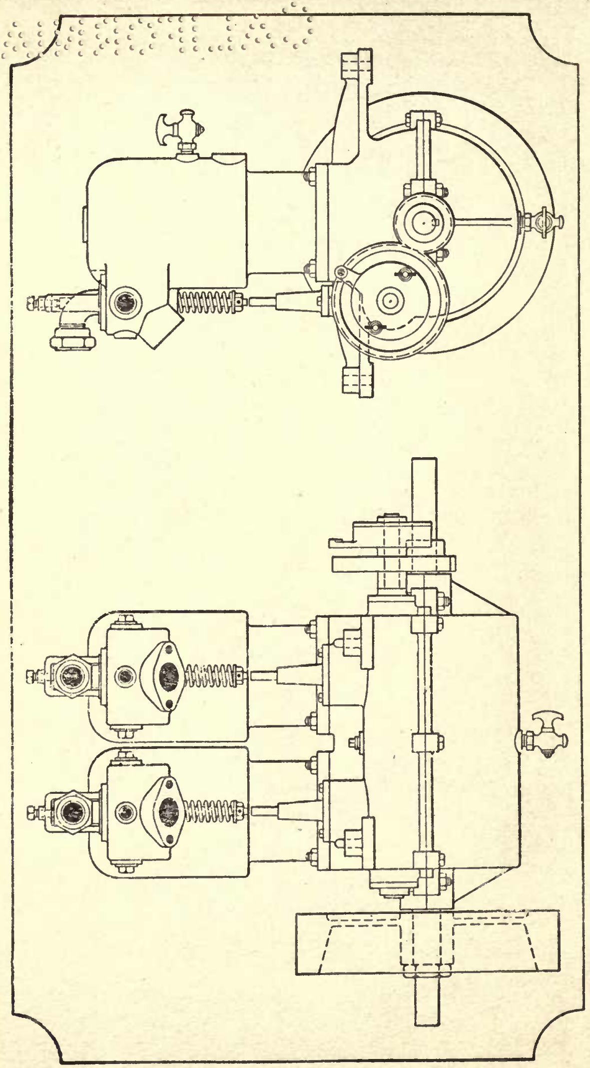
PRACTICAL GAS AND OIL ENGINE HAND BOOK

STATIONARY, MARINE AND PORTABLE GAS AND GASOLINE ENGINES

BROOKES



THE PRACTICAL

Gas and Oil Engine Hand-book

A MANUAL OF USEFUL INFORMATION ON THE CARE, MAINTENANCE AND REPAIR OF GAS AND OIL ENGINES

By

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PREFACE

This work gives full and clear instructions on all points relating to the care, maintenance and repair of Stationary, Portable, Marine and Automobile, Gas and Oil Engines, including How to Start, How to Stop, How to Adjust, How to Repair, How to Test, and has been written with the intention of furnishing practical information regarding gas, gasoline and kerosene engines, for the use of owners, operators and others who may be interested in their construction, operation and management.

In treating the various subjects it has been the endeavor to avoid all technical matter as far as possible, and to present the information given in a clear and practical manner.

THE AUTHOR.

Gas and Oil Engine Hand-book

Actual Horsepower. The expression actual horsepower is equivalent to brake horsepower and is used to designate the power which an engine develops at the driving pulley.

The actual or brake horsepower of an engine is obtained by means of a Prony brake or a dynamometer which gives the actual work or performance of the engine in foot-pounds for any given length of time.

Anti-freezing Solutions. To prevent freezing the water in the jacket when the engine is not in operation in cold weather, solutions are used, notably of glycerine and of calcium chloride. The proportions for the former solution are equal parts of water and glycerine, by weight, for the latter, approximately, one-half gallon of water to eight pounds of calcium chloride, or a saturated solution at 60 degrees Fahrenheit. This solution is then mixed with equal parts of water, gallon for gallon. Use the chemically pure salt only, avoiding the use of the crude calcium chloride or chloride of lime.

Another solution, which is recommended by other authorities, should consist of a mixture of water and glycerine, the latter being about 30 per cent of the former by weight, and adding to this mixture two parts, by weight, of carbonate of soda. This liquid should be entirely drawn off once a month.

Backfiring. Its principal cause is a prolonged combustion of the previous charge. When the charge entering the cylinder does not contain the proper amount of fuel it makes a slow burning mixture. This mixture may be so slow in combustion that it continues to burn not only during the working stroke, but also during the exhaust stroke of the piston, and there still remains enough flame in the cylinder to fire the fresh charge being drawn into the cylinder.

Any projecting point in the valve chamber or deposits of carbon in the cylinder may become heated and serve to ignite the incoming charge.

Regulating the fuel or air supply will remedy the backfiring if caused by a weak or a too strong mixture. If this does not remedy it, deposits of carbon or projecting points should be looked for and removed.

Bearings. Plain-bearings are almost invariably used in the construction of gas and oil engines on account of their simplicity, ease of renewal and practically inexpensive construction. Figure 1 shows a form of crank shaft bearing much used by the builders of stationary gas and oil engines.

For plain-bearings, the shafts of which are continuously running at a high rate of speed, the working pressure per square inch should not exceed 400 pounds. As the arc of contact or actual bearing surface of a journal-bearing is assumed as one-third of the circumference of the journal itself, the pressure per square inch upon a bearing is therefore equal to the total load upon the bearing, divided by the product of the diameter of the journal into the length of the bearing.

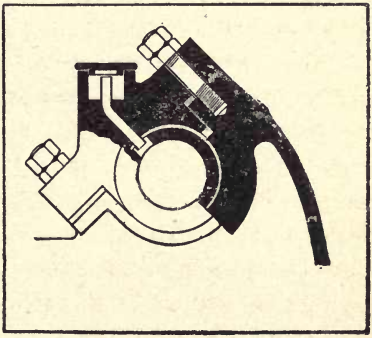

FIG. 1
Crank-shaft journal box for gas or oil engine, with wick-feed oiling device.

Let D be the diameter of the journal or shaft at its bearing, and L the length of the bearing, if W be the total load or pressure upon the bearing and P the pressure in pounds per square inch of bearing surface, then

$$P = \frac{W}{D \times L}$$

The crank shaft bearings are usually set at an angle of 45 degrees, they should be heavy, of ample area, and readily adjustable. Outside bearings should be fitted to large engines where the crank shaft overhangs. The connecting-rod bearings should be made of phosphor bronze, and be made adjustable for wear.

A rule followed by some manufacturers is to make the diameter of the crank shaft from one-third to one-half that of the cylinder diameter.

Bearings, Heated. Heated bearings may arise from a variety of causes, such as:

Bearings of insufficient surface for the load or strain put on them, engine running at too short centers with a tight belt, bad-fitting or sprung crank shaft, bearings screwed up too tight, insufficient lubrication, improper or poor oil, dust or dirt in the bearings, oil grooves too shallow or oil holes stopped, oil cups or lubricators becoming air-tight and preventing the proper flow of oil, from the engine being overloaded.

Calorific or Heat Values of Fuels. Blast-furnace gas for operating large engines has come considerably into use. It is of low calorific value, and requires a high degree of compression, but as it is a waste product in most steel mills its use will be greatly extended in the near future.

The calorific value of blast-furnace gas averages about 100 British thermal units per cubic foot, and requires about $1\frac{1}{2}$ times its volume of air for complete combustion.

What is known as producer gas is now largely used in gas engines, and for large engines. When made under favorable conditions, undoubtedly a considerable economy is effected, as the cost is usually only about one cent per horsepower, while coal gas at 60 cents per thousand feet would amount to about 2 cents per horsepower.

Producer gas is usually made from anthracite coal or coke, but a process has been introduced in which a superior quality of gas is made from bituminous coal, at the same time a large amount of sulphate of ammonia is obtained from the fuel, thus further reducing the cost of the gas.

The calorific value of water gas averages about 400 British thermal units per cubic foot.

The calorific value of good coal gas is about 650 British thermal units per cubic foot.

The calorific value of producer gas is about 150 British thermal units per cubic foot.

The calorific value of gasoline averages from 680 to 710 British thermal units per cubic foot.

Cams. The proper form of cam should give an easy lift to the valve and a longer time for the valve to remain fully open.

To attain this object the lift of the valve and consequently the throw of the cam should be about one-fifth more than is actually required with the ordinary form of cam, that is to say, the valve should lift more than the amount required for a full opening, or this additional amount of clearance should exist between the valve stem and the valve lifter.

As the duty of a cam is to transfer rotary motion of the cam shaft into the necessary reciprocating action required for lifting the valves, the quick opening and closing of the valves necessary in a four-cycle engine is more easily arrived at by means of a cam motion than otherwise. The valve is closed by a spring, the operation of opening the valve being performed by the cam only.

The width of the face of the cam in contact with the roller may be ascertained by calculating the work to be done due to the pressure in the cylinder at the time of the opening of the valve, together with the area of the valve. When the inlet valve is mechanically operated the cam controlling its movement may be of less width than the exhaust valve cam, as atmospheric pressure only is present when it is in operation, as compared with the exhaust valve cam, which has to open the exhaust valve against a pressure sometimes as high as 90 pounds per square inch, necessarily involving considerable strain.

Cam Shaft Gearing. In the four-cycle gas or oil engine the valves are only operated during alternate revolutions of the crank shaft. This, therefore, requires some form of two-to-one gear. A form of spiral gear is well adapted for this work. The power necessary to operate the valves is, in this case, transmitted from the crank shaft by the worm or skew gearing through the cam shaft, with separate cams opening the inlet and exhaust valves. Where spur gearing is used the cam shaft is mounted in bearings parallel to the crank shaft, the cams then operate horizontal rods which open the valves.

Gas or oil engines having the valve operating mechanism located near the crank shaft usually

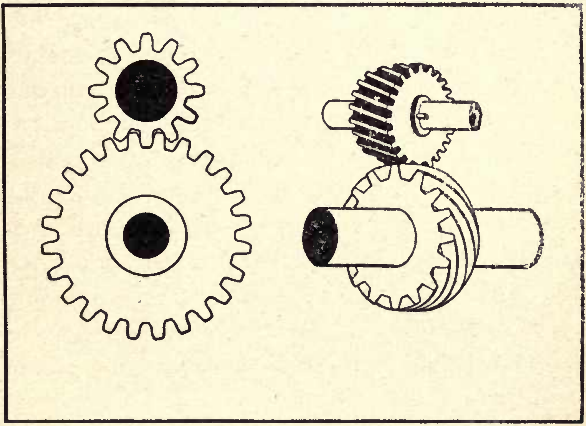

FIG. 2
Spur and spiral gear types of cam-shaft gearing.

have the spur form of gearing to transmit the motion from the crank shaft to the cam shaft. Engines having the valve mechanism adjacent to the valve chamber generally have the spiral form of gearing for the above purpose.

Figure 2 shows both forms of gearing, with the spur gear drive the shafts are parallel, while with the spiral form the shafts are at right angles to each other.

The left-hand view in the drawing shows the spur gear drive and that on the right hand the spiral form of gearing.

Carbureter, Use of. Marine gasoline engines, requiring a greater range of speed than is possible with the ordinary forms of mixing valves or vaporizers, are usually equipped with a carbureter of the float-feed type.

The float-feed type of carbureter consists of two principal parts: a gasoline receptacle which contains a hollow metal or a cork float, suitably arranged to control the supply of gasoline from the tank or reservoir, and a tube or pipe in which is located a jet or nozzle in communication with the gasoline receptacle, this tube or pipe is called the mixing chamber. The gasoline level is maintained about one-sixteenth of an inch below the opening in the jet in the mixing chamber.

A spray form of float-feed carbureter is shown in Figure 3, it has a gasoline chamber A, float B, needle-valve stem C, gasoline inlet D, regulating screw E, thumb-piece F, lock-nut G, spraying cone H, mixing tube J, jet or nozzle K, spring L and plunger M.

When the gasoline level in the float chamber is lowered, the needle-valve stem falls with the float, to which it is attached, and allows more gasoline to enter the float chamber through the opening above the needle-valve stem. During the suction stroke of the engine piston, air is drawn into and through the mixing-chamber, in the direction of the arrows, a small stream of

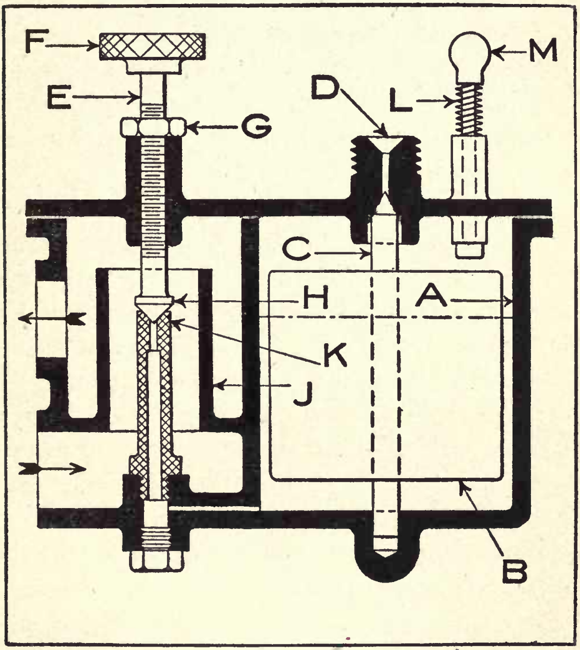

FIG. 3
Float-feed type of carbureter, showing float-chamber, mixing-tube and spray-feed.

gasoline is in consequence drawn up by suction from the jet or nozzle, mixing with the air in the tube around the spraying device. The carbureter may be flushed, for the purpose of more readily starting the engine, by depressing the float and consequently the needle-valve stem, with the small plunger on the top of the float-chamber, which is normally kept out of contact with the float by a spring, as shown in the drawing.

Care of Gas or Oil Engines, Directions for the. Keep plenty of fuel in the tank.

Water sometimes gets into the fuel tank and when this reaches the engine it begins to explode irregularly.

Sometimes the water will freeze in the fuel pipe and no fuel will come through. In this case, the pipes must be thawed out, which may be done without disconnecting, if the joints are all good and tight. There is no danger in applying heat to the pipes unless they are leaking.

Water in the fuel sometimes freezes on the inside of the inlet-pipe.

By removing the inlet-valve and applying a torch this can be safely thawed out.

The water collects from condensation in the tanks and otherwise.

One cause of obstructions in the inlet-pipe is the use of rubber or other soft gaskets.

This should never be done, as they will soon become loose and pieces get stuck in the pipe. Use nothing but metal gaskets. A ground joint does not require any packing.

Always use plenty of circulating water.

Never allow the water in the tank to get lower than the upper pipe connection, as the water cannot circulate unless this pipe is kept covered.

The lower water pipe and stopcock are liable to become clogged up when using dirty water, and it is well to see that they are kept clean.

Should water passages between the cylinder head and the main water jacket become clogged up they can be cleaned out by removing the cylinder head cover and scraping the passage with an old file.

If after an engine runs from fifteen to thirty minutes it becomes unusually warm, it is an indication that the water is not circulating freely.

If a gas or oil engine is working properly, it should run smoothly to the ear, without pounding either in the cylinder or bearings. The piston should work clean and be well lubricated, without any carbon or gummy deposit. The exhaust gases at the exhaust-pipe should be invisible or nearly so. The explosions should be regular and should be only reduced in pressure when the governor is reducing the volume of the charge and allowing only part or none of the charge to enter the cylinder.

Cleaning a Gas or Oil Engine. This should be regularly and thoroughly performed at stated intervals, as should the carbonized oil be allowed to accumulate, a great loss of power may result. The whole engine should be taken to pieces, and the cylinder, piston, valves, governors and levers taken apart and thoroughly cleaned and adjusted.

To remove the hard carbonized oil from the working parts copper tools should be used, and when the parts are thoroughly cleaned they should be rubbed over with kerosene. If nuts are set fast they should not be forced, but be loosened with kerosene. By using a little powdered plumbago and oil on the screw threads setting may be prevented.

Combustion Chamber, Design of. A simple and exceedingly practical construction for a combustion and valve-chamber is shown in Figure 4. The inlet-valve is atmospherically or suction operated, as shown in the drawing. The ignition plug is placed in the center of the end of the cylinder, which is cast integral or in one piece and is water-jacketed throughout. The combined combustion and valve-chamber is of funnel shape and affords a straight path for the passage of the gases without crooks or bends.

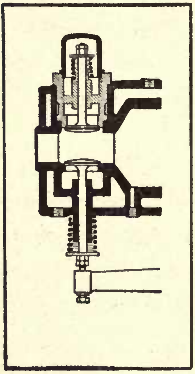

FIG. 4

Combustion Chamber, Dimensions of. If it is desired to ascertain the cubic contents or dimensions of the combustion chamber of an existing engine, they may be found by filling the combustion space with water, then obtaining the weight of the water in ounces, which multiplied by 1.72 will give the capacity of the chamber in cubic inches. If an engine is to be designed with a given bore and stroke, the first thing to do is to decide on the amount of clearance or combustion space at the end of the cylinder for the gases to occupy after compression.

If the combustion space could be made as a continuation or extension of the cylinder bore, it would be an easy matter to determine the required clearance, as it would simply be some fraction of the total piston stroke.

But as the general design of a combustion chamber deviates widely from a plain section or length of a cylinder as above described, some other method must be used to calculate the required clearance.

To do this correctly the required contents of the combustion chamber in cubic inches must first be ascertained, and then apportioned between the valve chamber or chambers and the clearance proper which lies directly behind the piston head.

To find the cubic contents of a combustion chamber when the degree of compression in atmospheres is known: Let S be the stroke of the piston in inches and A the area of the cylinder in square inches. If N be the number of atmospheres compression and C the required contents of the combustion in cubic inches, then

$$C = \frac{S \times A}{(N - 1)}$$

Example: Find the cubic contents of the combustion chamber for a motor of 8-inch bore and 10-inch stroke with 5 atmospheres compression.

Answer: Ten multiplied by 25.13 equals 251.3, which divided by 4 gives 62.8 as the number of cubic inches required.

Comparison of Gas and Steam Engines. The greater thermal efficiency of the gas engine as compared with that of the steam engine and its adaptability to use the poorer and cheaply produced gases made in producer plants, as well as the gases given off from blast furnaces, has resulted in its development and manufacture in units as high as 10,000 horsepower.

Until recently the gas engine, requiring no outside gas-making apparatus, of 100 horsepower was probably the largest unit made. Gas engines up to 500 horsepower are now being made.

The production of great quantities of petroleum in Texas and California chiefly useful for fuel purposes only, and which can be procured at a low price as compared with illuminating oils, has enabled the oil engine in many locations to compete in cost of installation and price of fuel with the most economical types of steam engines.

There can be but little doubt that large modern gas engines, using a good quality of producer or blast-furnace gas free from all impurities, compare very favorably on the score of economy with the steam engine. This arises from the cheapness of the fuel in the first place, from the superior calorific value of gas over steam, and the more efficient utilization of the heat in the gas engine.

Comparison of Horizontal and Vertical Engines. Accessibility of the parts in a horizontal engine is always considered a great advantage. The piston can always be seen and can be taken out of the cylinder and cleaned and replaced easily in this style of engine, while in a vertical engine it is necessary to remove the cylinder cover and sometimes the cylinder to gain access to the piston, and it is also necessary to have sufficient room above the top of the cylinder to lift the piston and connecting-rod out. The connecting-rod is more accessible for adjustment both at the crank-pin end and at the piston end in the horizontal type. This difficulty, however, has been overcome by arranging a removable plug in the piston head, which when taken out allows access to the piston end of the connecting-rod.

Vertical engines for places where space is restricted and where sufficient head room is available have the greater advantage of occupying less floor space than a horizontal engine. The mechanical efficiency of a vertical engine is, however, somewhat greater, the friction of the piston being less than in the horizontal type of engine.

Sometimes the vertical type of engine can only be used, but for ordinary uses the horizontal type of engine seems to be most in favor, one important point being the difficulty of suitably arranging the carbureting or vaporizing devices in the vertical type of engine, which are usually placed close to the cylinder, and are not so fully under the control of the attendant as in the horizontal engine.

Comparison of Two and Four-cycle Gas Engines. The trend in design of large-size gas engines using producer or blast-furnace gas is to the two-cycle principle of operation. Where the four-cycle principle is adhered to, two or more cylinders are necessary. As the four-cycle single-cylinder engine obtains an impulse only once in two revolutions, consequently during three idle strokes of the piston the power and speed of the engine must be maintained by the momentum of the flywheels, necessarily enormous in an engine of 500 horsepower or over, for the power obtained, in comparison with the flywheel of a steam engine of the same capacity. With the two-cycle engine of large horsepower, in which an impulse is obtained each revolution of the crank shaft, nearly double the power is said to be developed as compared with the four-cycle engine of the same size. The mechanical efficiency is increased, owing to the reduced weight of the flywheels, and the weight and cost of the engine per horsepower is reduced.

The difficulty of procuring proper combustion in the two-cycle oil engine, where crude oil is used, has, however, not yet been entirely overcome.

It may be stated that the larger size two-cycle engines, to compete with the four-cycle gas engine in cost of fuel, can do so only when a cheap grade of fuel is used. To use such fuel, it is imperative that proper combustion should take place in the cylinder.

Compressed Air Starters. On account of the difficulty of starting large engines by hand, self-starters are used for engines over 10 to 12 horsepower, and a great variety of methods are in use. Compressed-air starters are simple and consist usually of a hand or power air pump, which forces air under pressure into a tank.

The air tank is connected with the cylinder, and the flywheel being turned till the engine is in a position to start, that is when the crank is just above the dead center, the compressed-air valve is then opened and kept open until the piston approaches the end of its stroke. This operation is repeated once or twice, if necessary, to set the engine in motion.

A number of devices are also in use, in which charges of gas and air are forced into the engine cylinder, and ignited by a separate and special device, the operation being repeated till the ordinary ignition mechanism comes into play.

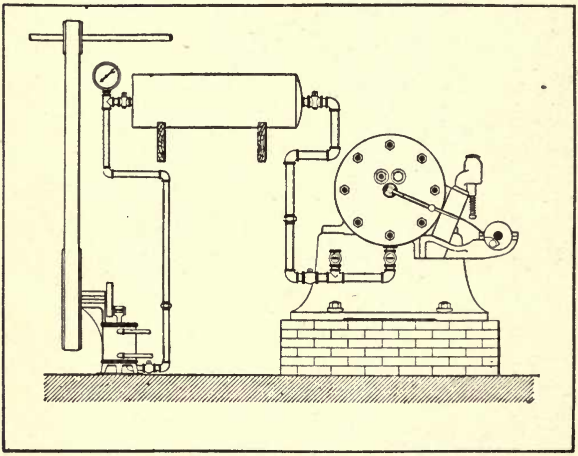

FIG. 5
Compressed air starter, showing air storage tank and drive from line shaft to air compressor.

Exhaust gases stored by the engine itself, under pressure in a reservoir, are also used.

Figure 5 shows a gas or oil engine equipped with a compressed air starter. The air compressor is belt-driven from the line shaft. The storage tank, supply pipe to the engine and starting valve are plainly shown.

Compression, Advantages of. High, but not excessive, compression of the explosive charge, combined with complete combustion and expansion, are the most important factors in the economical working of gas and oil engines.

With a high degree of compression the charge of gas and air becomes more homogeneous, is more rapidly ignited and with greater certainty, consequently the combustion is more complete, and the force arising from the explosion of the charge greater.

A smaller cylinder is required to give out the same power, and a weaker charge can be ignited. If, however, the compression be too great, premature ignition will occur.

If the engine loses its compression, it generally arises from a defective condition of the exhaust or inlet-valves, joints, or piston-rings. The valves should be taken out and carefully examined, and if the valves do not fit properly in their seats, they should be carefully ground in with fine emery powder and oil, the emery being afterwards cleaned off with kerosene.

If the valve stems are too tight, they should be eased with a smooth file.

It is also very important that the degree of compression be adjusted to suit the explosive qualities of the fuel used.

Compression, How to Calculate. The compression in atmospheres of an engine may be readily found by dividing the cubic contents of the piston displacement by the cubic contents of the combustion chamber in cubic inches, and then adding one to the result.

To ascertain the compression in atmospheres of an engine, when the cubic contents of the combustion chamber are known: Let S be the stroke of the piston in inches and A the area of the cylinder in square inches. If C be the contents of the combustion chamber in cubic inches and N the required compression in atmospheres, then

$$N = \left(\frac{S \times A}{C}\right) + 1$$

Example: Find the compression in atmospheres of an engine of 4-inch bore and 6-inch stroke, whose combustion chamber has a capacity of 18 cubic inches.

Answer: Six multiplied by 12.56 equals 75.36, which divided by 18 gives 4.19, and 4.19 plus 1 equals 5.19, or the compression in atmospheres required.

If it is desired to ascertain the compression in atmospheres of an engine, the combustion chamber of which is of such shape that its dimensions cannot be accurately calculated, its cubic contents may be found by filling the combustion chamber with water, and after removing the water, ascertaining its weight in ounces, and then multiplying the result by 1.72. This gives the capacity of the combustion chamber in cubic inches. The compression of the engine can then be readily calculated from the formula given herewith.

Compression, How to Test for Leaks in. To discover if there are any leaks in the compression of a gasoline motor, a small pressure gauge reading up to at least 75 pounds should be screwed into the ignition tube opening or in any other suitable opening in the combustion chamber. When turning the motor flywheel slowly the gauge should indicate at least 70 pounds per square inch if the compression is in good condition.

To test for leaks, fill a small oil can with soapy water and squirt round every joint where there may be a possible chance for leakage. Get an assistant to turn the flywheel and watch for bubbles at the joints.

If the joints are all tight, next examine the condition of the inlet and exhaust-valves, and if either of them needs regrinding it should be done with fine emery powder and oil.

When the valves have been ground to a perfect fit, if the compression still leaks, the piston-rings should be examined, as the trouble will be found to be there.

If there is a leakage by the piston, a hissing sound will be heard. This trouble may arise from badly fitted or badly worn piston-rings, the cylinder scored from insufficient or improper lubrication, or the cylinder worn oval or out of round, or overheated from insufficient cooling.

If the cylinder is worn, there is no remedy for it but reboring.

Compression, Loss of. If an engine leaks compression it will not pull its full load, and does not start easily. By forcing the piston back against its compression it may be readily determined whether it leaks or not. Examine both the inlet and exhaust-valves and see that they are fitting properly. Force them up and down a few times by hand to make sure they work freely.

With the engine at rest, take hold of the fly-wheel and turn it backwards until the piston moves in on the compression stroke with considerable force and if there is no leak the engine should move forward one-half or a full revolution, depending on the force with which it was driven in.

If the valves or ignition tube should leak there would be no rebound.

To find a leak in the packing, remove the piston from the cylinder and put a light inside.

Turn on the water and by looking in, the leak may be located.

Before replacing a gasket, scrape both surfaces clean. Use asbestos millboard soaked in oil.

Put the gasket in place and draw it up tight.

After the engine has become warm draw up the gasket several times until the joint is tight.

Connecting-rods. Connecting-rods of gas and oil engines are of various shapes in cross-section, but those principally in use are made of steel with rectangular or circular section, with an adjustable bronze bearing at the crank-pin end.

The crank-pin end bolts should be so proportioned as to have an area of at least 25 per cent of the mean cross-section of the rod.

A connecting-rod of rectangular section, when made of steel, should have a cross-sectional area at least 30 per cent greater than the circular one. For a rod of circular section the width of the rod should be at least one-third its mean depth.

For small engines a good and cheap form of connecting-rod may be made of phosphor bronze or cast steel.

Crank Shafts. The crank shaft of a gas or oil engine should be made of sufficient strength not only to withstand the sudden pressure due to the explosion, but also to withstand the strain consequent upon the greater explosive pressure which may possibly be caused by previous missed explosions. The crank shaft should be proportioned with relation to the area of the cylinder and the maximum pressure of the explosion.

The mechanical efficiency of an engine may be gauged by the strength of the crank shaft, because if the crank shaft is not sufficiently strong, it will spring at each impulse, causing the flywheels to run out of true and also wear the bearings unevenly.

