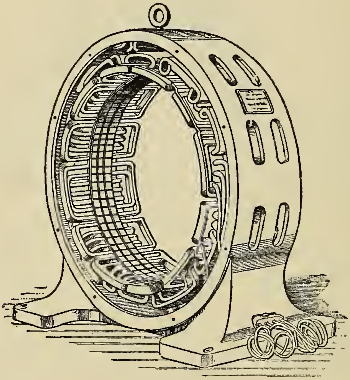


FIG. 110.—Alternator armature, showing details of coils, core and frame.

Ques. What is the advantage of polyphase distribution?

Ans. The ability to supply lamps and self-starting motors from the same circuit or from the same character of generator, avoiding a multiplicity of generator types at the station.

Ques. Cannot self-starting motors be operated on simple alternating current lines?

Ans. Yes; self-starting single phase motors are in use, but they do not give quite so satisfactory results as polyphase machines, especially in larger sizes. Moreover, they require special construction or auxiliary apparatus to enable them to be self-starting. A simple single phase motor, without any special starting device, will not move from a dead rest when thrown into circuit.

Ques. Are two phase and three phase motors self-starting?

Ans. Yes.

Ques. Is there any preference between two phase and three phase systems?

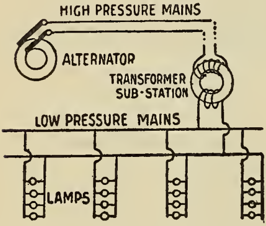
Ans. The three phase system is more economical in line wires, but the two phase system is easier to maintain in "balance," and consequently gives better regulation at the generators.

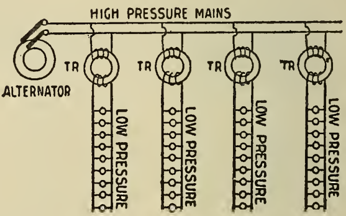
Ques. Why is the three phase system more economical in wire?

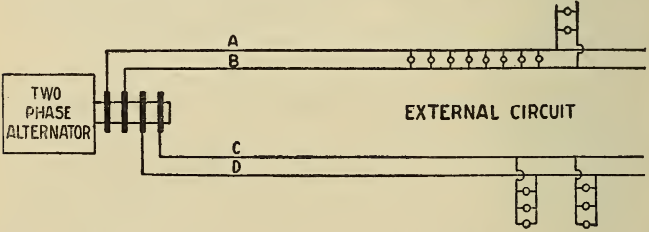
Ans. Because of the phase relations between the three currents. The three currents rise and fall at different instants; the result of this is that the "drop" in a three wire three phase line is exactly the same that it would be in a two phase line having four wires of the same size as those in the three phase line.

Ques. How does it compare with a single phase line?

Ans. Exactly the same way; the amount of copper required in a single phase two wire line is the same as that required in a two phase four wire line for the same load and drop; the two wires have each twice the cross section of each of the four wires of the two phase line. Therefore, the three phase three wire line requires three-fourths the amount of copper for a



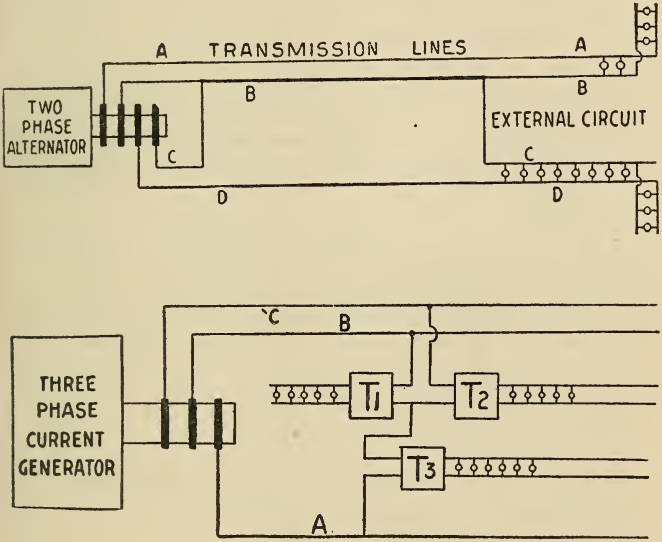




FIGS. 111 and 112.—Alternating circuit diagrams. High pressure currents are carried either from the central station to special sub stations (or transformer stations), from whence low pressure mains distribute the current to the houses, or the high pressure current enters each building in high pressure mains, and is transformed in the building by means of a transformer placed in the cellar or on the poles carrying the wires.

FIG. 113.—Two phase alternating system with separate circuit for each phase.

given set of conditions that is required by the simple alternating current line with two wires, and also by the four wire two phase line.



