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COMPRESSED AIR
FOR THE METAL WORKER

By
CHARLES A. HIRSCHBERG

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PREFACE

The author has frequently been called upon to explain in a practical way how compressed air is used for this or that purpose in the metal-working field. Upon many occasions he has sought assistance from current engineering literature in answering these questions. From these experiences he has been impressed with the dearth of *practical* information in published form relating to the industrial uses of compressed air. It is the rule that modern engineering practice is invariably in advance of its literature, and compressed air engineering is no exception to the rule. It was the recognition of this situation that led the author to undertake the writing of this work.

It is believed that this book is unique among those published in recent years in confining itself to discussion of the practical side of compressed air utilization. It aims to tell *how* and *why*. Theory—when referred to at all—is discussed concisely and in non-technical language.

It is felt that this method of treatment will appeal strongly to shop owners, superintendents, foremen and machinists or other artisans. At the same time, the book should prove of considerable value to mechanical engineering students, used to supplement a theoretical text-book on compressed air engineering. The numerous applications cited should suggest to the engineer many new and better ways for carrying on various shop operations.

The industries in the metal-working field served by compressed air are many and varied. To cite only a few, there are the machine tool builders; manufacturers of metal and coal mining machinery; quarrying machinery manufacturers; ammunition and firearms manufacturers; automobile manufacturers; gas and gasoline engine builders; steam engine builders; electrical manufacturers; hoisting and conveying machinery manufacturers; structural workers; ship builders, etc.

The narration of the story of Compressed Air in the Metal-Working Field is essentially a compilation of experiences and individual accomplishments. It presents certain difficulties due to the fact that not only are these applications carried out in machine shops, forge shops, foundries, power plants, etc., but accessory to each work is a repair shop for the maintenance of the manufacturing equipment. Likewise, such industries as textile, glass and furniture manufacturing, mining, engineering, etc., have their own repair shops, and the information in the following chapters applies equally as well to them, although it is not the intention to refer to such industries specifically.

The entire subject has been classified under the following heads:

Power Plants
Foundries
Machine Shops
Forge Shops
Boiler and Structural Shops
Miscellany

The chief uses of Compressed Air Power in the industries cited are:

Agitating, transferring and atomizing liquids.
Aerating liquids and metals.
Conveying, handling and hoisting.
Cleaning machinery.
Drying.
Metal spraying.
Painting, enameling and whitewashing.
Pumping water and other liquids.
Starting.
Testing.
Operating various tools, such as:
    Boiler tube cleaners, chipping, calking and riveting hammers, flue rollers, portable grinders, drills, augers, etc.
Operating heavy machines, such as:
    Bending presses, forging hammers, molding and sand blasting machines, smith forges, tempering furnaces, etc.

The author wishes to acknowledge his indebtedness to those who kindly assisted in gathering the information, also to the *Compressed Air Magazine* and other technical trade papers.

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CHAPTER I

HISTORICAL

The earliest record of the use of compressed air is that of Ctesibius of Alexandria, who invented an implement for war consisting of a tube out of which an arrow was shot by the compression of air.

Known history accords the honor as the second experimenter with compressed air to a certain Heron, a pupil of Ctesibius and also of Alexandria. He lived and invented and died under the reign of the Ptolemies of Egypt between the years 284 B. C. and 221 B. C. The pneumatic experiment known as Hero's Fountain, in which a jet of water is sustained by compressed air, is attributed to him. It will be noted that the early means for recording history were unkind to Heron, having dropped the 'n' from his name in referring to this experiment.

Heron is on record as the author of numerous writings and experiments on 'Pneumatics.' It is recorded that he applied his knowledge of the influence of heat, in expanding and contracting air, to the opening and closing of temple doors, which mystified the ancients and to them vested the priests of the temple with supernatural powers and caused them to be held in great awe.

From the efforts of Ctesibius and Heron to the next recording of history on the subject of compressed air, we are led in our journey over a space of several centuries to the discovery by Galileo in the early part of the 17th century of the underlying principle of the compressed air industry; namely, that air was ponderable, and then came the invention by Otto von Guericke of Magdeburg of the first air pump in 1650.

As with nearly all the great powers of modern science, progress in the early days was by slow and painful stages through a great many failures and seemingly insurmountable difficulties into the realm of practical knowledge and successful application of the present day.

The following is a brief chronology of some of the inventions and discoveries between the 17th century and the present time, in so far as they relate to the mission of this book.

In 1726, Rowe took out a patent in England for raising water by generated, expanded, or compressed air.

In 1753, Holl is credited with having used an air engine for raising water.

In 1757, Isaac Wilkinson patented a method of compressing air by the use of a column of water having a series of vessels, using one after the other, so as to keep up a constant pressure.

In 1788, Smeaton invented at Ramsgate Harbor, Kent, a pump for use in connection with diving apparatus.

In British patent No. 2,299, February 28, 1799, George Medhurst compressed air for motive power by means of a windmill.

Toward the end of the 17th century the first suggestion of the transmission of air power, through pipes for use at a distance, came from Dr. Denys Papin, of France, to whom we are also indebted for the first conception of the pneumatic dispatch tube.

The latter idea remained dormant for nearly one hundred years after his death, when George Medhurst secured an English patent (1810) "For a means of conveying goods, letters, parcels and passengers by means of a tube and blast of compressed air."

1816 witnessed the invention of a Dr. Sterling and his brother James Sterling, C.E., of Edinburgh, Scotland, of a compressed air engine. This engine was not, however, a commercial success, but proved an important step in the advancement of the science. It stimulated interest and further investigation.

Shortly after Medhurst's invention, Burnell is credited with having applied compressed air to caisson work.

April 29, 1828, Bompas, in a provisional British patent, No. 5,644, proposed to propel locomotives by compressed air.

The most decided advance in the principles of air compression occurred in 1829, when William Mann, in an application for a patent stated: "The condensing pumps used in compressing the air, I make of different capacities according to the density of the fluid to be compressed—those used to compress the higher densities being proportionately smaller than those previously used to compress it at the first or lower densities, etc."

He further stated that, by the application of compressed air, power and motion can be communicated to fixed machinery, carriages, locomotives and ships.

In 1830, Thilorier, a Frenchman, received a medal from the French Academy of Sciences for his method of compressing gases by stages.

James Surrey, in British patent No. 7,179, September 1, 1836, lays claim to the use of compressed air for the purpose of working engines hitherto worked by steam, and suggests portable vessels filled with compressed air; especially for railways, for which also he suggested having air pumps running from station to station.

In 1844, Caligny published his idea of applying the hydraulic ram to compressing air.

In 1847, von Rathen was granted an English patent for the process of cooling the air by water in the cylinder, or by surrounding it with cold water. He also described a reservoir for storing air, a means for cooling it after compression, and a mode of heating the air to give it greater tension after it is compressed.

October 7, 1847, Patent No. 11,897, Richard and James Fell—Compressor and Receiver or Reservoir for storing the air along the track of a railroad.

In 1849, von Rathen suggested the use of compressed air under high pressure for locomotive haulage.

It was also during the years intervening from 1816 to about 1860 that Captain Ericsson of war vessel fame conducted experiments with compressed air engines. His efforts failed of the desired results, i. e., successful commercial application.

1851 records the application of compressed air by William Cubitt to bridge work at Rochester Bridge.

In 1852 was patented by Professor Calladon of Geneva the application of compressed air for driving machine drills in tunnels. In collaboration with M. Sommeiller, he developed his idea and applied it to the driving of the Mt. Cenis Tunnel during 1861.

In 1854, the same patentee, however, describes a method of pumping air in which he claims the construction of end valves, so as to cover the whole end of the cylinders to which they are applied, and repeats Mr. Mann's process of stage-pumping (patented twenty-five years before) in the following words: "The construction of air pumps with a series of cylinders of progressively diminishing capacity."

Moses Poole, in a communication, British patent No. 692, March 21, 1853, suggests absorbing the heat of compression by a water jet, and supplies by artificial means the heat necessary to expand the air before use.

January 15, 1854—Patent No. 88—Arthur Parsey (British), double-acting air pump with hollow piston and rod, through which air is admitted above and below the piston. The valve may be as large as the cylinder. The rod passes through the valve and has a spiral spring to keep the valve seated. In this patent, stage-pumping is mentioned.

Augustin Grass, January 2, 1857, No. 21 (provisional protection only), obtaining motive power by a steam engine pumping air into a reservoir connected by a coil of tubes in the boiler furnace. The air in the coil becoming heated and highly elastic, to be used in an air engine.

James Harris, in British patent No. 25, January 2, 1857, proposes, in addition to compressing air to be used at a distance in air engines, exhausting it.

H. A. Jowett, in British patent No. 2,110, July 25, 1862, proposes compressing air by water power, and carrying it long distances in pipes, having sliding-valves at regular intervals, to test their tightness, and plugs at suitable stations, which will yield motive fluid to drive fire pumps.

W. A. Turner and T. T. Goughin, in British patent No. 3,140, December 17, 1864, obtained provisional protection on stage-pumping, there being reservoirs between the pumps.

In 1867, Sir George Cayley and Philander Shaw exhibited at the Paris Exhibition the first air-compressing engine approaching real commercial success.

In 1869, George Westinghouse invented his first type of railroad air brake, which finally culminated in its perfection in the year 1887.

In the United States patent granted December 23, 1879, to W. P. Tatham, of Philadelphia, there is a steam and an air piston, each reciprocating in a cylinder, and a double-armed rock shaft, connected with the steam and air piston rods, these members being combined for joint operation to compress air under a decreasing leverage of the air piston arm, and a correspondingly increasing leverage of the steam piston arm.

It was in the late forties that experiments were conducted and patents taken out by J. J. Couch of Philadelphia, on the percussive rock drill. This machine is an American invention. Couch was aided in his work by Joseph W. Fowle.

In 1848, these two separated, Fowle filing a caveat in 1849, covering the type of successful power rock drill in use today.

Wm. Fowle in his testimony before the Massachusetts Legislative Committee in the contest with Burleigh in 1874 described this important invention as follows—"My first idea of ever driving a rock drill by direct action came about in this way: I was sitting in my office one day after my business had failed, and happening to take up an old steam cylinder model I unconsciously put it in my mouth and blew the rod in and out, using it to drive in some tacks with which a few circulars were fastened to the walls."

The work of a German, Schumann, in 1854 was the nearest approach to rock-drilling inventions abroad.

Fowle being without means finally sold his patents to Charles Burleigh, and he produced the Burleigh drill in the year 1866. This drill was used in driving the Hoosac Tunnel in 1867.

The first air compressor used in America was in the driving of the Hoosac Tunnel.

Following these, came Haupt, De Volson Wood and Simon Ingersoll; after these men, Sergeant, Waring, and Githens, which brings this historical record up to the year 1871. And it was from this year that the real history of compressed air dates as an industrial and economic factor, starting with the rock drill, which in its turn called for the manufacture of the commercial air compressing machine bringing with it the invention of many of the devices employed in the modern manufacturing plant.

The success of compressed air in this field at once suggested its possibilities in other lines, until today its ramifications are multitudinous, and it stands second only to electricity in the extent and diversity of application.

In the arts, sciences and manufactures its use accomplishes economies which could otherwise never have been realized.

Compressed air appliances have exercised a tremendously beneficial influence upon improved standards of living.

CHAPTER II

THE COMPRESSED AIR POWER PLANT

GLOSSARY OF COMPRESSED AIR TERMS

Atmospheric Pressure. The pressure of the surrounding air. At sea level it is 14.7 pounds per square inch, becoming less and less with the rise in altitude.

Air Compressor. A machine for compressing air from atmospheric pressure to a higher pressure.

Air compressors are built in various classes, such as Vertical, Straight-Line and Duplex machines and Turbo, Rotary or Centrifugal machines; in single-stage, two-stage, three-stage, four-stage, etc., depending upon the desired ultimate pressure. They may, in all but the Turbo, Rotary or Centrifugal class, be either single or double acting.

Vertical Compressors. In this class the compressing element is placed in a vertical plane above and in line with the driving element.

Straight-Line Compressors. In this class the driving and compressing elements are placed in a horizontal plane in line with one another.

Duplex Compressors. Two straight-line units placed parallel on one common crank shaft.

Turbo, Rotary or Centrifugal Compressors. Machines in which the compressing element is of rotating construction.

Single-Stage. One compressing cylinder, from which the air is discharged into the air receiver of the transmission line.

Two or More Stages. More than one compressing cylinder, the air being compressed successively up to a certain pressure in each cylinder until it is discharged into the receiving line at the ultimate desired pressure. With stage compressors it is usual to employ an intercooler and moisture trap, and where the very greatest refinement is wanted, an aftercooler.

Single-Acting. The compression of air on but one stroke of the piston.

Double-Acting. The compression of air on both strokes of the piston.

Single-Stage, Duplex. A compressor of duplex type having two single-stage cylinders, each discharging directly into the receiving line.

Two-Stage, Duplex. A compressor of the duplex type having two air cylinders, the air being compressed successively in each to a certain pressure and then discharged into the receiving line at the ultimate desired pressure.

Air Receiver. A receptacle into which the compressed air is discharged from the compressor.

Intercooler. A device for extracting the heat of compression generated in the first cylinder (and not removed by the cylinder jacket cooler) before the air enters the next compressing cylinder of a two-stage compressor. Compressors of more than two stages usually have intercoolers between successive stages.

Cylinder Jacket Cooler. A space surrounding the compressing cylinder filled with water in circulation, for keeping the cylinder walls, piston, cylinder heads and valves cool, so as to keep down the heat of compression.

Valves, Inlet. Devices for admitting air to the air cylinder and to prevent its return when being compressed.

Valves, Discharge. Devices for permitting the discharge of compressed air from the air cylinder after its pressure has exceeded that in the transmission line.

Valves are of two distinct types, mechanically operated and automatic.

Mechanically operated valves depend for their opening and closing on some external mechanical means, usually driven from the crank shaft. Their time of opening and closing is fixed.

Automatic valves depend for their opening and closing entirely upon pressure differences—in the case of the inlet valve, between atmosphere and cylinder and with the outlet valve, between cylinder and discharge pressures.

Moisture Trap. A means for collecting and removing moisture, precipitated from the air during the process of cooling.

Aftercooler. A means for reducing the heat of compression, generated in the final stage of compression of stage machines and also for the further extraction of moisture.

Reheater. A means, adjacent to the point of use, for raising the temperature of the compressed air.

HEAT OF COMPRESSION. The action of compressing air generates heat above that of the intake temperature of the air. Most of the heat is due to the increased molecular activity of the air and part of it to mechanical friction, such as the rubbing of the piston in the cylinder and the friction of the air through the valves and air passages.

INTAKE TEMPERATURE. Temperature of the air entering the compressor from the atmosphere.

If the heat could be retained in the air it would result in the highest economy, but inasmuch as it is usually transmitted over considerable distances, radiation occurs and the result is a reduced volume of air.

The higher the temperature of the air, the greater it will expand in volume and, conversely, the lower the temperature, the smaller will be the volume. With the pressure constant the weight per unit of space occupied will be lower at high temperatures than at low; in other words reducing the temperature increases the air's density.

Therefore, to effect the greatest economy in compression of air, or stating it in still another way, to get the greatest volume of air compressed to a given pressure from a stated size of compressor, it is necessary to reduce, to the lowest practical point, the temperature of the air before and during compression in order that the air after compression may have the greatest density. To effect a still further economy, by increasing its volume after compressing, the temperature of the air should be raised to the highest possible point before use.

The foregoing explains briefly the desirability of cooling, by jacketing the cylinders, providing intercooling in two-stage compressors and in some cases aftercooling and reheating.

It also indicates the desirability of having the intake air of the lowest possible temperature consistent with economy in obtaining it.

MOISTURE is always present in air. When present in compressed air it tends to promote freezing where the air is used in driving reciprocating mechanisms, due to the expansion of the air in doing work. To eliminate this as a source of annoyance, it is advisable to make provision for the removal of moisture.

The higher the temperature the more moisture-absorbing capacity the air will have. Cooling of air, while effecting a reduction in its volume, also causes moisture in the air to be thrown off. To provide for the reception and removal of this moisture most compressor builders supply a moisture trap.

Piston Displacement. This is the volume swept through by the piston in the compressing cylinder. It is an arbitrary term employed for rating compressors. It is somewhat ambiguous, in that compressors of different manufacture, having the same cylinder areas, do not give the same amount of delivered compressed air due to their differences of design in essential details.

Delivered Capacity. The actual volume of free air at atmospheric pressure delivered. This represents the true capacity of a machine.

Selecting the Air Compressor. As the efficient application of compressed air and its economical use are largely dependent upon the air compressor, its selection is a matter of prime importance.

Of equal importance is the proper installation of the compressor and transmission lines and the discussion which follows is to give a more intimate acquaintance with compressor types and their details, as well as hints on foundation building and the general transmission question, based on the experience of the foremost builders of compressed air equipment.

The Cost of Compressed Air. The cost of compressed air for whatever purpose and however produced, involves three separate items; first, fixed charges such as interest on the investment and depreciation; second, cost of operation; third, cost of maintenance.

All three are fundamentally dependent upon the air compressor's design and construction. While it is true that a low first cost may reduce the element of initial investment, it will on the other hand increase the other two items, cost of operation and cost of maintenance. A cheap price can obtain only a cheap design and construction of but temporary value and having therefore a limited earning power. If low operating cost is to be realized the compressor best adapted to the conditions under which it is to work should be selected. Maintenance cost is mainly a question of materials and workmanship, and here again a saving in initial cost is more than likely to mean an ultimate extravagance.

There are a great many makes of air compressors and a wide range of sizes and types to choose from. In choosing, the inexperienced buyer should be guided by precedent, as the weight of judgment recognizes precedent as one of the safest guides in reaching a decision.

In addition to the consideration of initial, operating and maintenance costs, is the one of conditions under which the compressor is to operate; this latter will determine largely the matter of pressure, capacity and method of drive.

Compressor Types. Compressed air is a power-transmitting agency and must therefore derive its power from some prime power device, such as the steam engine, the electric motor, gas or gasoline engine, oil engine or water impulse wheel. In this respect the method of obtaining compressed air compares with that of generating electric current.

As a result of the varied means of drive employed, compressor manufacturers make provision for all power conditions, and the selection of the air compressor in this respect will depend upon individual conditions.

Classification of Air Compressors by Drive. The air compressor may be classified according to the means of drive as follows:

- Power-Driven
  - Long-Belted to
    - Line shaft
    - Gasoline engine
    - Gas engine
    - Oil engine
    - Electric motor
  - Short-Belted to
    - Electric motor
    - Gasoline engine
    - Gas engine
    - Oil engine
  - Direct Connected to
    - Electric motor
    - Gasoline engine
    - Gas engine
    - Oil engine
    - Water wheel or turbine
  - Geared to Motor
  - Chain Driven by Motor

Steam Driven
- Long-Belted to Steam Engine
- Short-Belted to Steam Engine
- Direct-Connected to
  - Steam engine
  - Steam turbine

Where power is already at hand by belting from line shaft or where cheap current is available by belting to electric motor, obviously it is more convenient to employ either one of these types of drive and the initial cost of equipment will be less than if a direct steam engine-driven machine were installed with its call for boiler power.

Fig. 1—The 'long-belted' type of air compressor drive. This shows a duplex two-stage machine.

In a great many factories an abundant supply of steam is available and this therefore must constitute the controlling factor in making a choice of the type of drive.

For the isolated plant or for semi-permanent installation, as well as for portable duty, the oil or gasoline engine-driven types have merits not possessed by any of the others. They constitute a source of cheap power supply and represent a decided saving in operating cost.

For the large installation, demanding the very highest refinement of design, economy and efficiency of operation, either the

Corliss steam-driven, drop valve steam-driven or direct connected to motor type is essential.

Where unusually large capacity is wanted and floor space is limited it may even be advisable to resort to the turbo type of compressor. This latter machine has reached a very high state of perfection and there are a number of manufacturers in the field in position to supply them, either driven by mixed or live steam turbine or coupled to electric motor.

In the chart covering classifications of air compressor drives is mentioned under 'power-driven', the 'long-belted' to engine type (gas, gasoline or oil), and the 'short-belted' to engine type (gas, gasoline or oil); these types of drive are generally supplied to meet special requirements or where the prime power mover is already at hand; they are the exceptions rather than the rule.

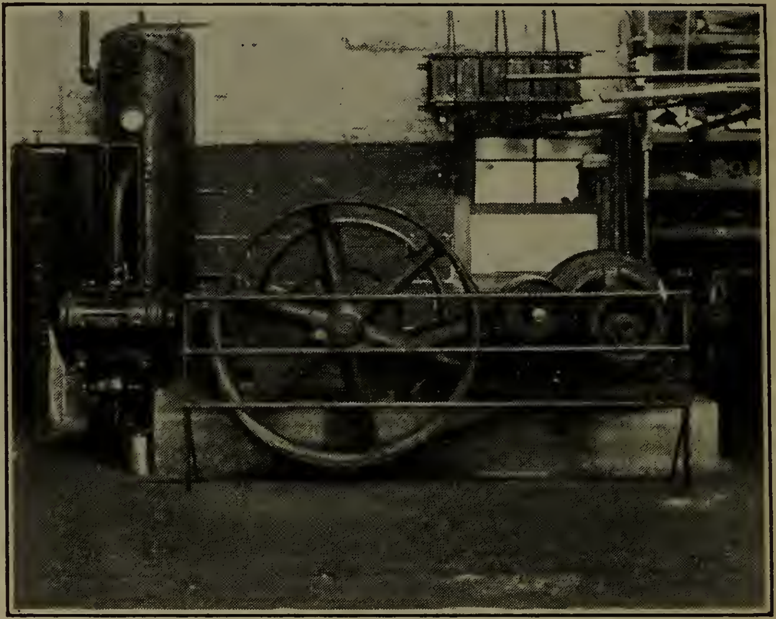


Fig. 2—The 'short-belted' type of air compressor drive. This shows a straight-line, single-stage machine.

The same thing may be said of the 'long-' and 'short-belted' to steam-engine division under steam-driven types.

The term 'long-belted' type is applied to a method of drive in which a belt is employed and the driver and the driven portions of the equipment are at a distance from one another, as shown in Fig. 1. The term 'short-belted' type is applied to a method of drive in which the two units are coupled close by a belt and an idler employed to obtain belt contact, as shown in Fig. 2.

The latter method of drive has certain peculiar advantages over the former, and these are explained at some length.

Fig. 3 illustrates the ordinary belt drive in which the distance between centers of pulleys must be sufficient to give a reasonable arc of belt contact on the motor pulley. With this type of drive the arc of contact rarely exceeds 170 degrees. Fig. 4 shows an arrangement sometimes resorted to if the first arrangement fails to work satisfactorily. This consists of a tightener pulley 'C' placed between the pulleys 'A' and 'B' and held firmly against the belt. While this increases the arc of contact on the motor pulley to between 185 and 190 degrees, it has an undesirable effect on the belt in that it increases its tension.

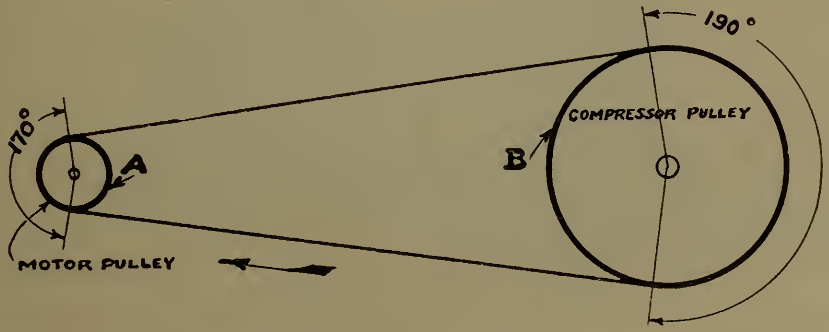


Fig. 3—The ordinary 'long-belt' drive.

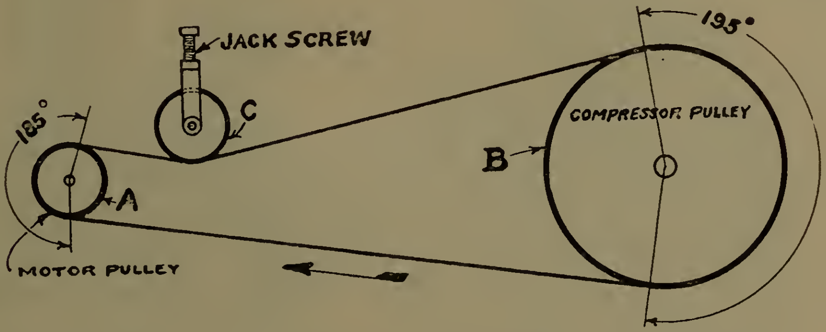


Fig. 4—The ordinary 'long-belt' drive employing a belt tightener.

Fig. 5 shows the so-termed 'Short-Belt Drive'. This, it will be noted, consists of a driving pulley, 'A', a driven pulley, 'B,' and a floating idler, 'C', the latter being placed on the slack side of the belt close to the driving pulley; the idler pulley being carried on swinging arms, is free to rise and fall, or in other words, to float on the belt.

This pulley, while light, has sufficient weight to enable it to take up the slack and hold the belt against the driving pulley. In operation, when the tension on the tight side of the belt increases and lengthens the slack side, the idler pulley descends upon the increased slack and wraps the belt further around the driving pulley, thus still further increasing the arc of contact. This entire operation is one of increasing belt contact without additional belt tension.

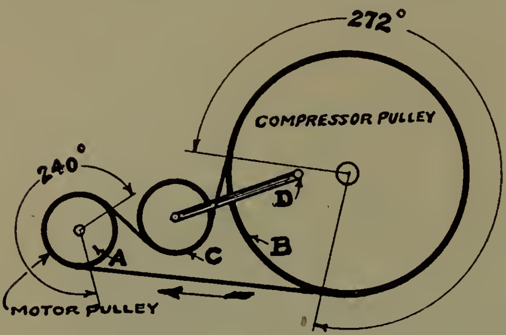


Fig. 5—The Imperial 'short-belt' drive.

Most belt transmission losses come from slippage or from excessive tension. These conditions are eliminated with the short-belt drive as there is no initial belt tension and but very little opportunity for slippage. When the motor is stopped there is no strain on the belt and while in motion there is only the strain of the effort.

Fig. 6—A vertical compressor arranged for long-belting. This particular compressor is equipped with a reservoir water head for cooling the air cylinder. It is a single-stage machine.

COMPRESSOR DESCRIPTIONS

Vertical Compressors. In Fig. 6 is shown a compressor of the vertical type arranged for long-belt driving. This design of compressor is generally confined to small sizes having single-stage compressing cylinders. They range in capacities up to about 50 cubic feet of free air per minute, piston displacement; pressures run between 60 and 125 pounds. See Table I. They are rarely built steam-driven and are commonly seen short-belted to electric motor or direct-con-

Fig. 7 — A vertical compressor 'short-belt' motor-driven. The compressor is arranged for cylinder cooling by circulating water.

nected by flexible coupling to gasoline engines, as shown in Figs. 7 and 8. See Table II.

Fig. 8—A vertical air compressor direct-connected by flexible coupling to a vertical gasoline engine,

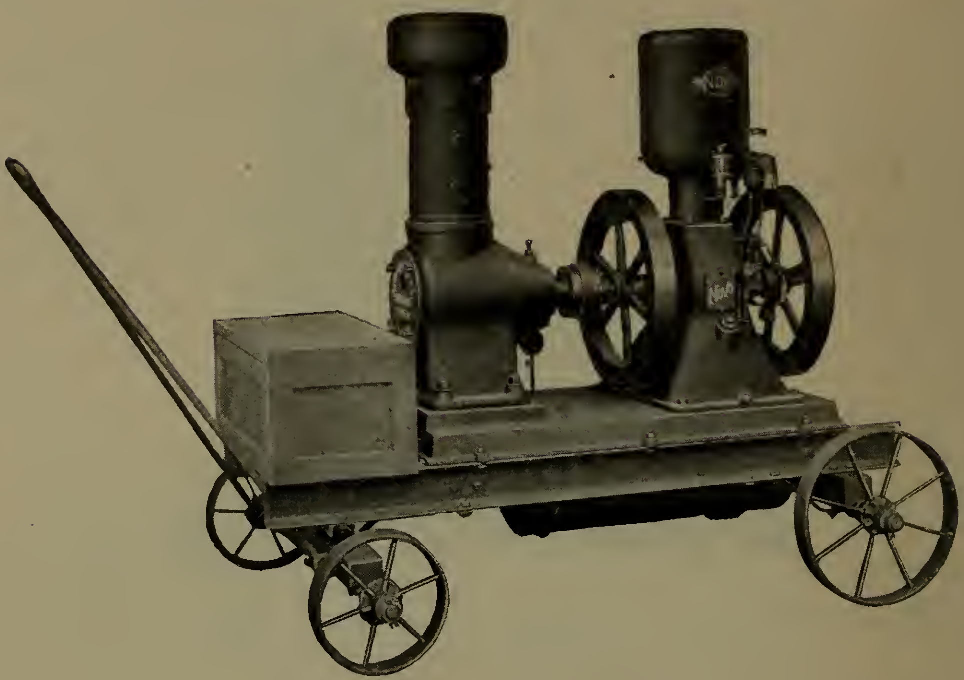


Fig. 9—A portable vertical air compressor.

Manufacturers furnish them with either air-cooled, circulating water-cooled, or reservoir head-cooled cylinders.

Air-cooled compressors should be employed only for work of an intermittent character; the other two classes, however, may be employed for general all-around work within their capacities.

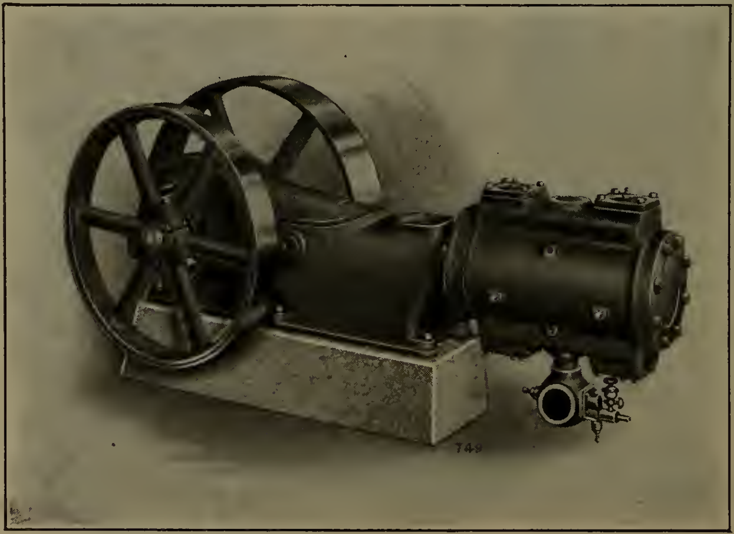


Fig. 10—A straight-line power-driven, single-stage air compressor arranged for 'long-belting' from line shaft, electric motor, or other prime mover.

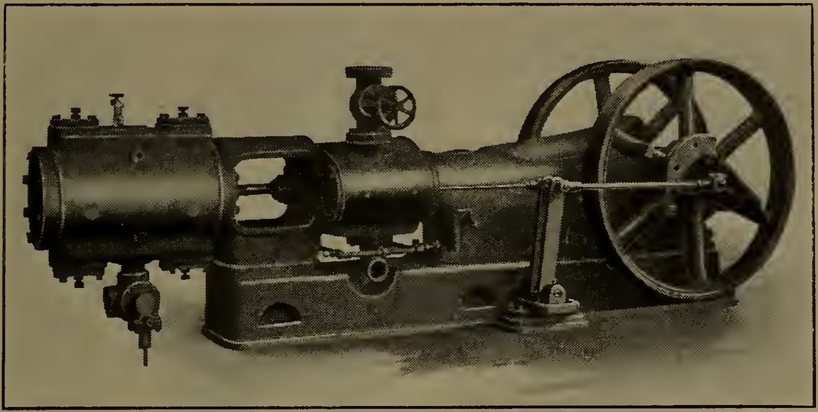


Fig. 11—A straight-line, direct-coupled, steam engine-driven air compressor. The engine is of the piston valve type. The valve is driven through the medium of a rocker arm off a crank pin located in the hub of one of the fly-wheels.

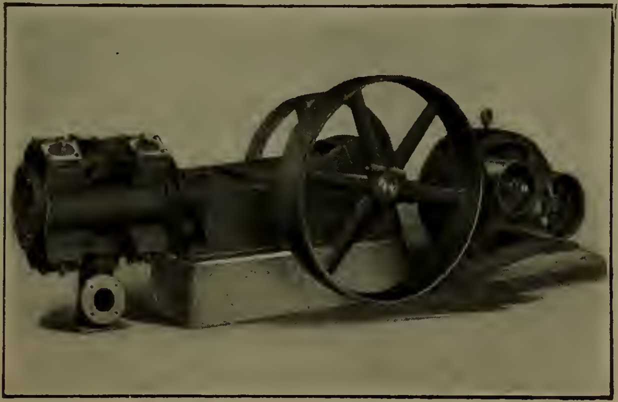


Fig. 12 — The straight-line 'short-belt' electric motor-driven air compressor.

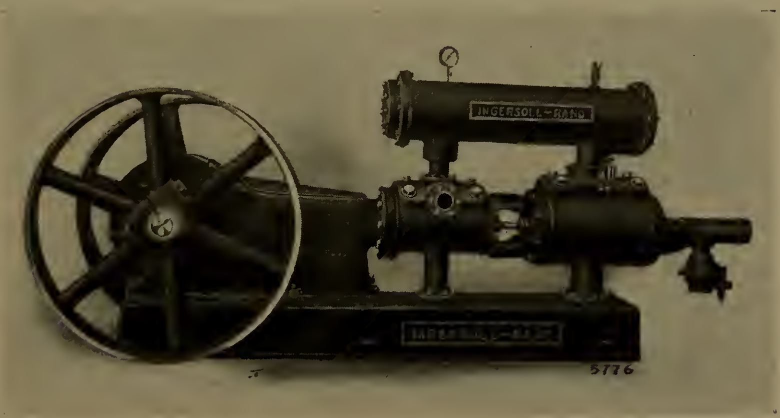


Fig. 13—Straight-line, two-stage, power-driven air compressor with overhead intercooler.

In Fig. 9 is shown a Portable Compressor of the vertical type. The principal advantage of the portable compressor around the shop is for yard use and cleaning purposes that do not justify the expense of installing a permanent air line.

Straight-Line Compressors. Fig. 10 is an illustration of a straight-line power-driven compressor arranged for long-belting and in Fig. 11 is shown a steam-driven compressor of the same class. The short-belt electric type is illustrated in Fig. 12.

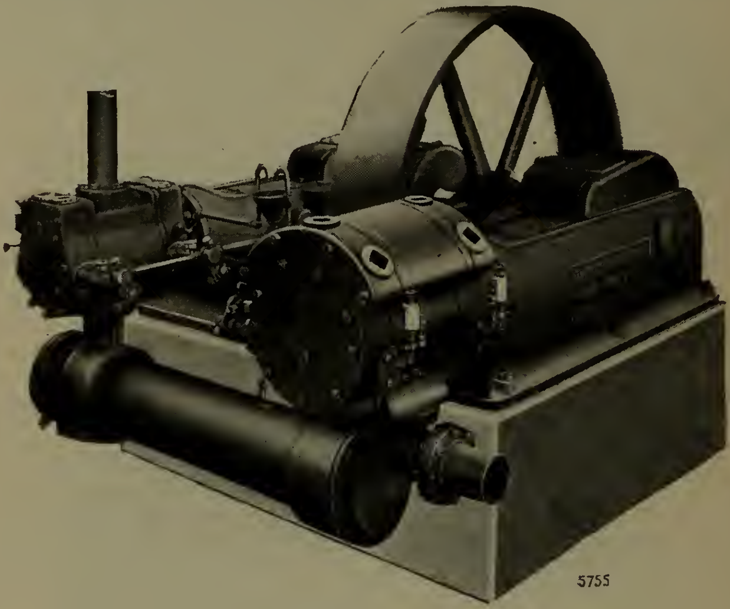


Fig. 14—Duplex, two-stage, power-driven air compressor arranged for 'long-belting' to electric motor or other prime mover.

All three depict single-stage, double-acting air compressors. Machines of this class range in capacities from 75 to 1,000 cubic feet of free air per minute piston displacement; and pressures up to 125 pounds. See Table III and Table IV.

The oil engine-driven type is shown in Table IX.

See Table X for straight-line steam-driven machines.

In Fig. 13 is shown a two-stage machine with intercooler. They are built in both power-driven and steam-driven types. The capacities range from 150 to 450 cubic feet of free air per minute piston displacement; pressure up to 500 pounds. This particular class of compressor is usually designated as a 'High-Pressure Compressor', and is also furnished in three- and sometimes four-stage construction for high-pressure duty.

These straight-line machines are equipped with automatic plate valves as described under the paragraph 'Valves' to follow. They are the ideal machines for the small shop or plant as they involve but low initial investment and embody a design of construction refined to such a degree as to make their use economical in the small plant.

Duplex Compressors. In Figs. 14, 15 and 16 are shown air compressors of the Duplex type 'Imperial' construction both long-belt and short-belt electric and Meyer, plain slide and piston valve steam-driven. These compressors range in capacities from 180 to 3,600 cubic feet of free air per minute piston displacement and pressures from 15 to 110 pounds. They are equipped with mechanical inlet valves and automatic outlet valves of the type referred to further on. See Table V, Table VI, Table VII, Table XI, Table XII, Table XIII, Table XIV, Table XV and Table XVI.

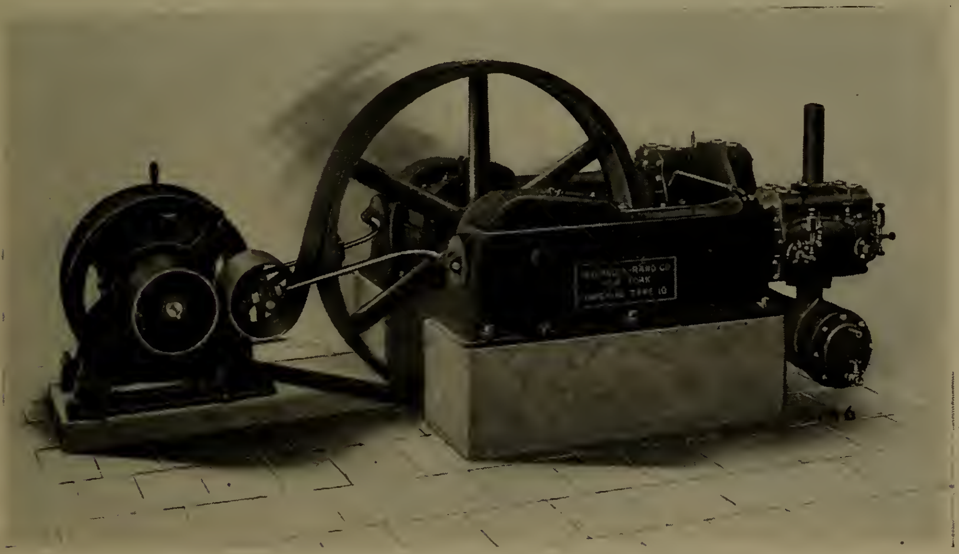


Fig. 15—Duplex, two-stage air compressor, 'short-belt' electric motor-driven.

This class of compressor is desirable for medium and fairly large capacities at low pressures only.

Manufacturers of such machines are prepared to furnish them in simple duplex, or compound two-stage construction. Steam cylinders may also be had—simple or compound. It will be noted that, unlike other duplex compressors, the steam machines

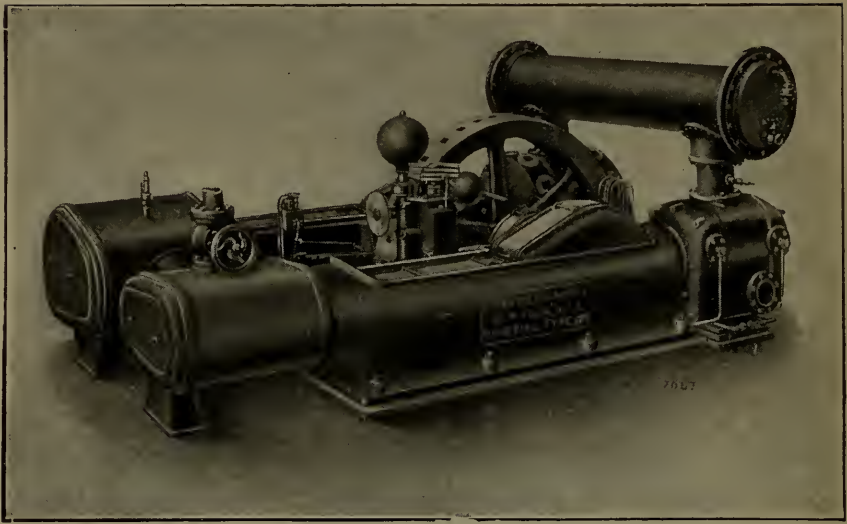


Fig. 16—Duplex, two-stage, direct-connected steam engine-driven air compressor showing steam engine which is of the automatic adjustable balanced piston valve type.

do not have the air and steam cylinders placed in tandem. They are placed at opposite ends of the driving frame.

Figs. 17 and 18 are illustrations of Corliss steam and drop valve engine-driven compressors, duplex type. In this class of compressor, employing a modification of the 'Tangye' frame, the cylinders are placed in tandem. They find their principal application in plants requiring a large volume of air and where the

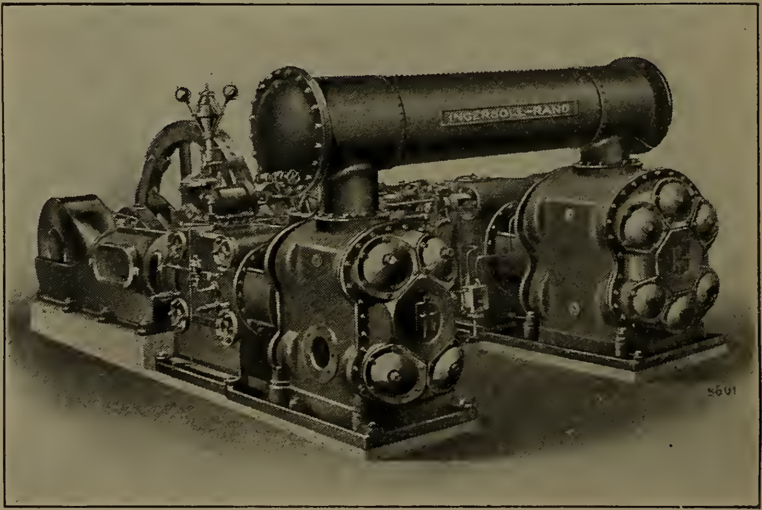


Fig. 17—Duplex, two-stage, Corliss steam engine-driven air compressor. In this type the air and steam cylinders are placed in tandem.

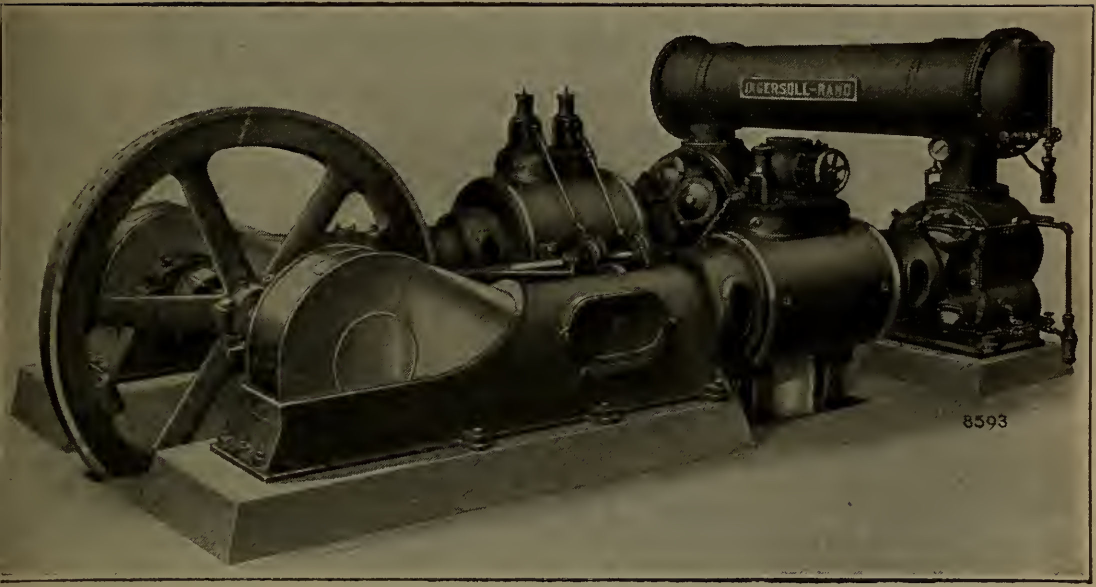


Fig. 18—Duplex, two-stage, drop valve steam engine-driven air compressor.

fuel conditions make it desirable to employ the most economical form of steam-driving engine.

See Table XVII and XVIII.

Cylinders for both steam and air are usually compounded and the compressor generally run condensing. They range in capacities from 3,500 to 10,000 cubic feet of free air per minute piston displacement; pressures from 80 to 125 pounds.

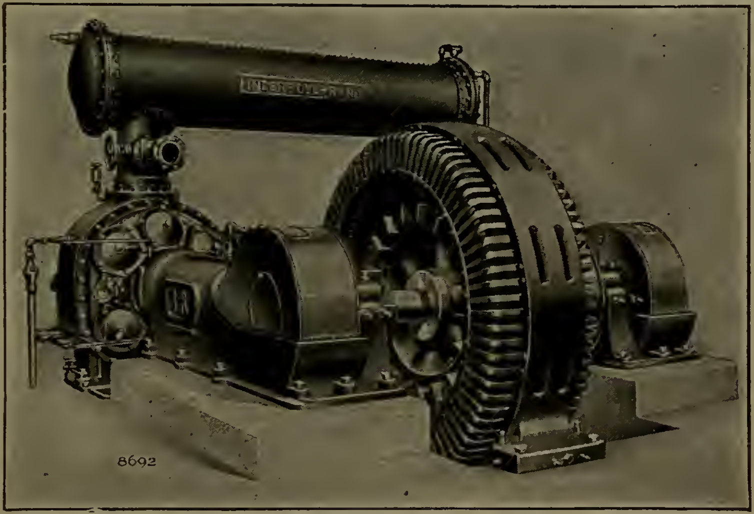


Fig. 19—Duplex, two-stage, direct-connected motor-driven air compressor.

Fig. 20—Steam turbine-driven turbo air compressor.

The Corliss steam engine of this type of compressor employs the familiar Corliss valve motion and, therefore, needs no extended description. The drop valve type, however, represents a comparatively new practice in this country and will, therefore, be described in some detail further on.

A duplex compressor direct connected to motor is shown in Fig. 19. The air end construction of this compressor has all the features embodied in the air ends of both the Corliss and drop valve machines. In fact, they are identical with one exception and that is in the provision made for regulation. The application of this type is principally where large capacity is desired and low cost electric current is available. This type of compressor generally ranges in capacities from 3,500 to 10,000 cubic feet of free air per minute piston displacement; pressures from 80 to 125 pounds. See Table VIII.

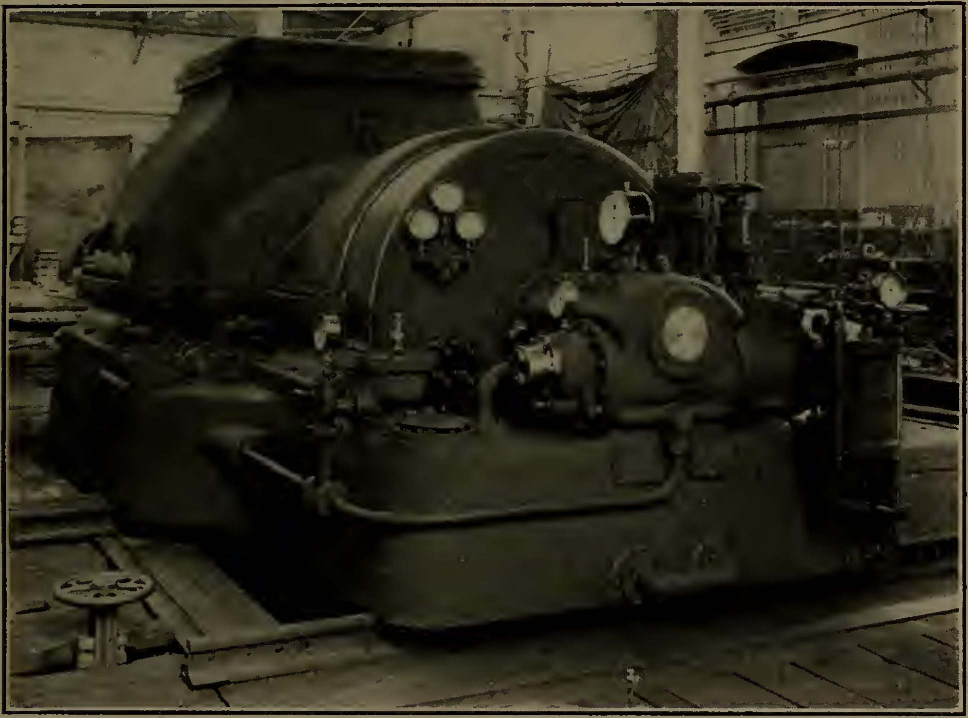


Fig. 21—Steam turbine-driven turbo blower.

High-Pressure Compressors. High-pressure compressors rarely find their application in the metal-working industry and will, therefore, not be discussed further than to state that in principle and operation they are identical with the types shown, being, however, of multi-stage construction.

Rotary Type. In Fig. 20 is shown a steam turbine-driven turbo air compressor designed for operation on mixed steam pressures. Such machines are also built for operation on live steam alone, as well as electric drive. They meet the demand for machines of large capacity, occupying the minimum floor space. In Fig. 21 is also shown a turbo blower for low-pressure work. These blowers can also be supplied with the various combinations of drive. The principal application of the turbo blower is in blast furnace and Bessemer converter work. They are also furnished for gas exhausting and in smaller units, such as is shown in Fig. 22 for cupola work, and for supplying blast to oil and gas heating and auxiliary furnaces.

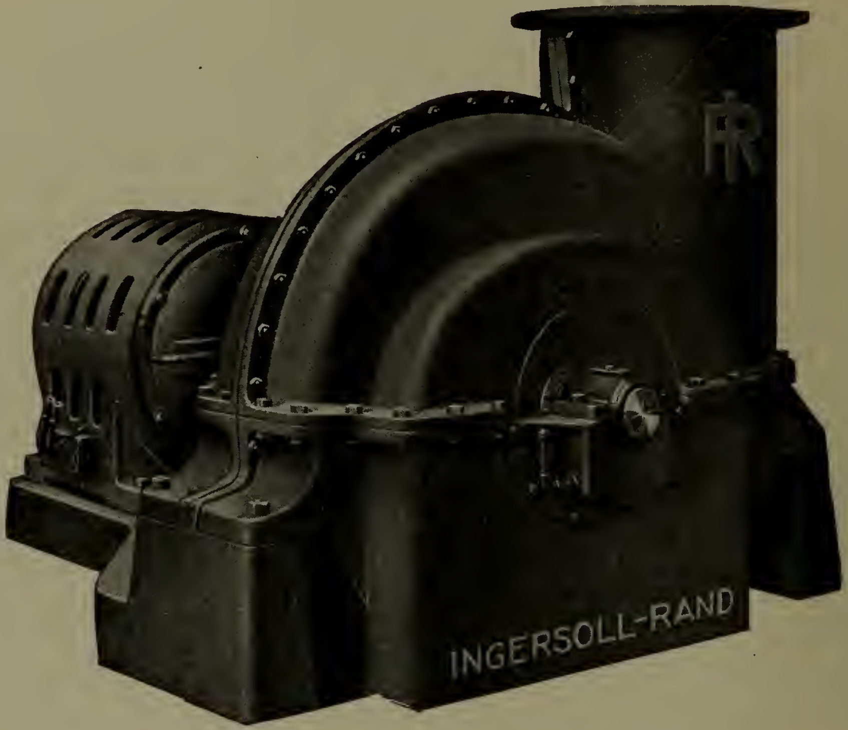


Fig. 22—Electric motor-driven low-pressure blower for cupola work, blowing furnaces, etc.

The rotary compressors range in capacities from 3,500 to 10,000 cubic feet per minute and pressures from 80 to 100 pounds. The blowers range in size from 3,000 to 60,000 cubic feet capacity per minute; pressures from 16 ounces to 30 pounds. The cupola blowers range in capacities from 3,000 to 40,000 cubic feet; pressures up to 1½ pounds.

TABLE I

VERTICAL SINGLE-ACTING POWER-DRIVEN COMPRESSORS

Size Cylinder Ins.		Speed Revolutions Per Minute	Piston Displacement Cu. Ft. Per Minute	B. H. P. Required at Belt Wheel				Belt Wheel Diameter and Face Ins.	Over-all Dimensions, Ins.			Height with Reservoir Cooler	Length with Tight and Loose Pulleys
				Minimum R. P. M.		Maximum R. P. M.							
Diam.	Stroke			60 Lbs. Air Pressure	100 Lbs. Air Pressure	60 Lbs. Air Pressure	100 Lbs. Air Pressure		Length	Width	Height Standard Cylinder		
2	2½	400–700	1.8–3.20	.5	.6	.85	1.	10x2½	14½	10	30	....	21
2½*	3	450–700	3.8–6.0	.76	.95	1.20	1.50	12x3	17	12	22½	29	22
3½	4	350–550	7.7–12.2	1.50	1.90	2.40	3.	16x4	19½	16	29	35	25
4½	5	325–500	14.9–23.0	2.75	3.60	4.20	5.50	20x5	22	20	37½	43½	28
6	6	300–450	29.5–44.2	5.3	6.8	7.7	10.	24x6½	28	24	45	51½	36½

* Either air or water-cooled cylinders.

Water-cooled types can be furnished with a reservoir in the cylinder head to hold enough water to last for several hours continuous operation. Any of these machines can be fitted with tight and loose pulleys.

Note: These machines weigh approximately 15 pounds per cubic foot of piston displacement for the larger units to 30 pounds for the small ones.

TABLE II
VERTICAL SHORT-BELT ELECTRIC-DRIVEN AIR COMPRESSOR UNITS

Compressor Size	Speed Revolutions per Minute	Piston Displacement Cu. Ft. Free Air Per Min.	Horse Power Required at 100 Lbs. Pressure	Over-all Dimensions, Ins.				Motor Equipment			
				Length	Width	Height with Standard Cyl.	Height with Reservoir Cooler	Alternating or Direct Current	Type and Phase	Voltage	Cycles
2 x 2½	700	3.2	1.0	29	18	22		A.C. A.C. D.C.	Single-Phase 2-3-Phase Squirrel Cage Compound Wound	110-220 110-220 -440 115-230	60 60
2½ x 3*	700	6.0	1½	31	19½	24	31	A.C. A.C. D.C.	Single-Phase 2-3-Phase Squirrel Cage Compound Wound	110-220 110-220 -440 115-230	60 60
3½ x 4	550	12.2	3	41	22½	31	37	A.C. A.C. D.C.	Single-Phase 2-3-Phase Squirrel Cage Compound Wound	110-220 110-220 -440 115-230	60 60
4½ x 5	450	21.0	5	45	26	40	46	A.C. A.C. D.C.	Single-Phase 2-3-Phase Squirrel Cage Compound Wound	110-220 110-220 -440 115-230	60 60
6 x 6	450	44.2	10	52	32	46	53	A.C. A.C.	Single-Phase 2-3-Phase Squirrel Cage	110-220 110 220-440	60 60 60
								A.C. D.C.	2-3-Phase Slip Ring Compound Wound	110-220 -440 115-230	60

Any of these machines larger than the 2 x 2½ size can be fitted with a reservoir in the cylinder head to hold enough water to last for several hours continuous operation.

*Both air- and water-cooled cylinder.

Note: The small units weigh about 87 pounds per cubic foot of piston displacement, and the large ones 40 pounds.

TABLE III

STRAIGHT-LINE LONG-BELT-DRIVEN AIR COMPRESSORS

Size of Cyl. Inches		Revolutions per Minute	Piston Displacement Cu. Ft. per Minute	Air Pressure		Brake Horse Power Required Including Belt Losses		Belt Wheel		Tight and Loose Pulley			Overall Dimensions Ft. and Ins.			Cu. Ft. in Foundation
Diameter	Stroke			Min.	Max.	Min. Pres.	Max. Pres.	Diameter, Inches	Face, Inches	Diameter, Inches	Face, Inches	Additional Weight, Pounds	Length, Ft.–Ins.	Width, Ft.–Ins.	Height from Floor, Ft.–Ins.	
6	6	275	52	80	125	6.7	7.1	36	5½	28	4	130	6–6	1–11	3–10	17
7	6	275	72	70	110	9.	10.	36	5½	28	4	130	6–7	1–11	3–10	17
8	6	275	94	40	70	10.	12.	36	5½	28	4	130	6–7	1–11	3–10	17
9	6	275	121	10	30	8.	11½	36	5½	28	4	130	6–9	1–11	3–10	17
8	8	250	113	80	125	17½	21	45	8½	39	6½	320	7–11	2–6¼	4–2½	27
9	8	250	145	70	100	21	24	45	8½	39	6½	320	8–1	2–6¼	4–2½	27
10	8	250	179	30	70	19	26	45	8½	39	6½	320	8–4	2–6¼	4–2½	27
12	8	250	258	15	30	16	24	45	8½	39	6½	320	8–2	2–6¼	4–2½	27
10	10	235	210	80	125	33	39	58	10½	48	8½	625	9–9	3–2¼	5–1	40
12	10	235	304	50	100	40	53	58	10½	48	8½	625	9–5	3–2¼	5–1	40
14	10	235	415	20	50	31	52	58	10½	48	8½	625	9–8	3–2¼	5–1	40
12	12	220	340	80	125	56	62	72	14½	....	.....	.....	11–0	4–1¾	6–3	69
14	12	220	464	45	100	58	79	72	14½	....	.....	.....	11–3	4–1¾	6–3	69
17	12	220	688	30	40	69	79	72	14½	....	.....	.....	11–4	4–1¾	6–3	69

Six-, eight- and ten-inch stroke size can be furnished with the tight and loose pulleys.

Note: These machines weigh approximately 15 pounds per cubic foot of piston displacement for the larger units to 20 pounds for the small ones.

TABLE IV

STRAIGHT-LINE SHORT-BELT ELECTRIC AIR COMPRESSOR UNITS

Cylinders, Ins.		Piston Displacement Cu. Ft. Per Min.	Maximum Rating		Motor	Volts	Electrical Horse Power Input to Motor	Motor R. P. M.	Full Load Motor Power Factor	Approximate Floor Space Ft. and Ins.		
Diam.	Stroke		Max. Pres.	H.P.						Length	Width	Height
6	6	52	125	7.15	DC	230	8.5	1,700		10–4	3–6	3–10
					AC	220–440	8.5	1,700	85			
7	6	72	100	10	DC	230	11.6	1,700		10–4	3–6	3–10
					AC	220–440	11.9	1,700	84			
8	6	94	70	12	DC	230	14.2	1,700		10–4	3–6	3–10
					AC	220–440	14.5	1,700	86			
9	6	121	30	11.5	DC	230	13.6	1,700		10–4	3–6	3–10
					AC	220–440	13.8	1,700	86			
8	8	113	125	21	DC	230	24.2	1,500		12–0	4–3	4–2½
					AC	220–440	24.8	1,150	88			
					AC	2,200	25	1,150	88			
9	8	145	100	24	DC	230	27.6	1,500		12–0	4–3	4–2½
					AC	220–440	28.2	1,150	88			
					AC	2,200	28.6	1,150	88			
10	8	179	70	26	DC	230	30	1,500		12–0	4–3	4–2½
					AC	220–440	30.6	1,150	88			
					AC	2,200	31	1,150	88			
12	8	258	30	24	DC	230	27.6	1,500		12–0	4–3	4–2½
					AC	220–440	28.2	1,150	88			
					AC	2,200	28.6	1,150	88			
10	10	210	125	39	DC	230	44.5	1,500		14–5	5–0	5–1
					AC	220–440	44.5	1,150	86			
					AC	2,200	45	1,150	83			
12	10	304	100	53	DC	230	60.5	1,500		14–5	5–0	5–1
					AC	220–440	60	1,150	84			
					AC	2,200	60.5	1,150	85			
14	10	415	50	52	DC	230	59	1,500		14–5	5–0	5–1
					AC	220–440	58.5	1,150	84			
					AC	2,200	59	1,150	85			
12	12	340	125	62	DC	230	70.5	1,200		16–9	6–3	6–3
					AC	220–440	70	1,150	85			
					AC	2,200	70.5	1,150	87			
14	12	464	100	79	DC	230	88	975		16–9	6–3	6–3
					AC	220–440	88	1,150	89			
					AC	2,200	88	1,150	89			
17	12	688	40	79	DC	230	88	975		16–9	6–3	6–3
					AC	220–440	88	1,150	89			
					AC	2,200	88	1,150	89			

Note: The small units weigh about 30 pounds per cubic foot of piston displacement and the large ones 25 pounds.

TABLE V—DUPLEX LONG-BELTED AIR COMPRESSORS—Single-Stage

Cyls. Ins.		Flexible Rating														Belt Wheel		Floor Space Ft. and Ins.			Approximate Cu. Ft. Contents in Foundation
Diam. Each Duplex Air Cyl.	Stroke	R. P. M.			Piston Displacement, Cu. Ft. Per Minute			Air Press.		Brake Horse Power Required at Belt Wheel of Compressor at Pres. Given						Diameter Inches	Face, Inches	Length	Width	Height, Above Floor	
										Minimum Air Pressure			Maximum Air Pressure								
		Min.	Stan.	Max.	Min.	Stan.	Max.	Min.	Max.	Min.	Stan.	Max.	Min.	Stan.	Max.						
7	10	200	215	225	176	189	198	60	100	24	26	27	33	35	37	54	10½	7–6	5–0	5–2	108
8	10	200	215	225	229	246	258	40	55	26	28	29	31	33	35	54	10½	7–6	5–0	5–2	108
9	10	200	215	225	290	312	327	27	35	24	26	27	30	32	34	54	10½	7–8	5–1	5–2	108
10	10	200	215	225	360	386	405	22	25	26	28	29	29	32	33	54	10½	7–8	5–1	5–2	108
11	10	200	215	225	436	469	491	15	20	25	27	28	31	33	35	54	10½	7–8	5–1	5–2	108
8	12	190	200	210	262	275	289	75	100	43	45	47	50	53	55	60	12½	8–2	5–3	5–7	162
9	12	190	200	210	332	349	367	55	70	45	48	50	52	55	58	60	12½	8–2	5–3	5–7	162
10	12	190	200	210	411	433	454	40	50	46	49	51	52	55	58	60	12½	8–4	5–5	5–7	162
11	12	190	200	210	497	523	549	27	35	42	44	46	52	54	57	60	12½	8–4	5–5	5–7	162
12	12	190	200	210	593	624	655	22	25	43	45	47	49	51	54	60	12½	8–4	5–5	5–7	162
13	12	190	200	210	697	734	770	15	20	40	42	44	50	53	55	60	12½	8–5	5–7	5–7	162
9	12	190	200	210	331	348	365	85	100	56	59	62	63	66	69	72	12½	9–7	5–10	6–1	189
10	12	190	200	210	410	432	453	60	80	58	61	64	68	72	75	72	12½	9–7	5–10	6–1	189
11	12	190	200	210	497	523	549	47	55	60	63	66	67	71	74	72	12½	9–7	5–10	6–1	189
12	12	190	200	210	592	623	654	37	45	61	64	67	71	75	78	72	12½	9–9	6–0	6–1	189
13	12	190	200	210	696	732	769	25	35	57	60	63	73	77	78	72	12½	9–9	6–0	6–1	189
15	12	190	200	210	927	976	1,025	15	20	52	55	58	65	69	72	72	12½	9–9	6–1	6–1	189
11	14	165	175	185	502	533	563	80	100	84	89	94	95	100	106	84	16½	10–10	7–4	6–9	297
12	14	165	175	185	598	634	671	60	75	85	80	95	96	102	108	84	16½	10–10	7–4	6–9	297
13	14	165	175	185	704	747	789	45	55	84	89	94	95	100	106	84	16½	11–0	7–6	6–9	297
14	14	165	175	185	816	866	916	35	40	85	90	93	91	97	102	84	16½	11–0	7–6	6–9	297
16	14	165	175	185	1,068	1,133	1,198	25	30	89	94	99	100	106	112	84	16½	11–0	7–6	6–9	297
18	14	165	175	185	1,354	1,436	1,518	15	20	78	82	87	96	102	108	84	16½	11–1	7–10	6–9	297
13	16	150	160	170	728	778	826	80	100	119	127	135	136	145	154	96	20½	12–4	8–2	7–9	378
14	16	150	160	170	847	903	959	65	75	125	134	142	137	146	155	96	20½	12–4	8–2	7–9	378
15	16	150	160	170	973	1,038	1,103	45	60	114	121	129	137	146	155	96	20½	12–4	8–2	7–9	378
17	16	150	160	170	1,251	1,335	1,419	30	40	114	121	129	140	149	158	96	20½	12–6	8–4	7–9	378
19	16	150	160	170	1,567	1,671	1,775	20	25	109	116	123	128	137	145	96	20½	12–6	8–4	7–9	378
21	16	150	160	170	1,915	2,043	2,171	15	20	111	119	126	139	148	157	96	20½	12–8	8–8	7–9	378
15	16	150	160	170	971	1,036	1,100	80	100	160	171	181	182	194	206	96	28½	12–10	8–2	8–4	486
16	16	150	160	170	1,105	1,179	1,253	55	75	166	177	188	178	190	202	96	28½	12–10	8–2	8–4	486
18	16	150	160	170	1,405	1,498	1,592	35	50	142	152	161	181	193	205	96	28½	13–0	8–4	8–4	486
21	16	150	160	170	1,914	2,041	2,168	25	30	156	167	177	178	190	202	96	28½	13–0	8–6	8–4	486
24	16	150	160	170	2,502	2,670	2,836	15	20	143	153	162	178	190	202	96	28½	13–1	8–10	8–4	486
15	20	135	145	155	1,090	1,172	1,254	75	100	172	185	197	202	217	232	108	31½	14–11	9–0	8–9	648
17	20	135	145	155	1,406	1,510	1,615	50	70	178	191	204	219	235	251	108	31½	14–11	9–0	8–9	648
19	20	135	145	155	1,760	1,890	2,020	35	45	187	200	214	211	226	242	108	31½	15–1	9–4	8–9	648
22	20	135	145	155	2,362	2,638	2,714	25	30	194	208	223	222	238	255	108	31½	15–1	9–4	8–9	648
25	20	135	145	155	3,058	3,282	3,508	15	20	177	190	203	220	237	253	108	31½	15–2	9–8	8–9	648

Note: These machines weigh approximately 15 pounds per cubic foot of piston displacement for the larger units to 20 pounds for the small ones.

TABLE VI
DUPLEX LONG-BELTED AIR COMPRESSORS
TWO-STAGE AIR CYLINDERS

Cylinders, Ins.			R. P. M.	Piston Displacement Cubic Feet per Minute	Brake Horse Power Required at Belt Wheel of Compressor at Pressures Given				Belt Wheel		Floor Space Ft. and Ins.			Approximate Cubic Feet in Foundation
Diam.														
Low-Pressure	High-Pressure	Stroke			80	90	100	110	Diameter, Ins.	Face, Ins.	Length	Width	Height above Floor	
											SEA LEVEL			
10	6½	10	200	180	28	30	32	33	54	10½	7–8	5–3	5–2	108
			215	194	30	32	34	36						
			225	203	32	34	36							
12	7½	12	190	296	46	49	51	54	60	12½	8–4	5–7	5–7	162
			200	311	48	51	54	56						
			210	327	50	54	57							
14	9	12	190	404	62	66	69	73	72	12½	9–9	6–1	6–1	189
			200	425	65	69	73	76						
			210	446	68	73	76							
16	10	14	165	534	82	88	93	97	84	16½	11–0	7–8	6–9	297
			175	567	87	93	98	103						
			185	599	92	98	104							
19	12	16	150	783	120	127	134	140	96	20½	12–6	8–9	7–9	378
			160	835	128	136	143	250						
			170	888	135	144	152							
22	13	16	150	1,051	163	173	183	191	96	28½	13–0	9–2	8–4	486
			160	1,121	173	184	195	203						
			170	1,190	183	196	206							
23	14	20	135	1,292	197	209	222	232	108	31½	15–1	9–11	8–9	648
			145	1,388	212	226	238	250						
			155	1,482	226	241	254							

Note: The small units weigh about 30 pounds per cubic foot of piston displacement and the large ones 20 pounds.

									5,000-FT. ALTITUDE					
11	6½	10	200 215 225	218 235 246	31 33 35	33 35 37	34 37 39	36 39	54	10½	7–8	5–3	5–2	108
13	7½	12	190 200 210	348 367 385	48 51 54	51 54 57	54 57 60	56 59	60	12½	8–5	5–8	5–7	162
15	9	12	190 200 210	464 488 513	64 67 71	68 71 75	71 75 79	75 78	72	12½	9–9	6–4	6–1	189
17	10	14	165 175 185	604 640 677	84 89 94	89 94 100	94 99 105	98 104	84	16½	11–0	7–11	6–9	297
20	12	16	150 160 170	868 926 984	120 128 136	127 135 144	133 142 151	139 148	96	20½	12–7	8–10	7–9	378
23	13	16	150 160 170	1,149 1,225 1,302	158 169 179	168 179 190	176 188 200	184 197	96	28½	13–0	9–2	8–4	486
24	14	20	135 145 155	1,407 1,512 1,616	194 208 222	205 220 235	216 232 248	226 242	108	31½	15–1	9–11	8–9	648
									10,000-FT. ALTITUDE					
12	6½	10	200 215 225	260 279 293	33 36 38	35 38 40	37 40 42	39	54	10½	7–10	5–4	5–2	108
14	7½	12	190 200 210	404 426 447	51 54 57	54 57 60	57 60 63	59 63	60	12½	8–7	5–9	5–7	162
16	9	12	190 200 210	528 556 584	66 70 73	70 74 77	73 77 81	76 80	72	12½	9–11	6–5	6–1	189
18	10	14	165 175 185	677 718 759	86 91 96	91 96 101	95 101 107	100 105	84	16½	11–1	7–11	6–9	297
21	12	16	150 160 170	958 1,022 1,085	120 128 136	126 135 143	133 142 150	139 148	96	20½	12–8	8–11	7–9	378
24	13	16	150 160 170	1,251 1,335 1,418	157 167 177	165 177 187	173 185 197	181 194	96	28½	13–1	9–4	8–4	486
25	14	20	135 145 155	1,528 1,641 1,754	191 206 220	203 217 232	212 228 243	222 238 254	108	31½	15–2	10–1	8–9	648

TABLE VII

SHORT-BELT ELECTRIC UNITS Duplex Two-stage Type

Cylinders Ins. Diam.			R. P. M.	Piston Displacement in Cu. Ft. Per Minute	Brake Horse Power Required at Belt Wheel of Compressor at Air Pressures Given				Approximate Floor Space with Motor Ft. and Ins.		Approx. Cu. Ft. in Foundation	A. C. or D. C.	Volts	Phase	Cycles	R. P. M.	Motor Pulley for Compressor Speed 225 R. P. M.		Electric H. P. Input to Motor	
L. P.	H. P.	Stroke			80	90	100	110	L' gth	Width							Diam. Ins.	Face Ins.	Full Load Comp. Speed 225 R. P. M. Air Pressure 110 Lbs. Gauge	Unloaded Comp. Speed 225 R. P. M.
10	6½	10	200 215 225	180 194 203	28 30 32	30 32 34	32 34 36	33 36	11–9	5–7	135	DC	230			1,500	8¼	9	41.5	7.5
												DC	230			1,500	8¼	9	42	7.6
												AC	220 or 440	2 or 3	60	1,140	10½	9	41	7.5
												AC	220 or 440	2 or 3	60	1,140	10½	9	41.5	7.5
												AC	2,200	2 or 3	60	1,160	10½	9	41.7	7.6
												AC	2,200	2 or 3	60	1,160	10½	9	42	7.6
12	7½	12	190 200 210	296 311 327	46 48 50	49 51 54	51 54 57	54 56	12–6	6–2	200	DC	230			1,150	10½	10½	64.3	11.5
												DC	230			1,025	12½	10½	65.6	11.6
												AC	220 or 440	2 or 3	60	1,150	10¾	10½	64	11.4
												AC	220 or 440	2 or 3	60	1,150	10¾	10½	65	11.7
												AC	2,200	2 or 3	60	1,150	10¾	10½	65	11.7
												AC	2,200	2 or 3	60	1,150	10¾	10½	65.8	12
14	9	12	190 200 210	404 425 446	62 65 68	66 69 73	69 73 76	73 76	14–10	6–6	235	DC	230			1,150	13½	14	85.8	15.7
												DC	230			975	15¼	14	85.7	15.6
												AC	220 or 440	2 or 3	60	1,150	13½	14	84.6	15
												AC	220 or 440	2 or 3	60	1,150	13½	14	85.8	15.7
												AC	2,200	2 or 3	60	1,150	13½	14	88.5	16.0
												AC	2,200	2 or 3	60	1,150	13½	14	88.5	15.7
16	10	14	165 175 185	534 567 599	82 87 92	88 93 98	93 98 104	97 103	16–6	8–0	370	DC	230			800	19½	16½	116.8	20.5
												DC	230			925	17	16½	117.3	21.0
												AC	220 or 440	2 or 3	60	870	18	16½	117.	21.0
												AC	220 or 440	2 or 3	60	870	18	16½	117.3	21.0
												AC	2,200	2 or 3	60	860	18	16½	117	21.0
												AC	2,200	2 or 3	60	860	18	16½	120.5	22.0
19	12	16	150 160 170	783 835 888	120 128 135	127 136 144	134 143 152	140 150	18–9	9–2	470	DC	230			700	23	20½	168.7	30.4
												DC	230			720	23	20½	171.5	31
												AC	220 or 440	2 or 3	60	690	23½	20½	166	30
												AC	220 or 440	2 or 3	60	690	23½	20½	169	30.4
												AC	2,200	2 or 3	60	690	23½	20½	167.5	30
												AC	2,200	2 or 3	60	690	23½	20½	169.5	30.5
22	13	16	150 160 170	1,051 1,121 1,190	163 173 183	173 184 196	183 195 206	191 203	20–8	10–0	610	DC	230			600	27	28½	226	41
												DC	230			600	27	28½	231	41.7
												AC	220 or 440	2 or 3	60	575	28	28½	234	42.5
												AC	220 or 440	2 or 3	60	575	28	28½	232	42
												AC	2,200	2 or 3	60	580	28	28½	232	42
												AC	2,200	2 or 3	60	580	28	28½	231	41.7

Note: These machines weigh approximately 25 pounds per cubic foot of piston displacement for the larger units to 40 pounds for the small ones.