The balancing of the crank shaft and reciprocating parts is an important feature of a gas or oil engine. With a single-cylinder explosive engine, to perfectly accomplish the balancing is impracticable. Most manufacturers, therefore, only balance their engines as far as the reciprocating parts are concerned.

Balancing by means of a recess in the rim of the flywheel has the advantage of requiring no extra metal, and is cheaper as regards workmanship as compared with the method of balancing the crank shaft by means of counterweights. In each of these methods, however, the flywheel itself is out of balance, and when rotating tends to make the crank shaft run out of true.

As it is important that the crank shaft be of ample strength, it is the best practice to make it of forged steel cut from the solid and finished bright all over. If the crank shaft be too weak, it will spring with the force of the explosions, thereby causing undue wear on the bearings.

Cycles of Gas and Oil Engines. The four-cycle engine, having only one working stroke or impulse during each two revolutions of the crank shaft, consequently requires larger and heavier flywheels than a two-cycle engine in order to maintain a practically uniform speed and also to transmit the power during the idle strokes of the engine.

The four-cycle engine has, however, many advantages over the two-cycle engine. The working stroke or impulse is more readily controlled, and during the inlet and exhaust strokes a longer time is allowed for the cooling of the valves and the more thorough expulsion of the exhaust products from the cylinder than is possible with a two-cycle engine.

In the two-cycle type of engine the charge must be independently compressed before entering the cylinder of the engine, in some two-cycle engines this is accomplished in a separate cylinder, but usually in the crank case of the engine.

A greater quantity of lubricating oil and more cooling is required with a two-cycle than a four-cycle engine on account of the greater amount of heat generated in the same length of time.

Six-cycle or scavenging engines have been largely used, in which after the termination of the exhaust stroke, a charge of air is drawn into the cylinder and the products of combustion thus entirely expelled.

As such engines have only one working stroke or impulse to every three revolutions of the crank shaft, the cylinder and flywheel dimensions require to be greatly in excess of those of engines of the four-cycle type, necessitating greater floor space, increased weight, excessive wear and tear and greater complication of the valve-operating mechanism.

Cylinders, Construction of. Cylinders made with a loose head require the joint to be made with great care. An asbestos or copper ring is

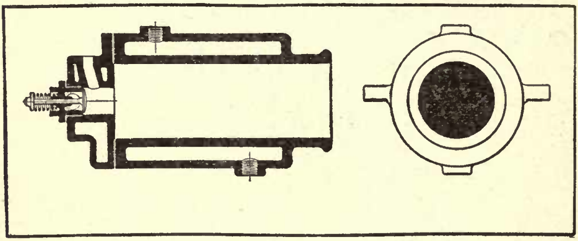

FIG. 6
Gas or gasoline engine cylinder, with detachable water-cooled head.

used to make this joint, sometimes wire gauze with asbestos is used, which has been found to give very good results.

Figure 6 shows a cylinder with a loose water-jacketed head in which both the inlet and exhaust-

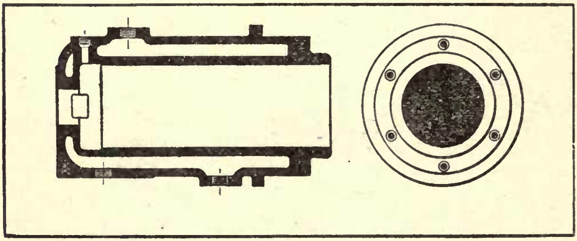

FIG. 7
Gas or oil engine cylinder, with cylinder and head cast integral.

valves are located. This style of cylinder has feet or lugs on either side to attach it to the bed-plate.

A form of cylinder is shown in Figure 7 in which the cylinder and head are integral or cast in one piece, it has a separate valve-chamber (not shown) which bolts on the side of the cylinder and communicates with the combustion chamber by a port or passage shown in the drawing. This style of cylinder is attached to the bed-plate by means of a circular sleeve which fits into an opening at the end of the bed-plate and is drawn up against the circular flange shown by means of bolts.

Cylinder, Method of Boring a. A good way to bore a cylinder is to make a boring-bar to fit in the drill socket of a back-geared drill press and a brass or phosphor bronze bushing to fit in the center hole of the table of the drill press. The cylinder can be clamped to the table of the drill press by its flange and bored out with a cutter set in the boring-bar. Not less than three, and preferably four cuts, should be taken to make a good job. A mandril should then be made with two flanged hubs, one of which should be fastened to the mandril and the other turned slightly taper so as to make a snug fit in the cylinder bore when in place. The ends of the cylinder can then be finished on the mandril and a perfect job will be the result. In case a back-geared drill press is not handy the cylinder can be clamped to the carriage of the lathe, bored out with a bar in the lathe centers and the ends finished in the manner above described, but it is a much slower job than in a drill press. The cutter for the bar should be made from a piece of round tool steel not less than five-eighths of an inch diameter. It can then be readily adjusted to any desired angle to obtain the best cutting effect.

Cylinder Sweating. Sometimes water will collect in the cylinder as a result of the interior walls of both the cylinder and cylinder-head sweating. This, however, does not often happen except on very warm days when a considerable volume of cold water has been allowed to flow through the water-jacket after the engine has been shut down, and this seldom applies where the thermo-syphon water-cooling system is used. It is more liable to happen where the cold water from a hydrant has been allowed to flow through the water-jacket.

Design of Gas and Oil Engines. Gas and oil engines should be of substantial design in order to withstand the continual shock and vibrations to which they are subject, and should be as accessible as possible in the working parts, which may require adjustment while in actual service. The starting gear and other parts to be handled by the attendant when starting and running the engines should be placed in close proximity to each other.

Simplicity in construction is the essential feature of a gas or oil engine. The oil engine is a machine intended for use in any part of the world where its fuel is obtainable, and where, perhaps, no mechanic is available. Accordingly, all the mechanism should be arranged so as to be easily removed for examination and repair. The igniting device, as well as the carbureter or vaporizer, should be so designed as to facilitate removal and repair. A gas or oil engine, to be successful mechanically and commercially, should be so designed that it can be successfully operated, cleaned and adjusted by unskilled attendants.

Deep Well Pumping Plants. A deep well pumping plant operated by a gasoline engine through a single reduction gearing is illustrated in Figure 8, the pump is of the single-acting type and is connected to the reduction gear by means of a pitman-rod with a forked lower end. Such plants are also used for draining mines and quarries.

Dry Batteries. In one respect dry batteries have a decided advantage over liquid batteries for ignition purposes, from the fact that on account of their high internal resistance they cannot be so quickly deteriorated by short circuiting.

On account of this high internal resistance, dry batteries will not give so large a volume of current as liquid batteries, but a set of dry batteries may be short circuited for five minutes without apparent injury and will recuperate in from twenty to thirty minutes, while a liquid battery

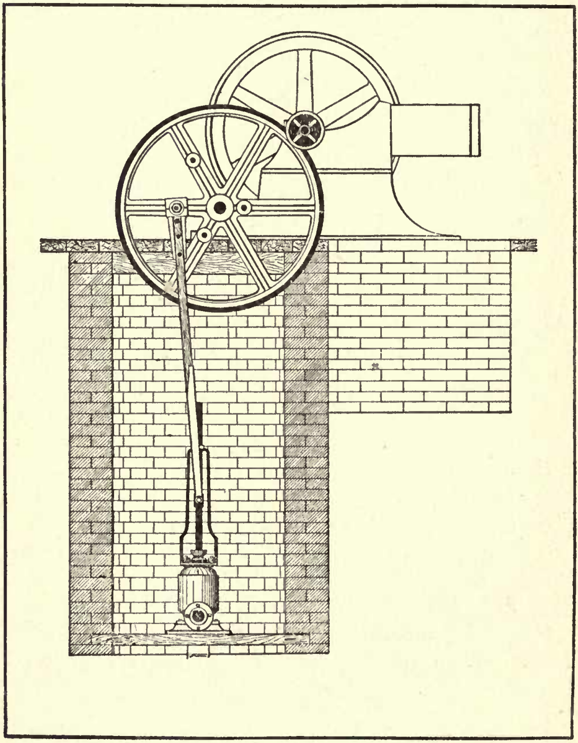

FIG. 8
Deep well pumping plant, showing engine, reduction gear, pitman-rod and pump.

would in all probability be badly deteriorated under the same conditions.

A dry battery of the usual type consists of a zinc cell which forms the negative element of the battery. The electrolyte is generally a jelly-like compound containing sal-ammoniac, chloride of zinc, etc. The carbon or positive element is enclosed in a sack or bag containing dioxide of manganese and crushed coke, which are the depolarizing agents of the battery.

Dynamometer. A dynamometer is a form of equalizing gear which is attached between a source of power and a piece of machinery when it is desired to ascertain the power necessary to operate the aforesaid machinery with a given rate of speed.

Efficiency, Mechanical. The mechanical efficiency of a gas or oil engine depends on its design, workmanship and proper lubrication, and also on:

The proper mixture of air and fuel.

The correct degree of compression.

The correct point of ignition.

The duration and completeness of combustion.

The rapidity and amount of expansion.

Efficient governing and free exhaust.

If any doubts exist as to the engine giving out its proper power, a brake test should be made.

To ascertain the mechanical efficiency of a gas or oil engine, both indicator and brake horsepower tests should be made, then if I.H.P. be the indicated horsepower and B.H.P. the actual or brake horsepower of the engine and M.E. be its mechanical efficiency, then

$$M.E. = \frac{B.H.P.}{I.H.P.}$$

If the brake horsepower of an engine be 7.5 and the indicated horsepower be 10, then the mechanical efficiency will be

$$M.E. = \frac{7.5}{10}$$

which equals 75 per cent.

In text-books the efficiency of an engine is usually considered as the relation between the heat-units consumed by the engine and the work or energy in foot-pounds given out by it. If the heat-units (which are measured by the quantity of fuel supplied to the engine) be large compared to the work or energy given out by the engine, its efficiency is small.

Efficiency, Thermal. The ratio of the heat utilized by the engine, as shown by the power developed, as compared with the total heat contained in the fuel absorbed by the engine, is known as the thermal efficiency. This can be obtained by the following formula:

Let F = consumption of fuel in pounds per brake horsepower per hour, and

C = calorific value of the fuel per pound in heat units, then

$$E = \frac{42.63 \times 60}{C \times F}$$

The thermal efficiency of the oil engine is low as compared with the gas engine. The best gas engine makers now claim a thermal efficiency for their engines of 27 per cent, whereas it is believed the maximum thermal efficiency recorded by any oil engine now in regular use is but 18 per cent.

Electricity, Forms of. Electricity or electrical energy may be generated in several ways—mechanically, chemically and statically or by friction. By whatever means it is produced, there are many properties which are common to all. There are also distinctive properties. The current supplied by a storage battery will flow continuously until the battery is practically exhausted, while the current from a dry battery can only be used intermittently: that is, it must have slight periods of rest, no matter how short they may be.

The dynamo or magneto current is primarily of an alternating nature or one which reverses its direction of flow rapidly. In use, this alternating current is changed into a direct or continuous current flowing in one direction only, by means of a commutator. Any of the forms described are capable of igniting an explosive charge in a motor cylinder, but the static or frictional form of electricity is not used for this purpose on account of its erratic nature.

Electric Light Outfits. Although gas and oil engines for electric lighting purposes are of special design, the lights may sometimes flicker. Flickering in the incandescent lights may be located by close inspection of the engine and dynamo, and may be due either to the flywheels, the governor or the belt. To locate this defect and remedy it, notice the lamps carefully. If the variations in the light are due to lack of weight in the rim of the flywheel, these variations will be seen to coincide with the revolutions of the engine. Again, if the variation in the lights is only periodical, then this defect should be remedied by adjustment of the governor. Examine the governing mechanism of the engine. If the variation is caused by the governor acting too slowly, then adjust the governor so as to cause more rapid action upon the controlling mechanism.

The cause of the trouble may not be, as already suggested, in the flywheel or in the adjustment of the governor, but in the belt, which is frequently the sole cause of flickering in the lights. The engine and dynamo pulleys over which the belt runs should be exactly in line with each other. The belt should be made endless, or if jointed the joints should be very carefully made. A thick, uneven joint in the belt will cause a flicker in the lights each time it passes over the dynamo pulley.

Figure 9 shows a two-cycle gasoline engine directly connected to a dynamo, both engine and dynamo being mounted on a cast iron base.

To secure a steady light with gas or oil engines, the practice has been to place a flywheel upon the dynamo shaft, as the speed of some engines sometimes varies as much as 5 per cent. The constructional details of some gas engines

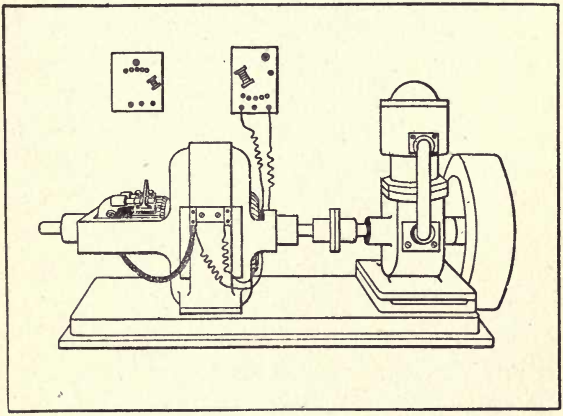

FIG. 9
Electric light outfit, showing two-cycle engine direct-connected to dynamo.

used for this purpose have been so considerably improved that the dynamo flywheel is not considered necessary.

This uniform speed has been largely secured by increasing the diameter and weight of the flywheels, together with an improved method of direct balancing, the balance being fitted to the crank, instead of to the rim of the flywheel, which is usually the case with ordinary engines. Very sensitive governing gear, however, is necessary.

Exhaust, Cause of Smoky. Smoke coming from the exhaust of a gas or oil engine is due to one of two conditions: Over-lubrication—too much lubricating oil being fed to the cylinder of the engine, or too rich a mixture, that is, too much fuel and an insufficient supply of air.

The first condition may be readily detected by the smell of burned oil and a yellowish smoke. The second, by a dense white smoke accompanied by a pungent odor.

Explosions in the Inlet-pipe. These usually only occur in engines with mechanically operated inlet-valves, a weak or a too rich charge of explosive mixture being ignited burns slowly in the combustion chamber and when the piston has reached the end of the exhaust stroke and the inlet-valve commences to rise, the burning gases in the combustion chamber ignite the explosive mixture in the inlet-pipe.

A further loss arises from this kind of explosion, as on the next admission or suction stroke these partly burned gases enter the combustion chamber, instead of an entirely fresh supply of gas and air, and consequently retard the combustion and reduce the power of the next explosion.

Explosions, Weak. These may be caused from improper mixture, ignition set too late, loss of compression from defective piston, valves, or joints.

Fire Insurance. The following are the general requirements of the various boards of fire underwriters for the installation and use of oil engines:

Location of Engine. Engine shall not be located where the normal temperature is above 95 degrees Fahrenheit, or within ten feet of any fire.

If enclosed in room, same must be well ventilated, and if room has a wood floor, the entire floor must be covered with metal and kept free from the drippings of oil.

If engine is not enclosed, and if set on a wood floor, then the floor under and three feet outside of it must be covered with metal.

Oil Feed Tank. If located inside of building, shall not exceed five gallons capacity, and must be made of galvanized iron or copper, not less than No. 22 B. & S. Gauge, and must be double seamed and soldered, and must be set in a drip pan on the floor at the base of the engine.

Fire Pot or Muffler. Gas or oil engines having a relief-exhaust in the form of a port or opening, which is uncovered by the piston shortly before the end of the explosion or working stroke of the engine, should have the fire pot or muffler connected with the relief-exhaust port opening and a separate pipe provided for the regular exhaust valve opening. If this is not done, back pressure from the relief-exhaust will oppose the free discharge of the exhaust gases from the main exhaust valve, thereby causing an excessive

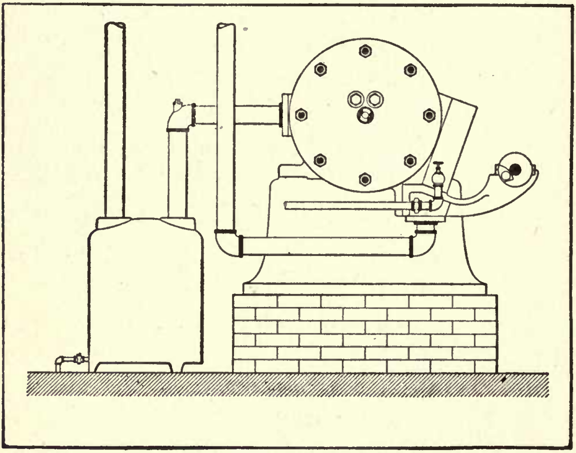

FIG. 10
Muffler installation, showing muffler connected to relief-exhaust on left-hand side of engine.

amount of the products of combustion to be left in the cylinder at the termination of the exhaust stroke. Figures 10 and 11 show methods of attaching the fire pot or muffler to the relief-exhaust on the left and right-hand sides of the engine respectively. The main exhaust connection is omitted in Figure 11.

Flash Test of Oils. The apparatus used for this purpose consists of a small copper vessel in which the oil to be tested is placed. This vessel is immersed in a larger vessel containing water, which forms part of the upper portion of the apparatus.

A thermometer is suspended with its lower

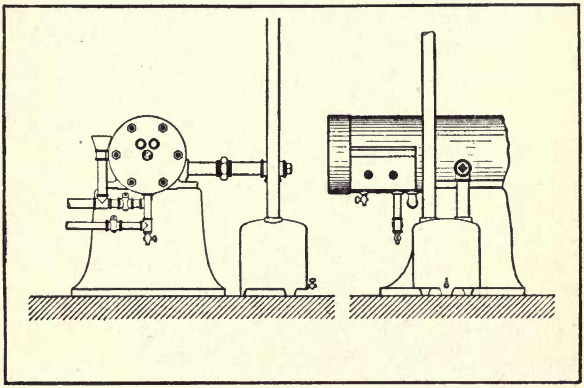

FIG. 11
Muffler installation, showing muffler connected to relief-exhaust on right-hand side of engine.

part in the oil. A heating lamp placed under the receptacle containing the water raises the temperature of both water and oil as required. A lighted taper is passed to and fro over the top of the oil as it becomes heated. When the vapor given off by the oil flashes the temperature is noted, and that is termed the flashing point of the oil tested.

Flywheels. The flywheels of a gas or oil engine require careful keying on the crank shaft. If the keys are not a good fit and are not driven home properly the engine may knock when running. Two keys are usually fitted to the shaft of large engines, one being a feather key, which is fitted in a keyway in the shaft as well as in a keyway cut in the flywheel hub, the second key being a taper key with a gib-head, which is recessed in the flywheel hub and made concave on the lower side to fit the shaft.

WEIGHT OF RIMS OF FLYWHEELS. The weight of the rim of the flywheel is the only portion which enters into the following calculations, the weight of the web or spokes and hub being neglected.

Let M.P be the mean pressure of the compression, and A the area of the cylinder in square inches. If S be the stroke of the piston in inches, and N the number of revolutions per minute of the engine, let D be the outside diameter of the flywheel in inches and W its required weight in pounds, then

$$W = \frac{M.P \times A \times S \times N}{2560 \times D}$$

DIAMETER OF RIMS OF FLYWHEELS. An engine that is intended to operate at a slow rate of speed and consequently with a high degree of compression, will require a flywheel of much greater diameter and weight than a higher speed engine of the same bore and stroke. It may be well to remember that within certain limitations the diameter and weight of a flywheel should be as small as is possible, as an increase in either means a reduction in engine speed, increased friction and a consequent loss of power.

To ascertain the proper diameter of a flywheel when all other conditions are known, if D be the required diameter of the flywheel in inches, then

$$D = \frac{M.P \times A \times S \times N}{2560 \times W}$$

Two flywheels should be used for steady running, at the same time, they equalize the wear on the crank-shaft bearings. They should be carefully turned and balanced, and run perfectly true at full speed. If one wheel is used, it should be of heavy construction and supported by an outside bearing.

Foundation Bolts. The number and size of these are usually determined by the builder of the engine and indicated by the number of holes in the engine base. The bolts should be long enough to extend from the bottom of the foundation to from two and a half to four inches above the capstone.

They should have iron anchor plates at the bottom and be threaded at the top to receive a nut.

Three or four days after the foundation is completed, and the cement firmly set, the engine may be placed in position and bolted down ready for work.

Foundations. A concrete foundation, if properly constructed, is the best. While foundations are usually built of brick or stone laid in cement, a foundation may be of concrete, mixed as follows: One part of cement, two parts of coarse sand, five parts of fine crushed stone or coarse gravel.

It is desirable to have the capstone from 3 to 6 inches wider and longer than the base of the engine. The depth of the foundation will depend entirely upon the condition of the ground in the vicinity where the engine is to be set up.

The foundation should always go below the freezing line and as much below as is necessary to get a firm base. Ordinarily from 3 to 4 feet is sufficient for small engines of from 4 to 12 horsepower. For larger engines from 15 to 40 horsepower, 4 to 6 feet is not too much.

Where possible, the sides of the foundation should have a slope or batter not less than 15 degrees.

Four-cycle Engine, Construction of. The general construction of a four-cycle gas or oil engine is plainly shown in Figure 12. The engine is equipped with both hot tube and electric ignition and an atmospherically or suction operated inlet-valve. Reference to the table and the corresponding letters in the drawing will give a clear understanding of the use of the various parts of the engine.

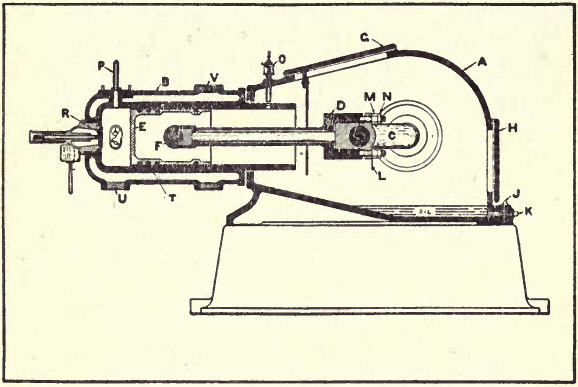

FIG. 12

Vertical longitudinal section of four-cycle motor, showing constructional details.

A—Crank Case.
B—Cylinder.
C—Crank Shaft.
D—Connecting-rod.
E—Piston.
F—Piston Wrist Pin.
G—Upper Hand Hole Plate.
H—Lower Hand Hole Plate.
J—Oil Test Plug.
K—Drain Plug.
L—Splash lubricator.
M—Crank Pin bearing Adjusting Nut.
N—Crank Pin bearing Lock Nut.
O—Cylinder Oiler.
P—Ignition Tube.
R—Admission Valve.
T—Piston-rings.
U—Inlet for cooling water.
V—Outlet for cooling water.

Four-cycle Engine, Operation of. A four-cycle engine has only one working stroke or impulse for each two revolutions. During these two revolutions which complete the cycle of the engine, six operations are performed:

1. Admission of an explosive charge of gas or gasoline vapor and air to the cylinder of the engine.

2. Compression of the explosive charge.

3. Ignition of the compressed charge by a hot tube or an electric spark.

4. Explosion or extremely sudden rise in the pressure of the compressed charge, from the increase in temperature after ignition.

5. Expansion of the burning charge during the working stroke of the engine piston.

6. Exhaust or expulsion of the burned gases from the engine cylinder.

As pressure increases with a rise in temperature, which in an engine the moment after ignition has taken place is about 2,700 degrees Fahrenheit, the higher the temperature of the ignited gases, the greater would be the pressure. As this pressure is expended in work on the engine piston, the whole of it might, if expansion of the burning gases were continued long enough, be utilized. Full utilization of the expansion of the gases is impossible from a mechanical point of view. The expansion of the gases should be as rapid as possible, as the faster the piston uncovers the cylinder wall, the less time will be left for the transmission of heat or energy to the cylinder wall. Gasoline vapor or gas in themselves are not combustible, but must be mixed with a certain amount of air before ignition and consequent combustion can be effected. The combustion of the gases is not instantaneous, but continues during the entire working stroke of the engine piston.

Four-cycle Engine, Principle of. Figure 13 gives four diagrammatic views of the operation of a four-cycle gas or oil engine. It shows an inlet-valve A, valve-openings B, cylinder C, cam D, exhaust valve E, combustion chamber F, piston G, valve springs H, crank case J, connecting-rod K and crank-pin L.

Diagram No. 1 shows the piston about to draw in a charge of explosive mixture, the suction or drawing in of the charge continues until the piston has reached the position shown in Diagram No. 2. Then the piston returns until it arrives at the position shown in Diagram No. 3, compressing the charge of mixture during this operation. Just before the piston has reached the end of its travel in this direction, the charge under compression is ignited either by an incandescent tube or by an electric spark and the force of the explosion drives the piston back to the position shown in Diagram No. 4, when the exhaust-valve is opened by means of the cam and valve-lifter rod. The exhaust valve remains open until the piston has reached the position shown in Diagram No. 1. Then it closes, the piston again

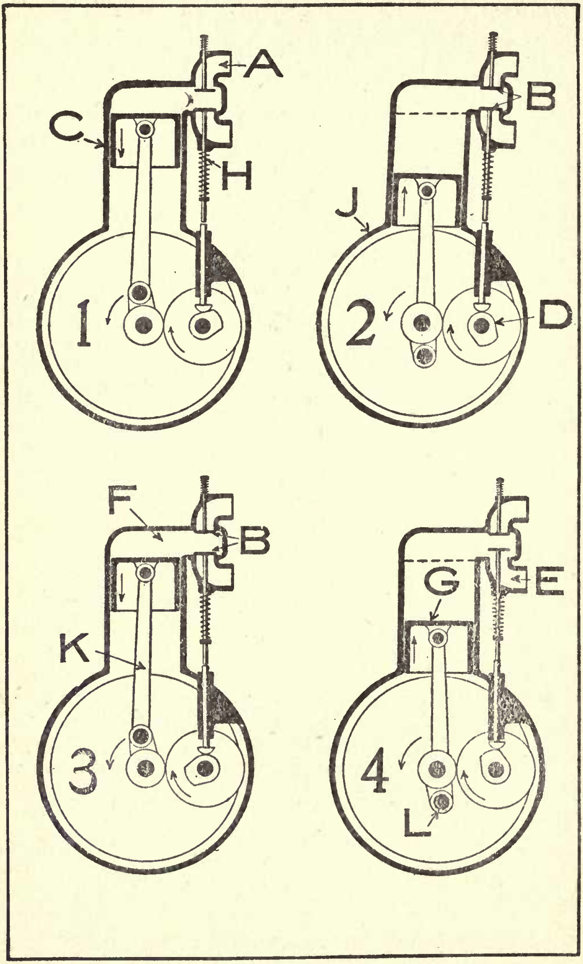

FIG. 13
Four-cycle motor diagram, showing the various operations during the cycles.

commences to draw in a charge of explosive mixture and the cycle of operation of the engine is repeated. As it requires four strokes of the piston or two complete revolutions of the crank shaft to complete the cycle, there is consequently only one impulse every two revolutions or one working piston stroke out of four.

Four-cycle Marine Engines. A single-cylinder four-cycle engine is shown in Figure 14. This style of engine may be used for either marine or automobile work, being light in weight, simple in construction and made in sizes from 4½ to 10 horsepower.

A two-cylinder engine of similar construction to the one just described is illustrated on the front page of this work. These engines are from 9 to 20 horsepower. Such engines are being greatly used for motor launches on account of their light weight and great power.