FIGS. 114 and 115.—Two and three phase circuits. In the two phase circuit, one wire may be saved by combining B and C, as shown in fig. 114. This arrangement is preferable for long distances, because of the saving in copper wire, but the chance of trouble increases. The wire B in such a case must have a cross section 41 per cent. greater than it would have otherwise. Fig. 115 is the diagram of a three phase circuit with transformers, T_1, T_2, T_3.

Ques. How are alternating current motors classified?

Ans. There are two general classes; synchronous and induction; each of these is again divided into single phase and polyphase.

Ques. What is the difference between synchronous and induction motors?

Ans. A synchronous motor has its field excited from some direct current source, while its armature takes current from the alternating current line, whereas an induction motor field is supplied from the alternating current circuit and its armature is not connected to any source of current, the currents in it being induced by the field—hence its name of " induction " motor.

A synchronous motor having a certain number of poles and being supplied with current from an alternator having the same number of poles will run at the same speed as that of the alternator, regardless of the load or voltage—hence the name "synchronous" motor; on the other hand, an induction motor, although tending to run in synchronism with the generator which supplied it with current, cannot do so, but lags behind the generator by a small amount, the actual lag, or "slip" as it is termed, varying with the load on the motor.

Ques. What means is usually employed for starting synchronous motors?

Ans. A small induction motor is mounted on the shaft or arranged to be belted to the synchronous motor shaft during the starting up period. The induction motor is thrown in circuit first, and brings the armature of the synchronous machine to a speed slightly above synchronism; then the synchronous armature is connected to the mains and the induction motor is cut out. The field magnet of the synchronous motor is fully excited beforehand.

Ques. Is either type of motor anything like an alternator?

Yes. A synchronous motor is precisely like an alternator. In fact, the two are interchangeable, exactly as in the case of dynamos and motors.

Ques. What is a recording watt hour meter?

Ans. A form of meter designed to register the watt hours expended during a perod of time. It is used to record the amount of electric power furnished to a consumer by a central station.

It is usually made in the form of a very small motor which drives a delicate train of gears, the hands of which indicate on dials the number of watt hours supplied. Watt hour meters are made for both alternating and direct currents.

Ques. What is meant by power factor?

Ans. The ratio between the true watts and the apparent watts of an alternating current, or the proportion of the apparent watts that is available for power.

In the direct current, the power, measured in watts, is the product of the volts and amperes in the circuit. In alternating current, this is only true when the current and electromotive force are *in phase.* If the current either lag or lead, the values shown on the voltmeter and ammeter will not be true simultaneous values. The power in an alternating current circuit at any instant is the product of the simultaneous values of current and voltage. *The volts and amperes indicated on the meters must be multiplied together and their product multiplied by the power factor before the true watts are obtained.*

Ques. What is understood by the term kilovolt ampere?

Ans. Apparent power in alternating current circuits is expressed in kilovolt amperes when the real power is expressed in kilowatts.

ELEVATORS

Ques. What two classes of elevator are in general use?

Ans. Electric and hydraulic.

Ques. What is an overbalanced elevator?

Ans. One having a counterweight heavier than the car.

Ques. What is the advantage of overbalancing an elevator?

Ans. It permits a *smaller* motor to be used.

Ques. Into what two classes are safety devices divided?

Ans. Into *motor* safeties and *car* safeties.

Ques. By what different means is the brake operated on electric elevators?

Ans. By mechanical and electrical attachments.

Ques. What kind of current is used for operating electric elevators?

Ans. Either alternating or direct current.