TABLE VIII

DIRECT-CONNECTED ELECTRICALLY DRIVEN TWO-STAGE AIR COMPRESSORS

Cylinder, Ins.			R. P. M.	Piston Displacement, Cu. Ft. Per Minute	Motor Brake Horse Power Full Load	Floor Space with Motor, Ft. and Ins.			Cubic Feet in Foundation
Low-Pressure	High-Pressure	Stroke				Length	Width	Height	
SEA-LEVEL MEDIUM DUTY—AIR PRESSURE OF 90–100 LBS.									
20	12½	14	257	1,302	211–220	11–9	11–9	7–2	750
22	14	16	225	1,574	250–261	14–3	12–6	7–3	900
25	15¾	18	200	2,033	316–332	15–6	13–6	8–0	1,150
28	17½	21	180	2,678	413–432	18–0	16–0	10–6	1,700
32	20¼	24	163.5	3,631	563–588	19–9	18–0	11–6	2,000
37	23	27	150	5,011	735–771	25–0	19–0	12–3	2,800
40	25½	30	138.5	5,967	937–981	29–3	20–0	12–9	4,700
44	28	36	120	7,505	1122–1178	30–9	26–0	15–10	5,200
SEA-LEVEL HIGH DUTY—AIR PRESSURE OF 100–115 LBS.									
19	11½	14	257	1,173	187–199	11–9	11–9	7–2	750
21	13	16	225	1,433	226–240	14–3	12–6	7–3	900
24	14½	18	200	1,873	292–310	15–6	13–6	8–0	1,150
27	16½	21	180	2,480	385–410	18–0	16–0	10–6	1,700
30	18½	24	163.5	3,189	492–520	19–9	18–0	11–6	2,000
35	21½	27	150	4,482	654–694	25–0	19–0	12–3	2,800
38	23½	30	138.5	5,378	845–895	29–3	20–0	12–9	4,700
42	26	36	120	6,829	1022–1085	30–9	26–0	15–10	5,200
5000-FT. ALTITUDE MEDIUM DUTY—AIR PRESSURE OF 90–100 LBS.									
21	12¾	14	257	1,435	213–223	11–9	11–9	7–2	750
23	14	16	225	1,721	246–258	14–3	12–6	7–3	900
26	15¾	18	200	2,195	309–324	15–6	13–6	8–0	1,150
29	17½	21	180	2,874	402–418	18–0	16–0	10–6	1,700
34	20¼	24	163.5	4,102	575–601	19–9	18–0	11–6	2,000
39	23	27	150	5,576	736–771	25–0	19–0	12–3	2,800
42	25½	30	138.5	6,586	943–985	29–3	20–0	12–9	4,700
46	28	36	120	8,212	1117–1168	30–9	26–0	15–10	5,200
5000-FT. ALTITUDE HIGH DUTY—AIR PRESSURE OF 100–115 LBS.									
20	11¾	14	257	1,302	192–202	11–9	11–9	7–2	750
22	13	16	225	1,574	225–237	14–3	12–6	7–3	900
25	14½	18	200	2,033	285–301	15–6	13–6	8–0	1,150
28	16½	21	180	2,678	377–398	18–0	16–0	10–6	1,700
32	18½	24	163.5	3,631	504–533	19–9	18–0	11–6	2,000
37	21½	27	150	5,011	657–693	25–0	19–0	12–3	2,800
40	23½	30	138.5	5,967	853–905	29–3	20–0	12–9	4,700
44	26	36	120	7,505	1010–1075	30–9	24–0	15–10	5,200

Note: The weights of these average from 15 to 20 pounds per cubic foot of piston displacement.

TABLE IX

DIRECT-CONNECTED OIL ENGINE-DRIVEN STRAIGHT-LINE AIR COMPRESSOR

Cylinder Diameter Ins.		Stroke—Inches	R. P. M.	Piston Displacement, Cu. Ft. Per Minute	I. H. P.—Power Cylinder, Sea Level Maximum Pressure	Air Pressure Ratings Lbs., Gauge		Fuel Consumption Gals. per Hr. Based on Fuel Oil-20,000 B. T. U. per Lb. Sea Level		Over-all Dimensions, Ft.-Ins.			Diameter, Fly-Wheels, Ft.-Ins.	Approximate Cu. Ft. Foundation
Two-Cycle Single-Acting Power Cylinder	Double-Acting Air Cylinder					Minimum	Maximum	Minimum Air Pressure	Maximum Air Pressure	Length	Width	Height		
7	6	6	450	83	13.0	55	100	1.1	1.2	9–3	2–0	3–0	3–0	48
7	7	6	450	116	13.0	25	50	1.1	1.2	9–4	2–0	3–0	3–0	48
7	8	6	450	153	13.0	10	20	1.1	1.2	9–6	2–0	3–0	3–0	48
9	7½	8	350	135	22½	50	100	1.6	1.8	11–6¼	2–3	4–0	4–0	60
9	8	8	350	155	22½	35	45	1.6	1.8	11–7	2–3	4–0	4–0	60
9	9	8	350	198	22½	25	30	1.6	1.8	11–9	2–3	4–0	4–0	60
9	10	8	350	247	22½	10	20	1.6	1.8	11–10	2–3	4–0	4–0	60
12½	10	10	300	261	43	70	100	3.2	3.5	14–0¼	2–9	5–0	5–0	90
12½	11	10	300	319	43	45	65	3.1	3.5	14–3	2–9	5–0	5–0	90
12½	12	10	300	381	43	25	40	3.0	3.5	14–4	2–9	5–0	5–0	90
12½	14	10	300	523	43	10	20	2.9	3.5	14–6	2–9	5–0	5–0	90

Note: These machines weigh about 20 pounds per cubic foot of piston displacement for the larger units to 30 pounds for the small ones.

TABLE X

STRAIGHT-LINE PISTON VALVE STEAM-DRIVEN AIR COMPRESSORS

Steam Pressure, 80–120 Lbs.

Size of Cylinders Ins.			Revolutions per Minute	Piston Displacement Cu. Ft. Per Minute	Air Pressure Rating, Lbs., Gauge	I. H. P. in Steam Cylinder	Boiler H. P. at Max. Air Pressure 100 Lbs. Steam Pressure	Diam. Fly-Wheels Ft.–Ins.	Over-All Dimensions Ft.–Ins.			Cubic Feet in Foundation
Diam.		Stroke							Length	Width	Height from Floor	
Steam	Air											
7	6	6	350	67	80–125	9–10	12	2–4	8–2	2–3	3–6	34
7	7	6	350	92	55–100	11–13	15	2–4	8–3	2–3	3–6	34
7	8	6	350	120	30–50	12–14	16	2–4	8–3	2–3	3–6	34
7	9	6	350	153	15–25	11–14	16	2–4	8–4	2–3	3–6	34
7	12	6	350	273	–10	–16	18	2–4	8–5	2–3	3–6	34
9	8	8	300	136	80–125	21–25	27	3–3	10–2	2–8	4–0	48
9	9	8	300	173	65–100	24–29	32	3–3	10–3	2–8	4–0	48
9	10	8	300	215	35–60	24–30	33	3–3	10–5	2–8	4–0	48
9	12	8	300	311	25–30	26–31	34	3–3	10–3	2–8	4–0	48
9	14	8	300	424	10–20	22–31	34	3–3	10–5	2–8	4–0	48
12	10	10	275	245	80–125	39–46	48	4–0	12–0	3–2	4–8	64
12	12	10	275	355	60–100	51–62	61	4–0	11–10	3–2	4–8	64
12	14	10	275	484	30–55	45–63	65	4–0	12–0	3–2	4–8	64
12	17	10	275	718	10–25	42–63	64	4–0	12–0	3–2	4–8	64
14	12	12	250	386	80–125	61–70	70	5–0	13–8	4–1	5–9	112
14	14	12	250	528	45–100	66–88	88	5–0	13–9	4–1	5–9	112
14	17	12	250	781	25–40	75–93	93	5–0	13–10	4–1	5–9	112
14	20	12	250	1,086	10–20	72–95	95	5–0	14–2	4–1	5–9	112

Note: The small units weigh about 25 pounds per cubic foot of piston displacement and the large ones 20 pounds.

TABLE XI

DUPLEX STEAM-DRIVEN MEYER VALVE AIR COMPRESSORS WITH OPPOSED CYLINDERS

Simple Steam Cylinders; Two-stage Air Cylinders

Steam Pressure, 80 to 150 Lbs.

Cylinders, Ins.				Rating						Floor Space Ft. and Ins.			Fly-Wheel Diameter, Ins.	Approximate Cubic Feet in Foundation
Diameters			Stroke	R. P. M.	Piston Displacement Cu. Ft. per Minute	I. H. P. in Steam Cylinders at Air Pressures Given				Length	Width	Height above Floor		
Duplex Steam Cylinders	L. P. Air Cylinder	H. P. Air Cylinder				80 Lbs.	90 Lbs.	100 Lbs.	110 Lbs.					
						SEA LEVEL								
7	10	6½	10	225	203	32	34	36	38	8–8	5–1	6–4	36	135
8	12	7½	12	210	327	52	56	59	62	9–5	5–5	6–5	45	189
9	14	9	12	210	446	71	76	80	84	10–5	6–0	6–9	54	243
10	16	10	14	185	599	95	102	107	112	11–9	7–8	7–4	63	324
12	19	12	16	170	888	142	150	159	167	13–5	8–9	7–10	72	486
14	22	13	16	170	1,190	190	202	213	223	13–10	9–2	7–0	72	702
14	23	14	20	150	1,436	226	241	254	266	15–9	9–6	7–2	84	756
						5000-FT. ALTITUDE								
7	11	6½	10	225	246	36	38	40	41	8–8	5–1	6–4	36	135
8	13	7½	12	210	385	56	59	62	65	9–6	5–6	6–5	45	189
9	15	9	12	210	513	74	78	82	86	10–6	6–1	6–9	54	243
10	17	10	14	185	677	98	104	109	113	11–10	7–9	7–4	63	324
12	20	12	16	170	984	142	150	158	164	13–6	8–10	7–10	72	486
14	23	13	16	170	1,302	188	199	209	218	13–10	9–2	7–0	72	702
14	24	14	20	150	1,564	223	236	248	259	15–9	9–6	7–2	84	756
						10,000-FT. ALTITUDE								
7	12	6½	10	225	293	38	41	43	45	8–10	5–2	6–4	36	135
8	14	7½	12	210	447	59	62	65	68	9–8	5–7	6–5	45	189
9	16	9	12	210	584	77	81	85	88	10–8	6–2	6–9	54	243
10	18	10	14	185	759	99	105	110	115	11–11	7–11	7–4	63	324
12	21	12	16	170	1,085	142	150	158	164	13–7	8–11	7–10	72	486
14	24	13	16	170	1,418	186	196	206	215	13–11	9–4	7–0	72	702
14	25	14	20	150	1,698	220	232	244	254	15–10	9–8	7–2	84	756

Note: These machines weigh from 25 pounds per cubic foot of piston displacement for the larger units to 35 pounds for the small ones

TABLE XII

DUPLEX STEAM-DRIVEN MEYER VALVE AIR COMPRESSORS WITH OPPOSED CYLINDERS

Simple Steam and Single-Stage Air Cylinders. Steam Pressure, 80 to 150 Lbs.

Cylinders, Ins.			Rating						Floor Space, Ft. and Ins.			Fly-Wheel Diameter Ins.	Approximate Cu. Ft. in Foundation
Diameter		Stroke	R. P. M.	Piston Displacement Capacity Cu. Ft. Per Min.	Air Pressure Designed For		I. H. P. in Steam Cyl. at Air Pressure Given		Length	Width	Height Above Floor		
Duplex Steam	Duplex Air				Min.	Max.	Min.	Max.					
7	7	10	225	198	60	100	28	38	8-6	5-0	6-4	36	135
7	8	10	225	258	40	55	30	36	8-6	5-0	6-4	36	135
7	9	10	225	327	27	35	27	34	8-8	5-1	6-4	36	135
7	10	10	225	405	22	25	29	34	8-8	5-1	6-4	36	135
7	11	10	225	491	15	20	29	36	8-8	5-1	6-4	36	135
8	8	12	210	289	75	100	48	57	9-3	5-3	6-5	45	189
8	9	12	210	367	55	70	51	60	9-3	5-3	6-5	45	189
8	10	12	210	454	40	50	53	61	9-5	5-5	6-5	45	189
8	11	12	210	549	27	35	46	59	9-5	5-5	6-5	45	189
8	12	12	210	655	22	25	47	56	9-5	5-5	6-5	45	189
8	13	12	210	770	15	20	46	57	9-6	5-7	6-5	45	189
9	9	12	210	365	85	100	65	72	10-3	5-10	6-9	54	243
9	10	12	210	453	60	80	67	79	10-3	5-10	6-9	54	243
9	11	12	210	549	47	55	69	78	10-3	5-10	6-9	54	243
9	12	12	210	654	37	45	69	81	10-5	6-0	6-9	54	243
9	13	12	210	769	25	35	66	84	10-5	6-0	6-9	54	243
9	15	12	210	1,025	15	20	61	76	10-6	6-1	6-9	54	243
10	11	14	185	563	80	100	98	110	11-7	7-4	7-4	63	324
10	12	14	185	671	60	75	98	112	11-7	7-4	7-4	63	324
10	13	14	185	789	45	55	97	110	11-9	7-6	7-4	63	324
10	14	14	185	916	35	40	96	105	11-9	7-6	7-4	63	324
10	16	14	185	1,198	25	30	103	116	11-9	7-6	7-4	63	324
10	18	14	185	1,518	15	20	90	112	11-11	7-10	7-4	63	324
12	13	16	170	826	80	100	141	161	13-3	8-2	7-10	72	486
12	14	16	170	959	65	75	149	162	13-3	8-2	7-10	72	486
12	15	16	170	1,103	45	60	135	163	13-3	8-2	7-10	72	486
12	17	16	170	1,419	30	40	135	165	13-5	8-4	7-10	72	486
12	19	16	170	1,775	20	25	128	151	13-5	8-4	7-10	72	486
12	21	16	170	2,171	15	20	131	164	13-7	8-8	7-10	72	486
14	15	16	170	1,100	80	100	186	212	13-8	8-2	7-0	72	702
14	16	16	170	1,253	55	75	173	209	13-8	8-2	7-0	72	702
14	18	16	170	1,592	35	50	166	212	13-10	8-4	7-0	72	702
14	21	16	170	2,168	25	30	183	208	13-10	8-6	7-0	72	702
14	24	16	170	2,836	15	20	168	209	13-11	8-10	7-0	72	702
14	15	20	150	1,213	75	100	196	232	15-7	8-5	7-2	84	756
14	17	20	150	1,562	50	70	204	251	15-7	8-5	7-2	84	756
14	19	20	150	1,955	35	45	204	242	15-9	8-8	7-2	84	756
14	22	20	150	2,626	25	30	224	255	15-9	8-8	7-2	84	756
14	25	20	150	3,395	15	20	203	253	15-10	9-4	7-2	84	756

Note: The small units weigh about 30 pounds per cubic foot of piston displacement and the large ones 20 pounds.

TABLE XIII

COMPOUND AND LOW-PRESSURE DUPLEX STEAM CYLINDERS FOR MEYER AND PLAIN SLIDE VALVE DUPLEX STEAM-DRIVEN AIR COMPRESSORS IN TABLES XI AND XII

EQUIVALENT COMPOUND STEAM CYLINDERS						Equivalent Low-Pressure Duplex Steam Cylinders for 60 to 80 Lbs. Steam Pressure
Condensing—90 to 120 Lbs. Steam Pressure Non-Condensing—100 to 125 Lbs. Steam Pressure				Condensing—125 to 150 Lbs. Steam Pressure Non-Condensing—130 to 150 Lbs. Steam Press.		
Standard Duplex Steam Cylinders Ins.		Diam. High-Pressure Cyl., Ins.	Diam. Low-Pressure Cyl., Ins.	Diam. High-Pressure Cyl., Ins.	Diam. Low-Pressure Cyl., Ins.	Diam. of each Duplex Steam Cylinder, Ins.
Diam.	Stroke					
7	10	7	11	7	11	8
8	12	8	13	8	13	9
9	12	10	16	10	16	10
10	14	12	19	10	19	12
12	16	14	22	12	22	14
14	16	16	25	14	25	16
14	20	16	25	14	25	16

TABLE XIV

DUPLEX PISTON VALVE STEAM-DRIVEN AIR COMPRESSORS WITH OPPOSED CYLINDERS

Simple Steam Cylinders; Single-Stage Air Cylinders

Steam Pressure, 30 to 120 Lbs.

Cylinders Ins.			Rating						Fly-Wheel Diameter, Ins.	Floor Space—Ft.-Ins.			Approximate Cu. Ft. in Foundation
Diam. Each Duplex Steam Cyl.	Diam. Each Duplex Air Cyl.	Stroke	R. P. M.	Piston Displacement, Cubic Feet per Minute	Air Pressure Designed for		I. H. P. in Steam Cyl. at Air Pressure Designed for			Length	Width	Height Above Floor	
					Min.	Max.	Min.	Max.					
10	11	14	200	608	80	100	86	97	63	11–8	7–4	6–1	324
10	12	14	200	725	60	75	91	105	63	11–8	7–4	6–1	324
10	13	14	200	952	45	55	108	123	63	11–10	7–6	6–1	234
10	14	14	200	990	35	40	103	113	63	11–10	7–6	6–1	324
10	16	14	200	1,295	25	30	113	128	63	12–0	7–8	6–1	324
10	18	14	200	1,640	15	20	105	131	63	12–3	7–10	6–1	324
12	13	16	180	876	80	100	125	141	72	13–2	8–6	6–8	485
12	14	16	180	1,016	65	75	137	149	72	13–2	8–6	6–8	485
12	15	16	180	1,166	45	60	131	157	72	13–4	8–7	6–8	485
12	17	16	180	1,504	30	40	139	170	72	13–4	8–7	6–8	485
12	19	16	180	1,880	20	25	141	168	72	13–6	8–9	6–8	485
12	21	16	180	2,300	15	20	146	181	72	13–9	8–11	6–8	485
14	15	16	180	1,164	80	100	164	186	72	13–8	8–8	6–5	700
14	16	16	180	1,326	55	75	159	193	72	13–9	8–10	6–5	700
14	18	16	180	1,686	35	50	164	208	72	13–10	9–0	6–5	700
14	21	16	180	2,296	25	30	198	225	72	14–0	9–2	6–5	700
14	24	16	180	3,002	15	20	188	234	72	14–3	9–4	6–5	700
15	15	20	160	1,294	75	100	181	213	84	17–0	10–0	6–6	1,080
15	17	20	160	1,666	50	70	194	238	84	17–2	10–2	6–6	1,080
15	19	20	160	2,086	35	45	211	249	84	17–2	10–2	6–6	1,080
15	22	20	160	2,800	25	30	241	274	84	17–4	10–3	6–6	1,080
15	25	20	160	3,620	15	20	227	281	84	17–6	10–6	6–6	1,080

Note: These machines weigh approximately 20 pounds per cubic foot of piston displacement.

TABLE XV

DUPLEX PISTON VALVE STEAM-DRIVEN AIR COMPRESSORS WITH OPPOSED CYLINDERS

Simple Steam Cylinders; Two-stage Air Cylinders

Cylinders Ins. Diameters						I. H. P. in Steam Cylinder at Air Pressure Given					Floor Space Ft. and Ins.			
Duplex Steam	Low-Press. Air Cyl.	High-Press. Air Cyl.	Stroke	R. P. M.	Piston Displacement, Cu. Ft. Per Minute	80 Lbs.	90 Lbs.	100 Lbs.	110 Lbs.	Fly-wheel Diameter, Ins.	Length	Width	Height Above Floor	Approximate Cu. Ft. in Foundation
						SEA LEVEL								
10	16	10	14	200	648	102	108	114	120	63	12–0	7–8	6–1	324
12	19	12	16	180	940	148	157	165	174	72	13–6	8–9	6–8	485
14	22	13	16	180	1,260	200	212	223	235	72	14–0	9–2	6–5	700
15	23	14	20	160	1,531	242	256	270	284	84	17–4	10–3	6–6	1,080
						5,000-FT. ALTITUDE								
10	17	10	14	200	731	104	111	116	122	63	12–2	7–9	6–1	324
12	20	12	16	180	1,042	148	157	165	173	72	13–8	8–10	6–8	485
14	23	13	16	180	1,378	196	209	218	229	72	14–2	9–3	6–5	700
15	24	14	20	160	1,668	237	254	264	277	84	17–6	10–4	6–6	1,080
						10,000-FT. ALTITUDE								
10	18	10	14	200	820	104	111	115	122	63	12–3	7–10	6–1	324
12	21	12	16	180	1,150	148	159	164	173	72	13–9	8–11	6–8	485
14	24	13	16	180	1,501	191	205	211	223	72	14–3	9–4	6–5	700
15	25	14	20	160	1,810	230	246	255	269	84	17–7	10–5	6–6	1,080

Note: These machines weigh about 25 pounds per cubic foot of piston displacement.

TABLE XVI

COMPOUND AND LOW-PRESSURE DUPLEX STEAM CYLINDERS FOR PISTON VALVE DUPLEX STEAM-DRIVEN AIR COMPRESSORS

Standard Duplex Steam Cylinders Ins.		EQUIVALENT COMPOUND STEAM CYLINDERS						Equivalent Low-Pressure Duplex Steam Cylinders.
		Condensing 100 to 115 Lbs. Steam Pressure Non-Condensing 100 to 130 Lbs. Steam Pressure Not over 1 Lb. Back Pressure Non-Condensing 110 to 140 Lbs. Steam Pressure Not over 5 Lbs. Back Pressure		Cond. 120 to 145 Lbs. Steam Pressure Non-Condensing 135 to 180 Lbs. Steam Pressure Not over 1 Lb. Back Pressure Non-Condensing 145 to 180 Lbs. Steam Pressure Not over 5 Lbs. Back Pressure		Condensing 150 to 180 Lbs. Steam Pressure		For 60 to 80 Lbs. Steam Pressure
Diameter	Stroke	Diam. H. P. Cylinder, Ins.	Diam. L. P. Cylinder, Ins.	Diam. H. P. Cylinder, Ins.	Diam. L. P. Cylinder, Ins.	Diam. H. P. Cylinder, Ins.	Diam. L. P. Cylinder, Ins.	Diam. of each Duplex Steam Cyl., Ins.
10	14	11	18	9	18	8	18	11
12	16	13	21	11	21	10	21	13
14	16	15	25	12	25	11	25	15
15	20	16	26	13	26	12	26	16

TABLE XVII

DUPLEX CORLISS STEAM-DRIVEN AIR COMPRESSORS WITH TANDEM CYLINDERS

Simple Steam Cylinders — Steam Pressure 90–120 Lbs. — Two-Stage Air Cylinders

Cylinders, Ins.				R. P. M.	Piston Displacement Cu. Ft. per Minute	I. H. P. in Steam Cyl. at Air Pressure Given		Fly-wheel Diameter, Inches	Floor Space, Ft. and Ins.				Approximate Cu. Ft. in Foundation
Diameters			Stroke										
Du-plex, Steam	Low-Pressure Air Cylinder	High-Pressure Air Cylinder				90 Lbs.	100 Lbs.		Length, Close Coupled	Length with Piston Rod Coupling	Width	Height	
Sea Level 90–100 Lbs.													
16	27	17	24	140	2,210	343	360	108	23–8	26–2	13–6	10–0	2,200 2,400
18	29	18½	24	140	2,250	411	431	108	23–8	26–2	13–6	10–0	2,200 2,400
18	30	18	27	125	2,740	439	461	120	25–9	28–3	14–2	11–0	2,600 2,800
20	32	20¼	27	130	3,242	501	525	120	26–2	28–8	15–0	11–0	2,600 2,800
22	36	22½	30	125	4,384	663	694	135	28–8	31–2	15–8	11–10	3,000 3,250
26	40	25½	36	110	5,715	906	949	156	33–0	36–0	17–2	12–10	3,800 4,200
28	44	28	42	100	7,323	1,142	1,196	180	39–8	42–10	18–6	14–0	
Sea Level 110–125 Lbs.													
18	28	17	24	140	2,376	408	429	108	23–8	26–2	13–6	10–0	2,200 2,400
20	30	18½	27	130	2,847	489	515	120	26–2	28–8	15–0	11–0	2,600 2,800
22	34	21	30	125	3,906	665	699	135	28–8	31–2	15–8	11–10	3,000 3,250
26	38	23½	36	110	5,153	876	921	156	33–0	36–0	17–2	12–10	3,800 4,200
28	42	26	42	100	6,666	1,113	1,172	180	39–8	42–10	18–6	14–0	
5,000-Ft. Altitude 90–100 Lbs.													
18	30	18½	24	140	2,731	375	392	108	23–8	26–2	13–6	10–0	2,200 2,400
20	34	20¼	27	130	3,663	500	522	120	26–2	28–8	15–0	11–0	2,600 2,800
22	38	22½	30	125	4,888	673	703	135	28–8	31–2	15–8	11–10	3,000 3,250
26	42	25½	36	110	6,305	881	921	156	33–0	36–0	17–2	12–10	3,800 4,200
28	46	28	42	100	8,010	1,095	1,144	180	39–8	42–10	18–6	14–0	

Note: These machines weigh about 30 pounds per cubic foot of piston displacement for the larger units to 40 pounds for the small ones.

COMPOUND AND LOW-PRESSURE DUPLEX STEAM CYLINDERS

For Above Duplex Simple Corliss Steam-Driven Compressors

Sea Level and Altitudes

Standard Duplex Cylinders	EQUIVALENT COMPOUND STEAM CYLINDERS				EQUIVALENT DUPLEX STEAM CYLINDERS FOR LOW STEAM PRESSURES
	Condensing		Non-Condensing		
	Diameter H. P. Cylinder, Ins.	Diameter L. P. Cylinder Ins.	Diameter H. P. Cylinder Ins.	Diameter L. P. Cylinder Ins.	Diameter, Ins.
100–120 LBS. STEAM PRESSURE	100–120 LBS. STEAM PRESSURE—NOT OVER 1 LB. B. P. 115–130 LBS. STEAM PRESSURE—NOT OVER 5 LBS. B. P.				70–90 LBS. STEAM PRESSURE
16 x 24	18	30	21	30	18
18 x 24	20	32	23	32	20
18 x 27	20	34	24	34	20
20 x 27	22	36	24	36	22
22 x 30	24	40	28	40	24
26 x 36	28	44	31	44	28
28 x 42	30	48	34	48	30
125–150 LBS. STEAM PRESSURE	125–150 LBS. STEAM PRESSURE—NOT OVER 1 LB. B. P. 135–165 LBS. STEAM PRESSURE—NOT OVER 5 LBS. B. P.				
16 x 24	16	30	18	28	..
18 x 24	18	32	20	32	..
18 x 27	18	34	20	32	..
20 x 27	19	36	22	34	..
22 x 30	21	40	24	38	..
26 x 36	24	44	28	42	..
28 x 42	26	48	30	46	..
155–180 LBS. STEAM PRESSURE	155–180 LBS. STEAM PRESSURE—NOT OVER 1 LB. B. P. 170–180 LBS. STEAM PRESSURE—NOT OVER 5 LBS. B. P.				
16 x 24	14	30	16	28	..
18 x 24	16	32	18	30	..
18 x 27	16	34	18	32	..
20 x 27	17	36	19	34	..
22 x 30	19	40	21	38	..
26 x 36	22	44	24	42	..
28 x 42	24	48	26	46	..

TABLE XVIII

DUPLEX STEAM-DRIVEN AIR COMPRESSORS; WITH DROP VALVE STEAM GEAR AND TANDEM CYLINDERS

SIMPLE STEAM CYLINDERS; TWO-STAGE AIR CYLINDERS

Steam Pressure 90–120 Lbs.

Cylinders, Ins.				R. P. M.	Piston Displacement, Cu. Ft. Per Minute	I. H. P. in Steam Cylinders at Air Pressures Given		Fly-Wheel Diameter Ins.	Floor Space Ft.-Ins.			Approximate Cu. Ft. in Foundation
Diameters			Stroke									
Duplex Steam	Low-Pressure Air Cylinder	High-Pressure Air Cylinder							Length	Width	Height Above Floor	
SEA LEVEL, 90–110 LBS.												
16	26	16½	21	160	2,046	90 Lbs. 344	100 Lbs. 362	108	21–10	12–6	9–0	1,850
SEA LEVEL 110–125 LBS.												
16	25	15	21	160	1,895	110 Lbs. 335	125 Lbs. 352	108	21–10	12–6	9–0	1,850
5,000-FT. ALTITUDE 90–100 LBS.												
16	27	16½	21	160	2,213	90 Lbs. 335	100 Lbs. 350	108	21–10	12–6	9–0	1,850

Note: These machines weigh about 30 pounds per cubic foot of piston displacement.

COMPOUND AND LOW-PRESSURE DUPLEX STEAM CYLINDERS FOR ABOVE DUPLEX SIMPLE DROP VALVE STEAM-DRIVEN COMPRESSORS

Sea Level and Altitudes

Standard Duplex Cylinders	EQUIVALENT COMPOUND STEAM CYLINDERS				EQUIVALENT DUPLEX STEAM CYLS.
	Non-Condensing		Condensing		
	Diameter H. P. Cylinder Ins.	Diameter L. P. Cylinder Ins.	Diameter H. P. Cylinder Ins.	Diameter L. P. Cylinder Ins.	Diameter Ins.
	(105-130 Lbs. Steam Press., not over 1 Lb. B. P.) (120-140 Lbs. Steam Press., not over 5 Lbs. B. P.)		100-120 Lbs. Steam Pressure		70-90 Lbs. Steam Pressure
16 x 21	19	28	19	28	19
	(135-170 Lbs. Steam Press., not over 1 Lb. B. P.) (150-180 Lbs. Steam Press., not over 5 Lbs. B. P.)		125-150 Lbs. Steam Pressure		
16 x 21	16	28	16	28	
	(175-200 Lbs. Steam Press., not over 1 Lb. B. P.) (185-200 Lbs. Steam Press., not over 5 Lbs. B. P.)		155-175 Lbs. Steam Pressure		
16 x 21	14	28	14	28	

CHAPTER III

COMPRESSOR DETAILS

AIR VALVES—POPPET TYPE. These valves are seen on many of the compressors in use today and under certain conditions are still being offered by manufacturers both for inlet and discharge, although they are rapidly giving way to a valve of the plate design—one representative type of which is described later.

Poppet valves are automatic in action. The inlet type consists of a mushroom-topped stem, a cage and a spring which holds the valve to its seat in the cage, the latter serving as a guide for the stem. The auxiliary nut locks the whole device in place in the cylinder.

Discharge types consist essentially of a mushroom-capped valve, spring and cap or bonnet; the spring which rests inside the hollow valve stem, between it and the cap, acting to hold the valve to its seat, and also as a guide.

Fig. 23 is a cross-sectional view, showing a typical poppet valve cylinder.

HURRICANE–INLET TYPE. Fig. 24 illustrates a type of automatic valve long in use but since displaced by the plate valve, already mentioned.

This valve is located in the air piston through which air is admitted to the cylinder; it consists of two ring valves of 'T' cross-section—one on each face. The cross-bar of the 'T' is the valve face seating over ports in the piston. The upright of the 'T' is a guide section sliding on a guide plate of steel bolted to the face of the piston.

In this type of valve, inertia alone is the force employed in its operation. The valves move with the piston. Starting from rest at the end of a stroke the leading valve lags until it closes the port; increasing pressure in advance of the piston holds it tight on the seat. The following valve lags until it strikes the guide plate, opening its port. The air rushes in through the hollow inlet tube, hollow piston and port, filling the space behind the piston. At the end of the stroke the following valve slides by inertia to its seat. Reversing, the leading valve is already closed. The following valve is held tight by the clearance pressure until the latter has been reduced to atmosphere. The valve then lags against its guide plate and free air rushes in.

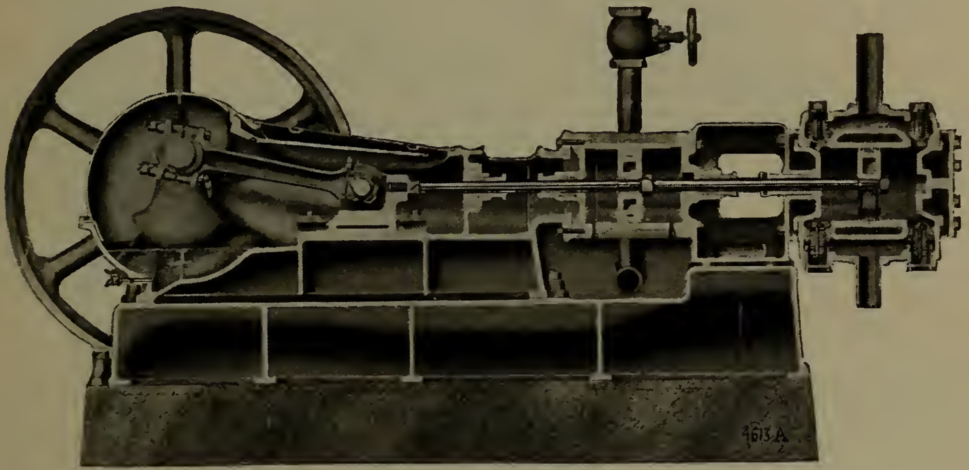


Fig. 23—Cross-section through air compressor equipped with a poppet valve cylinder.

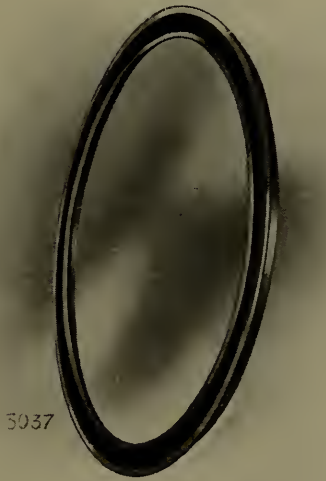


Fig. 24—Hurricane-Inlet valve. This type of air compressor valve was very popular for a great many years. It has since been displaced by the plate type of valve.

Fig. 25 shows a cross-section through a cylinder equipped with 'Hurricane-Inlet' valves and poppet discharge valves—this being the usual combination of air valve construction.

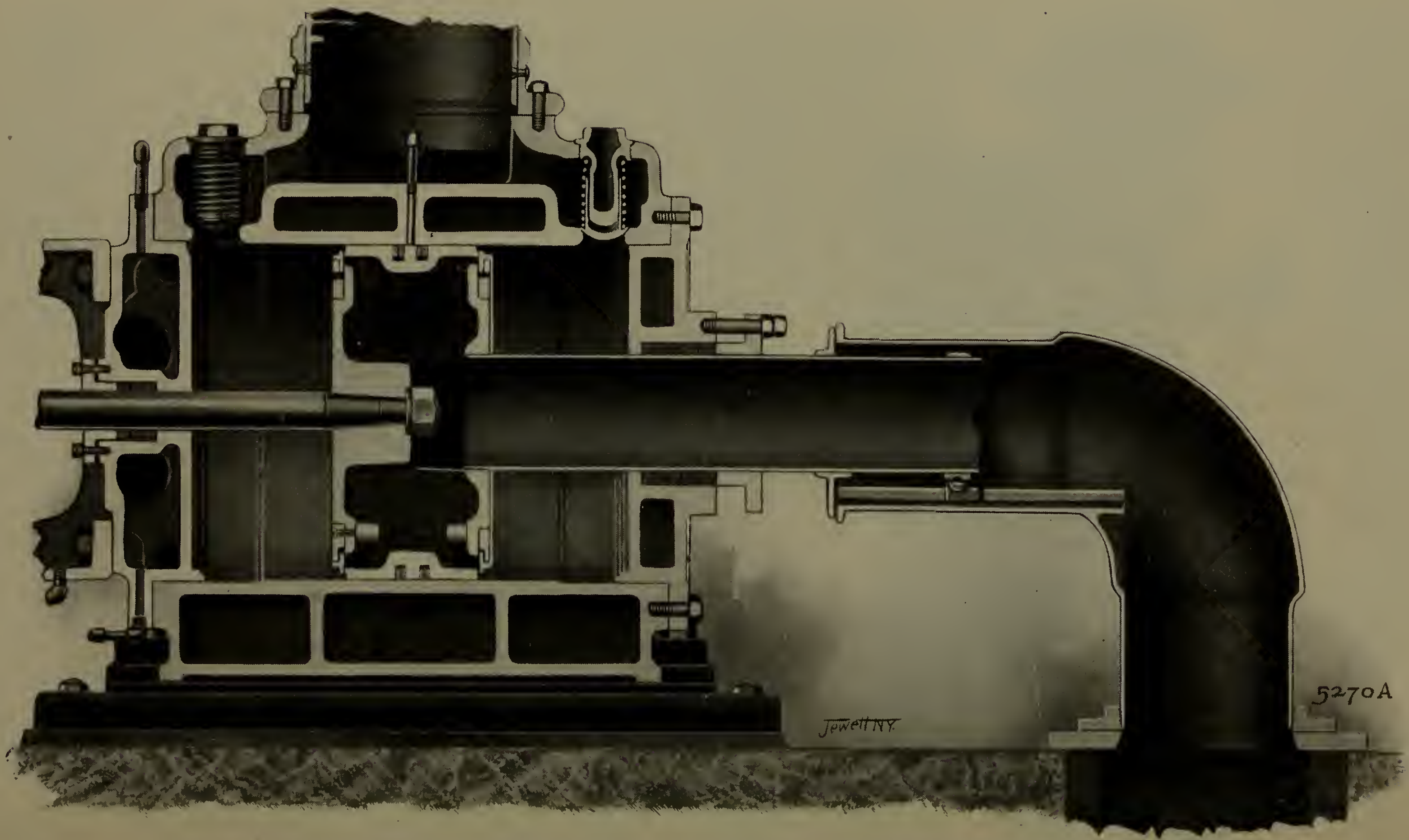


Fig. 25—A cross-section through a Hurricane-Inlet valve cylinder. The valves are located in the air piston faces.

Fig. 26—A Corliss air inlet valve.

Corliss Inlet Air Valves. In Fig. 26 is shown a mechanically operated air inlet valve which has been and is even today very popular with a great many compressor users. This valve is operated from eccentrics on the main shaft and its action is timed with the movement of the air piston, being partially open at the beginning of the stroke—this opening increasing until the piston is at its highest speed, when the valve is fully open.

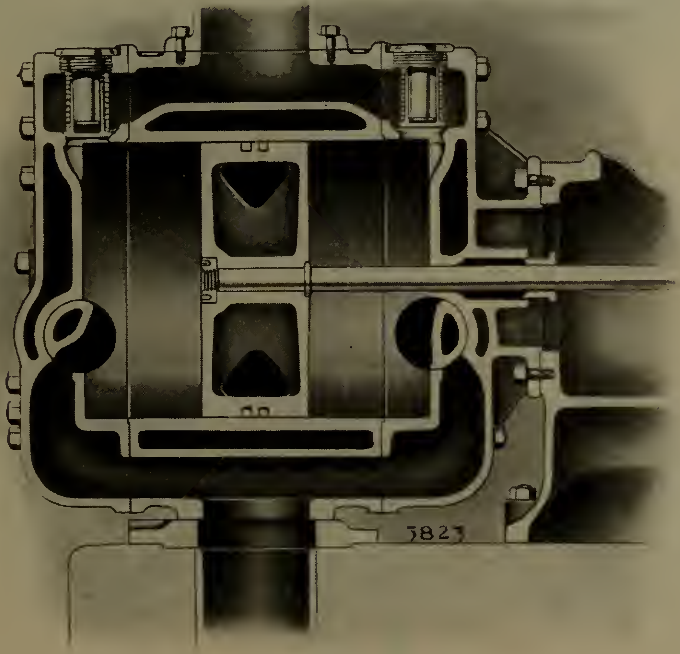


Fig. 27—A cross-section through an air cylinder equipped with Corliss air inlet and poppet air discharge valves.

Aside from the driving mechanism, it consists of two main parts—the Corliss valve proper and its driving stem.

This type of valve is commonly employed in conjunction with poppet discharge valves as shown in Fig. 27.

Plate Valves. Fig. 28 shows a completely assembled plate valve and Fig. 29 its various parts, with a cross-section illustrated in Fig. 30.

In Fig. 31 is shown the valve as applied to compressors of the straight-line type and in Fig. 32 as applied to cylinders in duplex compressor construction. The operation of this valve is as follows: When at rest the valve is held on its seat by the four spring arms of the cushion plate 'H' against a slight tension of the integral valve arms 'M'. As soon as the air pressure required to open is reached the valve opens against these spring arms to its full opening. The moment the piston starts on its return stroke the valve closes.

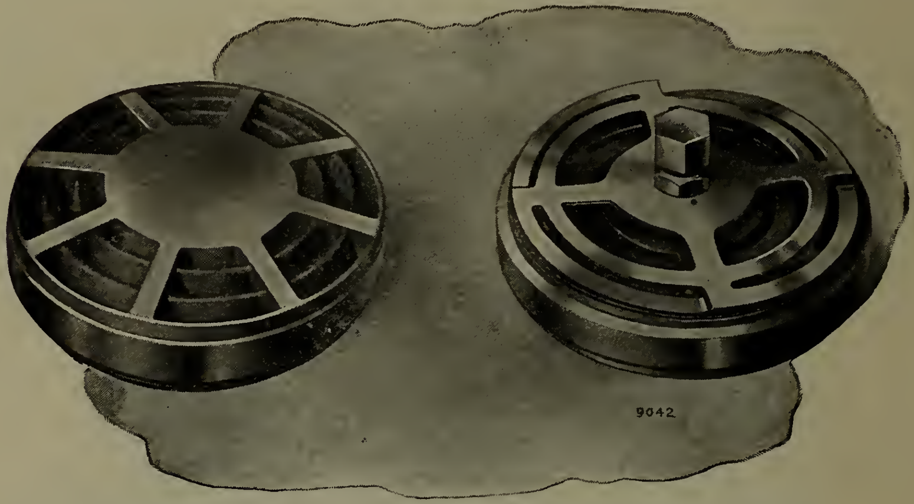


Fig. 28—A completely assembled plate valve—front and back views.

The function of the cushion plate is to act as a buffer, absorbing any shock that might otherwise fall on the valve.

Valves vary in size from 4½ to 15 inches in diameter, depending upon the size of the compressor. The number of valves also varies. They are extremely light for a given valve opening, approximately one-third the weight of a poppet valve.

The thickness of a medium size valve is approximately .07 of an inch.

The lift of the valve is very small, varying from .08 of an inch for the smallest size to about .14 of an inch for the largest.

Advantages Claimed for the Plate Type of Valve. Extreme simplicity, action independent of outside mechanical power sources, high mechanical efficiency, high compression efficiency, high speed, quiet operation, correct operation in any position, great accessibility, easily and cheaply replaced. Surfaces do not rub, hence no lubrication is necessary.

Fig. 29—The parts of the plate valve.

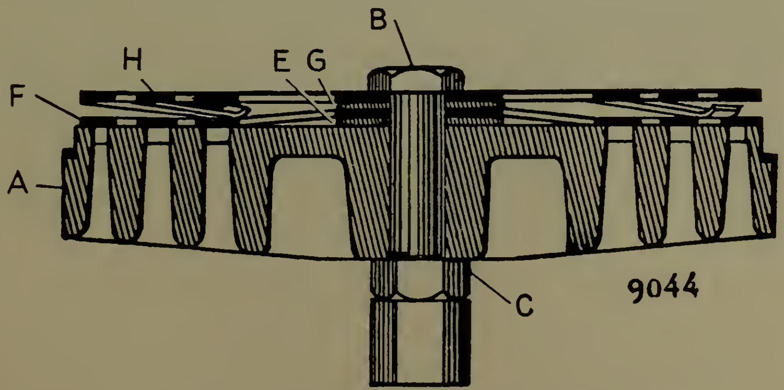


Fig. 30—A cross-section of the plate valve.

INTERCOOLERS. In designing the intercooler the aim of the engineer is to obtain a cooler which will cool the air to the greatest extent with a given quantity of cooling water, or conversely, where water is scarce, the assurance of a given degree of cooling with the minimum quantity of cooling water.

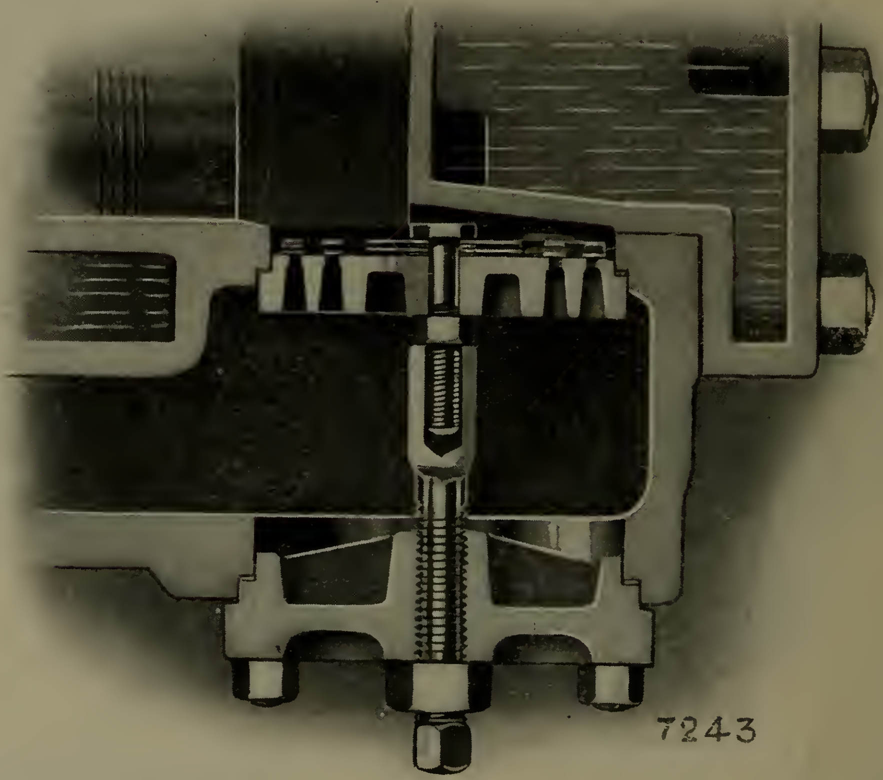


Fig. 31—A section of an air cylinder of the straight-line type, equipped with the plate valve.

Efficient intercooling in stage compressors, as explained in the forepart of this chapter, is of prime importance. It effects a decided saving in horse power. Were it possible to cool the air after it leaves the first-stage cylinder, so that its temperature when entering the next-stage cylinder would be identical with the temperature of the air when entering the first-stage cylinder, we would have perfect intercooling. This is not, however, obtainable in actual practice, but the importance of the results which may be obtained can be appreciated when it is borne in mind that with every increase in temperature, of 10 degrees of the

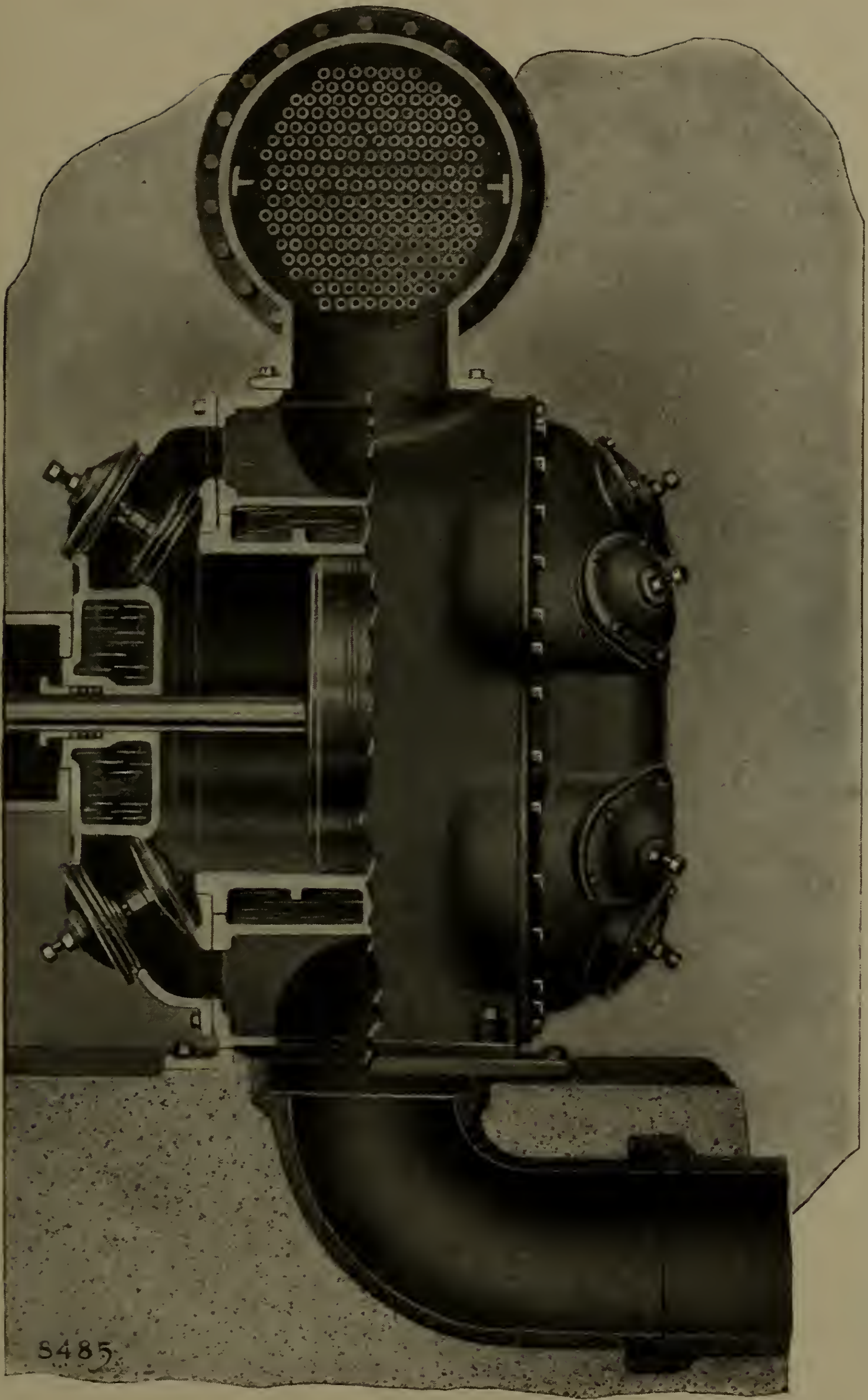


Fig. 32—A section through the air cylinder of a duplex compressor, equipped with plate valves.

high-pressure inlet air over the first-stage inlet air, the horse power required to compress is increased 1 per cent.

The further advantages are: the removal of moisture, already referred to, and the final delivery of air at a lower discharge temperature.

In Fig. 33 is shown a cross-section of an intercooler typical of present practice.

The process of cooling is as follows:
The shell contains tubes arranged in a series of groups through which water flows successively, entering the bottom row and finding an outlet through the top row. The travel of the water is directed by the water heads. At no time does the water come in actual contact with the air.

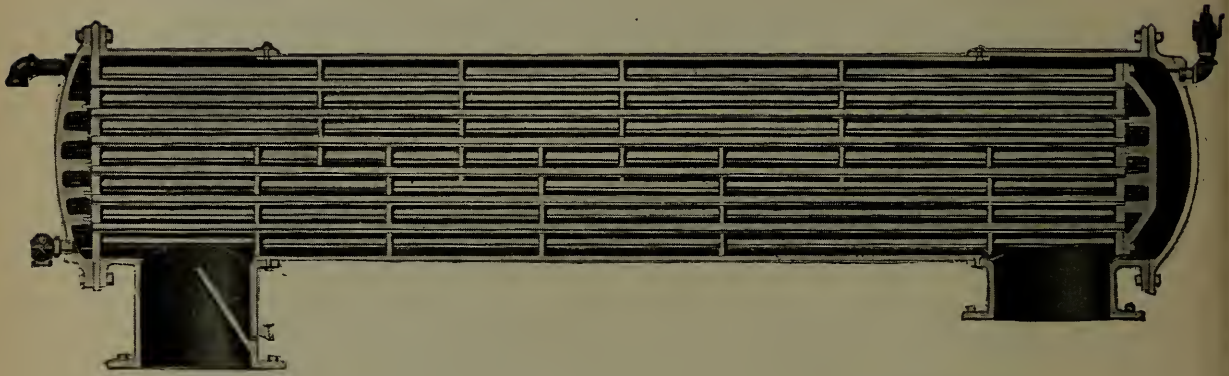


Fig. 33—Cross-section through a typical intercooler for two-stage compressors.

The air enters from the discharge of the first-stage cylinder into the intercooler, and is finally discharged into the second-stage cylinder.

Surrounding the water tubes is a series of baffle plates, which direct the flow of the air so as to split it up into thin films and insure intimate contact with the cold water tube surfaces. By reducing the spacing of these baffles as the high-pressure cylinder is approached the most efficient velocity of air in transit is attained.

A water separator through which all the air must flow is generally placed in the high-pressure inlet leg of the intercooler. This water separator consists of a baffle plate which causes the water condensed to be precipitated from the air into a pocket.

When the air comes in contact with the cold tube surfaces, condensation of the moisture occurs, and it drips and flows down into the bottom of the shell. In order to drain this condensed water the intercooler is usually placed at an incline, so that the water will flow into the pocket surrounding the water separator where a drain cock is provided for the occasional removal of the water.

Temperature changes in the intercooler cause the tubes to expand and contract, and in order to provide for this it is customary for the best of tubes to be fixed at one end only, while the other end, including the water box, is left free to move with the tube plate.

Steam Drives. The usual practice in furnishing steam-driven compressor units is to couple the steam engine direct to the air compressing element. Steam engines of various types are employed, depending to a large extent upon the size of the compressor and the ultimate economy desired.

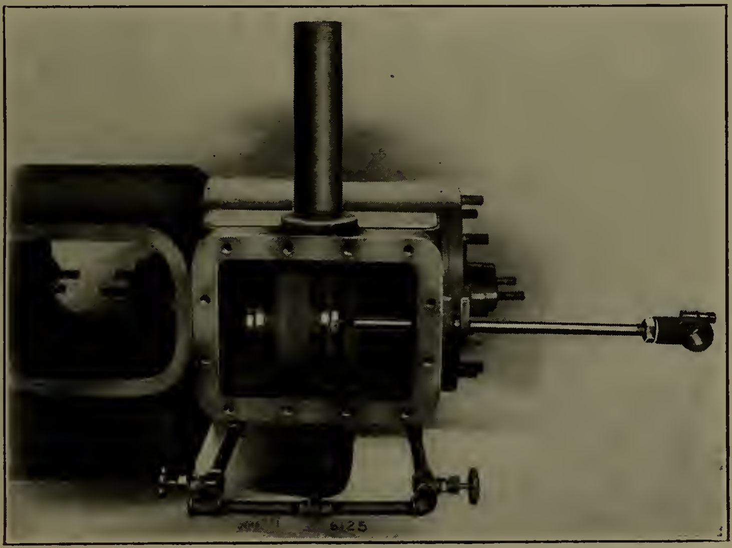


Fig. 34—An air compressor plain D slide valve steam cylinder.

Until recently one of the most common types of steam engines employed on compressors of comparatively small capacities was of the plain D slide valve construction, as shown in Fig. 34. In this construction the cut-off was fixed for average working conditions. Large sizes have been supplied with Meyer adjustable cut-off valves.

Recently a decided advance has been made in the adaptation of balanced piston steam valve engines. This has been due largely to the demand for small and medium size steam-driven air compressors, that would operate satisfactorily under high steam pressures and superheat, as well as meeting ordinary steam conditions. Fig. 35 shows this type of valve adapted to straight-line and duplex steam-driven air compressors.

Upon reference to Fig. 35 it will be noted that the steam valve is of the balanced telescopic piston type. The cut-off valves, one for each end of the cylinder, are right- and left-hand threaded to the cut-off valve stem, which telescopes through the main valve stem. Steam is admitted through the interior of the valve, passing in at the center and out through the ports near the end, the exhaust being by the ends of the valve.

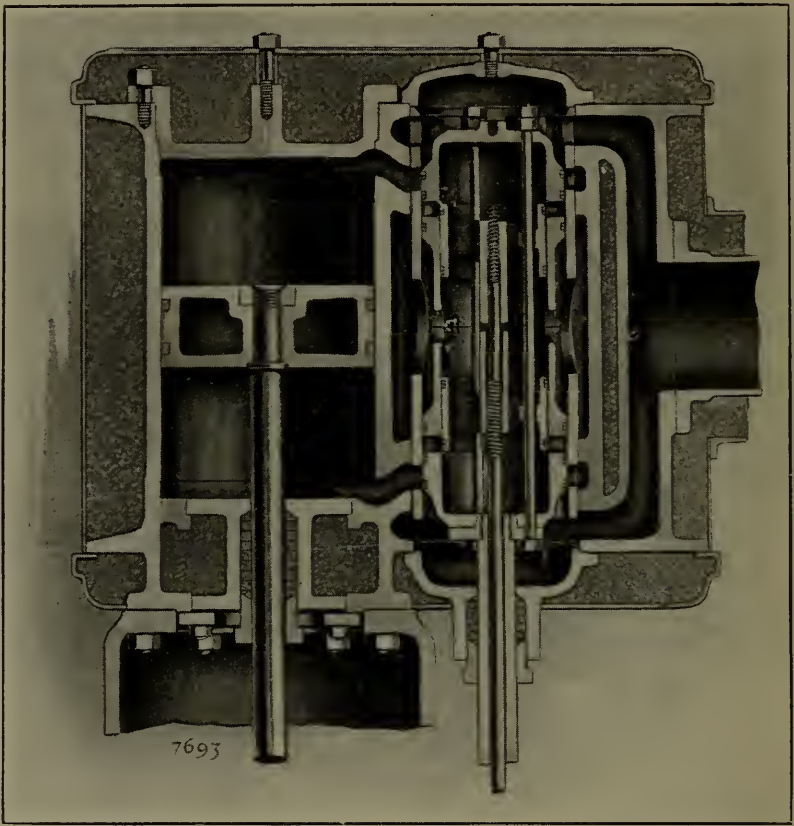


Fig. 35—A plan section through a piston valve steam cylinder.

The main valve is made in two halves joined midway of its length. The ends of the valve, separating the live steam from the exhaust, are cast integral with the valve halves.

As the steam exhausts past the ends of the valve, the valve covers and main valve stem packings are subjected to exhaust pressure only.

The suitability of this valve for service under high steam pressures and superheat is best illustrated by the following discussion: The slide valve, although well adapted for low-pressure saturated steam, is impractical for use with either high-pressure or high temperature steam. It can be only partially balanced and hence, when subjected to high pressures, the resulting friction is such as to create excessive wear and produce undue strains in the valve gear. Even though a valve gear of sufficient proportions be constructed, the power lost in driving the valve would seriously impair the mechanical efficiency of the compressor. When subjected to the high temperatures of superheated steam, the slide valve is liable to warp, thus preventing contact with the valve seat and permitting excessive leakage. Flat bearing surfaces are difficult to lubricate properly and, when subjected to the high temperatures and pressures of superheated steam, lubrication becomes practically impossible.

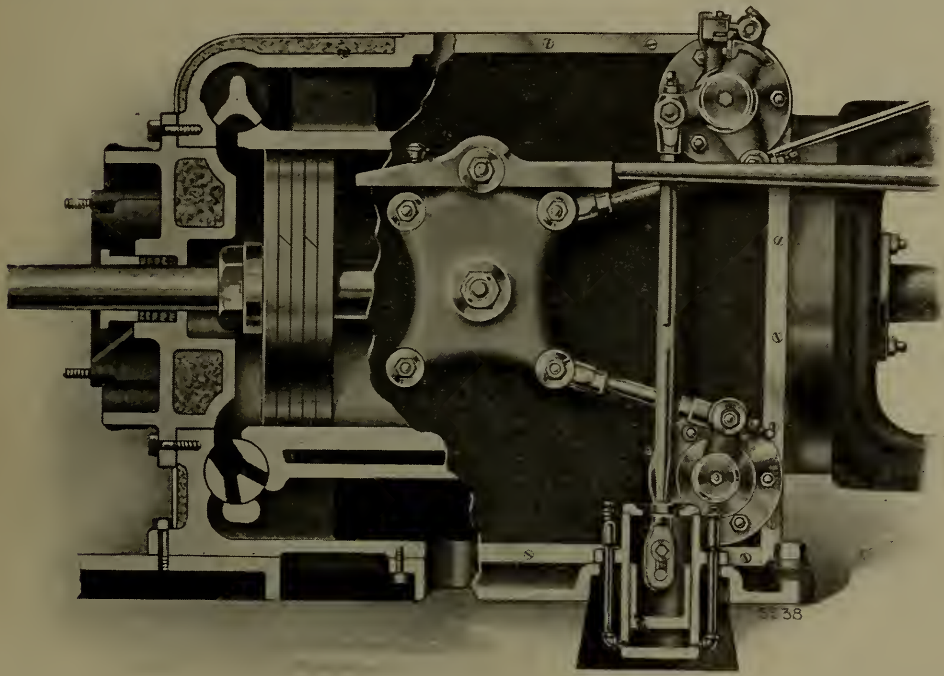


Fig. 36—A section through Corliss valve steam cylinder.

As will be seen from the illustration, the port edges of the bushing, as well as those of the main valve, are machined in the form of a groove which recesses the bridges as well as the port edges. This method provides, at the beginning of valve opening, a port equal in length to the circumference of the valve and permits simultaneous admission of steam at all points on the valve periphery.

The method of bridging the ports of the bushing and those of the main valve is worthy of mention. Unlike the customary method of dividing the circumference of piston valves into a few long ports and bridges which are inadequate to support the rings in passing over ports, the construction here shown embodies a sufficient number of ports and bridges of such proportions as to provide closely spaced supports about the periphery of the ring.

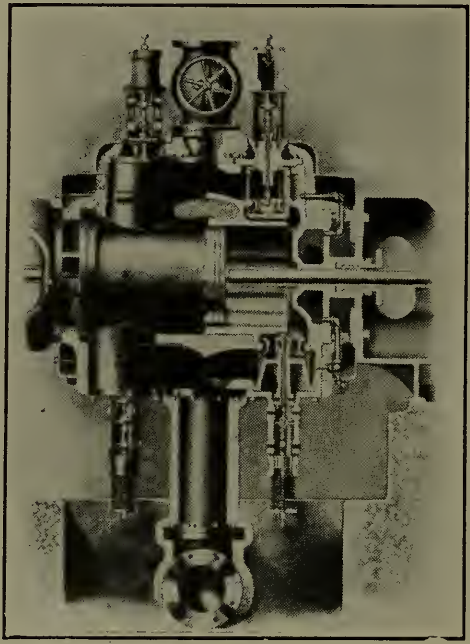


Fig. 37—A section through a drop valve steam cylinder.

Two very narrow rings are used in each ring groove of the valves. The rings are machined concentric. The sides of the rings are ground parallel and the circumference is a true circle.

In Fig. 36 is an illustration of a typical Corliss engine employed for driving air compressors. The valve gear is of the Corliss liberating type with vacuum dash-pots and double-ported steam and exhaust valves.

Drop Valve. The drop valve is a type admirably adapted for use on large and medium size steam cylinders and especially those operating under high pressures and superheated steam conditions. This valve, as shown in Fig. 37, is a double-ported poppet valve, lifted by the action of a cam and closed by the action of a spring. The valve operating cam derives its motion from a reach rod which in turn depends for its motion upon an eccentric mounted upon a lay shaft, the latter driven from the main shaft by level gears.

Due to the practically balanced nature of this valve and the absence of dash-pots the drop valve engine is capable of operating at considerably higher speeds than the Corliss type of engine. The large double valve ports and steam passages permit the steam to enter and leave the cylinder with great rapidity.

In the drop valve here illustrated, the valve cage, containing the seat, is cast as a separate part, which avoids warping tendencies under extreme changes of steam temperature. The valve is guided by its hollow hub which fits over a turned guide located in the bottom of the valve cage. The valve requires no lubricant in operation.

This type of engine is regulated by automatically changing the point of cut-off on the high-pressure admission valves. The point of admission of these valves is fixed but an increase in speed or an increase in air pressure beyond a certain predetermined point results in causing an earlier cut-off of steam and the reverse conditions result in a later cut-off.

The low-pressure admission valves and all exhaust valves have their eccentrics set to give constant points of admission and cut-off.

A safety stop is provided which shuts down the machine instantly should it over-speed for any cause. This is operated by a centrifugal weight mounted on the lay shaft, the centrifugal force of which is normally balanced by a spring. When the machine over-speeds, the weight flies out, strikes a lug which releases a weight and in so doing causes the high-pressure admission valve operating cams to change their motion in such a way that they fail to lift the valves.

Lubrication. There are a number of lubrication systems employed in air compressor design; broadly speaking, however, these may be divided into four distinct classes: open oil cup lubrication; combined automatic splash and oil cup; combined automatic splash and force feed; and force feed alone.

The first is met with only in machines of the very cheapest construction, and its use even on such is rapidly becoming obsolete practice.

The second and third are most commonly used as they combine good economy with a high degree of automatic action. These latter two systems are cleanly and as their operation involves an inclosure of all reciprocating parts, the machine itself is less subject to wear from dirt and other foreign substances.

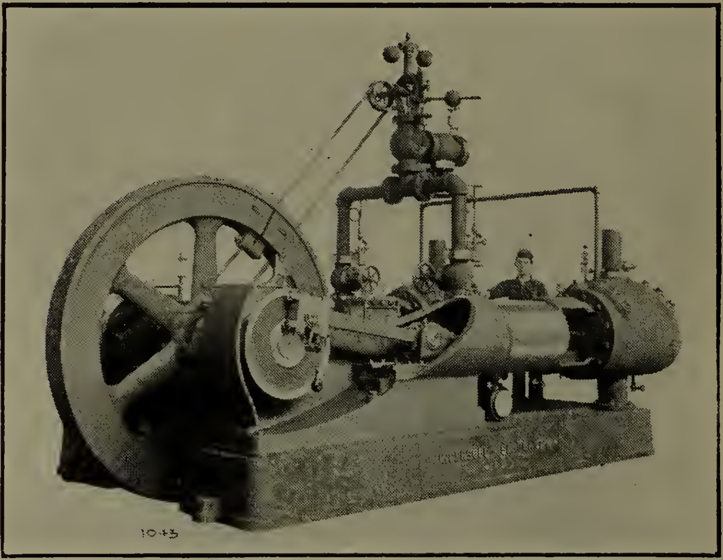


Fig. 38—Oil cup lubrication of air compressors. This represents a practice now practically obsolete. In fact, the machine shown in the illustration was built over 10 years ago.

Force feed alone is used only under special conditions, such as very high-pressure work, and is therefore not often encountered in the industries covered by this book.

In Fig. 38 is shown a compressor with oil cup lubrication. A machine having automatic lubrication is illustrated in Fig. 39.

As will be noted from the latter illustration the frame on each side has been carried up to form a basin in which the oil is carried. The crank disc revolves in the oil and carries it up to a wiper at the top, which gathers and causes the oil to flow through oil feeds to the various bearings.

In addition the action of the revolving crank disc and connecting rod causes the oil to be splashed to the various bearings.

Easily removable covers over the frame permit ready access, prevent oil from going out and dirt from getting in.

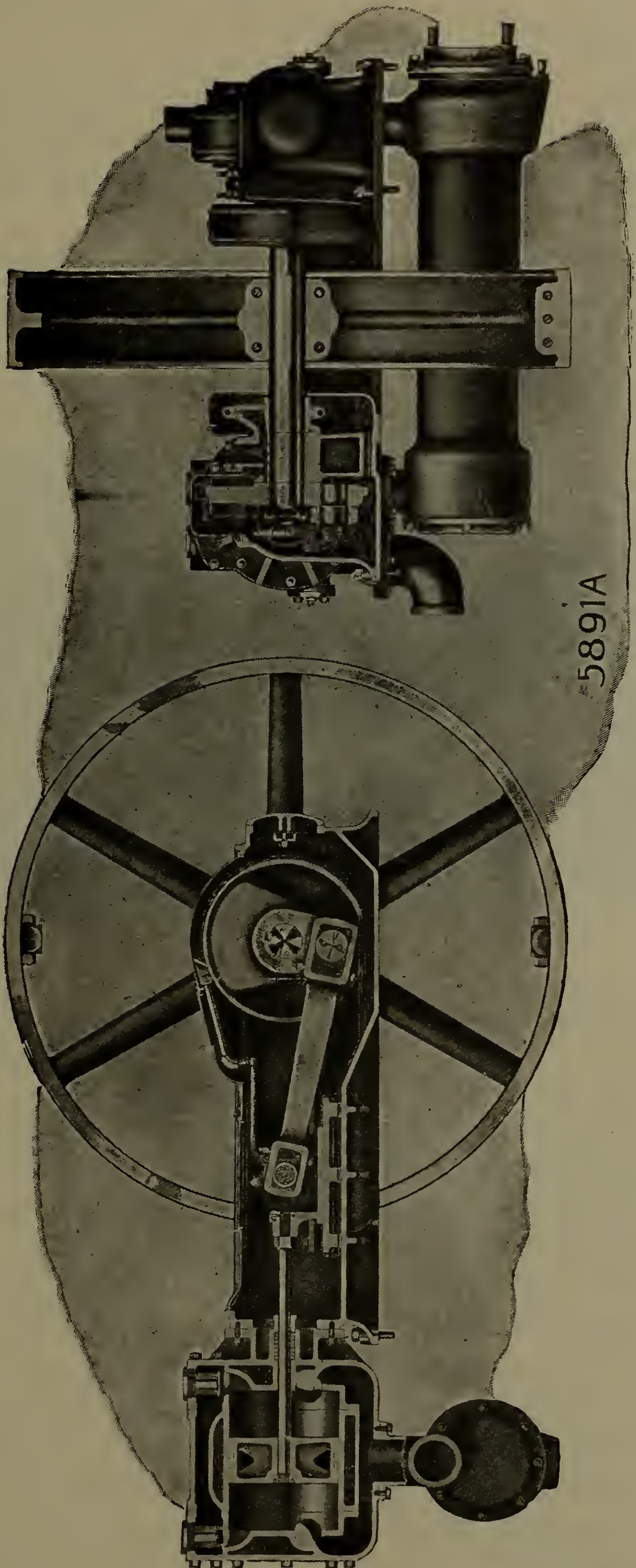


Fig. 39—Automatic lubrication of air compressors.

Air and steam cylinder lubrication is usually by means of sight feed oilers or force feed pump.

Regulation. While the regulating devices or governors used on air compressors vary in detail among the different builders, all may be divided, so far as the principle of operation is concerned, into two classes.