Friction Clutches. When fast-and-loose pulleys or friction clutches are used the advantages gained are: the ease with which the engine can be started, the loose pulley or friction clutch only, instead of the whole line shaft, has to be turned when the plant is started, and in case of accident or other emergency necessitating the quick stopping of the revolving machinery, this can be accomplished at once by simply moving over the lever of the friction clutch or tight-and-loose pulleys. Otherwise the heavy flywheels of the engine would keep revolving for some time after the fuel supply of the engine is shut off, and

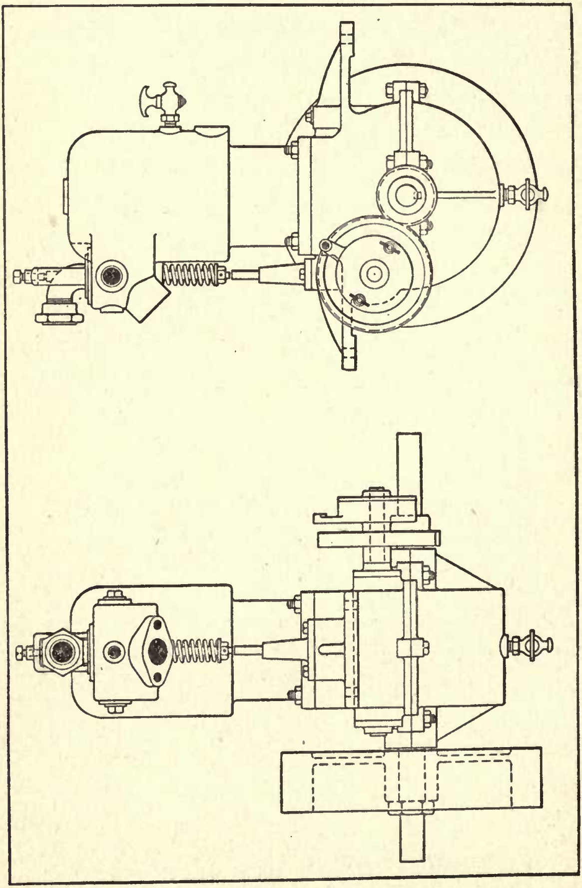

FIG. 14

Side and end views of a single vertical cylinder marine or auto-boat engine.

being directly connected by belt to the shafting and machinery, the whole plant is in motion as long as the flywheels keep revolving.

Fuel Consumption of Gas and Oil Engines. The fuel consumption of an engine is always one of grave importance to the purchaser, as well as to the manufacturer.

Ordinarily about $1\frac{2}{10}$ pints of gasoline or about 15 feet of natural gas, per horsepower per hour under full load, will cover the fuel consumption. That is, when the fuels used are of standard quality and the water comes from the water jacket at a temperature of about 140 to 160 degrees Fahrenheit.

The temperature of the water in the jacket around the cylinder has a great deal to do with fuel consumption.

To economize on the fuel consumption of an engine the following points should be observed:

1. To keep the jacket water at 160 degrees Fahrenheit.

2. To run the engine at a medium speed.

3. To use a good standard grade fuel.

4. To see that every charge the engine takes is exploded, for which a proper mixture and a good spark or hot tube are necessary.

5. The admission valve should close properly between charges, so as not to allow a continuous flow of fuel into the engine.

6. Never throttle the fuel so closely that the

engine cannot get a full charge every time it needs it.

7. Be sure that there is no leak in the supply or overflow pipes where fuel can escape.

8. When gasoline or kerosene is used, be sure that there is no leak in the supply tank.

9. See that the exhaust and inlet valves seat properly and do not leak. The piston-rings should hold the pressure due to the explosion.

Fuel Gas Oil. An oil known as fuel gas oil is procured in the process of fractional distillation after the lighter oils and the illuminating oils have been taken off. Tests of samples of this fuel gas oil, the characteristics of which vary considerably, are given in the following table:

FUEL GAS OIL.

Specific gravity	0.832	.878
Beaumé	36°	30.2°
Flash-point	144° F.	298° F.
Fire test	183° F.	247° F.

This fuel is much used in oil engines in the United States. With the heavier grades a slight deposit of carbon is left in the engines, which requires periodical removing.

Gas Bag. The gas bag of a gas engine should be entirely of vulcanized rubber, or it may be made with an iron frame and rubber sides.

The gas bag serves its purpose better the nearer it is to the engine. As the pulsating of the bag endangers its pulling off the pipe, care should be taken to secure the openings of the bag to the pipe by winding soft iron or copper wire around them.

As oil destroys rubber and changes it into a sticky, viscous mass, the gas bag should be placed out of reach of any oil which might be liable to splash upon it.

Gases, Expansion of. All gases expand equally, $\frac{1}{273}$ part of their volume for each degree of temperature, Centigrade, or $\frac{1}{491}$ part of their volume for each degree of temperature, Fahrenheit.

Gasoline, How Obtained. Gasoline, benzine, naphtha and the kindred hydrocarbons are the products of crude mineral oil.

They are separated from the crude oil by a process of distillation. The process is very similar to that of generating steam from water.

By the application of heat, water raised to a temperature of 212 degrees Fahrenheit changes from a liquid to a gaseous state, called steam. This conversion is only temporary. If steam is confined and cooled to a certain point it will quickly return to its liquid state, water, by the process known as condensation.

Crude mineral oil subjected to heat will give off, in the form of vapor, such products as gasoline, benzine, naphtha, etc. The degrees of heat at which these products are separated are comparatively low. Various degrees of heat will separate the distinct products. As a means of illustration, say that crude oil raised to a temperature of 110 degrees gives off vapor which when cooled will liquefy into what is known as naphtha, benzine at 125 degrees, and gasoline at 140 degrees. These degrees of temperature are not authentic—simply used to illustrate.

After these lighter products are separated there yet remains the thick, oily liquid from which the various lubricating oils are prepared.

Kerosene oil is one of the principal products of crude oil, and the oily sediment which frequently accumulates in the bottom of the tank or can in which gasoline is confined is kerosene oil, which distills over in small quantity with the vapor of gasoline.

Gasoline or Kerosene Fires. In case of fire due to gasoline or kerosene, use fine earth, flour or sand on top of the burning liquid. Never use water, it will only serve to float the gasoline or kerosene and consequently spread the flames.

A dry powder can be used for this purpose which will extinguish the fire in a few seconds. It is made as follows: Common salt, 15 parts—sal-ammoniac, 15 parts—bicarbonate of soda, 20 parts. The ingredients should be thoroughly mixed together and passed through a fine mesh sieve to secure a homogeneous mixture.

If by any chance a tank of gasoline or kerosene takes fire at a small outlet or leak, run to the tank and not away from it, and either blow or pat the flame out. Never put water on burning gasoline or kerosene, the gasoline or kerosene will float on top of the water and the flames spread much more rapidly. Throw fine earth, sand or flour on top of the burning liquid. Flour is best. The best extinguisher for a fire of this kind in a room that may be closed, is ammonia. Several gallons of ammonia, thrown in the room with such force as to break the bottles which contain it, will soon smother the strongest fire if the room be kept closed.

Gasoline explosions are often due to a pressure within a tightly-closed container, caused by high temperature, which vaporizes or gasifies the liquid within.

The changing of the liquid to the gaseous state causes expansion, and if there is no vent or safety valve connection the pressure within rises to a point sufficient to cause an explosion.

Gasoline Pump. A combined gasoline pump and gravity gasoline feed is shown in Figure 15. The gasoline is pumped into the cup to the right of the pump and is from this point drawn into the inlet-pipe of the engine by the inductive or suction action of the piston of the engine. The supply of gasoline to the engine is regulated by means of a needle-valve, the surplus gasoline fed to the cup is carried back to the supply tank through the pipe in the center of the cup. By this method a constant level is maintained in the cup, thus ensuring a uniform supply of gasoline to the engine at all times.

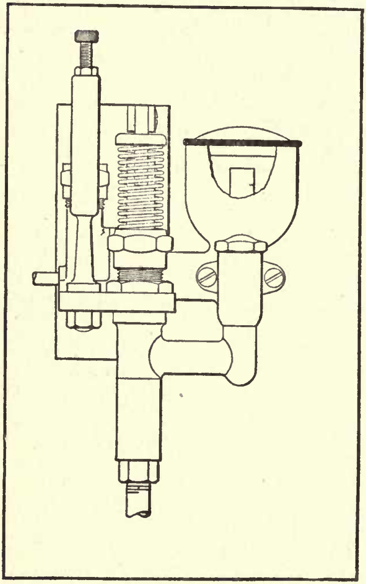

FIG. 15
Combined gasoline pump and gravity gasoline feed to engine.

Gasoline Traction Engines. From the result of experience it has been found that gasoline traction engines require a double cylinder construction, as the duty of the engine is to not only drive the traction gearing but to propel itself over the roads. It is found that for successful work in the field, which has heretofore been occupied by the steam traction engine, a gasoline engine of from 30 to 40 brake horsepower must be used. In an engine producing this amount of power in a single cylinder, the sudden impulses at intermittent intervals would require for successful operation a train of gearing so large and heavy that it absolutely precludes the possibility of making any reasonable construction. When, however, the engine develops the same power in two cylinders with impulses twice as frequent and only one-half as strong, it is possible to make a train of gears which will transmit the full power of the engine and consequently a strong and successful gasoline traction engine. The builders of gasoline traction engines have heretofore used engines of the old models, and while these engines have served their purpose in stationary work and to some extent in portable work, their use has not been as satisfactory as with the two-cylinder style of gasoline traction engine.

Gas or Oil Engines, Successful Operation of. Gas or oil engines are dependent for successful operation on two things: First, a charge of gas or vapor, mixed with sufficient air to produce an explosive mixture, and second, a method of firing the charge after it has been taken into the combustion chamber of the motor.

When coal or natural gas is used the supply is taken from the main and mixed directly with the necessary proportion of air. When gasoline or kerosene is used, air is mixed with them in the correct proportion by carbureting devices.

The principal parts of a gas or oil engine are the cylinder, the piston, the piston-rings which fit into grooves in the piston: two sets of valves, one to admit the charge and the other to permit it to escape after the explosion, a crank shaft and connecting-rod which connect it with the piston, and a flywheel, whose presence insures steady running of the motor, and whose further functions will be better understood as the description proceeds. In the two-cycle form of gas or oil engine there is really but one valve, which is located in the crank case, the exhaust and admission-ports being covered and uncovered by the piston itself.

Generator. This term is usually applied to any form of chemical or mechanical energy which can be used to produce a current of electricity. Mechanical generators of electricity used for ignition purposes are of two forms, dynamos or magnetos. The former is self-exciting by means of coils of wire wound upon the magnet limbs. The latter has permanent magnets instead of coils of wire to induce the current in the armature of the magneto. Magnetos, on account of their simplicity of construction and low first cost, are more generally used for ignition purposes than dynamos. They may be operated by the engine with a friction-pulley, gear or belt.

Governing Gas or Oil Engines. There are various methods of governing, which are here enumerated and described.

Hit-or-miss principle: Shutting off the gas or oil supply, opening or closing the exhaust, shutting off the ignition, disengaging the valve operator.

Throttling method: Throttling the gas or oil supply, throttling the charge of explosive mixture.

Varying the point of ignition: In cases where gas or oil engines are fitted with some form of electrical ignition, they are sometimes regulated by the governor being connected with a commutator, which automatically cuts the current off from the sparking device when the limit of speed has been passed, and the charge is not exploded till the revolutions of the engine are reduced to the proper speed, when the action of the governor closes the electrical circuit and the ignition again takes place.

A similar result may be attained also by varying the point of ignition, but both of these methods are not very economical.

Figure 16 shows a form of governor which operates by preventing the exhaust-valve from opening. When the speed of the engine passes its normal limit, the balls A of the governor move out towards the periphery of the gear or wheel which carries them, causing the cam B to be moved to the right by the action of the dogs on the governor arms, which engage in a grooved collar on the sleeve C.

The nose of the cam B is thus kept out of engagement with the roller D until the motor resumes its normal speed, thus preventing the valve-lifter from opening the valve.

Normally the cam is held in position by the springs attached to the governor balls, against

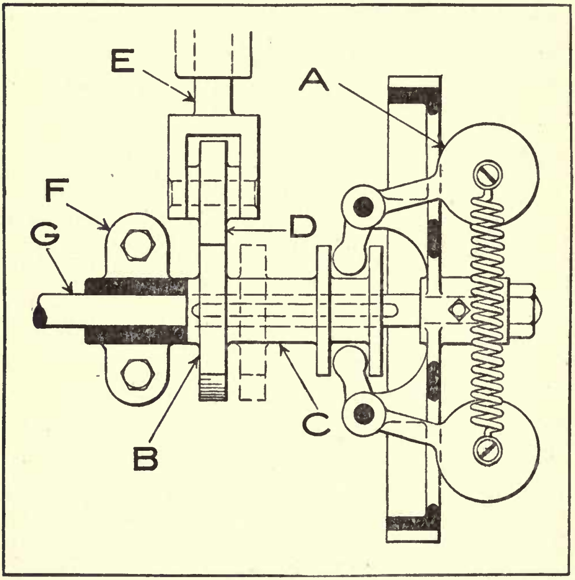

FIG. 16
Exhaust-valve governor which operates by throwing the cam out of contact with the cam-roller.

the shoulder of the bearing F, which carries the cam-shaft G.

A form of governor is shown in Figure 17 which may be used in connection with any of the methods of governing described above. It is usually located on an independent bracket and driven from the cam-shaft of the motor.

Figure 18 shows a governor working on the hit-and-miss principle. When the engine tends to run above its normal speed, the action of the governor balls causes knife-edge to move away from the notch in the end of the valve plunger, thus throwing the valve out of action.

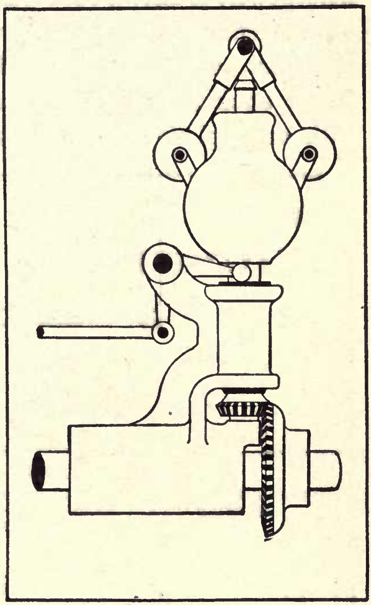

FIG. 17
Centrifugal governor for operating either hit-and-miss or throttling forms of speed regulating mechanism.

An inertia governor is shown in Figure 19. Should the engine attempt to increase its speed above normal, the lower end of the double-ended lever, at the left in the drawing, will be depressed by the cam and the valve-lifter thrown out of an engagement with the step immediately above the roller, in this manner preventing any further action of the valve-lifter until the speed of the motor is reduced.

Hand Starting Device. A hand starting device, for starting engines of from 10 to 25 horsepower, is shown in Figure 20, the flywheels of the engine are turned over until the piston is just past the dead center of the explosion or power stroke, the combustion chamber is filled with an explosive mixture by means of a hand

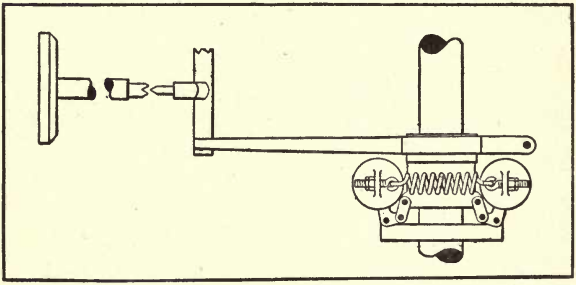

FIG. 18
Hit-and-miss type of centrifugal governor which operates by throwing the knife-edge out of contact with the valve-stem lifter.

pump, after a match has been inserted in the cock shown to the left in the drawing. The plug of the cock is closed, cutting off the match, the plunger is given a smart blow with the hand, the match is then consequently fired, the charge ignited and the piston started on its working or power stroke.

Horsepower of Gas or Oil Engines. A horsepower is the rate of work or energy expended in raising a weight of 550 pounds one foot in one second, or raising 33,000 pounds one foot in one minute. This is far more work than the average horse can do for any great length of time. A good horse for a short period of time can do much more.

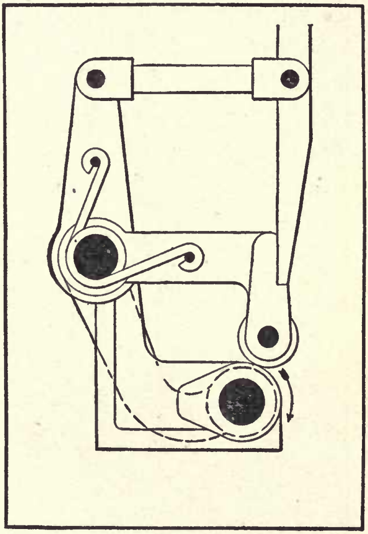

FIG. 19
Inertia type of governor, which operates by throwing the valve-lifter rod out of contact with the cam-roller lever.

As the ordinary formula used for the calculation of horsepower in connection with steam engines is not directly applicable to gas or oil engine practice, formulas are here given that are more suited to the purpose.

Let D be the diameter of the cylinder in inches, and S the stroke of the piston also in inches: if N be the number of revolutions per minute of the motor, and H.P the required horsepower of the motor, then for a four-cycle motor

$$H.P = \frac{D^2 \times S \times N}{18{,}000}$$

Example: What horsepower should be developed by an engine of 4½ inches bore and 6 inches stroke, at a speed of 600 revolutions per minute?

Answer: The square of the bore multiplied by the stroke is equal to 121.5, this multiplied by 600, and divided by 18,000, gives 4.05 as the horsepower of the motor.

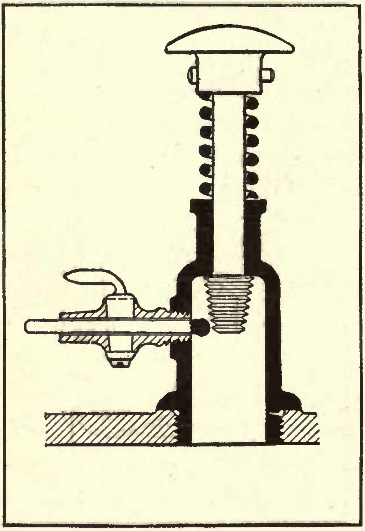

FIG. 20
Match igniter for starting gas or gasoline engines.

From a theoretical standpoint a two-cycle engine should not only have as great a speed but also be capable of developing almost twice the power that a four-cycle engine does. It is a fact, nevertheless, that its actual performance is far different.

The horsepower of a two-cycle engine may be calculated from the following formula:

$$H.P = \frac{D^2 \times S \times N}{21,000}$$

Example: Required, the horsepower of a

two-cycle motor of 4½ inches bore and 6 inches stroke, with a speed of 600 revolutions per minute?

Answer: The square of the bore multiplied by the stroke is equal to 121.5, which multiplied by 600, and divided by 21,000, gives 3.47 as the required horsepower. The results given by the above examples agree very closely with those obtained from actual practice.

Indicated horsepower is the actual power produced in the cylinder, from which must be deducted the power required for driving the engine itself.

Brake horsepower, also called actual horsepower, is the net effective power given off at the driving pulley of the engine, and this form of horsepower is the one for which a guarantee should be obtained from manufacturers by users.

Hot Tube Ignition. The incandescent tube system of ignition consists of a tube of metal or porcelain, one end of which is closed and the other screwed or fastened into the combustion chamber by suitable means.

The flame of a Bunsen burner is projected against the ignition tube, rendering it incandescent, resulting in the firing of the compressed charge slightly before the end of the compression stroke.

The Bunsen burner should be adjusted so as to give a small blue flame entirely round the ignition tube. If too much gas is being used, a smell will come from the chimney.

It is important that the ignition tube be always kept to a bright red heat, should it be allowed to get foul, misfires will occur.

Ignition tubes should be renewed as soon as they begin to appear defective, which will be indicated by irregularity in the firing, as, although the engine may continue working for some time, a considerable loss of gas may be going on.

In putting in a new ignition tube care should be taken that no grit is allowed to get into the passage leading to the combustion chamber.

Igniter, Cleaning an. The igniter should be taken off and cleaned after intervals of from sixty to ninety days of constant running. All carbon and corrosion should be removed from the igniter points and mica washers.

Ignition, Catalytic. This method of ignition for gas or oil engines is based on the property possessed by spongy platinum of becoming incandescent when in contact with coal gas or carbureted air. With this means of ignition, speed regulation or variation can only be had within very narrow limits. The principal objections to its extended use are, danger of premature ignition, lack of speed control and difficulty of starting the motor.

Ignition, Forms of. The earlier forms of gas engines built had the compressed charge ignited by means of a flame, which has, however, now given place to the three following methods of ignition:

Hot surface.

Hot tube.

Electric.

The first-named form of ignition is illustrated in Figure 26. In this form the heated walls of the vaporizer act as the igniter, aided by the heat generated during the compression of the gases. The chamber being first heated, afterward the proper temperature is maintained by the heat caused by the combustion of the gases. Various other devices in which heat is maintained to cause self or spontaneous ignition are now made.

The second type, that of the hot tube, is shown in Figure 12 at P. This form of ignition consists of a metal tube fitted into the vaporizer or cylinder wall. It is closed at one end, the other end being open to the cylinder. It is heated by a Bunsen flame over part of its length. When compression due to the inward stroke of the piston takes place in the cylinder the explosive mixture is compressed into the tube and is ignited by coming in contact with the heated portion of it. Nickel-steel tubes are preferable to wrought iron, although both are used for this purpose.

The third form, that of electric ignition, is of two kinds, the primary make and break, with which a mechanical device to make the primary circuit in the combustion chamber of the motor is used, and the secondary or jump-spark form of ignition, in which the spark jumps or arcs within the cylinder without the aid of any mechanical device.

Ignition Mechanism. A form of ignition mechanism used in connection with the primary make and break system of electrical ignition is illustrated in Figure 21. Upon the operating rod being moved to the left, the pawl carried by the upper arm of the bell-crank lever forces downward the small trigger carried upon the outer end of the movable electrode and in this manner passes by it. Upon the return stroke of the operating rod the upper end of the pawl engages with the trigger, bringing the contact-points of the movable and fixed electrode together for a short period of time. A further movement of the operating rod in the same direction causes the trigger to be released from contact with the pawl. This

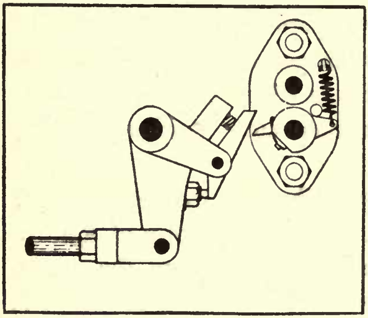

FIG. 21
Ignition mechanism for use in connection with a primary make and break spark.

action causes the contact-points of the electrodes to suddenly fly apart and a spark or arc is produced between them.

Ignition, Reason for Advancing Point of. It may be well to explain, without entering into theoretical details, that when an engine is running at normal speed the ignition mechanism is so set that ignition takes place slightly before the piston reaches the end of its compression stroke.

If the charge is fired at or after the end of the compression stroke, the average pressure on the piston, and consequently the power, is decreased in proportion. Therefore to ensure perfect combustion with a maximum pressure at the commencement of the explosion stroke, the point of ignition must be earlier, and advance as the speed increases.

Indicator Diagrams. The thermal or heat efficiency of a gas or oil engine may be determined from an indicator diagram, which gives a representation of the internal conditions throughout the entire cycle of operations. The diagram tells many things essential to be known.

It gives the initial explosive pressure, or the pressure a moment after ignition has taken place. It shows whether the volume of the charge is diminished during the period of admission. It gives the point of ignition, when the ignition is complete and when expansion begins. It indicates the pressure of expansion during the working stroke. It gives the terminal pressure when the exhaust is opened. It shows the rapidity of the exhaust. It indicates the back-pressure on the piston, due to the exhaust. It shows the point of opening of the exhaust. It gives the mean power used in driving the motor. It also indicates any leakage of valves or piston.

The usual method of ascertaining the area of an indicator diagram is by means of an instrument known as a planimeter, which is used to calculate the area of any irregular surface, by moving a tracing point attached to the instrument over the entire irregular boundary line of the figure.

But for the purpose of ascertaining the horse-power of an engine it will be sufficiently accurate to illustrate the principles involved, to calculate the area of the diagram by means of ordinates or vertical measurements.

The upper drawing in Figure 22 represents a card taken from an engine of 4 inches bore and 6 inches stroke, at 600 revolutions per minute, and under a full load. The diagram is divided into 12 parts as shown by vertical lines, the lengths of which are in terms of the spring, which is 100. Then 1.90+1.36+1.00, etc., divided by 12, equals 0.665 as the average height of the diagram. Its length is 6 inches, as shown, therefore the area of the card is approximately 3.99 square inches. As the initial explosive force from the diagram is 250 pounds per square inch, and a 100 indicator spring used, the height of the card is 250 divided by 100, which equals $2\frac{1}{2}$ inches as the height of the card. The mean effective pressure on the piston in pounds per

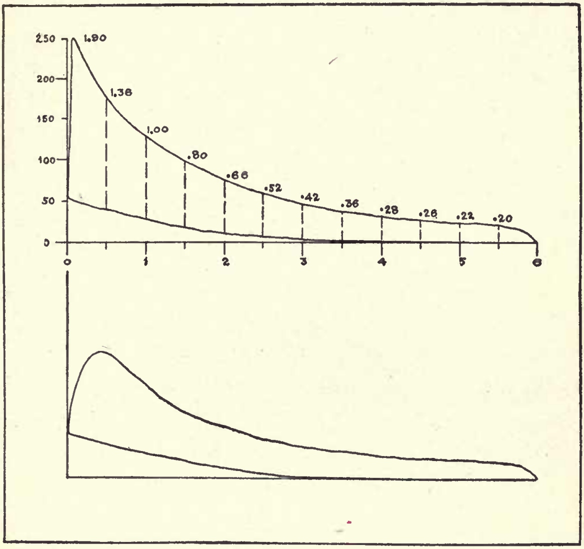

FIG. 22
Indicator diagrams, showing cards with engine at full and at half load.

square inch will therefore be equal to the area of the diagram 3.99, divided by the area of the whole card, which is $2\frac{1}{2} \times 6$, equals 15, and multiplied by 250, the initial explosive force, or 3.99×250, and divided by 15, equals 66.5 pounds per square inch as the mean effective pressure required.

From this the indicated horsepower of the engine can readily be found as follows:

Let M.P be the mean effective pressure in pounds per square inch, A the area of the cylinder in square inches, S the stroke of the piston in inches, N the number of explosions per minute, and H.P the indicated horsepower, then

$$H.P = \frac{M.P \times A \times S \times N}{396{,}000}$$

$$= \frac{66.5 \times 12.56 \times 6 \times 300}{396{,}000} = 3.79$$

as the required indicated horsepower of the engine. The indicated horsepower of any engine will always be greater than that obtained from a brake test, as it simply represents the actual thermo-dynamic (heat-pressure) conditions within the cylinder, and takes no account of friction and other external losses.

The lower drawing in Figure 22 is a card taken from the same engine running under half load.

Indicator, Use of the. An indicator consists of a cylinder within which works a piston under the tension of a helical spring of predetermined strength. The rod attached to the piston carries a pivoted arm which works on a horizontal lever. This lever carries a pencil bearing against a drum. This drum is so arranged with a spring that it may be partially rotated by the pull on an attached string. A sheet of paper is wound on the drum and held in place by spring clips. The pressure in the cylinder acting on the spring causes the pencil to mark the paper, the indicator card or diagram being traced by the forward and backward movement of the drum.

Inspecting Gas or Oil Engines. Before examining an engine with a light, care should be taken that the combustion chamber is free from gas mixture. This can be done by turning the engine round a few times. The ignition should be cut out and the fuel supply cock closed. It is more or less dangerous to look down the chimney of the ignition tube when the engine is running.

It is sometimes necessary to inspect the interior of the engine cylinder with a lighted candle, for the purpose of locating some sharp projection, burnt carbon, crack or sand hole, etc. When doing this, always remember that a charge of fuel may remain in the cylinder, and whether the candle is inserted through one of the valve ports or the open end of the cylinder, be sure to keep the face away from the opening.

Installing a Gas or Oil Engine. Secure the engine to a good foundation made according to the plans furnished by the engine builder.

Set up the water tank at any convenient distance from the engine, preferably as close as possible on the exhaust side. Use short pieces of rubber hose in the cooling tank piping. Put the shut-off valve close to the tank. Be sure that the vent pipe is long enough to be above the top of the tank. Water should always be at least 6 inches above the upper pipe or it will not circulate.

The water tank may be dispensed with by connecting a water feed pipe direct from a hydrant to the opening in exhaust valve chamber and running a waste pipe from top of cylinder jacket to carry off the water.

Regulate the amount of water by means of a stopcock placed in this pipe.