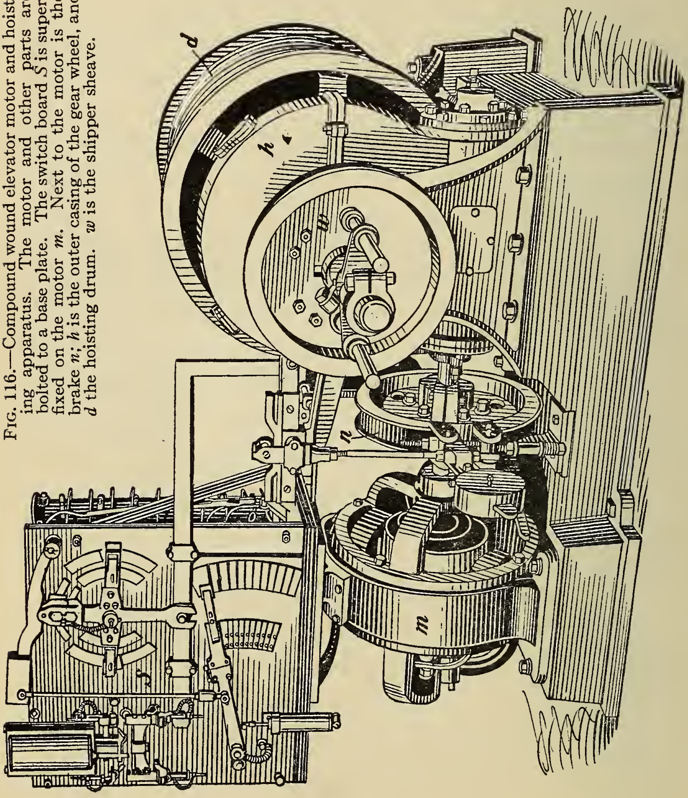


FIG. 116.—Compound wound elevator motor and hoisting apparatus. The motor and other parts are bolted to a base plate. The switch board *S* is superfixed on the motor *m*. Next to the motor is the brake *n*; *h* is the outer casing of the gear wheel, and *d* the hoisting drum. *w* is the shipper sheave.

Ques. How is the transmission of current to the motor of an electric elevator controlled?

Ans. By an electromagnet controller operated through a switch in the car.

Ques. What sets and what releases the brake on an electromagnet control elevator?

Ans. A spring or weight sets the brake, and a solenoid releases it.

Ques. How may considerable power be wasted in operating electric elevators?

Ans. By careless handling, that is, making unnecessary stops and starts.

Ques. What are limit stops?

Ans. The safety devices used to automatically stop the car at the upper or lower limit of its travel.

Ques. What limit stops are usually placed on the shipper rope?

Ans. *Buttons* or *knobs* against which the car strikes, causing the belt to be shifted, or power cut off. Such buttons or knobs are not sufficient protection in themselves, as they are apt to slip or break.

Ques. What is the most common form of motor limit stop?

Ans. A gear wheel working loosely on an extension of the drum shaft. Should the car overrun its limit, either on the up or down trip, jaws on the hub of the loose gear engage with jaws fastened to the threaded shaft, causing the loose wheel to rotate. This sets in operation the gear which turns the *shipper sheave*, thereby *reversing* the motion of the elevator.

Ques. Describe briefly the mechanism of a hydraulic elevator.

Ans. It consists of a cylinder and piston with one or more rods connected to a crosshead which carries the sheaves over which run the lifting cables from which the car is suspended.

Ques. What moves the piston?

Ans. Water under pressure admitted by means of suitable valves causes the piston to move from one end of the cylinder to the other, and back again.

Ques. How is this motion transmitted to the elevator car?

Ans. By means of the sheaves mounted on the crosshead which carry the lifting cables.

Ques. In what position is the cylinder placed?

Ans. Either vertical alongside the hatchway, or horizontal in the basement of the building.

Ques. How are the valves of a hydraulic elevator operated?

Ans. In some cases by a hand rope passing through the car and over small sheaves at the top and bottom of the hatchway, and connected with the main valve in the basement. By pulling this rope down the valve is opened, and the car will ascend, while pulling the rope up will cause the car to descend.

Ques. What safety devices are attached to this type of elevator?

Ans. Two balls are attached to the hand rope, one near the bottom, and the other near the top. These balls come in contact with the top, or bottom of the car, according as it is going up or coming down, and being carried along they, of course, move the cable, thus actuating the valve, bringing the car to a stop.

Ques. Mention another safety device connected with hydraulic elevators.

Ans. Safety clamps under the control of a speed limit centrifugal governor which causes the clamps to grip the guides and thus hold the car.

Ques. How is this safety governor operated?

Ans. By means of a small cable connected with the car and moving with it, which passes over the sheave pulley of the governor.

Ques. Why are some elevator pistons fitted with two piston rods?

Ans. To prevent the piston, and crosshead from turning or twisting, and also to strengthen the construction.