The first class is applied to compressors with plain or adjustable cut-off valves of flat or piston type. It operates by throttling the steam supply as load diminishes. Devices in this class consist fundamentally of a valve in the steam pipe, which is opened or closed by the action of a piston in a cylinder, this piston being actuated by air pressure from the receiver. The movement of this piston is opposed by weights on a lever or by a spring; and the spring tension or the weights may be adjusted so that the governor valve is full open at any desired normal air pressure. But when pressure exceeds this limit, the tension or weight is overcome, and the valve in the steam supply is closed in a degree corresponding with the amount of excess pressure. This slows down the machine and reduces the volume of air discharged until such time as the normal pressure is reached, when the weights or spring tension again open the governor valve, and full speed is restored. See Fig. 40.

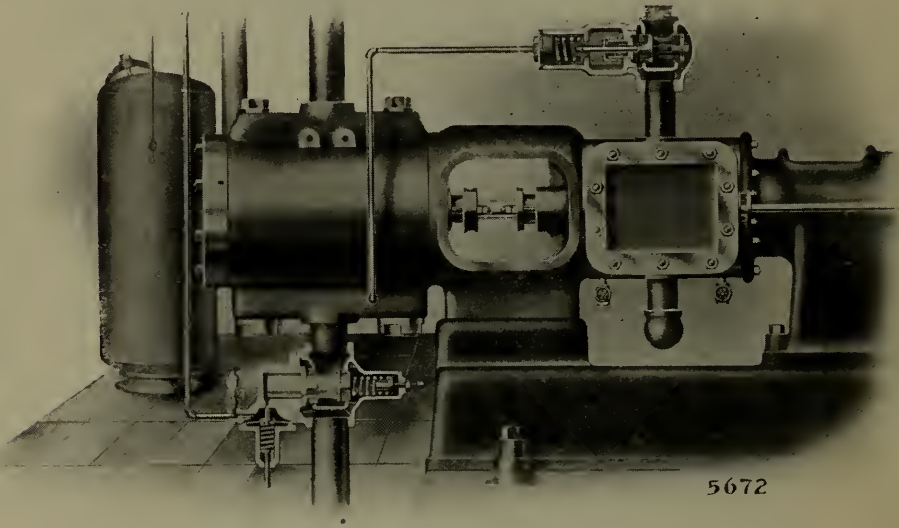


Fig. 40—Typical regulating device applied to compressors of the plain slide or piston valve type.

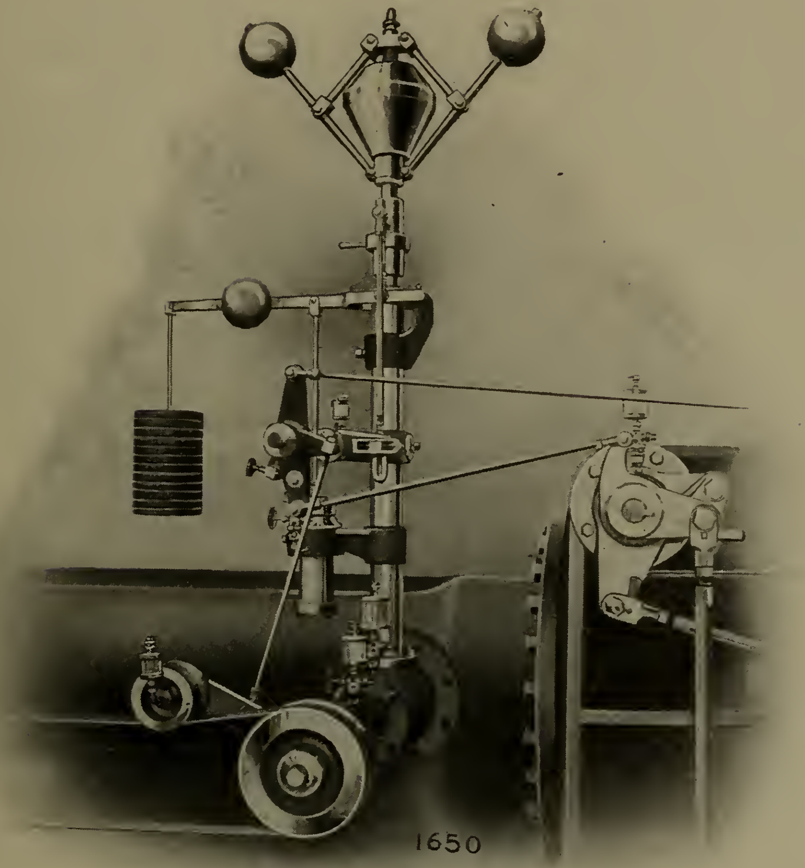


Fig. 41—Typical regulating device or governor as applied to compressors driven by Corliss steam cylinders.

The second class includes governors applied to machines with Corliss steam valves. The mechanism consists of a pressure cylinder and piston with opposing weights or springs as described in the preceding paragraph; but in this case the movement of the governor, instead of throttling the steam, changes the cut-off of the steam valves, reducing the speed under partial load, and restoring it as load increases. See Fig. 41.

Both of these classes of governors include also a speed-limiting device, the more common form being the familiar fly-ball arrangement, which throttles the steam supply or greatly shortens the cut-off when speed exceeds a certain limit, as it might in case an air pipe should break or other accident occur.

There are occasional instances in which governors of one or other of the above classes are used in connection with an unloader on the air end, so arranged that, as speed falls off, the load is partially taken from the air end. This is also shown in Fig. 40. The two general classes defined cover the general requirements of this book.

Since the power-driven compressor is almost always a constant speed machine, the methods of regulation and governing described for variable speed steam-driven machines evidently cannot here be applied. Constant speed means constant piston displacement; and the problem of delivering a variable volume of air with constant piston displacement becomes one of making a portion of that displacement non-effective in the compression and delivery of air. Only the fundamental principles of several methods of accomplishing this will be discussed.

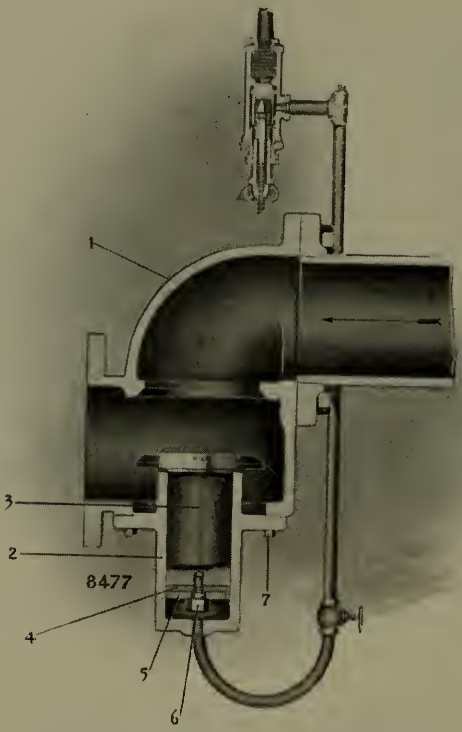


Fig. 42—An air intake regulator applied to power-driven air compressors.

The first method is really one of unloading, rather than of regulating. A pressure-controlled mechanism is arranged so that when pressure exceeds normal, due to excess of delivered volume over demand, a communication is opened between the two sides of the compressing piston. Usually this is accomplished by opening and holding open one or several of the discharge valves at both ends of the cylinder, the air then simply sweeping back and forth from one side of the piston to the other through the open valves and the air discharge passage. When normal pressure is restored, the valves are automatically closed, and compression and delivery are resumed. Evidently this is practically a total unloading of the machine for a longer or shorter period—a sudden release from load and a sudden resumption of load. Moreover, the air which is swept back and forth by the piston in its travel is air under full pressure; so that when the discharge valves suddenly close, the piston at once encounters a full cylinder of air at maximum pressure. These facts limit regulators of this class to machines of comparatively small capacity.

Another method provides, by means of a pressure-operated device, for the partial or total closing of the compressor intake under reduced load. See Fig. 42. To avoid the dangers attendant upon such an operation acting suddenly, these devices are provided with some damping mechanism so that they are compelled to operate slowly, making the release or resumption of the load gradual. The cutting down of the air intake results in a rarefication of the air entering the cylinder, and a greater range between initial and discharge pressures, with a corresponding increase in the range of temperatures. This method of regulation, therefore, is not suitable for very great load variations; nor is it recommended for such conditions by the builders responsible for it.

The third method is very similar to the first, except that here the inlet valves, instead of the discharge valves, are held open when the machine is unloaded, the piston thus simply drawing in and forcing out air at atmospheric pressure. It is open to the same criticism (though in somewhat less degree) as the first method, namely, shock and strain on release and resumption of load.

The fourth method uses a pressure-controlled valve on the compressor discharge of single-stage machines, combining also the functions of a check valve to limit the escape of air from the receiver or air line. Excessive pressure blows the discharge to atmosphere, instead of into the line. This arrangement is also used on two-stage machines by placing it on the low-pressure discharge to the intercooler. Then, when the governor valve is opened by excess pressure, the low-pressure cylinder discharges to atmosphere, and the high-pressure cylinder acts simply as a low-pressure cylinder with intake at atmospheric pressure. This device is more of a relief valve than an unloader, for the piston must continue to compress to a pressure which will open the discharge valves; and this volume of compressed air, with its power equivalent, is wasted.

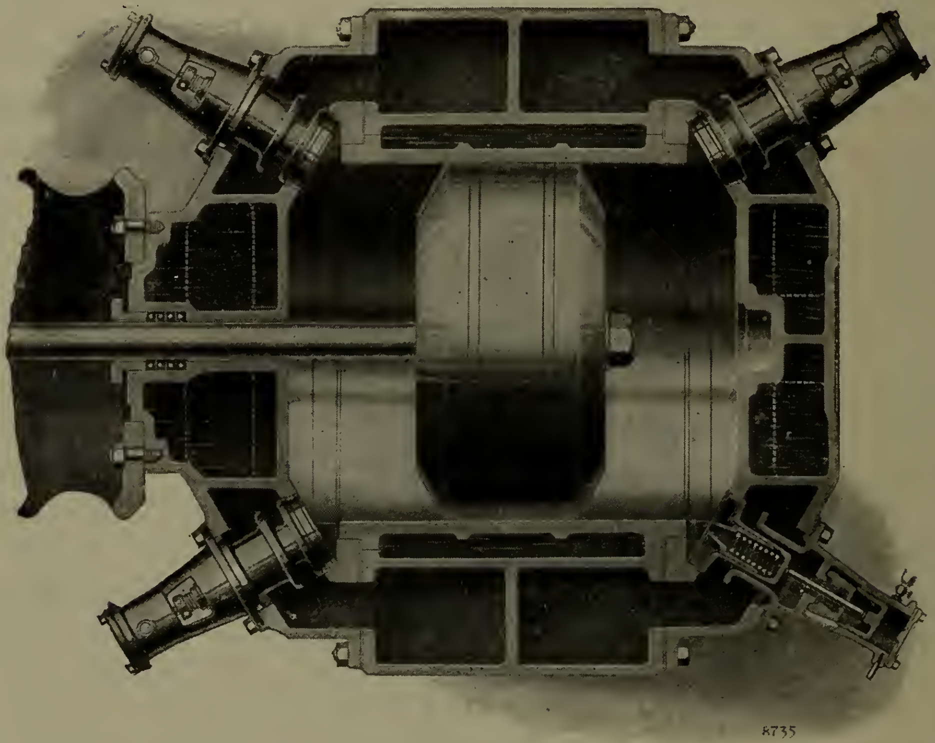


Fig. 43—A clearance regulator applied to large power-driven air compressors.

Yet another method of regulation provides auxiliary clearance spaces, or pockets, at each end of the cylinder which are successively 'cut in' as load diminishes. The excess air is simply compressed into these clearance spaces and expanded on the back stroke. The capacity of the cylinder is reduced without any appreciable waste of power, for the energy used in compressing the clearance air is given back by its expansion. See Fig. 43.

On power-driven compressors with Corliss intake valves, several different methods of unloading or regulating are used.

By one method, the Corliss valve is held open for the full admission stroke, and also for a part of the compression stroke, this latter portion being determined by the unloading called for. Evidently this is practically equivalent to a shortening of the stroke of the compressor.

By another method the Corliss intake valve is opened full at beginning of admission, but closes later in the admission stroke. The air admitted to that point is expanded or rarefied for the remainder of the compression stroke, and then compressed, the volume of compressed air delivered being of course reduced. This arrangement is productive of an excessive temperature range in the cylinder. Still a third method opens and holds open the intake valves at one end of the cylinder, or at opposite ends in duplex machines. The effect of this is to make ineffective one out of every two strokes. If still further unloading is necessary, the intake valves at the other end of the cylinder or cylinders are opened and held open. The three arrangements just outlined all operate by a pressure-controlled mechanism which actuates some form of trip on the Corliss air valve gear, somewhat similar to the release mechanism of the Corliss steam valve for varying the cut-off.

In the regulation of the power-driven compressor, less reliance must be placed upon the automatic regulation of the individual machine than upon the intelligent subdivision of the load between two or more machines and upon the careful management of the resulting plant. In designing a plant of these machines, maximum capacity must be cared for in the normal output of the machines, while partial loads are best provided for by starting or stopping one or more machines, the remainder running at or very near full load.

It is usually desirable to start a power-driven compressor with no load, throwing on the load gradually after normal speed has been reached. This is in fact essential in machines driven by electric motors, for the heavy inrush of current in starting under load is dangerous, particularly where power is taken from a transmission circuit supplying other motors. Evidently almost any of the unloading devices noted in the previous section can be used for this purpose if properly arranged for manipulation. The usual form, however, is simply a by-pass valve to atmosphere on the line close to the compressor protected by a check valve between it and the receiver to prevent the return of air from the line when the starting unloader valve is open. This check valve is essential where several compressors serve one line, permitting cutting in or out any machine without unloading the others. When normal speed is reached the by-pass or unloading valve is gradually closed and load resumed. On two-stage machines, an unloader valve should be provided on the low-pressure discharge to the intercooler, as well as on the high-pressure discharge to the line. In the latter case, both cylinders operate momentarily as low-pressure cylinders.

CHAPTER IV

COMPRESSOR ACCESSORIES

Aftercoolers. The air aftercooler performs the combined function of cooling and drying the air after it has left the compressor, by bringing the hot, moist air in contact with water-cooled surfaces of such extent and over such a duration of time, that the moisture in the air will be condensed and deposited before it can enter the distribution system.

The advantages of the aftercooler are best illustrated by a discussion of the action of moisture in compressed air. Where the air is to be used in reciprocating mechanisms, the presence of moisture has a tendency to wash away the lubricant, leaving bare surfaces in moving contact and increasing the opportunity for wear. This is particularly true of pneumatic devices, such as riveters, drills, hoists, etc., used in the metal-working industry, as their moving parts, of necessity limited in size, operate at high speeds.

Wear is not only destructive of the efficiency of the device, but wasteful of power, due to air leakage.

Moisture which condenses and collects in air pipe lines, causes 'water hammer', tends to leaky joints, often reduces the air passages and causes loss of power by accumulating at low points.

The exhaust air from these pneumatic devices expands, causing low exhaust temperature. If moisture is present in the air, it is apt to freeze and clog the exhaust and create an interference with efficient operation.

The way to guard against these evils is by the removal of the moisture from the compressed air before it enters the distribution system.

Figs. 44 and 45 show various types of aftercoolers of both the horizontal and vertical construction. See Table XIX.

Air Receivers and Moisture Traps. The air compressor discharge is pulsating in character and as a steady flow of compressed air to the pipe line is highly desirable it is usual to employ a large tank or so-termed 'air receiver' for storing the air and equalizing the flow. See Fig. 46.

The larger the air receiver the greater will be its storage capacity and the smoother will be the air flow. This is especially useful in work of an intermittent character. It makes the problem of regulation easier and assists the governor or regulator of the compressor in maintaining a steady pressure.

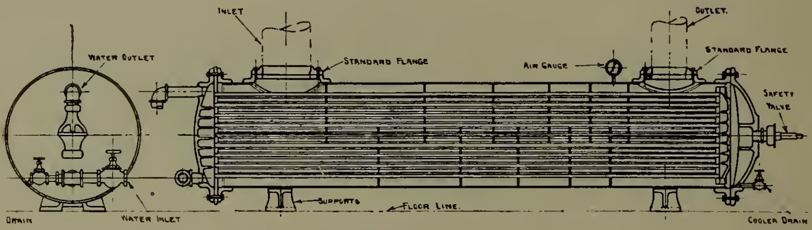


Fig. 44—A horizontal air aftercooler.

Air receivers are built both vertical and horizontal; preference should, however, be given to the vertical type on the grounds of economy in floor space. See Table XX.

The air receiver should be placed as close to the compressor (or aftercooler when used) as possible and pipe amply large used for connecting it up. It is customary and good practice to make this pipe larger than that leaving the receiver. The use of elbows between the compressor and receiver should be avoided; any bends necessary should be made by giving the pipe a wide sweep.

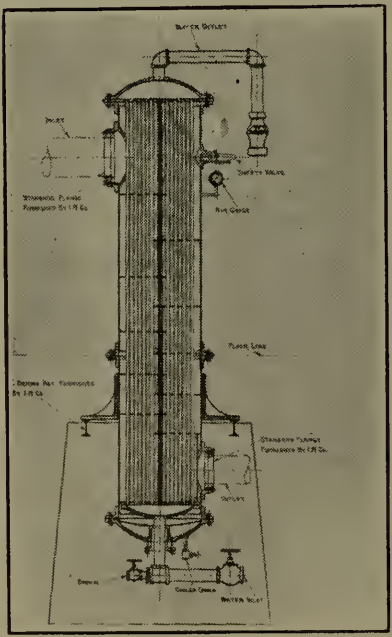


Fig. 45—A vertical air aftercooler.

A gate valve should never be used between the compressor and the receiver. If one is used a safety valve must be interposed in the line between the compressor and this valve.

The receiver should have a safety or relief valve and where receiver is installed out-of-doors, the relief valve should be piped back into the compressor room to avoid freezing.

The air receiver also acts partially as a cooler and moisture trap. Placing it out-of-doors will give greater cooling effect, resulting in greater condensation of moisture and therefore drier air in the transmission lines.

Provision is made for draining moisture by a drain-cock placed at the lowest point in the receiver. It should be opened at frequent intervals to expel the accumulated water.

Fig. 46—A typical air receiver.

It is good practice to pipe the receiver, with the inlet at the top and the outlet at the lower end, a sufficient height above the bottom to avoid the accumulated moisture.

Moisture Traps. On long pipe lines it is advisable to install small receivers or moisture traps at low points in the line, with the condition of piping reversed, namely, the entry at the bottom and exit at the top. These traps will catch the moisture condensed in the line, permitting its withdrawal at frequent intervals through drain-cocks.

Air Reheaters. Where the air is to be transmitted long distances and used out-of-doors the use of an efficient air reheater is highly desirable.

It will not only reduce the element of annoyance caused by freezing but will increase the working capacity of the air, as the air in being reheated to a temperature of 250 degrees Fahrenheit (which is usual with reheaters) is expanded in volume from 30 to 35 per cent.

Fig. 47—A typical air reheater.

The reheater should be placed as close as possible to the point of use of the air, to prevent loss due to radiation of heat after the air has passed through the reheater.

The construction of the air reheater is very simple, consisting of a cast body containing a fire box below and a coil of pipe above through which the air passes, the air entering at the bottom and leaving at the top.

Fig. 47 shows a typical Air Reheater. See Table XXI.

Protective Devices. The sources of danger from compressed air equipment are few and easily guarded against: First, running away of the compressor; Second, obstruction of the air lines causing the development of pressures beyond a point for which the equipment was built; Third, abnormal rise in air temperature.

The first is usually provided for by the governing and regulating devices furnished on the compressor itself; the second by the employment of pop safety valves placed in the receiver and transmission lines, and set for a predetermined pressure. When the pressure exceeds that provided for, the pop valves automatically blow off releasing the excess pressure until the trouble has been remedied.

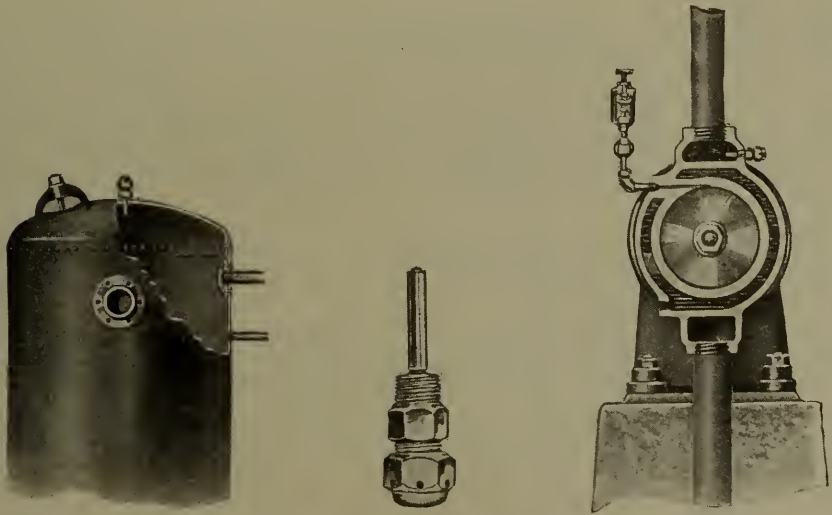


Fig. 48—Views showing how the fusible plug is applied to an air cylinder and air receiver.

The third, abnormal rise in temperature, may result from several causes, such as insufficient lubrication, interruption of the cooling process, sticking of the valves, etc. If allowed to persist explosions may result or parts may be strained to such an extent as to become unsafe or permit heavy leakage losses.

It is well known that lubricating oils if subjected to high enough temperature will either catch fire and burn, or will produce gases of a highly explosive character.

To provide against this latter condition it is highly desirable that safety devices, such as the fusible plug, described herewith, be employed at every point of possible danger throughout the plant. See Fig. 48. Its installation is recommended on the air-compressing cylinders at the point of discharge, in the air receiver and at intervals in the transmission lines.

The fusible plug shown consists of a body formed for readily screwing into a hole, tapped for ¼-inch pipe thread, in the wall of the apparatus to be protected. This body carries a fusible stem or plug and is covered by a cap having holes open to the atmosphere.

Upon a rise of temperature to a point for which the safety element is set, it melts, opening a passage to the cap and creating a distinctive whistle which persists until the trouble is remedied. It is then but a moment's work to replace the fusible element and the machine is again properly safe-guarded against recurring danger.

The plug illustrated is supplied in two sizes, 350-degree and 500-degree blowing points.

The 350-degree plug is suitable for use with a single-stage compressor working at pressures up to 40-pounds gauge and in two-stage compressors, working at 100-pounds gauge pressure, or in the discharge side of a three- or four-stage compressor delivering air at 1,000-pounds gauge pressure.

The 500-degree plug is for use in the discharge line of a single-stage compressor working at 100-pounds gauge pressure.

TABLE XIX

AIR AFTERCOOLERS

80 TO 100 POUNDS AIR PRESSURE

Size of Aftercoolers		Square Feet of Cooling Surface	Pipe Connections			Maximum Capacity of Aftercooler in Cu. Ft. of Free Air Per Minute with Cooling Water at								Shipping Weight Lbs.	
			Air			60 Degrees F.		70 Degrees F.		80 Degrees F.		90 Degrees F.			
Diam. Shell Ins.	Height or Length Ft. and Ins.		Inlet Ins.	Outlet Ins.	Water Inlet and Outlet	Single-stage Compression	Two-stage Compression	Single-stage Compression	Two-stage Compression	Single-stage Compression	Two-stage Compression	Single-stage Compression	Two-stage Compression	Domestic	Export
VERTICAL															
17½	10–6	99	6	5	1	475	795	433	721	390	650	350	585	2,400	2,900
20¾	10–6	152	7	6	1½	705	1,170	640	1,054	575	957	518	860	3,000	3,600
22½	11–6	204	8	6	2½	925	1,540	840	1,400	755	1,260	680	1,130	3,800	4,550
22½	14–6	305	10	8	2½	1,410	2,360	1,280	2,135	1,150	1,920	1,035	1,725	4,200	5,000
27¾	14–6	505	12	9	3	2,340	3,880	2,120	3,535	1,910	3,180	1,720	2,860	6,600	7,950
30	17–8	757	14	10	3	3,500	5,840	3,180	5,299	2,880	4,750	2,590	4,270	8,500	10,200
33¼	18–6	1,005	15	10	4	4,650	7,850	4,220	7,035	3,800	6,330	3,420	5,700	11,300	13,600
39	19–0	1,497	18	14	5	6,900	11,500	6,280	10,749	5,650	9,400	5,100	8,450	16,100	19,300
45¼	19–0	2,012	18	14	6	9,300	15,500	8,450	14,084	7,600	12,650	6,850	11,350	19,700	23,700
HORIZONTAL															
14	10–0	55	5	4	1	253	360	230	330	207	297	186	268	1,800	2,160
17½	10–6	99	6	5	1	475	795	433	721	390	650	350	585	2,400	2,900
20¾	10–6	152	7	6	1½	705	1,170	640	1,060	575	957	518	860	3,000	3,600
22½	11–6	204	8	6	2½	725	1,540	840	1,400	755	1,260	680	1,130	3,800	4,550
22½	14–6	305	10	8	2½	1,410	2,360	1,280	2,135	1,150	1,929	1,035	1,725	4,200	5,000
27¾	14–6	505	12	9	3	2,340	3,880	2,120	3,535	1,910	3,180	1,720	2,860	6,600	7,950
30	17–8	757	14	10	3	3,500	5,840	3,180	5,299	2,880	4,750	2,590	4,270	8,500	10,200
33¼	18–6	1,005	15	10	4	4,650	7,850	4,220	7,035	3,800	6,330	3,420	5,700	11,300	13,600
39	19–0	1,497	18	14	5	6,900	11,500	6,280	10,749	5,650	9,400	5,100	8,450	16,100	19,300
45¼	19–0	2,012	18	14	6	9,300	15,500	8,450	14,084	7,600	12,650	6,850	11,350	19,700	23,700

TABLE XIX (*Continued*)

COOLING WATER REQUIRED FOR AFTERCOOLERS, INTERCOOLERS, AND AIR CYLINDER JACKETS

Gallons of Water per 100 Cu. Ft. actual free air for different water temperatures

	60 Degrees	70 Degrees	80 Degrees	90 Degrees
1. Aftercooler or intercooler separate (80–100 Lbs. 2-stage compression)	2.5	3	3.5	4
2. Intercooler and jackets in series (80–100 Lbs. 2-stage compression)	2.9	3.4	4.0	4.5
3. Aftercooler for 80–100 Lbs. single-stage compression	4.0	4.5	5.2	6.0
4. Both low- and high-pressure jackets with water supply separate from intercooler (80–100 Lbs. 2-stage comp.)	0.85	1.0	1.2	1.4
5. Jacket for single-stage comp. 40 Lbs. air pressure	0.5	0.6	0.7	0.9
6. Jacket for single-stage comp. 60 Lbs. air pressure	0.6	0.7	0.8	1.0
7. Jacket for single-stage comp. 80 Lbs. air pressure	0.7	0.8	0.9	1.1
8. Jacket for single-stage comp. 100 Lbs. air pressure	0.8	0.9	1.0	1.2

With the amounts of water given in the above table, it is expected that the temperature of the air leaving the intercooler or aftercooler will be within 20 degrees of the temperature of the water entering the cooler for ordinary working conditions; namely, when the cooler is handling air from a two-stage compressor, 100 Lbs. work, and when the initial water temperature is around 70 degrees F.

Less water may be used without causing a very appreciable increase in this 20-degree temperature difference. To get good aftercooling, it is better to have a moderate quantity of cold water rather than an unlimited supply of water at a high temperature. In cases where water is very scarce, compressors may be run without material loss with considerably less water than shown in the table, especially for the jackets.

TABLE XX

AIR RECEIVERS AND MOISTURE TRAPS

For Standard Working Pressures

Number of Size	Diam. in Ins.	L. in Ft.	Contents Cu. Ft. (about)	Thickness of Shell Inches	Thickness of Heads Inches	Weight Lbs. (about)	Diam. of Safety Valve Ins.	Diam. of Inlet & Dis. V's Ins.	COMPRESSOR CAPACITY RECEIVER IS BEST ADAPTED FOR IN CUBIC FEET FREE AIR PER MINUTE
For Working Pressure up to 110 Pounds									
0	18	6	10	3/16	5/16	350	1	2½	90
00	24	6	18	7/32	5/16	575	1¼	2½	120
1	30	6	29	¼	3/8	950	1½	3	150
2	36	6	42	¼	3/8	1,000	1½	3½	150 to 200
3	36	8	56	¼	3/8	1,350	1½	4	200 to 300
4	42	8	77	9/32	3/8	1,750	2	5	300 to 500
5	42	10	96	9/32	3/8	2,000	2	6	500 to 700
5½	48	8	100	11/32	7/16	2,480	2½	6	500 to 800
6	48	12	150	11/32	7/16	3,000	2½	7	700 to 1,200
7	54	12	190	3/8	7/16	3,300	2½	8	1,200 to 2,100
7½	60	14	275	13/32	½	5,500	2½	9	2,000 to 3,000
8	66	18	437	7/16	9/16	7,500	2½	10	3,000 and over
9	24	6	18	7/32	5/16	625	1½	4	(These are only furnished horizontal style and are used as water traps in air lines.)
10	36	6	42	¼	3/8	1,100	1½	6	
10½	48	8	100	11/32	7/16	2,200	2½	6	

The tables of dimensions given in this list refer to either Vertical or Horizontal patterns, excepting for sizes Nos. 9, 10, and 10½ which are furnished only in Horizontal patterns, and are used as water traps in air lines. Vertical Receivers are usually preferred to Horizontal, on account of the small amount of floor space that they occupy.

Sizes 0 and 00 are suitable for use in machine shops and granite yards, for small air lifts, or anywhere in connection with a small air compressor. They are made of the best steel, single riveted, and tested to 165 Lbs. water pressure. Fixtures generally include Safety Valve, Pressure Gauge, Drain Cocks, and tapping for inlet and discharge pipes.

On Sizes Nos. 1 to 10½ inclusive fixtures generally include Manhole, Safety Valve, Pressure Gauge, Drain Cocks and from Nos. 4 to 8 inclusive and Nos. 10 and 10½ Flanges for inlet and discharge pipes.

When considering the use of Nos. 9 and 10 or 10½ for moisture traps, always use Size No. 10 or 10½ with 6-inch connections if air pipe is over 4 inches.

The sizes given for inlet and discharge openings are MAXIMUM. When necessary, they may be reduced on the smaller sizes by the use of 'reducers' and on Sizes No. 4 and up (which have flange connections), by the use of smaller flanges.

TABLE XX (*Continued*)
SPECIAL SMALL AIR RECEIVERS

FOR USE IN GARAGES AND SMALL MACHINE SHOPS WHERE COMPRESSORS OF SMALL CAPACITY ARE USED

Number of Size	Diameter Inches	Length Feet	Contents Cu. Ft. (about)	Diameter Inlet and Discharge Openings Inches	Diameter of Safety Valve Inches	Weight Lbs. (about)
FOR WORKING PRESSURE UP TO 110 LBS.						
01	12	3	2¼	1¼	½	70
02	14	4	4	1½	¾	100
03	16	5	6½	2½	¾	175
FOR WORKING PRESSURE UP TO 200 LBS.						
04	12	3	2¼	1¼	½	100
05	14	4	4	1½	¾	150
06	16	5	6½	2½	¾	275

Fixtures generally include Safety Valve, Pressure Gauge and Drain Cocks.

The sizes given for inlet and discharge openings are maximum. When necessary they may be reduced by the use of standard pipe 'reducers'.

TABLE XXI
AIR REHEATERS

Over-all Dimensions, Ins.		Square Feet Heating Surface	Inlet and Outlet Diam. Ins.	Capacity in Cubic Feet of Free Air per Minute at 80 Lbs. Pressure	Final Temperature Degrees Fahrenheit	Percentage of increase in Volume	Net Wgt. Lbs.
Outside Diam.	Height						
17	31	7½	2	200	250	30	380
42	56	22	4	550	250	30	2,980

The use of Reheaters is recommended in all plants where the air is to be transmitted long distances, and used out-of-doors. They are particularly essential in cold weather to prevent the freezing of the moisture in the air, and the consequent choking of the exhaust ports of the different motors operated. They should be located as close to the motors as practicable and it is desirable to insulate all hot pipes, to prevent loss of heat by radiation.

As the air passes through the reheater, and is heated to the usual temperature of about 250 degrees Fahrenheit, it expands in volume from 30 to 35 per cent., which increases its working capacity that amount.

CHAPTER V

INSTALLATION AND CARE OF COMPRESSORS, ACCESSORIES AND PIPE LINES

Before installing or using an air compressor familiarize yourself with the instructions issued by the manufacturer.

Locating the Air Compressor. If possible locate the compressor in a clean, light situation with room all around it so that it can be readily inspected and kept clean. If the air is taken into the cylinder directly from the room, see that there is no dust or dirt near the intake where it can be drawn in with the air. A small amount of dust constantly passing into the cylinder will often cause very rapid wearing of the valves and piston. A better arrangement is to run a pipe from the cylinder outside the building and up, so as to take in the air some eight or ten feet above the ground. The top should be covered and protected by a wire screen so that rain or large particles of anything cannot be drawn in.

Be careful to see that there are no exhaust pipes discharging steam, water, dust or other waste near the compressor intake, so that it can be carried into the machine by the intake suction.

The longer the intake pipe the larger should be its diameter A good rule is to increase it one inch in diameter over the size at the compressor for every ten feet in length. Wood is not a good material for it unless lined with tin, as cracks soon develop through which dust and dirt are free to enter.

Compressor Foundations. Foundations are preferably built of cement although if more convenient brick or stone may be used; but whatever the foundation material may be, cement mortar should be used. Lime mortar should be avoided, as it soon crumbles under the effect of compressor operation.

While nearly all compressors are built entirely self-contained, all machinery has a certain vibration and, as it is the place of the foundation to absorb this, it should be made amply large.

Manufacturers of compressors supply foundation plans giving all dimensions and locating all bolt holes, as well as instructions for building the foundations, and it is highly advisable to follow their plans. In giving the following general instructions it is assumed that the foundation is being built upon fairly solid ground. If the bottom is soft, or otherwise insecure, it is advisable to place beneath the foundation proper a footing course six inches to nine inches deep, and a foot or more larger around. Remember that the belt or engine is always trying hard to pull the compressor over and this pull must be resisted by the foundation.

In Fig. 49 is shown a skeleton sketch for building a typical foundation for a straight-line, single-stage air compressor.

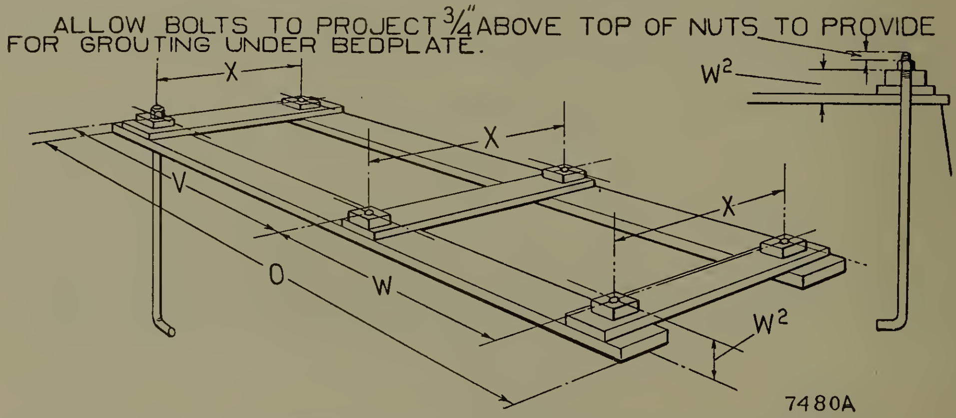


Fig. 49—Skeleton sketch showing how a compressor foundation should be built.

The best way to locate the foundation bolts is to build a wooden template of boards, somewhat as shown above, and support it in position so that the foundation can be built below it.

The letters 'W', 'X', 'Y', etc., refer to the dimensions on plans supplied with the machine by the manufacturer.

In building foundations two mistakes are often made. First, the bolts are built in solidly, with no allowance for moving them to suit slight differences between the hole in the bedplate and those in the template; and second, the foundation is built so high that the bolts do not project far enough to pass all the way through the nut.

All bolts should have large holes around them so that their tops can be moved an inch or so in any direction, and the easiest way to accomplish this is to slip over each bolt a square wooden box about 2½ inches inside or a piece of old 2-inch or 2½-inch pipe. The wooden box should be withdrawn when foundation is finished and to assist in this it can be made tapering, say one inch smaller at the bottom than at top. The iron pipe may be left in. In either case, after the compressor is set, the holes should be filled with grout or thin cement.

To insure the proper height of bolts above foundation, blocks should be placed upon the top of the template boards to make the total thickness of wood equal to the thickness of lug on bedplate, as shown on plan.

The bolts may be hung from the template and nuts placed on top allowing three-quarter inch of bolt to project above the nut.

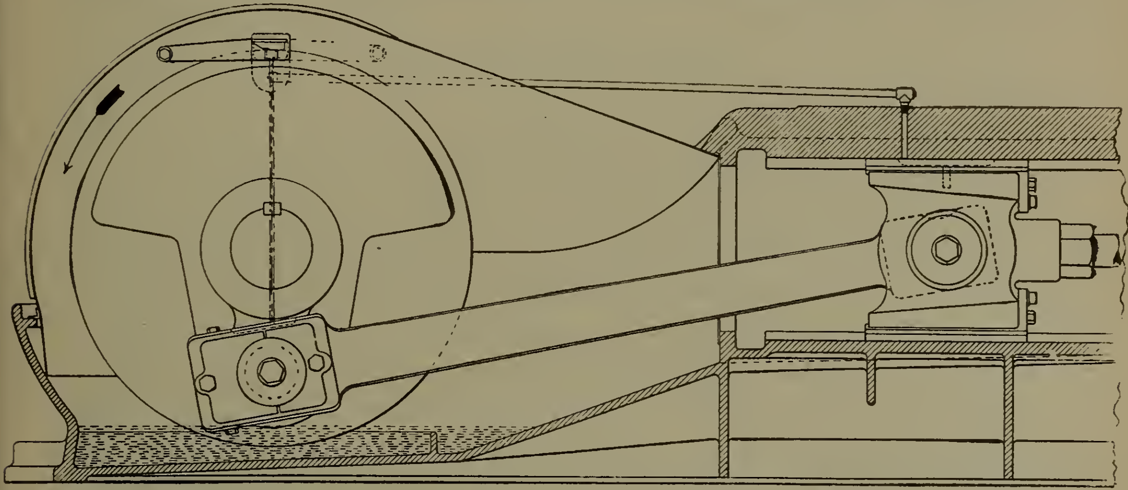


Fig. 50—Arrow shows direction of rotation for power-driven compressors.

This will allow for leveling the compressor and grouting it upon the foundation.

When the compressor is in place, level it and line it carefully by means of wooden wedges or liners at the four corners, and draw the nuts lightly down upon the bolts.

Build a dam about two inches high around the bedplate and pour in sufficient grout to fill all the space between foundation and bedplate. This grout should also fill the space around the foundation bolts.

Allow this cement to harden a few days before finally drawing the nuts down firmly upon the bolts.

Belted Compressors. An air compressor, like a steam engine is preferably run so that the pressure of the cross-head shoe will be down upon the lower guide, as this prevents any tendency to lift, and renders lubrication more efficient. For this reason the machine should be run under as shown by arrow in Fig. 50.

Use a belt half an inch or one inch narrower than the face of the belt wheel and do not make it any tighter than necessary to prevent slipping. Unnecessary tightening may place a heavy load upon the main bearings, causing them to heat and make trouble.

New belts are stiff and do not adhere like an old belt, so that trouble is sometimes experienced in starting up a new outfit. A good belt dressing will greatly assist in such cases, softening the belt and preventing slipping.

AIR COMPRESSORS

Steam Piping. The steam piping should drain toward the compressor throughout its whole length. This is important, for if the pipe contains low spots or pockets, where water could accumulate, a sudden increase in the demand for air, with a more rapid flow of steam through the pipe, might cause it to carry the entrained water with it to the cylinders and do serious damage. The use of a steam separator is recommended, particularly if the compressor is located at a considerable distance from the boiler. This would furnish drier steam to the compressor, increase the economy of the machine and be a safeguard against water being carried into the cylinders. Place a stop valve where the steam pipe branches from the main line. This is for convenience when making repairs or repacking or regrinding the throttle valve, and may also be used to shut down the compressor in the event of an accident to the regular throttle valve.

A drain should be provided in the steam pipe on the boiler side of, and as close as possible to, the compressor throttle. The steam pipe should all be covered with some form of non-conducting material such as asbestos or mineral wool.

Upon the completion of the steam piping it should be thoroughly blown out with a good pressure of steam. This should be done before making the final connection to the compressor at the governor; or, if the piping was begun at the compressor end, it should be especially disconnected for the purpose. There is usually an accumulation of chips and loose scale in the piping, which will be removed by the escape of the steam under pressure; this insures clean steam chests and cylinders free from any grit which would be apt to damage the valves and the seats.

Exhaust Piping. Best practice advocates the laying of the exhaust piping beneath the floor, running it to the side of the compressor room, then vertically to the atmosphere. The horizontal portion of the exhaust pipe leading to the riser should pitch slightly toward it. Its connection to the riser should be made with a tee or an elbow with a tapped hole in its heel to provide a drain for the condensed steam. If the compressor has compound steam cylinders the steam receiver must be properly drained; an opening is provided for this purpose at the end of the horizontal portion underneath the low-pressure cylinder. This should always be opened before starting the compressor, and steam turned into the receiver through a by-pass valve. The receiver, as well as both the steam cylinders, should be thoroughly warmed by steam before starting the compressor.

If a condenser is used the main exhaust pipe will be connected to it, but there should also be an opening to the atmosphere pro vided with an automatic relief valve. A stop valve should be placed in the exhaust pipe between the condenser and the relief valve. All of the exhaust piping should drain toward the condenser.

Steam Cylinder Lubricators. The steam and air cylinders are generally lubricated by means of a sight-feed oiler or force feed lubricator.

Where force feed is used the oil is pumped through sight-feed glasses and then to the cylinders. Full description and instruction sheets generally accompany each lubricator and they should be carefully studied and preserved for future reference.

The proper feed for the steam cylinder is from four to ten drops per minute.

With high steam pressures or superheat, more oil may be necessary. Do not allow the valve or piston to run dry.

Use a good quality of oil and be sure that it is suited to the work. The higher the pressure and temperature of the steam, the more important the quality of the steam cylinder oil becomes.

Gasket Joints. The front and back steam cylinder heads are generally made with a ground joint, no gaskets being used, both the heads being scraped and ground on the cylinder to make a steam-tight joint.

The other steam joints around the compressor usually are packed with sheet gasket. Any good oil-proof gasket will answer, but those of the sheet asbestos type are preferable.

STARTING. Turn the compressor over a couple of times by hand to be sure everything is free when ready to start. The proper direction of rotation is so that the top of the fly-wheel travels toward the steam cylinder, or, as it is commonly called, 'the engine runs under'.

Open a valve in the air line so compressor can run without building up air pressure in the receiver, or open the two indicator cocks in the side of the air cylinder.

Turn on the circulating water in the air cylinder jacket.

Open the drain cocks on steam cylinder and drain the steam pipe above the throttle valve until it is warmed up, then open the throttle a very little and let the steam blow through the steam cylinder until it is thoroughly heated up, turning the engine over so that the steam blows first through one end, and then through the other.

When well warmed up, give it a little more steam and let it run slowly a while, gradually bringing it up to speed.

Watch the governing devices and satisfy yourself that they are operating properly and will control the engine.

SETTING STEAM VALVES. No instructions can be given on this point which will apply to all types of steam valves.

It is well to note, however, that each manufacturer generally sees to it that the steam valves are properly set before the machine leaves the factory and under no circumstances should the adjustment be made differently from the marks usually indicated on the valve gear. Should it for any reason become necessary to tear down the valve gear, study the manufacturer's instruction book carefully when reassembling.

LUBRICATION. Compressors supplied with automatic splash or bath lubrication system require the filling of the crank case to the height usually indicated by the manufacturers. The crank case is inclosed and carries a quantity of oil into which the crank and connecting rod dip at every revolution. The crank is also provided with oil scoops, which, dipping into the oil, throw it all over the interior of the case. A portion of it runs into oil holes supplying the main bearings. That which works through the bearings to the outside is caught on oil rings and drains back to the crank chamber, so that no oil gets on the fly-wheels. Some of the oil is caught in a pocket inside the crank case and delivered by a pipe to cross-head pin and piston rod. Oil is splashed by the cranks direct to the cross-head guides.

The oil should be replenished from time to time and occasionally drained off and filtered, or strained through a thick woolen cloth, at the same time wiping out the bottom and corners of the crank case with kerosene or gasoline to remove any sediment that may have settled. A convenient way to ascertain if the crank case contains the proper amount of oil is to observe the height in the oil pockets below the main bearing. When the compressor is not running and all the oil has drained back to its level it should stand in the pockets about one-half inch below the point at which it would overflow.

Have regular times for inspecting the height of the oil and remember that with the proper amount of oil the lubrication is perfect, and all bearings are drenched with oil; if the oil level is allowed to fall to where the scoops cannot reach it, all lubrication ceases and the bearings will soon be ruined.

Compressors having oil cup lubrication for the driving element should have the cups inspected and filled daily, the flow being regulated in accordance with the manufacturer's instructions.

Air cylinders oiled by means of sight-feed lubricators which may be adjusted to feed the requisite amount, will require daily attention. The amount of feed varies with the size of the cylinder from one drop in two minutes for a 6 x 6-inch cylinder, to two drops per minute for a 20 x 12-inch, etc. A very small amount is required, as the oil is not washed out of an air cylinder as it is from a steam cylinder.

The inlet and discharge valves should be removed occasionally and cleaned, and by observing them it can be determined whether the cylinder is receiving the proper amount of oil. The surfaces should show a greasy appearance and not be dry.

The oil to be used in the crank case can be any good machine or engine oil that is of a medium density, such as Atlantic Red Engine Oil.

A special oil must be used in the air cylinder, as the heat of the compressed air is very high and decomposes the ordinary machine oils, not only forming carbon and sooty deposits on the valves and walls but also forming explosive gases which are dangerous and liable to cause explosions. Follow the manufacturer's directions.

INSPECTION AND CLEANING. Economical and efficient operation of compressed air machinery demands regular inspection, and the following is an outline of the practice prevailing in the majority of plants.

The compressor should be inspected at least once a month, making any necessary adjustments, such as take-up of packing glands and replacement of worn parts. Compressed air valves are accessibly constructed so that it is a simple matter to inspect them, and this should be done at the regular monthly inspection. The valves should present an oily surface free from carbon. Any carbon deposited should be immediately removed. It is also well to examine the ports and passages to see that they are free from obstruction.

Never use kerosene or coal oil in an air cylinder to clean it out. This is a very dangerous practice and should be absolutely prohibited. A good way to clean the cylinder is to fill the lubricator occasionally with strong soap suds or soda water, allowing this to feed freely. This is very effective.

The air receiver should be drained of water each day by means of the drain-cock usually provided.

Examine daily the height of the lubricating oil in the crank case, oil cup or force pump chamber and replenish if necessary. Where adjustable lubricators are used they should be adjusted to feed the proper amount of oil. After these preliminary inspections and adjustments are made, the next thing in starting up an air compressor is to start the circulating water before compressing begins. Valves should be examined, and if worn or cut should be reground. Safety valves should be tested by raising the pressure to the point of blow-off. Lost motion in pins and bearings should be taken up.

Once a month the crank case oil should be renewed, but before renewing, the crank case itself should be thoroughly cleaned and all other parts inspected.

It is advisable to carry on hand a stock of such parts as are liable to breakage or which wear out quickly. Inlet and outlet valves are the parts most likely to give way and it is advisable to carry on hand a complete set for emergency purposes. This will avoid costly shut-downs while waiting for new ones to come from the factory.

As a matter of economy, it is advisable to inspect pipe lines, air hose, shut-off valves, etc. at least once a month for leakage. A good way to do this is by the use of a lighted candle placed at all connections, for, unlike steam leaks which make themselves known by the escaping white vapor, air leaks cannot be seen, but can be felt.

WATER PIPING. Each air cylinder is provided with water inlet and outlet, and drain openings in the water jacket. A controlling valve should be placed on the water inlet, and the outlet should if possible be open, the water falling into an open pipe end or funnel so that it can be seen at a glance whether water is passing through the jacket or not. See Fig. 51.

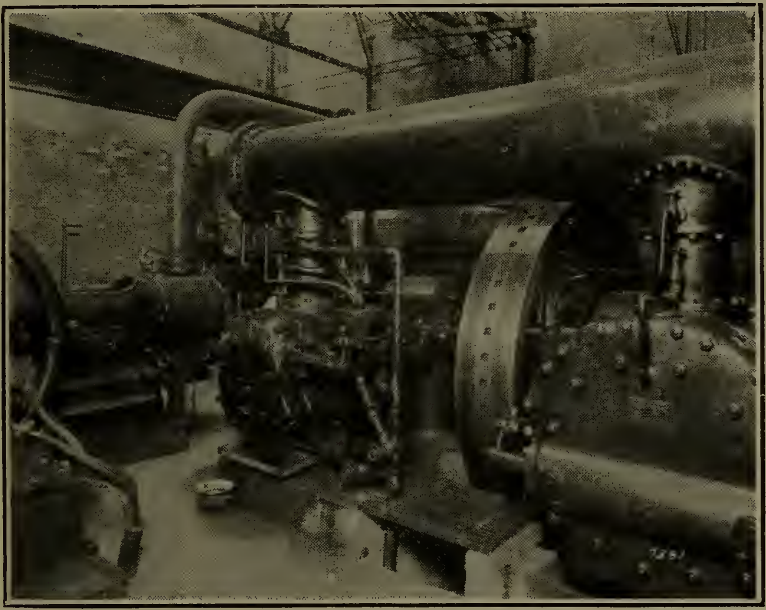


Fig. 51—Funnel arrangement on water outlet piping which permits instant inspection for flow and temperature.

If desired, the circulating water may be operated in a closed circuit, being used for other purposes after passing through the compressor. The water pressure in the jacket should never exceed fifty pounds per square inch unless specially provided for by the manufacturer.

Be careful to drain the cylinder thoroughly if it is to be allowed to stand in a freezing temperature, as water freezing in the jacket or heads will certainly crack them sooner or later.

Occasionally remove the back-head and inspect the water spaces to see that they are not stopped up with sediment and mud. All water spaces in heads and jackets should be kept free by washing out as often as found necessary.

Adjustment of Connecting Rod. It is well to occasionally inspect the bearings and connecting rod boxes for possible wear. Provision is usually made for take-up.

Gaskets. In replacing the gaskets between the heads and cylinder use rubber. Be careful to use the same material as the old gasket and have it of a similar thickness. A thicker gasket will increase the clearance volume and reduce the capacity of the compressor, while a thinner sheet will not allow sufficient clearance between the heads and piston. Be careful to use a packing that is oil-proof, as otherwise the oil and high temperature will soon destroy it.

The Short-Belt Drive. The short-belt drive affords a very efficient and convenient method of driving these compressors by electric motor.

As will be seen from the cut on page 12 the motor is placed as close to the compressor as possible. In order to obtain a large arc of contact on the small motor pulley, a swinging arm is attached to the bedplate and carries on its outer end an idler pulley which rides upon the top of the belt. This automatically takes up the slack due to stretching and its pulling power is increased.

In laying out the foundation, the distance between centers of compressor and motor shaft varies, depending on the size of motor and motor pulley, and the size of the belt wheel on the compressor.

Installing Pipe Lines. When installing pipe lines, care should be taken to have them of sufficient size, for small transmission lines mean excessive loss of pressure due to friction. Large pipe lines are especially desirable where the pipes are long, or the supply has to meet the demand of a great many devices. Small pipe lines reduce pressure with a resultant inefficient operation of tools.

Sharp bends or elbows should be avoided. They mean restriction and friction.

All joints should be made with red lead, so as to insure tightness. Provide sufficient outlets—doing so will save money in subsequent remodeling and will do away with the use of unnecessarily long air hose.

Avoid low spots and wherever possible install the pipe line so as to drain to suitable traps placed at intervals for the removal of moisture.

Provide a shut-off valve at every outlet and use sufficiently large air hose. It is good practice to standardize on one size of hose, so that all will interchange. The hose should be of good grade, oil- and water-proof and armored.

Racks should be provided for hanging the hose when not in use. Do not permit the hose to lie around on the ground or floor to be run over by trucks.

Workmen should not be permitted to use the air for the perpetration of pranks. It is dangerous and has been known to result in loss of life.

Where it is necessary to run air lines out-of-doors it is good practice to bury them in concrete conduits to which access may be had for occasional inspection.

It is surprising how rapidly the use of compressed air spreads after it has been made available, and it is not uncommon to find an air compressor running overloaded due to added uses not intended when the air power was first installed. Hence it is advisable to provide sufficient reserve capacity when selecting the air compressor.

The advisability of selecting an air compressor with reserve capacity is emphasized by the statement recently made by an experienced factory manager. He said, "Once compressed air is installed, it simplifies and accelerates many operations to such an extent, and there is such a marked improvement in shop practise that the number of applications multiply rapidly."

Not only is it advisable to provide ample compressor capacity, but pipe lines should be installed of a size sufficiently large to provide for future growth. The necessity for this can be readily appreciated from the following example: the loss in pressure in transmitting 50 cubic feet of free air per minute at 100 pounds pressure through 1,000 feet of 1-inch pipe is 11.89 pounds and only .27 pounds in transmitting the same volume of air through a 2-inch pipe.

When an installation is made and starts with a small diameter transmission line, perhaps fully capable of taking care of immediate requirements, and then the demand increases for air power, one of two things must be done: either the first line must be torn out and a larger one installed, or another line must be added. It is obvious that in the first case expense occurs which could have been avoided, and in the second case the loss of transmission is multiplied by two. Both can be avoided by installing a line of sufficient size in the first place at but a slight increase in cost of material.

As already indicated, the advantages of using air are many. It is not only cheap; it is reliable and flexible, and it is peculiarly adapted to portable work. It requires no insulation. Unlike steam, it may be transmitted over long distances without serious loss of power, nor are there any lurking dangers from exposed portable power lines, as in the case of electric transmission. The equipment is simple to install and is readily understood by the layman.

CHAPTER VI

PORTABLE PNEUMATIC TOOLS

In the metal industry it is not always possible to take the work to the tool, and when possible, not always convenient to complete all operations while the work is at the tool. This has resulted in the call for power tools of various kinds which are easily transportable to the work, to replace slow and irksome manual operations, and the rapidity with which the number of these tools has multiplied is the best evidence of their need.

This is especially true where work of a bulky nature is handled, such as boilers, structural steel forms, etc., and also out on the assembly floor where machines of great mass are put together and their movement is not to be thought of until the dismantling for shipment takes place. Then there are the repair shops for the work of repairing permanent machine installations, which present very similar problems.

This field of endeavor has fallen naturally to the pneumatically operated device, because of the ready adaptability of compressed air power, its availability, absence of danger, and the further fact that pneumatic tools embody within smaller confines greater range and power of action. The ruggedness of construction, simplicity and ready 'understandability' by all classes of labor are points in favor of pneumatic tools which cannot be claimed for portable tools, employing other kinds of power.

Their uses are many and varied in all divisions of the modern manufacturing plant.

In their adaptation they may be divided about as follows:

Power Plant
Hoists
Drills
Riveters
Chippers
Calkers
Scalers
Flue Rollers
Flue Cleaners
Tube Cutters
Stay Bolt Cutters
Flue Expanders

Machine Shop
Metal Drills
Close-Quarter Drills
Wood-Borers
Reamers
Grinders
Buffers
Chippers
Calkers
Tapping Machines
Bolt, Stud and Screw Seaters
Die Sinkers
Hoists

Foundry

Sand Rammers
Chipping Hammers
Hoists
Grinders
Lifts
Jib Crane Motors
Molding Machines
Pattern Vibrators
Jarring Machines
Jolt-Ramming Machines
Sand Blasters
Sand Sifters

Forge Shop

Forging Hammers
Bull Dozers
Bending Presses
Hoists
Forming Presses

Boiler Shop and Structural Steel

Riveters
Chippers
Metal Drills
Reamers
Calkers
Scalers
Flue Rollers
Tube Cutters
Rivet Busters
Hoists
Stay Bolt Cutters
Flue Expanders
Holder-Ons
Close-Quarter Drills
Stay Bolt Riveters
Jam Riveters
Yoke Riveters

HOISTS. Hoists which find their application most general are of four distinct types: Portable Vertical Cylinder Direct-Lift hoists, as shown in Fig. 52; Stationary Horizontal Cylinder Direct-Lift type, shown in Fig. 53; Portable Geared Motor type, shown in Fig. 54, and Stationary Motor type, shown in Fig. 55. The first and third always retain portability, the second and fourth types only when installed on traveling or jib cranes, which limit their range of field.

The Vertical Cylinder Direct-Lift type finds its application principally for work of a known height of lift, this lift being limited by the length of travel of the piston in its cylinder. They are built both single- and double-acting. The single-acting hoist is used for the more ordinary hoisting, such as warehouse and yard work, while the double-acting type, being air balanced and more easily controlled, is used for the more delicate classes of hoisting. See Table XXIV.

The vertical type of direct-lift hoist is also applied to short elevator lifts such as that shown in Fig. 56. In this type the hoist is placed directly over the elevator head-frame. Where longer lifts are required it is generally installed as shown in Fig. 57, employing a series of multiplying sheaves and rope.

The Horizontal Cylinder Direct-Lift type also finds its application principally for work of a known height of lift, and is commonly used in conjunction with traveling cranes, as shown in Fig. 58. See Table XXV.

The Geared Motor type of hoist is adapted for work requiring lifts of varying heights. It is built in a range of sizes up to 10,000 pounds capacity and lifts up to 100 feet. It is somewhat more sensitive to operation and control than the direct-lift type. Its design embodies a three-cylinder motor geared to a hoisting drum, which carries the rope with its hook block. Its control is from the ground by chain pulls, which operate the self-centering reversing valve that automatically returns to closed position upon the chains being released. See Table XXII.

Due to the greater height of lift afforded this type of hoist finds a more general adaptation. It may be used either hooked to an overhead beam or in conjunction with a traveler on an arm or on a traveling crane. It requires less headroom than the direct-lift type.

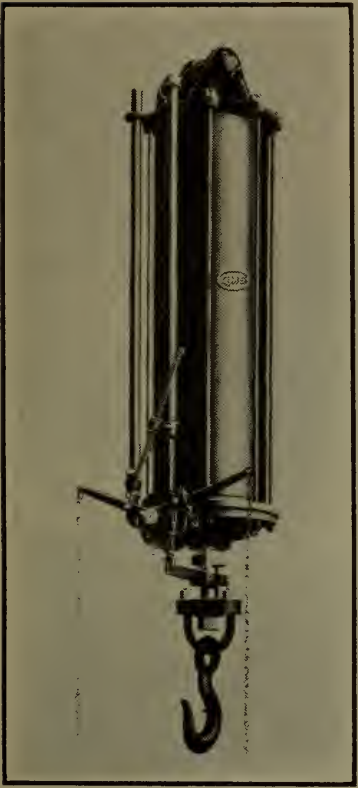


Fig. 52—Portable Vertical Cylinder Hoist.

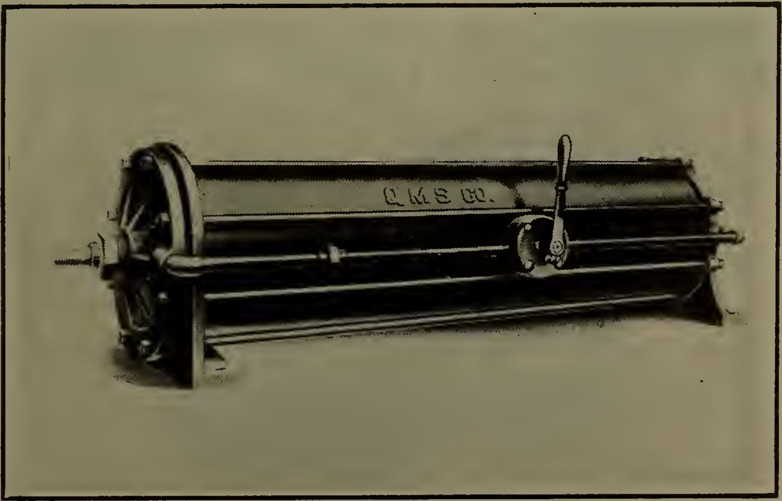


Fig. 53—Stationary Horizontal Cylinder Hoist.

Fig. 54—Portable Geared Motor Hoist.

The Stationary Motor type of hoist is intended for 'powerizing' small tools, jib cranes, winches, small lines of shafting, and for operating such tools as emery grinders, buffing and polishing wheels, fans, etc.

It consists of a motor of similar type to the portable geared motor hoist, driving a shaft, carrying at its exposed end a belt wheel.

It is built in several sizes. See Table XXIII.

Fig. 55—Stationary Motor Type of Hoist.

Few realize how comparatively inexpensive it is to install and operate such types of air hoists, or the convenience of their use, let alone the marked economy which they affect over hand-lifting. The table of costs shown on page 250 is a revelation in this respect.

PNEUMATIC DRILLS. The portable pneumatic drill may be divided into four general types: the reversible drill, Fig. 59; the non-reversible drill, Fig. 60; the wood-borer, Fig. 61; and the close-quarter drill, Fig. 62. The several types may also be given certain other minor divisions according to the use to which they are put; drilling, boring, reaming, tapping, flue rolling and seating studs, bolts and screws.

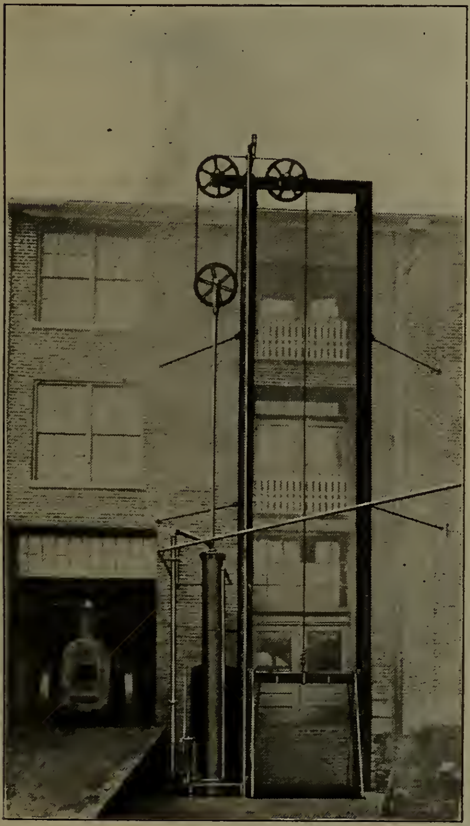


Fig. 56—Vertical Cylinder Hoist applied to short elevator lift.

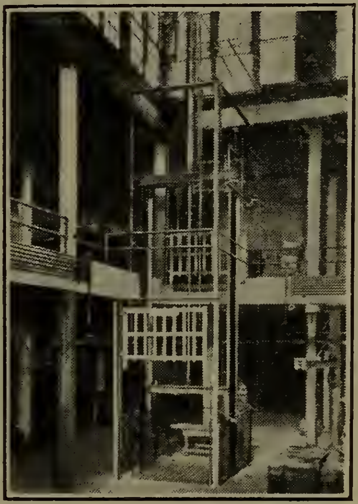


Fig 57—Vertical Cylinder Hoist applied to elevator lift of considerable height.

The difference in each minor division is represented almost solely by the type of chuck, and other such minor details as are required by the work to be done.

Both the reversible and non-reversible types are applicable to drilling, reaming, tapping, and bolt and screw seating.

Such work as flue rolling and stud seating is confined entirely to machines of the reversible type. When used for stud or bolt seating, special tools, such as that illustrated in Fig. 63, are required.

These drills range in drilling capacity up to 4 inches; reaming to 2½ inches; tapping to 2¼ inches; flue rolling to 4 inches. They are equipped with Morse taper sockets of various standard sizes. See Table XXVI and Table XXVII.

Fig. 58—Horizontal Cylinder Hoist used in conjunction with traveling crane.

For very light drilling in metal and for drilling tell-tale holes in stay bolts, the tool shown in Fig. 64 is manufactured. Tools may be had equipped with either feed screw, spade handle, or breast plate. Drilling capacity up to 9/16 inches.

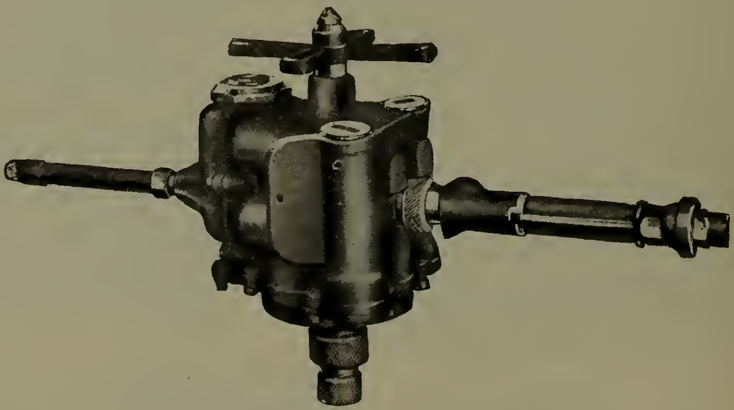


Fig. 59—Reversible pneumatic drill.

The wood-borer is distinguished by the use of aluminum castings for the sake of lightness and is equipped with spade handle and wood chuck, in place of feed screw and Morse taper socket furnished with the metal drills. These drills have a wood-boring range in the various sizes up to 4 inches. They are all built reversible.

The close-quarter type of drill is intended for drilling, reaming and tapping metal in cramped spaces. Capacity, drilling up to 3 inches, reaming and tapping to 2 inches. See Table XXVII.

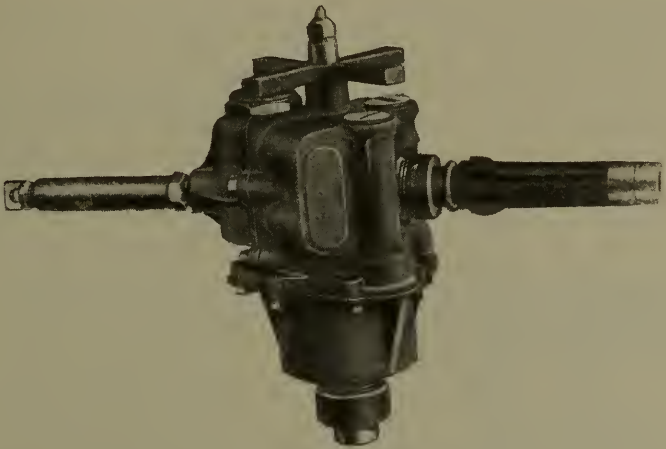


Fig. 60—Non-reversible pneumatic drill.

GRINDERS. Fig. 65 shows a typical portable grinder. It can be used with any size wheel not exceeding 6 inches in diameter, which is amply large for the run of portable grinding work. See Table XXVII.

BUFFERS. Any of the pneumatic drills or the grinder can be equipped with buffing wheels to meet various requirements.

Fig. 61—Pneumatic wood-boring drill.

Fig. 62—Pneumatic Close-Quarter Drill.

Pneumatic Hammers. This class of tool, like the pneumatic drill, is distinguished in name largely by the work to be performed with the added diversion of a change in size or weight.

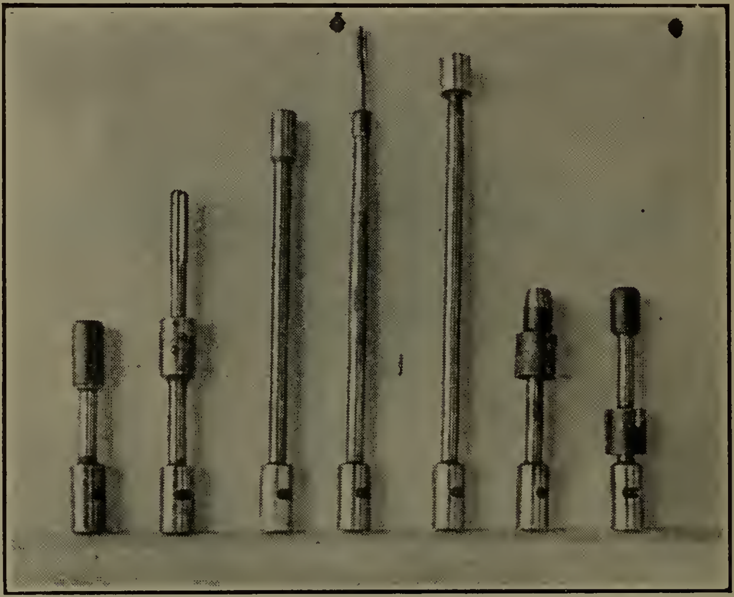


Fig. 63—Special sockets for seating bolts and studs.

Starting with the Riveting Hammer shown in Fig. 66 we find the range covers: Chipping Hammers (Fig. 67), Scaling Hammers (Fig. 68), Calking Hammers (Fig. 69), Rivet Busters (Fig. 70).

Fig. 64—Pneumatic drill for drilling tell-tale holes in stay bolts.

Fig. 65—Portable pneumatic hand grinder.

All of these hammers could be applied to the work of riveting, chipping metal, calking joints, scaling tubes, removing paint and rust and bursting rivets by the use of the proper tools. Experience, however, dictates the use of a hammer for each class of work of a certain weight and rapidity and strength of blow. Rivets of any appreciable size could not be driven economically or satisfactorily with hammers light enough for the rather delicate work of scaling or calking and vice versa a heavy riveting hammer would be out of place on delicate work.

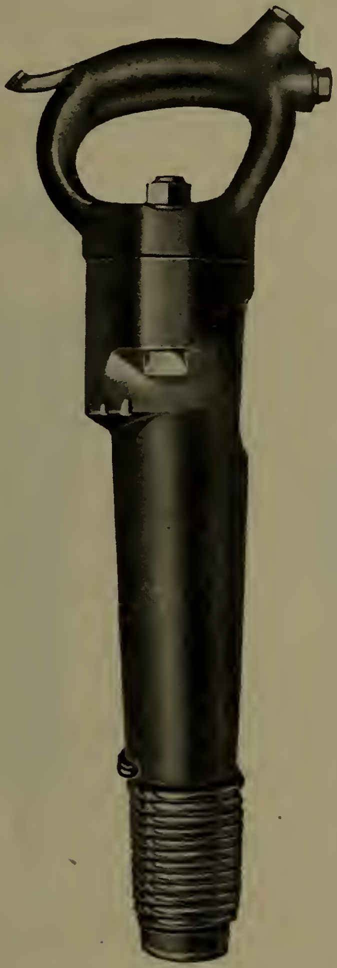


Fig. 66—Riveting Hammer equipped with safety rivet set retainer.

Fig. 67—Chipping Hammer.

In general design these hammers have features very much in common.

The Riveting Hammers range in weight up to about 25 pounds and will drive rivets up to 1¼ inches in diameter. It is only in exceptional cases that riveting work goes beyond this limit. The hammers are built with either an inside or outside trigger throttle handle to suit individual preference, and may be had with or without a safety retainer to prevent the accidental shooting out of the rivet set and piston. Rivet sets suitable for driving and forming various size rivets and heads are supplied by the makers. Fig. 71 shows the shape of a standard rivet set. See Table XXVIII.

The hammers for chipping, calking and scaling are all identical in construction. They are distinguished from the riveting hammers by lower weight, shorter but more rapid piston stroke, and the use of a nozzle bushing for holding the chiseling, calking or scaling tool.

They range in weight up to 14½ pounds and are applicable to work of the most delicate and heaviest nature encountered in metal work. Fig. 72 illustrates various standard chisel blank shanks and Fig. 73 various types of chiseling, calking and beading tools. See Table XXIX.

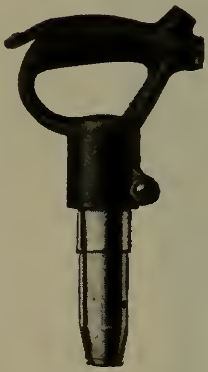


Fig. 68—Scaling Hammer.

Fig. 69—Calking Hammer.

Fig. 70—Rivet Buster.

The Rivet Buster is nothing more than a standard riveting hammer supplied with a chisel and chisel retainer for cutting off rivet heads. See Table XXVIII. For compressor capacity to drive a given number of tools see Table XXX.

Riveters of Other Forms. In addition to the pneumatic riveting hammer described and illustrated there are various other forms intended for riveting work presenting special problems.

The Jam Riveter. The Jam Riveter shown in Fig. 74 is intended for work in close quarters, such as riveting between the flanges of beams and columns, work on the inside of boilers, etc.