Keep the cylinder jacket just as hot as can be borne by the hand, say from 140 to 160 degrees Fahrenheit.

The fuel tank may be placed outside of the building and should be in a vertical position, twelve to eighteen inches lower than the top of the foundation, so that the fuel will flow from engine to tank. Care should be taken to wash out every piece of pipe with gasoline before connecting up, this removes all dirt and scale which would interfere with the proper working of the check valves. Extra care should be taken in making all water and fuel pipe connections tight. Use soap in the joints of the fuel pipes.

Run the exhaust pipe in any convenient direction, placing the muffler as near the engine as possible. Never use a pipe smaller than the opening in the muffler. Long and crooked runs should be avoided, but if necessary use a size larger pipe It is not advisable to exhaust into a chimney.

Long vertical pipes collect water and should be connected with a Tee fitting at the bottom provided with suitable connections for draining.

Connect the battery cells with the spark coil, switch and binding posts on the engine. The ends of wires where the connections are made should have all the insulation removed and all nuts tightened well to insure good connections.

Jump-spark Wiring Diagram. A method of wiring for a single cylinder engine using a set of batteries and a magneto-generator is illustrated in Figure 23. By moving the switch-finger, either the magneto-generator or the battery may be used as desired, or both cut out.

Knocking or Pounding in an Engine. May be due to any of the following causes:

Premature ignition: The sound produced by premature ignition may be described as a deep, heavy pound.

Using a poor grade of lubricating oil will cause premature ignition. The carbon from the oil will deposit on the head of the piston in cakes and lumps, and will not only increase the compression but will get hot after running a short time and will ignite the charge too early, and

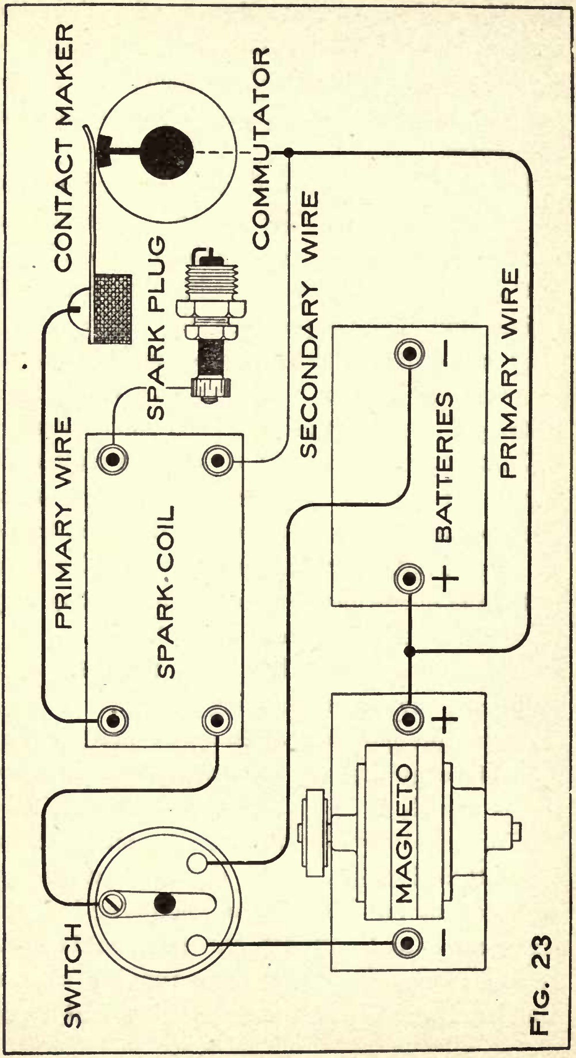
CONTACT MAKER
COMMUTATOR
SPARK PLUG
SECONDARY WIRE
PRIMARY WIRE
SPARK COIL
BATTERIES
PRIMARY WIRE
MAGNETO
SWITCH

FIG. 23

thereby produce the same effect as advancing the spark too much. If this is the cause the pounding will cease as soon as the carbon deposit is removed from the combustion chamber.

Badly worn or broken piston-rings.

Improper valve seating.

A badly worn piston.

Piston striking some projecting point in the combustion chamber.

A loose wrist-pin in the piston.

A loose journal-box cap or lock-nut.

A broken spoke or web in the flywheel.

Flywheel loose on its shaft.

If the sparking device be placed so as to be exactly in the center of the combustion space an objectionable knock occurs, which has never been fully explained. In some engines it renders a particular position of the ignition unusable, this form of knock disappears either on making a slight advance or retardation of the ignition.

If the cylinder is in good condition, and a bumping noise is heard when working at full load, it may arise from too much oil being supplied to the engine, which should be regulated accordingly.

Explosions occurring during the exhaust or admission stroke. This is almost always due to a previous misfire, and it may be prevented by stopping the misfires.

If the ignition is so timed that the gases reach their full explosion pressure during the compression stroke, that is, if the spark be unduly advanced, an ugly knock occurs, and great pressure is developed on the crank-pin bearing, wrist pin, and connecting-rod. The effect may be the bending or distorting of the connecting-rod.

The crank-pin may not be at right angles to the connecting-rod. This cause of knock is often hard to find.

The bearings at either end of connecting-rod may be loose. A knock during the explosion stroke, and also at each reversal of the direction of the piston.

If the crank shaft is not perfectly at right angles to the connecting-rod, the crank shaft and flywheels will travel sideways so as to strike the crank shaft bearings on one side or the other.

Liquid Fuels. The supply of petroleum is produced chiefly in the United States of America and in Russia, while it is also found in many other countries in small quantities.

Petroleum is found in the United States in the Central Eastern States, but principally in Pennsylvania, New York, Ohio and West Virginia, in Texas in the region around Beaumont and Corsicana, in California chiefly in the Kern County, Coalinga, Los Angeles, producing fields. In Russia, oil fields are found around Baku and in the range of the Caucasus Mountains.

Kerosene or shale oil, a liquid fuel produced by a slow process of distillation of shale and bituminous coal, is also produced in Scotland.

Crude petroleum as it issues or is pumped from the earth contains a variety of hydrocarbons of different characteristics, and after its sediment has settled it is subjected to a process of refining known as fractional distillation, by which process the various hydrocarbons are separated and are afterwards condensed into the different products known in commerce as benzine, gasoline, naphtha, being the lighter products, having a flash-point below 73 degrees Fahrenheit. Next the illuminating oils, such as W. W. 150 degree kerosene, White Rose and other brands of a similar composition, are obtained, having a flash-point above 73 degrees Fahrenheit. The next product is gas oil, or fuel oil, used largely for gas-making and also as fuel in gas and oil engines, having a flash-point of about 190 degrees. Lubricating oils, paraffine, wax and vaseline are afterwards procured, the residue being a heavy liquid sometimes used for fuel.

Locating an Engine. The engine should be placed in a separate, well-lighted room if possible and free from the dust of the shop or factory. At least three feet of space should be provided round the engine to enable the operator to get at the flywheel and other working parts, and it should be arranged so as to give a straight and fairly long belt drive.

Lubricants. To ensure easy running and reduce the element of friction to a minimum it is absolutely necessary that all such parts should be supplied with oil or lubricating grease, but it is also a fact, not so well understood, that different kinds of lubricant are necessary to the different parts or mechanisms of an explosive motor.

As the cylinder of a gas or oil engine operates under a far higher temperature than is possible in a steam engine, consequently the oil intended for use in these cylinders must be of such quality that the point at which it will burn or carbonize from heat is as high as possible.

While a number of animal and vegetable oils have a flashing-point, and yield a fire test sufficiently high to come within the above requirements, they all contain acids or other substances which have a harmful effect on the metal surfaces it is intended to lubricate.

The general qualities essential in a lubricating oil for use in gas or oil engine cylinders include a flashing-point of not less than 360 degrees Fahrenheit, and fire test of at least 420 degrees, together with a specific gravity of 25.8.

At 350 to 400 degrees Fahrenheit, lubricating oils are as fluid as kerosene, therefore the adjustment of the feed should be made when the lubricator and its contents are at their normal heat. Steam engine oils are unsuitable for the dry heat of motor cylinders in which they are decomposed whilst the tar is deposited.

All oils will carbonize at 500 to 600 degrees Fahrenheit, but graphite is not affected by over 2,000 degrees Fahrenheit, which is the approximate temperature of the burning gases in an explosive engine. The cylinder of these engines may attain an average temperature of 300 to 400 degrees Fahrenheit. So that graphite would be very useful if it could be introduced into the engine cylinder without danger of clogging the valves and could be fed uniformly. These difficulties have not yet been overcome.

The film of oil between a shaft and its bearing is under a pressure corresponding to the load on the bearing, and is drawn in against that pressure by the shaft. It might not be thought possible that the velocity of the shaft and the adhesion of the oil to the shaft could produce a sufficient pressure to support a heavy load, but the fact may be verified by drilling a hole in the bearing and attaching a pressure gauge.

Lubrication of Oil Engine Cylinders. On account of the rapid decomposition of the lubricating oil in gasoline and kerosene engine cylinders, it is very important that an oil should be selected which does not vaporize or carbonize easily and leave much residue. A pressure sight-feed lubricator should be employed, and no more lubricating oil used than is absolutely necessary.

For some reason gasoline and kerosene engines give more trouble in this connection than gas engines. One reason is that the hydrocarbon vapor of an oil engine affects the lubricating oil in a different manner to the explosive mixture of a gas engine.

Lubrication, Over or Improper. Smoke coming from the exhaust of a gas or oil engine is due to one of two conditions: Over-lubrication—too much lubricating oil being fed to the cylinder of the engine—or too rich a mixture, that is, too much gasoline and an insufficient supply of air.

The first condition may be readily detected by the smell of burned oil and a yellowish smoke. The second, by a dense white smoke accompanied by a pungent odor.

If the engine is working properly, the exhaust should be almost colorless or with a light blue haze. The oil used should be of the highest flash-point obtainable, as the heat in a gas or oil engine cylinder is very dry and intense.

The effect upon animal or vegetable oils of such heat would be to partially decompose the oils into stearic acids and oleic acid and the conversion of these into pitch.

Mineral oils are not so readily decomposed by heat, but at their boiling points they are converted into gas, and any oil, the boiling point of which is in the neighborhood of the working temperature of the engine cylinder, is useless, as its body is too greatly reduced to leave an effective working film on the cylinder walls.

Lubricators. Always ascertain from the builder of the engine how many drops of oil per minute are necessary for the different working parts of the engine. The lubricators or oil cups should then be set accordingly.

It should be remembered that in cold weather, when the oil is thick, a different adjustment of the lubricators will be necessary from that found suitable in warm weather. It is important that the lubrication should be regular, and good oil used, but not too much. Too much oil will foul the igniter points, clog the valves, and interfere with the quality of the explosive mixture. For this reason the lubricators should always be carefully closed when the engine is stopped. If a mechanical lubricator is used, examine the mechanism sometimes, and do not trust entirely to the feed. If a pressure lubricator is used, see that the piston or cap is tight, for if not the pressure will stop the lubrication.

Magneto Generator. The simplest form of magneto consists of two or more magnets of horse-shoe shape, the ends of which embrace the pole-pieces, between which rotates a shuttle armature wound with small insulated copper wire. Rotation of the armature of the magneto tends to disturb the path of the lines of force or magnetic flux flowing between the ends of the permanent magnets, which in turn set up powerful induced currents in the armature. The current produced by the magneto is of an alternating nature, but is converted into a direct or continuous current by means of the commutator on the armature shaft.

Misfiring, Causes of. Misfiring means failing to fire every explosive charge that the engine takes.

One of the most common causes of misfiring is an improper mixture of gasoline and air. Too much air or too much gasoline will cause misfiring.

Batteries which are almost exhausted will give rise to explosions in the engine cylinder which seem all the more violent on account of their irregularity. It is perfectly useless to connect a set of nearly exhausted cells with a new set, either in series or parallel, as it will reduce the new cells nearly to the voltage of the exhausted ones.

Examine the battery and all its connections at the terminals, and determine whether the battery is exhausted or not, or whether there are broken connections. It may be that the ignition contact points need cleaning or attention otherwise. Also ascertain whether the fuel is being fed to the engine in proper quantities. It may not be getting enough at each charge or perhaps too much.

Misfiring will also occur from the ignition tube being fouled from soot or oil.

Mixing Valve. For stationary or portable gasoline engines where the speed is not being constantly changed, mixing valves are specially

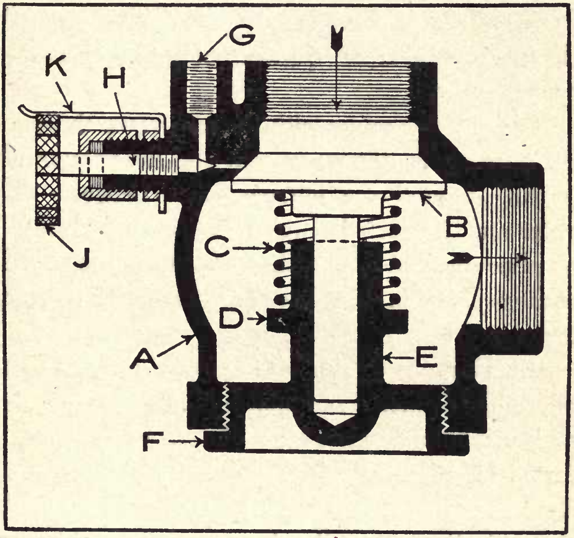

FIG. 24

Mixing valve for use with gasoline engine, showing air inlet-valve and gasoline needle-valve regulation.

adapted. A standard type of mixing valve is illustrated in Figure 24. It consists of a chamber A, valve B, spring C, collar D, valve-stem guide E, cover F, gasoline inlet G, needle-valve H, thumb-nut J and lock-spring K.

The gasoline is fed through a suitable pipe from the supply tank to the opening in the seat of the valve. The rate of feed or flow of the gasoline is regulated by means of the needle-valve. The inductive action of the engine piston draws the valve from its seat and at the same time uncovers the opening in the valve-seat leading from the gasoline supply pipe and allows of the flow of a small quantity of gasoline as the case may be.

The gasoline mixes with the air drawn through the opening in the valve-seat and the friction of passing around the narrow space between the valve and its seat insures a uniform mixture of gasoline and air. The air is drawn through the mixing valve in the direction indicated by the arrows.

Oil Engine Cycle. The cycle or series of operations which take place in the vaporizing and combustion chambers of one of the usual forms of oil engine is illustrated in Figure 25. Before starting the engine the vaporizing chamber, shown to the left in the drawing, is brought to a red heat by means of a Bunsen burner, this heat being afterwards maintained by the combustion of the gases in the vaporizing chamber.

During the suction stroke of the piston, a jet or spray of oil is forced through the opening in the nozzle at the bottom of the vaporizing chamber by means of a pump, and upon coming into contact with the hot interior of the chamber is at once transformed into vapor, at the same time a charge of pure air is drawn into the cylinder of the engine through the valve shown at the bottom of the combustion chamber. The piston then compresses the charge of air, forcing a portion of it into the vaporizing chamber and as soon as the explosive charge has reached the proper degree of temperature spontaneous or self-ignition takes place.

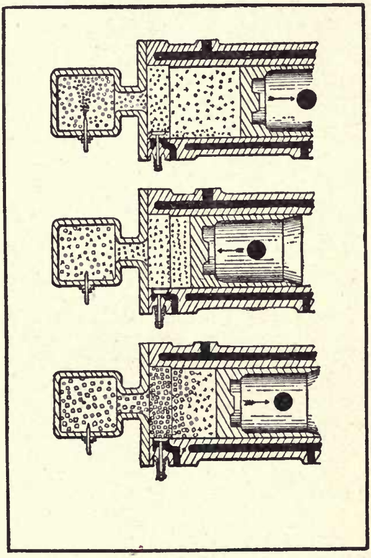

FIG. 25
Cycle of oil engine, showing the various operations during the cycle.

Oil Vaporization, Methods of. Oil engines have two methods of vaporization, one in which the oil is injected directly into the cylinder and the other where it is drawn in with the air. The mixture of oil vapor and air being carried on by compression in the cylinder, ignition is caused by an electric or tube igniter. The heat from the exhaust is sometimes utilized to raise the temperature of the chamber through which the oil passes to the cylinder, which, with the heat caused by compression, is sufficient to cause vaporization and a proper mixing with the air to form an explosive mixture, the chamber, which is heated by the exhaust in operation, being first heated by a burner.

The different types of vaporizers may be classed as follows:

A vaporizer into which the charge of oil is injected by a spraying nozzle connected to the combustion chamber through a valve.

A vaporizer into which the oil is injected, together with a small volume of air, the greater volume of air entering the cylinder through a separate valve.

A vaporizer into which the oil and all the air supply is drawn, but without a spraying device.

A form of vaporizer into which the oil is injected directly, air first being drawn into the cylinder by means of a separate valve, the explosive mixture being formed only with the compression.

Oil Vaporizer, Crude. On the Pacific coast crude oil is now largely used for fuel. In many instances the crude oil is vaporized in a separate apparatus and is then used in an ordinary gas engine. This apparatus is usually separate from the engine, the oil being entirely vaporized before it reaches the engine. Such vaporizing apparatus are made by various manufacturers, but in general principle they are similar. The heat of the exhaust gases from the engine is utilized to heat the vaporizer into which the crude oil is introduced, where it is converted into gas.

The fuel to be vaporized enters a ribbed chamber through suitable openings, and the gas is drawn from the chamber through a separate connection to the engine cylinder. The exhaust gases from the engine are connected to an outer chamber and pass around, heating the inner chamber to a temperature necessary for vaporization. Provision is made to draw off the residue of the crude oil, which is not capable of vaporization, and provision is also made to cleanse the vaporizing chamber of deposits of carbon and other non-combustible matter.

Oil Vaporizers. The usual form of oil vaporizers consists of a heated chamber in which the charge of oil is transformed into vapor before being mixed with the air in the cylinder of the engine.

Vaporizers vary considerably in their construction and operation.

In some the oil strikes the air as it enters, in others a pump forces a jet of oil against the sides of the vaporizing chamber and is in this manner broken up into spray and mixed with the hot air, which rapidly vaporizes it.

A form of oil vaporizer is illustrated in

Figure 26, in which the charge of oil is sprayed directly into the vaporizing chamber by means of

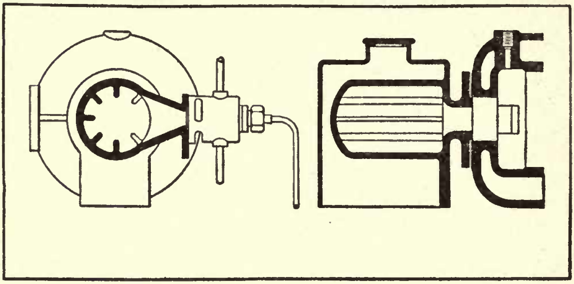

FIG. 26
Vaporizing chamber of oil engine, showing the flanges or ribs in the chamber and oil feed to the vaporizing chamber.

a pump, the oil passing to the chamber through the small pipe shown in the left-hand view in the drawing.

Overheating, Causes of. The effect of overheating is to burn up the lubricating oil in the cylinder. This causes a smell of burning and an odor of hot metal. There is sometimes a slight smoke and the engine will make a knocking sound.

A simple test in the case of an overheated engine is to let a few drops of water fall on the head of the cylinder. If it sizzles for a few moments the overheating is not bad, but if the water at once turns into steam, the case is serious.

As soon as any of the above symptoms are noticed:

The engine should be stopped at once.

Kerosene should be copiously injected into the cylinder and the engine turned by hand to free the piston-rings.

Insufficient lubrication increases the friction between the piston and cylinder, and so generates extra heat. Bad or unsuitable lubricating oil may have the same effect.

Too rich a mixture also causes increased heat.

Pistons. The piston used in a gasoline engine cylinder is usually of the single-acting or trunk type. It is made of an iron casting which is a good working fit in the cylinder. Around the upper end of the piston three or four grooves are cut, and in these grooves the piston-rings fit. The rings are made of cast iron, and the bore of the ring being eccentric to its outer diameter, there is a certain amount of spring in them, and so pressure is caused against the cylinder wall, preventing any of the expanding gases passing the piston.

The lubrication of the piston-rings is very important, for on that depends the proper working of the piston in the cylinder. In single-cylinder engines, the piston-rings require frequent attention, and kerosene should be injected into a suitable opening at frequent intervals. Occasionally the piston should be taken out, and the rings cleaned with a brush and kerosene.

Piston Displacement. The piston displacement of an engine is the volume swept out by the piston, and is equal to the area of the cylinder multiplied by the stroke of the piston. The expression, cylinder volume, is sometimes confounded with the term piston displacement. This is erroneous, as the cylinder volume is equal to the piston displacement, plus the combustion space in the cylinder head.

Pistons, Length of. For vertical cylinder gas or oil engines the length of the piston should not on any account be less than one and one-quarter its diameter, while a length equal to one and one-third or even one and one-half diameters is better. For engines with horizontal cylinders the length of the piston, in any case, should not be

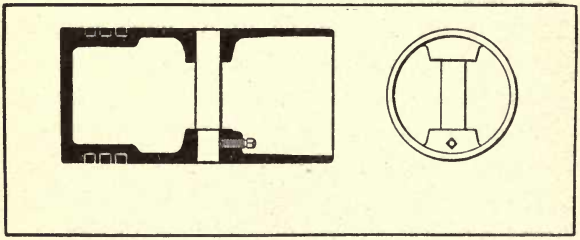

FIG. 27
Longitudinal section and end elevation of piston for gas or oil engine.

less than one and one-half diameters, and if possible one and two-thirds diameters or over.

A typical piston for gas or oil engine use is shown in Figure 27.

Piston-rings. To ensure proper compression, it is absolutely essential that the piston-rings should be kept lubricated, consequently if the engine has been standing for some time, the compression at the start is often poor. Any failure in the lubrication while running will, of course, have the same effect, such, for example, as in the case of overheating, or when the supply is intermittent. Sometimes the piston-rings get stuck in their grooves with burnt oil, through overheating, and the compression escapes past them. Thorough cleaning with kerosene and fresh lubricating oil will settle the matter. In engines where the rings are not pinned in position, the slots may sometimes work round so as to coincide.

A new method of making piston-rings has recently been introduced, for which several important advantages are claimed. The rings are turned and finished to the correct size of the cylinder in the usual way, and are afterwards automatically hammered on their inside surfaces, to give them the necessary elasticity.

The hammering is made heaviest and by this method a stress is set up diametrically opposite to the ring joint, and the hammering gradually reduced in both directions till the joint is reached.

Piston-rings, Method of Turning. A pattern should be made from which to cast a blank cylinder or sleeve with two projecting slotted lugs on one end to bolt same to face plate of lathe. This blank should first be turned off outside to the required diameter, making it, of course, sufficiently larger to allow for the cut in the rings, after cutting from the blank. The blank should then be set over eccentric sufficiently to allow the thick side of the rings to be twice the thickness of the thin side after turning. The inside of the blank can then be bored out, and the rings cut off to the exact thickness required with a good sharp cutting off tool. A mandril or arbor should be made with two cast iron washers or collars to fit on it, one fastened to the mandril and the other loose, with lock nut on mandril with which to tighten up the loose collar. After the rings have been sawed open and a piece cut out the required length, they can be placed in a collar or ring about 1-32 to 3-64 of an inch larger than the cylinder bore, and slipped on to the mandril one at a time of course, with the loose collar and nut off the same. The loose collar and nut can then be put on the mandril, the ring clamped tightly between the two collars, the mandril put in the lathe and the ring turned off, without leaving any fins or having to cut the ring off afterward as is done in many cases. This is the only way in which a perfectly true ring can be made.

Figure 28 shows two forms of piston-rings, the cut or slot in one being of the type known as the ship-lap and the other as the miter-cut. Both forms are in use, the ship-lap form, however, is the more expensive to make.

Piston Velocity. The rate of travel or speed of the piston of a gas or oil engine is from 600 to 750 feet per minute.

To ascertain the piston velocity in feet per

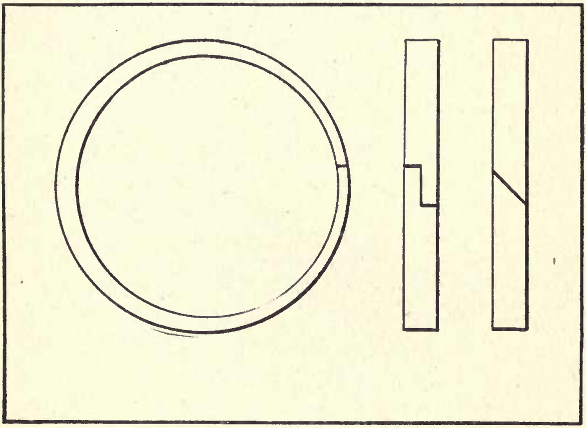

FIG. 28
Side and end elevation of piston-rings, showing ship-lap and miter-cut types.

minute, multiply the stroke of the piston in inches by the number of revolutions per minute and divide the result by 6.

Example: Required the piston velocity of an engine with 9-inch stroke, at 400 revolutions per minute.

Answer: Nine multiplied by 400 equals 3,600,

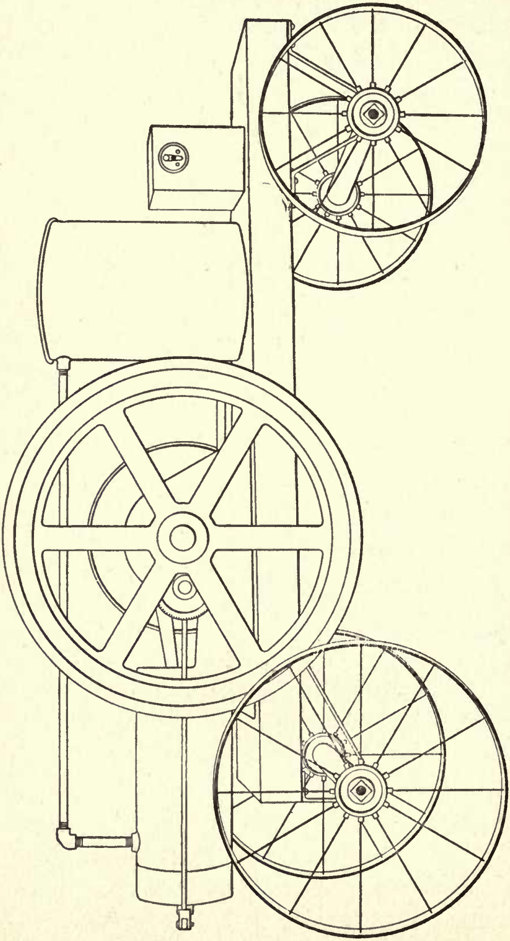

FIG. 29

this divided by 6 gives 600 feet per minute as the piston velocity.

Portable Oil Engines. Portable gasoline and kerosene engines are used for a variety of purposes. Such engines in connection with circular saws, electric light or pumping outfits are found very useful. Portable engines are also used for agricultural work, such as operating threshing machines, feed cutters and other farm machinery. Figure 29 shows a portable oil engine mounted upon a truck with wooden frame and steel wheels and running gear. The engine, cooling apparatus and battery are clearly shown in the drawing.

As portable engines require to be frequently moved from place to place, the design of the outfit should be as light as possible and yet substantial in construction, so that it may be moved from one place to another in the shortest possible time and with the least expense for transportation.

As portable engines are often in places where a supply of water is not available, the water-cooling apparatus forms an important part of the outfit.