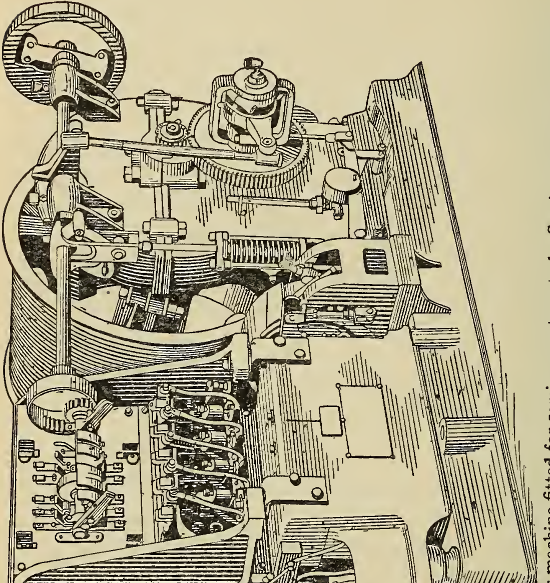


FIG. 117.—Otis elevator machine fitted for semi-magnet control. Semi-magnet control differs from full magnet control in that the main switch connecting the motor to the supply circuit is closed mechanically by means of a hand wheel, lever, or hand rope in the car. After this switch is closed, the controlling devices operate automatically as in the full magnet system, the motor being properly protected against overload. In the figure, the shipper sheave, at the right operates the reversing switch, through the internal gear and pinion. Below the reversing switch are the accelerating magnets. Both switches and magnets are mounted on the controller box, within which are the starting resistances.

Ques. What other methods are used for manipulating the water valve, besides the one already described?

Ans. Running ropes, and standing ropes, either of which may be operated by means of a lever, or wheel in the car.

Ques. Do these devices directly operate the main valve?

Ans. No. They operate a small valve called the piston valve.

Ques. What is the function of the pilot valve?

Ans. When opened it admits water under pressure to a small cylinder with piston connected to the main valve stem. This actuates the main valve, which in turn, by its movement, closes the pilot valve.

Ques. Upon what does the amount of opening given the pilot valve, and consequently the main valve, depend?

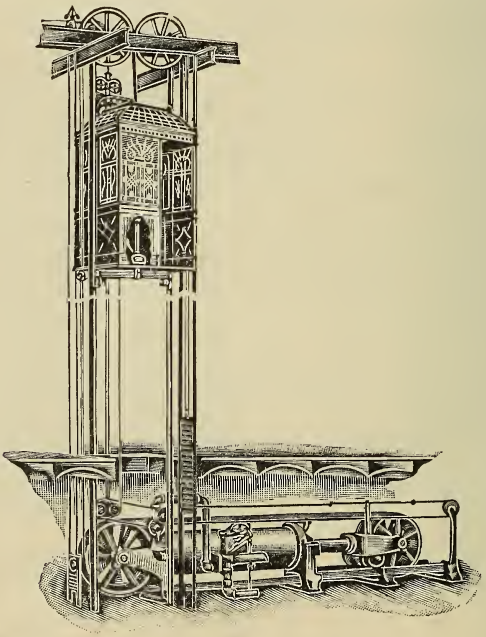
Ans. Upon the distance the lever in the car is moved from the central position.

Ques. What is meant by central position of lever?

Ans. That position in which there is no flow of water either into or out of the cylinder.

Ques. What is the result of moving the lever too quickly to central position when the car is moving at a high rate of speed?

Ans. The motion of the car will be arrested with a sudden jerk.



Fig, 118.—Pushing type of horizontal hydraulic elevator.

Ques. How many kinds of horizontal hydraulic elevator are in use?

Ans. Two. One is the pushing, and the other the pulling type.

Ques. Describe the action of the pushing type.

Ans. The car being at the bottom, the pressure of water is admitted behind the piston which then moves, pushing the crosshead and cable sheave and lifting the car.

Ques. Describe the action of the pulling type.

Ans. It is the opposite of that just described.

Ques. Is there much difference in the valve mechanism of the horizontal, and vertical, types of hydraulic elevator?

Ans. Very little except a few minor details.

Ques. How should an elevator rope be fastened to the drum?

Ans. It should be made long enough to encircle the drum at least *twice* when the elevator is in its *lowest* position.

Ques. What water pressures are used generally for operating hydraulic elevators?

Ans. From 150 to 200 lbs. per square inch. In high office buildings where high speed service is required greater pressures are used.