Fig. 71—Standard Rivet Set.

Fig. 72—Standard Chisel blanks.

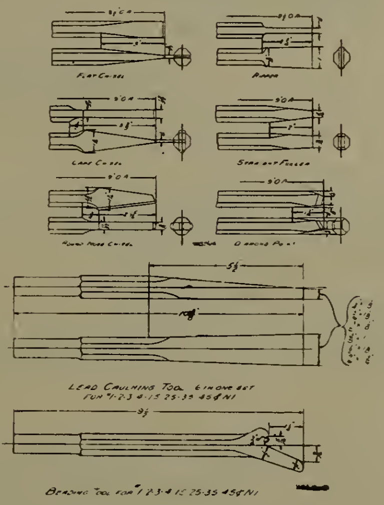


Fig. 73—Standard chisel, calking and beading tools.

It has a very short over-all length and is provided with a pneumatic feed and a fulcrum point enabling it to brace itself between its work and some nearby point. When desired the fulcrum point can be removed and a pipe screwed in, lengthening the riveter so that it will brace between points of greater length than the regularly equipped tool.

It is built in sizes for handling rivets up to 1 1/8 inches diameter. Its weight is around 32 pounds. See Table XXVIII.

The Yoke Riveter. The Yoke type of Riveter, such as illustrated in Fig. 75, is intended for fabricating indoors the heavier classes of riveting in boiler, tank and shipbuilding and structural iron and steel construction.

The particular type illustrated is known as the Pneumatic Compression Yoke Riveter, employing a pneumatic cylinder for transmitting power to the squeezing or riveting head through the medium of a combined toggle and lever joint. They are built both stationary and portable, the latter being most generally used.

Fig. 74—Jam Riveter.

This type of riveter operates on somewhat the same principle as the Hydraulic Yoke Riveter but it is claimed for it about one-third the cost for power.

Unlike the Pneumatic Riveting Hammer, which drives up the rivet by a number of light blows, the Yoke Riveter operates with one decidedly heavy squeezing blow.

The Yoke type of Riveter is manufactured in several distinct classes, distinguished by the work to be performed:

Boiler Plate Riveting,
Structural Riveting,
Boiler Door Ring Riveting, and
Lattice Framework.

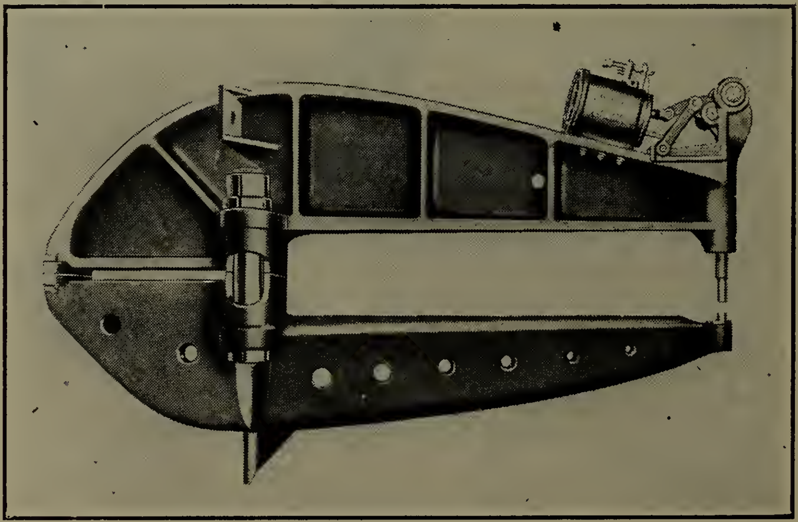


Fig. 75—Yoke Riveter.

The Yoke type of Riveter is also supplied for combination punching and riveting work. See Table XXXI and Table XXXII. See Table XXXIII for air consumption data.

The Pneumatic Holder-on. Fig. 76: This is a pneumatically cushioned tool for backing up rivets and in a large variety of work takes the place of the ordinary dolly bar and numerous other makeshifts to be seen in use on riveting work. It not only relieves the helper of the vibration but also enables rivets to be driven more strongly and without mutilation.

Fig. 76—Pneumatic Holder-On.

Fig. 77—Floor Sand Rammer.

Fig. 78—Bench Sand Rammer.

It is built with a fulcrum point, similar to the Jam Riveter, which may be removed and a pipe inserted so as to lengthen it. Weight 26 lbs. See Table XXVIII.

Sand Rammers. This device for ramming sand molds in foundry work is supplied by manufacturers in two distinct types, the

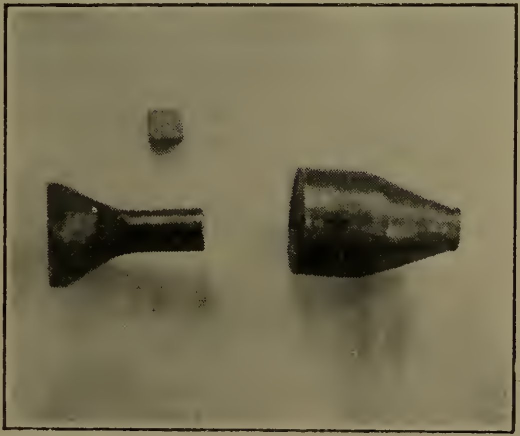


Fig. 79—Butts and peins for sand ramming.

Fig. 80—Die Sinkers and Pattern Carvers.

Floor Rammer (See Fig. 77) for working on large molds on the floor, and the Bench Rammer (See Fig. 78) for small molds made up on benches.

The work of both is alike and aside from their difference in length they are similar in construction. The Bench Rammer is in addition employed in core work.

They operate on the reciprocating principle and strike up to 800 blows per minute. The force and number of the blows are regulated at will by the operator in his manipulation of the throttle.

Both round butts and square peins of various sizes are furnished, which are quickly attached to the projecting reciprocating piston rods. See Fig. 79. Various sizes are furnished and the weight of the tool ranges up to about 25 pounds.

See Table XXXIV.

Die Sinkers and Pattern Carvers. See Fig. 80.

The device for this class of work is not unlike the pneumatic stone carving hammer employed by stone cutters, being, however, equipped with tools suited to each class of work.

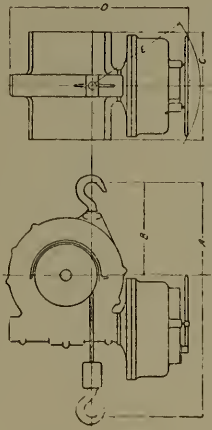
They are comparatively light in weight, ranging from 1½ to 10 pounds to cover a variety of work from the most delicate tracing to the heaviest cutting. See Table XXXV.

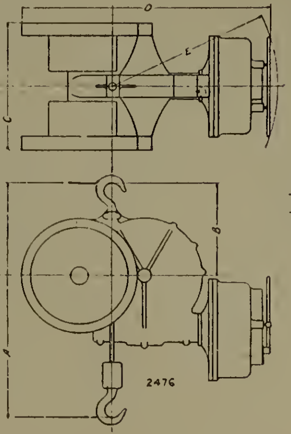
TABLE XXII

PORTABLE MOTOR HOISTS

Size No.	Capacity in Lbs.	Ft. Lift Per Minute 80 Lbs. Pressure	Maximum Lift Ft.	Size and Length Wire Rope Ins. x Ft. and Ins.	Cu. Ft. Free Air Per Minute 80 Lbs.	Net Weight Lbs.	Weight Boxed Lbs.
1	1,000	32	20	¼ in. x 42 ft. 10 ins.	45	270	324
2	2,000	16	20	¼ in. x 42 ft. 10 ins.	45	270	324
4	4,000	8	20	5/16 in. x 42 ft. 10 ins.	45	395	474
7	7,000	8	20	⅜ in. x 96 ft. 6 ins.	80	785	942
10	10,000	7	20	⅜ in. x 96 ft. 6 ins.	80	785	942

Nos. 1 and 2 Hoists





Nos. 4, 7 and 10 Hoists

DIMENSIONS, INCHES

A Ins.	B Ins.	C Ins.	D Ins.	E Ins.
32½	12⅛	17½	24¾	16¼
32½	12⅛	17½	24¾	16¼
40	13⅞	20¼	32¼	24¾
46¾	18¾	29½	39⅜	21⅝
46¾	18¾	29½	39⅜	21⅝

TABLE XXIII

STATIONARY AIR MOTORS

Size	H. P. 80 Lbs.	Speed R. P. M. 80 Lbs.	Cu. Ft. Free Air per Min. 80 Lbs.	Wgt. Lbs.	DIMENSIONS, INCHES						
					A	B	C	D	E	F	G
4	2	750	45	129	22⅞	13⅛	12⅛	8	3	8½	8½
10	3¼	750	80	230	27⅝	17	16	12	4	10½	10½

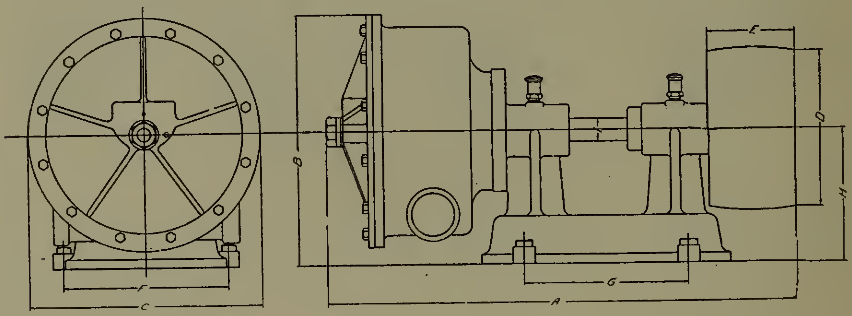


TABLE XXIV

VERTICAL CYLINDER HOISTS

	Diameter Ins.	CAPACITY		Size of Hose Connection Ins.	CUBIC FEET OF FREE AIR FOR 4-FT. LIFT		Add to Lift for Shortest Distance Between Hooks, Ins.	WEIGHT			
								STANDARD 4-FT. LIFT		EXTRA FOOT OF LIFT	
		At 80 Lbs.	At 100 Lbs.		At 80 Lbs.	At 100 Lbs.		Net	Gross	Net	Gross
Brass	4	920	1,150	½	1.83	2.29	16¼	100	165	10	20
	5	1,430	1,790	½	2.84	3.56	18⅞	110	165	14	28
	6	2,010	2,510	½	3.25	4.05	22⅛	120	180	16	32
Cast-Iron	7	2,840	3,550	½	5.97	7.47	22	230	315	54	74
	8	3,720	4,650	½	7.81	9.77	23¾	300	375	60	80
	9	4,700	5,875	¾	9.88	12.36	25⅛	350	440	76	100
	10	5,700	7,150	¾	11.96	15.00	28¼	425	550	80	116
	12	8,250	10,300	¾	17.31	21.68	30⅜	625	725	110	144
	14	11,250	14,050	¾	23.61	29.55	32¼	775	900	124	166
	16	14,600	18,200	1	30.58	38.28	37	1,100	1,200	150	200
	18	18,500	23,100	1	38.80	48.50	41¾	1,400	1,600	180	232
	20	22,800	28,500	1	47.88	60.00	43⅜	1,700	2,100	200	260

TABLE XXV

HORIZONTAL CYLINDER HOISTS

	Diameter of Hoist Ins.	CAPACITIES						Size of Hose Connection Ins.	CUBIC FEET FREE AIR FOR 4-FT. STROKE		WEIGHT			
		STRAIGHT		I SHEAVE 2 TO I		2 SHEAVES 4 TO I					STANDARD 4-FT. LIFT		EXTRA FOOT OF LIFT	
		At 80 Lbs.	At 100 Lbs.	At 80 Lbs.	At 100 Lbs.	At 80 Lbs.	At 100 Lbs.		At 80 Lbs.	At 100 Lbs.	Net	Gross	Net	Gross
Brass	4	920	1,150	450	565	215	270	½	1.83	2.29	100	170	10	20
	5	1,430	1,790	700	880	335	420	½	2.84	3.56	115	180	14	28
	6	2,010	2,510	980	1,225	470	590	½	3.25	4.05	130	195	16	32
Cast-Iron	7	2,840	3,550	1,390	1,740	670	835	½	5.97	7.47	270	400	54	70
	8	3,720	4,650	1,820	2,280	825	1,090	½	7.81	9.77	350	500	60	80
	9	4,700	5,875	2,300	2,880	1,100	1,380	¾	9.88	12.36	435	575	76	100
	10	5,700	7,150	2,800	3,500	1,340	1,680	¾	11.96	15.00	500	600	80	108
	12	8,250	10,300	4,040	5,050	1,940	2,420	¾	17.31	21.68	575	700	110	144
	14	11,250	14,050	5,550	6,900	2,620	3,300	¾	23.61	29.55	760	1,000	124	166
	16	14,600	18,200	7,150	8,925	3,430	4,275	1	30.58	38.28	900	1,300	150	200
	18	18,500	23,100	9,050	11,100	4,350	5,425	1	38.80	48.50	1,300	1,700	180	232
	20	22,800	28,500	11,150	13,650	5,350	6,700	1	47.88	60.00	1,900	2,200	200	260

TABLE XXVI
PNEUMATIC DRILLS—REVERSIBLE TYPE

Number	Average Free Speed 90 Lbs. Pressure R. P. M.	Weight, Lbs.	Length of Feed, Ins.	Size of Wood Bit Will Drive	Reaming, Ins.	Tapping, Ins.	Flue Rolling Ins.	Std. Twist Drill Will Drive	Length over All	Morse Taper Socket	Hose, Ins.	Cubic Feet Free Air	Distance from Side to Center of Spindle
1	325	57	5		1½	1½	2½	1¾	14-5/8	4	¾	55	4-3/8
2	250	57	5		1¾	1¾	3	2	14-5/8	4	¾	55	4-3/8
3	200	57	5		2	2	3½	2¼	14-5/8	4	¾	55	4-3/8
4	150	57	5		2½	2½	4	3	14-5/8	4	¾	55	4-3/8
5	100	70	5		Extra heavy reaming, tapping, and flue rolling				18	5	¾	55	4-3/8
6	375	42	4½		1	1	2½	1¼	13-3/8	3	¾	50	3-5/8
7	375	44	4½		1	1	2¼	1¼	14-7/8	4	¾	50	3-5/8
8	325	42	4½		1	1	2½	1¼	13-7/8	3	¾	50	3-5/8
9	325	44	4½		1¼	1¼	3	1½	14-7/8	4	¾	50	3-5/8
10	500	23	3¾		¾	¾		29/32	11-3/8	2	½	30	3
11	500	24	3¾		¾	¾		29/32	12	3	½	30	3
12	200	25	3¾		1	1		1¼	12-3/4	3	½	30	3
WOOD BORING MACHINES													
13	450	33		4					17-½		¾	50	3-5/8
14	700	20		2					15-3/4		½	30	3
15	400 to 900	14		1					15-9/16		3/8	17	2

TABLE XXVII
PNEUMATIC DRILLS—NON-REVERSIBLE TYPE

Number	Average Free Speed 90 Lbs. Pressure R. P. M.	Weight, Lbs.	Length of Feed, Ins.	Reaming, Ins.	Tapping, Ins.	Std. Twist Drill Will Drive	Length Over All	Morse Taper Socket	Hose, Ins.	Cubic Feet Free Air	Distance from Side to Center of Spindle
1A	325	57	5	1½	1½	1¾	14-5/8	4	¾	55	4-3/8
2A	250	57	5	1¾	1¾	2	14-5/8	4	¾	55	4-3/8
3A	200	57	5	2	2	2¼	14-5/8	4	¾	55	4-3/8
4A	150	57	5	2½	2½	3	14-5/8	4	¾	55	4-3/8
5A	100	70	5	Extra heavy drilling, reaming and tapping			18	5	¾	55	4-3-8
6A	375	42	4½	1	1	1¼	13-3/8	3	¾	50	3-5/8
7A	375	44	4½	1	1	1¼	14-7/8	4	¾	50	3-5/8
8A	325	44	4½	1	1	1¼	13-3/8	3	¾	50	3-5/8
9A	325	44	4½	1¼	1¼	1½	14-7/8	4	¾	50	3-5/8
10A	500	23	3¾	¾	¾	29/32	11-3/8	2	½	30	3
11A	500	24	3¾	¾	¾	29/32	12	3	½	30	3
12A	200	25	3¾	1	1	1¼	12-3/4	3	½	30	3
16	400 to 900	14	2½			9/16	13-3/8	1	3/8	17	3
17	1,400 to 3,000	10				5/16 chuck	15-1/2		3/8	17	2-7/8
CLOSE-QUARTER DRILL											
18	140	37	3¾	2	2	3	9	4	½	35	1-5/16
GRINDER AND BUFFER											
19	3,000	22					20-3/8		½	·	3-1/4

TABLE XXVIII

RIVETING HAMMERS

Size No.	Piston Stroke Ins.	Piston Diam. Ins.	Length (Exclusive of Set) Ins.	Length of Std. Piston Ins.	Weight (Without Set) Lbs.	Size Hose Connection Ins.	Size Hose Recommended Ins.	Rivet Set Shanks	Air Consumption Cu. Ft. Free Air Per Min.	Length Closed Ins.	Length Open Ins.	Distance from Side to Center of Rivet Set
*40	4	1 1/16	14½	2½	14	¼	½	1.217 inches diam. by 2¼ inches long	19	....	....	....
*50	5	1 1/16	15½	2½	19½	¼	½		20	....	....	....
*60	6	1 1/16	17½	3	21	¼	½		21	....	....	....
*80	8	1 1/16	19½	3	23	¼	½		23	....	....	....
*90	8	1 13/64	19½	4	23	¼	½		23	....	....	....
No. 0 Jam Riveter	4	1¾	10	2½	30	⅜	½	1.748 inches diam. by 1 inch long	35	10¾	13¾	....
No. 1 Jam Riveter	5	1¾	11 11/16	3	32½	⅜	½		35	12 7/16	15 7/16	....
No. 4 Holder On	..	..	18½	..	26	⅜	½	.....	..	14½	19	1 13/16

* Any size Riveter that is large enough can be used as a rivet buster when equipped with chisel and safety retainer.

TABLE XXIX

CHIPPING, CALKING AND SCALING HAMMERS

CHIPPING AND CALKING HAMMERS					SCALING HAMMERS		
Size No.	Weight Lbs.	Cu. Ft. Free Air Per Min. at 80 Lbs. Pressure	Piston Stroke Ins.	Length Over All Ins.	Weight Lbs.	Cu. Ft. Free Air Per Min. at 80 Lbs. Pressure	Length Over All Ins.
1	12½	21	1	11¼	...	....	....
2	12¾	22	2	12¼	6¼	7	10½
3	13	23	3	13¼	6¾	10½	10⅝
4	13¾	24	4	14¼	...	....	....
5	14½	25	4	14⅝	...	....	....

Suitable For

1 Chipping and Calking Bath Tubs and Range Boilers and other Light work.
2 Light Chipping and Calking, Beading Flues and Scaling Castings.
3 General Chipping and Calking.
4 Heavy Chipping and Calking.
5 Extra Heavy Chipping and Calking.

Suitable For

Very Light Chipping or Calking; Scaling paint or rust on iron; for Heavy Cutting or roughing on Stone.

TABLE XXX

COMPRESSOR CAPACITY FOR OPERATING PNEUMATIC HAMMERS

Stroke of Hammer Ins.	NUMBER OF HAMMERS IN USE										
	1	5	10	15	20	25	30	35	40	45	50
1	14.	68.6	134.4	197.7	257.6	315.	369.6	421.4	470.4	516.6	560
2	17.	83.3	163.2	239.7	312.8	382.5	448.	511.7	571.2	627.3	680
3	20.	98.	192.	282.	368.	450.	528.	602.	672.	738.	800
4	22.	107.8	211.2	310.	404.8	495.	580.8	662.2	739.2	811.8	880
5	25.	122.5	240.	352.5	460.	562.5	660.	752.5	840.	922.5	1000
6	33.	161.8	316.8	465.3	607.2	742.5	871.2	993.3	1108.8	1217.7	1320
8	36.	176.4	345.6	507.6	662.4	810.	950.4	1083.6	1209.6	1328.4	1440
9	38.	186.2	364.8	535.8	699.2	855.	1003.2	1143.8	1276.8	1402.2	1520

This Table gives the actual compressor capacity in cubic feet of free air DELIVERED (not piston displacement), required to operate from one to fifty pneumatic hammers of the size stated, in simultaneous operation under ordinary intermittent service. Compressor piston displacement corresponding can be figured by dividing these figures by the percentage of volumetric efficiency given for the compressor.

The tables are figured at a working air pressure of 80 pounds gauge at the tool, and at sea level.

The ratings for one hammer are the actual readings under water displacement meter test—the only absolutely accurate way of measuring pneumatic tool air consumption.

TABLE XXXI

YOKE RIVETERS

For 20 Tons on Rivet at 100 Lbs. Air Pressure, 8½-in. Cylinder Capacity, ½-in. Structural Rivets

Reach Ins.	Gap Ins.	Style	Weight
6	6	Special Lattice Frame Riveter	800
6	3	Compression Lever Riveter	750

For 30 Tons on Rivet at 100 Lbs. Air Pressure, 10½-in. Cylinder Capacity, ¾-in. Structural, ½-in. Steam Rivets

Reach Ins.	Gap Ins.	Style	Weight
15	12	Special Lattice Frame Riveter	1,600
12	12	Structural Riveter	1,400
12	15	" "	1,475
18	12	" "	1,700
18	15	" "	1,750
18	18	" "	1,800
24	12	" "	1,900
24	15	" "	2,000
24	18	" "	2,100
36	12	" "	2,400
36	15	" "	2,500
36	18	" "	2,690
75	18	Boiler Riveter, Rd. Stake, Plunger Central	6,500
75	18	" " " " Flush Top	6,800

TABLE XXXI (*Continued*)

For 50 Tons on Rivet at 100 Lbs. Air Pressure, 12⅞-in. Cylinder Capacity, ⅞-in. Structural, ¾-in. Steam Rivets

Reach Ins.	Gap Ins.	Style	Weight
31	6	Alligator Riveter	4,300
15	12	Special Lattice Frame Riveter	2,000
12	12	Structural Riveter	1,700
12	15	" "	1,750
18	12	" "	2,000
18	15	" "	2,100
18	18	" "	2,200
24	12	" "	2,400
24	15	" "	2,500
24	18	" "	2,600
36	15	" "	3,300
36	18	" "	3,400
48	15	" "	4,500
48	18	" "	4,600
102	18	Boiler Riveters, Rd. Stake, Plunger Central	15,000
102	18	" " " " Flush Top	16,000
4	12	Door Ring Riveter	2,000
12	12	Compression Lever Riveter	2,000

TABLE XXXI (*Continued*)

For 70 Tons on Rivet at 100 Lbs. Air Pressure, 15-in. Cylinder
Capacity, 1-in. Structural, 7/8-in. Steam Rivets

Reach Ins.	Gap Ins.	Style	Weight
12	12	Structural Riveter	2,400
12	15	" "	2,475
12	18	" "	2,550
18	12	" "	2,800
18	15	" "	2,900
18	18	" "	3,000
24	15	" "	3,100
24	18	" "	3,200
24	21	" "	3,300
24	24	" "	3,400
36	15	" "	4,200
36	18	" "	4,300
36	21	" "	4,400
36	24	" "	4,500
48	18	" "	6,100
48	21	" "	6,250
48	24	" "	6,400
60	18	" "	8,200
60	21	" "	8,350
60	24	" "	8,500
75	18–24	Boiler Riveter, Rd. Stake, Plunger Central	13,000
75	18–24	" " " " Flush Top	14,000
102	18–24	" " " " Plunger Central	19,000
102	18–24	" " " " Flush Top	20,000
126	18–24	" " " " Plunger Central	26,750
126	18–24	" " " " Flush Top	27,700
168	18–24	" " " " " "	50,000
16	8	Compression Lever Riveter	3,000

Above 70-Ton Riveters Furnished with 16-in. Cylinder for Exerting 80 Tons at 100 Lbs. Air Pressure
Capacity, 1¼-in. Structural, 1-in. Steam Rivets

TABLE XXXI (*Continued*)

For 100 Tons on Rivet at 100 Lbs. Air Pressure, 18-in. Cylinder
Capacity, 1⅛-in. Steam Rivets

Reach Ins.	Gap Ins.	Style	Weight
24	24	Structural Riveter	6,500
48	24	" "	12,000
60	24	" "	15,000
75	24	" "	18,000
126	24	" "	34,500

Above 100-Ton Riveters Furnished with 20-in. Cylinder for Exerting 125
Tons at 100 Lbs. Air Pressure
Capacity, 1¼-in. Steam Rivets

TABLE XXXII

COMBINATION YOKE PUNCHES AND RIVETERS

Description	Pressure Tons	Reach Ins.	Gap Ins.	Wgt. Lbs.	
For work in close sections	20	6	3	835	See Fig. No. 192
Punching Channels and Angles	50	12	12	1,800	See Fig. No. 191
Punching Flanges of Heavy Angles and Channels	80	24	21	3,600	See Fig. No. 191

PORTABLE RIVET HOLE PUNCH

Description	Reach Ins.	Weight Lbs.	
For $\frac{3}{16}$-in. to ½-in. holes in plates up to ¼ in.	8	225	See Fig. No. 189

TABLE XXXIII

YOKE RIVETERS

APPROXIMATE PRESSURE REQUIRED TO DRIVE COLD RIVETS

¼ in	12 Tons
5/16 “	15 “
⅜ “	22 “
½ “	31 “
⅝ “	56 “

APPROXIMATE CONSUMPTION OF FREE AIR PER RIVET FOR THE VARIOUS SIZES OF RIVETERS AT 100 POUNDS AIR PRESSURE

2	to	3½	cu. ft. for the	8½-in.	Cylinder
4	“	7	“ “ “ “	10½ “	“
6	“	10	“ “ “ “	12-⅞ “	“
7½	“	15	“ “ “ “	15 “	“
9½	“	16	“ “ “ “	16 “	“
20	“	35	“ “ “ “	18 “	“
24	“	45	“ “ “ “	20 “	“
30	“	55	“ “ “ “	22 “	“

Use	¾-in.	Supply Hose for	20-ton Riveters
“	1 “	“ “ “	30- and 50-ton Riveters
“	1¼ “	“ “ “	70- “ 80- “ “
“	1½ “	“ “ “	100-ton and larger

TABLE XXXIV

SAND RAMMERS

Description	Bench Rammer	FLOOR RAMMERS	
		Light	Heavy
Cylinder Bore	1 in.	1 in.	1¼ in.
Piston Stroke	4 “	4 “	5 “
Weight Unboxed	13 lbs.	15 lbs.	22 lbs.
Length over all	21 in.	42 in.	48 in.

TABLE XXXV

DIE SINKING AND CARVING TOOLS

Size	Weight Lbs.	Diameter of Piston Ins.	Length of Stroke Ins.	Chisel Shank Dimensions Ins.	Air Consumption Cu. Ft.
AA	1–5	⅝	15/32	½ x 2⅛	2
AB	2–0	¾	⅝	½ x 2⅛	3
AC	3–9½	1	13/16	½ x 2⅛	4
AD	5–1½	1¼	17/32	⅝ x 2⅛	5½
B	9–4	1	1 11/16	11/16 x 2½	12
L	6–12	1	1 11/16	11/16 x 2½	12

CHAPTER VII

CARE AND OPERATION OF PNEUMATIC TOOLS

Like other machinery the satisfactory operation of a pneumatic tool is largely dependent upon the amount of attention paid to its care.

Pneumatic tools are high-speed machines and it is therefore reasonable to expect that wear will occur in time, especially on such parts as pistons, valves, hammers, connecting rods, bearings, etc. The rapidity of wear will largely depend upon the attention paid to the matter of lubrication, cleaning, etc.

All manufacturers of pneumatic tools provide for suitably lubricating the various parts of such machines. Instruction tags generally accompany the tools and it is a good plan to study the instructions carefully before starting work.

The oiling and cleaning should not be delayed until the tools stop working on account of dirt, rust or gummed oil.

Oiling. Use only a good, light-body oil. Heavy oils should be avoided as they gum up and cause the tool to operate sluggishly, resulting in loss of power.

Such tools as hammers and rammers are generally lubricated by oil poured in at the hose connection. There are also sundry makes of automatic oilers which can be placed in the hose line or short distances from the tool, and which are refilled at any time without disconnecting the tool from the hose line. They are made in various sizes, one filling of oil lasting from six to eight hours. Their use is strongly recommended.

Such tools as drills, motors and geared hoists are generally grease-packed and therefore do not require as frequent attention as tools lubricated by fluid oils. A medium weight grease is generally employed.

Cleaning. Pneumatic tools can be cleaned by immersing the entire tool in kerosene overnight. When doing this suspend the tool so that the dirt and foreign matter will settle to the bottom. As kerosene leaves the tool dry it is essential that it be thoroughly oiled before being put into operation.

As the air taken into the compressor generally contains some grit or dust, which finds its way to the tool, it is a good plan to occasionally clean the tool by pouring kerosene freely into the throttle handle. This will dislodge the foreign matter and cut the thick oil which can then be removed by blowing air under pressure through the tool. It should then be lubricated in like manner with a good quality of light-body oil.

Where the air is laden with foreign matter the use of strainers or filters in the air line is recommended. A good form of home-made filter can be made by taking two cast flanges properly tapped to fit the pipe line. A piece of gauze or fine mesh wire screen is placed between the flanges and the two bolted together. Fig. 81 illustrates this filter. It can readily be taken apart and cleaned.

OVERLOADNG TOOLS. It is inadvisable to apply pneumatic tools for work beyond the range specified by the manufacturer, as this places an overload on the tool, and soon results in wear and falling off of power.

One of the most flagrant abuses to which pneumatic riveting hammers are put, is the substitution of pistons of lengths shorter than those designed and adopted by the makers as standard. The practice should be condemned. The hammer as it leaves the manufacturers' hands is a properly balanced tool and proportioned to meet the requirements of the work for which it is recommended. Workmen, however, have discovered that a piston shorter than that supplied with the hammer will deliver a more powerful blow and for a time it increases the speed at which work is turned out. To secure these shorter pistons, the standard ones are ground down, thus removing the hardening and leaving the striking part softer than it should be. These pistons have a tendency to crumble or batter up and cut the cylinder, and if it does not result in damage beyond repair, it is only a matter of a short time when the cylinder will crack or other damage result.

It is almost impossible to lay down any hard, fast rules on this subject, but attention to the following suggestions will insure more and better work and longer life to tools.

All tools should be cleaned and oiled before being put in operation.

Pipe lines should be blown out before connecting tools.

Use a good grade of lubricant.

Use filters or strainers wherever possible.

Inspect all drills daily and see that all bolts are tight and that tools operate freely.

Inspect all hammers for loose handles and see that they are tightened.

Operators should hold hammers firmly against the work. If the die or chisel is permitted to play in and out of the hammer it will result in damage to the tool.

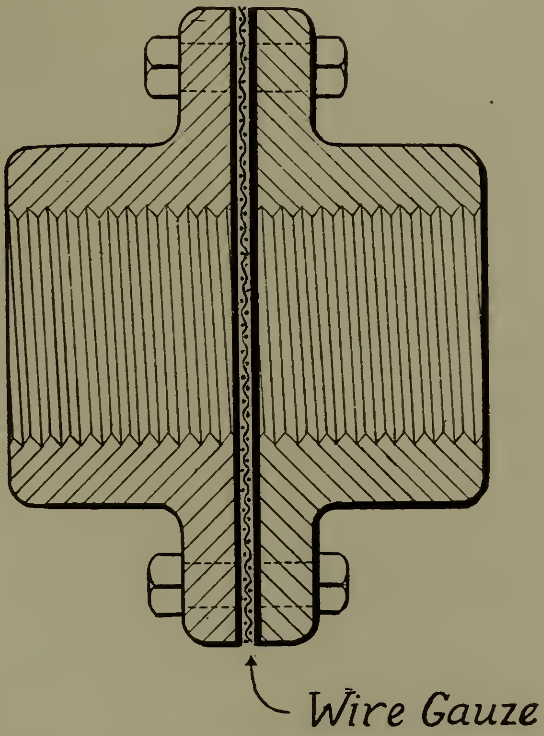


Fig. 81—A readily made filter for the air line.

CHAPTER VIII

COMPRESSED AIR USES IN THE POWER PLANT

In the majority of installations the compressed air power plant (the air compressor) is housed with the regular power plant equipment in a centrally located power house.

The power plant engineer soon finds a wide variety of uses for this ever-ready power. Not the least of these uses is the cleaning of power plant equipment. Generators, engines, pumps, control boards, etc., are quickly and thoroughly cleaned by means of the compressed air jet. The subject of compressed air for cleaning is treated fully in Chapter XV, and will, therefore, not be discussed at great length here.

The flues of fire tube boilers are most easily kept free of soot and dirt by blowing them out with compressed air. A pipe, connected by hose with the air line, is run back and forth in the tube and special nozzles are obtainable which give the air a whirling motion which is most effective in cutting out the dirt. (Fig. 82.) Steam is also used for this purpose but where air is available it is decidedly preferable. It pays to use the air jet frequently on fire tubes, and also to clean the outside of water tubes occasionally. The inevitable result is more steam or less coal burned.

Most waters contain mineral substances which precipitate upon the boiler surfaces, reducing the efficiency greatly and perhaps endangering the boiler. Hence, the scale should be removed as often as circumstances warrant. Very efficient compressed air operated boiler tube cleaners are available. They accomplish their work rapidly and efficiently.

Figure 83 shows a few types of scale removers operating directly on air pressure. Some types employ a ream-like head, while others employ teethed rollers which press against and cut the scale, due to the centrifugal effect of the rotating head. Others break the scale by a rapid succession of light hammer blows, the latter type, with a modified vibrator, also being applicable for removing scale deposited on the outside of fire tubes. Some of these cleaners employ the principle of the rotary engine, while others employ the reciprocating principle. Water is run into the tubes to wash out the cuttings.

The plant operating surface condensers or refrigerating units finds the scaling hammer, in Fig. 68 on page 100, a handy device for scaling condenser tubes. The condensers, which form a very important part of the refrigerating machinery, as well as of a plant dependent upon a small water supply, necessitating the use of the water over and over again, usually consists of a series of coils of pipes or nests of pipes through which the hot water or steam is forced for cooling. Most waters contain certain impurities, which, becoming deposited in the pipes, soon reduce the available pipe area. This has a decided effect, not only on the efficiency of the condensers, but upon the machinery dependent on them.

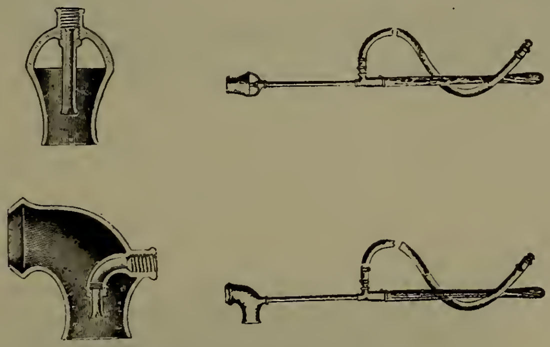


Fig. 82—Nozzles used with compressed air for cleaning flues of fire tube boilers.

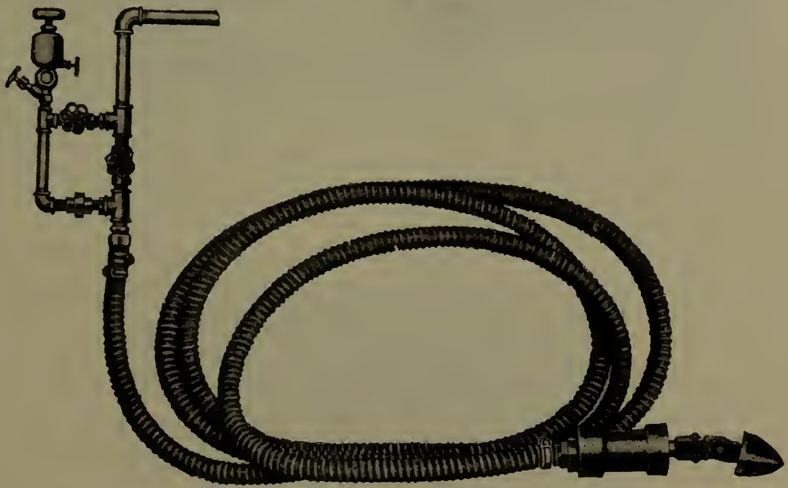


Fig. 83-A—'Cyclone' Water Tube Cleaner with Drill Head for removing heavy scale.

Fig. 83-B—'Cyclone' Water Tube Cleaner working in curved boiler tube.

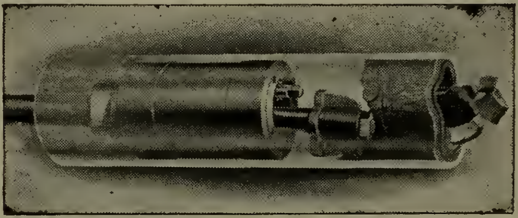


Fig. 83-C—'Dean' Boiler Tube Cleaner (Water Tube Type).

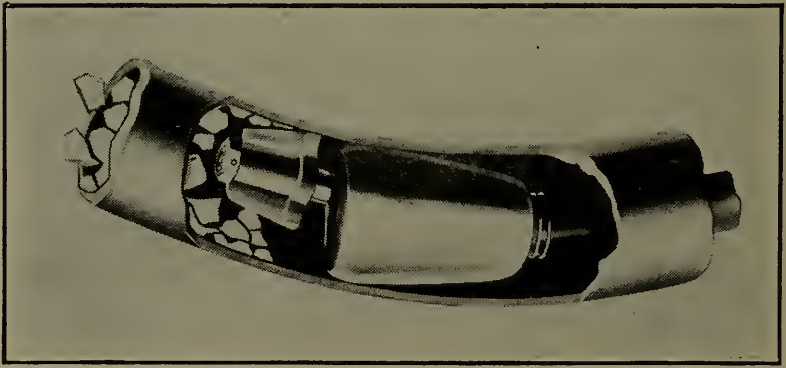


Fig. 83-D—'Dean' Boiler Tube Cleaner operating in a Stirling Boiler Tube.

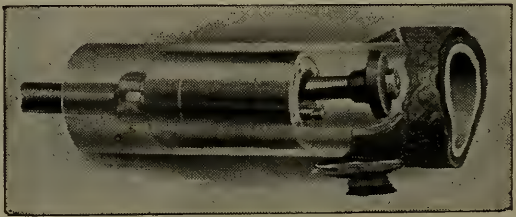


Fig. 83-E—'Dean' Boiler Tube Cleaner (Fire Tube Type).

The incrustations of these foreign substances must be removed, and while it can and is in some plants done by rapping the pipe with a hammer, it is both a dangerous and expensive method. Pipes are apt to be cracked and joints started, while the inequality of the blow only partially removes the incrustations.

The pneumatic scaler does the work uniformly and more quickly, without harm to the condenser. The blow of the scaler is light, rapid and uniform. It requires about one-fourth the time of the hand and hammer method.

Fig. 84 shows one of the special tools employed with the scaler for this class of work, and in Fig. 85 is shown how it is used.

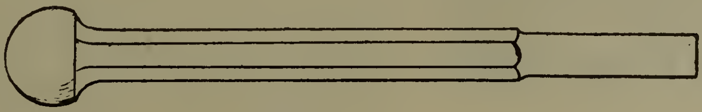


Fig. 84—Special tool used with pneumatic hammer for scaling condenser tubes.

In making boiler repairs a section of plate can be quickly cut out by means of the chipping hammer, shown in Fig. 67, holes drilled in the shell to take the patch with the pneumatic drill, shown in Fig. 59, and the joints quickly riveted together with a pneumatic riveter, as shown in Fig. 66, and the patch is finally calked by the substitution of the proper tool in the chipping hammer. Without air this is a long, laborious hand job, necessitating a lengthy shut-down of the boiler unit.

In like manner, these tools may be employed in making all sorts of tank repairs.

Not infrequently it is desired to tear out an old concrete foundation for the installation of some new piece of machinery.

Once more compressed air comes to the rescue, saving time and labor. Either the pneumatic core breaker or a heavy riveting hammer borrowed from the foundry or boiler shop is called into use and the problem solved. Where these are not available, a small pneumatic hand rock drill, shown in Fig. 86, can be employed.

The removal of concrete foundations is a difficult job, as the concrete is composed of a heterogeneous composition.

Almost every large industrial plant has at some time or other been confronted by the problem of growth; buildings are to be enlarged, or obsolete or inadequate machinery is to be replaced by more modern equipment, calling for new and heavier foundations, and, therefore, the alteration or removal of the old.

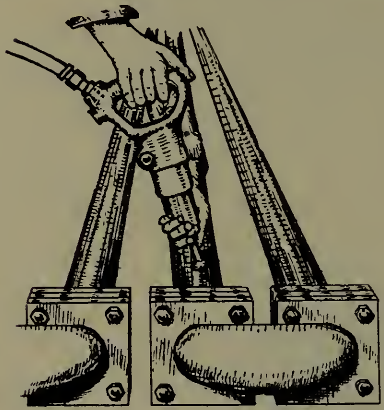


Fig. 85—Method of scaling condenser tubes with pneumatic hammer.

An illustration of the adaptability of compressed air for this service is given in the following description of what occurred in one plant.

Quite recently the Philadelphia Electric Company of Philadelphia had in one of their local power stations a large machine foundation, which they were obliged to remove in order to install a machine of another character from that previously occupying the space. This foundation was surrounded on all sides by expensive and delicate machines calling for a very careful selection of the method and means for removing the old foundation. After several possible methods

Fig. 86—Pneumatic hand rock drill for removing concrete and masonry foundations; drilling anchor bolt holes and digging trenches in rock formations. Illustration shows holes being drilled for window bolts in concrete, Edison Phonograph Co., Orange, N. J.

had been considered, the drill illustrated in Fig. 86 was used. The holes were drilled at close enough intervals to permit of breaking the concrete structure by means of wedges driven into the holes. It was found that the drilling progressed at the rate of 24 inches in 1 minute and 12 seconds.

Fig. 87—Rolling boiler flues on a repair job with a Little David Pneumatic Drill.

The rolling of boiler flues, an awkward hand job, yet frequently necessary in the power plant, is one of the uses to which the pneumatic drill is peculiarly adapted. See Fig. 87.

Pneumatic drill motors may also be applied in connection with a mechanical type of boiler scale-removing cutter head, operating the latter through the medium of a flexible shaft for curved tubes. Pneumatic drills are also useful for expanding the ends of new boiler tubes and flues, as well as for drilling metal, reaming, tapping, wood-boring and running in studs and bolts.

Fig. 88—Removing ashes from pit underneath boiler by means of a pneumatic horizontal cylinder hoist, operating from an overhead trolley runway.

For hoisting machines into and out of place, one of the portable pneumatic hoists already referred to will be found a device of safety and convenience, eliminating the arduous part of the task.

Pneumatic hoists are also most convenient for handling ashes in the boiler house. See Fig. 88.

Within the last few years the vacuum principle has been applied successfully to conveying and disposing of ashes from a number of boilers. Such a system has been installed in at least one large cotton mill recently built.

In some types of central lubricating systems, oil flows by gravity to a filter, and after being purified it is automatically forced by compressed air to an overhead clean-oil reservoir from which it flows by gravity to the various engines and auxiliaries of the plant.

Compressed air is used in connection with some forms of oil and gas engines, principally for starting the engine and for forcing in the fuel.

A great many steam power plants are today equipped with boiler furnaces arranged for burning oil as fuel. The oil is fed to the furnace in an atomized state by means of compressed air through nozzles. There are two general types of nozzles or burners employed, one utilizing low-pressure air supplied by a fan or blower, and the other high-pressure air supplied by a compressor.

Other boiler plants are operating with powdered coal as fuel. The method is almost identical with that employed with oil burning boilers, the fuel being in a finely divided state.

CHAPTER IX

COMPRESSED AIR IN THE FOUNDRY

The application of compressed air to foundry work was almost coincident with the introduction of machinery in the art of founding. In this respect it is unique among the powers. Its only rival can be said to be solely that of manual labor.

Not only is its benefit felt in the handling of raw materials for founding, but in mixing, melting, molding, core making and in cleaning.

In no instance can any pneumatic device for foundry service be said to have found its use entirely one of convenience. Each and every one has a permanent place entirely on the grounds of the economy it is able to effect; saving labor, increasing production and improving the quality of the product.

Sand Rammers. The ramming of molds, a long and arduous work when done by hand is now accomplished by means of the pneumatic sand rammer. Molds are rammed not only harder, but more uniformly, resulting in castings that are true to pattern and costly overweight avoided. Straining of the mold is eliminated and the job accomplished in less time. The molder is relieved of the most fatiguing part of his work and he therefore accomplishes more work.

Fig. 89 shows the Bench Rammer at work. It is effectively used on small and medium work, usually done on the bench, also in connection with molding machines. For ramming shelving patterns the rammer is ideal. This work is usually inaccessible to other means.

Fig. 90 illustrates the Floor Rammer at work. It is used for heavy molding, such as ramming flasks and copes for engine beds, sub-bases, fly- and belt-wheels, etc., also for butting off copes and drags rammed on jarring machines. See Table XXXIV.

Records of Performance. The following figures show the result of some observations made in representative foundries all over the country. They are not merely test figures, but show what can be accomplished with the Pneumatic Sand Rammer under everyday working conditions:

TIME IN PEINING AND RAMMING

Size of Cope	By Hand	By Sand Rammer	Ratio of Reduction	Per Cent. Time Saved
12′ x 18″ x 4″	5 min.	1 min.	1:5	80
12′ x 18″ x 10″	10 min.	1½ min.	1:6.6	85
6′ x 3′ x 6″	20 min.	3 min.	1:6.6	85
6′ x 6′ x 8″	35 min.	8 min.	1:4.4	77
8′ x 6″ x 6″	1 hour	10 min.	1:6	83
7′ x 3′ x 12″	1 hour 30 min.	16 min.	1:5.6	82
15′ x 30″ x 16″	2 hours	27 min.	1:4.4	77
12′ x 7′ x 16″	2 hours 12 min.	34 min.	1:3.9	74
87″ x 159″ x 10″	4 hours	40 min.	1:6	83
19′ x 90″ x 15″	3 hours	1 hour 30 min.	1:5.3	81

These figures include not only the final ramming but the more careful peining as well and the total time covers the completed job.

In another instance, a pulley 78 inches in diameter with 24-inch face, was peined and rammed complete in three hours.

These results show a ratio of advantage of machine over hand ramming varying from 1:39 to 1:66 and a time saving of 74 to 85 per cent. may be considered fairly representative of the reduction in time and labor cost.

The Superintendent of one of the best organized and most representative foundries in this country had the following comments to make regarding his use of the Pneumatic Sand Rammer.

"The Pneumatic Sand Rammer for foundry work has demonstrated that it is one of the greatest friends and labor savers of the progressive foundryman today. When the sand rammer was first introduced, there was some criticism concerning it, mainly arising from the natural antipathy mechanics had for anything in the 'machine' line, but as the operators became familiar with its use and recognized the effectiveness, this feeling rapidly disappeared. Today in our foundry the men take kindly to these rammers, and use them for work of every description.

"Some claim that while sand rammers are valuable for ramming drags, they cannot be used successfully on copes. We have exploded this contention completely in our shop and use the rammers on both copes and drags indiscriminately and with equal success."

Fig. 89—Bench Rammer at work on small flasks.

Fig. 91.

"The Pneumatic Bench Rammer is a very handy tool as an auxiliary to the larger rammer. This rammer is very satisfactory for ramming under a shelving pattern where the construction of the pattern is such that it is difficult to ram under it with the larger tool. We find the bench rammer practically indispensable for work of this nature.

"Speaking generally, it is my opinion that the Sand Rammer has increased our efficiency in this line fully four or five times, and since we have had them installed we would regret very much to be obliged to go back to the old way of ramming."

Sand Sifters. In the preparation of molding and core sand, its thorough screening plays an important part.

One of the most satisfactory methods of accomplishing this is sifting the sand by means of the pneumatic riddle and the pneumatic shaker.

Fig. 90—Crown Floor Rammer at work in the foundry of the Lidgerwood Mfg. Co.

Fig. 92 shows a typical portable tripod shaker and Fig. 93 a stationary wall or post shaker.

The portable type being readily moved from one part of the foundry to another enables the screening of the sand right at the mold where it is to be used.

The stationary type is intended to serve bench work or molding machines.

These shakers are built in various sizes and to supply various grades of material.

In the particular machine shown, the screen-holder is fastened directly to the piston rod of the air cylinder and is supported by two rocking uprights. The screen-holder is made to accommodate an 18-inch foundry riddle.

The air pressure required for its operation is 20 pounds or greater. At 80 pounds pressure with the valve wide open and

Fig. 91—Floor Sand Rammer used in conjunction with a pneumatic jarring machine.

the riddle kept full, the air consumption is about 25 cubic feet of free air per minute. See Table XXXVI.

The saving effected by these shakers over hand screening ranges from 50 to 70 per cent. per day, all costs considered.

Molding Machines. The molding machine has also taken a very prominent place among foundry labor-saving devices,

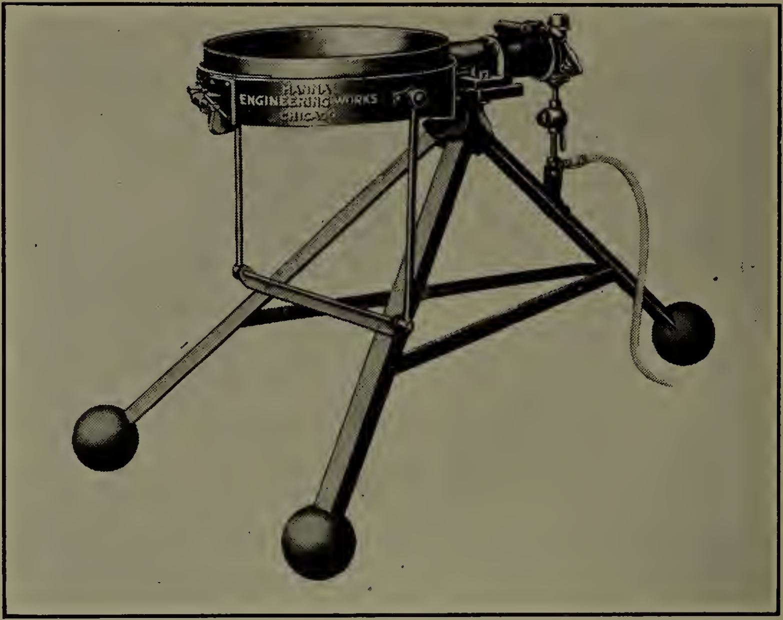


Fig. 92—A typical portable sand shaker.

enabling increased output and a higher grade product to be accomplished.

It has the distinction of being equally as well operated by all classes of labor. Practically every line of castings can now be successfully and economically molded on such machines.

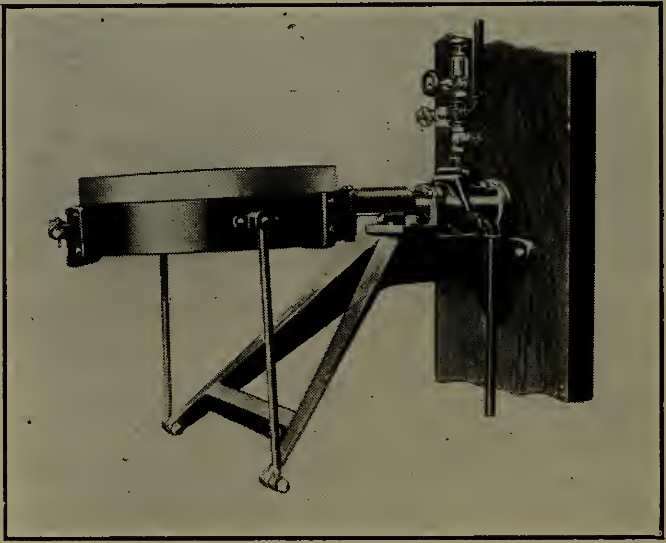


Fig. 93—A stationary wall or post sand shaker.

Compressed air operated molding machines ram the molds in three different ways—

First: By the application of static cylinder pressures, effecting a squeeze on the sand. See Fig. 94.

Second: By dropping the sand surrounding the pattern upon an anvil with impact sufficient to ram— called 'jolt ramming'. See Fig. 95.

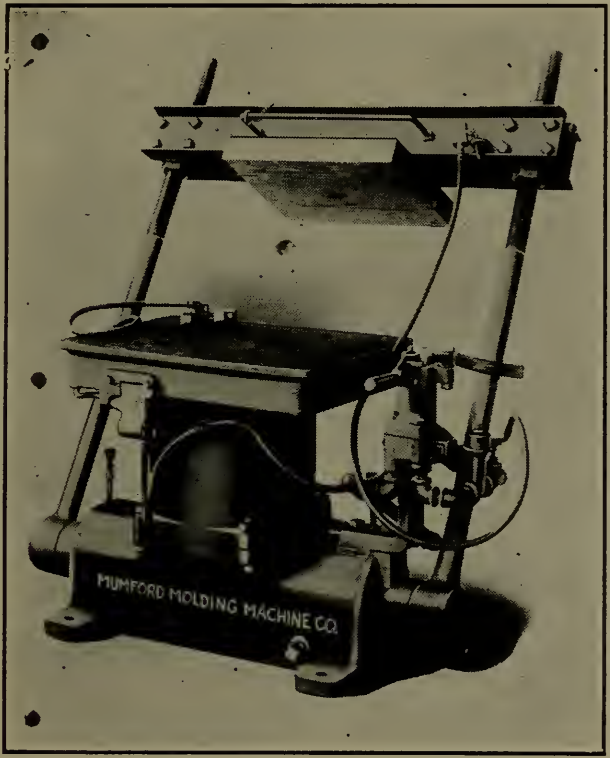


Fig. 94—Pneumatic squeeze molding machine.

Third: By ramming with a blow, often utilized to fill pattern spaces with loose sand just prior to ramming.

In addition there is the application of pneumatic vibrators to freeing patterns from the sand.

Air pressures usually employed for the foregoing classes of work range from 60 to 80 pounds.

The economies effected in pneumatic molding machines are of a wide range, and it is not always the foundry economy alone which is to be considered: thus uniformity of ramming and pattern drawing through machine molding in a brass foundry will often save more in waste of metal through strained molds than the saving in wages amounts to, but it may be generally stated that plain pneumatic squeezes are being installed in foundries where hand squeezes had been used before for a comparatively small wage saving, hardly proportionate to the amount of labor taken off the operator by the air power. In fact, operators are constantly found who will not increase output in proportion to the manual effort actually saved by power molding machines, and the employer has to be content with only a portion of the real saving in labor effected by the machine. From economies as low as 15 to 25 per cent. in such cases, we may find a range of saving extending up to reductions of direct labor cost of 75 to 90 per cent., where the flasks are filled with sand by buckets on a traveling crane and the cores for these large molds, as well as the molds, are jolt-rammed on a machine.

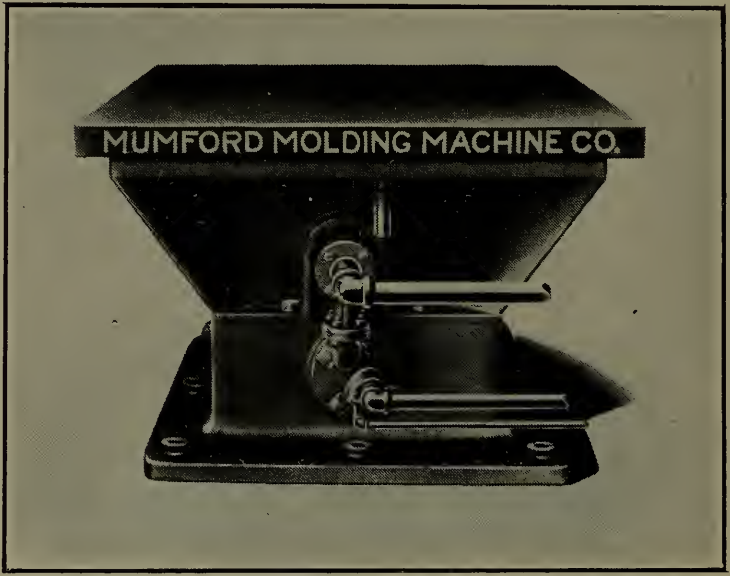


Fig. 95—Jolt Ramming Machine.

In this work, the great saving is due to two factors—

First: Making it possible to fill and ram a mold weighing perhaps 25 tons in a single operation, not a little sand at a time, and then more sand added, and rammed as of old.

Second: The fact that the ramming is accomplished often at a rate of several hundred horse power, in never to exceed one minute and often in 20 seconds.

POWER SQUEEZING MACHINES. Fig. 96 depicts perhaps the simplest type of pneumatic molding machine.

It is a development of the hand squeezer, but unlike the latter, it not only relieves the molder of the fatiguing work of ramming the mold but of squeezing as well.

This type of machine is intended especially for use in molding light snap flask work in quantity. It is designed to exert a steady squeezing pressure, not a jolt. It is adjustable for different depths of flasks.

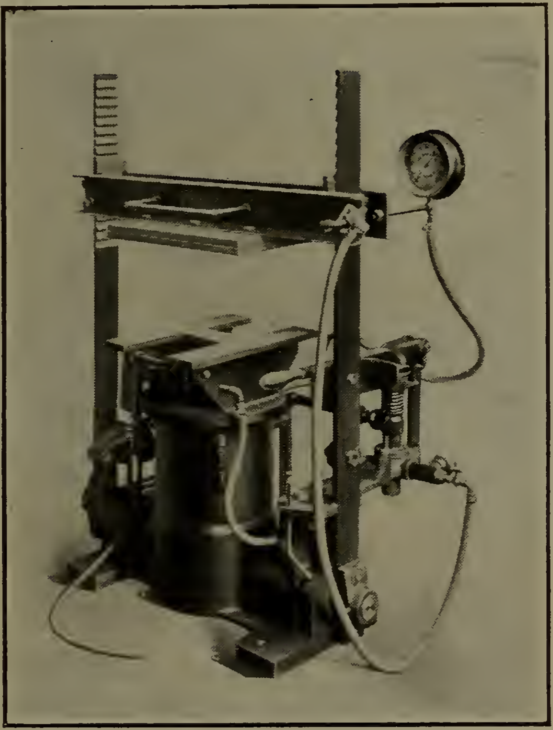


Fig. 96—Power squeezing molding machine.

It is supplied with or without a vibrator which not only assists in the drawing of the pattern, but also in obtaining uniform castings.

These squeezing machines may be used either with hard sand match, Fig. 97, aluminum match plate, Fig. 98, or with steel match plate, as shown in Fig. 99. See Table XXXVII.

The operation of molding on a squeezer equipped with a vibrator is as follows:

This description contemplates work employing a hard sand match.

The match with pattern in place is set on the machine table, the drag half of flask placed and filled with sand. Strike off with the edge of the bottom board all excess sand.

Place the bottom board over the flask, draw the yoke of the machine forward to the vertical position, squeezing the mold to the proper density. The yoke is then thrown back and the half flask together with pattern and match is rolled over.

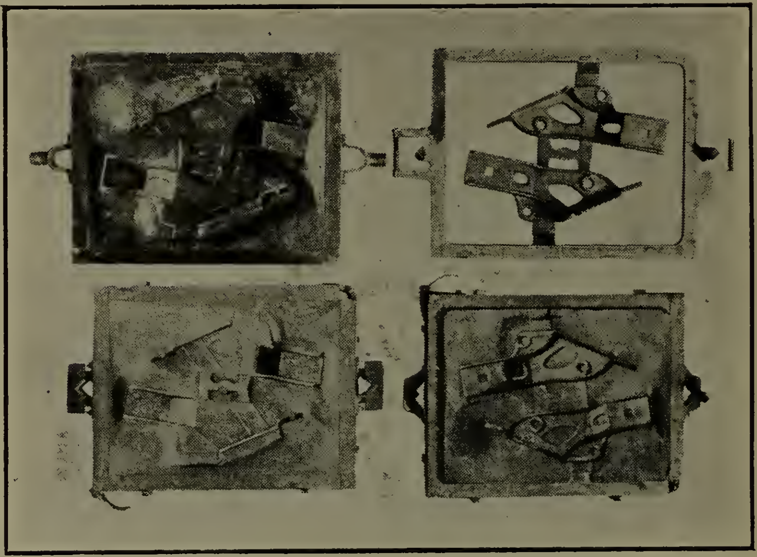


Fig. 97—Hard sand match.

Next remove the match and shake parting on the mold. Place the cope half of flask in position, fill with sand and squeeze as described above.

This completes the ramming operation and the cope board is then removed and a sprue cut with a tubular sprue cutter. The operator then starts the vibrator and grasping the cope by the handles, raises it and sets it to one side. The vibrator is again started and the pattern withdrawn by lifting the vibrator frame.

After the pattern has been withdrawn the two flasks are placed together, the cope half on the drag, the flask unsnapped and the finished mold set on the floor for pouring.

Where an aluminum plate is employed, the operation is identical excepting that the plate is placed between the two halves of the flask with the drag side up. The parting is shaken on the drag side of the plate, the drag filled with sand. After the excess sand has been struck off and the bottom board put in position, the flask is rolled over and the same operations performed for the cope half of flask, when the squeezing yoke is brought forward and the entire mold squeezed in one operation.

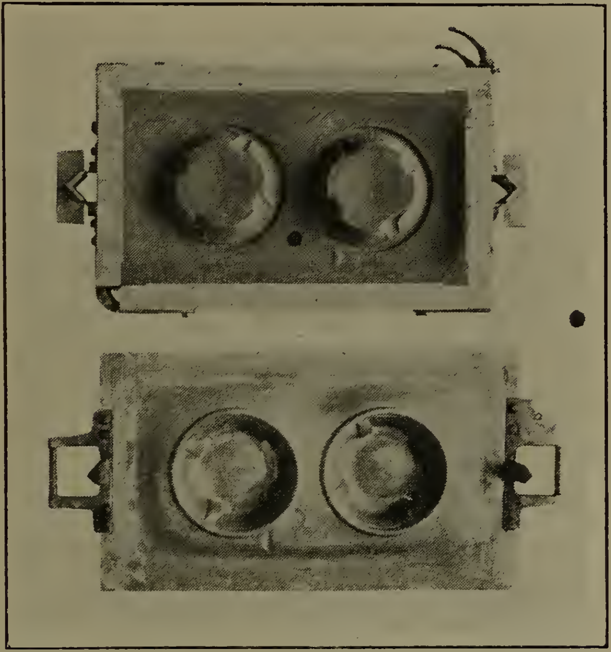
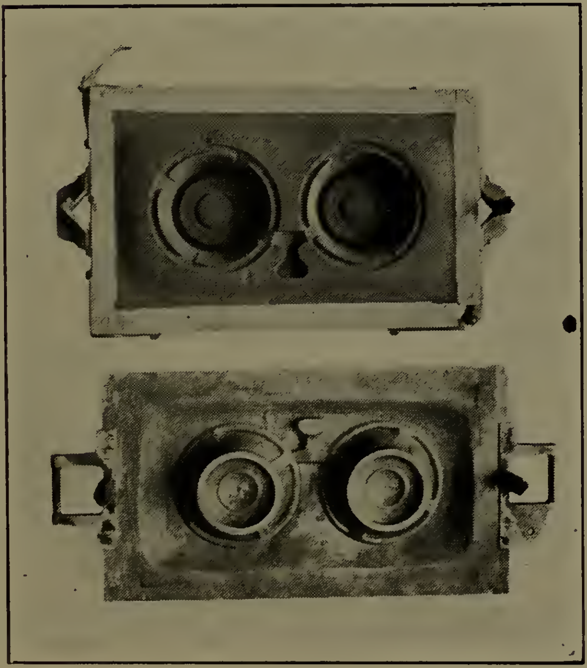


Fig. 98-A—Aluminum match plate.



Fig˙ 98-B—Aluminum match plate.

The steel plate method is employed for split patterns, from which castings are to be made in quantities.

The patterns are mounted one-half on each side of a steel plate about 3/16 inches thick and the same process of molding followed as with the aluminum plate.

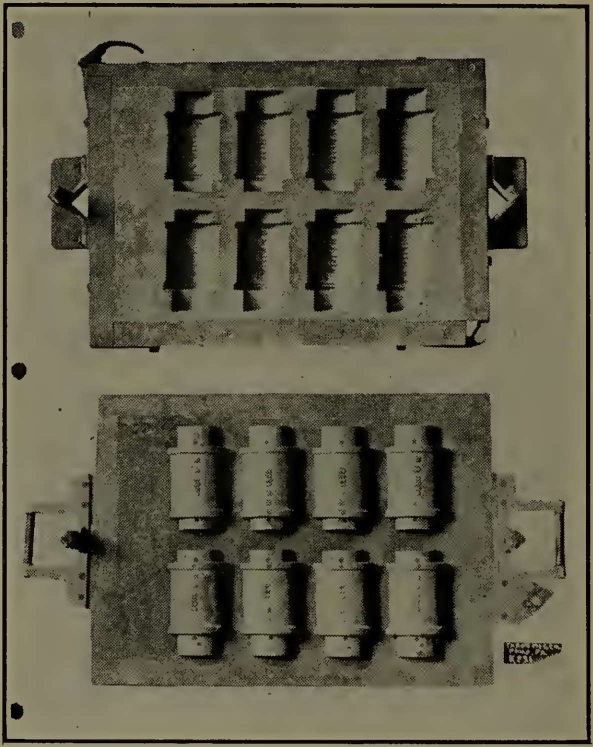


Fig. 99-A—Steel match plate.

In mounting the patterns for this method, brass stock is employed in holes drilled through the patterns and plate, being riveted down to the countersinks.

Power Squeezing Machines are also built in still another type known as the 'Split Pattern Machine'. See Fig. 100. They are intended for use with symmetrical patterns, split to a flat or nearly flat joint and fastened to a flat, single-faced pattern plate. These machines may also be used for other classes of work provided the pattern may be split on a true plane. See Table XXXVII.

In operating this machine, the half flask is placed over the pins in the flask frame of the machine; parting is shaken on the pattern and the flask filled with sand.

The squeezing yoke is drawn forward and pressure applied. When the sand has been squeezed to the proper density, the pressure is released and the yoke thrown back. The vibrator is started, loosening the pattern in the sand while the mold is being mechanically lifted from the pattern.

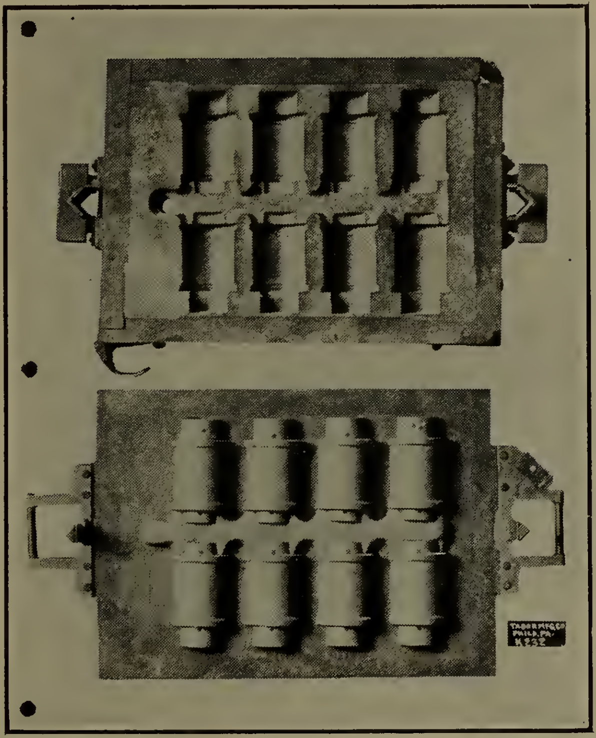


Fig. 99-B—Steel match plate

The mold is then picked up and set on the floor and the operation repeated for as many half molds as wanted. The plate is then changed to make copes and close the molds, any necessary

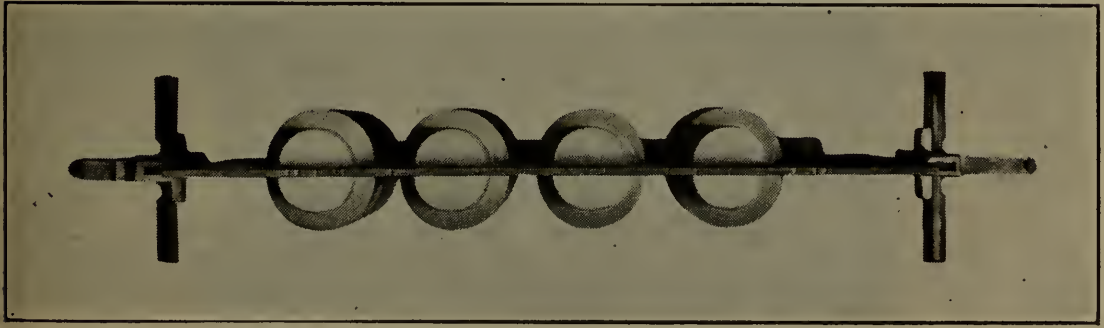


Fig. 99-C—Steel match plate.

cores having previously been set, a cope board being used with a sprue locating button and the sprue cut.

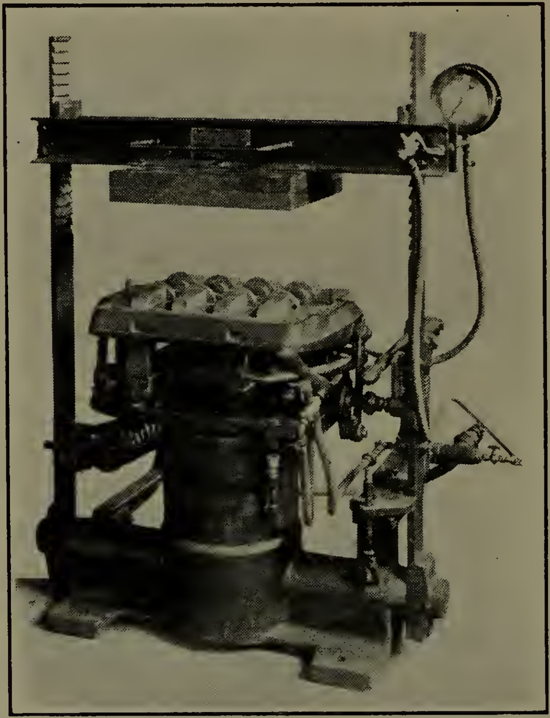


Fig. 100—Power Squeezing Split Pattern Molding Machine.

RECORDS OF PERFORMANCE. Fig. 101 shows a power squeezing machine, equipped with vibrator, in the plant of a large New

Fig. 101—Mumford power squeezing machine in the foundry of a New England Machine Tool Builder.

England Machine Tool Builder, and Fig. 102 shows the two patterns which are used in this particular machine. The operator it will be noted is in the act of removing the matching plate from the drag half of the flask. On the bench may be seen the cope half of flask. The molding has been done in one operation.

Fig. 102—Patterns employed with mold in Fig. 101.

Fig. 103 is a photograph, taken in the foundry of the Sanitary Company of America, Linfield, Pa., of work performed on split pattern vibrator squeezing machines. One man with one machine has an output of 50 molds 14 x 14 inches, four cores set in each mold, each casting weighing 12 pounds and 50 molds

Fig. 103—Split pattern power squeezing machines in the foundry of the Sanitary Co. of America.

12 x 12 inches, no cores set, casting weighing 5 pounds. The operator sets his own cores, carries all his own iron, pours its weight, shakes out and cuts his own sand.

In the foundry of the American Hardware Corporation where a great many power squeezes are employed, one man in six hours turns out 270 molds, 12 x 16 x 7 inches deep.

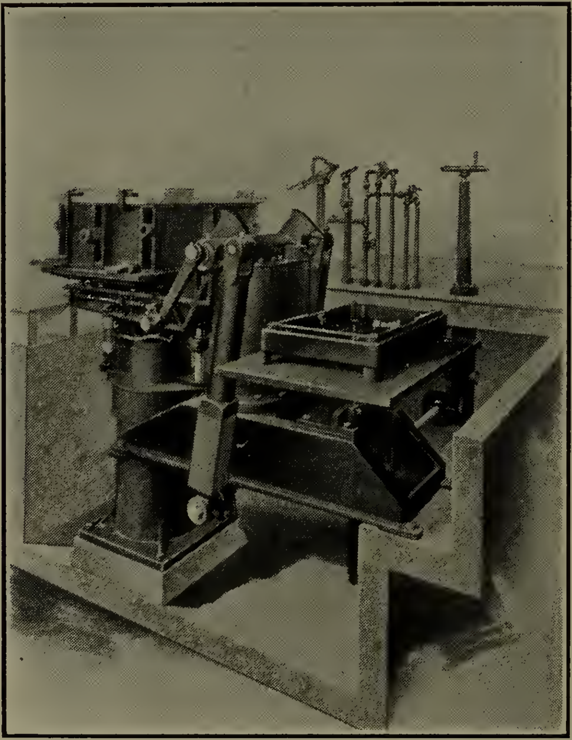


Fig. 104—Roll-over jarring molding machine.