Another form of portable engine is shown in Figure 30, which is simply mounted on skids and may be moved from place to place by two persons. Such an outfit is of much smaller capacity than the one previously described and illus-

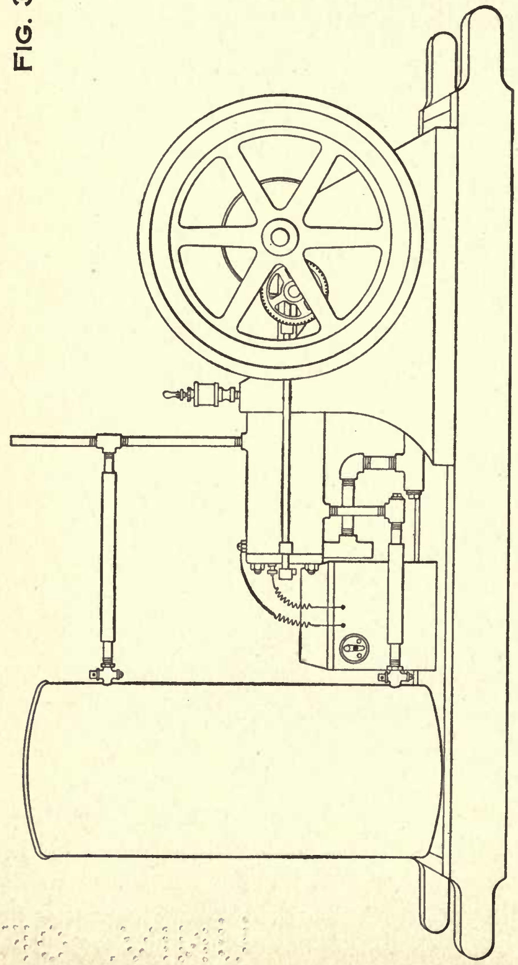

FIG. 30

trated, but is found useful for many purposes where small power is needed.

Premature Ignition, Causes of. Too great a degree of compression of the charge, an incandescent deposit of soot or foreign substance in the combustion chamber, from slow or incomplete combustion of the previous charge, which remains sufficiently heated to fire the new charge before the completion of the compression stroke, burning gases drawn from the exhaust-pipe into the combustion chamber, from the overheating of the exhaust valve. Premature ignitions are also attributed to the use of low-flash test oils for lubricating the cylinder, and too little air in the charge will also cause too rapid firing, or in the case of the primary form of electric ignition from overheated igniter points.

Primary-spark Coil. This form of induction coil is generally used for ignition purposes on gas and gasoline engines fitted with a mechanical make-and-break form of spark, which is located within the combustion chamber of the engine itself.

It consists of two principal parts, a core, made of a bundle of soft iron wire, and a coil of wire around this core composed of from 3 to 5 layers of turns of insulated copper wire, varying in diameter from No. 16 to No. 12, B. & S. Gauge, according to the battery conditions under which the coil has to operate. The iron core may vary from three-eighths of an inch in diameter and 6 inches long, to three-fourths of an inch in diameter, and 12 to 15 inches long, depending upon the intensity and capacity of the spark required.

Primary-spark Plug. The construction of one of the usual forms of make-and-break primary-spark plugs is clearly shown in Figure 31. The upper and fixed electrode is insulated by

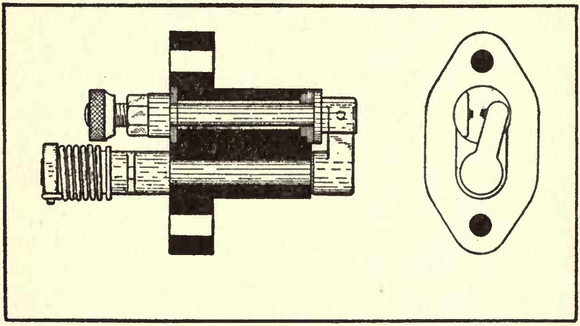

FIG. 31
Primary-spark plug, showing fixed and movable electrodes and platinum contact-points.

means of mica or lava washers and is secured in place by means of a lock nut and washer. The movable electrode has a coil spring around its outer end, one end of the spring secured to the spindle of the electrode and the other to the hub of a small trigger on the extreme end of the spindle. This construction allows for any wear on the contact-points and at all times ensures a good contact between them.

Prony Brake. This simple device gives the actual energy in foot-pounds per minute delivered by the engine at its driving shaft.

The apparatus for making a brake test is fully illustrated in Figure 32. Two brake-blocks A partially surround the pulley P and are attached to the clamping pieces B and C, which hold the brake-blocks upon the pulley by means of the bolts D, springs E and thumb-nuts F. The lever G is double-ended for the dual purpose of balancing itself and also supplying a place of attachment for the weight W to balance the weight of the spring scale S.

In using this form of Prony brake, the engine is started in the direction indicated by the arrow on the drawing, the brake-blocks A are then tightened by means of the springs E and thumb-nuts F. Then the reading of the spring scale S and the speed of the pulley P are taken.

The engine should be tested at varying speeds and the pull on the spring scale S noted for each.

The actual horsepower can then be calculated for each test and what is known as the critical speed of the engine determined, that is the speed at which the engine develops the greatest brake horsepower.

The following formula gives the actual horsepower obtained from the results of a Prony brake test: Let L be the length of the scale lever in inches, and S the pull indicated by the spring

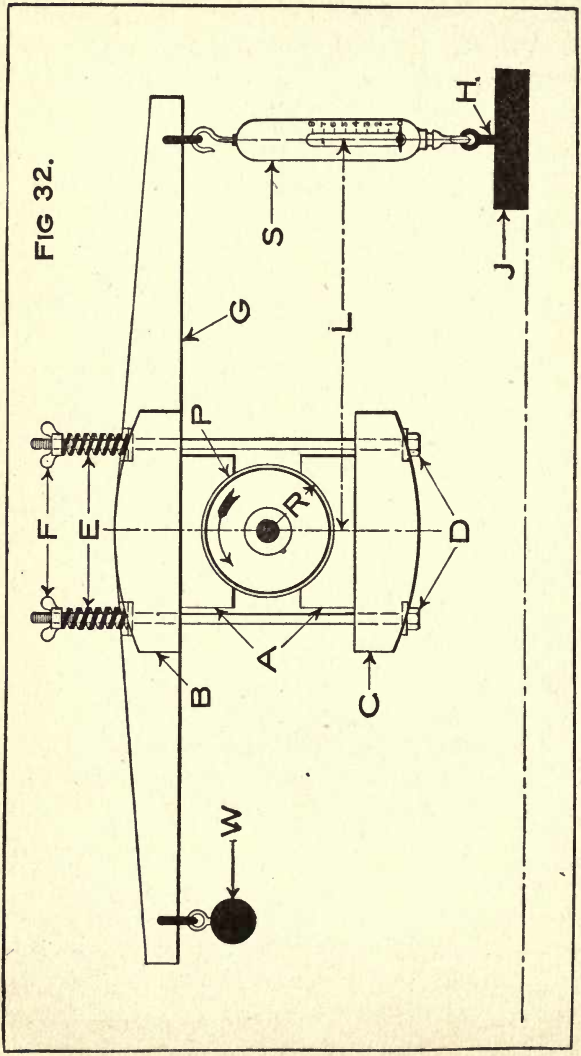

FIG 32.

scale in pounds. If N be the number of revolutions per minute of the pulley R and B.H.P the actual or brake horsepower of the engine, then

$$B.H.P = \frac{L \times S \times N}{63,025}$$

Example: A motor of 5 inches bore and $7\frac{1}{2}$ inches stroke at 400 revolutions per minute gives a pull at the spring scale of 48 pounds, the scale lever is 24 inches long. What is the brake horsepower of the motor?

Answer: Twenty-four inches multiplied by 48 and by 400 equals 460,800—this divided by 63,025 gives 7.30 as the brake horsepower of the motor.

The weight J is shown for use in case the floor of the testing room should be of brick or cement: if of wood the eye-bolt H can be screwed directly into the floor.

Repairing a Gas or Oil Engine. The piston should be thoroughly washed with kerosene. When putting the piston back in the cylinder, each ring should be put separately in exact position in its groove as regards the dowel-pin (if any) in the ring groove before the ring enters the cylinder. The piston, the rings, and the inside of the cylinder should all be carefully cleaned and well lubricated with proper oil before the piston is again put in place. Where the rings require cleaning, this should be done by washing with kerosene. If the piston-rings require to be taken off the piston, they should be sprung open by having pieces of sheet metal about one-sixteenth of an inch thick and about one-half inch wide inserted between the ring and the body of piston.

The inlet and exhaust-valves should be frequently taken out, cleaned and examined, and, if necessary, reground in. Finely-powdered emery or tripoli are very satisfactory to grind the valves in with.

Care should be taken, in replacing the valves, that they are clean and free from rust or carbon, and are allowed to drop on their seats freely and do not stick in their guides.

The crank-shaft bearings will occasionally require taking up as they show signs of wear and commence to knock or pound. For this adjustment, liners are placed between the cap and the lower half of the bearings. These liners can be occasionally reduced in thickness, so that the cap is allowed to come down closer to the shaft.

Secondary Coil. Any form of electrical ignition requires some outside source of electric energy such as a generator or battery to produce a spark in the combustion chamber of the motor. A primary or secondary induction coil is necessary in connection with the source of electric energy to give a spark of sufficient intensity to properly ignite the compressed charge in the combustion chamber of the engine. This method of ignition provides a means of regulating the motor speed by advancing and retarding the point of ignition, or time of igniting the explosive charge.

The coil first mentioned is known as a primary-spark coil, from the fact that the spark or arc is produced by the direct effect of the battery or generator current flowing in the coil. This form of spark will not arc or jump across a space

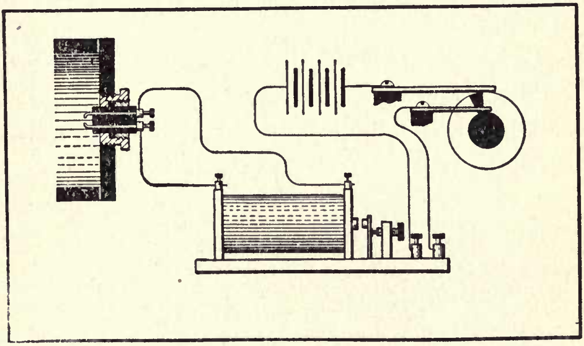

FIG. 33

Secondary-spark circuit, showing coil spark plug, battery and commutator.

between two points, but simply occurs between the contact-points on the breaking of the contact.

The second form of induction coil is generally known as a secondary-spark coil, because the arc or spark is produced in the secondary winding of the coil, and will jump or arc across a space between two fixed points, without the points first coming in contact.

Figure 33 shows the wiring circuit for a gas or oil engine equipped with the secondary or jump-spark form of electrical ignition. The battery, commutator, spark coil and spark plug are plainly indicated, also the wiring connections from the spark coil to the engine and between the coil, battery and commutator.

Smoke from Cylinder, Cause of. If black smoke comes from the cylinder, it may arise from leaky piston, overheating, want of or excessive lubrication, too rich mixture, faulty combustion, faulty ignition.

Solders and Spelters. Solders and spelters for use with different metals, and their proportional parts by weights are

Solder for:

Electrician's use	1—Tin, 1—Lead.
Gold	24—Gold, 2—Silver, 1—Copper.
Platinum	1—Copper, 3 Silver.
Plumber's—Hard	1—Lead, 2—Tin.
Soft	3—Lead, 1—Tin.
Silver—Hard	1—Copper, 4—Silver.
Soft	1—Brass, 2—Silver.
Tin—Hard	2—Tin, 1—Lead.
Soft	1—Tin, 1—Lead.

Spelter for:

Fine brass work	8—Copper, 8—Zinc, 1—Silver.
Common brass	1—Copper, 1—Zinc.
Cast iron	4—Copper, 3—Zinc.
Steel	3—Copper, 1—Zinc.
Wrought iron	2—Copper, 1—Zinc.

Starting a Gas Engine. If an incandescent tube is used for the ignition, the Bunsen burner should first be lighted. While the tube is being heated, oil up all the working parts of the engine.

If electric ignition is used, close the battery switch.

Next, open the gas valve so as to admit a charge of gas into the inlet-valve chamber, along with the air, then give the flywheels four or five quick turns until the engine starts.

Open the lubricator on the cylinder and see that it is adjusted so as to allow about 10 drops of oil to flow per minute.

The water in the cooling tank should always be at least 6 inches above the overflow pipe from the top of the cylinder jacket.

If the engine does not ignite its first or second charge there is a reason for it, and the cause of the trouble should be located.

Starting a Gasoline Engine. The instructions given for starting a gas engine apply also to a gasoline engine, with the exception that the supply of gasoline from the carbureter or mixing valve should be regulated according to the instructions given by the manufacturer of the engine.

The fuel supply of a gasoline engine is usually regulated by means of a needle-valve, which should be carefully cleaned at regular intervals. In engines using a pump feed, the supply of gasoline is usually regulated by adjusting the stroke of the pump, or by regulating the opening in a by-pass, so that a portion of the fuel is pumped through the by-pass and returns to the supply tank.

Starting a Gasoline or Kerosene Engine for the First Time. Don't attempt to start an engine the first time until the following points are found to be right:

That there is good compression.

That the batteries are set up properly and wired correctly.

That a good bright spark is obtained by touching the ends of the two wires at the engine together.

That there is a good supply of gasoline or oil in the supply tank.

That the gasoline or oil pump works freely and that the gasoline or oil reaches the vaporizer.

That the inlet and exhaust-valves are not stuck, and that they work freely and seat quickly.

Starting a Gas or Oil Engine, General Directions for. The successful starting or running of an engine depends entirely on the mixture of gas and air, and proper ignition.

As all of these are under full control of the operator at all times, it lies entirely with him as to whether the engine starts and runs properly or not.

The engine cannot start itself, it must be started.

If the above conditions and the following instructions are properly carried out, the engine will start without fail.

Before starting up the engine, go over all the connections carefully and see that everything is in place according to the instructions.

See that the gasoline tank is full.

Pump up the gasoline by working the pump lever until the feed chamber is full.

Close the cock in the bottom of the water tank and fill the tank to near the top pipe, but not full enough to run into the pipe if the weather is freezing.

Never let the water enter the cylinder or valve chamber jackets in cold weather until the engine has run long enough to become warm.

Open the burner-valve, first passing a nail or match down through a hole in the burner tube, and hold it so as to turn the stream of gasoline down and fill the burner pan, then close the valve and light the gasoline.

When the gasoline in the pan is burned out, open the valve and light the vapor, which should burn with a strong, steady blue flame.

The globe-valve, next to the burner, is to help regulate the flame, and should be closed nearly tight.

While the burner is heating the tube, which should take from two to three minutes, if it is properly regulated, see that the grease cups are full.

Oil up all parts of the engine. Fill the lubricator and start it to feed.

Turn the engine round by hand several times to see that everything is in its proper place, and nothing binding.

Examine the flywheel keys and see that they are driven tight.

When the tube is hot the engine is ready to start.

If electric ignition is used, close the battery switch. Almost close the air-valve before starting the engine.

The object of closing the air-valve is to obtain a rich charge and make it surer to explode.

The amount of fuel can be regulated at will.

It can be made so weak that it will not explode or so strong it cannot be ignited.

When black smoke issues from the exhaust pipe, the mixture is too strong.

Starting a Kerosene Engine. The methods usually employed to ignite the explosive charge in the combustion chamber of an oil engine are: By means of an electric spark, an incandescent tube, or a vaporizing chamber with projecting ribs which are kept incandescent by the heat of the previous charge.

The proper heating of the vaporizing chamber is the first and most important thing to be attended to when starting an oil engine and care should be taken that the vaporizer is sufficiently hot before attempting to start the engine.

The Bunsen burner or lamp should be kept burning for five or ten minutes or even longer, according to the size of the engine. When the vaporizer is sufficiently heated, turn on the fuel oil supply and give the flywheels four or five quick turns, if all other conditions are right the engine should at once start. See that the cylinder lubricator and the oil cups on the crank shaft bearings are filled before starting the engine, also oil the wrist-pin end of the connecting-rod and the cam shaft bearings. After the engine is started, open the valve in the air-inlet pipe until the engine attains its normal speed.

When electric ignition is used, the battery switch should always be closed before an attempt is made to start the engine.

With the hot tube form of ignition, the tube should always be incandescent before starting the engine.

Always be sure that the supply of water to the cylinder jacket is ample.

With oil engines which operate on the vaporizer principle, it is found absolutely necessary to heat the fuel before it enters the cylinder. In some oil engines it is not necessary to heat the fuel before it enters the cylinder, as it is injected against a highly heated surface.

Starting Oil Engines, New Method of. A method of starting an oil engine has of recent years been used in which alcohol, gasoline, or naphtha is burnt for a few minutes instead of kerosene.

This method is advantageous in that the engine when cold can be started without the use of an external heater. The lighter fuel is supplied to the vaporizer or cylinder until the vaporizing attachment has become heated by the internal combustion to the temperature necessary for vaporizing the heavier fuel, then the fuel supply is changed, the supply of lighter fuel being stopped. Where a vaporizer is used in which the charge is not explosive until after compression, an independent electric igniter is used to ignite the charge, and is only in operation until the vaporizer becomes properly heated.

Starting Troubles. If, after turning the flywheels of the engine four or five times, it refuses to start, the trouble may be due to any one of the following causes: Loss of compression, faulty ignition, improper mixture, water in the cylinder, or oil on the igniter contact-points.

Sometimes an engine will start readily, but dense smoke having a strong odor will issue from the exhaust-pipe. This may be an indication that the mixture is too rich, although it is frequently due to an excess of lubricating oil in the cylinder. To correct the mixture, more air should be admitted to the cylinder.

Failure of an engine to start is more often occasioned by too weak than by too rich a mixture. The first thing to do, if regulating the air does not correct it, is to ascertain if the fuel supply pipe is free from obstructions. This pipe is generally not very large, and is more or less crooked. A partial stoppage of the pipe will therefore result in a too weak mixture.

Stopping a Gas or Oil Engine. The first things to do when stopping an engine are:

Shut off the gas or oil supply.

Close all oil cups or lubricators.

Switch off the battery or turn out the ignition tube burner.

Wipe off the engine and see that it is in good shape for the next run.

While cleaning the engine examine all nuts and bolts, all points needing adjustment. Examine the condition of the crank shaft and other bearings. If they are hot or show signs of heating, locate the cause if possible and remove it before again starting the engine.

Do not fail to throw the battery switch off when the engine is not running, as there is always a possibility of short circuiting the battery and possibly ruining it in a few hours.

It will pay to always keep the engine neat and clean. Examine the engine occasionally and see that everything is working properly.

If the engine has not to be re-started for some days, it is a good plan to turn off the oil supply to the cylinder for a short period before stopping, as what oil remains will be burnt out, and there is less liability to the gumming of the piston and cylinder or valves.

Stopping Troubles. Some of the principal causes of stopping of gas or oil engines are as follows:

Bad design or construction of the engine, improper mixture of fuel and air, defective water circulation or insufficient cooling of the cylinder, leakage of the piston, leakage of the valves or valve joints, improper or insufficient lubrication, governor gear defective, back pressure from fouling of the exhaust with residue, ignition mechanism worn or defective, imperfect compression or combustion, leak in the inlet-pipe, premature ignition, misfiring, backfiring, or the ignition wrongly timed.

Tachometer. A tachometer is an instrument for indicating the number of revolutions made by a machine in a unit of time—usually one minute.

Tanks, Capacity of Cylindrical. To ascertain the capacity in gallons of a cylindrical tank of given length, multiply the area of the cross-section of the tank in square inches by the length of the tank in inches, and divide the product by 231, the result will be the capacity of the tank in gallons.

Tanks, Installation of Gasoline. The proper method of installing the supply tank for a gasoline engine is shown in Figure 34.

The vault for the reception of the supply tank should be walled with brick of good quality and well cemented so as to exclude water, the cover of the vault should also be water-tight. Shut-off

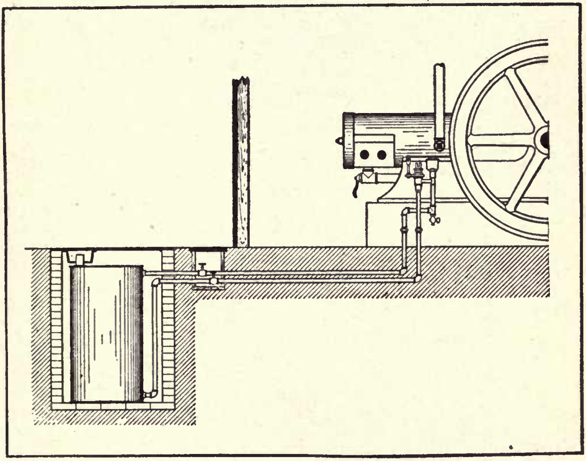

FIG. 34
Gasoline tank installation, showing location of tank, shut-off cocks and method of piping.

valves or cocks should be placed in both the supply and overflow pipes as shown. The supply tank should be made of heavy galvanized iron or steel and well riveted.

A screen of fine wire gauze should always be fitted in the mouth of the filling opening of the supply tank, to prevent the entrance of dirt or other foreign substances which may be in the gasoline.

A small vent opening should be made in the cap or cover of the filling opening to allow of the ingress of air, otherwise the gasoline pump will not work properly.

Throttle, Use of. For the purpose of regulating or controlling the speed of gas or oil engines, throttling devices are sometimes used to choke or partially cut off the supply of explosive mixture, being drawn in the cylinder of the engine.

A butterfly-valve or form of throttle commonly used for this purpose is shown in Figure 35. It has a valve-chamber A, valve B and lever C. The valve is located at any suitable point in the inlet-pipe of the engine, between the mixing-valve or vaporizer and the inlet-valve chamber.

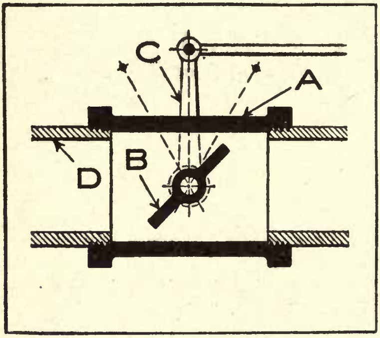

FIG. 35
Throttle for regulating the volume of explosive charge to the engine cylinder.

Two-cycle Engine, Construction of. Figure 36 shows a vertical cross-section of a two-cycle type of marine engine. C is the crank chamber. It has two feet, or lugs, D as shown in the drawing, for the purpose of attaching it to its position in a boat or elsewhere. There is an opening at A for the reception of the mixing-valve. The flywheel F, crank shaft G, connecting-rod H, piston P, inlet-port B, baffle-plate J and exhaust-opening E, are plainly shown in the drawing.

To the top of the piston P is attached a cone-pointed projection K. This is on the right-hand side and is placed there to break the electrical circuit between the contact-points of the igniter. This is effected by the cone-point K striking the right-hand end of the lever L, which causes the lever to rise at that end and fall at the other, thus breaking the contact between it and the insulated igniter terminal M. This breakage of the circuit causes a spark to occur between the left-hand end of the lever L and the point with which it was, a moment before, in contact. This

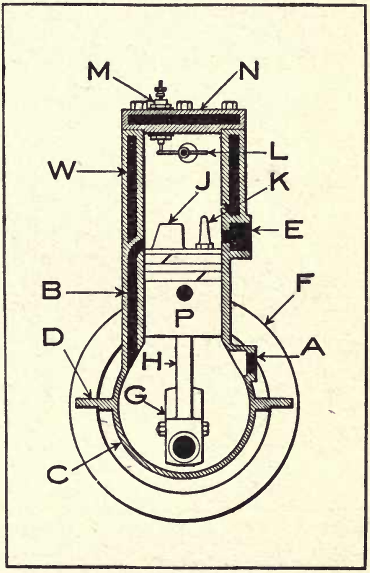

FIG. 36
Vertical cross-section, showing the construction of a two-cycle gas or gasoline engine.

action takes place once in each revolution of the motor and just before the piston reaches the end of its upward stroke.

The ignition may be retarded or advanced by raising or lowering the fulcrum of the lever L, by means of the eccentric shown.

The upper part of the cylinder is incased by a water jacket W, as is the cylinder head or cover N.

Two-cycle Engine, Principle of. Figure 37 gives two diagrammatic views of the operation of

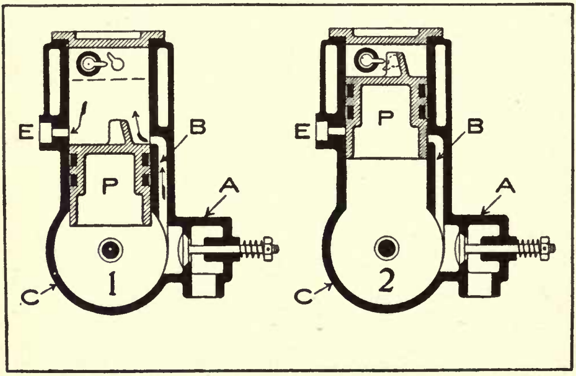

FIG. 37
Two-cycle motor diagrams, showing the various operations during the cycles.

a two-cycle gas or oil engine. It shows an inlet-valve A, port or passage B, crank case C, exhaust opening E and piston P. When the piston has reached the position shown in Diagram No. 1, it has forced a charge of explosive mixture from the crank case through the port or passage into the cylinder. The piston then moves to the position shown in Diagram No. 2, and while doing so, closes the port or passage and the exhaust opening, the compressed charge is then ignited, an explosion occurs and the piston is forced out to the position shown in Diagram No. 1.

The admission of the new charge of explosive mixture to the crank case is controlled by the action of the piston. As the latter travels away from the crank case, it has a tendency to create a partial vacuum in the latter. This operation draws the inlet-valve inward and admits the new charge.

The baffle-plate shown on the head of the piston directs the new charge from the crank case towards the combustion chamber end of the cylinder, providing as nearly as possible a pure charge of mixture and assisting in the expulsion of the burned gases left in the cylinder from the last explosion.

As this type of engine draws in a charge of explosive mixture, compresses it, ignites it and discharges the products of combustion while the piston makes one complete travel backward and forward, it consequently has a working stroke or power impulse every revolution of the crank-shaft.

Two-cycle Marine Engine. A single cylinder two-cycle type of marine engine mounted on a base with reversing gear, propeller and shaft is shown in Figure 38. Such outfits are made in single units of from $1\frac{1}{2}$ to $7\frac{1}{2}$ horsepower.

Valves. A valve in a very bad or pitted condition causes bad compression and the exhaust-valve should be ground occasionally. After

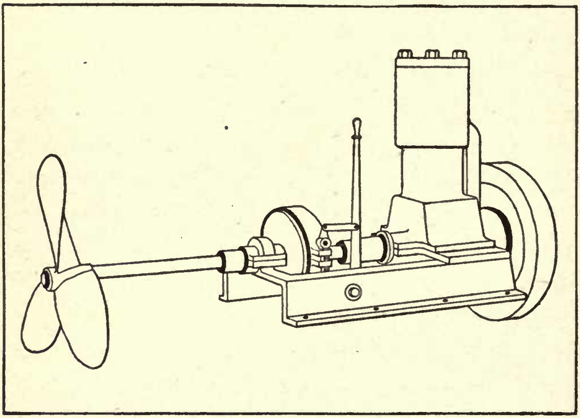

FIG. 38
Two-cycle marine engine, with reversing mechanism, propeller shaft and propeller mounted on base plate.

grinding a valve be sure that there is ample clearance between the valve and the lifter. It should have not less than one-thirty-second of an inch, otherwise when the valve becomes hot it will not seat properly, poor compression being the result. In grinding a valve there is no occasion to use force, and the grinding should be done lightly, the valve being lifted from time to time so that any foreign substance in the emery will not cut a ridge in the seat or the valve itself. After grinding a valve always wash out the valve seat with a little kerosene and be careful that none of the emery is allowed to get into the engine cylinder.

Sometimes an engine may suddenly stop from the failure of a valve to seat properly. This may be due to the warping of the valve through the engine having run dry and become hot, or it may be from the failure of the valve spring or the sticking of the valve-stem in its guides. The valve should be removed, and the stem cleaned and scraped, or straightened if it requires it, until it moves freely in the guide, and the spring is given its full tension. If the valve still leaks so that the engine will not start or develop sufficient power, the valve will have to be ground into its seat.

Valves which need re-seating should first be ground in place with fine emery and oil, then finished with tripoli and water.

Valves and Valve-chambers. The dimensions of the inlet and exhaust-valve openings are governed by the diameter of the cylinder and the piston velocity in feet per minute. The form of valve-chamber in general use is made separate and bolted to the cylinder. The valve-chamber can then be entirely renewed if necessary and at small expense. Other forms of valve-chambers have the valves placed horizontally in the cylinder head. In any case the valves should be brought as close as possible to the inside of the cylinder, the clearance space in the ports being reduced to a minimum.