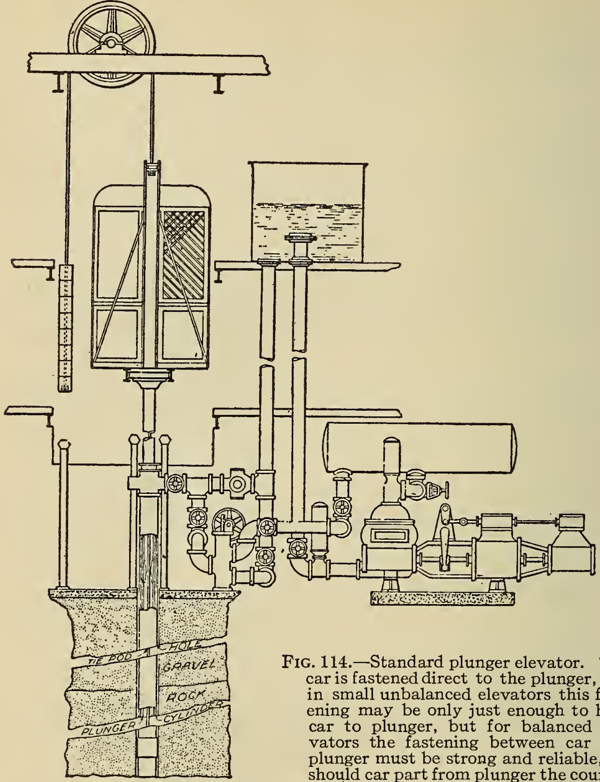


FIG. 114.—Standard plunger elevator. The car is fastened direct to the plunger, and in small unbalanced elevators this fastening may be only just enough to hold car to plunger, but for balanced elevators the fastening between car and plunger must be strong and reliable, for should car part from plunger the counter weights would jerk car up against overhead work, with the chances in favor of a very serious accident. Plunger elevators are never overbalanced as the power acts only in one direction, the up stroke of plunger. Enough weight of car and plunger must be left unbalanced to cause the car to make the descent at the proper speed, when empty. As the plunger goes up the pressure under plunger diminishes by an amount corresponding to the height of water that displaces plunger. This is where the variable counterbalance is applied to the plunger elevator. To equalize this change of pressure the rope or chain that supports the counter weight must be of such size that the wieght per each foot of length passing over the overhead sheaves will be equal to half the weight of one foot in height of water displacing the plunger. The entire mechanism is shown in the illustration, from which the operation is easily understood.

Ques. What is a plunger elevator?

Ans. One in which the car is placed directly on *top* of a plunger or piston.

Ques. Describe briefly the mechanism and operation of a plunger elevator.

Ans. A cylinder is set vertically in the ground under the center of the car, and the length of it is slightly greater than the travel of the car. In this cylinder is a plunger which carries the car. Water under pressure is forced into the cylinder which lifts the car, and allowed to run out at the top when the car descends. The cylinder is always full of water.

Ques. What is the usual diameter of the plunger?

Ans. $6\frac{1}{2}$ to 7 inches.

Ques. How is it constructed?

Ans. Of lengths of polished pipe, joined together with an internal sleeve, and having its lower end closed.

Ques. What pressure is ordinarily used on this type of elevator?

Ans. 150 to 200 lbs. per square inch.

Ques. How is the top of the cylinder arranged?

Ans. With a packing gland through which the plunger moves up and down.

Ques. What is the purpose of a pilot valve?

Ans. To give better control of the main controlling valve.

Ques. Why can not a plunger elevator be overbalanced?

Ans. Because the power acts only during the up stroke of the elevator.

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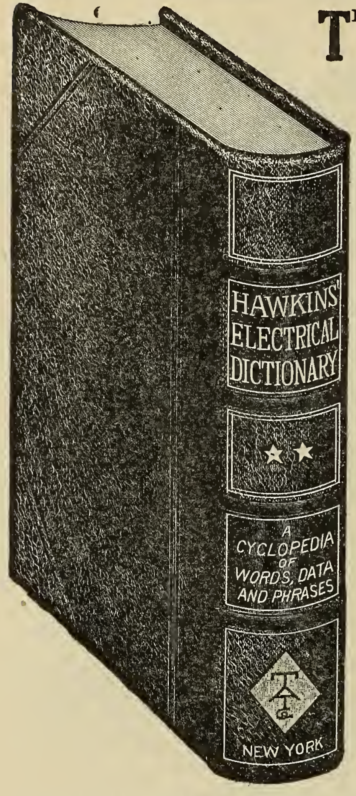

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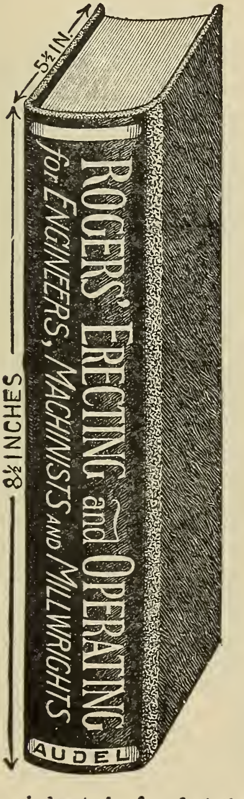