Roll-Over Jarring Molding Machines. The fact that Split Pattern Power Squeezing Machines are limited to flasks of fixed dimensions and somewhat inflexible in their application led to the design and construction of the Roll-Over Jarring machine as illustrated in Fig. 104.

In nearly all such machines the mold is dropped away from the pattern, an air cylinder being provided for drawing the pattern.

These machines are particularly suitable for such medium and large size floor work where it is desirable to make a saving in the time of ramming, finishing and handling.

The machines are not commonly used in connection with split patterns having irregular joints, although where castings are required in sufficiently large quantities they may be economically applied.

The design embodies a base, at one end of which is attached a jarring machine. The roll-over air cylinder has already been referred to. The roll-over arms carry the pattern plate, which is centered on the table by dowel pins and when the pattern plate is lowered upon the jarring table, the roll-over arms are dropped away; there is therefore no connection with the jarring table during the jar-ramming process.

Fig. 105—A roll-over jarring machine employed on cylinder head-work.

Fig. 106—Flasks filled ready for jar-ramming.

The jarring feature saves nearly all of the ramming time, while the shop crane is relieved by the roll-over feature.

See Table XXXVIII.

The operation of molding is as follows: A flask is placed on the pattern plate and clamped. An extension to the flask is used to contain the extra loose sand required for the mold as it becomes compacted from jarring.

The flask is filled with sand and jar-rammed and butted off with pneumatic hand rammers when they are in use in the shop.

Fig. 107—Complete mold with pattern withdrawn.

The sand frame is then removed, the excess sand struck off and the bottom board clamped on.

Next the roll-over frame is brought in contact with the pattern plate, picking it up. After the frame has passed the balancing point, pressure is released and the inverted mold is deposited on the receiving table.

The clamps are next released from the flask, the vibrator started while admitting air to the roll-over cylinder, which now acts as a pattern drawing cylinder. When the pattern is withdrawn, the roll-over frame valve is opened causing the frame to roll back quickly to its original position, leaving the pattern plate on the jarring machine table.

After blowing the pattern plate and pattern clean, the machine is ready for another flask.

Records of Performance. Fig. 105 shows a roll-over jarring machine at work in a large foundry on a cylinder head mold. In this view the pattern is shown on the pattern plate ready to receive the flask. Fig. 106 shows the flask filled ready for jar ramming. Fig. 107 shows the pattern plate and pattern suspended after having been withdrawn from the mold.

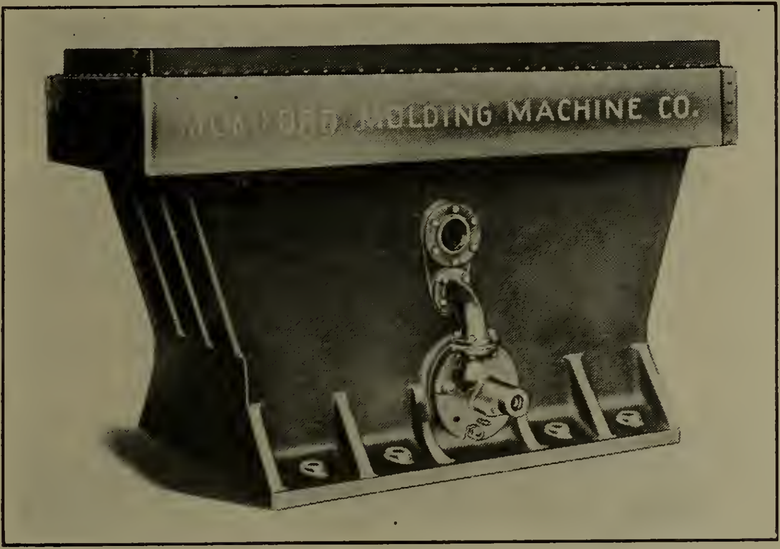


Fig. 108—Anvil type jarring machine.

In the foundry of the Best Manufacturing Company, Pittsburgh, Pa., manufacturers of high-pressure valves and fittings, three molders and five helpers produce eighty-eight flasks—ninety-seven castings of a total weight of 16,136 pounds in one and one-half days. Flasks are of miscellaneous sizes, 30 x 38 x 14 inches, 32 x 41 x 14 inches, 27 x 46 x 13 inches, etc., both cope and drag.

Jolt Ramming or Jarring Machines. Such machines are particularly adapted to large deep work or where the ramming forms a large part of the time consumed in molding. They are also useful for ramming large cores. The action is one of packing the sand in the mold by impact between the table carrying the mold and an anvil on which the table drops. Fig. 108 shows a machine for jarring molds and Fig. 109 a machine designed specially for core work. See Table XXXIX.

Records of Performance. Figs. 110, 111 and 112 depict scenes in the foundry of the separator works of the King Sewing Machine Company, Buffalo, N. Y. They cover the molding of the two heaviest and most important castings, the frame and base, on jolt, pit pattern drawing machines.

The information which follows was largely furnished by the publishers of *Iron Age*.

Fig. 109—Jarring machine designed specially for core work.

Referring to the frame casting, the patterns are split and each half is mounted on a jolt machine with pit-draft stripping mechanism. As indicated in one of the illustrations, the pattern is bolted rigidly and directly to the table of the machine, the stripping plate being loose, and in another the pattern is shown mounted with the stripping plate in position ready for putting on the flask. The former illustration shows the flask stripped from the pattern and removed from the stripper, on the top of which it is left standing, on edge. The body and end cores are shown at the left of the machine, the resulting casting appearing at the right with the bearing cores. The flask for this job is 15 x 26 inches, the drag being 7 inches in depth and the cope only 6 inches. Notwithstanding this very shallow depth of flask and the fact that the casting weighs but 56 pounds the ramming of the mold is accomplished with uniform firmness.

Fig. 110—Jolt ramming machine at work on separator pedestals.

Fig. 111—Jolt ramming machine at work on cream separator frames.

Three men, one handling the cores and the other two men molding, comprise the gang. None of them have had previous experience with this class of work, and they are now turning out 155 molds as well as pouring off. With three men and no core setter 165 molds are produced, while with three men and a core setter 200 molds are produced daily. Thus an aggregate casting weight of from 8,680 to 11,200 pounds is produced on this floor each day. As indicated two men are required to carry off each half mold. No bottom boards are used as planed cast-iron plates are set level in the floor.

The ordinary method of making work of this size and character has been to mount the pattern on a plain stripper, roll-over machine or split pattern squeezer with stripping plate. It is apparent that with the pattern and equipment properly designed it is possible to accomplish a greater volume of work by jolting, even with a small size and weight of casting, than can be produced by any other method. The experience with these separator frames has indicated that such castings made on a jolt machine with a pit pattern stripper on frames can be produced with marked uniformity both as to weight and size, considerations of great importance, in view of the fact that the castings are finished in automatic machines and must fit the jigs. It is estimated that the annual saving in overweight on castings made by this jar-ramming method, as compared with hand ramming or squeezing, has amounted to a considerable tonnage and a direct saving of several hundred dollars.

Fig. 112—Shows a jolt ramming machine with a completed mold for a cream separator frame, the pattern employed in making this mold and a finished casting.

In the engraving of the machines on which the molds for the separator base are made, the drag machine is the one at the left, and the illustration shows a completed drag half of the mold suspended on the air hoist. The cope is made up on the machine at the right and, being much smaller, no hoist is required as two men can readily handle it. No stripping plate is used on these machines, the mold being stripped direct from the pattern. The base, which has a cross-section of metal only 5/16 inches thick, suggests a rather difficult job of ramming to avoid soft spots at the point where the pedestal curves out to form the legs. As may be noted, air holes are drilled through the flask so that any tendency to form air pockets at the points where difficulty was likely to be encountered is avoided, and it has been found that the sand packs in uniformly.

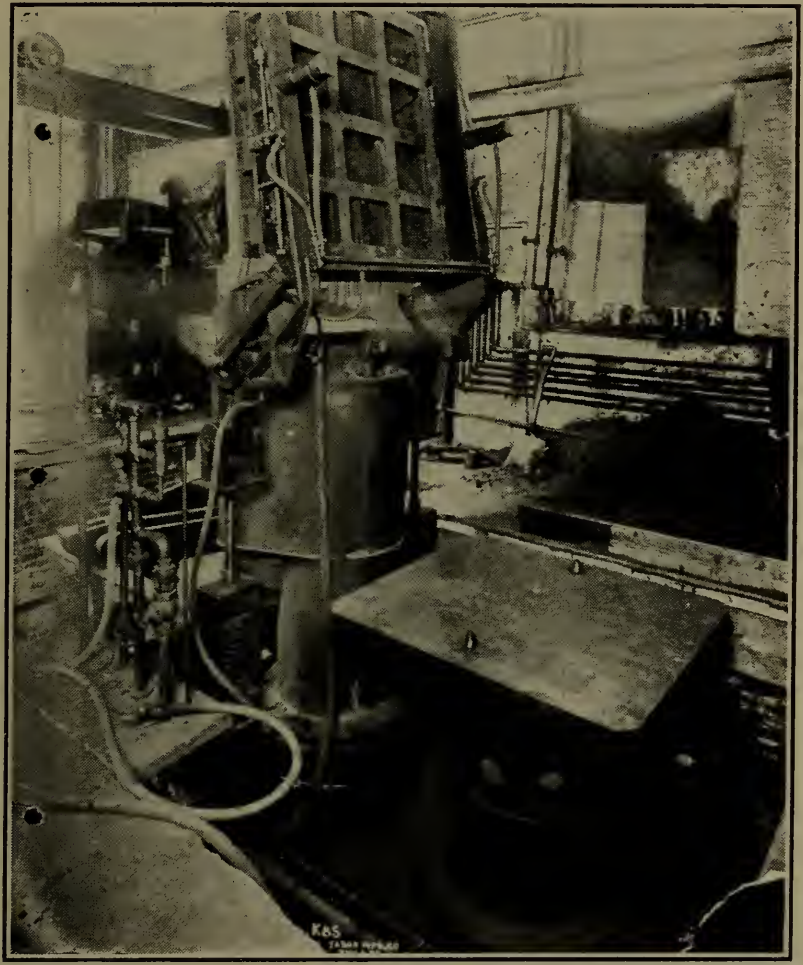


Fig. 113—Power roll-over jarring molding machine.

Referring further to the drag machine, the pattern base is cast in one piece, as it was found that the original pattern made with the pattern proper cast separately from the base could not be kept in good working condition without excessive cost for repairs. The present pattern has proved highly satisfactory. It has two lugs, as shown in the illustration, and a novel feature involved in the making of this casting arises from the jolting of the mold with lugs in extended positions, then opening the door on the side of the flask, ramming sand firmly around them and closing the door, following which the lugs are thrown back by a special mechanism to permit of stripping. The completed drag is then raised from the pattern by the elevation of the four vertical rods on which it rests. From these supporting rods the drag is lifted by an air hoist. On this job four men and a core setter turn out and pour off 130 molds per day, the core setter having a large body core to place. The castings weigh 41 pounds

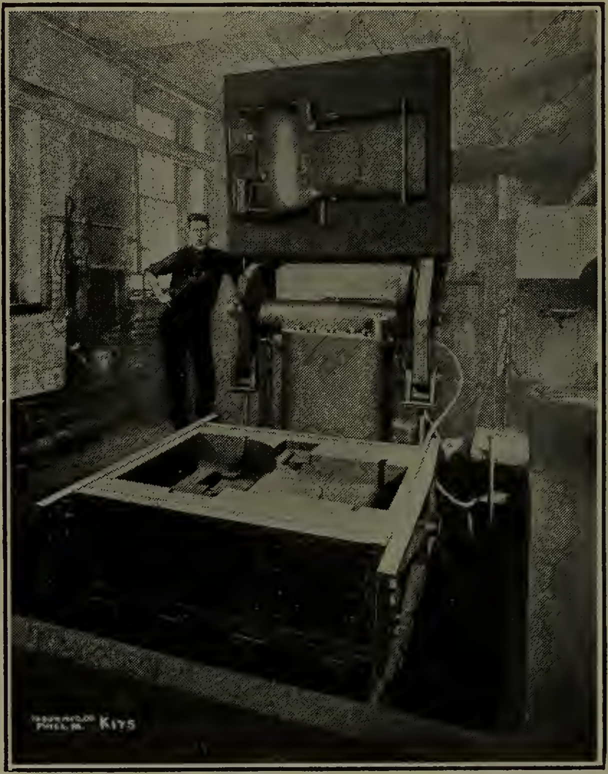


Fig. 114—Grinder frame mold made on combined roll-over and jarring molding machine.

each, and it is estimated that the production on the jar-ramming machine, as compared with other methods, results in an increased tonnage of castings amounting to at least 40 per cent.

COMBINATION JARRING AND ROLL-OVER MACHINES. Jarring machines are being used to good advantage in combination with other molding machines. Fig. 113 shows a power roll-over machine in combination with a jarring machine.

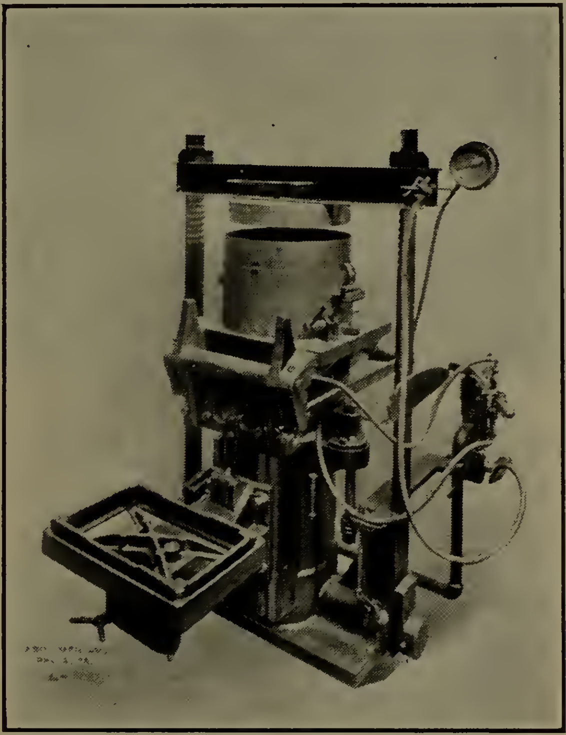


Fig. 115—Jarring, squeezing, roll-over and pattern drawing molding machine.

See Table XL.

Fig. 114 shows a grinder frame mold made on this combination machine. This half mold was made by two men in ten minutes and a complete mold, including core setting, could be made in half an hour.

Originally two men made two molds per day, working by hand. With the aid of a jarring machine this was increased to five per day and from the performance of the combination, roll-over and jarring machines, on the half mold, a production of twenty a day could be expected.

Fig. 115 shows a combination machine for jar-ramming, squeezing, roll-over and drawing the pattern by compressed air power. This same machine may be used just for squeeze, roll-over and pattern drawing where shallow work is to be done.

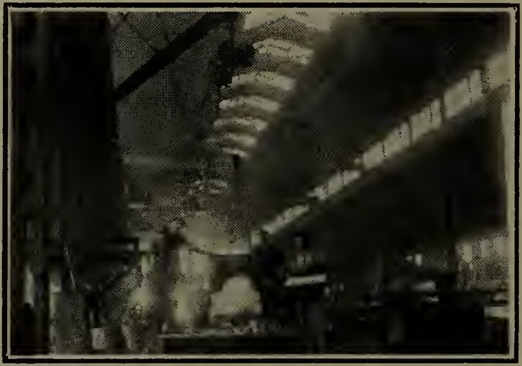


Fig. 116—In the foundry of the Lidgerwood Mfg. Co., Newark, N. J., air motor hoists are used in conjunction with swinging wall cranes for handling molds, patterns, etc. Note that it has been found advantageous to install these wall frames and hoists, in spite of the fact that the traveling crane serves the entire foundry.

Fig. 117—In the foundry of McNab & Harlin, Paterson, N. J., a number of air motor hoists operating in conjunction with hand operated travelers meet all the requirements for hoisting and handling molds, patterns, cores, etc.

Air Hoists. The air hoist in the foundry finds its application for lifting off copes, without jar; for lifting large patterns clear of molds (See Fig. 116, 117 and 118); lifting large green cores and for placing them in position for drying; for setting dry sand cores; in the latter work absence of shock or jar is highly essential.

Fig. 118—View in the foundry of the Pratt & Whitney Co., Hartford, Conn. Both motor and cylinder hoists are used in conjunction with swinging post cranes as auxiliaries to a large traveling crane.

They are also employed for conveying flasks outside of the foundry to storage sheds, patterns to pattern shop and finished castings to machine shop.

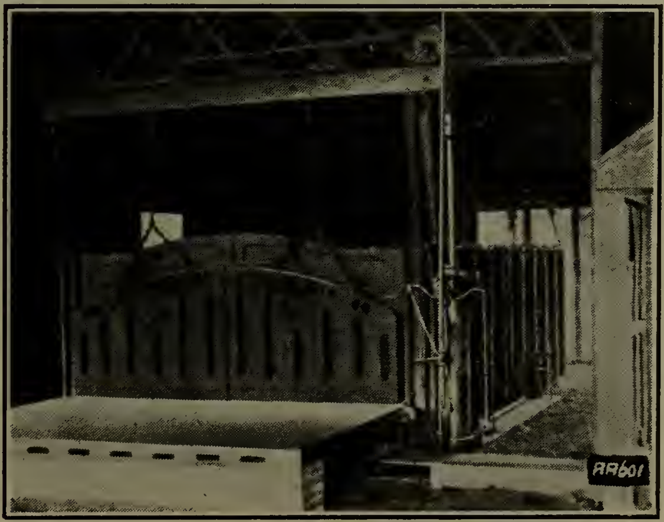


Fig. 119—A pneumatic cylinder hoist arranged to raise and lower annealing furnace doors.

Cupola elevators and core oven doors may be advantageously operated and putting up cupola doors accomplished by the pneumatic hoist. See Fig. 119.

Cranes are powerized by means of the Air Motor and Air Hoists. See Fig. 120

Fig. 120—A view in the foundry of the National Car Wheel Co., Sayre, Pa. In this foundry air motors have been used to powerize hand cranes. The hand operating feature has been retained.

A complete description of Hoists is given in Chapter VI on Portable Pneumatic Tools, also in Chapter XIV on Hoisting, Handling and Conveying.

Chipping Hammers. The value of the Pneumatic Chipping Hammer in a foundry, as a saver of time and labor, is universally conceded. Suffice it to say that for all classes of chipping in foundry work, such as chipping fins off castings, cutting gates, risers, buttons off anchors, and general trimming, one man with one hammer of the proper size will do as much work as three to

Fig. 121—Chipping Hammers at work on a large fly-wheel. The use of pneumatic chipping hammers for this class of work has enabled the foundryman to make a considerable saving in the cost of trimming and finishing castings.

Fig. 122—In the foundry of McNab & Harlin, Paterson, N. J. small chipping hammers are employed for all kinds of casting trimming.

four men chipping by hand. Chipping Hammers are made in different sizes and it is important that the proper size tool should be selected for the work to insure the best results; the short stroke tools being intended for the lighter work, requiring a light and very rapid blow, the longer stroke tools for the heavier work, requiring a heavy and slower blow. The medium sizes are the ones most generally used for foundry work.

Fig. 123—Skin drying a gear wheel mold, 4 ft. in diameter to a uniform depth of ½ in. in 12 minutes with a Hauck Portable Oil Torch operated by compressed air.

Fig. 124—Baking ornamental molds with a Hauck Burner. The molds are placed in a sheet-iron box lined with asbestos or fire clay.

Fig. 125—This view shows one method of applying the oil burner to drying foundry ladles.

Fig. 121 shows several pneumatic chipping hammers at work on a large fly-wheel in the foundry of a large Pennsylvania machinery manufacturer. Fig. 122 shows still another application.

Pneumatic Drills. The usefulness of the pneumatic drill to the foundry is somewhat limited except perhaps in its applica-

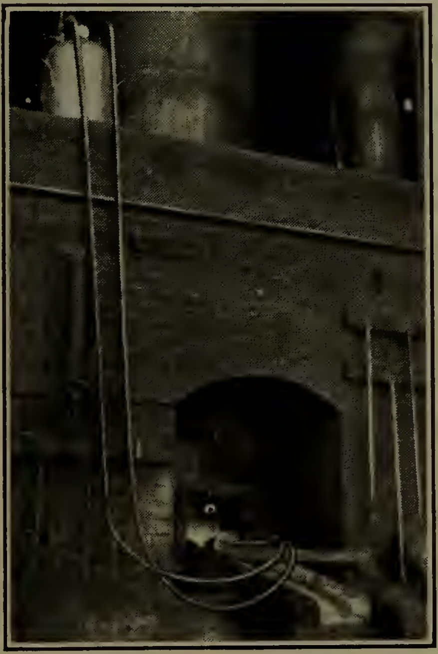


Fig. 126—Method of applying the oil burner to cupola firing.

tion to repair of boilers and other machinery. They may, however, be applied to advantage in drilling salamanders. This is a mass of cast-iron or steel which pours out of the cupola when the bottom falls out. This metal runs out on the floor, mixing with the sand and clinker and forming a very tough composition which must be broken up into small pieces before it can be remelted.

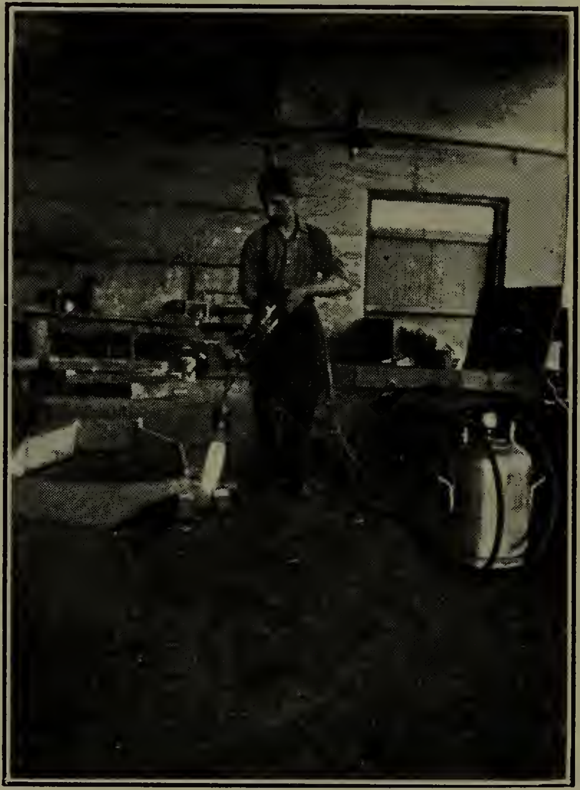


Fig. 127—Oil burners can be used to salvage condemned castings. The illustration shows the method of applying the burner to this class of work.

Air Operated Oil Torch. The use of the air torch has become quite prevalent in the foundry for skin drying and baking molds and cores, drying ladies, and lighting cupolas and spraying blacking on molds.

They have the advantage of doing away with obnoxious gases and smoke, are cleanly and instantly available.

See Table XLII.

Molds may be dried where made, thus avoiding danger of breakage, and the saving of time and labor. See Figs. 123 and 124.

For drying ladles no better or quicker means could be devised. Fig. 125 shows how one foundry accomplishes this work.

The air torch used for cupola lighting has solved the problem of safety while making it possible to light the cupola bed quickly and evenly without the use of shavings or other combustible material.

Fig. 126 illustrates the method of applying the air torch to cupola lighting.

The burner is placed in the spout, at the tap hole, or the breast, or at a specially cut hole and the flame directed by the compressed air against the coke bed, producing immediate ignition. This is accomplished without injury to the cupola lining, enabling the fan blast to be started in the least time and insuring clean, hot iron as there is an entire absence of ashes.

These torches can also be applied to the repair of castings which would otherwise be condemned and go into the scrap pile.

Fig. 127 shows the method of applying the torch. The defective parts are heated to the melting point and the fluid metal allowed to amalgamate with the original casting.

TABLE XXXVI

SAND SIFTING MACHINES

Type	Size Ins.	Screen Box	Weight Lbs.	Air Pressure Lbs.	Air Consumption at 80 Lbs. Cu. Ft. Per Min.
Tripod Shaker . . .	$2^7/_{16}$	18-in. Dia.	120	20–80	25
Tripod Shaker . . .	3	2 x 3 ft.	250	20–80	35
Stationary Post Shaker	$2^7/_{16}$	18-in. Dia.	65	20–80	25
Swivel Post Shaker .	$2^7/_{16}$	*18 " "	115	20–80	25
Trough Shaker . . .	$2^7/_{16}$	18 " "	70	20–80	25

* This takes ordinary 18-in. round foundry riddle. It can be furnished for square screen boxes 9 x 12 ins. or 12 x 14 ins.

NOTE—Any desired mesh of screen may be used.

TABLE XXXVII
POWER SQUEEZERS

Type	Draft	Size of Cylinder Ins.	Flask Size	Distance Between Uprights Ins.	Weight	Floor Space	Air Pressure Lbs.	Approx. Air Consumption Cu. Ft. at 80 Lbs. per Min.
Plain Power Squeezer	....	10	Up to 14 x 20 ins.	32			60–80	4
" " "	....	13	20 x 24 "	36			60–80	4
" " "	....	16	20 x 26 "	40			60–80	4
Split Pattern "	3-in. Hand	10	14 x 16 "	. .			60–80	4
" " "	" "	10	13 x 18 "	. .			60–80	4
" " "	4-in. Machine	13	14 x 16 "	. .			60–80	5
" " "	" "	13	13 x 18 "	. .			60–80	5
" " "	" "	13	15 x 15 "	. .			60–80	5
" " "	" "	13	13 x 20 "	. .			60–80	5
" " "	" "	13	14 x 18 "	. .			60–80	5
" " "	" "	13	16 x 16 "	. .			60–80	5
" " "	" "	16	18 x 18 "	. .			60–80	6
" " "	" "	16	16½ x 21 "	. .			60–80	6
" " "	" "	20	16 x 26 "	. .			60–80	7
" " "	6-in. "	20	18 x 26 "	. .			60–80	7
" " "	10-in. "	24	24 x 24 "	. .			60–80	8
" " "	" "	24	24 x 30 "	. .			60–80	8
" " "	" "	30	24 x 36 "	. .			60–80	10
" " "	12-in. "	30	30 x 30 "	. .			60–80	10
" " "	10-in. "	36	24 x 48 "	. .			60–80	12
" " "	12-in. "	36	36 x 36 "	. .			60–80	12
" " "	" "	36	30 x 48 "	. .			60–80	12

NOTE—Sizes 30-in. and 36-in. have power operated squeezing yoke.

TABLE XXXVIII

ROLL-OVER MOLDING MACHINES

Type	Machine Size Ins.	Draft Ins.	Capacity Air Pressure 80 Lbs.	Portable or Stationary	Weight	Floor Space	Air Consumption Cu. Ft. Per Min.
Hand Roll-Over, Hand Draft	18	5	Up to 400 Lbs.	Portable			
" " " "	18	8	400 "	"			
Power " " "	24	7	800 "	"			
" " " "	24	12	800 "	"			
" " Power "	30	8	1,000 "	Portable or Stationary			
" " " "	30	12	1,200 "	" " "			
" " " "	40	18	2,500 "	Stationary			

TABLE XXXIX

JOLT RAMMING MACHINES

Size of Cylinder	Capacity at 80 Lbs. Air Pressure Lbs.	Size of Table Ins.	Gross Weight Lbs.
3-in. Jolt	350	15 x 20	350
4 " "	700	18 x 24	500
4½ " "	800	18 x 24	650
6 " "	1,500	20 x 30	1,050
8 " "	2,500	30 x 42	2,150
10 " "	3,700	42 x 54	4,600
10 " "	3,000	30 x 144	9,000
14 " "	7,200	48 x 72	10,000
14 " "	7,200	30 x 144	15,000
16 " "	8,500	72 x 72	16,000
16 " "	8,000	32 x 168	22,600
20 " "	12,000	33 x 93	16,800
20 " "	15,000	72 x 72	15,800
20 " "	14,000	72 x 108	26,000
22 " "	18,000	40 x 96	26,000
24 " "	24,000	72 x 72	19,400
24 " "	23,000	72 x 108	26,250
32 " "	44,000	72 x 108	36,300
32 " "	39,000	96 x 144	43,000
32 " "	39,000	84 x 168	44,200
36 " "	50,000	96 x 144	......

TABLE XL
COMBINATION JARRING AND ROLL-OVER MACHINES

Jarring Cyl. Ins.	Roll-Over Cyl. Ins.	Pattern Plate Ins.	Flask (Inside) Ins.	Draft Ins.	Capacity Net Lbs. Wgt. at 80 Lbs. Pressure	Weight of Lbs. Complete Machine Lbs.	Floor Space	Air Consumption Cu. Ft. Per Min.
6	12	28x42	24x36	12	1,200			
10	18	44x70	36x54	13	2,500			
13	24¼	55x76½	48x60	12 to 21	3,500			
20	32	64x76	54x54	12 to 24	5,000			

TABLE XLI
CORE BREAKERS

	Weight Lbs.	Length Over All Ins.	Bore of Cyl. Ins.	Length of Stroke Ins.	Size of Inlet Ins.	Size of Hose Ins.
VALVE TYPE	18	19¾	1¼	3½	⅜	½
VALVELESS TYPE	16	18	1$\frac{7}{16}$ and 1$\frac{11}{16}$	2½	⅜	½

TABLE XLII
PORTABLE OIL BURNERS

No.	Capacity of Tank Gals.	Length of Hose Ft.	Oil Consumption per Hour Gals.	Air Consumption Cu. Ft. Free Air Per Min.	Shipping Weight Lbs.	Weight of Burner Lbs.
1	16	24	4	20	110	15
2	15	24	3	15	100	10
4	12	24	2	12	90	6
5	10	24	1	8	85	3
6	8	24	1	5	75	2

CHAPTER X

SAND BLASTING

The usefulness of the sand blast is not alone confined to cleaning castings in the foundry, although this is one of its important, if not the most important application.

It is being very successfully applied to such work as putting a satin finish on completed work; removing scale, paint and rust from various surfaces; preparing metal surfaces for painting, enameling, tinting, sherardizing, or galvanizing; cleaning and finishing castings, etc.

In addition to producing a better class of work the cost for cleaning shows a decided reduction, ranging from a few minutes on the small job to days on large, intricate work.

The Sand Blast in the Foundry. Next to the actual molding and pouring of the casting there is, perhaps, no foundry operation of greater importance than that of thorough and satisfactory cleaning of castings.

Under the old methods of hand cleaning, and the use of plain tumbling barrels and similar apparatus, the operation was always one requiring considerable time and extreme patience. It meant high cost, and above all tended to restrict the capacity of the foundry, for deliveries were dependent upon the cleaning and this, in turn, placed a restriction on the molding capacity.

While it is true that some of the older methods, such as brushing, tumbling, pickling and blowing still have their advantages for particular classes of work, the real solution for general commercial work, including all classes of castings, large, medium and small, is to be found in the sand blast.

There are many makes, styles and kinds of sand blast apparatus from which to choose, each having its own peculiar advantages. Some are designed to employ high- and others low-pressure air.

There has been some question as to the relative merits of high- and low-pressure air for sand blasting, and a great many experiments have been conducted to determine the best air pressure for various classes of cleaning work. As a general thing the results have seemed to favor the employment of high-pressure air for all-round general use.

It has been determined and is generally conceded that the volume of air required is governed by the size of the opening in the sand blast nozzle, and the pressure maintained, based on the standard flow of air at a given pressure through a given size orifice. Therefore, the higher the pressure, the greater the volume of air used, but the amount and quality of work done increases correspondingly without added labor costs. It has been further proven in these tests[2] that twice as much work can be done at 50 lbs. pressure as at 20 lbs.; at 64 lbs. as at 30 lbs.; and at 72 lbs. as at 40 lbs. It has also been shown that gray iron and malleable castings can be cleaned best and quickest with an air pressure of 80 lbs.; brass and aluminum castings at not lower than 60 lbs.; while for steel castings, the hardest to clean, not less than 90 lbs. The character of the material and its ability to withstand the impact of the sand will determine the pressure adaptable.

Nozzles. The following table shows the volume of air (compressor piston displacement) required at 80 lbs. pressure with standard sizes of nozzles:

Size of Nozzle	3/16-in. I.D.	1/4-in. I.D.	3/8-in. I.D.	1/2-in. I.D.
Grain of Sand	10 mesh	8 mesh	7 mesh	5 mesh
Sand Delivered per hour	500 lbs.	900 lbs.	1,700 lbs.	3,000 lbs.
Free Air Used per min.	45 cu.ft.	85 cu.ft.	191 cu.ft.	340 cu.ft.

As these nozzles have to withstand considerable wear, and all nozzles will wear in spite of the class of material used, it is highly desirable that the foundry purchase them from the manufacturer of the sand blast equipment. A short nozzle usually wears better than a long one, as the latter gives the sand an opportunity to eddy from side to side, resulting in the expenditure of valuable energy in wearing out the nozzle. On the nozzle is dependent the economy of operation of the sand blast itself, for, as already stated, the size of the opening governs the flow of air and sand. This point is well illustrated by the series of nozzles shown in Fig. 128. Nos. 2 and 3 illustrate the quarter-inch nozzle before

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[2] See paper by Professor W. T. Magruder, "Transactions American Society of Mechanical Engineers."

use; Nos. 1 and 4 show this same nozzle in similar positions to Nos. 2 and 3 after considerable service; No. 5 shows an ordinary nozzle after an equal amount of work, it originally being the same size as the nozzle shown in No. 3.

For the sake of economy in consumption of power the nozzle should be changed when the outlet shows any appreciable enlargement over the original bore.

It is becoming quite general practice where the sand blast equipment is employed on a large scale to provide a special cleaning room, the walls of which are substantially constructed of metal to resist wear. Such matters as ventilation, drying and conveying of the sand, means for holding the castings, and general convenience for the operator are all given careful consideration.

Fig. 128—Effect of wear on Sand Blast Nozzles.

In fact, so important has the problem become that it is not uncommon for the foundry to contract with the manufacturer of sand blast equipment for the complete installation of the plant. In the following pages will be discussed the several methods and types of equipment adapted to foundry work more particularly and which can also be applied to other uses.

Condition of Air. To obtain the most satisfactory operation from the sand blast equipment, there are a number of things which require careful consideration on the part of the foundryman—for instance, the condition of the air is of prime importance. It must be perfectly dry, free alike from moisture and oil before contact of the air with the sand, making it imperative that a thoroughly reliable separator be employed.

Abrasives. Clean, sharp sand is necessary for the best results, and it is surprising to what extent the class of sand affects both operating expense and production. The sand should be free from clay, loam or any other substances not possessing abrasive qualities.

It is to be noted that the sand can be used over and over again, although after each use it should be put through a separating process to remove all dust and other foreign substances gathered while cleaning the castings.

The above reference to the use of sand should not be taken to mean that other abrasive materials cannot be used. Angular grit, crushed steel, steel shot, etc., are equally adaptable for the work.

Fig. 129—Hose Sand Blast Machine.

While any of these abrasives may be used separately, experience has shown that the most economical results for general classes of work are obtained with a mixture of chilled iron grit 75 per cent., and sand 25 per cent. The grades of materials most commonly used are No. 1–I Sand, No. 30 Grit, and No. 7 Shot.

It is highly desirable that the flow of air and sand be uniform. If too little sand is fed the abrasive action will be light and air wasted, while unequal flow causes the partial loss of abrasive power.

Regulate the flow of sand so that just enough will issue from the nozzle to give a good cutting effect. The sand cleans by striking an infinite number of sharp blows and not by the friction of the particles sweeping over the surface. Just enough sand will permit each grain to do its most effective work. Too much sand will cause the particles to rub on one another and reduce their energy.

As a rule the nozzle is held from 6 to 12 inches from the surface to be cleaned, and usually an angle of from 30 to 45 degrees will be found most effective.

Sand Blast Equipment. Fig. 129 shows a typical high-pressure sand blast hose machine. This machine is furnished complete with hose and nozzles and pressure gauge all ready for operation. The flow of air and sand is controlled as follows: the compressed air after passing through the moisture and oil separator shown at the side of Fig. 129 is carried to the air regulating valve (101) under the control of handle (102). The air is full-on when the handle is in line with air pipe as shown in Fig. 130; with handle at right angles to the air line the regulator is closed. It is possible to regulate the air to any desired volume between fully closed and fully open at the option of the operator.

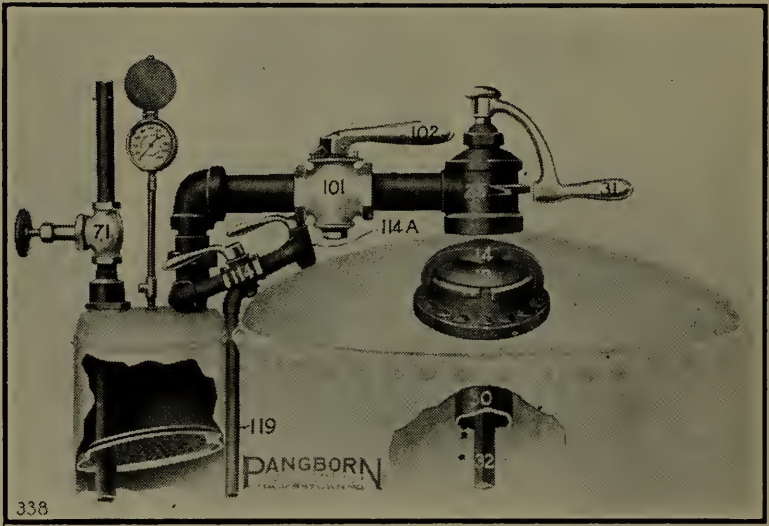


Fig. 130—Air and Sand Control of Hose Sand Blast Machine.

From the regulator the air is transmitted to and down the cylinder (30) by opening the valve (114) and is admitted to the sand chamber maintaining an equal pressure above the sand and assuring constant uniform flow. The air can be released from the sand chamber at any time through pipe (119) by opening the exhaust valve (114 A). The sand controller handle (31) moves on a quadrant, having limit stops for its off- and full-on positions. By means of this handle, a plate (40) shown in Fig. 131, is rotated, opening and closing the sand ports as desired.

The mixing of the sand and air and their transmission to the hose is clearly shown in Fig. 131. When lever (31) is opened the sand falls into the mixing chamber through an elliptical opening in the casing (38) and through the plates (39 and 40). The air is carried into the cylinder (30) through the center of the valve casing to the mixing chamber (47), where it mixes with the sand by a swirling motion imparted by the shape of the mixing chamber itself and is transmitted from there to the hose. The mixture of sand and air is carried through openings that gradually reduce as they approach the hose connection. See Table XLIII.

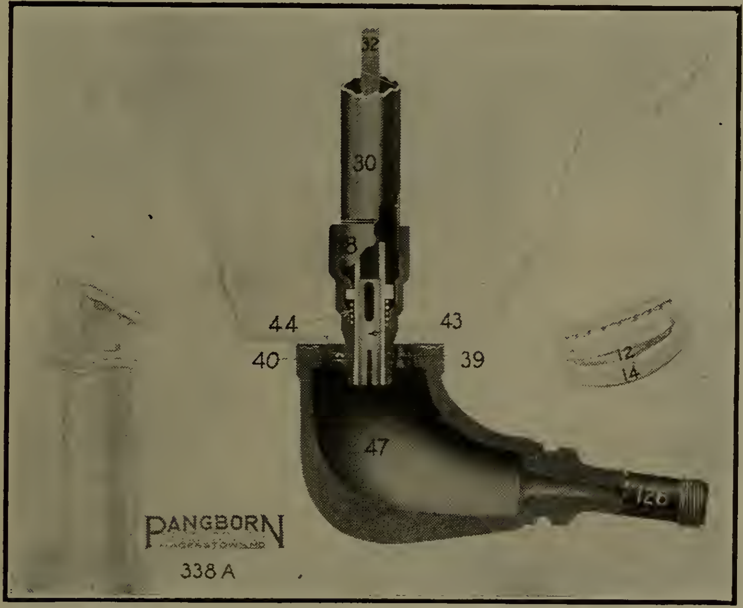


Fig. 131—Mixing Chamber of Hose Sand Blast Machine.

Air Separator. Most manufacturers provide an air separator as a part of the sand blast machine, the purpose of which is to remove the moisture and oil from the air before it is mixed with the sand. This device generally consists of a steel tank containing a series of perforated shields and solid baffle plates which deflect the air in such a manner as to cause the precipitation of the moisture or any other liquids. The desirability of eliminating moisture and oil from the air has already been touched upon. A typical moisture separator is shown in section in Fig. 132. See Table XLIV.

Sand Blast Barrel. Fig. 133 shows another type of sand blast equipment known as a sand blast barrel. The purpose of this machine is to quickly and economically clean small castings or other metal parts, and is equally adaptable to the use of either sand or other forms of abrasive. The operation of this machine is not unlike the tumbling barrel. It contains a drum which rotates at a predetermined speed, continuously turning the castings and presenting new surfaces to the action of the sand blast, the sand blast nozzles being introduced at carefully determined points of the barrel. In the sand blast barrel the flow of sand is automatic. It starts when air is turned on and stops when it is turned off.

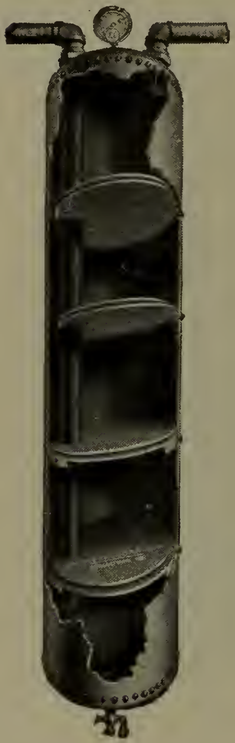


Fig. 132—Air Separator.

Power for rotating the drum is obtained by belting to line shaft or other power-transmitting means. Access to the drum is had by means of a door, the discharge of the castings being automatic with the opening of the door and the rotation of the barrel. See Table XLV.

Sand Blast Table or Car. In Fig. 134 is shown a common type of sand blast table or car used with the sand blast machine shown in Fig. 129. This table or car is built substantially of metal and fitted with a series of rollers which enable the quick and easy handling of castings. This table will be referred to further on in connection with sand blasting room operations. The casting shown required eighteen minutes to clean by the sand blast.

Rotating Sand Blast Table Machine. This machine has been developed to handle castings which cannot be cleaned to advantage in a tumbling barrel. It comprises an inclosed, slowly rotating table, constructed of heavy cast-iron removable grates on which the castings are placed. As the table rotates a number of nozzles, depending upon the size of the table, play on the castings. In operating the machine the operator stands in front

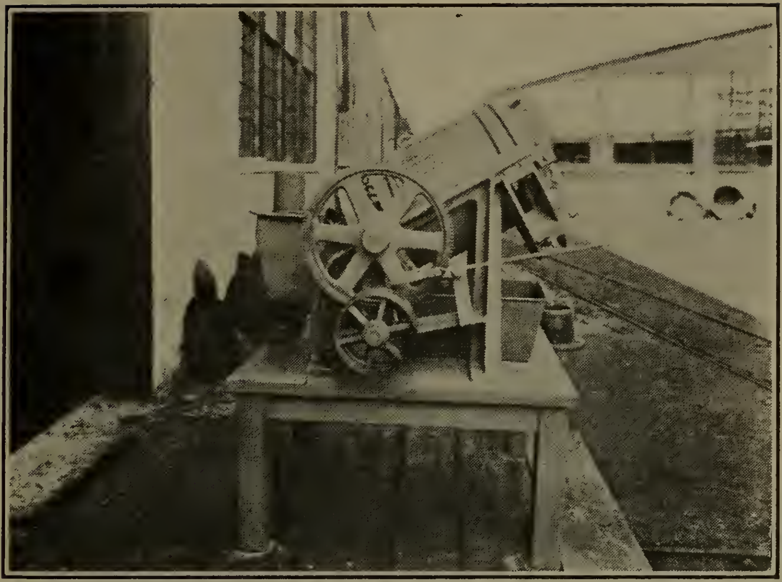


Fig. 133—Sly Sand Blast Barrel.

where he is protected from flying particles of dust and sand by means of a split rubber curtain which allows the castings to pass by easily. A dust exhauster, as well as a dust arrester, are usually a part of this machine. This latter equipment is described further on. See Table XLVI.

Fig. 134—Sand Blast Car.

Fig. 135 illustrates the rotating sand blast table machine. It will be noted that a sand hopper is a part of the machine, this hopper having sufficient capacity to feed the nozzles continuously. A bucket elevator forming an endless chain belt arrangement and operating in a steel dust-proof housing, elevates the sand to the hopper from where it flows by gravity to the sand valves.

Fig. 135—Sly Rotating Sand Blast Table Machine.

In operation the sand falls through the table gratings into a steel hopper located below the table. Steel brushes below this table brush the sand into the lower hopper, from which it falls into the buckets and is elevated to the upper hopper. The sand is thoroughly sifted and all refuse removed on its way to the hopper.

The operation of sand blasting is as follows:

The castings are placed in position on the table, which is rotated at the speed necessary to give best results with the particular castings. The nozzles are arranged to revolve in the opposite direction to the rotation of the table. When one side of the castings has been sufficiently cleaned, they are turned over by the operator and the cleaning process finished.

Sand Separators. The necessity for sand separation has been previously referred to. Figs. 136 and 137 depict two types of sand separators. These separators are essentially screening machines used to separate dust and refuse from the usable sand, both new and old. They are an economical necessity to sand blast equipment, making it possible to use the sand a number of times over. See Table XLVII.

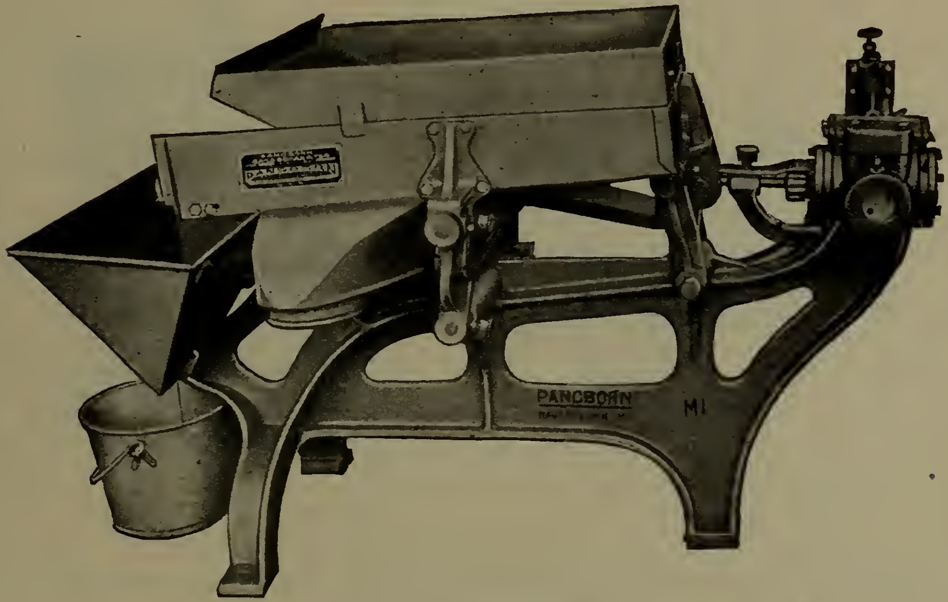


Fig. 136—Sand Separator.

The separator shown in Fig. 136 consists of an air operated cylinder with piston attached to a screen box. It operates very much on the hand riddle principle in which the sand is tossed up from the ends of the screen box to the center of the screen, effectually breaking up the lumps and carrying the sand through.

In operation the material is shoveled into an upper screen in the separator. This box contains a screen of mesh designed to retain all large and heavy sand that would clog the nozzles. The fine dust and disintegrated sand having no abrasive value pass through a lower screen and are deposited through a chute at the side, while the clean, sharp sand suitable for re-use is carried to the hopper. The screens are interchangeable, permitting the use of any size mesh.

The separator shown in Fig. 137, while an effectual sand separator, is intended for screening sand where but one separation is required. It consists of a heavy galvanized box, which can be fitted with detachable screens of the required mesh. The screening action is performed by a small air engine to the reciprocating piston of which is attached a screen box.

In operation the clean sand is delivered to the hopper shown below the screen box, from where the sand is delivered to a pail by means of a gate on the hopper. This sand separator being portable can be used for general foundry purposes in connection with screening molding sand.

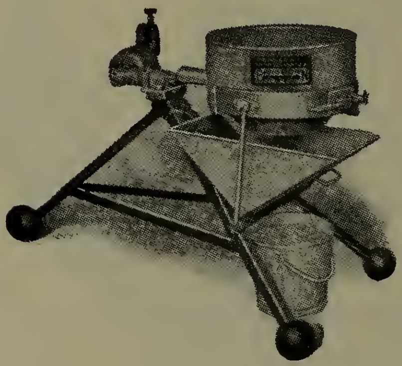


Fig. 137—Light Portable Sand Separator.

Fig. 138—Sand Drier.

These separators are also built in stationary wall and post types.

Sand Drier. It has also been previously mentioned that a sand drier is essential to the most efficient operation of sand blast equipment. Moist sand tends to clog the nozzles and does not flow freely. The result is wasted power and ineffectual abrasive action.

In Fig. 138 is shown a typical sand drier. This drier consists of a stove or fire box over-capped by a conical sand box containing a perforated screen.

In operation the sand is dumped into the sand box where it drops on the perforated screen, keeping the sand away from direct contact with the fire box and allowing the heated air to pass under the sand. The heated air carries off the moisture and as the sand becomes dry it drops through the perforations of the screen and runs down the inclined top of the fire box onto the floor. In order to insure the complete drying of the sand a number of inverted flues project from the fire box through the sand box into the open air.

In drying sand it is highly desirable that it be dried without rendering the sand friable, also that it does not become baked.

Most of these sand driers are arranged to burn soft coal, coke or wood. See Table XLVIII.

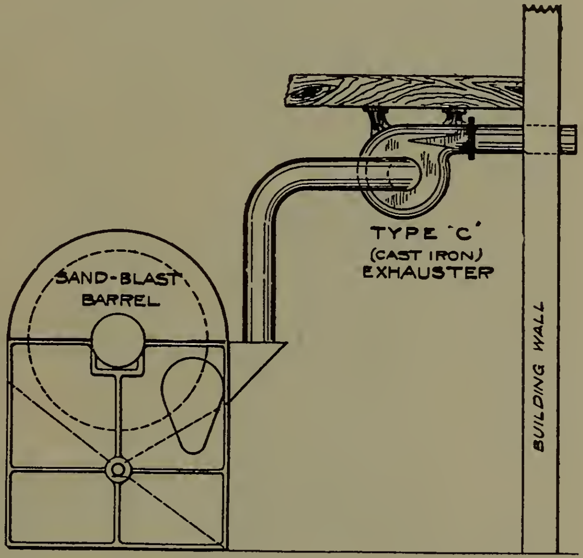


Fig. 139—Dust Exhauster to Atmosphere.

Dust Arresters or Ventilating Systems. In order to have blasting room conditions the most conducive to the greatest production, it is essential that a dust arrester be employed.

In Fig. 139 is shown a common type of dust arrester. See Table XLIX.

With this type of ventilating system the dust is drawn out-of-doors from the barrel or room by the exhauster.

It is applicable to plants where the exhausting of the dust to the atmosphere is not objectionable.

Fig. 140 shows a system in which the dust is drawn from the room or barrel into an arrester which will retain very nearly all the dust. It is suitable for plants where the surroundings are such that it is not absolutely essential to confine all the dust. See Table L.

In the particular system, shown in Fig. 141, the air laden with dust is drawn into the chamber at the left, while the fan exhausts the chamber at the right. Intermediately between the chamber and the fan is located a battery of screens through which the dust cannot pass. The dust remains in the chamber and none but clean, purified air is drawn into the fan and discharged into the sand blasting room, eliminating discomfort and annoyance to workmen and the destruction of machinery. This system is ideal for plants where it is important to confine and collect all the dust. See Table LI.

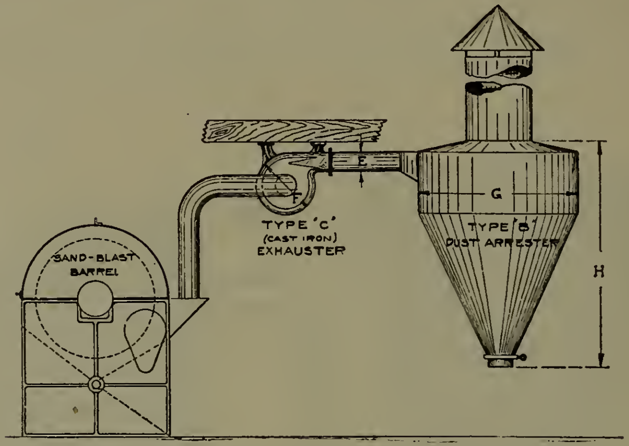


Fig. 140—Exhauster System which retains nearly all the dust.

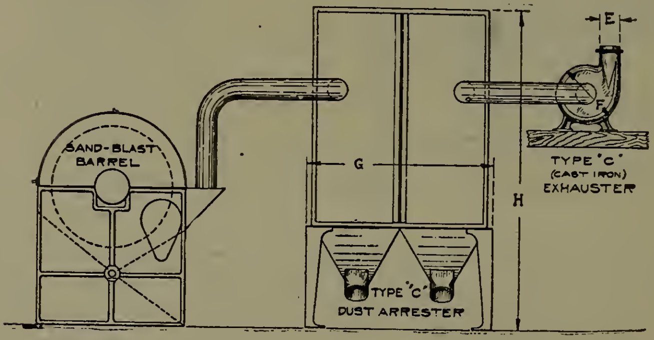


Fig. 141—With this System the purified air is returned to the Blasting Room.

Hose. Sand blast hose should be of good quality. It has been found that rubber-lined, closely woven duck, sufficiently heavy to withstand the pressure of the air as well as presenting a wear-resisting surface to the cutting action of the flowing abrasive, is best for the purpose.

The sizes most generally employed range from ¾ to 1½ inches. Couplings and clamps specially fitted for the duty may be purchased from manufacturers of sand blast equipment.

Gloves. The protection afforded by a good leather or rubber glove to the operators' hands cannot be ignored. The operation of sand blast equipment should not be permitted without this protection. See Fig. 142.

Fig. 142—Two Styles of Sand Blasting Gloves.

Hoods and Respirators. Figs. 143, 143A and 144 illustrate two articles of apparel necessary to the comfort and protection of the operator of a sand blast. The hood not only protects the operator from flying sand but effectually keeps out dust.

In certain classes of work the hood is not sufficient for the purpose, and in such cases it is strongly urged that the operator wear a suitable respirator. These respirators generally carry a dampened sponge through which the operator breathes, the dust being retained in the sponge.

Sand Blast Rooms. For the small foundry, perhaps the simplest plan is to employ the sand blast hose machine shown in Fig. 129 in conjunction with an ordinary metal-grated covered table or car in a conveniently partitioned off corner of the foundry. An open shed located close to the foundry will often be found adaptable for the purpose. The work to be cleaned is placed on the table or car and the operator, properly protected by hood and gloves, directs the sand at the object, occasionally stopping to shift the castings so as to reach all sides.

In installations of this sort no special provision is made to recover the sand or to arrest the dust.

Fig. 143—Dust Hood without Respirator.

In selecting the location of the Sand Blast Department, it is always well to place it so that castings may go to it and be removed with the least delay. It is necessary to the saving of time that all unnecessary motions be eliminated.

It is well to remark here that the operator should not at any time kink or bend the hose in order to shut off the sand. This not only destroys the hose very quickly and causes the sand to pack, but causes a decided loss in power. When sand blasting operation ceases, it is desirable that no sand under pressure remain in the hose and for that reason the shut-off valve is placed at the inlet end of the hose. The perpetration of pranks with the sand blast should not be permitted as it is dangerous.

Another method quite often resorted to involves the construction of a special room, or small building, of either metal or wood, and devoted solely to sand blasting operations. In such instances it is not usually the case that all refinements are embodied, such as sand conveying system, mechanical ventilation, etc. This represents a step in the right direction, but the author ventures the opinion that the 'home-built' sand blast room, generally lacking in certain conveniences, usually costs its builder as much or very nearly as much in the initial outlay as the carefully planned special rooms, supplied by manufacturers, having all conveniences. It is obvious that the greater convenience afforded by the latter is bound to result in a superior product and a saving in the cost for doing the work.

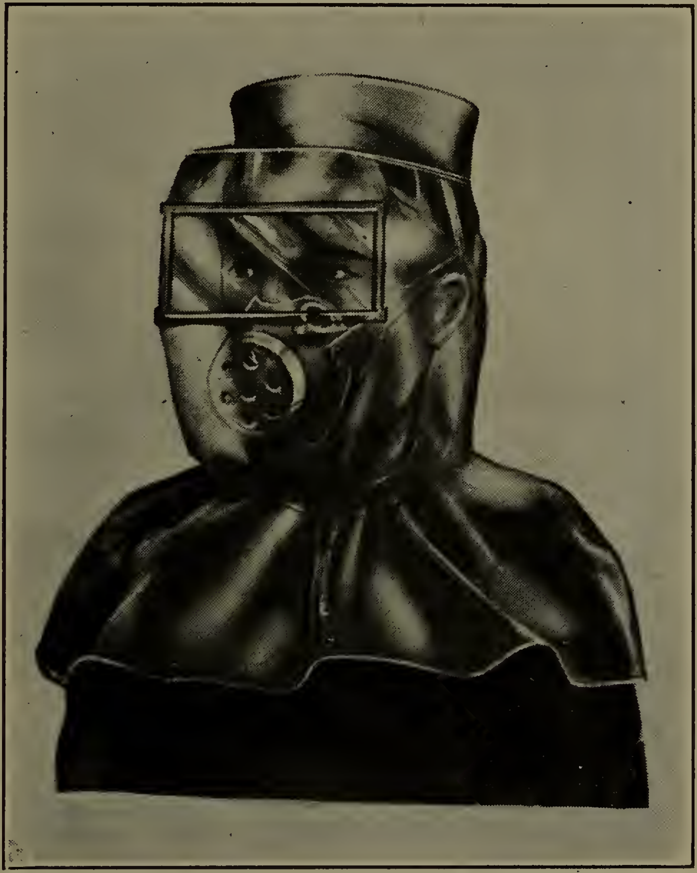


Fig. 143-A—Dust Hood with Respirator.

A typical sand blast room as supplied by the sand blast equipment manufacturer is shown in Fig. 145.

In this room the sand is blown through the grated floor to the elevator boot in the bottom of the pit. From the pit it is raised to a sand separating machine, which at one operation removes all large particles that would clog the nozzles and the fine dust and disintegrated sand which have no abrasive value, delivering them to a waste bin.

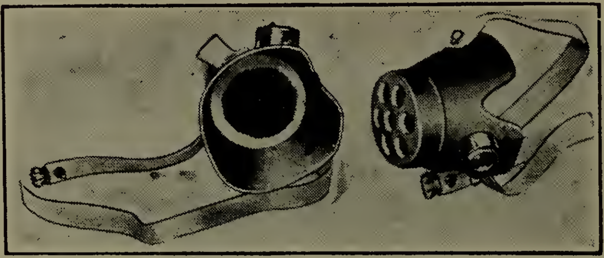


Fig. 144—Respirator.

Fig. 145—Sand Blast Room.

The usable material is delivered to a storage bin located overhead.

The dust-laden air is drawn downward away from the work and the operator's head, through the grated floor by means of suction pipes beneath, from where it is carried to the dust arrester, all dust removed, and the cleaned air again introduced into the room through the ceiling.

The air being used over and over again constant temperature is assured as well as dry air.

Still another type of room is shown in Fig. 146. In this room the handling of the sand and dust is automatic. The sand blast machine is submerged below a grated floor through which the sand falls into a chute or hopper feeding the sand blast machine by gravity.

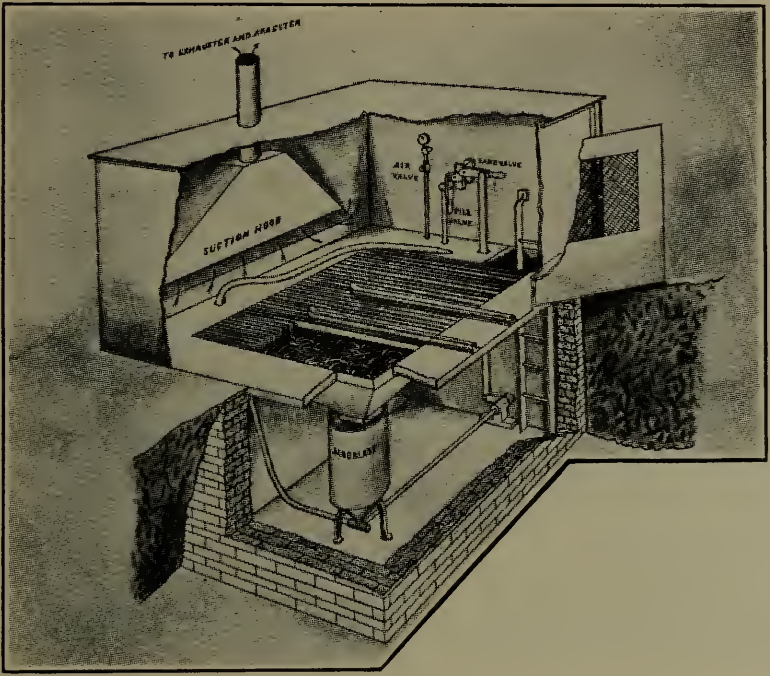


Fig. 146—Sand Blast Room with Gravity Feed to Machine

Ventilation is secured through a suction hood extending across one end of the room.

Fig. 147

RECORDS OF PERFORMANCE. Fig 147 shows a large cylinder casting with a number of cored spaces placed on a car ready for cleaning by the sand blast. Fig. 147A shows this same casting after cleaning. Time required, 50 minutes.

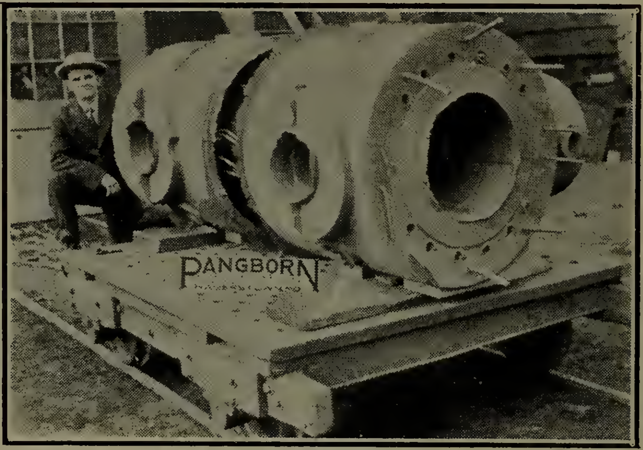


Fig. 147-A

In Figs. 148 and 148A is shown a large cast-iron annealing box before and after cleaning by the sand blast. The time previously required for cleaning this casting by hand was 30 hours; by air, 4 hours.

Fig. 148

Some idea of the saving effected by the sand blast in cleaning castings may be gained when it is understood that the company casting annealing boxes was able to reduce the cleaning force from 19 to 9 men.

Fig. 148-A

Fig. 149

Fig. 149 shows a number of gas engine cylinders. Time required by the sand blast, 30 minutes; old methods required 4 hours. This is a particularly difficult job, as the castings are intricate and small, and require careful cleaning both inside and out.

Fig. 150 shows a steel ingot mold before and after cleaning.

In the Open Hearth Steel Foundry of the Prime Steel Company the cost for cleaning with the sand blast per ton of good castings produced, for a period of 4 months, was 50 cents. The wage paid the head sand blast man is 30 cents per ton for all metal charged into the furnace. About 1,500 pounds of sand blast sand is used per day.

Fig. 150

The following items, given at random, on various lines of work, will show the comparative time and labor required to clean castings by hand, brushing and tumbling, as compared with sand blasting. The difference in the character and quality of the work, in favor of the sand blast, is as great as in the time and labor saved.

These are actual accomplishments and no mere statements:

	TIME REQUIRED			
	Hand cleaned		H.P. Sand Blast	
	Hr.	Min.	Hr.	Min.
Mower frames, weight 75 lbs. 12-in. cores, 2 to 2½-in. diam., 3 pieces	1	30		9
Mower wheel, 28-in. diam., 7 arms, ratchet gear cast on one hub, wgt. 30 lbs., 3 pieces	1			6
50 x 60-in. pulley-weight 3,800 lbs.	10		1	
Spur gear, 6-in., 34 teeth, ¼-in. pitch, 98 pieces				27
Oval blades, cored work, wgt. 5 lbs., 16 pieces.	2			20
Aluminum gear, case, 10-in. diam., 16-in. long, 24 pieces	2			24
Safe base plate, Manganese Iron, 24 ins. high, 12 ins. across top, 24 ins. across base, wgt. 250 lbs., having 4 cores 4 x 6 ins.	2			4
Door frames for fire safes, one 24 x 36 ins., four 12 x 36 ins.	2	25		20
Miscellaneous gray iron castings, wgt. 600 lbs.	2			15
Boring mill head, weight 7,200 lbs., with 9 cores, ranging from 6 to 18 ins. diam.	15		1	
Steel gear, 5½-in. diam., 8 arms, 7-in. face, 1¾-in. pitch, wgt. 1,700 lbs.	2 days		2	
Air compressor cylinder, wgt. 3,500 lbs., water jacketed, 32 cores	6			22
Steel spur gear, 20-in., 1⅛-in. pitch	10		3	
Steel pipe cast, wgt. 910 lbs.	5			30
Annealing pit, 12-ft. outside length, 10-ft. inside length, 3-ft. inside depth, 4-ft. inside width, wgt. 12,000 lbs.	5 days		7	
Steel pinion, wgt. 3½ tons, pinion teeth set in V shape	25		6	
Printing press casting, wgt. 22 tons, combination cores and straight work, pieces weighing from 30 lbs. to 1 ton			10	

	Hand Hr.	Cleaned Min.	H.P. Sand Hr.	Blast Min.
Machine frame, wgt. 1 ton, 8 x 12 ft., combination cored and straight work	2			30
Plate wheels, with bevel gear cast on one side, wgt. 12 lbs., 4 pieces, formerly rumbled, after which the teeth required filing to assure bevel meshing into the pinion, filing alone required 10 mins. each piece				4
Journal Boxes, wgt. 60 lbs., 90 pieces, rumbling	2	16	1	30
Automobile castings, 868 pieces			2	30

Miscellaneous Uses for the Sand Blast. As stated in the opening paragraph the sand blast may be used for other work than that of cleaning castings. As the process involved is very much akin to that of cleaning castings, the actual use will only be touched upon here.

Sand blasting forgings in place of pickling to remove the scale has decided advantages.

It does away with shop fumes and the bother of the pickling department. Pickled forgings must be washed to neutralize the pickling acid remaining on the forgings.

Quite often the washing is done carelessly and the result is that when machining is done the acid quickly destroys the edge of the cutting tool and a lot of time is wasted. If the forgings are not used immediately, they rust very quickly, due to the acid.

Above all, the sand blast is quicker and does a better job.

Structural steel and iron work is usually best cleaned of rust, scale, grease, etc., by the sand blast, and it has been found that the paint on sand blasted structural steel work wears so much longer that it represents an ultimate reduction in the cost for painting, and in addition the work is more attractive. The sand blast is a decidedly quicker method than that of scraping or hammering.

Structural steel, subject to corrosion from sulphurous gases, is best cleaned by the sand blast, as it is able to penetrate the smallest crevices, both inside latticed columns over all surfaces, girders, stringers, caps and base plates.

Workers in silver, brass and aluminum, as well as manufacturers of hardware of various kinds, desiring to give a frosted or matted finish to the work can employ the sand blast advantageously.

Metal ware, such as bath tubs, sinks and kitchen utensils are better prepared for enameling by the use of the sand blast.

One of the most profitable applications of the sand blast is in the cleaning of metal joints for brazing or welding, both before and after welding.

Automobile bodies and similar items of manufacture are commonly prepared for painting, enameling and varnishing by the sand blast.

TABLE XLIII

HOSE SAND BLAST MACHINES

No.	Sand Capacity Lbs.	Erected Dimensions Ins.	Weight Net	Lbs. Shipping
1	1,000	24 x 33 x 58	650	800
2	2,000	30 x 39 x 68	1,000	1,200
3	3,000	36 x 49 x 70	1,200	1,400
4	4,000	40 x 51 x 72	1,350	1,550
* 5	4,000	40 x 51 x 72	1,425	1,750
6	6,000	48 x 59 x 78	1,650	2,000
* 7	6,000	48 x 59 x 78	1,800	2,150

* Sizes 5 and 7 are equipped with two nozzles for two-man operation.

XLIV

AIR SEPARATORS

Size No.	DIMENSIONS IN INCHES			
	A	B	C	D
1	6	28	1	1
2	8	30	1½	1½
3	10	36	1½	1½
4	10	38	1½	1½
5	10	40	1½	1½
6	12	42	2	2
7	14	44	2	2
8	14	60	3	3

TABLE XLV
SAND BLAST BARRELS

No.	No. of Nozzles	Diam. of Barrel Ins.	Length of Barrel Ins.	R. P. M. of Barrel	H. P. Required by Barrel	Wgt.	Cu. Ft. Air Used
1	1	24	30	2½	1¼	3,200	See Table on page 167 for Air Consumption with various size Nozzles and multiply by number of Nozzles.
2	1	30	30	2½	1½	4,100	
3	2	36	36	2½	2	5,100	
4	3	30	36	1½	2	3,500	
5	4	42	48	1½	3	8,000	
6	5	54	60	1½	5	10,500	

TABLE XLVI
ROTATING SAND BLAST TABLE MACHINES

No.	Diameter of Table Ft.	No. Nozzles	H. P. Required to Drive Table	Approximate Weights Lbs.
1	6	2	1	5,000
2	7	3	1¼	6,000
3	8	3	1½	7,000
4	10	4	2	9,000
5	12	4	2½	11,000

TABLE XLVII
SAND SEPARATORS

No.	Type	OVER-ALL DIMENSIONS			Weight Lbs.	Approx. Air Consumption Cu. Ft. per Min. at 80 Lbs.
		Length Ins.	Width Ins.	Height Ins.		
1	Tripod-Portable	64	30	40	150	25
1-A	Post-Stationary	28	28	34	90	25
2	Floor-Stationary	61	36	40½	450	35

NOTE—Screens of varying mesh can be used.

TABLE XLVIII
SAND DRIERS

No.	Height Over All Ins.	Height Floor to Top Fire Box	Diameter of Hopper at Top Ins.	Diameter of Hopper at Bottom Ins.	Diameter of Base Ins.	Weight Lbs.
1	47	20	37	29	24	800
2	48	18	48	37	30	1,400

TABLE XLIX

DUST EXHAUSTING SYSTEM SHOWN IN FIG. 139

SIZES FOR NUMBERS 1, 2, 3 AND 4 SAND BLAST

Size	Shell Diameter Ins.	Cu. Ft. Per Min.	PULLEY		Speed	Brake H. P.
			Diameter Ins.	Face Ins.		
OPERATING ONE BARREL						
2	17	649	3	2½	3,070	0.71
OPERATING TWO BARRELS						
4	25	1,590	6	4	2,030	1.74
OPERATING THREE BARRELS						
5	31	2,375	7	4½	1,655	2.5

SIZES FOR NUMBER 5 SAND BLAST

OPERATING ONE BARREL						
4	25	1,590	6	4	2,030	1.74
OPERATING TWO BARRELS						
5	31	2,375	7	4½	1,655	2.5
OPERATING THREE BARRELS						
6	37	3,380	8	5½	1,400	3.69

SIZES FOR NUMBER 6 SAND BLAST

OPERATING ONE BARREL						
5	31	2,375	7	4½	1,655	2.5
OPERATING TWO BARRELS						
6	37	3,380	8	5½	1,400	3.69
OPERATING THREE BARRELS						
8	51	5,820	10	7½	1.065	6.35

TABLE L

DUST EXHAUSTING AND ARRESTING SYSTEM ILLUSTRATED IN FIG. 140

BARREL SIZES	EXHAUSTER			ARRESTER		
	Size No.	Dimensions		Size No.	Dimensions	
		E Ins.	F Ins.		G Ins.	H Ins.
Numbers 1, 2, 3 and 4 Barrels						
For one barrel	2	6	17	51	48	64
For two barrels	4	9	21	52	60	82
For three barrels	5	11	31	53	66	90
Number 5 Barrel						
For one barrel	4	9	25	52	60	82
For two barrels	5	11	31	53	66	90
For three barrels	6	13	37	54	78	107
Number 6 Barrel						
For one barrel	5	11	31	53	66	90
For two barrels	6	13	37	54	78	107
For three barrels	8	17	51	55	94	127

TABLE LI

DUST EXHAUSTING AND ARRESTING SYSTEM SHOWN IN FIG. 141

BARREL SIZES	EXHAUSTER			ARRESTER			
	Size Number	Dimensions		Size Number	Dimensions		Width Ins.
		E Ins.	F Ins.		G Ins.	H Ins.	
Numbers 1, 2, 3 and 4 Barrels							
For one Barrel	2	6	17	51	68	96	60
For two Barrels	4	9	21	52	108	102	78
For three Barrels	5	11	31	53	120	126	78
Number 5 Barrel							
For one Barrel	4	9	52	25	108	102	78
For two Barrels	5	11	53	31	120	126	78
For three Barrels	6	13	54	37	88	144	96
Number 6 Barrel							
For one Barrel	5	11	53	31	120	126	78
For two Barrels	6	13	54	37	88	144	96
For three Barrels	8	17	55	51	140	144	96

CHAPTER XI

COMPRESSED AIR USES IN THE MACHINE SHOP

The machine shop is perhaps one of the most fertile fields for the application of compressed air power. The opening up of new avenues for its application and the creation of new appliances is almost an unending daily occurrence.