In engines of large size the inlet and exhaust-valve chamber is surrounded by a water jacket, which maintains its proper temperature and prevents the valve seats being warped from overheating, which might otherwise occur.

When the inlet-valve is atmospherically or suction operated, it is opened by the partial vacuum in the cylinder during the suction period, and closed by a spring. The inlet and exhaust-valve openings are usually made of such a diameter that the velocity of the gas as it enters the cylinder is about 100 feet per second, the velocity of the exhaust gases through the exhaust opening being about 80 feet per second.

Valves, Diameter and Lift of. To ascertain the proper diameter of inlet and exhaust-valve openings and the lift of the valve to give an opening equal to the area of the valve opening, the following formulas will be found useful.

Let B be the bore of the motor cylinder in inches, and S the stroke of the piston also in inches. As R is the number of revolutions per minute and D the required diameter of the valve opening, then

$$D=\frac{B\times S\times R}{15,000}$$

Example: Required the diameter of the admission-valve opening for a motor of 6-inch bore and 9-inch stroke at 600 revolutions per minute.

Answer: As 6 multiplied by 9 and by 600 equals 32,400, then 32,400 divided by 15,000 gives 2.16 inches as the diameter of the valve opening.

The lift of the 45-degree bevel-seat form of valve requires to be about three-eighths of the diameter of the valve opening: that is, if L is the required lift of the valve and D the diameter of the valve opening, then

$$L = \frac{D}{2.83} = 0.35\,D$$

The bevel-seat form of valve is to be preferred to the flat-seat or mushroom type of valve, for two reasons: first, that it is more readily kept in shape by re-grinding, and second, it gives a freer and more direct passage for the gases.

For an atmospherically operated admission-valve which will insure practically a full charge in the motor cylinder the formula should be

$$D = \frac{B \times S \times R}{12{,}750}$$

Both inlet and exhaust-valves should be of ample area and short lift, and be arranged so that they may be readily inspected and adjusted, and with as few joints as possible.

Valve Lifters. Figure 39 illustrates a form of valve operating mechanism in which the valve is actuated by means of a roller upon the end of a rocker arm, to the upper side of which is secured a hardened steel plate, which in most cases acts directly upon the end of the valve-stem.

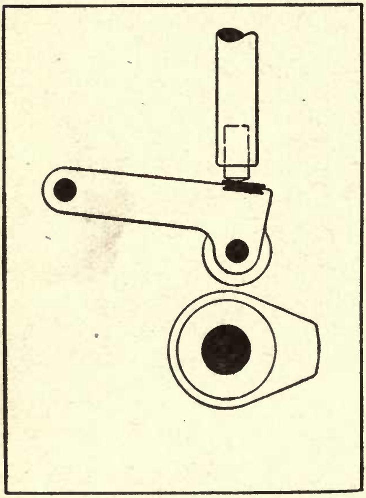

FIG. 39
Valve lifter and roller lever with hardened steel lifter plate.

Another form of valve lifter is shown in Figure 40, in which the rocker arm is omitted, the cam operating the valve through the medium of a plunger rod and roller.

Valve Operating Mechanism. A form of valve operating mechanism is shown in Figure 41, in which both the inlet and exhaust-valves are operated independently by means of a rocker-shaft and lifting arms, through the medium of two cam-rods and levers shown at the right of the drawing. The lifter-arm and cam-rod lever of the inlet-valve are in one piece, and work free on the end of the rocker shaft.

Valve Stems, Fit of. The inlet and exhaust-valve stems should not be a very close fit in their

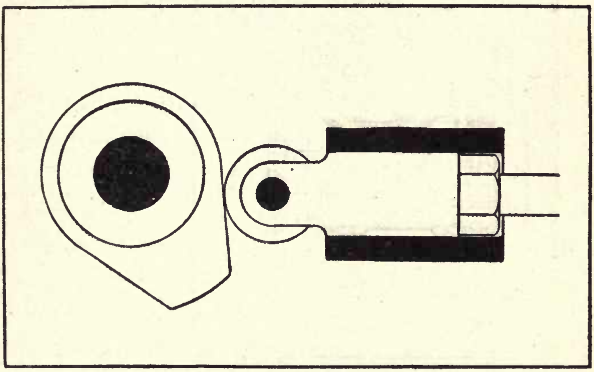

FIG. 40
Valve lifter with cam acting directly on the lifter.

guides. If the fit in these guides is made too close, when the valve-chamber becomes heated the consequent expansion may cause the valve-stem to stick in the guides, and leakage of the valve will result.

The valve seats are in some engines left almost sharp, being not more than one-sixteenth of an inch wide before grinding.

Valves, Timing of. The movement of the valves should always be timed to give the proper results. This is an important point to remember. The cam shaft on a four-cycle engine is usually driven by the two to one gear on the crank shaft, and if for any reason the gears are taken apart and put together, even if only one tooth out of place, it will throw the valve mechanism out of time.

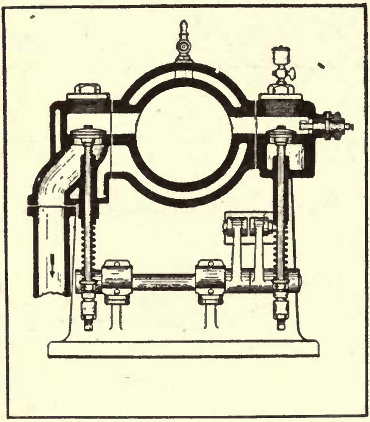

FIG. 41
Valve operating mechanism, showing inlet and exhaust-valves and lifter rods.

To ascertain if the valves of an engine are properly timed, turn the fly-wheel over slowly and notice at what points the valves open and close, and when the ignition, if electric, takes place.

The exhaust-valve should open when about five-sixths of the stroke is completed and close at the end of the next stroke. The next inward stroke is the compression stroke, when all valves should be closed. At the beginning of the next outward stroke the inlet-valve should be slightly open.

If the engine is taken to pieces, it is important that a tooth of the gear wheel on the crank shaft and a corresponding space of the gear on the cam shaft should be marked, so that when put together again the same teeth may mesh together, and so avoid altering the throw of the cams and consequent timing of the valves.

Viscosity of Oils. The figures given for the viscosity of an oil denote, in seconds, the time taken by 1,000 grains of oil to flow through a small orifice in the testing apparatus at various temperatures.

The standard usually adopted for viscosity is genuine sperm oil, which is taken as 100 at 70 degrees Fahrenheit.

Water Cooling System. The pipes should be of ample capacity, and the pipe leading from the top of the cylinder jacket to the upper part of the water tank should be arranged so as to be as short as possible, and any necessary bends should be as large as possible.

The water supply should enter near the exhaust opening and leave it at the highest point of the cylinder jacket.

The water required in the tank should be from 20 to 25 gallons per horsepower, and the quantity required to circulate in the water jacket to keep the cylinder cool is about 4½ gallons per horsepower.

The temperature of the water from the cylinder jacket should never be over 140 to 160 degrees Fahrenheit, and if the load is constant this may be reduced, but be never less than 100 degrees Fahrenheit.

If the temperature of the cylinder is allowed to exceed 400 degrees Fahrenheit lubrication will be difficult, and if the cylinder jacket is found to be much hotter than the water in the tank, the water circulation is poor from scale or incrustation, and should be at once attended to.

Never run the engine without water in the cylinder jacket, and always keep the level of the

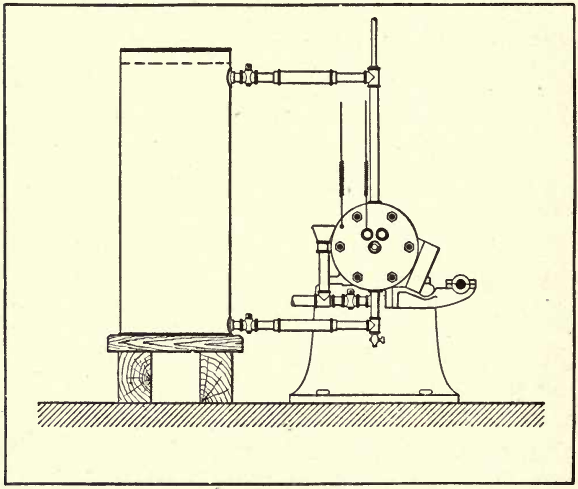

FIG. 42

Proper method of installing water-tank for thermo-syphon or gravity water cooling system.

water in the tank at least six inches above the upper pipe.

Figure 42 shows the proper manner of connecting the water tank to the cylinder jacket. The tank should be connected to the engine with short lengths of rubber hose in the piping to prevent any joints or connections working loose from the engine vibration.

The object of the water is not to keep the cylinder cold, but simply cool enough to prevent the lubricating oil from burning. The hotter the cylinder with effective lubrication the more power the engine will develop.

It should be remembered that a hot engine is the more economical in fuel.

Water-jackets. The thickness of the water-jacket space around the cylinder of a gas or oil engine should not be less than one-eighth of the bore of the cylinder, while the water space surrounding the head of the combustion chamber of the cylinder should not be less than one-sixth of the cylinder bore.

Bosses for pipe connections to the water-jacket outlet should always be placed at the highest point of the jacket, so as to prevent an air space being formed above the outlet of the jacket. Steam will be formed in this space, and with a gravity or thermal-syphon system is liable to blow or force the water out of the cylinder jacket.

To obtain the greatest degree of fuel economy and engine efficiency the jacket water should be always of a temperature slightly under the boiling point of water. A cool water-jacket is a sign of an inefficient engine.

Water-jacket Circulation. Figure 43 shows the proper manner of making the water-jacket

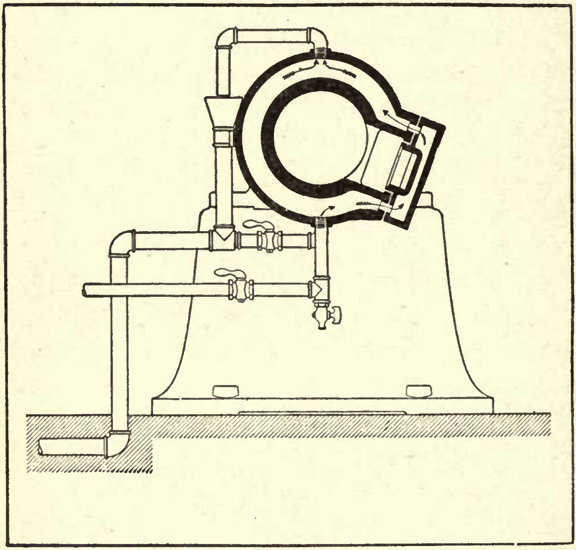

FIG. 43
Water-circulation through the cylinder and valve chamber of a gas or oil engine.

pipe connections when the cooling water is taken from a hydrant.

The water from the inlet-pipe enters the bottom of the cylinder near the combustion chamber, passing around the valve chamber and out through the upper pipe into the funnel at the top of the waste pipe. A connection should be made into the waste pipe from the bottom of the water-jacket as shown, so as to enable the jacket water to be drawn off in cold weather.

Water-jacket, Draining the. During cold weather always close the tank valves and open the drain cock so as to drain all the water from the water-jacket and the pipes leading from the water-jacket to the tank, as a freeze-up in the water-jacket would be sure to injure the cylinder jacket and possibly ruin it. It is a good rule during the cold weather to shut off the water from the cooling tank and drain the cylinder jacket from three to five minutes before shutting the engine down, thereby making sure that all traces of water are out of the cylinder jacket and pipes. Also in starting the engine in cold weather it is best not to turn on the water until the engine has been running from three to five minutes.

Water-jacket, Testing of. The water-jackets of cylinders or valve-chambers should be all tested by air pressure to at least 120 pounds pressure per square inch before the piston is put into the cylinder.

TABLES

Density and Specific Gravity Equivalents.

Baumé	Specific Gravity	Baumé	Specific Gravity	Baumé	Specific Gravity
10°	1.0000	37°	0.8395	64°	.7423
11°	0.9930	38°	.8346	65°	.7205
12°	.9861	39°	.8299	66°	.7168
13°	.9791	40°	.8251	67°	.7133
14°	.9722	41°	.8204	68°	.7097
15°	.9658	42°	.8157	69°	.7061
16°	.9594	43°	.8110	70°	.7025
17°	.9530	44°	.8063	71°	.6990
18°	.9466	45°	.8017	72°	.6956
19°	.9402	46°	.7971	73°	.6923
20°	.9339	47°	.7927	74°	.6889
21°	.9280	48°	.7883	75°	.6856
22°	.9222	49°	.7838	76°	.6823
23°	.9163	50°	.7794	77°	.6789
24°	.9105	51°	.7752	78°	.6756
25°	.9047	52°	.7711	79°	.6722
26°	.8989	53°	.7670	80°	.6689
27°	.8930	54°	.7628	81°	.6656
28°	.8872	55°	.7587	82°	.6619
29°	.8814	56°	.7546	83°	.6583
30°	.8755	57°	.7508	84°	.6547
31°	.8702	58°	.7470	85°	.6511
32°	.8650	59°	.7432	86°	.6481
33°	.8597	60°	.7394	87°	.6451
34°	.8544	61°	.7357	88°	.6422
35°	.8492	62°	.7319	89°	.6392
36°	.8443	63°	.7281	90°	.6363

The scale generally used for indicating the densities of liquids is that of Baumé. Zero on this scale corresponds to the density of a solution of salt of specified proportions, and 10 degrees corresponds to the density of distilled water at a specified temperature or to a specific gravity of unity. The portion of the stem of the instrument lying between these two points is divided into ten equal parts and the rest of the stem is divided into divisions of equal size up to 90 degrees. Higher numbers indicate lower specific gravities. The above table shows the relation existing between the Baumé scale and specific gravity proper.

Dimensions of Machine Screws.

Number of Screw.	Threads per Inch.	Diameter of Body.	Diameter at Bottom of Thread.	No. of Tap Drill for Full Thread.	No. of Drill for Body.	Diameter of Head.		
						Flat Head.	Button Head.	Philister Head.
2	56	.084	.053	54	44	.16	.15	.13
4	36	.110	.062	52	34	.22	.20	.17
6	32	.136	.082	45	28	.27	.25	.22
8	32	.163	.109	35	19	.32	.29	.26
10	32	.189	.135	29	11	.37	.35	.30
12	24	.216	.144	27	2	.43	.39	.34
14	20	.242	.156	22	$\frac{1}{4}$	.48	.44	.39
16	20	.268	.182	14	$\frac{9}{32}$	.53	.49	.43
18	18	.294	.198	8	$\frac{19}{64}$	.58	.52	.47

Safe Working Load of Steel Balls.

Diameter of ball.	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$
Working load per ball in pounds . .	500	780	1125	1530	2000	2530	3125

Composition of Alloys.

	Tin.	Copper.	Zinc.	Antimony	Lead.	Bismuth.
Bronze, for Engine bearings . .	13	110	1	. . .	. . .	. . .
Brass, for light work, other than bearings.	. . .	2	1	. . .	. . .	. . .
Bronze flanges, to stand brazing	. . .	32	1	. . .	1	. . .
Genuine Babbitt metal	10	1	. . .	1	. . .	. . .
Bronze, for bushings	16	130	1	. . .	. . .	. . .
Metal, to expand in cooling for patterns	. . .	. . .	. . .	2	9	1
Genuine bronze.	2	90	5	. . .	2	. . .
Spelter, hard.	. . .	1	1	. . .	. . .	. . .
Spelter, soft.	1	4	3	. . .	. . .	. . .

Strength and Weight of Materials.

Material.	Tensile Strength in pounds per square inch.	Resistance to Compression.	Weight per cubic inch.	Weight per cubic foot.
Aluminum	12,000	....	.094	162
Brass—Cast	18,000	10,000	.290	504
Sheet	23,000	12,500	.295	510
Bronze—Aluminum	60,000	12,000	.290	500
Phosphor	63,000	12,000	.300	530
Copper—Cast	18,000	30,000	.313	542
Sheet	30,000	40,000	.317	548
Wire	50,000	....	.317	548
Gun Metal	36,000	15,000	.290	504
Iron—Cast	16,000	100,000	.260	450
Malleable	18,000	80,000	.267	460
Wrought	50,000	36,000	.280	480
Lead	33,000	....	.410	711
Steel—Tool	100,000	40,000	.284	490
Cr. Cast	63,000	36,000	284	490
Mild	60,000	36,000	.284	490
C. Rolled	63,000	40,000	.284	490

Dimensions of Involute Tooth Spur Gears.

Diametrical Pitch.	Circular Pitch.	Width of Tooth on Pitch Line.	Working Depth of Tooth.	Actual Depth of Tooth.	Clearance at Bottom of Tooth.
1	3.142	1.571	2.000	2.157	0.157
2	1.571	0.785	1.000	1.078	0.078
3	1.047	0.524	0.667	0.719	0.052
4	0.785	0.393	0.500	0.539	0.039
5	0.628	0.314	0.400	0.431	0.031
6	0.524	0.262	0.333	0.360	0.026
7	0.447	0.224	0.286	0.308	0.022
8	0.393	0.196	0.250	0.270	0.019
10	0.314	0.157	0.200	0.216	0.016
12	0.262	0.131	0.167	0.180	0.013
14	0.224	0.112	0.143	0.154	0.011
16	0.196	0.098	0.125	0.135	0.009

Melting Point of Metals.

Metal.	Temperature in Degrees Fahrenheit.	Metal.	Temperature in Degrees Fahrenheit.
Aluminum	1160°	Lead	620°
Bronze	1690°	Platinum	3230°
Copper	1930°	Silver	1730°
Gold	1900°	Steel	2400°
Iron—Cast	2000°	Tin	445°
Wrought	3000°	Zinc	780°

Weight per Cubic Foot of Substances.

Materials.	Weight in Pounds.	Materials.	Weight in Pounds.
Ash, White	38	Mercury	849
Asphaltum	87	Mica	183
Brick—Pressed	150	Oak, White	50
Common	125	Petroleum	55
Cement—Louisville	50	Pine—White	25
Portland	90	Northern	34
Cherry	42	Southern	45
Chestnut	41	Platinum	1342
Clay, Potter's	110	Quartz	165
Coal—Anthracite	93	Resin	69
Bituminous	84	Sand—Dry	98
Earth	95	Wet	140
Ebony	76	Sandstone	151
Elm	35	Shale	162
Flint	162	Silver	655
Gold, Pure	1204	Slate	175
Hemlock	25	Spruce	25
Hickory	53	Sulphur	125
Ivory	114	Sycamore	37
Lignum Vitæ	83	Tar	62
Magnesium	109	Peat	26
Mahogany	53	Walnut, Black	38
Maple	49	Water—Distilled	62⅓
Marble	168	Sea	64

Wrought Iron Welded Steam, Gas and Water Pipe.

Diameter.			Thickness. Inches.	Internal Area. Square Inches.	Nominal Weight per Foot. Pounds.	Number of Threads per Inch.	Tap Drill.
Nominal Internal. Inches.	Actual External. Inches.	Actual Internal. Inches.					
1/8	.405	.27	.068	.0573	.241	27	3/8
1/4	.54	.364	.088	.1041	.42	18	15-32
3/8	.675	.494	.091	.1917	.559	18	19-32
1/2	.84	.623	.109	.3048	.837	14	3/4
3/4	1.05	.824	.113	.5333	1.115	14	31-32
1	1.315	1.048	.134	.8626	1.668	11½	1 7-32
1¼	1.66	1.38	.14	1.496	2.244	11½	1 17-32
1½	1.9	1.611	.145	2.038	2.678	11½	1 25-32
2	2.375	2.067	.154	3.356	3.609	11½	2 7-32
2½	2.875	2.468	.204	4.784	5.739	8	2 11-16
3	3.5	3.067	.217	7.388	7.536	8	3 5-16
3½	4.	3.548	.226	9.887	9.001	8	3 13-16
4	4.5	4.026	.237	12.73	10.665	8	4 5-16
4½	5.	4.508	.246	15.961	12.34	8	4 13-16
5	5.563	5.045	.259	19.99	14.502	8	5 11-32
6	6.625	6.065	.28	28.888	18.762	8	6 11-32
7	7.625	7.023	.301	38.738	23.271	8	7 7-16
8	8.625	7.982	.322	50.04	28.177	8	8 7-16

Properties of Compressed Air.

Comp. in Atmospheres.	Mean Pressure.	Temp. in Degrees Fahr.	Gauge Pressure.	Absolute Pressure.	Isothermal Pressure.
1	0	60	0	14.7	
1.68	7.62	145	10	24.7	30.39
2.02	10.33	178	15	29.7	39.34
2.36	12.62	207	20	34.7	48.91
2.70	14.59	234	25	39.7	59.05
3.04	16.34	252	30	44.7	69.72
3.38	17.92	281	35	49.7	80.87
3.72	19.32	302	40	54.7	92.49
4.06	20.57	324	45	59.7	104.53
4.40	21.69	339	50	64.7	116.99
4.74	22.76	357	55	69.7	129.84
5.08	23.78	375	60	74.7	143.05
5.42	24.75	389	65	79.7	156.64
5.76	25.67	405	70	84.7	170.58
6.10	26.55	420	75	89.7	184.83

Decimals of an Inch for Each $\frac{1}{32}$

$\frac{1}{32}$ds.	Decimal.	Fraction.	$\frac{1}{32}$ds.	Decimal.	Fraction.
1	.03125		17	.53125	
2	.0625	1-16	18	.5625	9-16
3	.09375		19	.59375	
4	.125	1-8	20	.625	5-8
5	.15625				
			21	.65625	
6	.1875	3-16	22	.6875	11-16
7	.21875		23	.71875	
8	.25	1-4	24	.75	3-4
9	.28125		25	.78125	
10	.3125	5-16			
			26	.8125	13-16
11	.34375		27	.84375	
12	.375	3-8	28	.875	7-8
13	.40625		29	.90625	
14	.4375	7-16	30	.9375	15-16
15	.46875				
			31	.96875	
16	.5	1-2	32	1.	1

Average Weight of Square Head Machine Bolts per 100.

Length	Diameter. ¼	5/16	⅜	7/16	½	⅝	¾	⅞	1
1½	4.0	6.8	10.6	15.0	23.9	40.5	70.0	......	......
1¾	4.4	7.3	11.3	16.1	25.1	42.7	73.1	......	......
2	4.7	7.8	12.0	17.2	26.3	44.8	76.2	......	......
2¼	5.1	8.4	12.6	18.2	27.7	47.0	79.3	......	......
2½	5.4	8.9	13.3	19.2	29.0	49.2	82.4	120.5	......
2¾	5.8	9.5	14.0	20.2	30.4	51.4	85.5	124.7	......
3	6.1	10.0	14.7	21.2	31.8	53.5	88.7	128.9	185.0
3½	6.8	11.1	16.0	23.2	34.7	57.9	95.0	137.4	196.0
4	7.5	12.2	17.4	25.2	37.5	62.3	101.2	145.8	207.0
4½	8.2	13.2	18.7	27.2	40.2	66.7	107.5	159.2	218.0
5	8.9	14.3	20.0	29.1	43.0	71.0	113.7	167.7	229.0
5½	9.6	15.4	21.4	31.2	45.7	75.4	120.0	176.1	240.0
6	10.3	16.5	22.8	33.1	48.4	79.8	126.2	184.6	251.0
6½	11.0	17.6	24.1	35.1	51.2	84.1	132.5	193.0	262.0
7	11.7	18.6	25.9	37.1	54.0	88.5	138.7	201.4	273.0
7½	12.4	19.7	27.7	39.1	56.7	92.9	145.0	209.9	284.0
8	13.1	20.8	29.5	41.0	59.4	97.2	151.2	218.3	295.0
9	......	......	33.1	45.0	64.8	106.0	163.7	240.2	317.0
10	......	......	36.7	49.0	70.3	114.7	176.2	257.1	339.0
11	......	......	40.4	53.0	75.8	123.5	188.7	273.9	360.0
12	......	......	44.0	57.0	81.3	132.2	201.0	290.0	382.0
13	......	......	......	......	86.7	140.7	213.4	307.7	404.0
14	......	......	......	......	92.2	149.2	225.9	324.5	426.0
15	......	......	......	......	97.7	157.6	238.3	341.4	448.0
16	......	......	......	......	103.1	166.1	250.8	358.3	470.0
17	......	......	......	......	108.6	174.6	263.2	375.2	492.0
18	......	......	......	......	114.1	183.1	275.6	392.0	514.0
19	......	......	......	......	119.5	191.5	288.1	408.9	536.0
20	......	......	......	......	125.0	200.0	300.5	425.8	558.0
Per Inch Additional.	1.4	2.2	3.6	4.0	5.5	8.5	12.4	16.9	22.0

Approximate Weight of Nuts and Bolt Heads, in Pounds.

Diameter of Bolt in Inches.	¼	5/16	⅜	7/16	½	⅝	¾
Weight of Hexagon Nut and Head...	.017	.042	.057	.109	.128	.267	.43
Weight of Square Nut and Head...	.021	.049	.069	.120	.164	.320	.55
Diameter of Bolt in Inches.	⅞	1	1¼	1½	1¾	2	2½
Weight of Hexagon Nut and Head..	.73	1.10	2.14	3.78	5.6	8.75	17.0
Weight of Square Nut and Head...	.88	1.31	2.56	4.42	7.0	10.5	21.0

COPPER WIRE GAUGE TABLE.

Gauge Number.	Size.		Weight and Length.		Resistance.		
	Diameter in Inches.	Square of Diameter or Circular Mils.	Pounds per 1000 Feet.	Feet per Pound.	Ohms per 1000 Feet.	Feet per Ohm.	Ohms per Pound.
0000	.460	211600.0	639.60	1.564	.051	19929.7	.0000785
000	.409	167804.9	507.22	1.971	.063	15804.9	.000125
00	.364	133079.0	402.25	2.486	.080	12534.2	.000198
0	.324	105592.5	319.17	3.133	.101	9945.3	.000315
1	.289	83694.49	252.98	3.952	.127	7882.8	.000501
2	.257	66373.22	200.63	4.994	.160	6251.4	.000799
3	.229	52633.53	159.09	6.285	.202	4957.3	.001268
4	.204	41742.57	126.17	7.925	.254	3931.6	.002016
5	.181	33102.16	100.05	9.995	.321	3117.8	.003206
6	.162	26250.48	79.34	12.604	.404	2472.4	.005098
7	.144	20816.72	62.92	15.893	.509	1960.6	.008106
8	.128	16509.68	49.90	20.040	.643	1555.0	.01289
9	.114	13094.22	39.58	25.265	.811	1233.3	.02048
10	.101	10381.57	31.38	31.867	1.023	977.8	.03259
11	.090	8234.11	24.89	40.176	1.289	775.5	.05181
12	.080	6529.93	19.74	50.659	1.626	615.02	.08237
13	.071	5178.39	15.65	63.898	2.048	488.25	.13087
14	.064	4106.75	12.41	80.580	2.585	386.80	.20830
15	.057	3256.76	9.84	101.626	3.177	306.74	.33133
16	.050	2582.67	7.81	128.041	4.582	243.25	.52638
17	.045	2048.19	6.19	161.551	5.183	192.91	.83744
18	.040	1624.33	4.91	203.666	6.536	152.99	1.3312
19	.035	1252.45	3.786	264.136	8.477	117.96	2.2392
20	.031	1021.51	3.086	324.045	10.394	96.21	3.3438
21	.028	810.09	2.448	408.497	13.106	76.30	5.3539
22	.025	642.47	1.942	514.933	16.525	60.51	8.5099
23	.022	509.45	1.539	649.773	20.842	47.98	13.334
24	.020	404.01	1.221	819.001	26.284	28.05	21.524
25	.017	320.41	.967	1034.126	33.135	30.18	34.298
26	.015	254.08	.768	1302.083	41.789	23.93	54.410
27	.014	201.49	.608	1644.737	52.687	18.98	86.657
28	.012	159.79	.484	2066.116	66.445	15.05	137.283
29	.011	126.72	.384	2604.167	83.752	11.94	218.104
30	.010	100.50	.302	3311.258	105.641	9.466	349.805
31	.0089	79.71	.239	4184.100	133.191	7.508	557.286
32	.0079	63.20	.190	5263.158	168.011	5.952	884.267
33	.0070	50.13	.151	6622.517	211.820	4.721	1402.78
34	.0063	39.74	.121	8264.463	267.165	3.743	2207.98
35	.0056	31.52	.094	10638.30	336.81	2.969	3583.12
36	.0050	25.00	.075	13333.33	424.65	2.355	5661.71
37	.0044	19.83	.060	16666.66	535.33	1.868	8922.20
38	.0039	15.72	.045	22222.22	675.22	1.481	15000.5
39	.0035	12.47	.038	26315.79	851.789	1.174	22415.5
40	.0031	9.88	.030	33333.33	1074.11	.931	35803.8

Squares and Square Roots of Numbers from 1 to 100.