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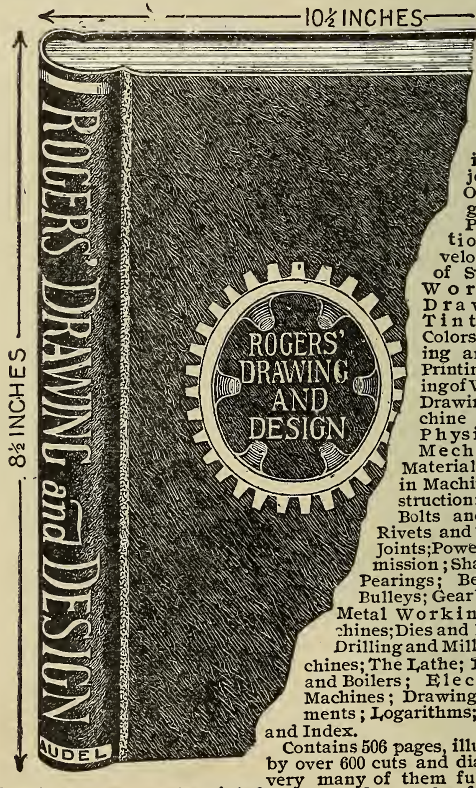

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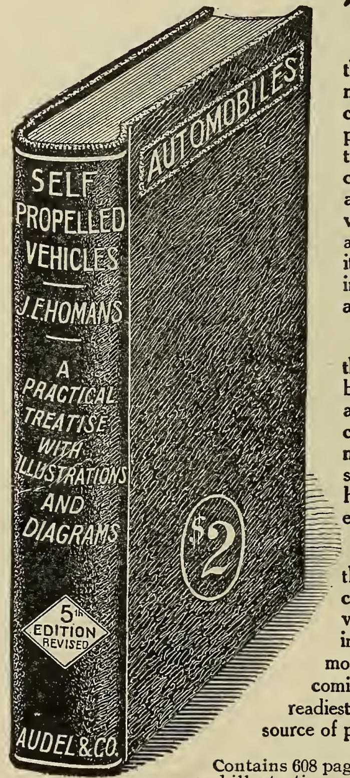

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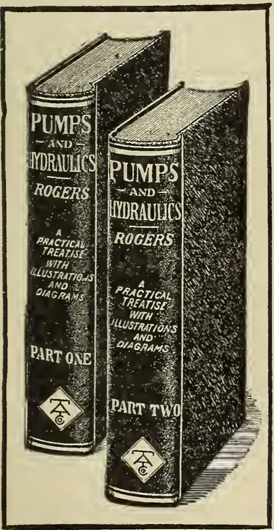
IT is with pleasure we call your attention to the recent publication on pumping machinery. This work, issued under the title of "ROGERS' PUMPS AND HYDRAULICS," is a complete and practical handbook, treating on the construction, operation, care and management of pumping machinery; the principles of hydraulics being also thoroughly explained. The work is illustrated with cuts, diagrams and drawings of work actually constructed and in operation; the rules and explanations of the examples shown are taken from everyday practice. No expense has been spared in the endeavor to make this a most helpful instructor on the subject, useful to all pump attendants, engineers, machinists and superintendents.



Subjects Treated

The Air Pump; Air and Vacuum Pumps. Air Compressors; The Air Lift Pump; The Steam Fire Engine; Miscellaneous Pumps; Mining Pumps; Marine Pumps; "Sugarhouse" Pumps; Circulating Pumps; Atmospheric Pumps; Ammonia or Acid Pumps; The Screw Pump; Aermotor Pumps; Rotary and Centrifugal Pumps; Turbine Pumps; Injectors and Ejectors; Pulsometer-Aqua-Thruster; Pump Speed Governors; Condensing Apparatus; Utilities and Attachments, Tools, Valves and Piping, Pipes, Joints and Fittings, Useful Notes; Tables and Data; Glossary of Pump and Hydraulic Terms; Elementary Hydraulics; Flow of water Under Pressure; Water Pressure Machines, Water Wheels; Turbine Water Wheels; Turbine Pumps; Water Pressure Engines; Hydraulic Motors; Hydraulic Apparatus; Hydraulic Jack; Hydraulic Press; Hydraulic Accumulator; Hydraulic Ram; Pumps as Hydraulic Apparatus: Classification of Pumps; Hand Pumps; Power Pumps; Belted Pumps; The Electric Pump; The Steam Pump; The Duplex Pump; Underwriter Fire Pump; Specifications of the National Board of Fire Underwriters Relating to Duplex Fire Pumps.

These two volumes of nearly nine hundred pages, illustrated with about seven hundred wood cuts, are admirable specimens of bookmaking; they are printed on fine white paper in large clear text, with ample margins, and bound in black vellum cloth with titles and tops in gold. In size they are six by nine inches.