Beginning with the air hoist which plays a conspicuous part as a time and labor saver, and on through the standard manufactured line of pneumatic devices, there is scarcely one that does not find its particular niche in the machine shop.

The past few years especially have witnessed a marked advance in the economical application of compressed air. Compressed air has never enjoyed a reputation for economy—that is, mechanical economy as distinguished from commercial economy. That it is being so widely used is due almost entirely to the fact that no other power medium would accomplish the same results. If, for instance, electricity could have been applied to the operation of chipping hammers, and other tools for which compressed air is used, there might have been a marked saving in the operating cost. But, owing to the mechanical difficulties, electricity cannot be successfully applied to work of this kind and compressed air, consequently, remains the motive power par excellence of the many portable labor-saving tools in the machine shop.

AIR HOISTS. The air hoist is undoubtedly a more efficient and economical helper for the machine hand than manual help, which in most shops requires an order from the foreman and therefore entails a great loss in non-productive time. How often have you seen several men tugging and straining to place a piece of work by hand for a machine tool, with the attending danger of injury and the stoppage of other work for perhaps ten to twenty minutes while 'lending a hand'. All of these annoyances and the most of the expense may be and is overcome in a great many shops by putting air lifts over all lathes above 20 inches swing and over all planers, shapers, drilling machines and drill presses, working on pieces too heavy for one man to lift.

The air hoist is so quick and satisfactory in its action as to preclude the necessity for any comparison with chain blocks or chain rigs.

A cheap form of air lift is the cylinder type, already described in Chapter VI, suspended from a trolley traveling on a swinging arm, the cylinder being about four feet long, and for all lathes below 36 inches swing or planers 30 x 30 it need not be more than 6 inches in diameter and yet lift 2,000 lbs. with an air pressure of 80 lbs.

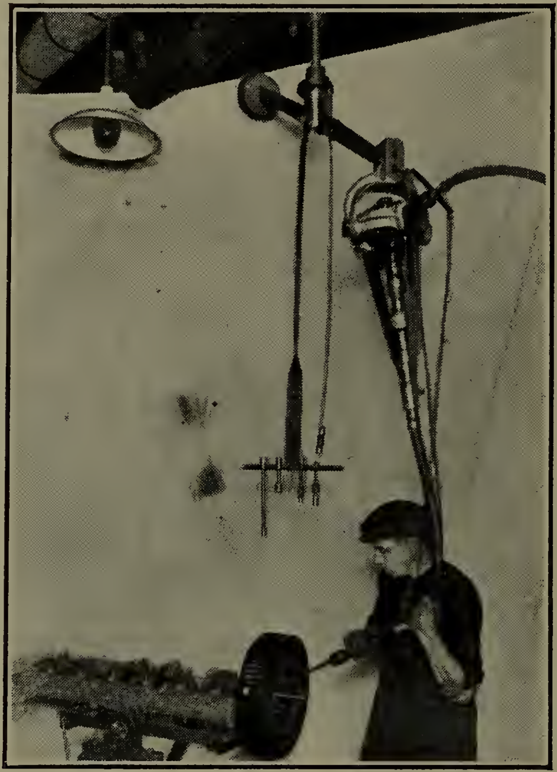


Fig. 151—Utilizing a pneumatic drill for assembling motor fly-wheel to crank shaft flange.

The motor type of hoist is the most desirable for all lifts where the lifts are of extended heights or when the head-room is small.

Chucks, face plates and steady rests can be lifted from the floor and placed in position by the aid of the air hoist in less time than by hand, and work can be lifted and placed against the face plate or in the chuck with more satisfaction and in less time than by any manner of 'blocking up' in vogue with the helper system.

Pneumatic Drill. The pneumatic drill is of special value in the machine shop for all classes of reaming, tapping and drilling where the work cannot be conveniently carried to the drill press, and for all classes of breast drill work. These machines are also frequently resorted to for operating special boring bars, and in emergency cases for independent drive of a machine tool, where the horse power required is within its capacity.

Nearly all shops have more or less affixing of name plates to completed machines. These require the drilling and tapping of holes in the machine. For this class of work the type of machine shown in Fig. 64 is particularly adapted.

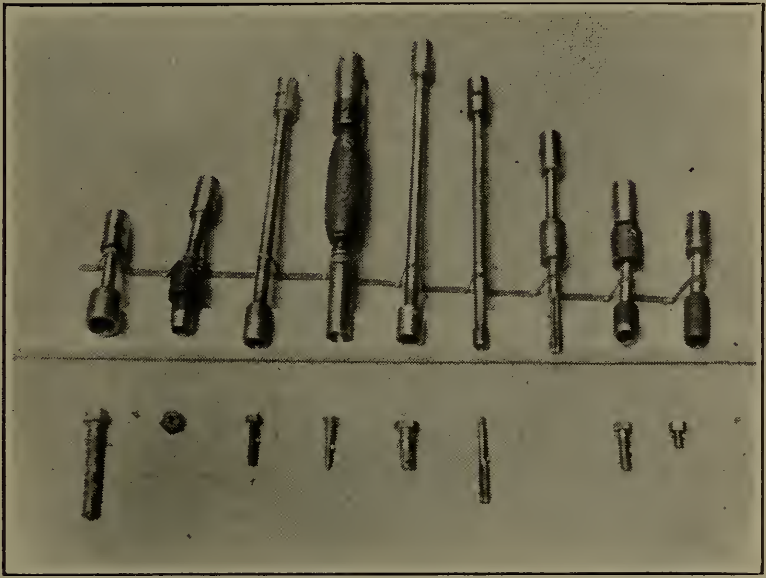


Fig. 152

A noteworthy example of the great saving in time and labor, also the convenience in operating a pneumatic drill, was the drilling and tapping of 16 half-inch holes on a convex surface of a large cylinder. The size of the cylinder and the location of the holes made it very inconvenient to do the work under a drill press. These sixteen holes were drilled and tapped with a pneumatic breast drill, pieces to be bolted on were applied and cap screws screwed down tight in a total time of 45 minutes.

In driving in cylinder head and steam chest studs of 7/8 inches diameter a distance of 1 5/16 inches it required but 15 seconds per stud. Compare this performance with hand work.

In the shops of the H. H. Franklin Manufacturing Company, Syracuse, N. Y., the pneumatic drill is applied to a number of uses to facilitate and quicken production, reduce cost and lighten the labor for the operator.

This company manufactures automobiles. Automobiles are notorious for the great many screws, nuts, studs, etc., employed in their assembly. These screws and studs, mean drilling, tapping and reaming of holes. Mr. George D. Babcock, Production Manager, in the search for means to quicken assembly and production, evolved the practices which are herein described, employing for the purpose standard manufactured pneumatic drills.

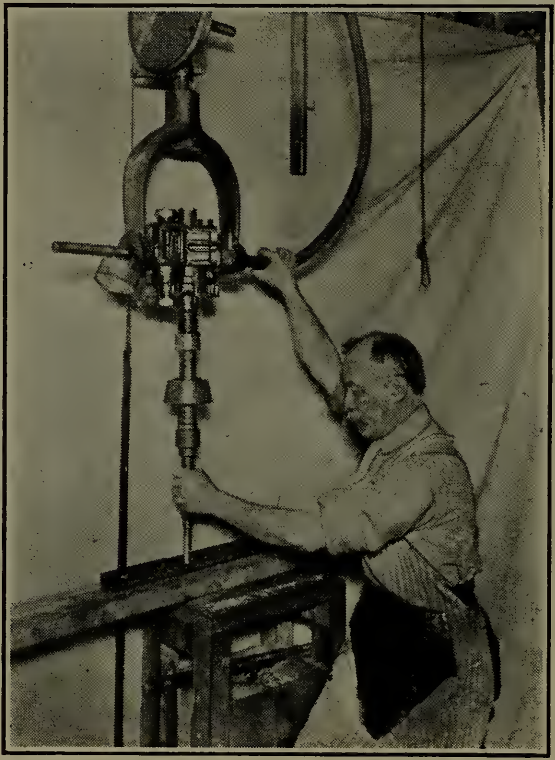


Fig. 153

Fig. 151 depicts the process of assembling the motor fly-wheel to the flange of the crank shaft. Large bolts, with slotted heads make the joint. This is a screw-driver job.

In applying the pneumatic drill to this work, it was suspended overhead in a gimbal which allows the tool to tip freely in any direction, the gimbal being attached to the end of a lever which is weighted at the other end to balance the entire apparatus.

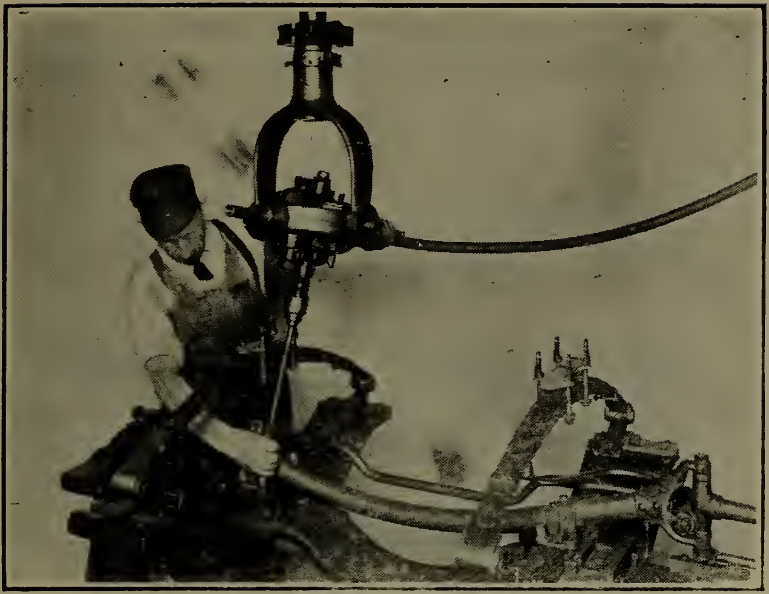


Fig. 154

The fork in which the balancing lever is fulcrumed extends down from a small traveling trolley. The spindle of the pneumatic drill is extended by means of a flexible shaft which carries the special socket for the various tools. To guard against overtightening of the screw or bolt a friction clutch has been introduced

Fig. 155—A special pneumatic device for clipping off bolt ends.

between the machine and flexible shaft, so that when the right tension of the screw or bolt is attained, it will instantly allow the shaft to stop.

Two light straps lead from the operator's hands to the ends of the cross-lever for operating the controlling air valve. A rack has also been provided for conveniently carrying the auxiliary sockets required for this particular job.

Fig. 156

In Fig. 152 are shown a variety of special sockets and the several pieces for which each is adapted.

Fig. 153 shows the pneumatic drill for driving home wood screws.

Fig. 154 shows the operation of driving on front axle spring clip nuts.

In Fig. 155 is shown a compressed air operated, compound lever device for clipping off the projecting ends of bolts.

Fig. 156 shows the operation of running down nuts in assembling cylinder half of crank case to main half.

The savings effected by some of these special compressed air applications are stated to be as follows:

1. Driving front axle spring clip nuts as compared with hand wrench, 56%.
2. All engine studs, screws and nuts, 71%.
3. Rear axle tubes to rear axle gear case, 41%.
4. Transmission studs and screws, 68%.
5. Steel angle iron wood screws and other wood screwing on the sill, 75%.
6. Bolt clipping, 56%.

One of the tools of the pneumatic drill family, the grinder and buffer, can be used to good advantage and save both time and labor for polishing side and main rods and other work of a similar nature.

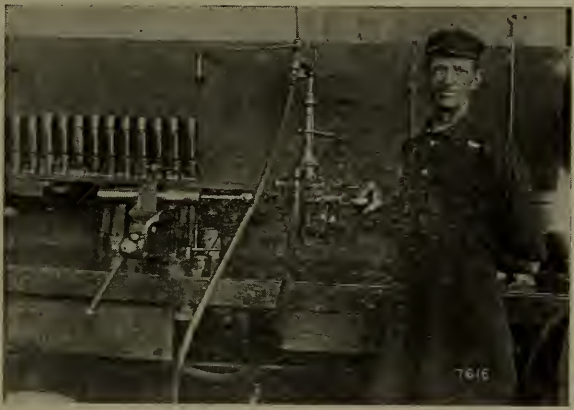


Fig. 157—A pneumatic drill rigged in a swing for lapping cylinders.

It is apparent from the foregoing that the pneumatic drill lends itself readily to rigging up for special applications.

Fig. 157 shows it rigged up in a swing for lapping small cylinders.

Fig. 158 shows a pneumatic drill used for seating studs in cylinders in a large pump factory. Swinging wall arms have been provided as shown in Fig. 159 from which the tool is suspended and counterweighted and the drill is moved from arm to arm as may be required.

Fig. 160 shows a drill rigged up as a motor to operate a circular saw for cutting belt slots through floors, making floor repairs, and also for machine boxing purposes.

Fig. 161 shows a drill being used for recentering shafts, which have been roughed out and cut off to approximate lengths and are ready for the final turning and grinding. The universal lathe chuck is connected by three rods which serve as guides for the drill, with a casting at the back through which the feed screw passes. The drill chuck fits a central bushing in the large chuck, insuring accurate centering. The chuck is quickly secured on the end of the work by the usual socket chuck-wrench.

Fig. 158—Pneumatic drill applied to seating cylinder studs.

Fig. 159—Assembly Department of a large pump works. Swinging wall arms have been provided for suspending pneumatic stud seating tools and other pneumatic devices.

Fig. 160—Pneumatic drill rigged as a portable saw for cutting belt slots, repairing floors, etc.

The operator controls the air with one hand by the throttle handle shown while turning the feed wheel with the other.

Fig. 162 shows a drill being used as a motor for operating a portable boring bar.

Fig. 161—Recentering shafts with a pneumatic drill.

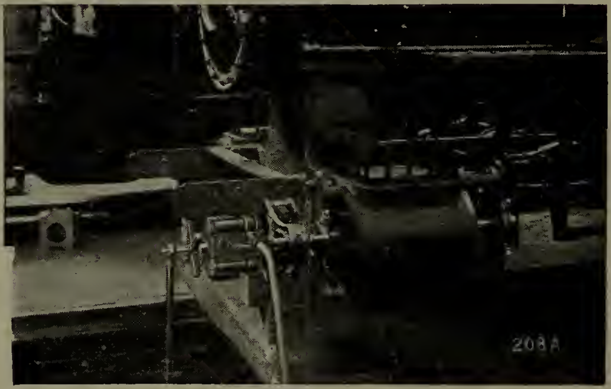


Fig. 162—Pneumatic drill employed with a special jig for reboring cylinders.

Fig. 163 illustrates the use of portable pneumatic drills on the assembly floor.

Fig. 164 applying the pneumatic drill to otherwise inaccessible work.

Fig. 165. The pneumatic drill on this class of work eliminates special jigs required with the regular drill press.

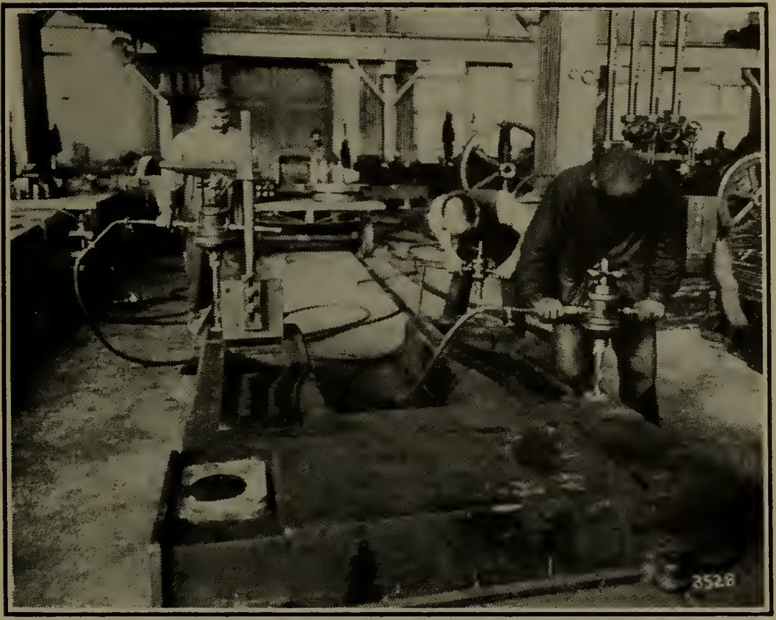


Fig. 163—Drilling a bed-plate on the assembly floor.

Chipping Hammers. The pneumatic chipping hammer, for chipping and calking, is employed profitably in a great many shops.

One particular application is the chipping of oil grooves in cross-heads. In one case, requiring the cutting of two diagonal

Fig. 164—Drilling an otherwise inaccessible hole with a pneumatic drill.

grooves, 11 inches long on the curved shoe of the cross-head, the time required was only one minute and 15 seconds.

In chipping steam cylinder ports, smoothing down cast parts, trimming metal lagging, cutting out 'V's' in angles and many other uses, this tool has demonstrated its right to a place in the modern machine shop. In the manufacture of shrapnel, it has been rigged up for calking the base plates. See Fig. 166.

Turbine blade riveting is accurately and quickly performed in the shops of the Fore River Shipbuilding Corporation by means of a pneumatic hammer, as shown in Fig. 167.

Fig. 165—The pneumatic drill on automobile axle housing work.

Pneumatic Presses. Very convenient little presses can be rigged up for driving mandrels, pressing work and the like.

In Fig. 168 is shown a pneumatic broaching press designed and employed in a large western shop.

The broaching press is a home-made product of the shop using it. It is controlled by a valve, which controls the passage of oil, regulating it at will, and preventing surging action due to the elasticity of the air. Many different kinds of work are broached by this machine.

The piece to be broached is laid on the supporting collar at the top of the upright in the center, the point of the broach entered in the work and the ram brought down by admitting air pressure through the cylinder above.

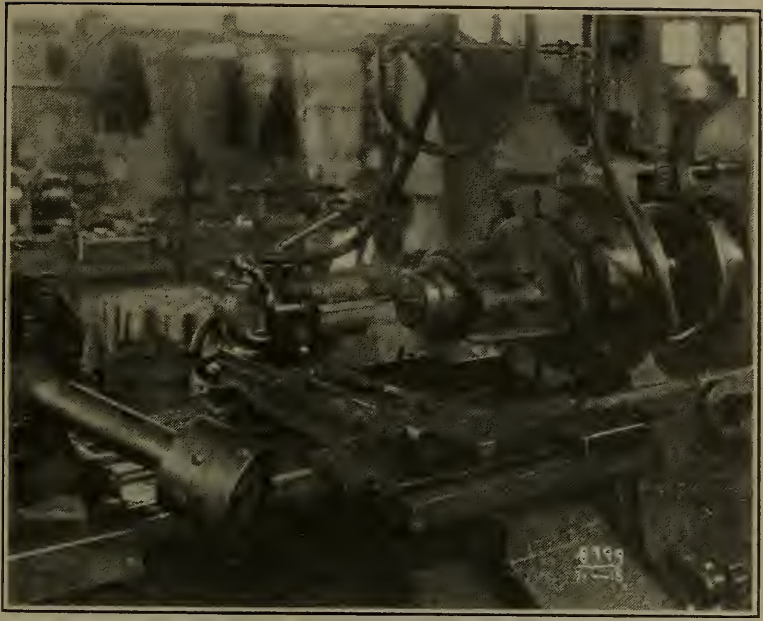


Fig. 166-A—Two methods of applying a pneumatic hammer to calking base plates in shrapnel.

The speed of the ram can be varied to suit the needs of the piece being broached. The broach is not fastened to the ram, but is simply forced through by it and dropped through the work onto a cushion.

Fig. 166-B—Two methods of applying a pneumatic hammer to calking base plates in shrapnel.

Fig. 169 shows a pneumatic device for lapping long cylinders, also a product of this shop.

This machine consists of two vertical rods or uprights, which carry both the work-supporting device and the lapping head, so that they can be adjusted to almost any position with relation to each other.

The work to be lapped is clamped in place at the bottom and the motor-driven lapping head is brought down so that the lap enters the work. The head carrying the lap is fed up and down so as to cover the length of the cylinder bore, at the same time the lap is being revolved by the motor. The feeding mechanism is controlled entirely by air through the valve shown at the side.

Fig. 167—A pneumatic hammer riveting turbine blades in place.

Chucking Work by Air. This application of compressed air promises to become a wide-spread one in modern machine shop practice, as a result of the saving it effects in the operation of chucking work.

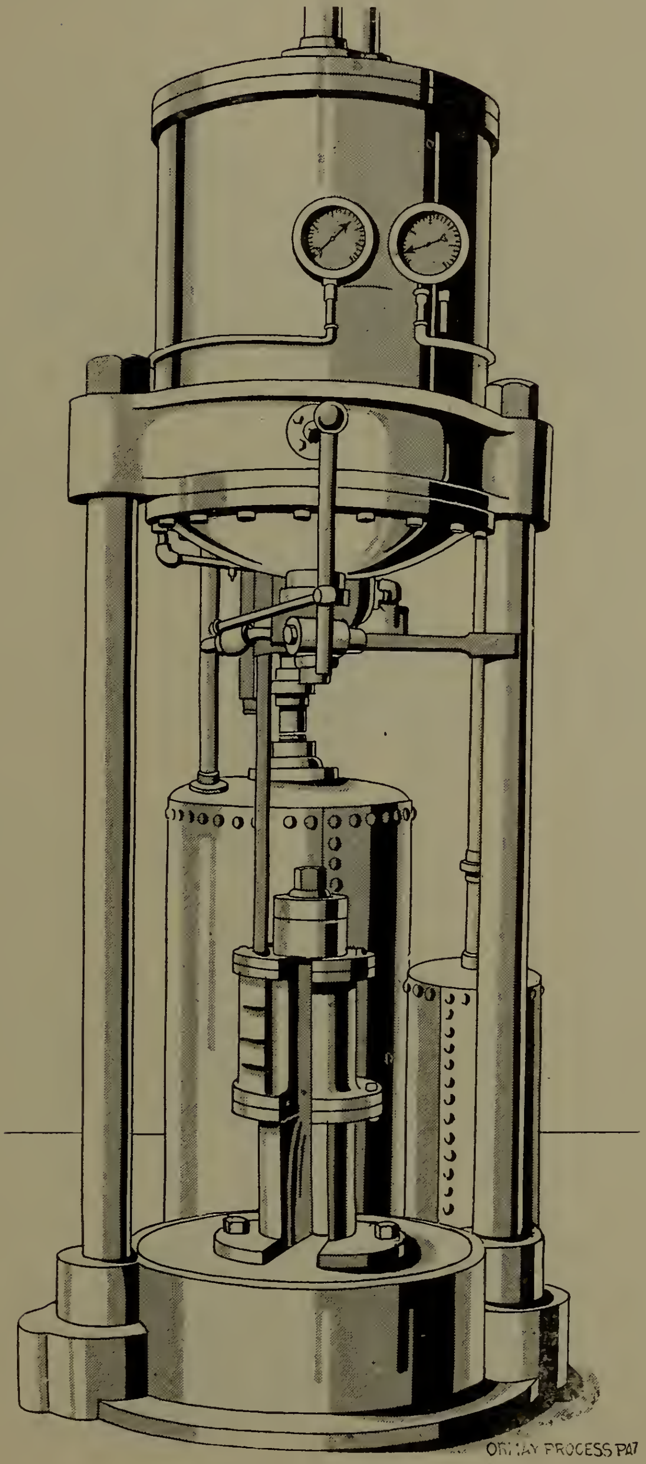


Fig. 168—A home-built hydro-pneumatic broaching press.

Most shops already have compressed air available. By using it for the operation of chucking, the workman is left free to apply all his energy in rapid production.

Compressed air is easy to regulate, almost instantaneous in its action, and at a pressure per square inch of anywhere from 60 to 100 pounds, provides a source of power fully adequate for the requirements of machine tools.

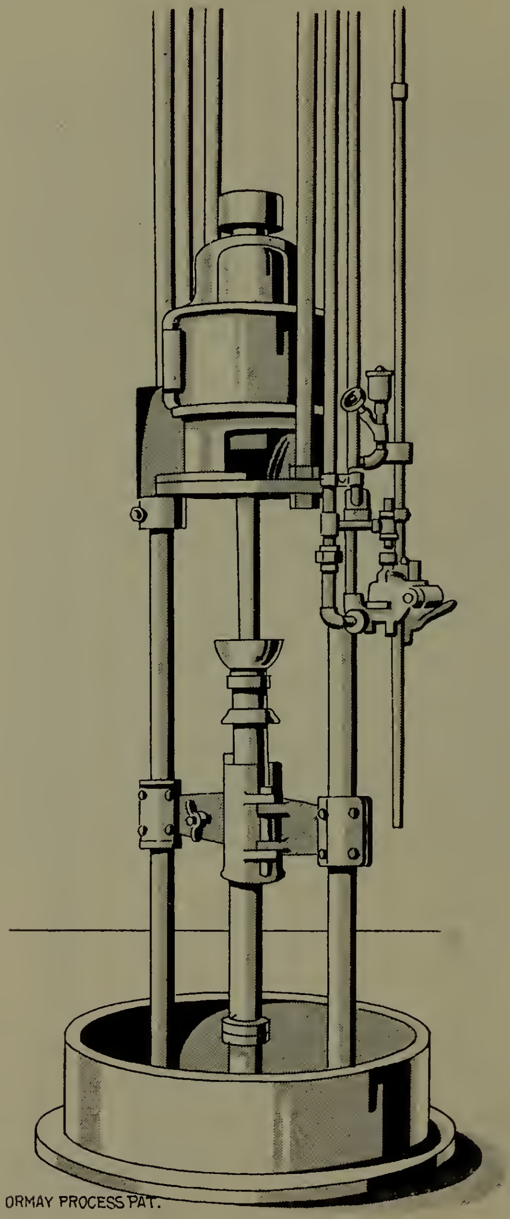


Fig. 169—A home-built electro-pneumatic lapping machine.

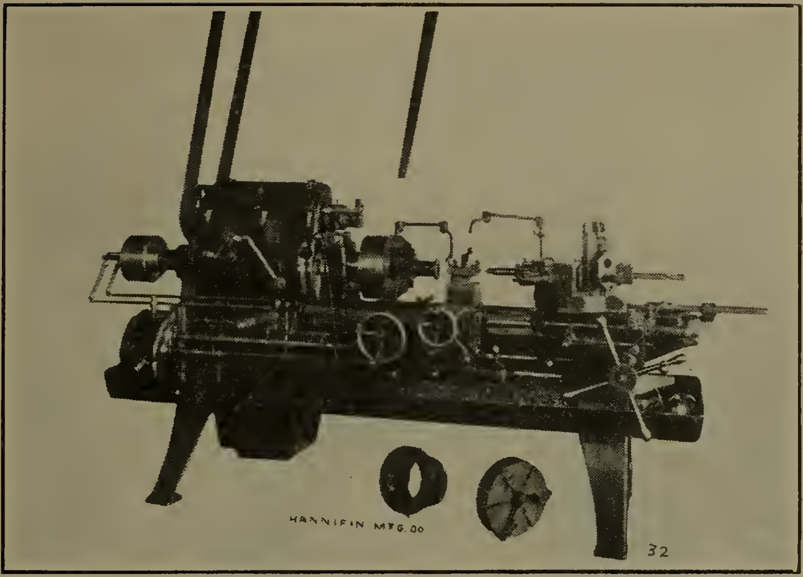


Fig. 170—A large turret lathe equipped with an air operated universal chuck.

In Fig. 170 is shown a large Turret Lathe equipped with an air operated universal chuck for large gear and bushing work. The chuck is operated by means of a cylinder shown at the ex-

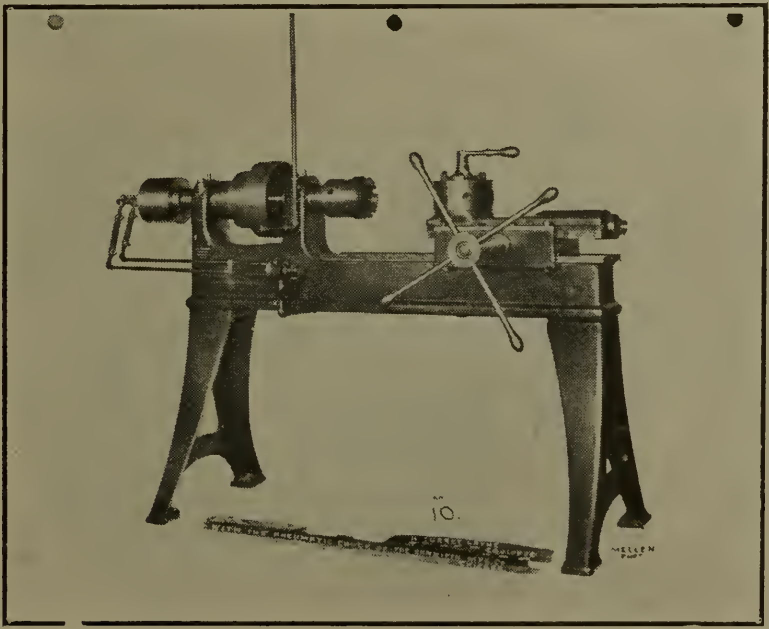


Fig. 171—A master hinge Collet chuck, air operated, applied to a small turret lathe.

treme left and under the control of the small lever shown just below the front of the speed change box.

These chucks are made in two- and three-jaw types.

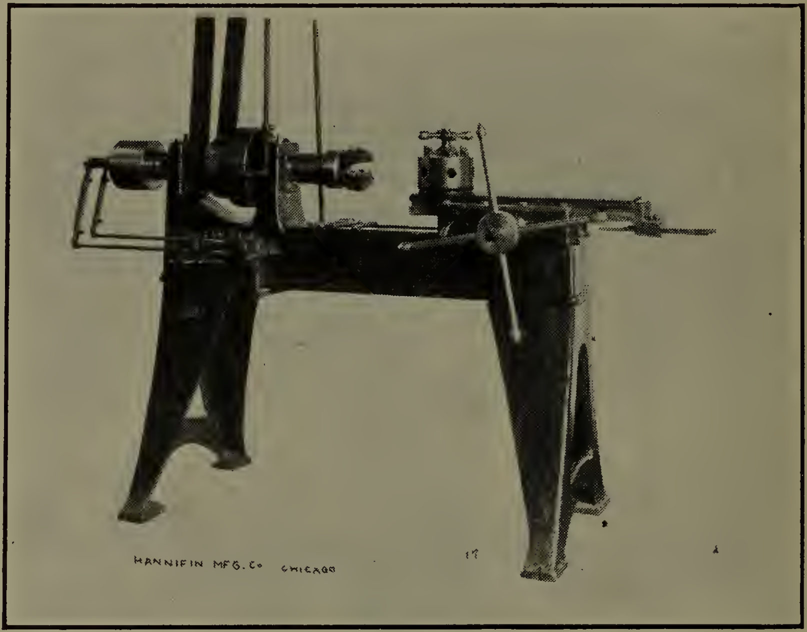


Fig. 172—An air operated alligator chuck applied to a small turret lathe.

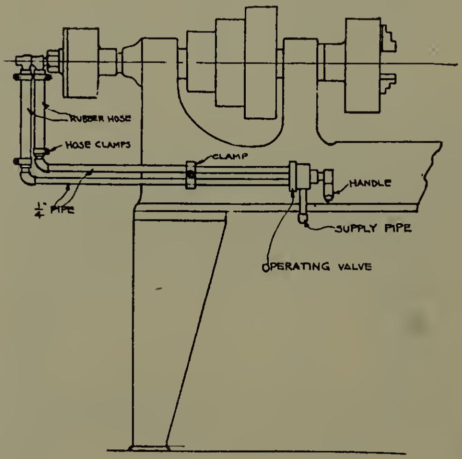


Fig. 173—Piping diagram for air chuck.

Fig. 171 shows an air operated Master Hinge Collet Chuck applied to a small Turret Lathe. They are furnished in three- and four-jaw types. These chucks are designed to hold round, square and hexagon work, such as valve bonnets, nuts, etc.

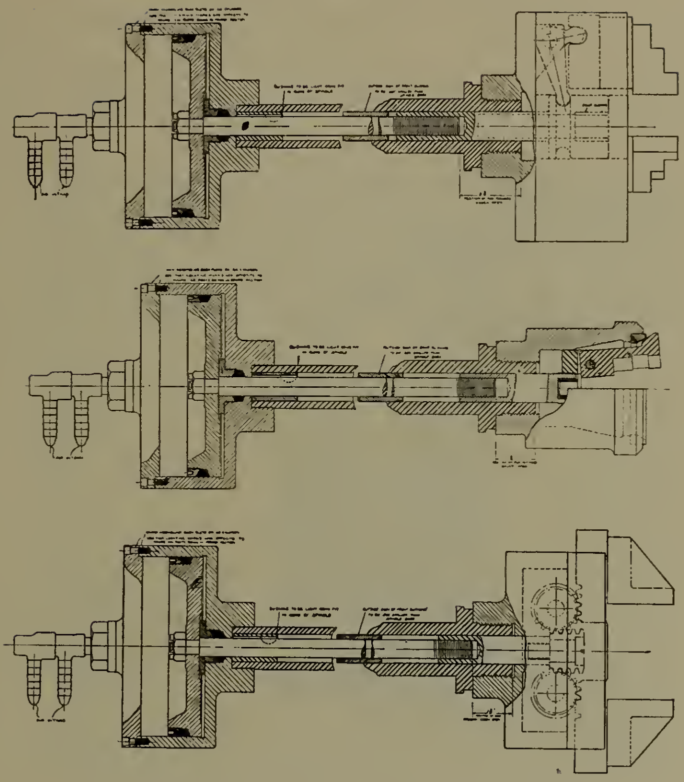


Fig. 174—Assemblies of three types of air chucks.

Fig. 172 shows a Turret Lathe equipped with an air operated Alligator Jaw Chuck. These chucks are intended for holding irregular-shaped work.

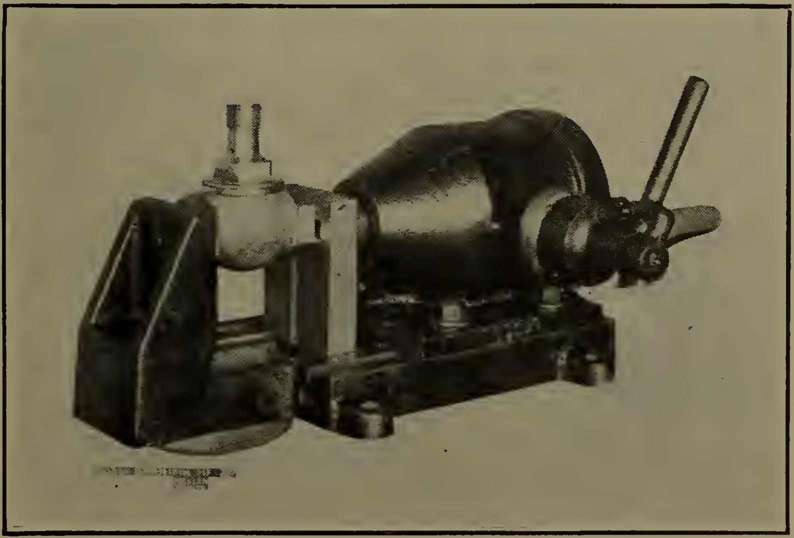


Fig. 175—Air operated vise.

In Fig. 173 is shown a general piping diagram of the air-operated chuck. Fig. 174 shows the general assembly of three types of chucks and their operating mechanisms.

Fig. 176—Air operated arbor press.

In addition, air operated chucks of the following types are rapidly coming into use: Releasing Chuck, Milling Machine Chuck, Gate Valve Seating Chuck. See Table LII.

In Fig. 175 is shown an air operated vise, designed for use in the assembling department, for use on drill presses, milling ma-

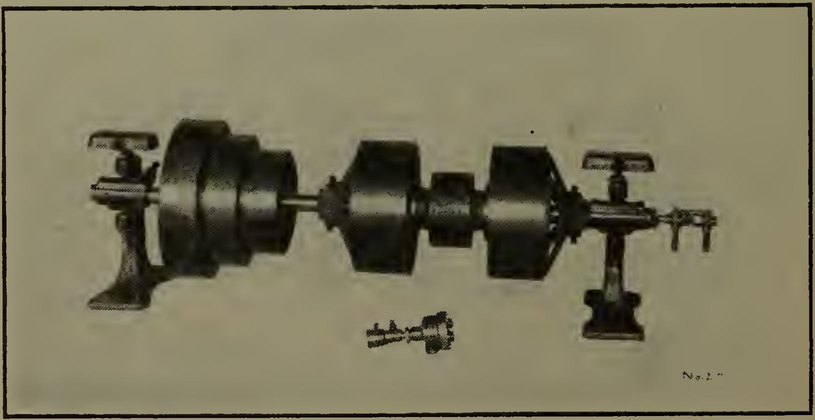


Fig. 177—Air operated countershaft.

chines and other places where a vise or chuck is used to hold work while being assembled or machined.

Fig. 176 depicts an air operated arbor press which eliminates the slow and tiresome operations of hand work.

Another use to which air is being put in the machine shop is the operation of countershafts. Fig. 177 shows such a countershaft. Its operation is controlled by two air cylinders under the control of a two-way air valve placed in convenient proximity for the operator.

TABLE LII

PNEUMATIC CHUCKS

No.	Capacity (Less False Jaws) Ins.	Length of Jaws Ins.	Largest Outside Diameter Ins.	Length of Chuck Ins.	Approximate Weight Lbs.
TWO-JAW UNIVERSAL PNEUMATIC CHUCKS					
1	2½	2½	7	7	38
2	4½	3½	9	8	55
3	7	4	12	8	80
THREE-JAW UNIVERSAL PNEUMATIC CHUCKS					
4	10	...	10	6	75
5	12	...	12	7	100
6	15	...	15	7	140
7	18	...	18	8	165
MASTER HINGE COLLET PNEUMATIC CHUCKS					
8	1¼	...	5½	4¾	10
9	2	...	5¾	6¼	24
10	3½	...	7¼	7⅛	40
11	5	...	8¾	8	55
ALLIGATOR PNEUMATIC CHUCKS					
12	1½	...	4	5½	10
13	2	...	5½	8¼	25
14	3	...	5¾	9½	40
15	5	...	7¼	10¾	55

CHAPTER XII

COMPRESSED AIR USES IN THE FORGE SHOP

A realization of the benefits to be derived from the uses of compressed air by the forge shop has been comparatively recent. While the slowest of all to take up its use, the forge shops bear the distinction of having pioneered in its use, due in part to the force of circumstances and partly to a search for some convenient power for the conduct of many operations peculiar to each line of manufacture and calling for the creation of home-built special apparatus.

One of the earliest efforts in the harnessing of compressed air to the needs of the forge shop is found in the conversion of steam forging hammers to pneumatic operation.

A typical example is that of the Buffalo Pitts Company, Buffalo, N. Y., one of the earliest shops to demonstrate the advantages of air operation for forging hammers. They made the change primarily because of the fact that the balance of the manufacturing plant was operating on electric current. For the operation of one big steam hammer, however, they were running a battery of high-pressure steam boilers. It was desirable that the hammer be electrified and as current could not be applied direct, the transmitting power agency, compressed air, was resorted to. A motor-driven compressor was installed, sufficiently large not only to operate this hammer, but many other pneumatic devices.

Another pioneer in this direction is the Nisqually-Russel Car and Locomotive Works of Tacoma, Wash. About five years ago (1912) the city boiler inspector condemned the boiler in this plant. It was chiefly used to furnish steam for the large hammer shown in Fig. 178. Instead of buying a new boiler the old one was converted into a vertical air receiver and a belted-to-motor compressor installed to furnish power to the hammer. In converting the steam hammer to compressed air operation the action of the inlet and exhaust valves was improved by giving them a slight taper.

In Fig. 179 is shown the compressor plant. It is stated that $50 a month is a liberal estimate for the power consumption of the compressor, whereas the fixed charges under the old system were $62.50 per month for the licensed fireman at $2.50 per day and $31.25 for 12½ tons of coal at $2.50 per ton, making a total of $93.75 or a saving in favor of air operation of $43.75 a month.

Fig. 178—Steam Forging Hammer converted to pneumatic operation.

In addition the air is used for operating other tools, therefore the saving is in reality greater than the figures show. On the above basis, however, the saving per year in this plant is $525. This company further stated that aside from the saving there is a decided advantage in the increased efficiency of the hammer, as they were only able to carry 90 pounds pressure on the boiler and they figured this gave them about 60 pounds working pressure at the hammer. The air, on the other hand, is practically at the same pressure at the hammer as in the receiver, and they got fully 90 pounds on the piston. It is further stated that "the air is quicker, and although not quite so elastic as the steam (?), is nevertheless very satisfactory."

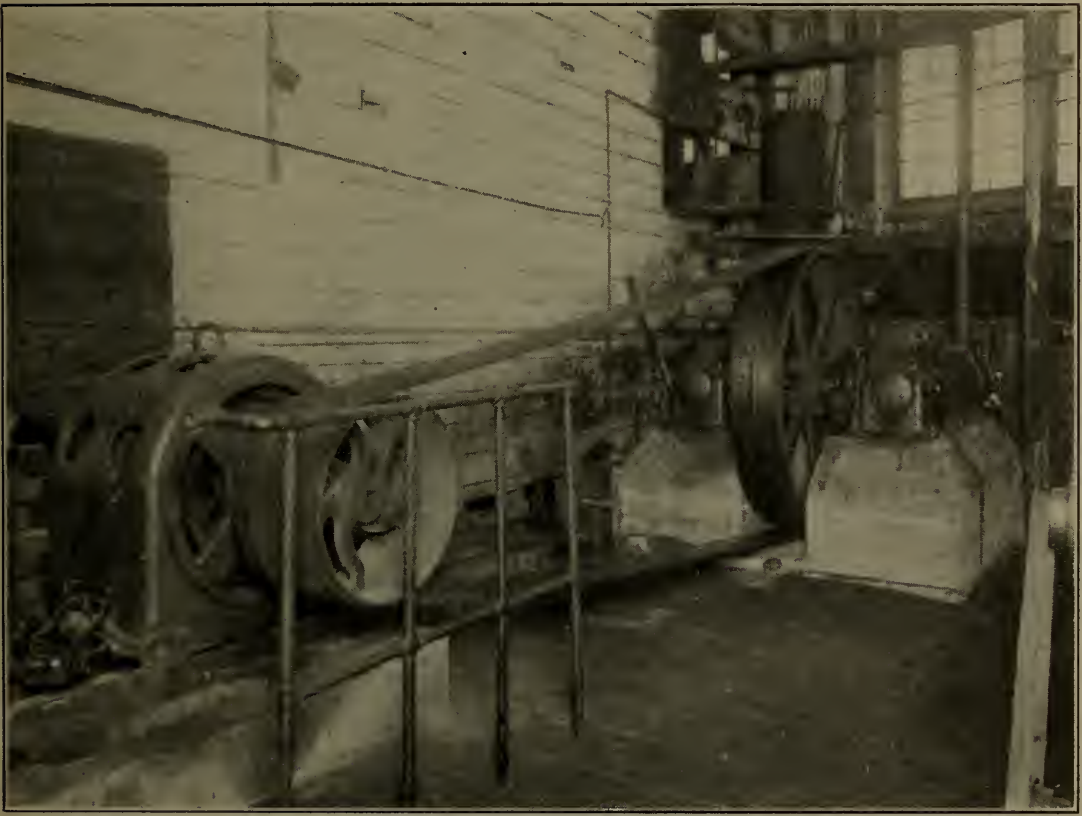


Fig. 179—The compressor plant for operating the forging hammer shown in Fig. 173.

A further saving might be claimed in the expense of handling the ashes which they had to cart away. In so far as the item of cost for boiler feed water is concerned, this is about offset by the consumption of the cooling jackets of the compressor.

In Fig. 180 is shown a pneumatic drop press designed for stamping sheet metal hot. Sizes range up to 46 x 72 inches, face of hammer. The power consumption ranges from 60 cubic feet of free air per minute for the smallest size, to 200 cubic feet for the largest at a pressure of 90 pounds.

Fig. 180A shows another pneumatic drop hammer. The design of this tool eliminates the board, friction rollers, gears, clutches and other such appurtenances which mark the ordinary steam drop hammer. Compressed air at a pressure of 60 to 100 pounds is required, striking a blow of between 250 and 350 pounds. The air consumption is but 3 cubic feet of free air per minute at 60 pounds pressure, or about 5 cubic feet at 100 pounds pressure.

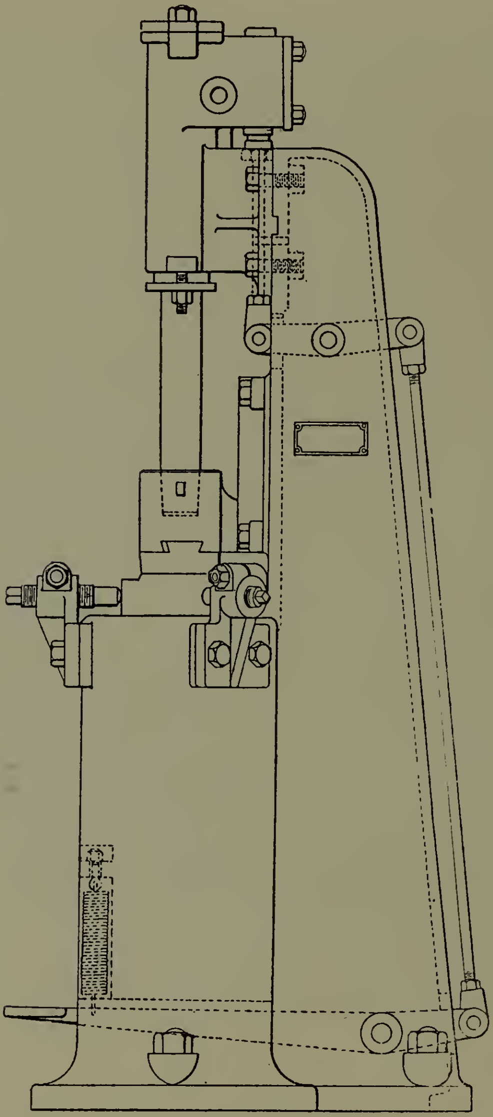


Fig. 180—A Pneumatic Drop Press

The Buffalo Foundry and Machine Company, of Buffalo, N. Y., are now supplying their Bell Hammers for compressed air operation. Fig. 181 shows a typical plant, consisting of the hammer, a receiver and short-belt motor-driven compressor, complete with necessary valves and gauges.

These hammers operate on pressure from 60 to 100 pounds per square inch.

It is claimed for these outfits great flexibility and the same sensitive control as obtained from steam hammers. The force, position and rapidity of the blow is under absolute control and can be varied instantly at the will of the operator.

Power is only used when work is actually being done and in forging the work is in direct proportion to the power being used. Maximum power is always available when the forging is at the highest temperature and, therefore, in the most plastic condition.

These hammers are built in a wide range of sizes and types for all kinds of shaping and forging work.

Figs. 182 and 183 show samples of work done on these hammers.

Air and Steam Operation Compared. Compressed air is lively and instantly available for use, so that there is no delay when starting up in the morning or any time it may be wanted.

Lubrication is simplified. When starting up the steam hammer it is usually cold and the steam condenses, the lubrication is partly washed out, and there is a lot of water dripping, so that you cannot put a forging under the hammer at once. If you do, the dripping water is likely to spatter and scald the operator. Nor can the forging always be left in the fire, waiting for the water to stop dripping, because it is liable to burn, and all this happens several times a day unless the hammer is in continuous use.

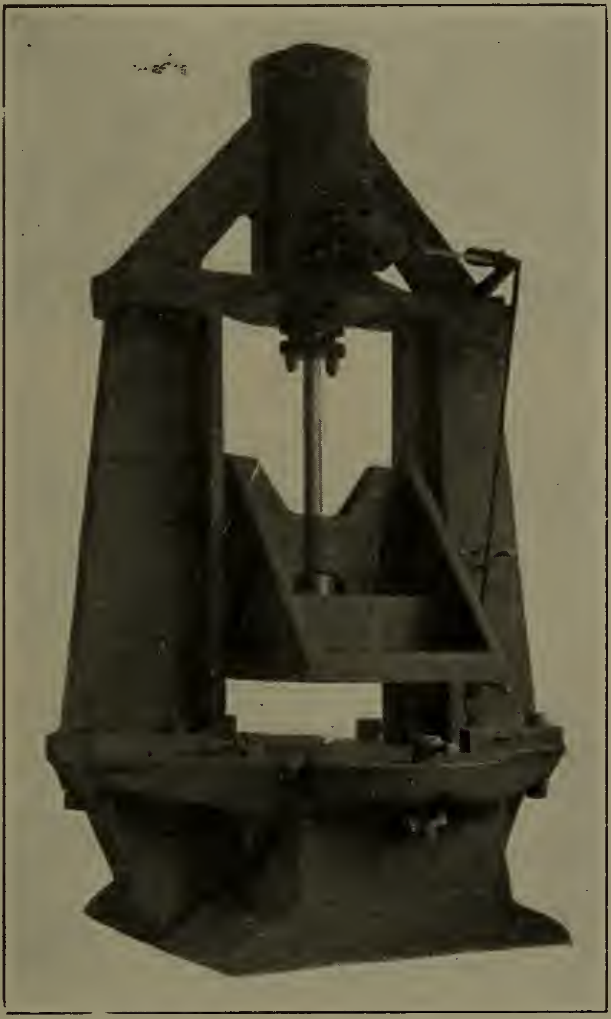


Fig. 180-A—A pneumatic drop hammer for forming work.

Aside from its application to forging hammers and the usual line of small portable pneumatic tools and hoists, the use of compressed air, in the forge shop, as already stated is to operate special devices often of home manufacture.

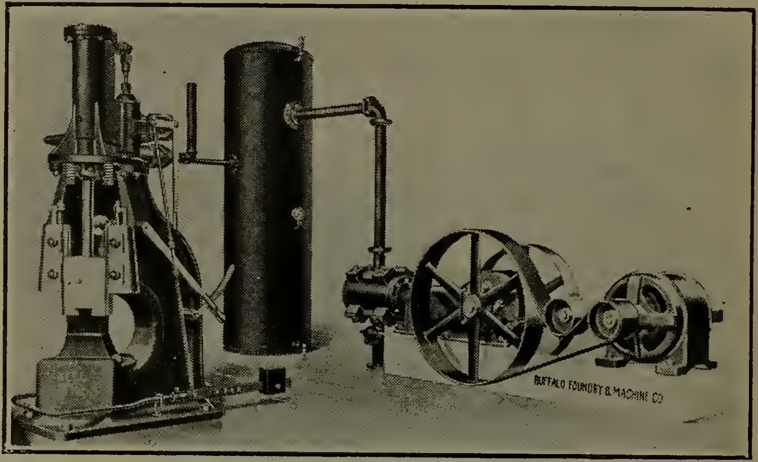


Fig. 181—A complete pneumatic Forging Plant.

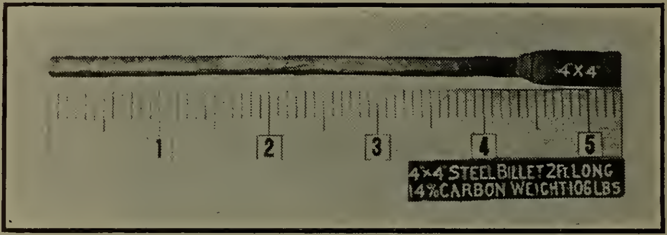


Fig. 182—Sample of pneumatic forge hammer work.

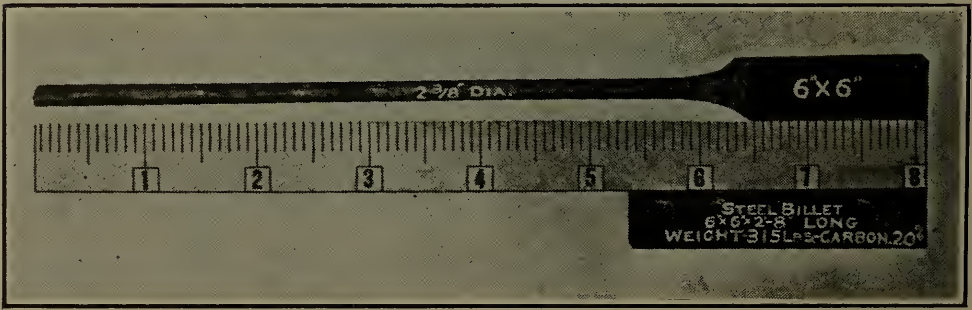


Fig. 183—Sample of pneumatic forge hammer work.

Fig. 184 shows a compressed air operated machine which has been manufactured for some years for the forging of bits and shanks on steel used for drilling rock.

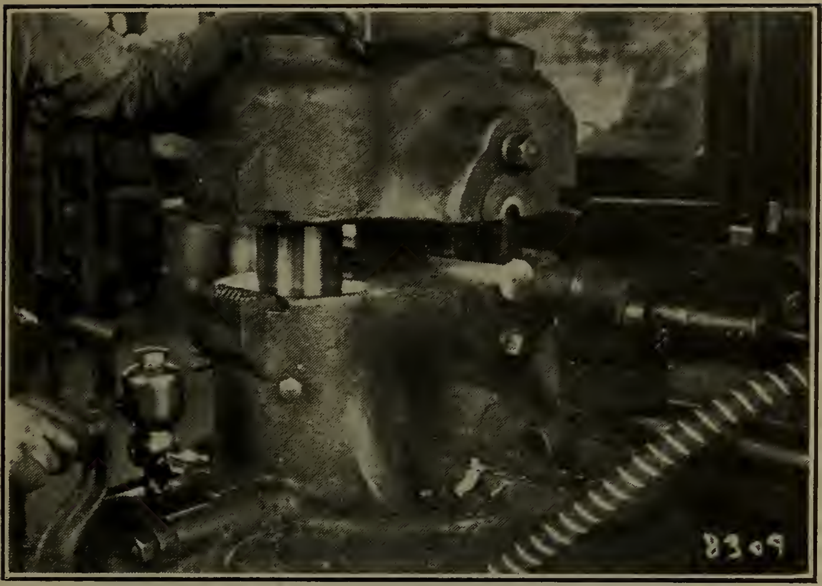


Fig. 184—A rock drill sharpening machine applied to forging bolt heads.

One shop appreciating its adaptability to other work, is employing it for the forging of odd shape-and-size bolt heads by the use of special dies which it manufactured for the purpose. This machine has an up-and-down moving vise to hold dies and

Fig. 185—Dies and dolly for forging bolt heads and sample of stock and finished work.

a horizontal hammer for operating a dolly to force the heated metal back into the dies for shaping while the vise grips the shank of the bolt.

Both the vise or vertical hammer and the horizontal hammer are operated by air controlled by a central three-way throttle. Moving the throttle lever part way lowers the vertical hammer, moving it still further sets the dolly working. Returning the lever to normal position raises the vertical hammer. The vertical hammer may be operated for swaging or squeezing independent of the horizontal hammer.

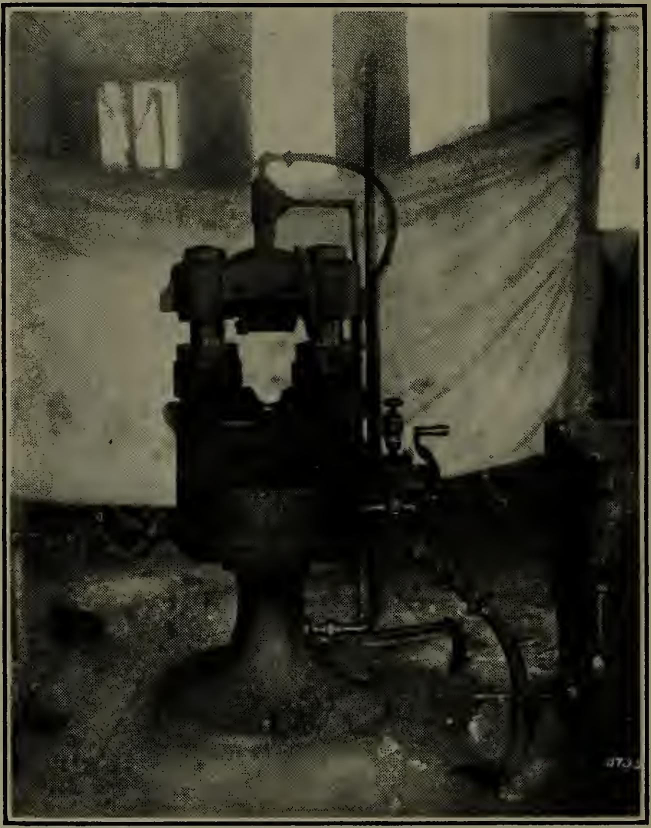


Fig. 186—A rock drill sharpening machine applied to nosing shrapnel.

Fig. 185 shows a set of dies for forging round head bolts and samples of bolt stock and finished bolt head. The capacity on this particular size stock, 1¼ inches, was 2 per minute.

It often happens that a need arises for special sizes of rivets, or stock of certain sizes is out. For supplying this want the

Fig. 187—Still another converted hammer.

machine shown fills a real want. The process of forging is the same as for bolts. Different dies are required for different sizes and in the case of rivets different dollies for the various types of rivet heads.

Fig. 186 shows a modification of this machine adapted to the work of nosing shrapnel. The horizontal hammer has been eliminated and the work is performed entirely by the vertical hammer.

Fig. 187 shows still another converted steam hammer in the repair shop of a large contractor. Note the blow gun for removing scale from the hammer faces.

This contractor was operating all equipment on electric current purchased from a service company and therefore found it simplified his problem to operate his forging hammer on air.

CHAPTER XIII

COMPRESSED AIR USES IN BOILER SHOPS AND STRUCTURAL STEEL PLANTS

Out of the field of brawn and awkwardness, into the realm of brain and science. Such is the story of the progress made during a period of years, comparatively brief, in boiler and structural shop practice.

This entire change may be said to be due to the advent of pneumatic devices for chipping, calking, drilling, riveting, punching and a hundred and one other uses. They have liberated these plants from the methods of slow and costly manual labor and placed them on a plane equal to the refined methods of machine shop practice, and it may be truly said that today, plate steel, beams and girders are machined into tanks, boilers, automobile trucks, bridges, cranes and what-not, even as much so as cast-iron, brass and steel are machined into engines, lathes, pumps, etc.

The uses of pneumatic tools in this division of the manufacturing plant may be grouped according to the service performed, as follows:

Forming or Pressing
Bending or Shaping
Punching
Drilling
Grinding
Reaming
Riveting
Chipping
Trimming
Calking
Welding Flues and Tubes

Forming or Pressing. Forming or pressing until comparatively recently has been considered the legitimate field of the steam operated forming press, but, like in the forge shop, a realization of the advantages of compressed air for operating such presses has led to a number of transformations in such machinery and the appearance on the market of presses of great simplicity covering a wide range of capacities and work, designed especially for compressed air operation.

Many up-to-date shops with special problems have even gone so far as to construct special compressed air operated machines to meet these problems.

Bending or Shaping. This is a class of work heretofore largely performed by hand or by steam operated tools and at times in the forge shop over the anvil. Today it is under the spell of compressed air and we find manufacturers building machines having in mind the requirements of this power, for bending pipe, bars, angle iron and other material to all shapes, turns and twists.

Where large quantities of various given shapes are required it is not uncommon to see a battery of these machines, each operating on a different class of work.

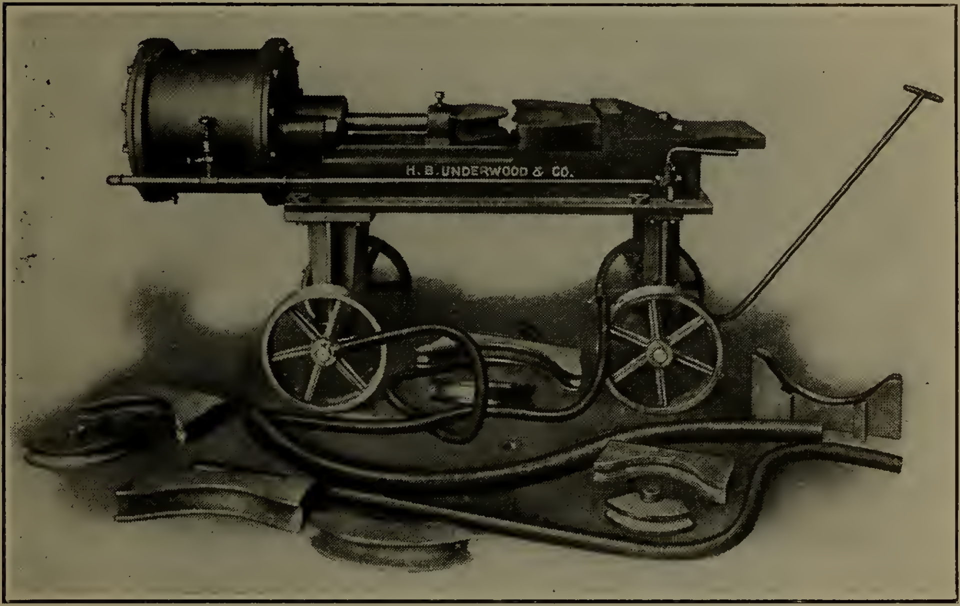


Fig. 188—Portable pneumatic pipe bending machine.

In Fig. 188 is shown a portable machine designed for bending pipe. The dies are changeable, making it possible to handle an almost unlimited variety of shapes.

It will handle any size pipe up to 2½ inches cold and without filling. It does not flatten or split the pipe. Tests show that it will put a 90-degree angle in a 2-inch pipe in two minutes. It operates on an air pressure of 80 to 100 pounds. Weight with the following set of dies: ¾ – 6 inches radius
1 – 7 inches radius
1¼ – 8½ inches radius
1½ – 10 inches radius
2 – 13 inches radius
is 1,500 pounds.

While sold for pipe bending, it may also be applied to the bending of various shapes of bar iron, light angles, etc., by the use of special dies, readily made in most any shop.

HOISTING. Air hoists are employed for lifting the heavy plates and placing them in position on the laying-off table, in the bending rolls, on the shears and punches and for lifting the various courses into position for riveting.

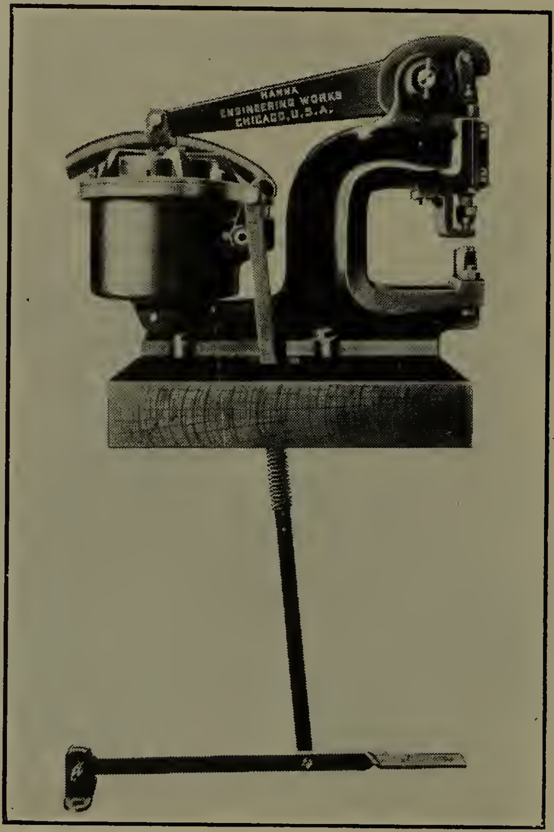


Fig. 189—A convenient portable pneumatic punch.

PUNCHING. The portable pneumatic punch shown in Fig. 189 has come into extensive use for the many special jobs of punching holes which, due either to immobility of the work or peculiar location, cannot readily be handled in the stationary punches.

Fig. 190 shows one of these portable pneumatic punches at work in a large railroad shop. It is used for all kinds of odd jobs.

Figs. 191 and 192 illustrate portable combination pneumatic yoke riveters and punches adapted for special work.

Drilling and Reaming. The pneumatic drill comes in for all classes of drilling, reaming, tapping, running in stay bolts, rolling flues, grinding, etc.

Examples of performance:

Thirty seconds was the average time required by a pneumatic drill in expanding copper locomotive tubes 1 7/8 inches outside diameter. The operating pressure was 70 pounds.

Fig. 190—A portable pneumatic punch in the Meadow Shops of the Pennsylvania Railroad.

Fifty-two 5/16-inch holes drilled in 70 minutes through the ¾-inch end plate furnace flange of a marine boiler, furnace being in position. Hand work required 8½ hours.

In drilling test or tell-tale holes in stay bolts, two men with two of the small pneumatic breast drills drilled 140 stay bolts per hour.

In one instance two men with two drills tapped out the holes and screwed in 700 stay bolts in a fire box in 14 hours.

Figs. 193 to 203 inclusive show various applications of pneumatic drills.

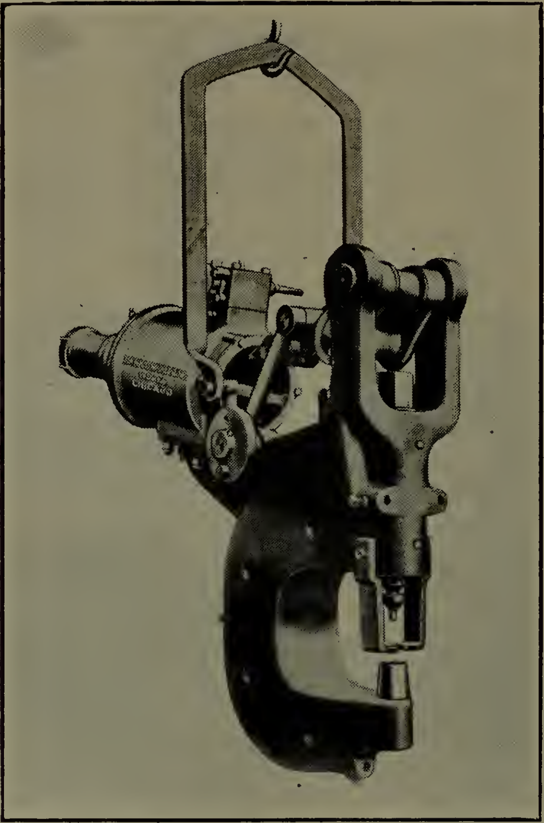


Fig. 191—A combination pneumatic yoke riveter and punch specially adapted for channel and angle work.

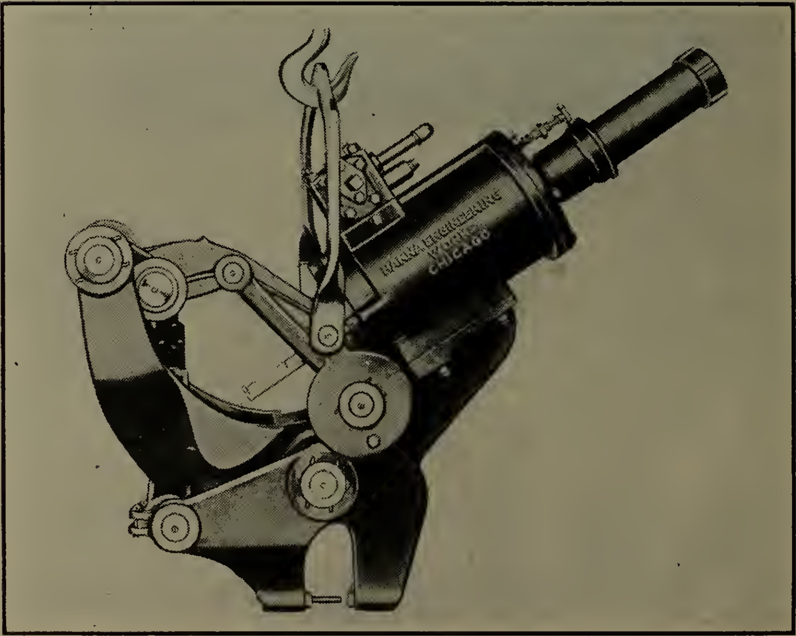


Fig. 192—A combination pneumatic yoke riveter and punch for work in close quarters.

Fig. 193—A pneumatic drill at work drilling and reaming holes on a large battleship.

RIVETING. In riveting work, the pneumatic hammer is applied to all classes of riveting, giving more tightly drawn-up joints with unmutilated rivet heads, to say nothing of the time and labor saving.

Fig. 194—Pneumatic drill at work reaming holes in car frames in the plant of the J. G. Brill Co., Philadelphia.

Fig. 195—Running up ½-inch nuts on car corner straps with a pneumatic drill in the Collingwood-Ashtabula Shops, N. Y. Central R. R.

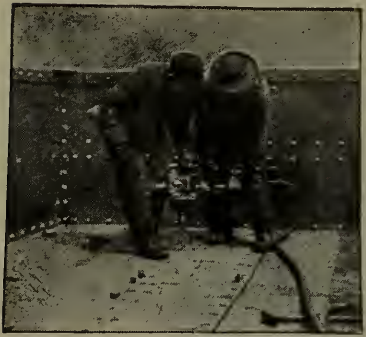


Fig. 196—Reaming $\frac{13}{16}$ inch holes in steel freight car—Scully Yards, Penna. Lines West of Pittsburgh.

Fig. 198—Tightening bolts in guard rail on Louisville Bridge.

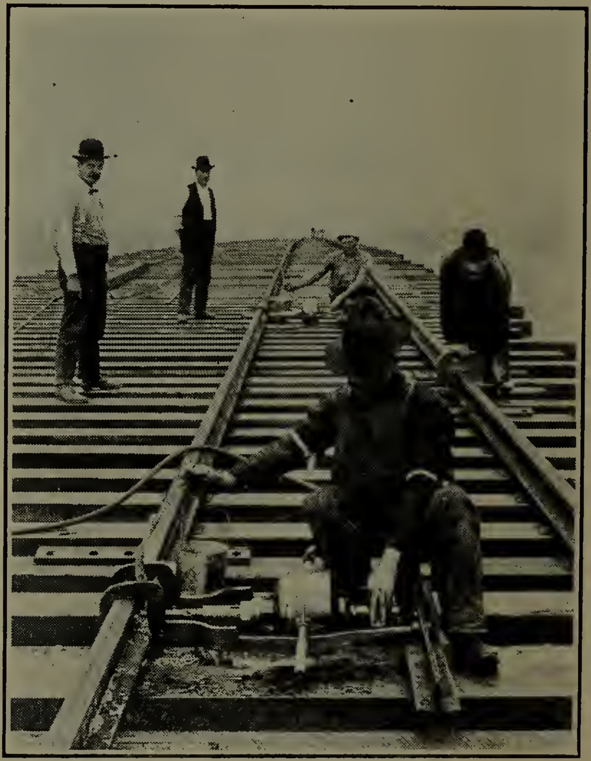


Fig. 197—Drilling rail-bonding holes. This shows the Williamsburg Bridge across the East River, between New York and Brooklyn, in course of construction.

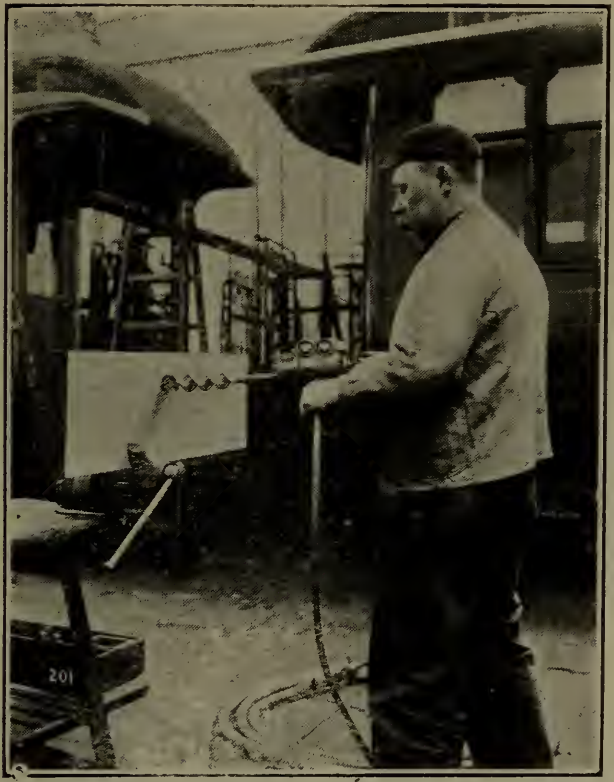


Fig. 199—Boring wooden end sills for passenger coaches.