Nos.	Squares.	Square Root.	Nos.	Squares.	Square Root.
1	1	1.000	51	2601	7.141
2	4	1.414	52	2704	7.211
3	9	1.732	53	2809	7.280
4	16	2.000	54	2916	7.349
5	25	2.236	55	3025	7.416
6	36	2.449	56	3136	7.483
7	49	2.646	57	3249	7.550
8	64	2.828	58	3364	7.616
9	81	3.000	59	3481	7.681
10	100	3.162	60	3600	7.746
11	121	3.317	61	3721	7.810
12	144	3.464	62	3844	7.874
13	169	3.606	63	3969	7.937
14	196	3.742	64	4096	8.000
15	225	3.873	65	4225	8.062
16	256	4.000	66	4356	8.124
17	289	4.123	67	4489	8.185
18	324	4.243	68	4624	8.246
19	361	4.359	69	4761	8.307
20	400	4.472	70	4900	8.367
21	441	4.583	71	5041	8.426
22	484	4.690	72	5184	8.485
23	529	4.796	73	5329	8.544
24	576	4.899	74	5476	8.602
25	625	5.000	75	5625	8.660
26	676	5.099	76	5776	8.718
27	729	5.196	77	5929	8.775
28	784	5.292	78	6084	8.832
29	841	5.385	79	6241	8.888
30	900	5.477	80	6400	9.944
31	961	5.568	81	6561	9.000
32	1024	5.657	82	6724	9.055
33	1089	5.745	83	6889	9.110
34	1156	5.831	84	7056	9.165
35	1225	5.916	85	7225	9.220
36	1296	6.000	86	7396	9.274
37	1369	6.083	87	7569	9.327
38	1444	6.164	88	7744	9.381
39	1521	6.245	89	7921	9.434
40	1600	6.325	90	8100	9.487
41	1681	6.403	91	8281	9.539
42	1764	6.481	92	8464	9.592
43	1849	6.557	93	8649	9.644
44	1936	6.633	94	8836	9.695
45	2025	6.708	95	9025	9.747
46	2116	6.782	96	9216	9.798
47	2209	6.856	97	9409	9.849
48	2304	6.928	98	9604	9.900
49	2401	7.000	99	9801	9.950
50	2500	7.071	100	10000	10.000

AREAS AND CIRCUMFERENCES OF CIRCLES FROM 0.05 TO 8.80, ADVANCING BY $\frac{1}{20}$ OF ONE INCH.

Diam.	Area.	Circum.	Diam.	Area.	Circum.
.05	.0019	.16	2.15	3.63	6.75
.10	.0078	.31	2.20	3.80	6.91
.15	.017	.47	2.25	3.98	7.07
.20	.031	.63	2.30	4.15	7.22
.25	.049	.78	2.35	4.34	7.38
.30	.070	.94	2.40	4.52	7.54
.35	.096	1.09	2.45	4.71	7.69
.40	.12	1.26	2.50	4.91	7.85
.45	.16	1.41	2.55	5.11	8.01
.50	.19	1.57	2.60	5.31	8.17
.55	.24	1.73	2.65	5.56	8.32
.60	.28	1.88	2.70	5.72	8.48
.65	.33	2.04	2.75	5.94	8.64
.70	.38	2.19	2.80	6.16	8.79
.75	.44	2.36	2.85	6.38	8.95
.80	.50	2.51	2.90	6.60	9.11
.85	.57	2.67	2.95	6.83	9.27
.90	.64	2.83	3.00	7.07	9.42
.95	.71	2.98	3.05	7.31	9.58
1.00	.78	3.14	3.10	7.55	9.74
1.05	.86	3.29	3.15	7.79	9.89
1.10	.95	3.46	3.20	8.04	10.05
1.15	1.03	3.61	3.25	8.29	10.21
1.20	1.13	3.77	3.30	8.55	10.37
1.25	1.23	3.93	3.35	8.81	10.52
1.30	1.33	4.08	3.40	9.08	10.68
1.35	1.43	4.24	3.45	9.35	10.84
1.40	1.54	4.39	3.50	9.62	10.99
1.45	1.65	4.56	3.55	9.89	11.15
1.50	1.77	4.71	3.60	10.18	11.31
1.55	1.89	4.87	3.65	10.46	11.47
1.60	2.01	5.03	3.70	10.75	11.62
1.65	2.14	5.18	3.75	11.04	11.78
1.70	2.27	5.34	3.80	11.34	11.94
1.75	2.40	5.49	3.85	11.64	12.09
1.80	2.54	5.65	3.90	11.94	12.25
1.85	2.69	5.81	3.95	12.25	12.41
1.90	2.84	5.97	4.00	12.57	12.57
1.95	2.99	6.13	4.05	12.88	12.72
2.00	3.14	6.28	4.10	13.20	12.88
2.05	3.30	6.44	4.15	13.53	13.04
2.10	3.46	6.59	4.20	13.85	13.19

Diam.	Area.	Circum.	Diam.	Area.	Circum.
4.25	14.19	13.35	6.45	32.67	20.26
4.30	14.52	13.51	6.50	33.18	20.42
4.35	14.86	13.66	6.55	33.69	20.58
4.40	15.20	13.82	6.60	34.21	20.73
4.45	15.55	13.98	6.65	34.73	20.89
4.50	15.90	14.14	6.70	35.26	21.05
4.55	16.25	14.29	6.75	35.78	21.20
4.60	16.62	14.45	6.80	36.32	21.36
4.65	16.98	14.61	6.85	36.85	21.52
4.70	17.35	14.76	6.90	37.39	21.68
4.75	17.73	14.92	6.95	37.94	21.83
4.80	18.09	15.08	7.00	38.48	21.99
4.85	18.47	15.24	7.05	39.04	22.15
4.90	18.86	15.39	7.10	39.59	22.30
4.95	19.24	15.55	7.15	40.15	22.46
5.00	19.63	15.71	7.20	40.71	22.62
5.05	20.03	15.86	7.25	41.28	22.78
5.10	20.43	16.02	7.30	41.85	22.93
5.15	20.84	16.18	7.35	42.43	23.09
5.20	21.23	16.34	7.40	43.01	23.25
5.25	21.65	16.49	7.45	43.59	23.40
5.30	22.06	16.65	7.50	44.18	23.56
5.35	22.48	16.81	7.55	44.77	23.72
5.40	22.90	16.96	7.60	45.36	23.88
5.45	23.33	17.12	7.65	45.96	24.03
5.50	23.76	17.28	7.70	46.57	24.19
5.55	24.19	17.44	7.75	47.17	24.35
5.60	24.63	17.59	7.80	47.78	24.50
5.65	25.07	17.75	7.85	48.39	24.66
5.70	25.52	17.91	7.90	49.02	24.82
5.75	25.97	18.06	7.95	49.64	24.97
5.80	26.42	18.22	8.00	50.26	25.13
5.85	26.88	18.38	8.05	50.89	25.29
5.90	27.34	18.54	8.10	51.53	25.43
5.95	27.80	18.69	8.15	52.17	25.60
6.00	28.27	18.85	8.20	52.81	25.76
6.05	28.75	19.01	8.25	53.46	25.92
6.10	29.22	19.16	8.30	54.11	26.07
6.15	29.70	19.32	8.35	54.76	26.23
6.20	30.19	19.48	8.40	55.42	26.39
6.25	30.68	19.63	8.45	56.08	26.55
6.30	31.17	19.79	8.50	56.74	26.70
6.35	31.67	19.95	8.75	60.13	27.49
6.40	32.17	20.11	8.80	60.82	27.65

Dimensions of Cap Screws.

Diameter of Screw.	Number of Threads per Inch.	Hexagon Head.		Square Head.		Philister Head.	Round Head.
		Short Diameter.	Long Diameter.	Short Diameter.	Long Diameter.		
1/4	20	7/16	1/2	7/16	5/8	3/8	7/16
5/16	18	1/2	37/64	1/2	45/64	7/16	9/16
3/8	16	9/16	41/64	9/16	51/64	9/16	5/8
7/16	14	5/8	23/32	5/8	29/32	5/8	3/4
1/2	12	3/4	55/64	3/4	1 1/16	3/4	13/16
9/16	12	13/16	15/16	13/16	1 5/32	13/16	13/16
5/8	11	7/8	1	7/8	1 1/4	7/8	1
3/4	10	1	1 5/32	1	1 7/16	1	1 1/4
7/8	9	1 1/8	1 23/64	1 1/8	1 39/64	1 1/8	
1	8	1 1/4	1 7/16	1 1/4	1 13/16	1 1/4	
1 1/8	7	1 3/8	1 37/64	1 3/8	1 31/32		
1 1/4	7	1 1/2	1 23/32	1 1/2	2 9/64		

Dimensions of Tap-Drills for Standard V-Threads.

Diameter of Screw.	Number of threads per inch.	Diameter at bottom of thread.	Nearest drill for full thread.	Correct size of tap drill.
1/4	20	.163	11/64	3/16
5/16	18	.216	7/32	1/4
3/8	16	.267	17/64	7/32
7/16	14	.314	5/16	23/64
1/2	12	.356	23/64	13/32
9/16	12	.418	27/64	31/64
5/8	11	.468	15/32	35/64
3/4	10	.577	37/64	43/64
7/8	9	.683	11/16	25/32
1	8	.784	25/32	29/32
1 1/8	7	.878	7/8	1 1/32
1 1/4	7	1.003	1	1 5/32

Calorific Power of Various Fuels in British Thermal Units.

Combustible.	Calorific Power.	Evaporative Power from and at 212° F.	Carbon Value.
Carbon, burned to carbonic acid	14,500	15.00	1.000
Carbon, burned to carbonic oxide	4,450	4.61	0.307
Charcoal from wood.	12,000	12.4	0.827
Coke	13,000	13.45	0.896
Coal, bituminous, average	14,000	14.48	0.965
Coal, anthracite, average	15,000	15.52	1.035
Coal, Welsh, average	14,800	15.31	1.021
Creosote or tar refuse.	17,400	18.00	1.199
Naphtha refuse	19,200	19.86	1.324
Petroleum, average.	20,000	20.68	1.379
Hydrogen.	62,060	64.19	4.280
Coal gas, average.	21,000	21.72	1.448
Natural gas (Pennsylvania)	26,000	26.89	1.793
Olefiant gas	21,343	22.08	1.472
Marsh gas.	23,513	24.32	1.621
Block fuel.	15,000	15.52	1.035
Sulphur.	4,000	4.138	0.276

Weight per Cubic Foot and Specific Heat of Various Gases.

Name.	Pounds per Cubic Foot.	Specific Heat.
Marsh gas.	.0447	.470
Olefines	.1174	.332
Hydrogen	.00559	2.406
Carbon monoxide	.0783	.173
Nitrogen	.0783	.173
Carbon dioxide.	.1060	.171
Oxygen	.1060	.155

These weights are for the gases when at an atmospheric pressure of 14.7 lb. per square inch and a temperature of 32 degrees Fahrenheit. The specific heat of a mixture may be found in the same manner as the weight, by multiplying the specific heat for each gas by the per cent contained in the fuel and adding the results. The weight of air at 32 degrees Fahrenheit and at a pressure of 14.7 lb. per square inch is .08082 pounds. The specific heat of air at constant volume is .1688.

HEAT VALUES OF FUELS.

Fuel.	B. T. U. Per Lb.	B. T. U. Per Cu. Ft.
Hydrogen @ 32° F	62,030	348
Carbon	14,500	
Carbon monoxide (C O)	4,396	539
Penn. heavy crude oil	20,736	
Caucasian heavy crude oil	20,138	
Caucasian light crude oil	22,027	
Petroleum refuse	19,832	
Anthracite gas	2,248	
Bituminous gas	3,484	
28-candlepower illum. gas	....	950
19- " " "	....	800
15- " " "	....	620
New York city water-gas	....	710.5 Ave.
London coal gas	....	668
Benzine, C_6H_6	18,448	
Gasoline and its vapor	21,900	690
Ethylene C_2H_4	21,430	1,677
Marsh gas (Methane) CH_4	23,594	1,051
Nat. gas, Leechburg, Pa.	....	1,051
Nat. gas, Pittsburg, Pa.	....	892
Acetylene, C_2H_2	21,492	868
Semi-water gas	....	185
Producer gas	....	150

AREAS OF CIRCLES, FROM 0.01 TO 100.9, ADVANCING BY 10THS.

Diam.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Diam.
0	.0	.0078	.0314	.0706	.1256	.1963	.2827	.3848	.5026	.6361	0
1	.7854	.9503	1.1309	1.3273	1.5393	1.7671	2.0106	2.2698	2.5446	2.8352	1
2	3.1416	3.4636	3.8013	4.1547	4.5239	4.9087	5.3093	5.7255	6.1575	6.6052	2
3	7.0686	7.5476	8.0424	8.5530	9.0792	9.6211	10.1787	10.7521	11.3411	11.9459	3
4	12.5664	13.2025	13.8544	14.5220	15.2053	15.9043	16.6190	17.3494	18.0951	18.8574	4
5	19.6350	20.4282	21.2372	22.0618	22.9022	23.7583	24.6301	25.5176	26.4208	27.3397	5
6	28.2744	29.2247	30.1907	31.1725	32.1699	33.1831	34.2120	35.2566	36.3168	37.3928	6
7	38.4846	39.5920	40.7151	41.8539	43.0085	44.1787	45.3647	46.5663	47.7837	49.0168	7
8	50.2656	51.5300	52.8102	54.1062	55.4178	56.7451	58.0881	59.4469	60.8213	62.2115	8
9	63.6174	65.0389	66.4762	67.9292	69.3979	70.8823	72.3824	73.8982	75.4298	76.9770	9
10	78.5400	80.1186	81.7130	83.3230	84.9488	86.5903	88.2475	89.9204	91.6090	93.3133	10
11	95.0334	97.7691	98.5205	100.287	102.070	103.869	105.683	107.513	109.359	111.220	11
12	113.097	114.990	116.898	118.823	120.763	122.718	124.690	126.677	128.679	130.698	12
13	132.732	134.782	136.848	138.929	141.026	143.139	145.267	147.411	149.571	151.747	13
14	153.938	156.145	158.368	160.606	162.860	165.130	167.415	169.717	172.034	174.366	14
15	176.715	179.079	181.458	183.854	186.265	188.692	191.134	193.593	196.067	198.556	15
16	201.062	203.583	206.120	208.672	211.241	213.825	216.424	210.040	221.671	224.318	16
17	226.980	229.658	232.352	235.062	237.787	240.528	243.285	246.057	248.846	251.650	17
18	254.469	257.304	260.155	263.022	265.905	268.803	271.716	274.646	277.591	280.552	18
19	213.529	286.521	289.529	292.553	295.593	298.648	301.719	304.805	307.908	311.026	19
20	314.160	317.309	320.474	323.655	326.852	330.064	333.292	336.536	339.795	343.070	20

AREAS OF CIRCLES FROM 0.01 TO 100.9, ADVANCING BY 10THS—*Continued.*

Diam.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Diam.
21	346.361	349.667	352.990	356.328	359.681	363.051	366.436	369.837	373.253	376.685	21
22	380.133	383.597	387.076	390.571	394.082	397.608	401.150	404.708	408.282	411.871	22
23	415.476	419.097	422.733	426.385	430.053	433.737	437.436	441.151	444.881	448.628	23
24	452.390	456.168	459.961	463.770	467.595	471.436	475.292	479.164	483.052	486.955	24
25	490.875	494.809	498.760	502.726	506.708	510.706	514.719	518.748	522.793	526.854	25
26	530.930	535.022	539.129	543.253	547.392	551.547	555.717	559.903	564.105	568.323	26
27	572.556	576.805	581.070	585.350	589.646	593.958	598.286	602.629	606.988	611.363	27
28	615.753	620.159	624.581	629.019	633.472	637.941	642.425	646.926	651.442	655.973	28
29	660.521	665.084	669.663	674.258	678.868	683.494	688.136	692.793	697.466	702.155	29
30	706.860	711.580	716.316	721.067	725.835	730.618	735.417	740.231	745.061	749.907	30
31	754.769	759.646	764.539	769.448	774.372	779.313	784.268	789.240	794.227	799.230	31
32	804.249	809.284	814.334	819.399	824.481	829.578	834.691	839.820	844.964	850.124	32
33	855.300	860.492	865.699	870.922	876.160	881.415	886.685	891.970	897.272	902.589	33
34	907.922	913.270	918.635	924.011	929.410	934.822	940.249	945.692	951.150	956.625	34
35	962.115	967.620	973.142	978.679	984.231	989.800	995.384	1000.98	1006.60	1012.23	35
36	1017.87	1023.54	1029.21	1034.91	1040.62	1046.34	1052.09	1057.84	1063.62	1069.40	36
37	1075.21	1081.03	1086.86	1092.71	1098.58	1104.46	1110.36	1116.28	1122.21	1128.15	37
38	1134.11	1140.09	1146.08	1152.09	1158.11	1164.15	1170.21	1176.28	1182.37	1188.47	38
39	1194.59	1200.72	1206.87	1213.04	1219.22	1225.42	1231.63	1237.86	1244.10	1250.36	39
40	1256.64	1262.93	1269.23	1275.56	1281.89	1288.25	1294.62	1301.00	1307.40	1313.82	40

AREAS OF CIRCLES FROM 0.01 TO 100.9, ADVANCING BY 10THS—*Continued.*

Diam.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Diam.
41	1320.25	1326.70	1333.16	1339.64	1346.14	1352.65	1359.18	1365.72	1372.28	1378.85	41
42	1385.44	1392.05	1398.67	1405.30	1411.96	1418.62	1425.31	1432.01	1438.72	1445.45	42
43	1452.20	1458.96	1465.74	1472.53	1479.34	1486.17	1493.01	1499.87	1506.74	1513.62	43
44	1520.53	1527.45	1534.38	1541.33	1548.30	1555.28	1562.28	1569.29	1576.32	1583.37	44
45	1590.43	1597.51	1604.60	1611.71	1618.83	1625.97	1633.12	1640.30	1647.48	1654.68	45
46	1661.90	1669.13	1676.37	1683.65	1690.93	1698.23	1705.54	1712.87	1720.21	1727.57	46
47	1734.94	1742.33	1749.74	1757.16	1764.60	1772.05	1779.52	1787.01	1794.51	1802.02	47
48	1809.56	1817.10	1824.67	1832.25	1839.84	1847.45	1855.08	1862.72	1870.38	1878.05	48
49	1885.74	1893.45	1901.17	1908.90	1916.65	1924.42	1932.20	1940.00	1947.82	1955.65	49
50	1963.50	1971.36	1979.23	1987.13	1995.04	2002.96	2010.90	2018.86	2026.83	2034.82	50
51	2042.82	2050.84	2058.87	2066.92	2074.98	2083.07	2091.17	2099.28	2107.41	2115.56	51
52	2123.72	2131.89	2140.08	2148.29	2156.51	2164.75	2173.01	2181.28	2189.56	2197.87	52
53	2206.18	2214.52	2222.87	2231.23	2239.61	2248.01	2256.42	2264.85	2273.29	2281.75	53
54	2290.22	2298.71	2307.22	2315.74	2324.28	2332.83	2341.40	2349.98	2358.58	2367.20	54
55	2375.83	2384.48	2393.14	2401.82	2410.51	2419.22	2427.95	2436.69	2445.45	2454.22	55
56	2463.01	2471.81	2480.63	2489.47	2498.32	2507.19	2516.07	2524.97	2533.88	2542.81	56
57	2551.76	2560.72	2569.70	2578.69	2587.70	2596.72	2605.76	2614.12	2623.89	2632.98	57
58	2642.08	2651.20	2660.33	2669.48	2678.65	2687.83	2697.03	2706.24	2715.47	2724.71	58
59	2733.97	2743.25	2752.54	2761.85	2771.17	2780.51	2789.86	2799.23	2808.62	2818.02	59
60	2827.44	2836.87	2846.32	2855.78	2865.26	2874.76	2884.26	2893.79	2903.34	2912.89	60

AREAS OF CIRCLES FROM 0.01 TO 100.9, ADVANCING BY 10THS—*Continued.*

Diam.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Diam.
61	2922.47	2932.06	2941.66	2951.28	2960.92	2970.57	2980.24	2989.93	2999.63	3009.34	61
62	3019.07	3028.82	3038.58	3048.36	3058.15	3067.96	3077.79	3087.63	3097.49	3107.36	62
63	3117.25	3127.15	3137.07	3147.01	3156.96	3166.92	3176.91	3186.90	3196.92	3206.95	63
64	3216.99	3227.05	3237.13	3247.22	3257.33	3267.46	3277.59	3287.75	3997.92	3308.11	64
65	3318.31	3328.53	3338.76	3349.01	3359.28	3369.56	3379.85	3390.17	3400.49	3410.84	65
66	3421.20	3431.57	3441.96	3452.37	3462.79	3473.23	3483.68	3494.16	3504.64	3515.14	66
67	3525.66	3536.19	3546.74	3557.30	3567.88	3578.47	3589.08	3599.71	3610.35	3621.01	67
68	3631.68	3642.37	3653.08	3663.80	3674.54	3685.29	3696.06	3706.84	3717.64	3728.45	68
69	3739.28	3750.13	3760.99	3771.87	3782.76	3793.67	3804.60	3815.54	3826.50	3837.47	69
70	3848.46	3859.46	3870.48	3881.51	3892.56	3903.63	3914.71	3925.81	3936.92	3948.05	70
71	3959.20	3970.36	3981.53	3992.73	4003.93	4015.16	4026.40	4037.65	4048.92	4060.21	71
72	4071.51	4082.83	4094.16	4105.51	4116.87	4128.25	4139.65	4151.06	4162.49	4173.93	72
73	4185.39	4196.87	4208.36	4219.86	4231.38	4242.92	4254.48	4266.04	4277.63	4289.23	73
74	4300.85	4312.48	4324.12	4335.79	4347.47	4359.16	4370.87	4382.60	4394.34	4406.10	74
75	4417.87	4429.66	4441.46	4453.28	4465.12	4476.97	4488.84	4500.72	4512.62	4524.54	75
76	4536.47	4548.41	4560.37	4572.35	4584.35	4596.35	4608.38	4620.42	4632.47	4644.54	76
77	4656.63	4668.73	4680.85	4692.99	4705.14	4717.30	4729.49	4741.68	4753.96	4766.12	77
78	4778.37	4790.63	4802.90	4815.20	4827.50	4839.83	4852.16	4864.52	4876.89	4889.27	78
79	4901.68	4914.09	4926.53	4938.98	4951.44	4963.92	4976.42	4988 93	5001.45	5014.00	79
80	5026.56	5039.13	5051.72	5064.32	5076.95	5089.58	5102.24	5114 90	5127.59	5140.29	80

AREAS OF CIRCLES FROM 0.01 TO 100.9, ADVANCING BY 10THS—*Continued.*

Diam.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Diam.
81	5153.00	5165.74	5178.48	5191.25	5204.02	5216.82	5229.63	5242.45	5255.29	5268.15	81
82	5281.02	5293.91	5306.82	5319.74	5332.67	5345.62	5358.59	5371.57	5384.57	5397.59	82
83	5410.62	5423.66	5436.72	5449.80	5462.89	5476.00	5489.12	5502.26	5515.42	5528.59	83
84	5541.78	5554.98	5568.20	5581.43	5594.68	5607.95	5621.23	5634.53	5647.84	5661.17	84
85	5674.51	5687.87	5701.25	5714.64	5728.04	5741.47	5754.90	5768.36	5781.83	5795.31	85
86	5808.81	5822.33	5835.86	5849.41	5862.97	5876.55	5890.15	5903.76	5917.39	5931.03	86
87	5944.69	5958.36	5972.05	5985.76	5999.48	6013.21	6026.97	6040.73	6054.52	6068.32	87
88	6082.13	6095.96	6109.81	6123.67	6137.55	6151.44	6165.35	6179.28	6193.22	6207.18	88
89	6221.15	6235.14	6249.14	6263.16	6277.19	6291.20	6305.31	6319.39	6333.49	6347.61	89
90	6361.74	6375.88	6390.04	6404.22	6418.41	6432.62	6446.84	6461.08	6475.34	6489.61	90
91	6503.89	6518.19	6532.51	6546.85	6561.20	6575.56	6589.94	6604.34	6618.75	6633.18	91
92	6647.62	6662.08	6676.55	6691.05	6705.55	6720.07	6734.61	6749.16	6763.73	6778.32	92
93	6792.92	6807.54	6822.17	6836.82	6851.48	6866.16	6880.85	6895.56	6910.29	6925.03	93
94	6939.79	6954.56	6969.35	6984.16	6998.98	7013.81	7020.67	7043.53	7058.42	7073.32	94
95	7088.23	7103.16	7118.11	7133.07	7148.05	7163.04	7178.05	7193.07	7208.11	7223.17	95
96	7238.24	7253.33	7268.43	7283.55	7298.69	7313.84	7329.00	7344.18	7359.38	7374.59	96
97	7389.82	7405.07	7420.33	7435.60	7450.90	7466.20	7481.53	7496.87	7512.22	7527.59	97
98	7542.98	7558.38	7573.80	7589.23	7604.68	7620.14	7635.62	7651.19	7666.63	7682.16	98
99	7697.70	7713.26	7728.83	7744.42	7760.03	7775.65	7791.29	7806.94	7822.61	7838.29	99
100	7854.00	7869.71	7885.44	7901.19	7916.95	7932.73	7948.53	7964.34	7980.16	7996.00	100

Dimensions of U. S. Standard Screw Threads, Nuts and Bolt Heads.

Recommended by the Franklin Institute and adopted by the Navy Department of the United States, by the Railroad Master Mechanics and Master Car-Builders Associations and by many of the prominent engineering and mechanical establishments of the United States.

Diameter Screw.	Threads per inch.	Diameter at root of Thread.	Diameter Screw.	Threads per inch.	Diameter at root of Thread.
1/4	20	.185	2	4 1/2	1.712
5/16	18	.240	2 1/4	4 1/2	1.962
3/8	16	.294	2 1/2	4	2.176
7/16	14	.344	2 3/4	4	2.426
1/2	13	.400	3	3 1/2	2.629
9/16	12	.454	3 1/4	3 1/2	2.879
5/8	11	.507	3 1/2	3 1/4	3.100
3/4	10	.620	3 3/4	3	3.317
7/8	9	.731	4	3	3.567
1	8	.837	4 1/4	2 7/8	3.798
1 1/8	7	.940	4 1/2	2 3/4	4.028
1 1/4	7	1.065	4 3/4	2 5/8	4.256
1 3/8	6	1.160	5	2 1/2	4.480
1 1/2	6	1.284	5 1/4	2 1/2	4.730
1 5/8	5 1/2	1.389	5 1/2	2 3/8	4.953
1 3/4	5	1.491	5 3/4	2 3/8	5.203
1 7/8	5	1.616	6	2 1/4	5.423

Angle of the thread 60°. Flat at top and bottom $\frac{1}{8}$ of the pitch.

Nuts and Bolt Heads are determined by the following rules, which apply to Square and Hexagon Nuts both:

Short diameter of rough nut = $1\frac{1}{2} \times$ diam. of bolt + $\frac{1}{8}$ in.

Short diameter of finished nut = $1\frac{1}{2} \times$ diam. of bolt + $\frac{1}{8}$ in.

Thickness of rough nut = diam. of bolt.

Thickness of finished nut = diam. of bolt — $\frac{1}{8}$ in.

Short diameter of rough head = $1\frac{1}{2} \times$ diam. of bolt + $\frac{1}{8}$ in.