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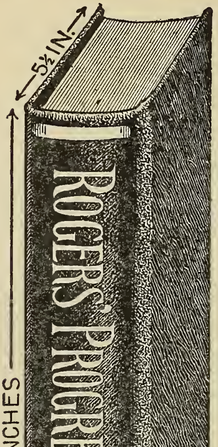

THIS is a valuable volume for all Metal Workers;—the following are a few of the many subjects treated:

Materials.—Definitions; Qualities of Matter; Iron, Steel; Various Metals, Alloys, etc.; Gravity and Tables; Three Laws of Motion; Strength of Materials; Fatigue of Metals; Table of Melting Points of Solids; Useful Weights and Measures.

Shop Drawing.—Free-hand Drawing; Instruments; Penciling; Inking; Lettering Drawings; Dimensioning; Shading; Section-Lining; Reading Working Drawings; Problems in Geometrical Drawing—Points Relating to Drawing.

Gearing.—Cog Wheels, Spur and Bevel Wheels; Mitre Wheel Mortise Wheel; Worm Gearing; Helical Wheel; Designing Gears; Speed of Gear Wheels.

Bench and Vice.—Tempering and Hardening Metals; Grades of Steel; Cementation Process; Bessemer and Siemen-Martin Process; Case-Hardening; Annealing; Hand Tools; Machine Tools; Work Benches; Sledge and Anvil; Surfacing; Red Marking; Hand Drilling; Broaching; Screw Cutting by Hand; Pipe Cutting.

Tools and Machines.—Machine and Hand Tools; Portable Tools; Action of Machines; Classification of Machine Work; Turning and Boring; Planing; Milling; Drilling; Grinding; Punching and Shearing.

Lathe Work.—Forms and use of Foot Lathes; Hand Lathes; Chuck or Surfacing Lathe; Engine Lathe; Parts of the Lathe; Cutting Tools Used in the Lathe; Tempering of Lathe Tools Rule; Lathe Practice; Measuring Instruments; Mandrels; Lathe-Dogs; Driving Work Between Centers; Turning Work Between Centers; Lathe Speed; Chuck and Face-plate Work; Drilling and Boring in the Lathe; Proportion of Parts of a Lathe; Useful References; Tables and Index.

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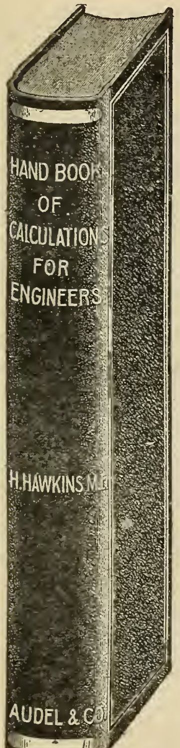

THE Hand Book of Calculations is a work of instruction and reference relating to the steam engine, the steam boiler, etc., and has been said to contain every calculation, rule and table necessary to be known by the Engineer, Fireman and a steam user.

Giving a complete course in Mathematics for the Engineer and steam user; all calculations are in plain arithmetical figures, so that the average man need not be confused by the insertion of the terms, symbols and characters to be found in works of so-called "higher mathematics."

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Tables of Weights, Measures, Strength of Rope and Chains, Pressures of Water, Diameter of Pipes, etc.; The Indicator, How to Compute; The Safety Valve, How to Figure; The Steam Boiler; The Steam Pump; Horse Powers, How to Figure for Engines and Boilers; Steam, What It Is, etc.

Index and Useful Definitions.

This work contains 330 pages and 150 illustrations; it is durably and handsomely bound, uniform in style and size with the "Instructions for the Boiler Room" and the "Catechism of the Steam Engine;" it has gold edges and titles, and weighs over 28 ounces.

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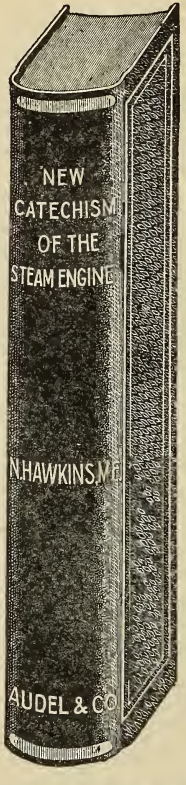
STEAM ENGINE PRACTICE $2



"It has been well said that engineers are born, not made; those in demand to fill the positions created by the great installations of power-producing machinery now so common, are men who are familiar with the contents of good books, and as well, are the product of a hard bought practical experience."

THIS work is gotten up to fill a long-felt need for a practical book. It gives directions for running the various types of steam engines that are to-day in the market.