In riveting on a standard fire box leg containing 253 ¾-inch rivets, a pneumatic hammer drove all the rivets in 9 hours at a total cost of $4.32. This same job by hand required 15 hours, costing $10.95.

Fig. 200—Close quarter drill at work in the Middletown, N. Y., Car Repair Shop of the New York, Ontario and Western R. R.

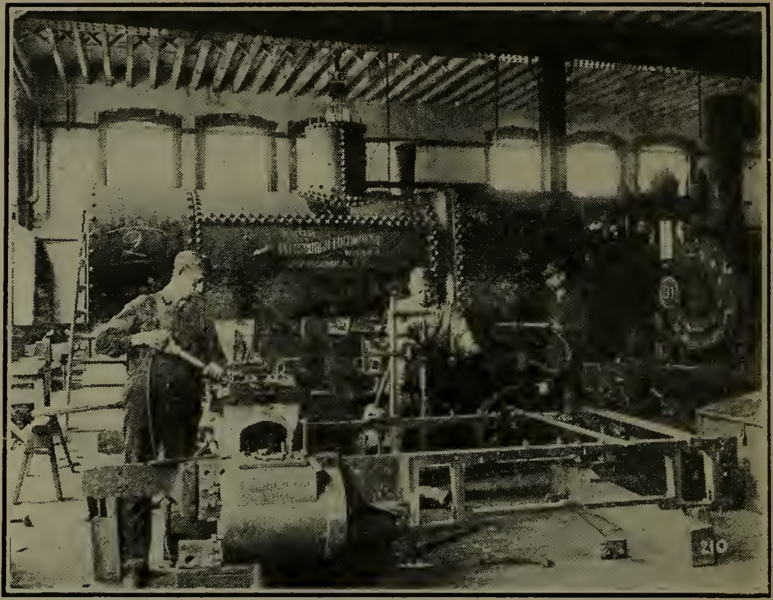


Fig. 201—Drilling and chipping on locomotive repair work.

In another case 1¼-inch rivets were driven in a boiler to withstand 360 pounds pressure, at one-third the cost of hand work.

Figs. 204 to 218 inclusive show various applications of the pneumatic riveter.

Fig. 202—Drilling and riveting structural steel shapes in a Brooklyn structural works.

Fig. 203—Drilling Fire box in the shops of the Seaboard Air Line.

Fig. 204—Little David Riveter on boiler work in the Murphy Boiler Works, New Orleans, La.

Fig. 205—Riveting angle iron on locomotive running board. Rivets ¼-inch diameter, driven cold with a medium weight chipping hammer.

Fig. 206—Riveting a locomotive boiler.

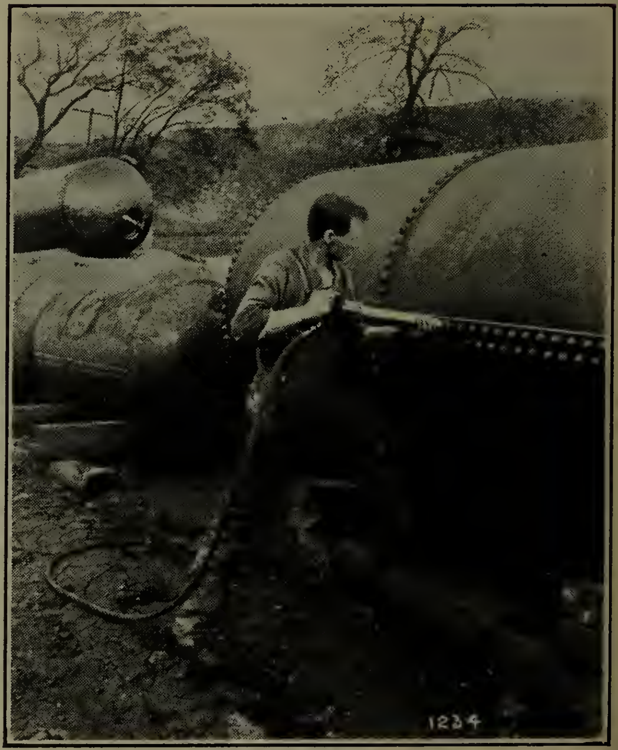


Fig. 207—Air receiver and tank riveting.

Fig. 208—Assembling automobile axle housings with a pneumatic hammer at the plant of the Walker-Weiss Axle Co., Flint, Mich.

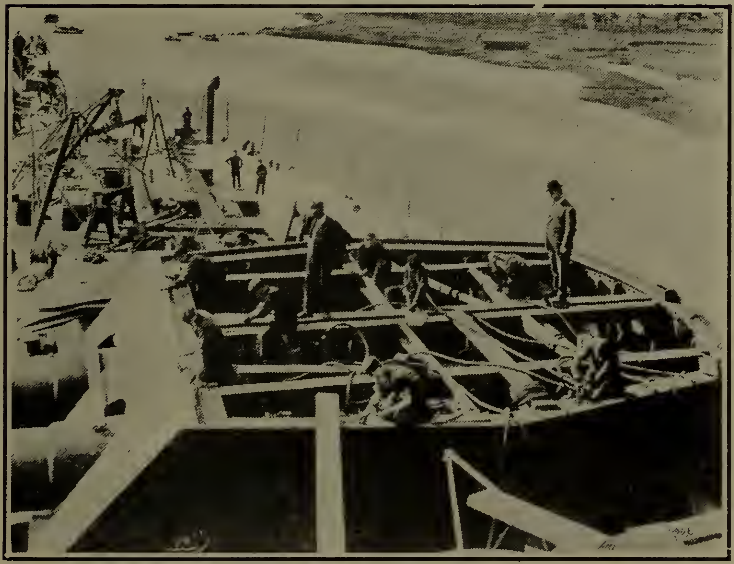


Fig. 209—Riveting together a turret on a large battleship.

Fig. 210—Driving $\frac{5}{8}$-inch rivets cold in end piece of coal car.

Fig. 211—This illustration shows the application of the pneumatic holder-on in riveting work.

Fig. 212—Pneumatic riveters at work on a large railroad viaduct.

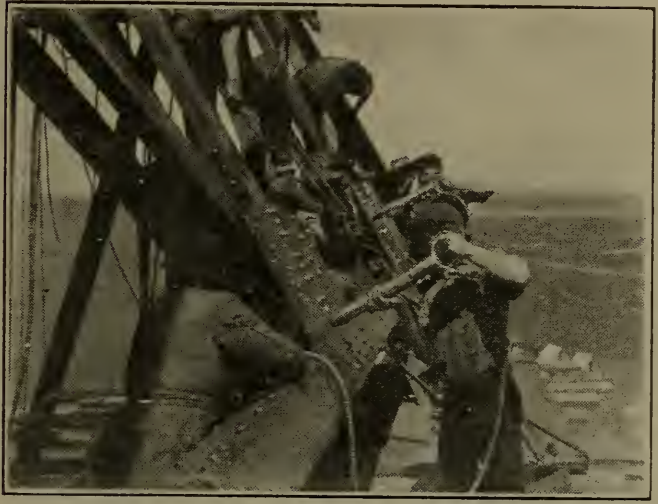


Fig. 213—Riveting together from slings the head frame of a deep mine shaft.

Fig. 214—Pneumatic riveter and pneumatic holder-on at work on new Public Service Building, Newark, N. J. Notice the **Tee** connection in the hose line for feeding air to both tools by means of one main hose line.

Calking, Trimming and Chipping. The pneumatic hammer for calking and trimming seams of boilers and tanks, pipe joints and the like is not only more rapid in its action, saving nearly two-thirds the time required for hand work, but the resultant job is a more uniformly calked joint. This is due to the sustained quality and weight of the pneumatic hammer blow as against the variable one of even the skilled hand mechanic.

In chipping metal, cutting off angles and tubes, trimming edges and for restricted quarters work, the pneumatic hammer has decided advantages.

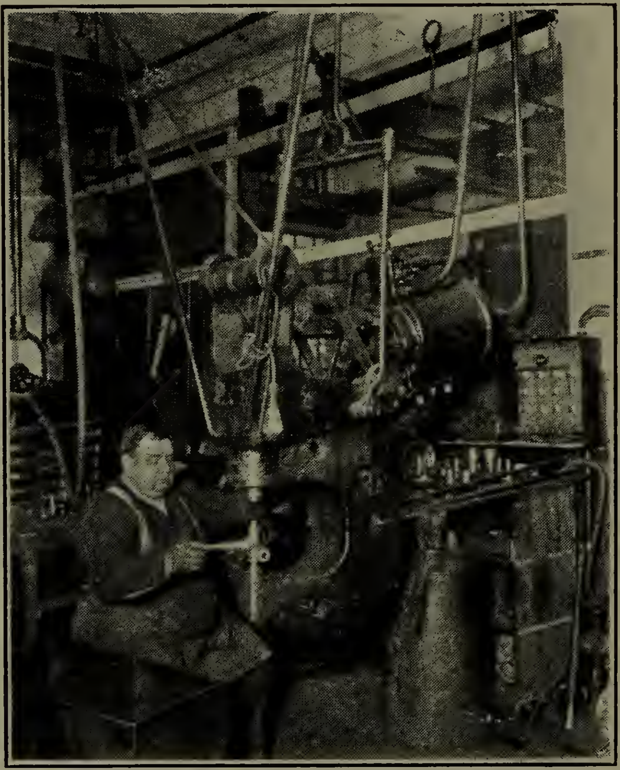


Fig. 215—Hanna Pneumatic Yoke Riveter used on automobile work in the H. H. Franklin Mfg. Co's. Plant, Syracuse, N. Y.

In heading over ⅜-inch rivets on differential gears, one man is accomplishing the same amount of work in one-third the time required by previous method with two men. Rivets are driven cold thereby completely filling the hole.

This machine is also used for pressing in bushings.

It is also extensively used for beading boiler flues. A case is on record of 235 2-inch flues being beaded in 2 hours and 10 minutes, a job requiring 10 hours for hand labor.

In chipping, a 3/8-inch chip has been removed from a boiler plate ½-inch thick at the rate of 7 inches in 48 seconds.

Tubes of 2½-inch diameter have been cut off in 36 seconds, as against 2½ minutes by hand, and in one case 46 tubes were cut off, turned over and beaded with the same tool in 1 hour and 45 minutes, as against 5 hours for the old method.

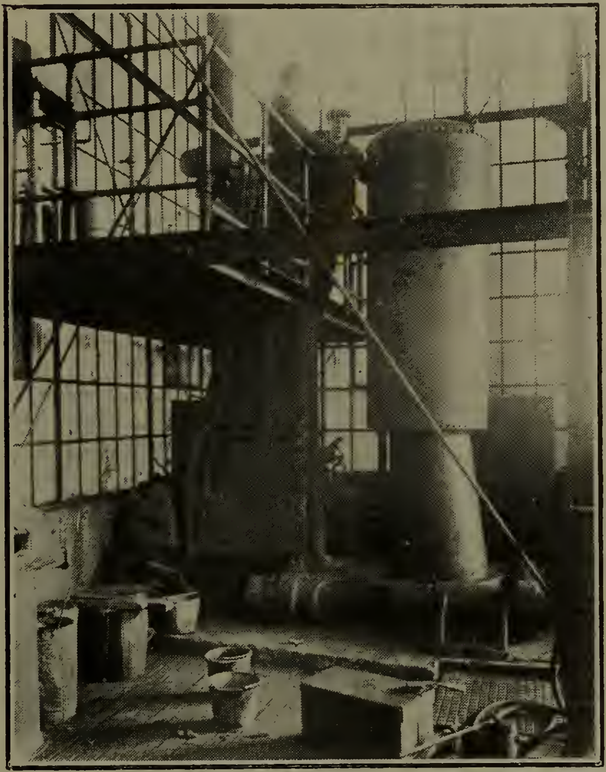


Fig. 216—A Hanna Yoke Riveter in the Plant of the Griscom-Russell Co., Massillon, Ohio.
This machine has a range of 126 inches and exerts 80 tons pressure on 100 pounds air. It is equipped with a special form of stake especially adapted to the riveting of small diameter shells.
The shell shown in the illustration is 30 inch diam. x 96 inches long, made of ¼ inch plate; the rivets being ⅝ inch diam. With two men, comprising the operator and rivet heater, 1,500 to 1,800 rivets driven per day of 10 hours. The machine had been in use about 3 years at the time photograph was taken.

Fig. 217—A Hanna Pneumatic Yoke Riveter in the plant of the General Electric Co., Pittsfield, Mass., employed on transformer work.

Fig. 218—Imperial Pneumatic Hoists and Pneumatic Yoke Riveter used in combination for fabricating structural steel shapes in the Lassig Plant of the American Bridge Co., Chicago, Ill.

Fig. 219—Chipping a locomotive flue sheet with a No. 3 Little David Chipper.

Calking seams requires about one-third the time. For recalking old seams the pneumatic hammer is ideal. It can be used for making a fresh cut on the sheet and the joint recalked in short order, giving a perfect repair.

Figs. 219 to 225 inclusive show various applications of chipping and calking hammers.

Fig. 220—Cutting off projecting ends of countersunk rivets on large structural columns. Hay Fdy. & Machine Wks., Newark, N. J.

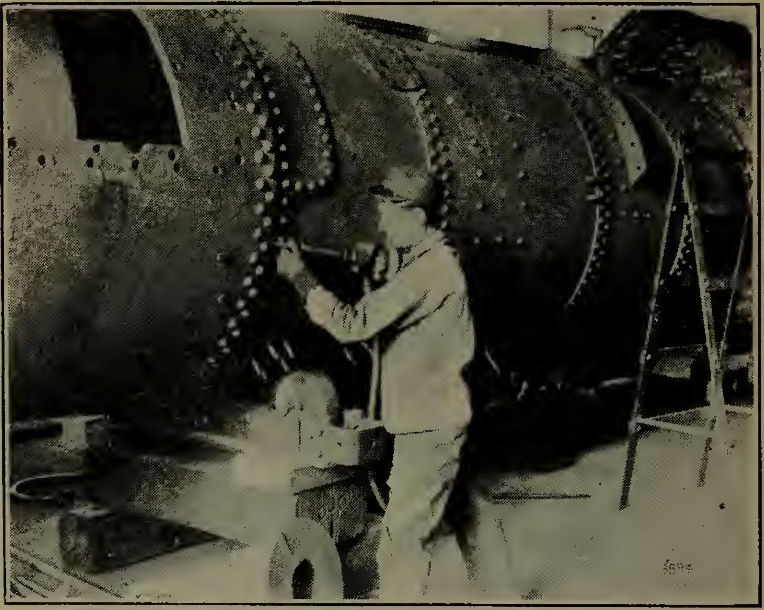


Fig. 221—Calking smoke-head on locomotive boiler in the shops of the Lehigh Valley R. R. at Easton, Pa.

Stay Bolt Drivers and Cutters. Pneumatic stay bolt drivers, holder-ons and cutters are profitable investments for the boiler shop. In one instance a pneumatic stay bolt cutter cut off 100 ¾-inch bolts in 30 minutes—a 2-hour hand job.

The stay bolt cutter is also useful for cutting off rivets, knocking out cylinder and frame bolts, driving pins and similar work about the shop.

Fig. 222—Calking air drum underneath locomotive boiler.

Fig. 223—Chipping mud-ring on locomotive boiler.

Fig. 224—Calking riveted steel pipe joints.

The heavier types of pneumatic hammers are also employed for knocking off rivet heads and driving out the rivets in repair work. A record is cited of 430 7/8-inch rivets per hour.

Flue and Tube Welders. Pneumatic machines for welding flues and tubes are rapidly coming into use. They are effecting

Fig. 225—Calking lead joints, cast-iron pipe line.

decided economies. They may also be applied to various kinds of light forging. The machine shown in Fig. 226 is used for welding boiler flues. This machine, it will be noted, is equipped with two cylinders operating over two sets of dies—one for welding and the other for swedging. In one shop they report welding and swedging 26,000 flues per month with one machine.

Fig. 226—Pneumatic boiler flue welding machine.

Another case records the swedging and welding of 2-inch flues in an average time of 5 seconds, the weld being smooth both inside and out, and the flue of even thickness.

Fig. 227 shows a machine for swedging and welding superheater tubes up to 6 inches in diameter.

An extensive use to which air is being put is for testing tanks, boilers, etc., for leakage. See Fig. 228.

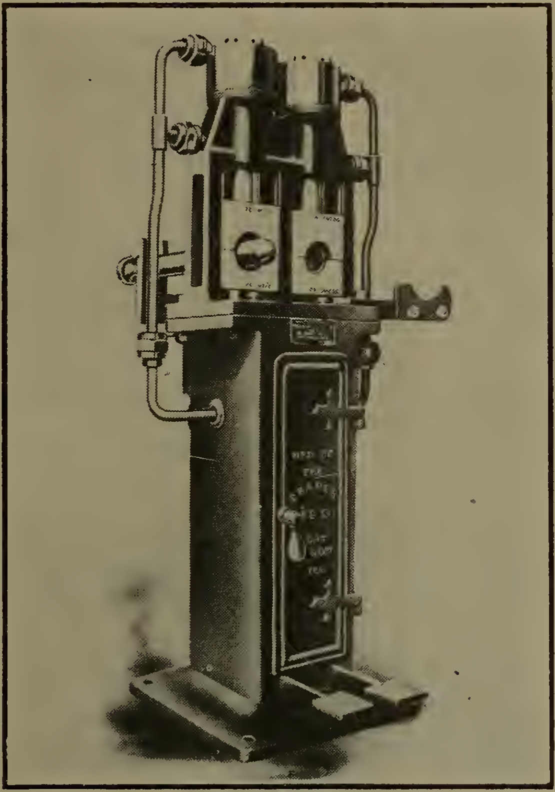


Fig. 227—Pneumatic machine for welding and swedging superheater tubes.

A feature of riveting work in many shops is the increasing use of portable oil rivet heaters. These are generally self-contained, mounted on trucks, as shown in Fig. 229. The tank carrying the

Fig. 228—Testing automobile radiators by air pressure in the plant of the Fedders Mfg. Co., Buffalo, N. Y.

oil supply is usually of sufficient size to carry a day's supply. The heating capacity of such a furnace is usually about 400 ¾-inch or 7/8-inch rivets per hour. Pressure is applied to the burner and tank from any convenient outlet in the shop compressed air line. Regulating valves on the furnace generally control the pressure applied to the tank.

The use of these furnaces makes it possible to fabricate work anywhere in the shop or out in the yard without experiencing inconvenience and delay in obtaining heated rivets.

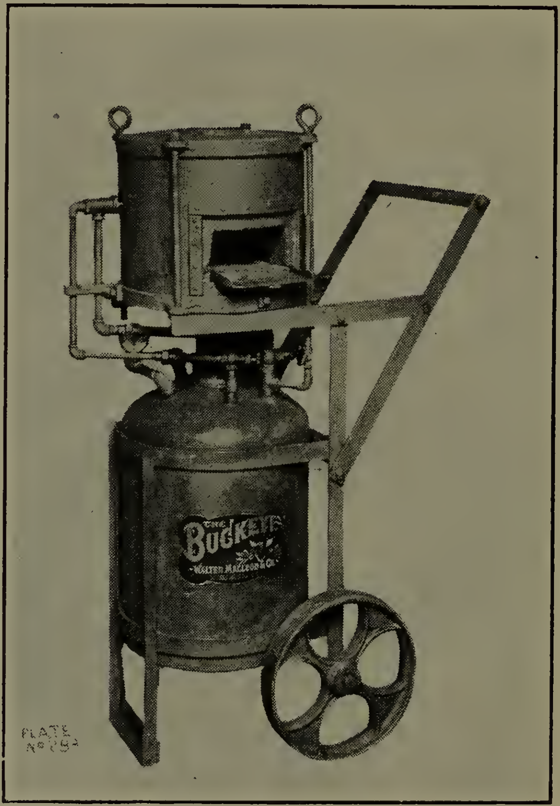


Fig. 229—Portable compressed air oil rivet heating forge.

CHAPTER XIV

HOISTING—HANDLING—CONVEYING

The advantages of compressed air for hoisting, handling and conveying materials in the manufacturing plant have long been appreciated and there are, therefore, innumerable examples and much available data to be cited concerning the practice in various classes of work.

In the following are described and illustrated a number of installations and records of experience and it is hoped that they may act as a guide to others confronted with similar problems.

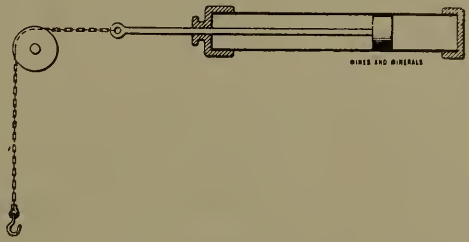


Fig. 230

Hoisting and Handling. The application of compressed air for this class of work ranges from the simple job of auxiliary aid for placing work on the bench or machine tool to the more complex work of the traveling shop crane.

Mr. Frank Richards, Managing Editor of *Compressed Air Magazine*, in commenting on the cost of hoisting with air hoists, estimates that at 100 lbs. gauge pressure, compressed air costs about 5 cents per 1,000 cubic feet of free air and basing his determinations on this, the rated lifting capacities of various size hoists, their free air consumption per 4-foot lift, at 90 lbs. pressure and providing a margin of 30% to cover such contingencies as taking up the slack of the rope, the attaching means, etc., has compiled the following very interesting table of costs. The table shows the cost per single 4-foot lift and also the cost for 100 4-foot lifts.

TABLE OF HOISTING COSTS

Diam. of Cyl.	Effective Area of Piston	Maximum Weight Lifted	Cu.Ft. of Free Air per 4-ft. Lift	Cost of Air Per Lift	Cost of Air per 100 Lifts
2	3.05	274	.74	$0.000037	$0.0037
3	6.87	618	1.67	.000084	.0084
4	12.22	1,099	2.97	.000149	.0149
5	19.09	1,718	4.64	.000232	.0232
6	27.49	2,444	6.68	.000334	.0334
7	37.42	3,367	9.09	.000455	.0455
8	48.87	4,398	11.88	.000594	.0594
9	61.85	5,566	15.03	.000752	.0752
10	76.36	6,872	18.56	.000928	.0928
11	92.39	8,315	22.46	.001123	.1123
12	109.96	9,896	26.73	.001337	.1337

Under Chapter VI has already been described a number of standard manufactured pneumatic hoisting devices and it is suggested that they be studied in conjunction with this chapter.

Special apparatus, generally designed and built to meet individual problems will, however, be touched upon here.

The application of air hoists to cranes may be made in an almost endless variety of ways to meet special requirements. Hand power cranes already in use may be powerized by means of simple cylinder hoists of both the vertical or horizontal types or by means of inexpensive air motors.

A few typical installations follow:

In Figs. 230 and 231 are shown two methods which may be employed in utilizing cylinder types of hoists where headroom does not permit of their being placed vertically. They are supported in the manner most convenient and a chain or a wire rope lead from the piston rod one-quarter way around a sheave down to a hook to which the load is attached, as shown in Fig. 230. Of course in this case the length of lift is limited by the travel of the piston.

By rigging up as shown in Fig. 231 the length of lift may be doubled. By the employment of still more sheaves the length of lift may be still further multiplied. In this latter case, however, the fact must not be overlooked that relatively larger hoists must be employed than with the arrangement shown in Fig. 230.

Fig. 232 shows a novel application of a vertical cylinder hoist to an existing hand crane in a foundry. The cylinder was bolted to the upper part of the mast and by means of a multiplying sheave arrangement somewhat similar to that already described, the motion of the lifting hook was made double that of the travel of the cylinder piston. As will be noted, one end of the rope passed over the lifting sheave down to the crane hook, the other end being attached to the usual winding drum of the hand windlass of the mast. This addition was made without interference with the hand apparatus and the crane may be operated either with power or by hand.

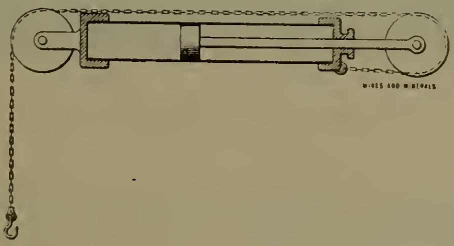


Fig. 231

Still another converted hand foundry crane is shown in Fig. 233. An air motor of the reversible direct-acting piston type was attached between the legs of the mast and geared to the main hoisting drum gear by a small pinion keyed to the air motor shaft. No alteration of the existing apparatus was necessary and the crane may be operated either by power or hand.

Some idea of the economy of this air operated crane may be gathered from the statement that the air compressor is stopped at the end of the day's work with the air receiver charged. This supply of air is sufficient to operate the crane for drawing off all castings in the evening.

Fig. 232

This type of motor is preferable for crane work because its height of lift is not limited; it is very compact and will hold the load safely at any point of the lift.

Fig. 234 illustrates a 20-ton traveling crane installed in a machine shop and operated by air. This crane has a span of

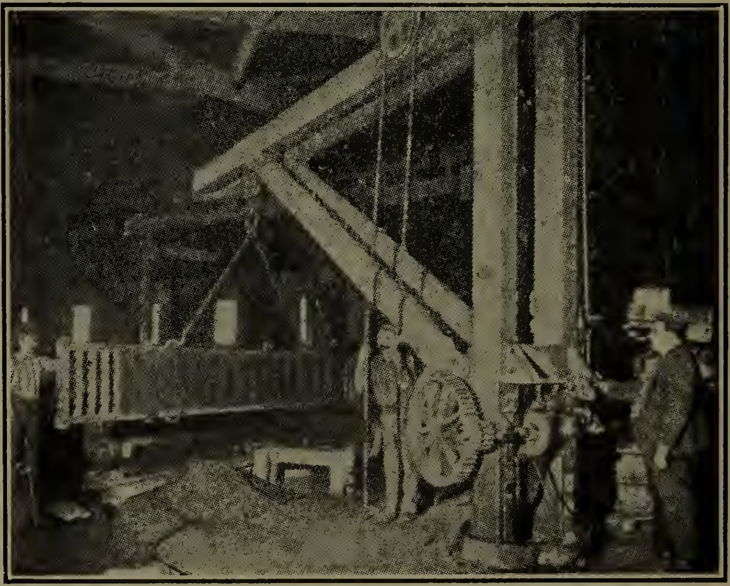


Fig. 233

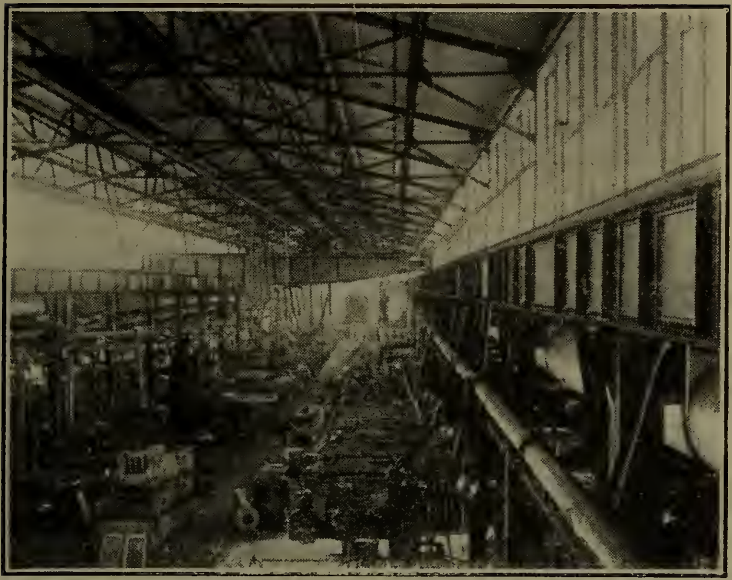


Fig. 234—A 20-ton pneumatic traveling crane in a large machine shop.

40 feet and a travel of 460 feet. Each movement of the crane is controlled by a separate engine, three of them being used, all piped, to a control valve located in the operator's cage.

Fig. 235—Pneumatic traveling crane and powerized stationary crane in a foundry.

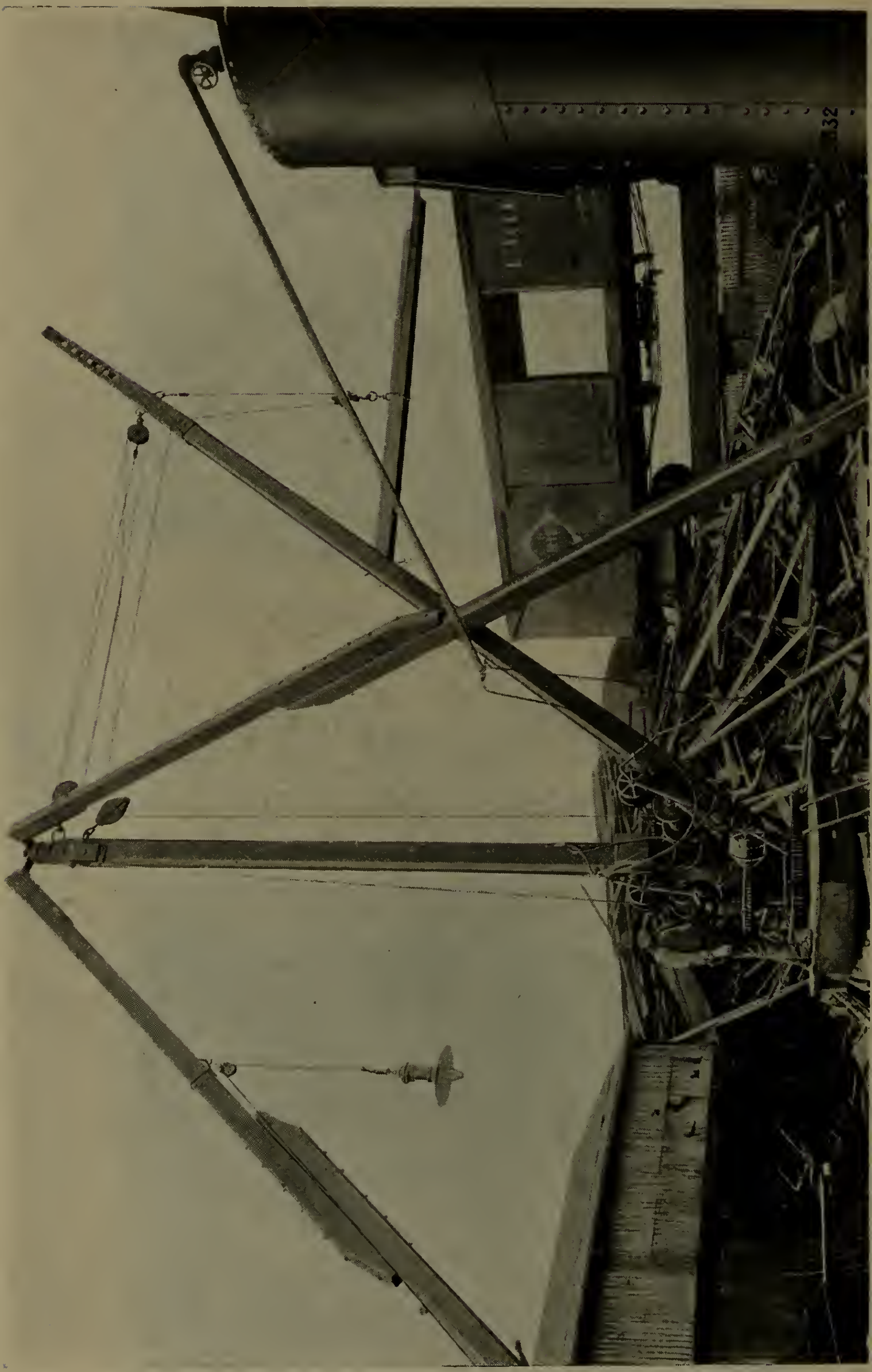


Fig. 236—Compressed air motor operated derrick in yard of the American Iron & Steel Co., Lebanon, Pa.

The air supply line consists of a continuous hose built up of 50-foot lengths coupled together, each coupling being made in combination with a swiveled sliding block, which slides on the overhead rail. As the crane moves away from the hose, it is pulled along, straightening out, and pulling the next length.

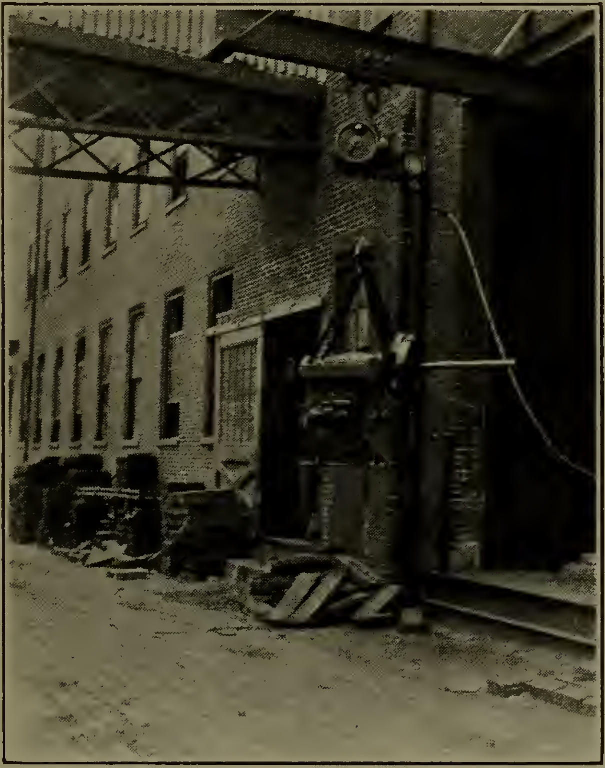


Fig. 237—A pneumatic motor hoist employed on overhead trolley. Morse-Williams Plant, Otis Elevator Co., Philadelphia, Pa.

On the return travel of the crane, the swivel blocks come together and the hose falls in loops.

Fig. 235 shows a hand power crane fitted with an air lift installed in a foundry. Two pipes with swing joints carry the air to the crane; the center joint being made with a roller runs on a circular track hung from the roof.

This illustration also shows a small pneumatic traveling crane.

Fig. 236 shows a derrick operated by compressed air at the plant of the American Iron and Steel Company, Lebanon, Pa.

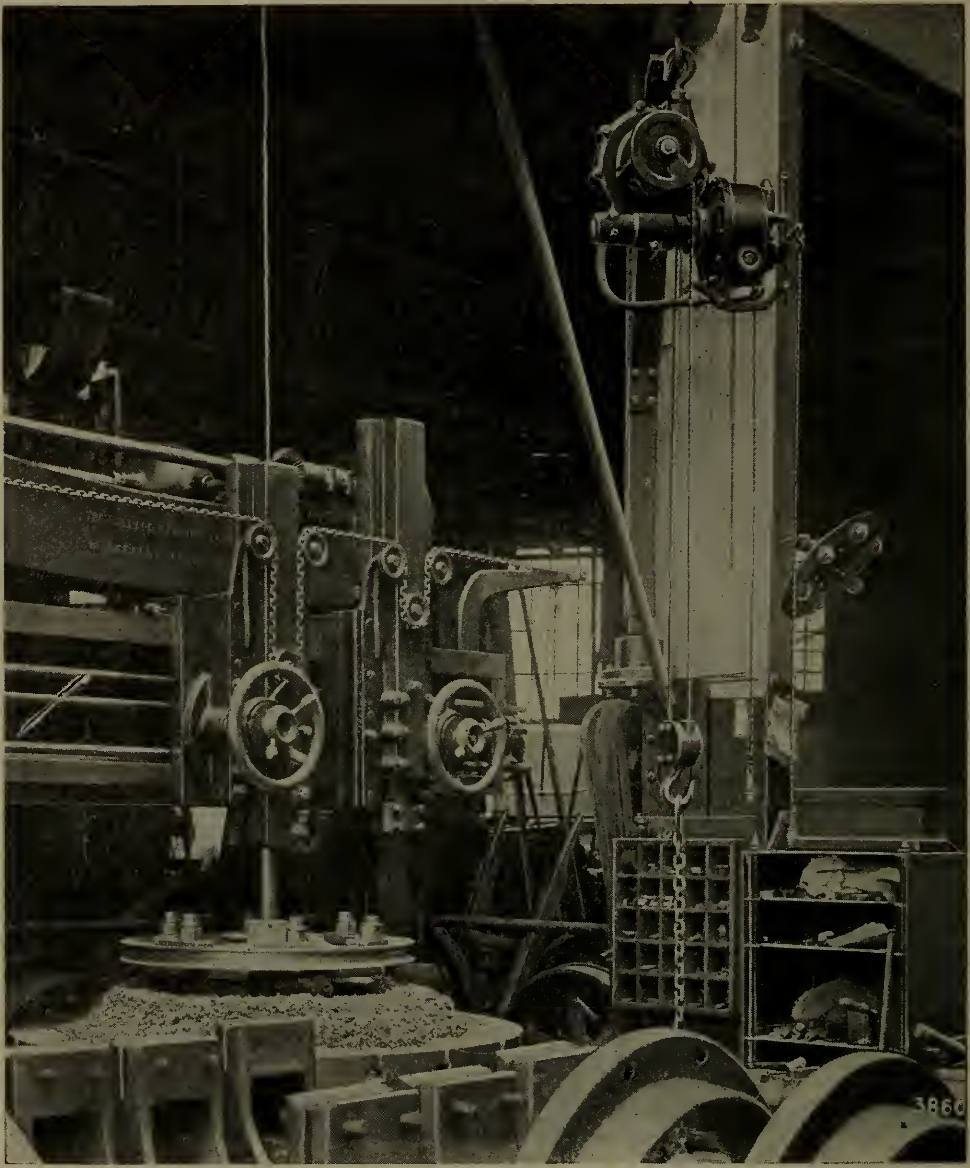


Fig. 238—Air motor hoist assisting machine tools in the Morse-Williams Plant, Otis Elevator Co., Philadelphia, Pa.

This derrick is employed in the yard for handling iron of various shapes. It is equipped with three air motor hoists geared to the several rope drums—one for swinging the derrick, the second for operating the boom and the third for handling the load. It takes its air from a large receiver placed nearby, as shown in the illustration.

Fig. 237 shows a geared motor hoist used in conjunction with a trolley track leading into and out of the Morse-Williams plant of the Otis Elevator Company, Philadelphia, Pa.

In Fig. 238 is shown the manner in which this same company has arranged the motor type of hoist as assistant to machine tools.

Fig. 239 is a close-up view of an air motor applied to a hand foundry crane in the plant of the National Car Wheel Company, Sayre, Pa. It is operated entirely by the long lever shown at the side.

Fig. 239—Air powerized foundry crane, National Car Wheel Co., Sayre, Pa.

To the same extent these hoists and motors can be applied to elevator lifts such as that described in the following and shown in Fig. 240.

Aside from low initial cost of installation they have in their favor low cost for maintenance as the equipment is exceedingly simple.

The hoist is suspended directly over an elevator lift, the hook-block being attached to the cross-frame of the cage. The lift is a short one, operating between two floors. The two long chains

Fig. 240—Air motor hoist applied to elevator lift, City Forge & Iron Co., Dayton, Ohio.

Fig. 241—Horizontal cylinder hoists serving machine tools.

seen in the illustration control the operation of the hoist. This installation is in the plant of the City Forge and Iron Company, at Dayton, Ohio.

Fig. 241 shows the manner in which one large shop applied the horizontal cylinder type of hoist for serving machine tools throughout the floor.

Overhead track was installed at intervals the full length of the side bays and projecting into the central bay, so that if necessary the load could be transferred across the shop.

Fig. 242—Vertical cylinder hoists on swinging cranes serving machine tools.

The cylinder was suspended from a four-wheel trolley by means of bands. A novel feature is the manner in which the movement of the piston has been applied to hoisting. The under side of the piston rod has been racked to operate on a pinion located between and keyed to the shaft carrying the two chain drums. The cylinder is double-acting and the action of the piston is controlled by a two-way valve operated by pull cords.

With this type of cylinder power is employed both for lifting and lowering the load.

Fig. 242 shows the assembly floor of a large shop, equipped with swinging cranes, from which are suspended vertical cylinder hoists attached to the familiar track trolley. For this class of work, calling for quick lifts of comparatively short heights, this type of hoist has proven a decided economy over the chain block and is especially suited for the shop where either head-room for a traveling crane is not sufficient or in a shop where the assembling of comparatively small units is going on simultaneously all over the floor.

Fig. 243—An air motor hoist in the yard of a structural steel plant.

Fig. 243 is a view in the yard of a structural steel plant. A geared air motor hoist operating from a trolley on a track stretching across the yard, is employed for loading freight cars. Note the size of beam being handled and the chain pulls by which the operator controls the action of the hoist.

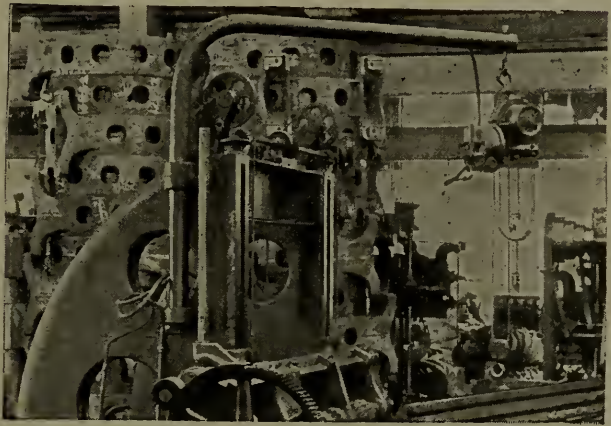


Fig. 244—Method of applying individual machine hoists in the Bullock Electric Co's. Plant, East Norwood, Ohio.

Fig. 244 is a view in the plant of the Bullock Electric Company, East Norwood, Ohio. This shows still another method of applying a motor hoist to machine tools.

Fig. 245 is a view in the car shops of the Manhattan Elevated Railroad of New York City. In this illustration two distinctly

Fig. 245—Vertical cylinder hoists in a railroad car shop.

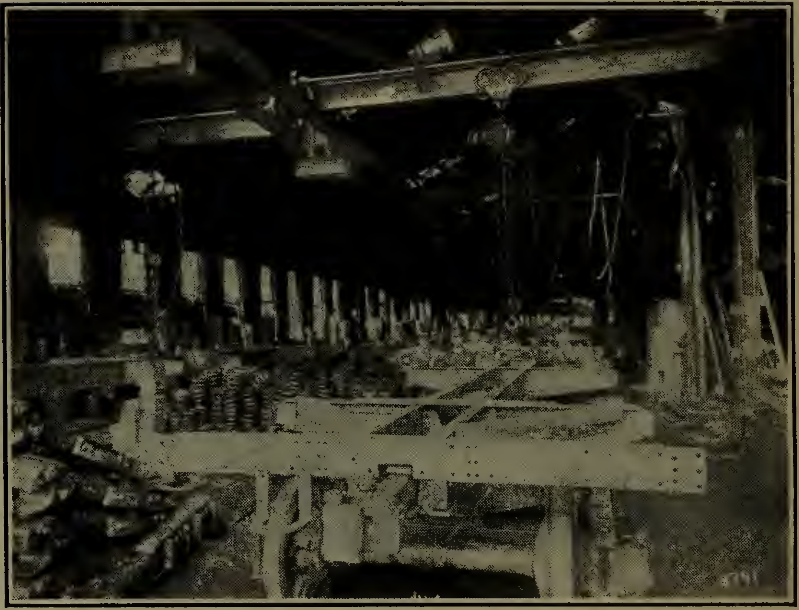


Fig. 246—Pneumatic hoists used in conjunction with traveling cranes in the plant of the American Car & Foundry Co., Jeffersonville, Ind.

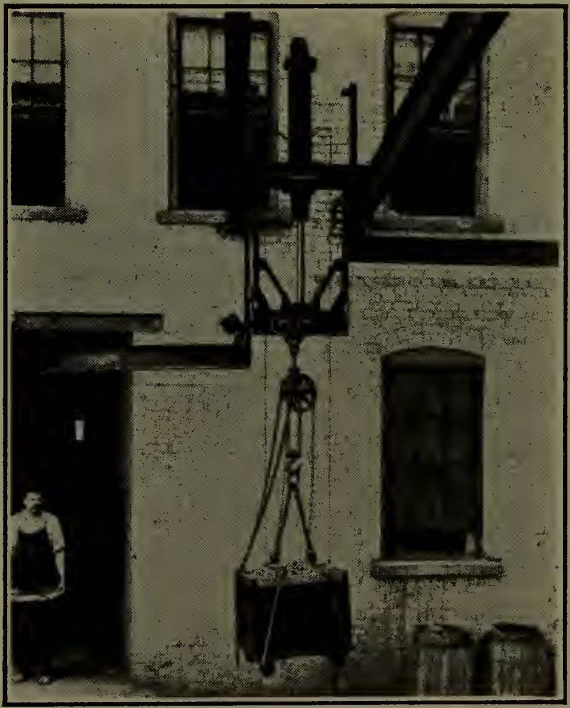


Fig. 247—A vertical cylinder hoist adapted to the transferring of loads from one level to another.

different methods of using the vertical cylinder hoist are shown: one operates on a trolley, while the other has been applied to 'powerizing' a swinging crane. Note particularly the multiplying sheave and chain arrangement to increase the height of lift beyond the travel of the piston.

Figs. 246 to 248 inclusive depict various other special applications.

Fig. 248—Vertical cylinder hoists traveling on roof trusses employed in the warehouse of the Peerless Drawn Steel Co., Massillon, Ohio.

RECORDS OF PERFORMANCE

Savings made with air hoists in a large Railroad Shop—*Railway Age:*

Placing wheels in wheel lathe, three lathes in the shop with an average of one change per day; saved the time of one man in handling this work, or a saving of $1.60 per day.

Hoisting steel-tired wheels and axles in lathe, average of six changes per day; saving one hour's time and the labor of one man, or $1.80 per day.

Hoisting axles into cut-off lathe, an average of ten changes per day; saving one hour per day, or twenty-five cents per day.

One large boring mill averaging two changes per day; saving 30 minutes in time and the labor of one helper, or $1.85 per day.

In handling cylinders for a large boring mill and planer the saving in time was one-half hour for each change and the labor of one man dispensed with, or $1.60 per day.

Three men working on pistons, etc., in raising them from the floor to the bench, serving three machinists; saving of one helper five hours per day or 80 cents per day.

Raising chucks, face plates and other heavy work; saved the labor of one helper per day or $1.50 per day.

Lifting driving wheels and other heavy work onto a large slotting machine; saving $1.50 per day.

A pneumatic hoist employed for unloading scrap at the foundry requires but two men and four hours' time for the same amount of work formerly requiring six men and ten hours.

The economy of an air hoist is well illustrated by the following recital of the experience of one large foundry:

In making wheels for traction engines, a molder and helper made one mold per day of a wheel 16 inches face by 66 inches diameter, employing a hand crane. During the entire operation of molding and pouring, it was necessary to make 104 hoists and lowers. It required the two men and a laborer on the crane and took from five to six minutes to turn a flask; with the air hoist, the laborer on the crane was dispensed with and the flask is turned in two minutes.

The saving in time alone is 52 x 3½ minutes, or three hours per day, and the molder and helper now make two 58 x 12-inch wheels in addition to the large wheel, which formerly constituted a day's work.

In this same foundry a test of one of their jib cranes operated by air gave the following:

Area of piston, 452.39 square inches (24-inch diameter).

Height of lift, 6 feet.

Hoist, 2 feet to 1 foot of piston travel.

Weights lifted, 2,000, 4,000, and 5,000 pounds.

Main air receiver gauge, 100 feet from crane, registered 63 pounds pressure.

Gauge on hoisting cylinder 30, 40 and 45 pounds for the respective hoists.

It was found that it took ten pounds pressure on the hoisting cylinder gauge to overcome all the friction of the chains wrapping around the sheaves, as well as the packing in the stuffing box of the piston rod and the frictional resistance of the piston in the cylinder.

Weight Lifted 6 Feet Lbs.	Pressure on Piston Lbs.	Deducting 4,523.9 lbs. as being amount required to overcome all resistance except load we get— Lbs.
2,000	6,785.85	2,261.55
4,000	9,047.80	4,523.90
5,000	10,178.77	5,654.87

The excess of 261.55, 523.90 and 654.87 pounds in the respective cases is no doubt due to the fact that the chains are hugging the sheaves tighter under the loads than when empty; and this increased friction must be overcome at the expense of pressure.

A 24-inch cylinder with a piston traveling 3 feet would contain 28,275 cubic feet of free air if the gauge on the cylinder showed 30 pounds pressure. Estimating the cost of compressed air at 5 cents or less per 1,000 cubic feet of free air delivered at 100 pounds pressure, it is evident that this performance is vastly more economical than a gang of men on a hand crane, with molders standing idle an indefinite time.

Conveying. The conveying of bulk materials, such as ashes, powdered coal, sand, and similar material, by means of air, has recently been given considerable attention by engineers. The practice has been successfully applied abroad. There are some cases on record where such materials are being conveyed advantageously and economically over distances as great as 2,000 feet.

As this problem is largely an engineering one, intending users should consult with those who have made a special study of the subject.

The Pneumatic Conveyor Company of Chicago, and the Guarantee Construction Company of New York City, are specializing in this class of work.

There are two distinct systems employed in conveying such materials, the suction system and the pressure system.

The pressure system utilizes low-pressure air, 2 pounds being ordinarily sufficient, although on occasion as much as 7 pounds pressure has been employed.

In Figure No. 22 is shown a low-pressure blower of the type suitable for this class of work, the capacities varying from 1,000 to 12,000 cubic feet per minute.

Experience has shown that this system for handling ashes and coal should not be applied to boiler plants of less than 1,000 horse power.

A great many plants today are equipped with boilers for burning powdered coal, and this system is especially adapted for its conveyance.

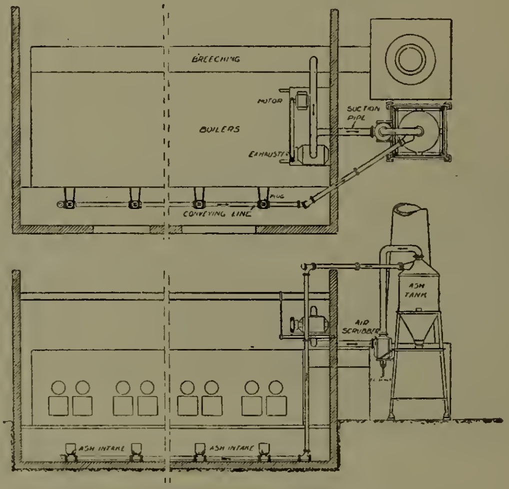


Fig. 249—General plan of pneumatic ash conveyer.

With the suction system the ashes are taken from the boiler dry and drawn into a storage tank where they are automatically quenched and the dust settled. Fig. 249 shows the general arrangement of an ash conveyer system.

To facilitate handling it is usual to install ash storage hoppers under the boilers, these hoppers being provided with gates from which the ashes feed through heavy intake hoppers, the rate of feeding being regulated by the attendant. From these intake hoppers the ashes are conveyed by the air current through steel or cast-iron pipes to a storage tank where a water spray quenches the live cinders and at the same time settles the dust.

The exhauster is employed to draw the air from the storage tank, creating a sufficient vacuum to cause an inrush of air through the conveying pipe line. It is this air current that carries the ashes to the tank. Special elbows provided in the line break up the clinkers, so that no obstruction can occur in the conveying line.

As the air is taken from the storage tank it passes through an air scrubber before going through the exhauster. The duty of this scrubber is to remove all dust and grit from the air.

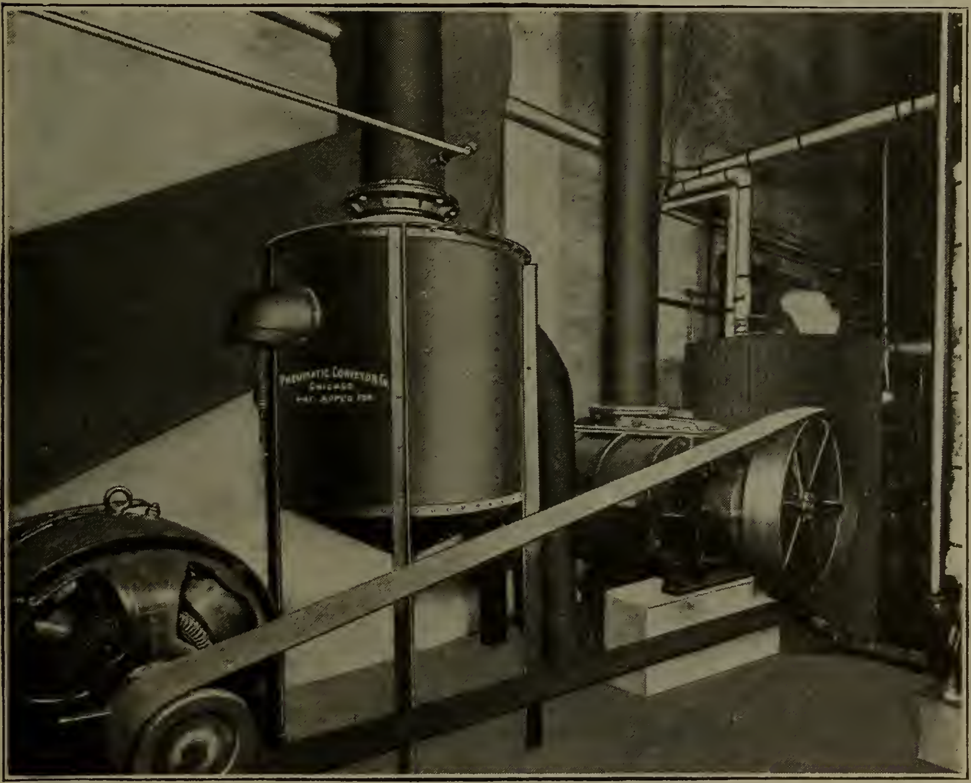


Fig. 250—Exhauster and air scrubber for pneumatic ash conveyer.

Where the pressure system is employed, the material to be conveyed is discharged into a large hopper from which it is redischarged into a power-driven feeder, which in turn feeds it into the conveying line. As the material enters the conveying line, the air current carries it into a receiving or separating tank. In the case of coal, it is usually located above the coal bunkers. From this tank it is discharged either directly into the bunkers, or into a traveling hopper where the coal is to be distributed over a large area.

A dust collector is provided for collecting the dust which escapes from the separating tank.

Fig. 251—Ash Conveying line and storage hoppers.

Fig. 252—Ash receiving tank.

The systems are identical for either ash or coal with minor modifications. For instance, where coal is being conveyed with the suction system, an automatic gate or special feeder is used for discharging the coal. Also, long sweep bends or turns are used in the pipe line instead of short radius elbows.

Fig. 250 shows the exhauster and air scrubber for a pneumatic ash conveyer installed in the Rand-McNally Building, Chicago. Fig. 251 shows the conveying line and storage hoppers, and Fig. 252 shows the receiving tank.

In foundry practice it is not uncommon to elevate the sand supplied to the molding machines by means of air to an overhead bin, from which the sand is conveyed through a pipe or in a chute by gravity to the molding machine. A gate, in the chute or pipe, regulates the amount of sand fed to the mold.

It is claimed that this system greatly increases the capacity of the molder as it eliminates the handling of sand with shovels.

CHAPTER XV

CLEANING WITH COMPRESSED AIR

Cleaning nozzles, or 'blow guns' as they are sometimes called, are used to great advantage in many modern plants, having completely superseded bellows, brushes and cloths for many cleaning operations. An air jet is much more effective than a brush for cleaning out-of-the-way corners and at the same time it avoids injury by contact, which is possible with brushes under certain circumstances. The hand bellows is a clumsy device which does not clean as effectively as a jet of compressed air and which is also liable to injure delicate work by coming in contact with it.

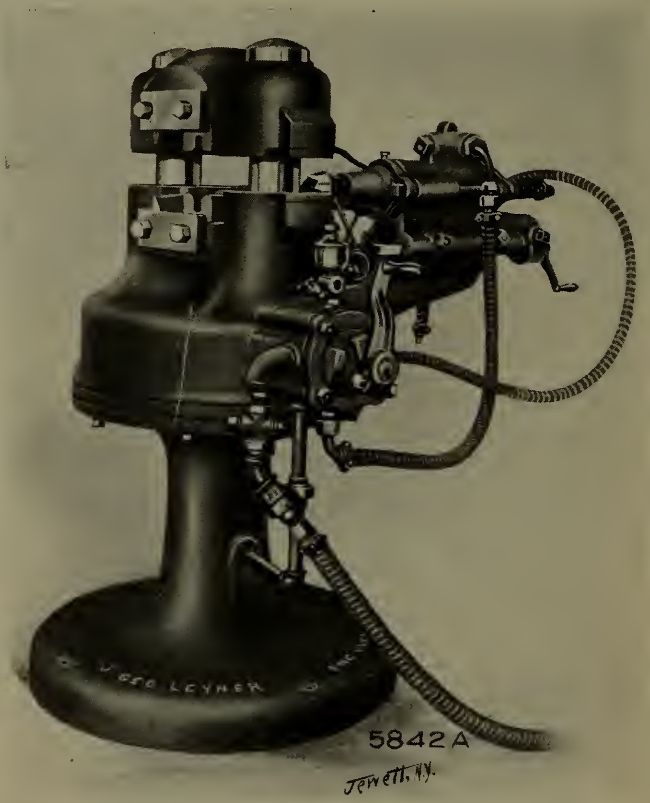


Fig. 253—Sharpening machine equipped with air jet.

Some Uses for Blow Guns. In the foundry and pattern shop the blow gun is used largely for cleaning core boxes, flasks, patterns, and for blowing out loose sand and graphite from molds before pouring; the latter work is generally of too delicate a nature for brushing and molders who have used the old-fashioned bellows will recall that time was often lost in 'slicking' over gashes made in the sand by the nose of the bellows.

In the blacksmith shop compressed air is commonly used for keeping the dies clean while hammering and for blowing scale from the part being forged; at the same time the air jet often assists by reviving the heat in the hot metal. Sometimes a nozzle is arranged as a stationary fixture to direct a jet of air during each return stroke of the hammer, but more often it is attached to the end of a short length of hose and is operated by hand whenever desired. Fig. 253 shows such a jet attached, as a regular part, to an air operated drill sharpening machine. By keeping the dies and swages clean and free from scale this nozzle saves time and improves the quality of the work of the machine.

Steam hammers sometimes have a similar nozzle for cleaning with a jet of steam instead of air. Air jets are, however, preferable to steam jets as the heat of the latter makes it difficult to handle and particles of condensed steam are often scattered about assisting the accumulation of dirt and the formation of rust.

Sometimes a jet of air is used for the purpose of tempering, instead of immersing in oil or water. Where this method is applicable, it is, of course, cleaner than the others.

In machine shops, there is no handier and quicker means of cleaning taps, dies, reamers, lathe and bench tools, milling machines, planers, drills, work benches, etc., blowing the chips, turnings, filings, shaving, etc. to the floor where they are readily collected by brushes or brooms.

Compressed air has been employed in machine shops for the two-fold purpose of blowing out the chips and keeping the drill cool while drilling deep holes in cast-iron. It has even been applied in a similar manner while drilling in steel. In one interesting instance, where holes 5 inches in depth had to be drilled into machine steel, it was found that the regular method of cooling with oil was unsatisfactory as the chips became packed in the hole before the bottom was reached. This caused the drill bit to heat up and bind. Compressed air, at 75 pounds pressure, was substituted for the lubricant, forcing it through the piping previously used for feeding oil. The cutting edges of the fluted drill bit were so ground as to produce small chips. The feed was made heavier than usual—about .015 inch per revolution—but the speed of rotation was rather slow. This resulted in chips of a size that were easily blown out of the hole as soon as cut. The work was equally as good, the chips were cooler than with oil cooling and the bit did not have to be removed from the hole until it had cut the full depth of 5 inches.

Fig. 254—Automatic pneumatic ejecting device attached to punch press.

In passing, it may be of interest to note that a somewhat similar practice to the above is employed in several types of drills for cutting rock. Some have hollow steels through which a jet of air is continually blowing, expelling the cuttings as fast as they are formed. Other types employ a combination of air and water which keeps down the dust while expelling the cuttings with equal facility.

Many punch presses and other automatic machines making small parts employ a nozzle which projects a jet of air during the up-stroke of the machine, for the two-fold purpose of removing any foreign substances and for ejecting stampings as formed. It is apparent that such an arrangement produces better work by keeping the dies clean, prolongs the life of the dies and contributes to safe operation by making it unnecessary for the operator to clean between the jaws of the machine or to insert his hands to remove the stampings. Naturally these factors all tend to increase and improve the production of a machine.

Fig. 254 shows such an arrangement on a punch press which is used for ejecting the work as formed as well as for keeping the dies clean. The operation is as follows: The valve 'A' is operated on every up-stroke by an adjustable valve 'B' carried by the ram, by means of the support 'C'; the trip has a steel roller, thus minimizing friction and is adjustable, making it possible to time the opening of the valve and vary the duration and intensity of the blast. In a recent 9-hour test with this machine it was found that the production was 47½ per cent. greater when the air attachment was used than when it was absent.

Fig. 255—A unit air compressor for pneumatic ejecting device.

A modification of the idea shown in Fig. 254 is necessary when a regular supply of compressed air is not available. In such cases a small unit air compressor is attached to and operated by the press, as shown in Fig. 255.

Air jets are used for cleaning in practically all metal-working industries. They are invaluable in clock and watch factories and in other places where the delicate nature of the product precludes the use of any other means. It is almost a universal practice in printing establishments to clean type, cuts, etc. with air. It is practically impossible to use any other means for the effective cleaning of complicated machinery, as is demonstrated by the very extensive use of air nozzles in textile mills, saw mills, in steam and electric railway shops, in garages and in electrical shops. Air cleaning is particularly handy for removing dust from overhead pulleys, shafting, pipes, wires and beams; by mounting the cleaning nozzle on the end of a pipe through which the air passes, the use of ladders and scaffolds may be avoided when doing overhead cleaning, not only saving time but also increasing the safety of the operation.

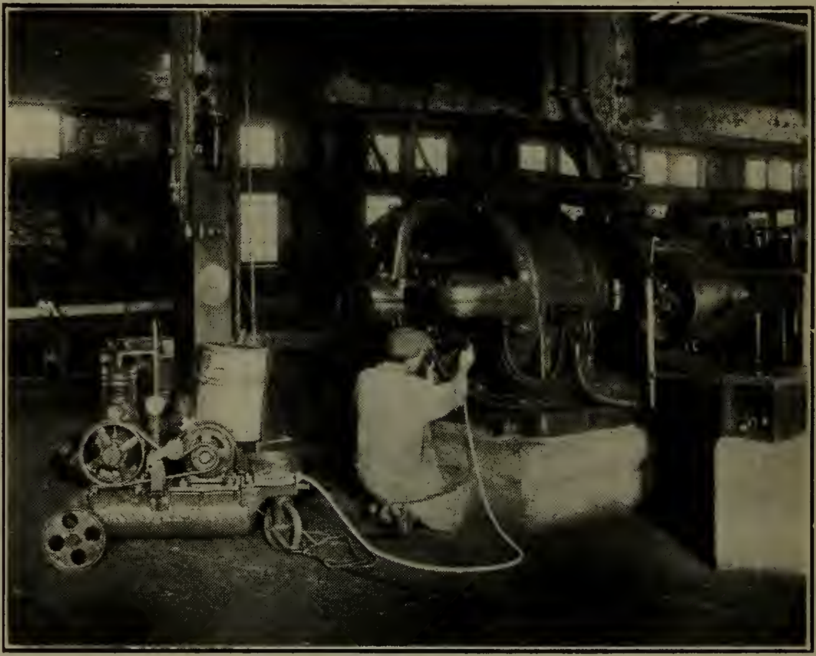


Fig. 256—Cleaning motor with the air jet, employing a portable air compressor.

Electric motors and generators require frequent cleaning to prevent dust, lint or other foreign substances settling upon the armatures, fields and other parts. It is particularly necessary to clean out the air spaces, as otherwise the temperature of the motor would tend to rise, greatly affecting the efficiency and perhaps even endangering the insulation by overheating. Fig. 256 shows such an application. Switchboards, controllers and other electrical apparatus can be cleaned best by a jet of compressed air without danger of injury, as might occur with brushes.

When cleaning out gas engine cylinders and valves, the easiest way to remove the scale, dirt and loosened carbon deposit is by means of an air jet. Other types of power machinery are also cleaned most conveniently by blowing. Compressed air is almost a necessity for blowing soot and dirt from the flues of boilers. Steam is also used for this purpose, but if compressed air of around 80 to 100 pounds pressure is available, it is decidedly preferable for the purpose.

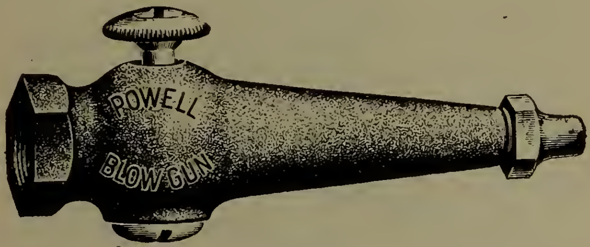


Fig. 257—Blow gun for cleaning with compressed air.

Air jet cleaning is a particularly satisfactory way of cleaning surfaces preparatory to painting, varnishing or lacquering, effectively removing any dirt, scale or particles left by sandpaper or emery cloth.

One advantage of the air jet over other methods of cleaning, that is particularly appreciated in manufacturing establishments, is its ability to dislodge dirt and dust while machinery is running, thus keeping the machines in the cleanest possible condition while in no way interfering with the rate of production.

Types of Cleaning Nozzles. The apparatus used for cleaning is frequently a crude home-made affair—often merely a length of garden hose with a plug-cock on the end. Naturally such a device wastes a great deal more air than it applies usefully and is extravagantly expensive. There is little excuse for following such practices as there are many types of very economical cleaning nozzles on the market which can be purchased for a dollar or two.

Fig. 257 shows a type of air-cleaning nozzle commonly employed in shops and factories. To use the nozzle, the button is pressed with the thumb, a greater or less pressure regulating the force of the blast. When pressure is released, the air supply is shut off. This is a good feature which insures air being consumed only when actually needed. The tip is removable, which is frequently found desirable either when replacing or substituting other types of tips. Fig. 258 shows a button head tip, which is more suitable when the nozzle is to be inserted in small openings. Fig. 259 shows a bent nose tip which can work around corners with great facility.

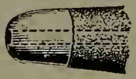


Fig. 258—Button head cleaning nozzle tip.

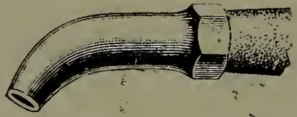


Fig. 259—Bent nose cleaning nozzle tip.

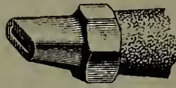


Fig. 260—Flat cleaning nozzle tip.

The flat tip, Fig. 260, spreads the air over a greater area, but is not so useful for general purposes. It has an opening of about ½ x 1/16 inch and finds a wide employment in hat factories for raising the nap on certain kinds of goods, such as velours. Fig. 261 shows a still wider nozzle which has an opening 1/100 x 1 5/8 inches used for general cleaning of flat surfaces, as car seats and floor coverings.

Fig. 262 illustrates a type of nozzle used extensively for blowing motors and for general machinery cleaning, where it is often desired to reach into remote corners. The nozzle has an extension of about 15 inches of ¼-inch pipe, reduced to an opening of about 1/8 inch at the tip. This type has a lever-operated valve, which is self-closing upon release of the pressure of the hand. Fig. 263 is another type of lever-operated nozzle.

When the blow gun is used for cleaning in very inaccessible places, for instance engine ports, valve passages or jacket, it is often a good plan to attach to the end of the gun a short length of flexible copper tubing which may be bent into any shape desired. At other times, for instance when there is danger of injury by the metal of the nozzle coming into contact with the objects being cleaned, it is often desirable to slip a short piece of rubber tubing over the end of the nozzle.

Fig. 261—A Westinghouse nozzle suitable for cleaning wide, flat surfaces.

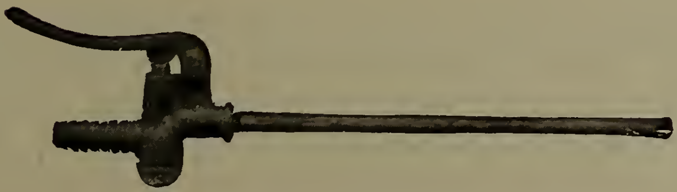


Fig. 262—Parks blow gun nozzle for reaching remote corners.

Knowing the service for which a cleaning nozzle is intended, it is a simple matter to select the most suitable type. Various air pressures are employed. Pressures of 10 to 35 pounds are common for blowing very small or light particles, but for heavy or oil-laden particles it is probable that pressures from 60 to 100 pounds are more effective. It is the sharp impact of the air upon the material to be removed which accomplishes the cleaning. With a suitable pressure this is usually accomplished as well with a small jet as with one of large diameter. Nothing is gained by employing a large volume of air when a small one will do, in fact a heavy blast may result in scattering the dust instead of merely dislodging it. A nozzle of 1/8-inch diameter is believed to be most commonly employed, although 1/16-inch, 3/32-inch, 3/16-inch, ¼-inch and 3/8-inch diameter nozzles are also used. The following table gives the approximate air consumption of jets of different sizes using different air pressures.

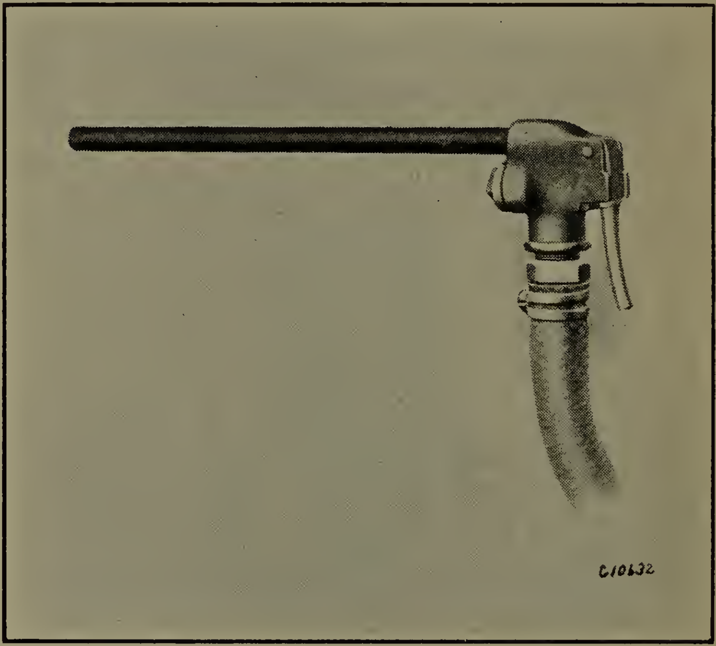


Fig. 263—Westinghouse blow gun nozzle with angular throttle, for cleaning in remote corners.

DISCHARGE OF AIR THROUGH AN ORIFICE

IN CUBIC FEET OF FREE AIR PER MINUTE

Flowing from a Round Hole in Receiver into the Atmosphere

Copyrighted, 1906, by Ingersoll-Rand Company

RECEIVER GAUGE PRESSURE	DIAMETER OF ORIFICE													
Pounds	$\frac{1}{64}$ inch	$\frac{1}{32}$ inch	$\frac{1}{16}$ inch	⅛ inch	¼ inch	⅜ inch	½ inch	⅝ inch	¾ inch	⅞ inch	1 inch	1¼ inch	1½ inch	2 inch
	DISCHARGE IN CUBIC FEET OF FREE AIR PER MINUTE													
2	.038	.153	.647	2.435	9.74	21.95	39.	61.	87.60	119.50	156.	242.	350.	625.
5	.0597	.242	.965	3.86	15.40	34.60	61.60	96.50	133.	189.	247.	384.	550.	985.
10	.0842	.342	.136	5.45	21.8	49.	87.	136.	196.	267.	350.	543.	780.	....
15	.103	.418	1.67	6.65	26.70	60.	107.	167.	240.	326.	427.	665.	960.	....
20	.119	.485	1.93	7.7	30.8	69.	123.	193.	277.	378.	494.	770.	....	....
25	.133	.54	2.16	8.6	34.5	77.	138.	216.	310.	422.	550.	860.	....	....
30	.156	.632	2.52	10.	40.	90.	161.	252.	362.	493.	645.	1000.	....	....
35	.173	.71	2.80	11.2	44.7	100.	179.	280.	400.	550.	715.	....	....	....
40	.19	.77	3.07	12.27	49.09	110.45	196.35	306.80	441.79	601.32	785.40	....	....	....
45	.208	.843	3.36	13.4	53.8	121.	215.	336.	482.	658.	860.	....	....	....
50	.225	.914	3.64	14.50	58.2	130.	232.	364.	522.	710.	930.	....	....	....
60	.26	1.05	4.2	16.8	67.	151.	268.	420.	604.	622.	....	....	....	....
70	.295	1.19	4.76	19.	76.	171.	304.	476.	685.	930.	....	....	....	....
80	.33	1.33	5.32	21.2	85.	191.	340.	532.	765.	1004.	....	....	....	....
90	.364	1.47	5.87	23.50	94.	211.	376.	587.	843.	....	....	....	....	....
100	.40	1.61	6.45	25.8	103.	231.	412.	645.	925.	....	....	....	....	....
125	.486	1.97	7.85	31.4	125.	282.	502.	785.	....	....	....	....	....	....

In cleaning machinery it is advisable to start at the top and work downwards, thus avoiding the necessity of going over any part a second time. Sometimes operators need special instructions as to how to manipulate the nozzle so as not to blow dirt over the part being manufactured or into the bearings of the machine; also so as to avoid blowing the lubricant out of bearings. If difficulty is experienced in the latter connection, it is usually eliminated by adopting a lower air pressure.

If an air nozzle is permanently attached to a machine, the hose should be suspended so that it will not be in the operator's way. It is sometimes convenient to suspend it from above so that it will fall back out of the way when released and will just reach to the lowest point that it may be desired to clean. Sometimes it is more convenient to arrange the hose so that it will drop into a hole in the work bench or table when not in use; with the latter plan it is, of course, necessary to fasten a disc of wood or sheet rubber back of the nozzle to prevent its following the hose through the hole.

As cleaning hose has to withstand considerable wear, it is advisable to have it armored or wire-wound.

Where it is desired to clean several machines in a room or on a floor at infrequent intervals, it is often advisable to install one or more permanent air pipe lines, running through the rooms, spaced conveniently, within easy reach and having numerous outlets. Sometimes these pipes are run overhead and branches from them are run down various columns to the outlets. Both of these arrangements avoid the employment of lengthy coils of hose stretched over the floor—a danger to the operators and often a source of annoyance due to kinking with consequent drop in air pressure. Instead, a short length of hose, with a quick coupling device on one end and a cleaning nozzle on the other, may be used. The latter is easily carried from place to place and can be plugged into any of the openings without delay. 'Quick-detachable' hose couplings are preferable to threaded couplings for this purpose, not only because they save time, but also because they are less apt to leak. Three-eighths-inch hose is amply heavy for most cleaning purposes and is a size easy to handle. Although there is no advantage in employing a hose heavier than needed, it is most advisable to select a hose of the best quality, for the wear caused by dragging the hose about is bound to be considerable.

In situations where the expense of installing permanent air lines is not warranted, it is often advisable to employ a portable motor-driven air compressor similar to that shown in Fig. 256. By simply plugging the electrical feed connection into a convenient wall socket, the compressor is ready for use in an instant.

Uninstructed employees sometimes remove the nozzle thinking to do better cleaning by blowing more air. They have also been known to enlarge the nozzle opening by filing. The former practice has been combated at times by inserting a reducer in the air supply line, thus limiting the air consumption. A hardened steel bushing forced into the tip of the nozzle prevents its enlargement by filing. The best way, however, to combat these abuses is to instruct the operators carefully and insist upon instructions being followed.

Fig. 264—A combined air acid gasoline gun for cleaning.

The air, as taken from a compressor receiver, is generally in satisfactory condition for ordinary cleaning purposes. With some of the older types of compressor plants, however, lubricant is used too copiously, resulting in occasional minute particles of oil being blown from the cleaning nozzle. For the majority of purposes this is of no importance; however, at times it is necessary to have the air *absolutely* free from oil, for instance when cleaning around fabrics in process of manufacture or when cleaning surfaces preparatory to painting or varnishing. An oil separator placed in the supply line will remove practically all of this oil, but in order to remove the last trace of oil, manufacturers have at times passed the air through cotton or cloths, in addition.

The correct basis for figuring the relative cost of any system of pneumatic cleaning is the savings that can be effected rather than the cost involved. The value of the increased production, made possible by cleaning while machines are in operation instead of while shut down, very often exceeds the expense of supplying the air many times over.

The air jet is most convenient for cleaning parts that are covered with grit and grease; after lapping a cylinder with grease and emery, for instance, the remaining grit can be removed easily by swabbing with gasoline or kerosene and following with a blast of air, which leaves clean surfaces free from grit. A device employed extensively in garages and engine repair shops combines a spray of gasoline or kerosene with a blast of air, which is a most effective means of removing caked dirt and grease, such as accumulates on automobile mechanism. This is illustrated in Fig. 264. The upper pipe is connected to the compressed air line while the lower curved pipe is connected by rubber tubing with a vessel containing kerosene or gasoline. The force of the air emerging from the nozzle not only expels the fluid at high velocity but it also raises it from the receptacle below.

CHAPTER XVI

THE APPLICATION OF PAINT, LACQUER, ENAMEL, METAL COATING, ETC. BY COMPRESSED AIR

The introduction of compressed air to painting, varnishing, enameling, whitewashing and the application of protective or ornamentative coatings of other natures marked a quick transition from slow and costly brushing methods, to systems, by comparison so efficient, rapid and economical as to make hand work undesirable practice. The application of such coatings by compressed air is accomplished by blowing or spraying them on, and in the following paragraphs this subject will be considered without specific reference to the material to be sprayed.

The subject is one which touches, in some form, nearly every industry, but it is the intention to confine the discussion to its application in the metal-working field. Manufactured products are covered with primers, fillers, paints, surfaces, varnishes, japans, lacquers, enamels, bronzes, asphaltum, and by a recently perfected process, with metals of various kinds; buildings, walls and ceilings are painted or whitewashed; structural steel work is metal coated. Steel cars, ships and bridge structures are painted; in the foundry, molds are sprayed and cores are blackened, tanks are lined with metal coatings, gasometers are painted —and a host of others—all by spraying. The result in each case is an immense saving of time, approximating from one-half to nine-tenths. That is, one man will do the work of from five to ten men, or, to put it another way, work costing two dollars by hand can be done for from twenty to forty cents, a saving of eighty to ninety per cent.

Spraying produces a coating more thorough and even than hand work. The coating is projected on the surface or object with force sufficient to enter small cracks and crevices ordinarily untouched. This insures an unbroken coating. Again, an intricate surface can be finished in approximately the same time as a flat panel of the same size, and without the accumulation of excess material in depressions or around small raised parts. This time saving is also true in the finishing of thin edges and corners where extra effort is needed with hand work. Sprayed coatings are smooth and uniform, without sags or runs.

Among some people the idea prevails that spraying means blowing on a smother of liquid coating. Such is distinctly not the case, as with suitable apparatus the flow is under perfect control, far more so than with a brush. Of course, either method requires a certain amount of skill but spraying can be far more easily and quickly mastered than brush work.

Fig. 265—Paint spraying in the body department of an automobile manufacturing plant.

In spraying, the object is to apply a fog-like spray of the coating until the fine heads of liquid coalesce and evenly cover the surface. Beyond this point a further application would cause runs and tears. It is a well-known fact that three thin coats are better and more durable than two thick ones even if the total amount of coating used in each case is the same. Spraying permits the exact gauging of the thickness of the coating to secure the best results, at the same time effecting maximum economy in the quantity of material used.

Spraying readily adapts itself to work in which part of the object is to be left untouched. All that is necessary is a mask or shield of the proper shape with some simple means for affixing it to the object. In painting gas meters, for example, it has been found a simple matter to mask the dials and name plates with sheet brass shields attached to spring clips. Another method is the employment of rubber cups which hold the mask by suction. Portable objects are usually placed on turn-table mountings for painting, avoiding the necessity of touching the object and permitting the speedy coating of all sides.

Where small objects are to be painted in quantities it is always advisable to provide a hood and an exhaust to carry off the fumes. This is essential to the health of the operators. Fig. 265 shows a typical installation in an automobile manufacturing plant.

While some have found it advisable to collect the surplus paint drawn through with the exhaust, such is the rare exception rather than the rule. There is, of course, some wastage of material but this is balanced by the fact that there is no evaporation or drying in the pots or absorption in the brushes. In selecting a ventilator it must be borne in mind that the slight amount of liquid carried along by the air will accumulate on the fan and possibly impair its operation. Manufacturers of spray apparatus either furnish or recommend hoods and exhaust apparatus for specific duties and it is always best to follow their suggestions. The volume of exhaust air required is merely enough to keep a steady current moving away from the workman.

Here it may be well to state that both paint manufacturers and spray manufacturers are always willing to give advice and suggestions about any specific problem and in the majority of cases will supply finish samples and estimates of the time, of cost, labor, materials and workmanship.

The air pressure required in spraying varies with the consistency of the material, its viscosity and thickness. Thin lacquers may be sprayed with a pressure of from five to ten pounds while very heavy materials may require pressures as high as eighty pounds. The air pressure to a certain extent determines the character of the finished job, low pressures being used for fine work and higher pressures where volume of output rather than quality of finish is desired. The lowest point at which the paint breaks up is best to use, as higher pressures are wasteful of material. Regulation of pressure is easily obtained by means of a reducing valve in the air line.

The volume of air required varies with different materials and the various size nozzles or spray tips used with them and also to a limited extent with the particular apparatus used. The spray tip used for varnishing, lacquering and similar fine work has an opening of from .04 to .18 inches and the average air consumption per spray is from one to three cubic feet per minute.

In laying out a spraying system particular care should be taken to entirely exclude dust, oil and moisture from the air supply. Dust will impair the finish, and oil or moisture seriously interfere with the smoothness and permanence of the coating.

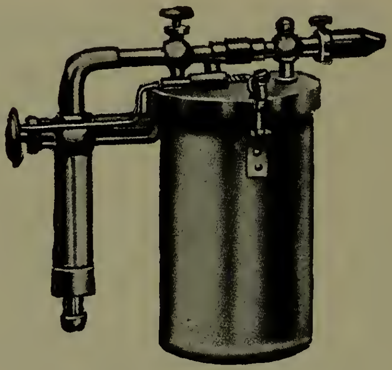


Fig. 266—Eclipse air brush.

Care should be taken in the selection of the compressor as one of inferior grade will surely cause trouble with the product. A machine of the plate valve type is perhaps the best for this purpose, as the correctly designed plate valve needs no lubrication. This being the case, cylinder lubrication can be closely regulated and the possibility of oil being carried into the air line minimized. The compressor intake pipe should be large enough to permit its being screened with the finest gauze, without reducing the necessary intake volume. An air filter of reliable make should be placed in the discharge line to trap any dust, oil or moisture carried in the air. When air is taken from the shop air supply these same precautions should in every case be followed.

The device used for spraying varnishes, lacquers, enamels, paints and the like is called an air brush—of which there are several types. One commonly used type has an attached point cup or reservoir (Fig. 266). Where a considerable quantity of material of one kind is to be applied the separate container type (Fig. 267) may be preferred. This type draws its supply from an elevated tank holding about five gallons. Where small quantities of material of different kinds and colors are to be successively applied a single air brush of the first type can be supplied with a number of interchangeable cups. When fluids of heavy body are used it is necessary to constantly agitate them to prevent 'settling out.' This is accomplished by an air agitator in the tank or cup.

The attached reservoir type of air brush may be classed as either low-pressure or high-pressure. In the first, air is admitted to the reservoir forcing the fluid out by air pressure. In the high-pressure type the blast of air past the tip of the fluid tube draws the paint up and out by vacuum. The low-pressure type is generally considered more economical in air consumption though higher in first cost.

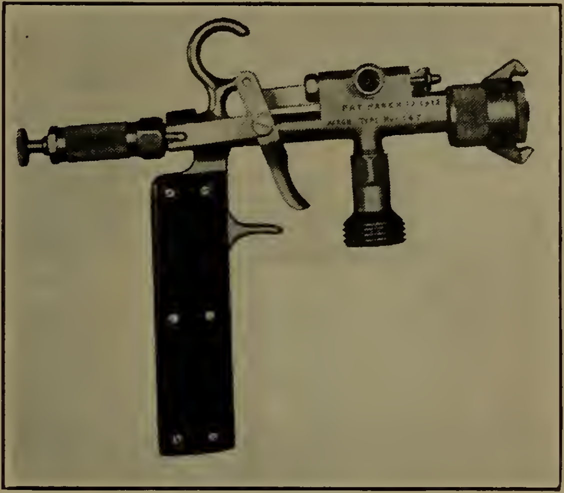


Fig. 267—Aeron piston type air brush.

The action of the air brush can best be explained by reference to the sectional diagram (Fig. 268). This is a typical device of the low-pressure type and is the product of the Eclipse Air Brush Company. Air is admitted at *H*, the supply being controlled by plunger valve *P*. Needle valve *V* admits a slight amount of air from *A* to reservoir *R*. This forces the fluid in the reservoir up the fluid tube *F* and out of the tip *T* where it is caught by the air blast from nozzle *N*, is atomized and projected on the work. Air nozzle *N* is adjustable and is locked in position by set screw *S*. Leather gasket *W* prevents leakage around the edge of the cup. When valve *P* is released an exhaust passage is opened permitting the escape of the air from the reservoir and sucking the fluid out of the tip and fluid tube.

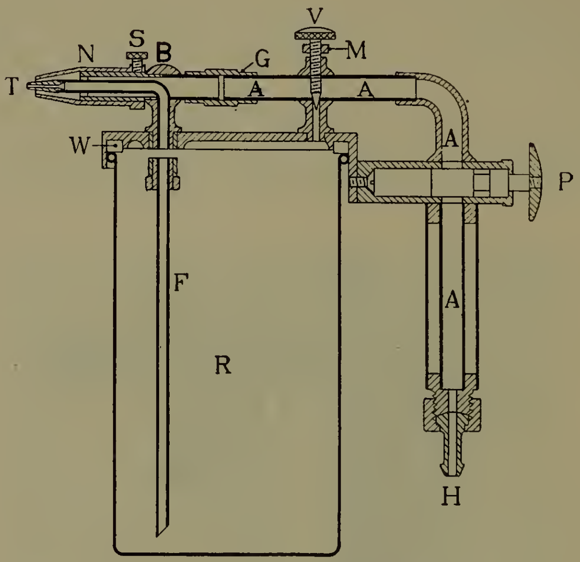


Fig. 268—Cross-section view of typical air brush.

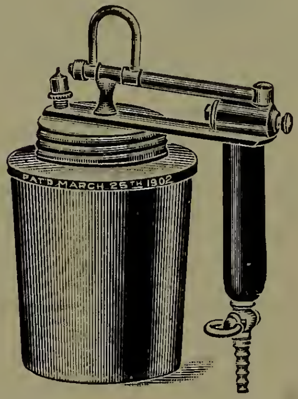


Fig. 269—Eureka air brush.

The air pressure in the reservoir *R* is regulated according to the consistency of the material used. A little experimenting on the part of the operator easily determines the best air pressure to secure proper flow from the tip, after which valve *V* is locked in position by knurled nut *M*.

Fig. 269 shows the Eureka Air Brush, an example of the high pressure, open tip type. This, as well as the other general types is to be had with a variety of spray tips and special adaptations for spraying different liquids.

The separate container outfit is best typified by the 'Aeron', manufactured by the De Vilbiss Manufacturing Company. Fig. 270 shows the pistol type air brush connected by flexible tubing to the elevated container and to the air supply. This shows the correct air piping arrangement with moisture trap, reducing valve, pressure gauge and air filter. At the right of the illustration will be noted an Air Duster or blow gun, a very efficient and handy means for removing dust particles prior to spraying.

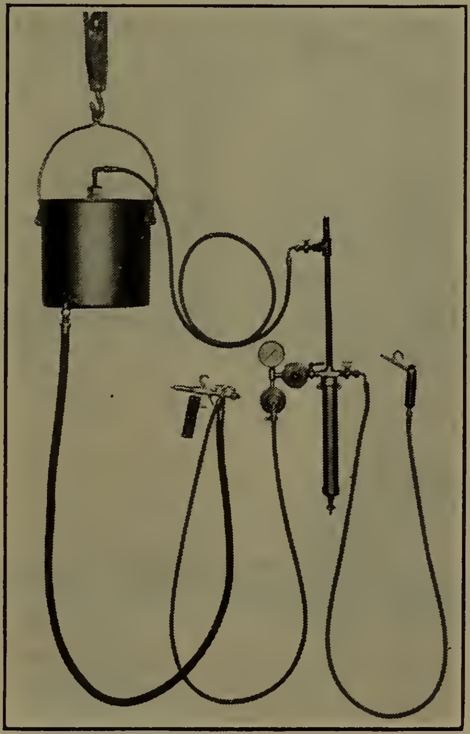


Fig. 270—Complete Aeron Spraying outfit.

The operation of the 'Aeron' is essentially the same as the inclosed tip, cup type air brush, except that the pressure feed of the latter has been replaced by a gravity flow from the elevated container. The trigger control is very easy to manipulate and very sensitive. The flow of material is automatically adjusted by varying the air pressure by means of the reducing valve. The elevated receptacle is equipped with an air agitator, connected to the pressure supply. This maintains the material in constant motion and prevents the settling out of the heavy pigments.

An air brush must be kept free from gummed accumulations, but its very simplicity makes this an easy task. A small amount of thinner or solvent sprayed through the tip will thoroughly clean the parts which have been in contact with the paint or other material. If desired, the air brush can be easily dismantled (Fig. 271), and the fluid tube and tip placed in a bath of whatever thinner is being used. With a little common-sense care the air brush should operate without any serious trouble.

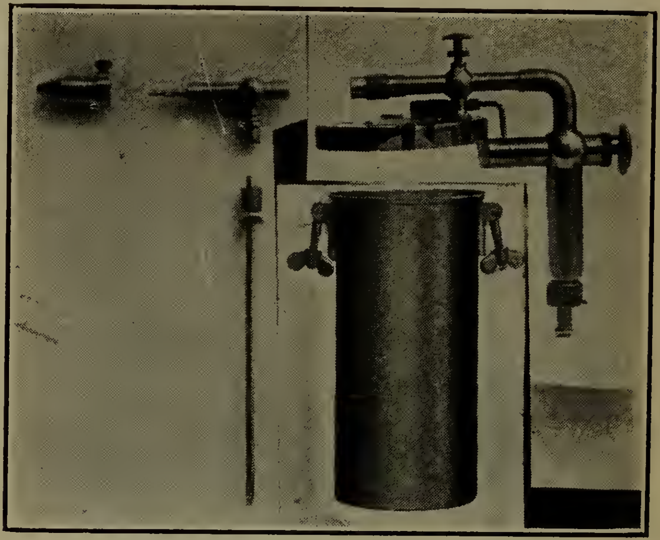


Fig. 271—Dismantled air brush showing simplicity.

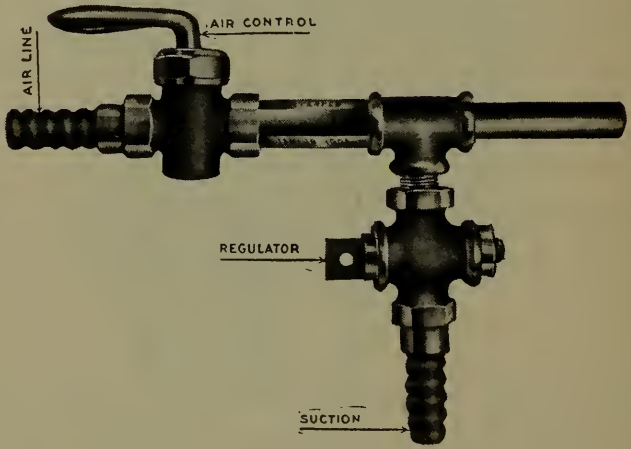


Fig. 272—Air brush for rough work.

For work of a more rough and ready nature the simple device (Fig. 272), is very efficient. It is particularly adapted to spraying whitewash on factory interiors, painting tank cars and work of similar nature. It finds use in foundry work, in spraying cores and blacking molds.

Paint, whitewash or other material is drawn by suction from an open pail or container and sprayed on the work in a blast of compressed air.

Special industries, such as munitions manufacture, bring into use devices which adapt the principles of the spraying apparatus described, to particular work.

Paint in bulk can be quickly and evenly mixed by compressed air. A length of pipe bent in a circle, having one end plugged and small holes drilled at 4-inch intervals, connected to the air line, will, if placed at the bottom of the mixing tank, agitate and mix the lead and oil or paste and oil in a manner as superior to other means as it is simple.

Concrete evidence of the scope and the decided economies of applying coatings by spraying will be found in the following briefly outlined

RECORDS OF PERFORMANCE

At the shops of the Chalmers Motor Company spraying, together with improved drying facilities, has reduced the time required to coat an automobile body with two coats of paint from forty-eight hours to two hours.

With a spray similar to that shown in Fig. 272 it is possible to apply a coat of paint to the body frame and trucks of a 50-ton steel coal car in thirty minutes, or a 12,000-gallon tank car in an equal time.

Fig. 273 shows the process of painting small machines with the air brush.

Six men with air brushes finish metal parts at the factory of the Empire Cream Separator Company, Bloomfield, N. J.—work that formerly required nineteen hand painters.

Tests made by a manufacturer of kitchen ranges show that one man with an air brush will coat 100 standard size ranges with air dry enamel while a hand workman does from 20 to 25.

Brass electric bulb sockets can be lacquered at the rate of 3,000 per day by a single air brush operator as against 500 to 600 by hand.

In applying rough undercoating or primer to five-passenger automobile bodies an operator can coat 20 per hour by spraying. Brush-coating a single body would consume an equal period of time.

Fig. 273—Painting small engines with air brush.

In munitions manufacture 16-pound high explosive shells can be enameled on the inside or lacquered on the outside at the rate of 400 to 500 per hour as compared with an output of 30 to 40 with hand work.

Klaxon Horns are being sprayed with one coat of baking japan at the rate of 600 per day, per operator. It is estimated that an expert brush workman could do no more than 100 in an equal time.

Stamped metal rims for buttons are sprayed on trays holding 1,000 each at the rate of 50,000 per hour.

A large manufacturer of brass bedsteads employs only ten sprayer hands in the lacquering department. This concern finishes 400 brass beds per day.

A manufacturer of lamp shades finds that a single air brush workman can white-enamel the inside of from 800 to 1,000 pieces per day or coat the outside of 800 with green enamel. In brushing, a workman who can turn out 200 per day is considered an expert.

A gas company handling from 900 to 1,500 five-light gas meters per 48-hour week finds that two men with air brushes can finish 30 meters per hour as compared with 3 by hand.

METAL SPRAYING. The recently perfected Schoop process for applying metal coatings by spraying occupies a unique position in the production of non-corrosive surfaces. It is capable of depositing lead, tin, zinc, aluminum, copper, nickel and their alloys on any coherent object, whether metallic or not. The thickness of the coating is under instant control and the application can be limited to any portion of the object.

Of the alternate processes electroplating is limited to the application of two or three elements on metallic or metalized objects of suitable size and shape; tinning, galvanizing and sherardizing are fusion processes and can only be applied to metallic objects not liable to injury or distortion by heat. These processes ordinarily necessitate the coating of the entire object, part of which deposit is often unnecessary. Coatings are irregular and hard to control as to thickness and quality.

The Schoop process involves the use of a 'pistol' (Fig. 274), air at 40 pounds pressure, a tank of hydrogen and one of some reducing gas, usually oxygen, acetylene or blau-gas. The 'pistol' is in reality a metal spraying air brush. A fine wire of any metal is fed into a reducing flame of ignited gas, being drawn through the pistol by an air turbine at a rate regulated to be exactly equal to the melting rate of the metal. As each molten drop is formed it is seized by the air blast and projected from the spray tip.

The metal leaves the 'pistol' in the form of a spray or fog of hot, impalpable particles moving at high velocity, which while still plastic, impact themselves upon the object. The minute metal particles enter the surface pores of the object and dovetail the coating to it, forming a firm, closely adherent film of metal. The supply of reducing gas is always maintained in excess of that of the oxygen and the metallic particles strike the object in the presence of the surplus reducing gas, eliminating the possibility of oxidation at the junction point and forming perfect metal to metal contact.

In coating metallic objects the degree of adherence is determined by the relative hardness of the coating and the object. The greater the difference and the more porous the object the greater will be the closeness of the union. Spraying is accomplished by passing the 'pistol' over the surface at a distance of about 5 inches, the operator's eye readily guiding the application. A single coating is about 0.001 inches thick. The thickness of the deposit depends upon the number of times the 'pistol' is passed over the surface but experiments have demonstrated that two-thousandths of an inch well impacted is as effective as a much thicker coating. A thin coat is more firmly adherent than a thick one, and of course more economical of metal.

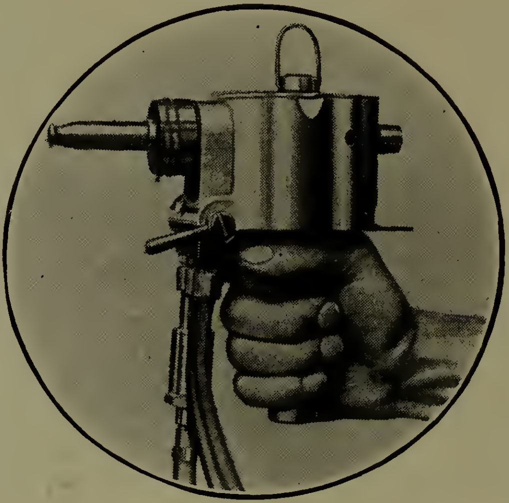


Fig. 274—Schoop Metal Spraying Pistol.

In the particular case of zinc a special apparatus has been devised to use the zinc dust which is a by-product of the smelters and much cheaper than the same metal in wire form. This device uses only one gas, ordinarily acetylene, instead of two. It takes advantage of the fact that metals in a very finely powdered state have many of the characteristics of a liquid. They flow easily, mix together like drops and unite under the influence of very little force.

The applications of the metal spraying process are varied and its uses are being extended more widely as its possibilities become more clearly understood. It is particularly effective in repairing defects in galvanized coatings, and copper coatings such as that on the familiar Prestolite acetylene tanks. In the electrical field carbon brushes and resistance rods are being coated with copper. Steel tanks are being protected from interior corrosion by lining them with a zinc coating. This is particularly effective in protecting the joints and seams as the sprayed coating is an unbroken film. Large gate valves are being similarly lined and the same is true of large gas and water mains. In this latter case lead is also used as a coating. Stove ovens are being effectively protected by spraying with aluminum, a light, cheap and non-corrosive coating that cannot be applied by any other method. See Fig. 275.

Fig. 275—Metal coating stove oven linings.

Bridge and structural steel work is being zinc coated after erection, effectively protecting both surfaces and joints.

It is useless to expect perfect adherence of enamel, japan, metal spray or other material or the permanent protection of the metallic surface if scale, rust, grease and dirt have not first been removed.

Pickling in acid solutions, tumbling barrels and wire brush cleaning are now considered less effective than sand blasting, in that by the former methods portions of intricate surfaces are often left untouched.

The most rapid and efficient cleaning can be accomplished by sand blasting. The greatest merit of the sand blast is that it removes from every portion of any surface—ornamental designs, angles, edges, joints—every trace of dirt, rust, grease and scale, and the bright metallic surface is everywhere exposed and perfectly cleaned. This is an ideal condition to secure strong adhesion of the coating so that it will as far as possible protect the metal.

In metal coating a preliminary sand blasting is a necessity. It opens up the minute pores of the metallic surface so that the metal spray can penetrate.

The methods of sand blasting, as applied to objects of various kinds, are described in Chapter X and need no further explanation here.

The coating to be used should be applied immediately after sand blasting and before any surface corrosion can take place.

CHAPTER XVII

PUMPING WITH COMPRESSED AIR

Compressed air is employed extensively for pumping water and various other liquids and semi-liquids used in the industries.

There are four general methods of pumping by means of compressed air in common use, which may be classified as follows:

1. The air lift pump.
2. The pneumatic displacement pump.
3. The return air system of pumping.
4. The reciprocating steam pump operated by air.

The Air Lift Pump. The air lift is peculiarly adapted for raising water from deep driven wells, although it is also frequently applied successfully for raising water from shallow wells.

The air lift is characterized by extreme simplicity as there are no moving parts whatever in the well, simply the water supply pipe and the air pipe which carries the air to the bottom of the water supply pipe. The water from the air lift system is as pure as the source of supply, if not actually purer, as aeration of water results in purification. The water is also slightly cooled due to the expansion of the air in contact with the water. With the use of the air lift the well is steadily improved and the flow is increased. With the deep well pump of the rotary or reciprocating type foreign matter, as sand, must be screened off and in time the well becomes clogged. The air lift draws out the sand and sludge, enlarging the water-bearing cavities and so increases the flow.

It is natural that at first the air lift system should have been lacking in the efficiency now possible. Its rapid growth in favor everywhere shows a foundation of solid merit and an adaptability to certain conditions which no other pumping system can meet so well. A certain prejudice exists that the system is lacking in economy, based on results obtained with improper methods of well piping in connection with inefficient compressors. The superior air compressor of today operates with a half or quarter of the fuel formerly required for a given power. Refinements in well piping and a better understanding of conditions have reduced both the pressure and the volume of air needed.

The initial cost of the air lift in small installations, say under 300 gallons per minute, is slightly in excess of that of other competitive methods; from 300 to 800 gallons the cost is about equal, and above this limit the air lift has a decided advantage as to cost. We are considering now, of course, the total cost of plant including the wells, this difference in favor of the air lift being due to the fact that fewer wells are required for an equal amount of water and assurance of continuous operation.

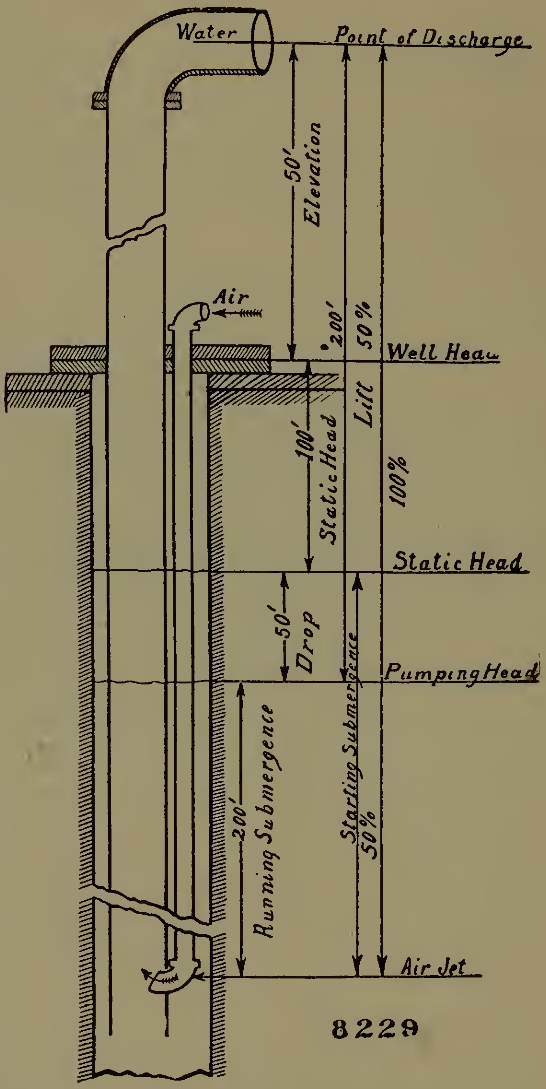


Fig. 276—Diagram of side inlet type of air lift.

Fig. 276 shows the principle of the air lift and indicates the various factors that enter into a typical air lift proposition. In this case the 'lift', that is the total vertical height from the pumping level of the water in the well to the point of discharge, is assumed to be 200 feet and the 'submergence', that is the depth that the air pipe is submerged below the pumping level of the water in the well, is assumed to

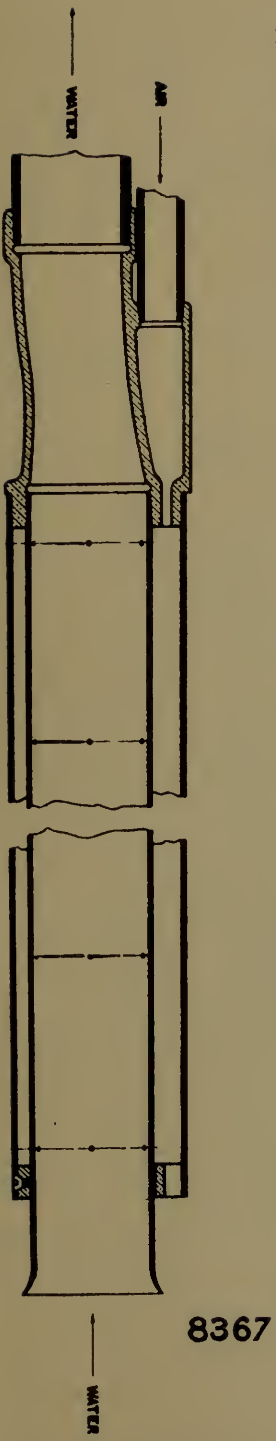


Fig. 277—Typical foot-piece for side inlet type of air lift.

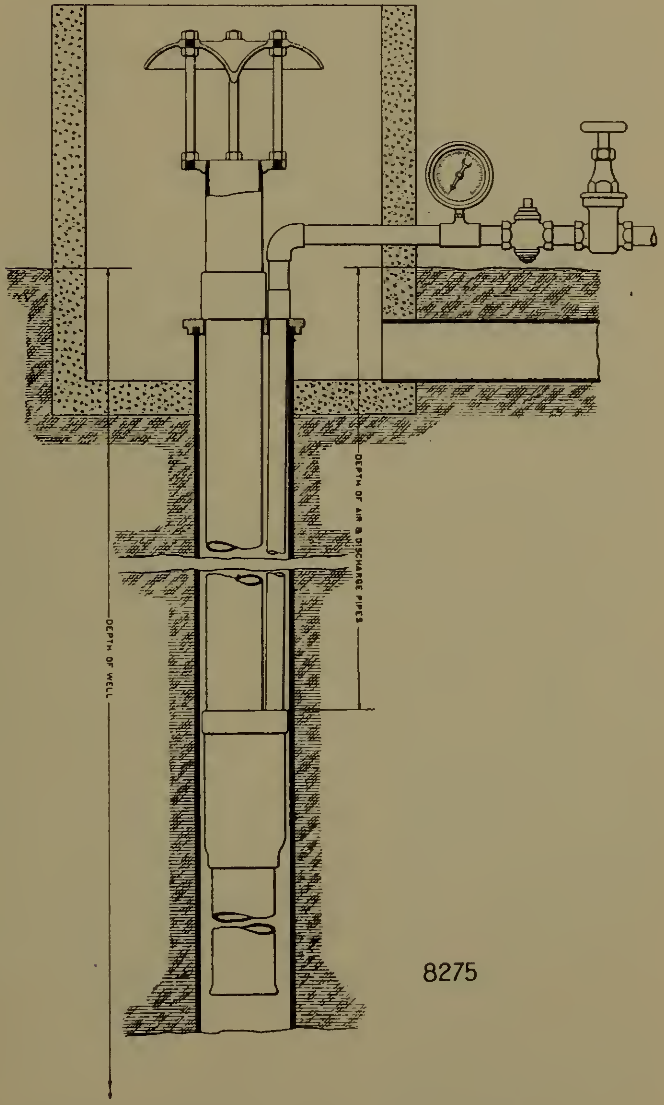


Fig. 278—Diagram of complete air lift well with umbrella discharge.

be 200 feet. The percentage of submergence is the percentage of the total length of pipe which is submerged in the well water when pumping down to the point of air admission, and in this case is 50 per cent. The necessary percentage of submergence varies with the lift; low lifts require proportionately more submergence than high lifts, or in other words, the necessary submergence decreases as the lift increases. The range of these percentages is found within the following limitations:

For lifts of 20 feet,	66% submergence
For lifts of 500 feet,	41% submergence

In the diagram of Fig. 276 it will be seen that when pumping, the water level recedes 50 feet from its normal level, so that the starting submergence is 50 feet greater than the running submergence and consequently a proportionately higher air pressure is required to start the air lift.

In operation, the weight of the column of water outside of the eduction pipe overbalances the combined weight of the column of mixed air and water and forces it up the eduction pipe and out of the discharge. The tendency of the air bubbles to rise results in a certain loss of efficiency for in slipping through the water the bubbles do not assist levitation but tend to retard it. Hence it is customary, in the improved forms of air lifts, to employ a foot-piece which divides the air into very small bubbles before mixing it with the water. These minute bubbles ascend through the water at a much slower rate than large bubbles and hence cut down the slippage loss very materially. Fig 277 shows a type of foot-piece operating on this principle suitable for use with the air lift shown in Fig. 276, as indicated in the diagram Fig. 278. The arrangement of the perforations in the foot-piece permits only as much air to be blown into the water column as will be sufficient to keep this column moving upward to the point of discharge. When the pump is first started it is likely that in order to blow out the column en masse most or all of these perforations are in action and an uneconomical condition exists momentarily. After the first impulse, however, the relation between the head of water, the diameters of the pipes and the air pressure establishes a state of equilibrium which automatically causes the water to cover some of the lower perforations and in this way to restrict the admission of compressed air to that only which is required to keep the aerated column moving upward.

Fig. 279 shows a type of air lift in which the air pipe passes through the center of the water discharge pipe. This form, known as the central air pipe system, is used instead of that shown in Fig. 276, known as the side inlet pump, when it is desired to obtain the greatest possible output for a given size of well

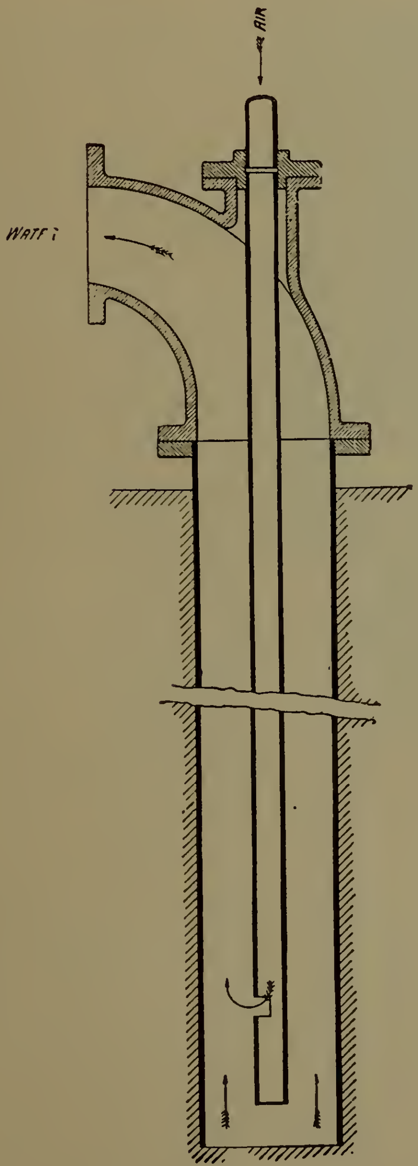


Fig. 279—Diagram of central inlet type of air lift.

Fig. 280—Typical foot-piece for central inlet type of air lift.

casing. Fig. 280 illustrates a type of perforated foot-piece used with this system. It is essentially the same as that shown in Fig. 277, and requires no extended description. In both of these foot-pieces there is no opportunity for particles of foreign matter as scale in the air pipe to clog the foot-piece as they will settle through the open end of the foot-piece into the bottom of the well.

Fig. 281 shows an arrangement which is especially suited for low lifts where the well pressure is strong.

In the operation of air lifts it has been difficult to transfer water for any distance horizontally or at an angle, due to the tendency of the air to separate from the water under such circumstances and rise to the upper side of the pipe, thus impairing the efficiency very materially. The booster is a device recently perfected which overcomes this difficulty and permits the conveyance of water for a considerable distance horizontally as well as vertically. Fig. 282 shows an exterior view of a typical air lift booster and Fig. 283 shows diagrammatically the arrangement of a booster in the well head. Here two forms of discharge pipe are indicated leading to the water storage tank, one having a deflector or umbrella type of discharge head and the other having a plain return bend discharge.

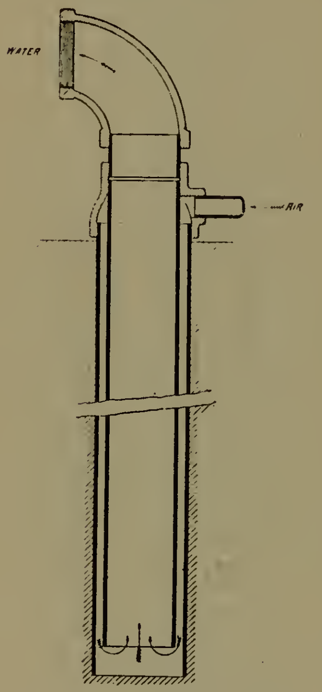


Fig. 281—Saunders air lift system.

The mixed air and water, as delivered by the air lift, separates in the booster and the pressure of the air is utilized to do the work. The operation is simple. The amount of air within the booster is controlled by the water level. An automatic valve operates so that as the water rises the valve is closed and a pressure is built up in the booster, and vice versa, as the water falls, the valve opens to allow the air to escape from the booster. The air either passes to the atmosphere or to the intake side of the compressor, as may be desired. In returning the air to the compressor, care should be taken to separate as much moisture as possible from it before it is taken into the compressor.

The most important feature of the booster is the advantage gained by being able to deliver the water at the desired place, without the extra expense of additional pumping equipment.

The compressor to operate an air lift system may be located at a considerable distance from the source of water supply and a single compressor may be used to operate a number of wells scattered over an extensive area. The advantages of controlling all the wells from some central point and having the compressor where it can receive proper care, for instance in a power plant, are too apparent to require further comment.

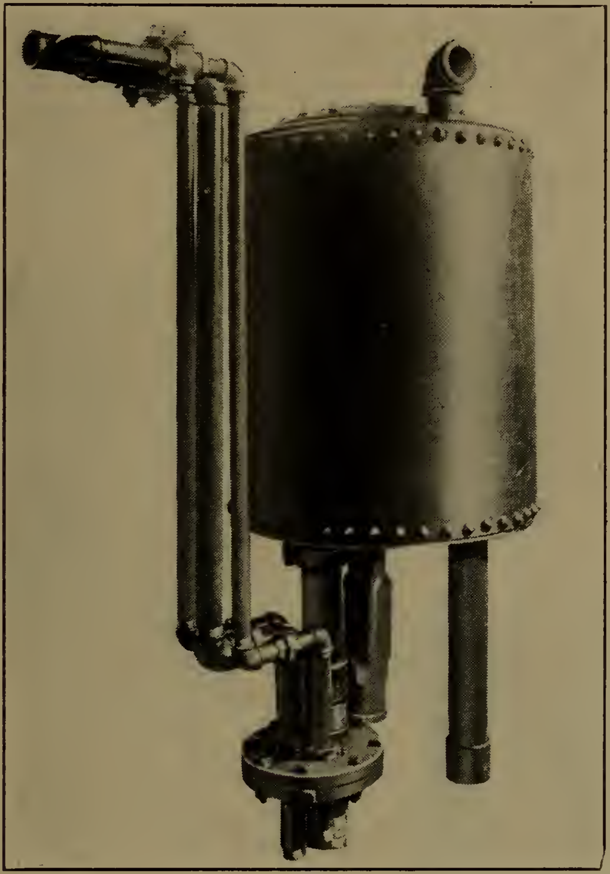


Fig. 282—Air lift booster.

Fig. 284 shows an application of the air lift principle for transferring chemical solutions from one vessel to another in a factory. The process calls for the solution to fill first one vessel, remaining there a definite length of time and then draining off, later to fill the other vessel. The two vessels are thus filled and emptied alternately.

These vessels, each of about 55 gallons capacity, drain into a barrel about 2 feet, 6 inches deep, which is set flush with the floor. Through the bottom of the barrel a hole about 4 inches in diameter is bored, and a pipe of this size is carried down for about

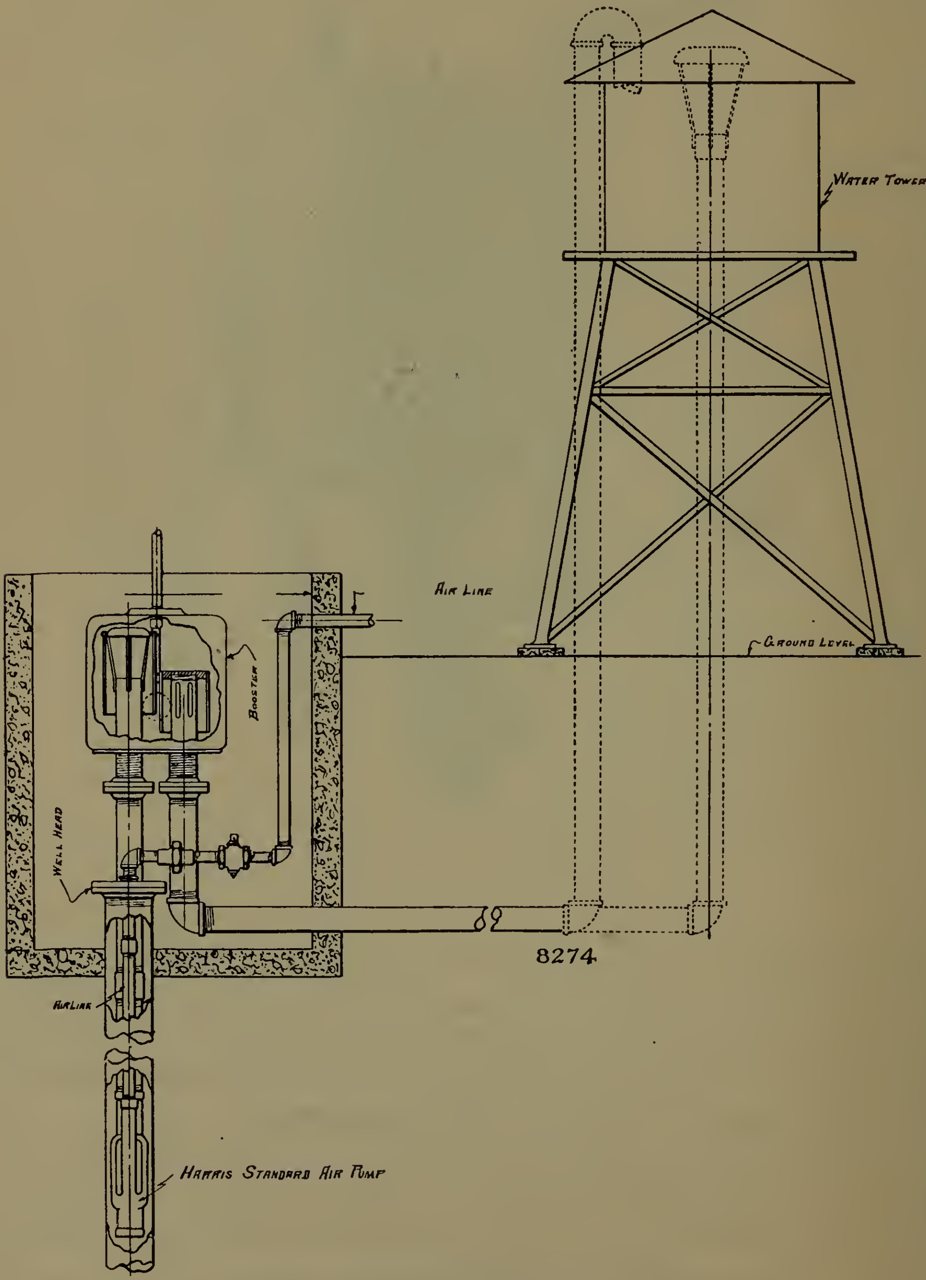


Fig. 283—Diagram of air lift and booster.

8 feet. This gives the necessary submergence, and the hydrostatic pressure of the liquor in the barrel forces the lighter column of mixed liquor and air up to the kettle. The total lift from the bottom of the pipe to the discharge is 13 feet, 6 inches. Each of the vessels is filled fifteen to seventeen times per day by this little lift, each operation requiring about two and one-half minutes. The saving in liquor by this scheme amounts to about three-quarters of a barrel per day, and this, together with the saving in manual labor forms quite an item in the day's work.

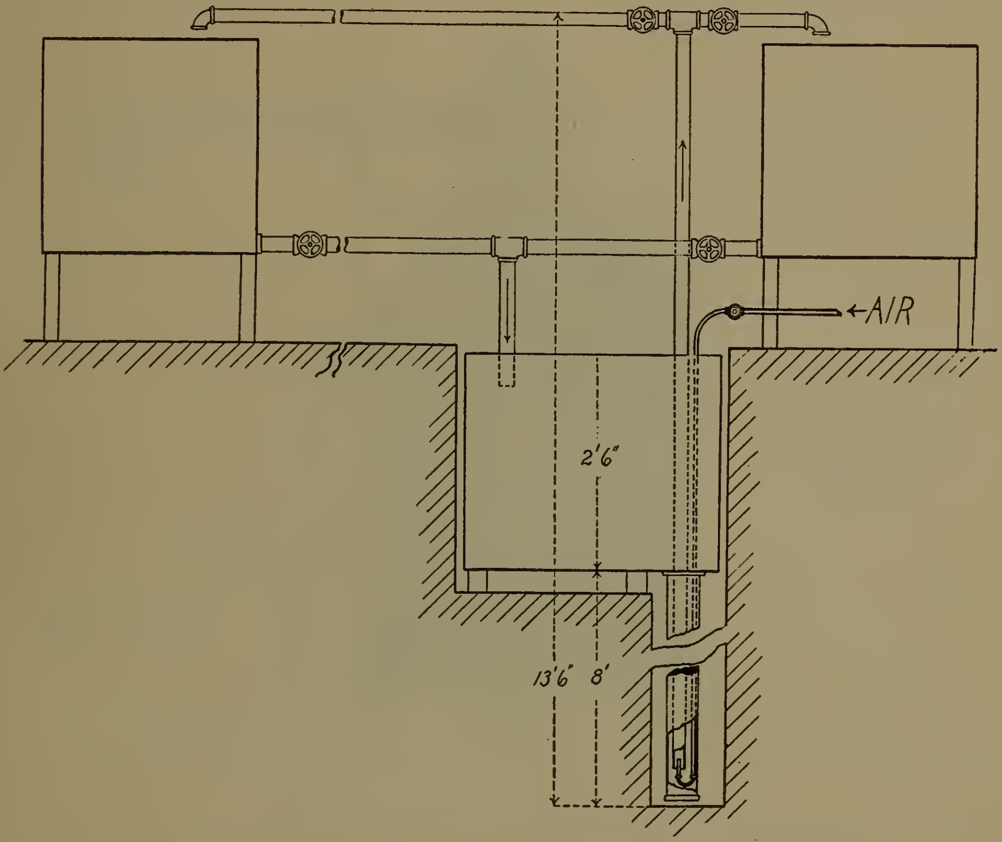
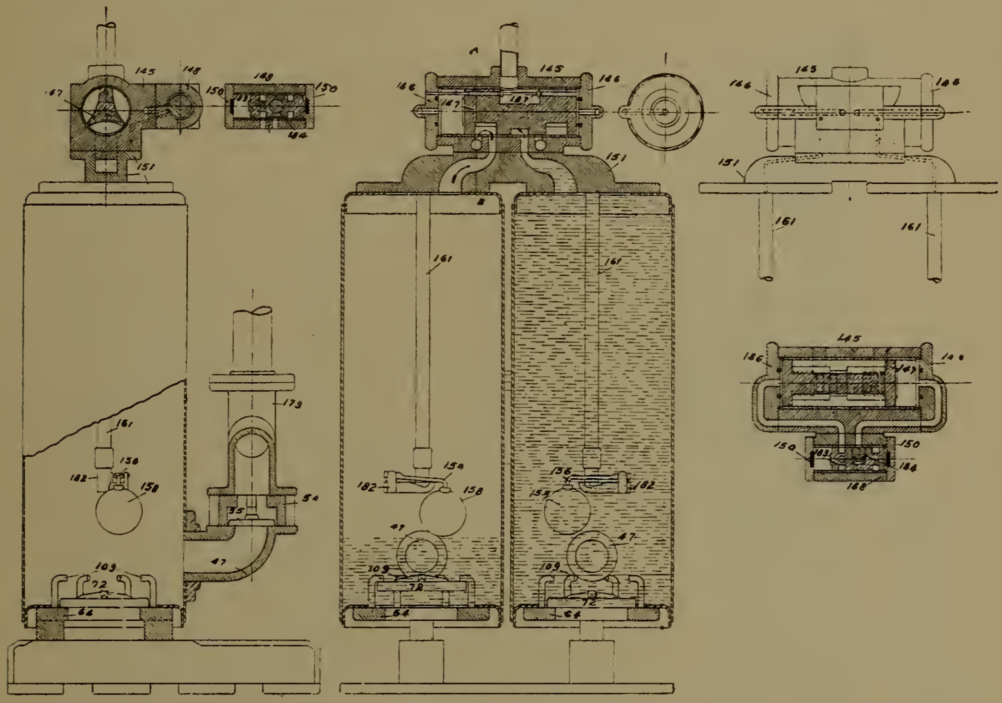


Fig. 284—Diagram of air lift employed for transferring chemical solutions.

The Pneumatic Displacement Pump. The pneumatic displacement pump is suitable for raising large or small quantities of water or other liquids over moderate lifts. In this type of pump the air pressure acts directly upon the fluid pumped without the intervention of pistons or other mechanical parts. The pneumatic displacement pump (Fig. 285) must be placed so that fluid will flow into it by gravity. This may be accomplished by submerging it in a stream or in a well. Beyond this limitation, it is an extremely simple and convenient means of supplying water. The simplest form would be a single cylinder having the valves controlled by hand. Such an arrangement would do for a small intermittent supply, but for a continuous supply twin cylinders are employed, as represented in Fig. 286. Air pressure is always on one or the other of the tanks and while one is filling the other is discharging, resulting in an absolutely steady stream. The copper float located in the bottom of each tank operates the main air valve so as to put air pressure on the opposite tank when the water has receded to a given level.

Fig. 285—Pneumatic displacement pump.

This type of pump uses air non-expansively but, due to its extreme simplicity, is considered a satisfactory and efficient way of pumping under moderate heads, say up to 100 feet. Regarding the efficiency of the displacement pump, the case of a pump supplying 150 gallons per minute through a 4-inch main 1,000 feet in length, and operating against a 60-foot lift, will be cited. Making liberal allowances for the loss of air pressure and allowing for losses in the compressor, the total efficiency of the system came to 33 per cent. This figure is the ratio of the theoretical horse power required to raise the water as compared to the indicated horse power in the steam cylinder of the compressor. Putting it another way, it is the ratio of the amount of power that ought to be required for conveying and raising the water (with pumping machinery 100 per cent. efficient) as compared to the amount of power that was available in the actual steam consumed in running the compressor for the pumping operation.



SECTION OF VALVE THROUGH A B AND PUMP THROUGH DISCHARGE CHECK VALVE

CROSS SECTION OF PUMP

Fig. 286—Details of pneumatic displacement pump.

Any kind of water may be pumped, whether muddy or gritty, without materially affecting the valves. In fact this device has been successfully used for pumping sewage, heavy chemical solutions and semi-fluids. Neither lubrication nor packing is necessary and there are no restricted valves or water passages likely to clog up.

The Automatic Montejus (Fig. 287) is an apparatus working on the displacement principle used for pumping chemical solutions. The liquid flows to the machine by gravity and enters at 'A' through a ball check valve. Assuming the tank 'D' empty, the full weight of the lower float 'B' keeps the exhaust valve 'E' open so that the liquid can easily run into the tank. The buoyancy of float 'B' alone is not sufficient to open the air valve 'H' until the liquid has ascended to the upper float 'C'. The combined action of these two floats shuts the air exhaust valve 'E' and opens the compressed air inlet 'H'. The air pressure discharges the liquid through the ball check valve and discharge pipe 'G'. The liquid recedes below 'C' but not until float 'B' has been partly uncovered is the weight sufficient to shut the compressed air inlet valve and open the exhaust valve. When this occurs, the conditions are the same as at starting and the pumping operation is repeated. Air pressures of from 30 to 70 pounds have been used with this apparatus.

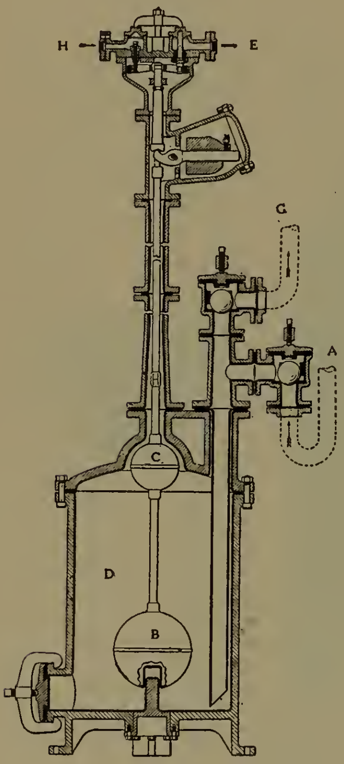


Fig. 287—Automatic Montejus.

Fig. 288 shows diagrammatically the method employed in a large factory for elevating acid by air displacement. Heavy commercial oil of vitriol is raised and the correct quantity is allowed to flow into a vat, partially filled with pure water, after which a small quantity of hydrochloric acid is added by hand from a carboy. The sulphuric acid is unloaded from the tank car (capacity usually about 5,000 gallons), with the aid of compressed air. Fig. 289 is a view of the air compressor and controlling valves located near the vats. This air compressor has a displacement of 15 cubic feet of free air per minute and operates at about 40 pounds air pressure. The compressor discharges into an enlarged pipe length which acts as a receiver. The tank car is connected with the acid reservoir tanks (the latter being provided with air vents), and air pressure of about 15 pounds per square inch is admitted to the top of the tank. It takes about two hours to empty the car.

There are four heavy iron tanks each with a capacity of 3,500 gallons. Pipes lead from the bottom of these to the top of a

100-gallon supply tank placed on a lower level. In each of these connecting pipes is a check valve to prevent the acid from returning to the large tanks. Leading from the top of the small tank is an air pipe. Normally this is used as a vent to allow the acid to flow into the small tank and fill it. When a charge of acid is wanted, this vent is closed by a valve near its outlet and air pressure is put on this line by opening the proper valve. The acid immediately begins to flow from the bottom of the 100-gallon tank up the line to the vat, a height of about 40 feet, it taking about five minutes ordinarily to pump the 100 gallons. This arrangement has proven ideal for the purpose of pumping acids as there is no mechanism to come in contact with the acid and get out of order. Pressure is put on the line only when actually pumping and then this pressure is on only the small tank. Another advantage is in having the control where the acid is used. The flow of acids from the large tanks to the smaller ones is entirely automatic and reversal cannot occur.

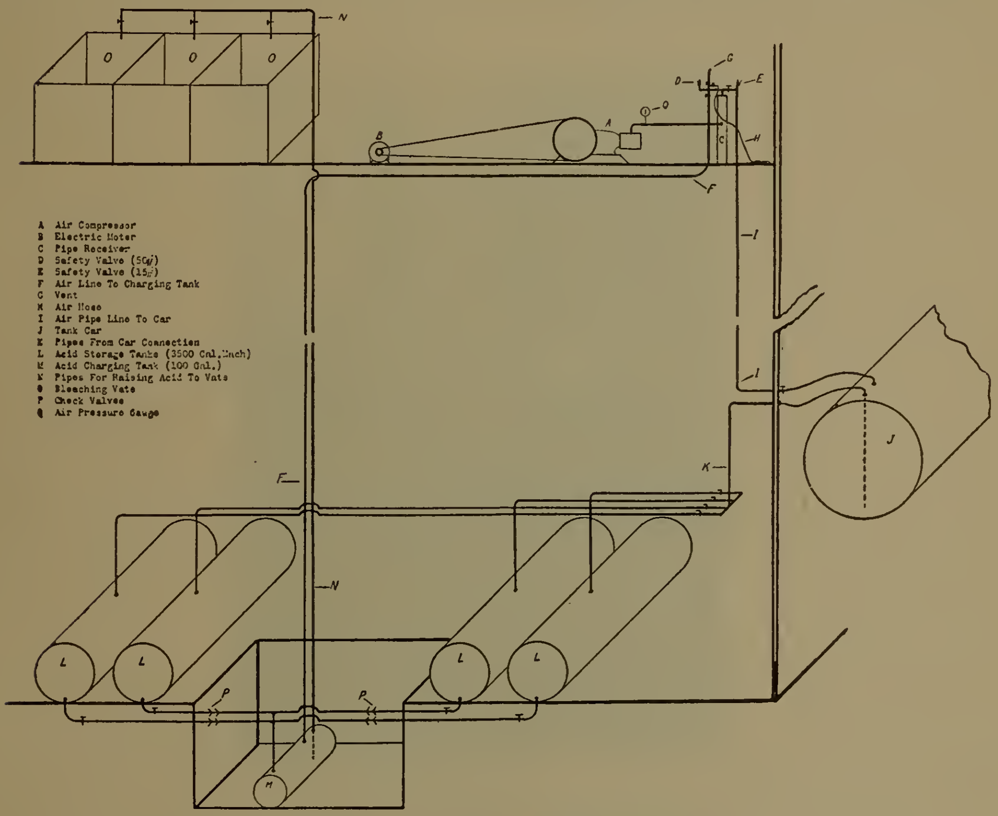


Fig. 288—System for storing and raising acid.

Fig. 290 shows a device known as an acid egg or acid elevator which is useful for pumping acid or corrosive solutions in comparatively small quantities. Acid is admitted through the opening on the upper right side and the cock is closed. Upon admitting air pressure through the stop cock on the left-hand side, the acid is forced up the dip arm which extends to the bottom of the vessel.

The contents of barrels or tanks, such as oils, acids or other fluid or semi-fluid substances, may be easily removed with the aid of compressed air. One very convenient arrangement for this purpose is described in *Power* from which we have reproduced Fig. 291. Care must be taken to avoid using excessive air pressure which might burst the barrel. The illustration shows how the pipes and fittings were assembled to form the pumping rig. The smaller pipe extends through the reducing tee into the bottom of the barrel. The nipple screwed into the lower end of the reducing tee screws into the hole in the barrel and air is admitted through the side of the tee passing between the nipple and the discharge pipe into the barrel.

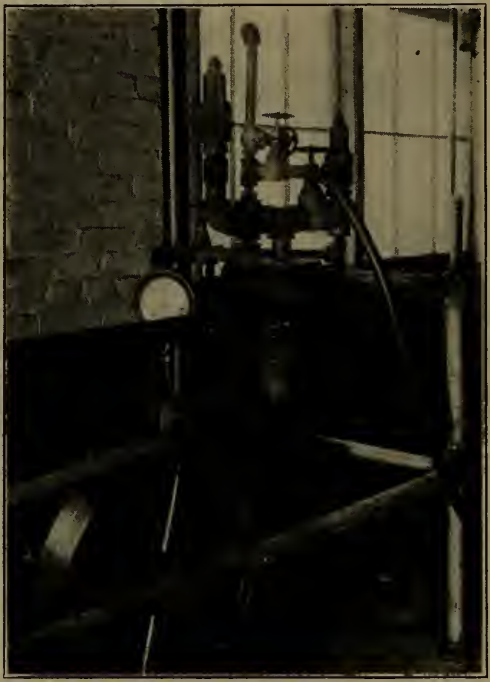


Fig. 289—Air plant and controlling valves for system shown in Fig. 288.

The pneumatic displacement principle is most advantageously employed for discharging waste products of a plant. These often drain by gravity to a sump or other low collecting basin situated below the sewer level and it becomes necessary to elevate them a few feet so that they will drain away by gravity. The fact that they usually contain considerable quantities of solid matter in suspension and are often corrosive in character makes the ordinary type of reciprocating pump altogether unsuitable for handling them. Several special appliances, known as sewage ejectors, have been developed for this service. One type, known as the Shone ejector, is shown in section in Fig. 292. Sewage is admitted through the inlet pipe, 'A,' gradually rising in the ejector until it reaches the under side of the bell 'D.' As the sewage continues to rise the buoyancy of the bell causes it to rise and open

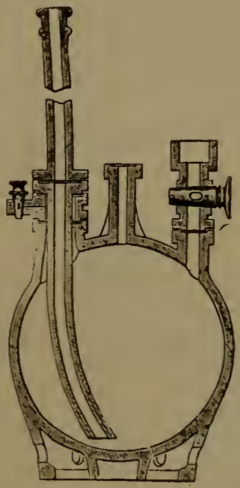


Fig. 290—Acid elevator.

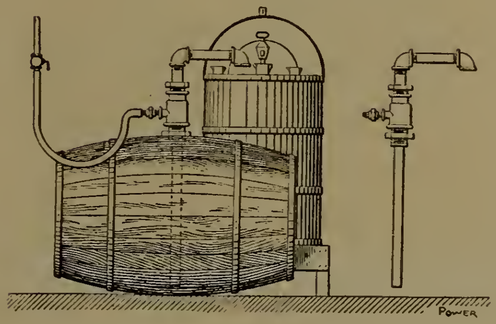


Fig. 291—Discharging contents of barrel by air.

the compressed air admission valve 'E' through the medium of the spindle attached to the bell. Air pressure is admitted on top of the contents of the ejector, the check valve in the inlet closes, that in the outlet pipe 'B' opens, and the sewage is forced out through 'B', which communicates directly with the gravity sewer. As the sewage passes out, its level falls until the cup 'C' is left full of liquid unsupported by the liquid pressure, whose weight causes the cup to descend, pulling down the bell and spindle, thereby reversing the compressed air admission valve, first cutting off the supply of compressed air, and then opening the exhaust valve through which the air in the ejector exhausts down to atmospheric pressure. The cycle is then repeated, the ejector continuing to fill and discharge automatically so long as there is liquid to pump.

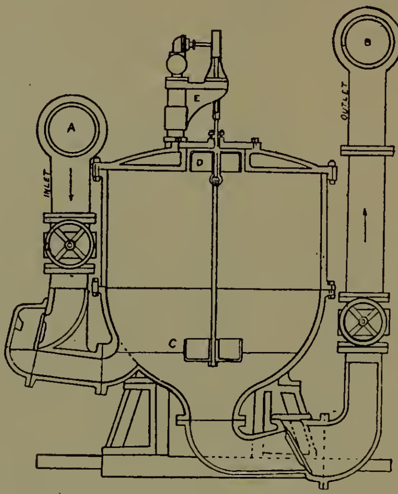


Fig. 292—Shone ejector.

The Return-Air System. The principal difference between the displacement pump and the return-air system is that the former method releases the air to atmosphere at practically full pressure after the pumping action, whereas the latter system returns this air to the compressor to be used over again. The return-air system therefore conserves most of this potential energy, whereas the displacement system throws it away. As a result the return-air system will show an average efficiency of about 55 per cent.

The essentials of the system are an air compressor driven by any convenient motive power; an automatic reversing switch in the compressor room; two air lines, each leading from the compressor through the switch to one pump tank; two tanks submerged in the fluid pumped, or within easy range of syphon action. Provision is, of course, made for automatically replacing the air which may be lost in the cycle by leakage, absorption, or in the operation of the switch. The single disadvantage of the system, as compared with the pneumatic displacement pump, is that a separate compressor must be used for the return-air pumping and it cannot be used for other purposes while pumping.

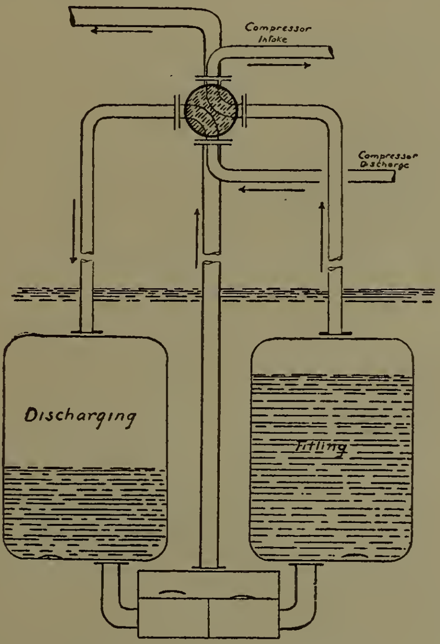


Fig. 293—Return-air system.

The principle of the return-air system is very simple. Compressed air is admitted to a tank full of fluid, forcing the fluid out through a suitable discharge pipe, its return being prevented by a check valve. The air which has displaced the fluid from the tank is then drawn back through the air line and switch, through the compressor intake valves, the compressor cylinder and the discharge valves, until equilibrium is secured throughout the system which then contains a charge of air at a certain pressure above atmosphere. This equalizing operation takes but a short time during which the compressor operates at no load, pressures being balanced on both sides of its piston. The moment that equilibrium is attained the compressor takes up the load, compressing the air in the second tank and drawing its intake, already at high pressure, from the first tank and pipe line. As pressure increases in the second tank the fluid is discharged, while as pressure diminishes in the first tank, the fluid enters.

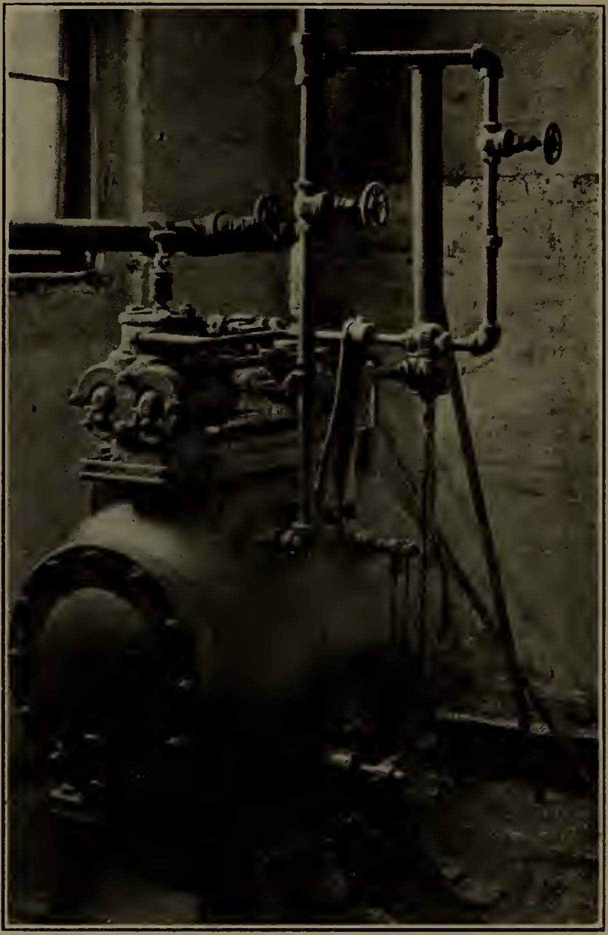


Fig. 294—Pump operated by compressed air for pumping oil.

The cycle of operations will be readily understood from the diagram, Fig. 293.

Steam Pumps Operated by Air. Ordinary steam pumps can be operated by compressed air for pumping water but are uneconomical and stand in an unfavorable light when compared with the more usual means for pneumatic pumping. Of course, occasions arise when a steam pump can be converted to such use advantageously, for instance in an emergency or in isolated locations, but generally speaking such a course is inadvisable. An example is illustrated in Fig. 294. This is a small reciprocating steam pump for supplying crude oil to burners. It pumps the oil into the chamber beneath the pump proper, where the oil is subjected to the pressure of compressed air which is admitted to the top of the chamber. In this way any fluctuations caused by the pump are equalized, insuring a steady flow of oil.

There are many pumping operations like this one where compressed air is the ideal source of power. The simplicity and certainty of operation by compressed air far outweigh any other consideration. The small amount of power required for operation makes the steam or air consumption of secondary importance and, in fact, in small pumps of this character it is probable that even on the basis of the cost of power the air operated pump would often have the advantage.

AGITATING LIQUIDS. In certain processes the solution must be agitated. For such purposes air agitation is often superior to mechanical means of stirring. It does not introduce any injurious foreign substances, as dirt, oil or grease, as a mechanical stirrer might do, and in some processes the oxidizing effect of the air may be turned to direct account.

Agitation by means of compressed air may be accomplished in one of many ways, as by inserting a jet downwards in the midst of the material or by arranging a set of jets around the edge of the tank to force the air into the body of the material. If gentle agitation is desired, this can easily be accomplished by laying one or more perforated pipes on the bottom of the tank and connecting same with a source of compressed air. In this case it would be desirable to have the perforations facing downwards not only to assist in spreading the rising bubbles of air, but also to prevent the solution from entering the air pipe when the air pressure is off and perhaps clogging the perforations. The perforations nearer the inlet should be made smaller or spaced further apart than those further away as otherwise the agitation might be more violent in that section than elsewhere.

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