A list of subjects, which are fully yet concisely discussed, are as follows:

Introduction; The Steam Engine; Historical Facts Relating to the Steam Engine: Engine Foundations; The Steam Piston; Connecting Rods; Eccentric; Governor; Materials; Workmanship; Care and Management; Lining up a Horizontal or Vertical Engine; Lining Shafting; Valve Setting; Condensers; Steam Separators; Air, Gas, and Compressing Engines: Compounding; Arithmetic of the Steam Engine; Theory of the Steam Engine; Construction.

There also is a description of numerous types of the engines now in operation, such as the Corliss, Westinghouse, and many others.

The book also treats generously upon the Marine, Locomotive and Gas Engines.

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STEAM ENGINE INDICATOR $1

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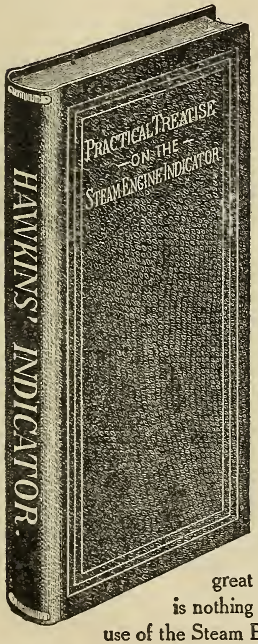

The following is a general outline of the subjects defined, illustrated and presented most helpfully in the book.

Preparing the Indicator for use; Reducing Motions; Piping up Indicator; Taking Indicator Cards; The Diagram; Figuring Steam consumption by the diagram; Revolution Counters; Examples of Diagrams; Description of Indicators; Measuring Diagram by Ordinates; Planimeters; Pantagraphs, Tables, etc.

He who studies this work thoughtfully will reap great benefit and will find that there is nothing difficult or mysterious about the use of the Steam Engine Indicator. This knowledge is necessary to every well-informed engineer and will undoubtedly be highly appreciated and a stepping-stone toward promotion and better things.

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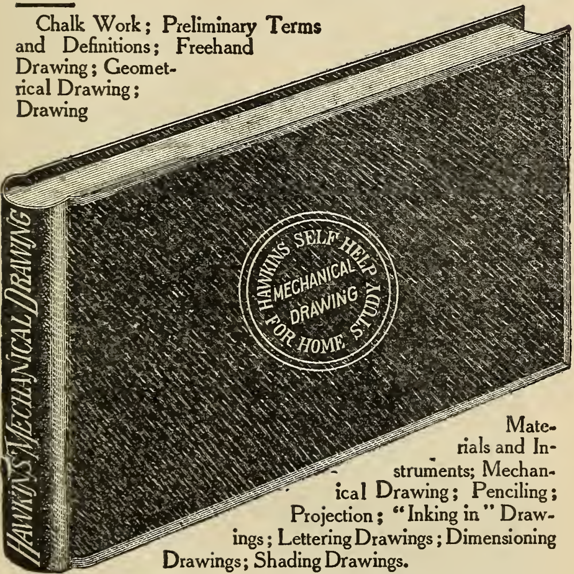

Section Lining and Colors; Reproducing Drawings; Drawing Office Rules; Gearing; Designing Gears; Working Drawings; Reading Working Drawings; Patent Office Rules for Drawings; Useful Hints and Points; Linear Perspective; Useful Tables; Personal, by the Editor.

The book contains 320 pages and 300 illustrations, consisting largely of diagrams and suggestive drawings for practice. It is bound in dark green cloth with full gold edges and titles; it is printed on fine paper, size 7x10 inches; it weighs 33 oz., and will fit into any engineer's or mechanic's library to good advantage. **PRICE, $2, Postpaid**

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ENGINEERS' EXAMINATIONS $2

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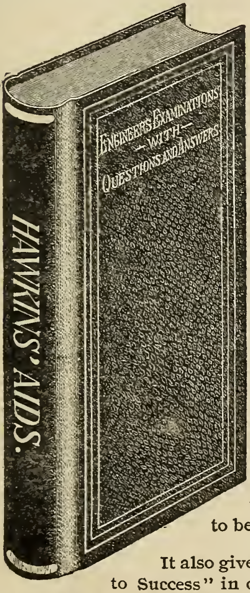

It contains various rules, regulations and laws of large cities for the examination of boilers and the licensing of engineers. It contains the laws and regulations of the United States for the examination and grading of all marine engineers.

The book gives the underlying principles of steam engineering in plain language, with very many sample questions and answers likely to be asked by the examiner.

It also gives a short chapter on the "Key to Success" in obtaining knowledge necessary for advancement in engineering.

This helpful volume contains 200 pages of valuable information not elsewhere obtainable ; it is bound in rich red leather with full gold edges and titles ; it measures 5x7½ inches and weighs twenty-two ounces.

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