Short diameter of finished head = $1\frac{1}{2} \times$ diam. of bolt + $\frac{1}{8}$ in.

Thickness of rough head = $\frac{1}{2}$ short diam. of head.

Thickness of finished head = diam. of bolt — $\frac{1}{8}$ in.

The long diameter of a hexagon nut may be obtained by multiplying the short diameter by 1.155, and the long diameter of a square nut by multiplying the short diameter by 1.414.

CIRCUMFERENCES OF CIRCLES FROM 0.01 TO 80.9 ADVANCING BY 10THS.

Diam.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Diam.
0	.00	.31	.62	.94	1.25	1.57	1.88	2.19	2.51	2.82	0
1	3.14	3.45	3.77	4.08	4.39	4.71	5.02	5.34	5.65	5.96	1
2	6.28	6.59	6.91	7.22	7.53	7.85	8.16	8.48	8.79	9.11	2
3	9.42	9.74	10.05	10.36	10.68	10.99	11.30	11.62	11.93	12.25	3
4	12.56	12.88	13.19	13.50	13.82	14.13	14.45	14.76	15.08	15.39	4
5	15.70	16.02	16.33	16.65	16.96	17.27	17.59	17.90	18.22	18.53	5
6	18.84	19.16	19.47	19.79	20.10	20.42	20.73	21.04	21.36	21.67	6
7	21.99	22.30	22.61	22.93	23.24	23.56	23.87	24.19	24.50	24.81	7
8	25.13	25.44	25.76	26.07	26.38	26.70	27.01	27.33	27.64	27.96	8
9	28.27	28.58	28.90	29.21	29.53	29.34	30.15	30.47	30.78	31.10	9
10	31.41	31.73	32.04	32.35	32.67	32.98	33.30	33.61	33.92	34.24	10
11	34.55	34.87	35.18	35.50	35.81	36.12	36.44	36.75	37.07	37.38	11
12	37.69	38.01	38.32	38.64	38.95	39.27	39.58	39.89	40.21	40.52	12
13	40.84	41.15	41.46	41.78	42.09	42.41	42.72	43.03	43.35	43.66	13
14	43.98	44.29	44.61	44.92	45.23	45.55	45.86	46.18	46.49	46.80	14
15	47.12	47.43	47.75	48.06	48.38	48.69	49.00	49.32	49.63	49.95	15
16	50.26	50.57	50.89	51.20	51.52	51.83	52.15	52.46	52.78	53.09	16
17	53.40	53.72	54.03	54.35	54.65	54.97	55.29	55.60	55.92	56.23	17
18	56.54	56.86	57.17	57.49	57.80	58.11	58.43	58.74	59.06	59.37	18
19	59.69	60.00	60.31	60.63	60.94	61.26	61.57	61.88	62.20	62.51	19
20	62.83	63.14	63.46	63.77	64.08	64.40	64.71	65.03	65.34	65.65	20
12	65.97	66.28	66.60	66.91	67.22	67.54	67.85	68.17	68.48	68.80	21
22	69.11	69.42	69.74	70.05	70.37	70.68	71.00	71.31	71.62	71.94	22
23	72.25	72.57	72.88	73.19	73.51	73.82	74.14	74.45	74.76	75.08	23
24	75.39	75.71	76.02	76.34	76.65	76.96	77.28	77.59	77.91	78.22	24
25	78.54	78.85	79.16	79.48	79.79	80.11	80.42	80.73	81.05	81.36	25
26	81.68	81.99	82.30	82.62	82.93	83.25	83.56	83.88	84.19	84.50	26
27	84.82	85.13	85.45	85.76	86.07	86.39	86.70	87.02	87.33	87.65	27
28	87.96	88.27	88.59	88.90	89.22	89.53	89.84	90.16	90.47	90.79	28
29	91.10	91.42	91.73	92.04	92.36	92.67	92.99	93.30	93.61	93.93	29
30	94.24	94.56	94.87	95.19	95.50	95.81	96.13	96.44	96.76	97.07	30
31	97.38	97.70	98.01	98.33	98.64	98.96	99.27	99.58	99.90	100.2	31
32	100.5	100.8	101 1	101.4	101.7	102.1	102.4	102.7	103.0	103.3	32
33	103.6	103.9	104.3	104.6	104.9	105.2	105.5	105.8	106.1	106.5	33
34	106.8	107.1	107.4	107.7	108.0	108.3	108.6	109.0	109.3	109.6	34
35	109.9	110.2	110.5	110.8	111.2	111.5	111.8	112.1	112.4	112.7	35
36	113.0	113.4	113.7	114.0	114.3	114.6	114.9	115.2	115.6	115.9	36
37	116.2	116.5	116.8	117.1	117.4	117.8	118.1	118.4	118.7	119.0	37
38	119.3	119.6	120.0	120.3	120.6	120.9	121.2	121.5	121.8	122.2	38
39	122.5	122.8	123.1	123.4	123.7	124.0	124.4	124.7	125.0	125.3	39
40	125.6	125.9	126.2	126.6	126.9	127.2	127.5	127.8	128.1	128.4	40
41	128.8	129.1	129.4	129.7	130.0	130.3	130.6	131.0	131.3	131.6	41
42	131.9	132.2	132.5	132.8	133.2	133.5	133.8	134.1	134.4	134.7	42
43	135.0	135.4	135.7	136.0	136.3	136.6	136.9	137.2	137.6	137.9	43
44	138.2	138.5	138.8	139.1	139.4	139.8	140.1	140.4	140.7	141.0	44
45	141.3	141.6	142.0	142.3	142.6	142.9	143.2	143.5	143.9	144.2	45

CIRCUMFERENCES OF CIRCLES—*Continued.*

Diam.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Diam.
46	144.5	144.8	145.1	145.4	145.7	146.0	146.3	146.7	147.0	147.3	46
47	147.6	147.9	148.3	148.6	148.9	149.2	149.5	149.8	150.1	150.4	47
48	150.7	151.1	151.4	151.7	152.0	152.3	152.6	152.9	153.3	153.6	48
49	153.9	154.2	154.5	154.8	155.1	155.5	155.8	156.1	156.4	156.7	49
50	157.0	157.3	157.7	158.0	158.3	158.6	158.9	159.2	159.5	159.9	50
51	160.2	160.5	160.8	161.1	161.4	161.7	162.1	162.4	162.7	163.0	51
52	163.3	163.6	163.9	164.3	164.6	164.9	165.2	165.5	165.8	166.1	52
53	166.5	166.8	167.1	167.4	167.7	168.0	168.3	168.7	169.0	169.3	53
54	169.6	169.9	170.2	170.5	170.9	171.2	171.5	171.8	172.1	172.4	54
55	172.7	173.1	173.4	173.7	174.0	174.3	174.6	174.9	175.3	175.6	55
56	175.9	176.2	176.5	176.8	177.1	177.5	177.8	178.1	178.4	178.7	56
57	179.0	179.3	179.9	180.0	180.3	180.6	180.9	181.2	181.5	181.9	57
58	182.2	182.5	182.8	183.1	183.4	183.7	184.0	184.4	184.7	185.0	58
59	185.3	185.6	185.9	186.2	186.6	186.9	187.2	187.5	187.8	188.1	59
60	188.4	188.8	189.1	189.4	189.7	190.0	190.3	190.6	191.0	191.3	60
61	191.6	191.9	192.2	192.5	192.8	193.2	193.5	193.8	194.1	194.4	61
62	194.7	195.0	195.4	195.7	196.0	196.3	196.6	196.9	197.2	197.6	62
63	197.9	198.2	198.5	198.8	199.1	199.4	199.8	200.1	200.4	200.7	63
64	201.0	201.3	201.6	202.0	202.3	202.6	202.9	203.2	203.5	203.8	64
65	204.2	204.5	204.8	205.1	205.4	205.7	206.0	206.4	206.7	207.0	65
66	207.3	207.6	207.9	208.2	208.6	208.9	209.2	209.5	209.8	210.1	66
67	210.4	210.8	211.1	211.4	211.7	212.0	212.3	212.6	213.0	213.3	67
68	213.6	213.9	214.2	214.5	214.8	215.1	215.5	215.8	216.1	216.4	68
69	216.7	217.0	217.3	217.7	218.0	218.3	218.6	218.9	219.2	219.5	69
70	219.9	220.2	220.5	220.8	221.1	221.4	221.7	222.1	222.4	222.7	70
71	223.0	223.3	223.6	223.9	224.3	224.6	224.9	225.2	225.5	225.8	71
72	226.1	226.5	226.8	227.1	227.4	227.7	228.0	228.3	228.7	229.0	72
73	229.3	229.6	229.9	230.2	230.5	230.9	231.2	231.5	231.8	232.1	73
74	232.4	232.7	233.1	233.4	233.7	234.0	234.3	234.6	234.9	235.3	74
75	235.6	235.9	236.2	236.5	236.8	237.1	237.5	237.8	238.1	238.4	75
76	238.7	239.0	239.3	239.7	240.0	240.3	240.6	240.9	241.2	242.5	76
77	241.9	242.2	242.5	242.8	243.1	243.4	243.7	244.1	244.4	244.7	77
78	245.0	245.3	245.6	245.9	246.3	246.6	246.9	247.2	247.5	247.8	78
79	248.1	248.5	248.8	249.1	249.4	249.7	250.0	250.3	250.6	251.0	79
80	251.3	251.6	251.9	252.2	252.5	252.8	253.2	253.5	253.8	254.1	80

Mensuration of Surface and Volume. The area of a rectangle is equal to the length × breadth.

Area of a triangle is equal to the base × one-half the perpendicular height.

Diameter of a circle is equal to the radius × 2.

Circumference of a circle is equal to the diameter × 3.1416.

Area of a circle is equal to the square of diameter × .7854.

Area of a sector of a circle is equal to the area of the circle × number of degrees in arc ÷ 360.

Area of surface of a cylinder is equal to the circumference × length, plus the area of both ends.

To find the diameter of a circle having a given area: Divide the area by .7854, and extract the square root.

To find the volume of a cylinder: Multiply the area of the section in square inches by the length in inches, this equals the volume in cubic inches. Cubic inches divided by 1728 is equal to the volume in cubic feet of any body.

The surface of a sphere is equal to the square of diameter × 3.1416.

Volume of a sphere is equal to the cube of diameter × .5236.

The side of an inscribed cube is equal to the radius of the sphere × 1.1547.

The area of the base of a pyramid or cone, whether round, square or triangular, multiplied by one-third of its height is equal to the volume.

A gallon of water (United States Standard) weighs $8\frac{1}{3}$ pounds and contains 231 cubic inches.

ADDENDUM

Gas Engine Troubles. For those who have not the time to study gas engine principles this section is included.

Many of the troubles are due to the operator's ignorance of the principles of operation, or to negligence in taking care of the engine.

One of the most common mistakes is trying to make the engine run without fuel. The operator will turn the starting crank until out of breath when he will suddenly discover that the gasoline tank is empty!

A gas engine will not run without gas, but it is hard to get this simple fact fixed permanently in the mind of the operator.

Another trouble, similar to the empty gasoline tank, is trying to make the engine run without a spark to ignite the compressed charge. Sometimes a connection in the wiring will break which will deceive the operator.

A short circuit, in an unexpected place, will lead to the same trouble.

See that the engine gets a proper charge, then see that the spark is heavy enough to fire it.

Do not turn the starting crank or fly wheel until patience and endurance are entirely expended.

If the engine does not start promptly in four or five turns, the right conditions are not present and the operator should use a little common sense instead of so much muscle. Correct the faulty conditions and the engine will start at once.

The simplicity of the causes leading to the above mentioned troubles is sufficient reason for their existence.

Oiling a Gas Engine. The oiling of the engine should be done in a thorough manner. Use machine oil on the various parts of the engine, **except in the cylinder.** A special oil for gas engines should be used for the cylinders.

Steam cylinder oil is not well adapted to a gas engine cylinder. A light cylinder oil, of high fire test, is best adapted to use in the gas engine cylinder. Some gas engines are fitted at the wrist pin and journal bearings with grease cups, which should be filled with shafting and set so as to feed automatically.

When oil and grease cups are filled and all bearing parts that are liable to wear are oiled, the **valve stems** should be tried by lifting the valve from its seat a number of times after putting some kerosene oil on the stem with an oil can. The stems should be frequently examined and kerosene oil used occasionally to keep them clean. Never use ordinary lubricating oil on them. The heat simply burns it and leaves a gummy deposit on the stem which interferes with the free movement of the valve.

It is said that oil is cheaper than machinery and we want to earnestly emphasize the truth of that statement.

It should be **good** oil, however, for there is a great difference in the quality of oils, and good oil only can be considered if the cost of the machine is kept in mind.

Some of the so-called lubricating oils on the market have but little more value than so much water.

It is not only a question of economy in using a good lubricant with an engine, but also of increasing the net power for effective work. This is especially true with the gas engine for it depends on the oil to make the piston and rings tight to hold both the compression and the high pressure of the explosion.

The most accurate job of machining and fitting of the cylinder, piston and rings would not hold these pressures without a film of good gas enine oil between the piston and the cylinder walls.

The importance of proper lubrication can hardly be overestimated as will be readily apparent when the action of a good oil, either on the cylinder walls or in a properly adjusted bearing is thoroughly understood.

A good oil forms an almost frictionless film between the surfaces of the piston, rings and walls of the cylinder, or between the shaft and the bearing as the case may be, and thus prevents the metals from coming in direct contact. Without direct frictional contact there is, of course, no wear or deterioration of the metals so long as the proper condition is maintained, hence we must conclude that the natural wear we figure on in the life of any machine is due to imperfect lubrication a portion of the time.

It is a difficult thing to maintain a perfect condition at all times, but the use of good oil and proper attention to the oiling will greatly increase the life of the machine to say nothing of the saving of repairs, trouble and loss of time in repairing, etc.

It does not follow, however, that an excessive amount of oil should be applied as is often done on the theory that if a little is good more is better. When too much oil is applied the surplus runs out of the bearing and is often wasted besides making a greasy, dirty engine.

In the case of the cylinder too much oil will accumulate and burn in the combustion chamber, leaving a carbon deposit on the walls of the compression space besides fouling the sparking mechanism and causing a disagreeable smoke at the exhaust.

Probably the worst possible result of a too liberal use of oil is the danger of the machine running dry between spasmodic oilings.

The operator, feeling sure that he has used plenty of oil to last a considerable length of time (which he has if it had been properly applied) will neglect the machine and overlook the fact that only a limited amount of oil will be retained in the bearing.

The all-important thing in perfect lubrication is to supply a good oil frequently and regularly, or continuously if possible, to the parts where there would be great friction.

Do not feel content in seeing that the oil is flowing, but know positively that it is going to the right place.

Many fine bearings have been utterly ruined by the oil holes and channels becoming clogged so that the oil, though freely applied, could not reach all parts of the bearing.

Cylinders and the more important bearings of the gas engine are generally oiled by pressure feed and sight feed oilers.

These oiling devices should be kept in first class condition and set to feed the oil in the right quantity and regularly while the engine is running.

Ordinary machine oils are of little value for gas engines because the fire test is entirely too low to stand the high heat of the cylinder and piston.

Use a good gas engine oil, feeding it constantly or at least frequently and regularly, but do not be wasteful, keep in mind the old adage revised, Good oil is cheaper than machinery.

For main bearings and similar places it is very common to use cup grease or what is sometimes called "hard oil" which is fed or forced to the bearing by a special grease cup.

As the bearing warms up under service the grease melts and produces the film, similar to liquid oils, to prevent wear and relieve the friction. The process of converting the grease to an oil film, being somewhat automatic, is a good point for cup grease as against liquid oil for some kinds of service, but do not forget that the quality of the grease to be used is just as important as with the liquid oils.

Timing the Spark. The timing of the spark is of much greater importance than was realized for many years after the gas engine came into use.

Although the charge under compression fires easily and burns rapidly, yet it requires a small period of time, and the spark must occur far enough ahead of the end of the stroke so that the charge will be ignited and the expansion taking place when the piston starts on its power stroke. If the spark occurs too late a part of the effective power stroke is lost, while if the spark occurs too early the heat expansion begins before the piston reaches the end of its stroke. This will cause the engine to pound or perhaps stop, if the ignition occurs very much too early.

The correct time for the spark depends entirely on the speed of the engine. At high speeds the spark must be advanced or made further ahead of the end of the stroke to give the necessary time for ignition, while at low speeds the spark may be retarded or made later.

It is necessary to provide high speed engines with a device for retarding the spark when starting and changing to the advanced position after the engine gets up speed.

Owing to the varying speeds used it is impossible to give a set position for the correct point of ignition, but the proper timing of the spark may be readily determined by a little experimenting with the engine under full load. The correct position will soon be ascertained by observing the results of early or late ignition.

A gas engine will run with the valves and spark considerably out of time, but its full power and efficiency will not be developed unless the timing is right.

Cooling the Cylinder. The process of keeping the heat of the walls and head of the cylinder down to the proper temperature is called cooling the cylinder.

It is not intended to make the cylinder cold, for a cold cylinder would absorb a great amount of the heat of the explosion. As it is the heat that does the work the object is therefore to turn the greatest possible per cent of it into useful work.

The usual way of cooling the cylinder is to circulate a quantity of water around the cylinder and over the head, through a water jacket. This water space is generally cast as an integral part of the head and cylinder.

The water must be made to circulate through this space or otherwise it would become very hot and the temperature of the cylinder walls would rise too high.

This circulation may be obtained by a pump, or by the natural heat of the engine. If the water for cooling comes directly from a hydrant and is allowed to waste after passing through the jacket, care must be taken to admit only enough to properly cool the engine.

An excessive supply of cold water pumped through the jacket will produce bad results.

When natural circulation is used a water tank is used and placed so that the water level in the tank will be higher than the engine cylinder. The tank is connected to the water space around the cylinder by two pipes, an inlet from the bottom of the tank to the lower part of the jacket and an outlet from the top of the cylinder to the upper part of the tank.

As the water in the jacket becomes heated it rises through the outlet pipe to the top of the water level in the tank. As the heat radiates or leaves the surface the water becomes heavier and settles to the bottom of the tank.

The same water is thus used over and over again with only a small loss by evaporation. The size of the tank must be in proportion to the size of the engine, it must hold enough water so that the hot water, coming from the engine, will have time to cool before it is needed again in the jacket.

Oil, instead of water, is being used to a considerable extent by some manufacturers. A radiator or system of pipes is used when oil is employed and the circulation through the jacket is obtained similar to the processes just described for water, as the general principles of water and oil cooling are the same. As the oil will not freeze and burst the jacket a distinct advantage over water cooling is thereby gained.

The next and last means of cooling the cylinder is air cooling.

The cylinder is made with radiating ribs or fins, usually cast on, from which the high heat, that passes through the cylinder walls, is radiated to the surrounding air.

This form of cooling was first exploited in small bicycle engines with cylinders ranging from $2\frac{1}{2}$ to $3\frac{1}{4}$ inches bore and stroke. Recently it is being used by automobile manufacturers to cool multiple-cylinder engines.

Water Jacket Temperature. The object of the water-jacket on a gas engine cylinder is to maintain the cylinder at an even temperature without over-heating. If the cylinder were run perfectly hot, the expansion of the metals would be such that the piston would soon stick, or seize, and the high temperature would consume the lubricating oil. To get the best results, the temperature of the water in the cylinder jacket should be as near 180 degrees as possible, but in the marine motor little attention is ever given to this. As long as the motor keeps reasonably cool and continues to work well, the average operator lets things alone. A number of motors have been failures owing to insufficient water-jacketing, and there are others which have had too much water-jacketing. The first means that the motors do not work at all, the latter, that they do not get the full benefit of the expansion of the gases and are consequently wasting gasoline.

Pumps. All pumps on two-cycle motors have an impulse at every revolution of the crankshaft. This is unavoidable, but it is mechanically very bad practice, as the average marine motor will make about 500 revolutions per minute, and any plunger pump loses its efficiency above a speed of 300 strokes per minute.

This is one reason why in practice these pumps give such a poor circulation. The remedy would be to gear the pump so that the motor would make about four revolutions to one of the pump, and increase the size of the pump. This would, however, add considerably to the cost of the engine. On some engines a pump of the rotary type is used, and while these pumps will deliver a perfectly steady and constant flow they will soon lose their efficiency if there be any sand or grit in the water.

Vaporizing Valves. While these valves are exceedingly simple and operated entirely by the suction of the engine, they are capable of giving a great deal of trouble. At the point where the gasoline is fed under the seat of the valve the opening is generally less than one thirty-second of an inch, and it very often happens that a small particle of foreign substance contained in the gasoline will settle at this point.

When the valve is pressed up by hand, the gasoline will apparently flow all right, but when the engine is started it will make but a few revolutions and stop for want of gasoline. The small particle, by the quick suction of the engine, will be drawn into the gasoline opening, shutting off the flow of gasoline, falling back again when the engine stops, in other words, acting as a check valve. This is a very common occurrence, and a small wire for cleaning the gasoline inlet should always be on hand. It often happens that the spring in the vaporizer becomes weak, and in this case it will admit of an overcharge of air. To remedy this, remove the spring and stretch it out. In order to determine how much the spring has been stretched, it is a good plan to measure it first.

Gasoline Pipes. A source of trouble is in the location of the gasoline tank. This in many cases has to be placed so low that if the boat is loaded by the head the gasoline will not flow to the vaporizer when the tank is nearly empty. A source of annoyance is the practice of running the gasoline pipe around under the lockers, especially where the gasoline tank is low, as in this case the pressure of the gasoline in the tank is influenced by the rolling of the boat or overloading on either side. In some cases the gasoline is entirely shut off when the boat is out of trim. The gasoline pipe should in all cases be led down as close to the keel of the boat as possible.

Regrinding Valves. The valves of a gas engine have to be reground in case any leakage occurs, for, a leak once started rapidly grows worse and a serious leak makes starting difficult or perhaps impossible. An engine may run along for many months without leakage of valves, but it is good policy to make occasional tests or inspection to avoid future trouble.

All valves made by experienced manufacturers are provided with a slot for a screwdriver as a means of rotating the valve on its seat.

The best material for grinding, tripoli ground, but as this may be hard to obtain in some places flour of emery may be substituted. Flour of emery may be purchased at any drug store, but it does not grind so rapidly or make as smooth a surface as the tripoli.

A little lard oil is used to retain the grinding material between the valve and its seat. If lard oil is not at hand common kerosene will answer the purpose. Ordinary machine oil is a very poor substitute and should not be used if lard oil can possibly be obtained.

Apply the oil and grinding material to the face of the valve and replace in its position in the guide. With a common bit brace and screw-driver blade revolve the valve on its seat until an even bearing is obtained. An ordinary screw will do if the bit brace and screw-driver blade are not available.

Use a firm steady pressure on the valve while grinding but not too much. Lift the valve from its seat at short intervals to allow the oil and grinding material to run back over the surfaces. Clean the valve and seat occasionally and stop as soon as a full even bearing is shown.

Restricted Exhaust or Inlet Ports. A restricted exhaust may retain a higher degree of heat in the cylinder and thereby assist in maintaining incandescent some projecting point in the combustion chamber.

Restricted valve ports are a hindrance to the development of power. The valve proportions should always be carefully figured from the piston speed and the cylinder area.

The inlet valve area should be such as to give the gases a speed of from 90 to 100 feet per second. The exhaust gases should leave the cylinder at from seventy-five to eighty-five feet per second at atmospheric pressure.

The exhaust valve should be larger than the inlet valve, because at the time of opening the exhaust valve there is a pressure of from twenty-five to thirty-five pounds in the cylinder to relieve, and the velocity of the exhaust gases at the moment of release is above 100 feet per second, and if it had to pass through a restricted valve port it would maintain the initial high speed throughout the exhaust stroke of the piston, resulting in back pressure during the entire exhaust stroke.

The point, then, is to figure the exhaust port of such proportions as to relieve the exhaust gases at an average speed throughout the exhaust stroke of not over 100 feet per second.

It is the height of folly to have a big cylinder port, and then choke the passage with a little valve or vice versa.

The passage should be of uniform area and of ample capacity from the cylinder port to the end of the pipe.

Types of Gasoline Engines. When choosing a gasoline engine for operating a boat there are a number of points to be dealt with. The gasoline engine is expected to be in working order at all times and it must never break down. If it does, the operator will decry the gasoline engine, its builders and all who have anything to do with it. If a steam engine breaks down, there may be some strong words used with reference to its maker, but as a rule nothing is said against the steam engine as a prime mover, for the simple reason that we are accustomed to its vagaries.

While much more is expected of the gasoline engine than of the steam engine, the previous assertion is none the less true that reliability of operation is the primary consideration. Economy of fuel, which is a matter of first importance with all prime movers on land, becomes a secondary requirement as far as the marine gasoline engine is concerned, and more especially when these engines are to be used for small powers. It is a mistaken notion that anyone can operate a gasoline engine. A child will get on very well after being taught, and until something happens. Then comes the necessity for a man with reasoning powers that are well developed and with a clear head. All kinds of things may happen to a vessel, if its motive power gives out. A great many things may happen to a gasoline engine in indifferent hands.

Before going further it may be necessary to explain briefly the principles of operation of the two types used for marine purposes. These types are the four-cycle engine, in which there is but one impulse for each two revolutions of the crankshaft, and the two-cycle engine, in which an impusle occurs at each revolution of the crankshaft. Of the two, the four-cycle engine is most used for stationary purposes, but in marine practice the two-cycle engine is in the lead. Although not generally considered as economical of fuel as the four-cycle engine, it can be built much lighter for the same power, and the great frequency of the impulses makes it much steadier in operation. This can perhaps be realized better when it is remembered that a single cylinder steam engine receives an impulse at every stroke of the piston, or two impulses at every revolution of the crankshaft, while the four-cycle gasoline engine receives but one impulse to two revolutions, or one impulse to four in the steam engine. The steam engine also receives two impulses during the same time that the two-cycle engine receives one.

Multiple-Cylinder Engines. Multiple-cylinder engines of the two-cycle type have until quite recently been constructed by adding successively separate engines. While these in a great many cases have given satisfaction, they have not as a whole been satisfactory. The chief trouble being that when operated by one carbureter, they have been inclined to flood in the after-cylinders. The gasoline gas being of greater specific gravity than air, has a tendency to go to the lowest point, which in the majority of boats would be the after-cylinders. The distance apart of the separate engines also tending to condense the vaporized gasoline, flooding the crank bases of the engines with the consequence that no two of the cylinders have a uniform mixture of gas, and in many cases the after cylinders refuse to work at all. In order to avoid these difficulties, many multiple-cylinder engines have separate carbureters for each crank case. While this is all right in theory it is not good practice, as it is difficult to obtain the correct regulation of each cylinder when they are all in operation. There have been placed on the market a number of multiple-cylinder engines with the cylinders in one integral casting and surrounded by one water-jacket. By this means the cylinders are brought very close together, using one carbureter, the connections from it to the engines by this plan are very short and compact. These engines in their very best form are not adapted to be operated by a novice. Owing to their high speed and the number of moving parts, it is very difficult to detect and locate troubles of any kind, and determine in which cylinder the trouble exists. The four-cycle multiple-cylinder engine is an entirely different proposition, and especially, the double cylinder, which is very successful. The two-cylinder four-cycle engine produces the same results and only has the same number of movements as in the single-cylinder two-cycle, therefore a four-cycle four-cylinder is equivalent to a two-cylinder two-cycle engine. One of the principal troubles of the multiple-cylinder high speed engine is the ignition, as they are very hard on generators and batteries.

Selecting a Boat Engine. The thing for the prospective purchaser to do is naturally to write to different makers of gasoline engines and obtain their catalogues and price lists. It will be found that each one is building the best engine on earth, if his story is to be believed. It is a sad truth, indeed, that there are many poor gasoline engines offered for sale in the open market. Several catalogues will probably contain an engine very nearly the size which has been selected for the new boat. If the catalogues received contain testimonials from persons who live in the vicinity, make it a point to call on them, and have a private talk with them about their engines.

Find out how much the engine has been run, and obtain a narrative of all experiences with the engine when running. Find out the longest as well as the shortest period of time it has taken to get the engine started, and how long it has been run at any one time without stopping. Find out if the engine is addicted to thumping or pounding in any part of the mechanism, and whether such

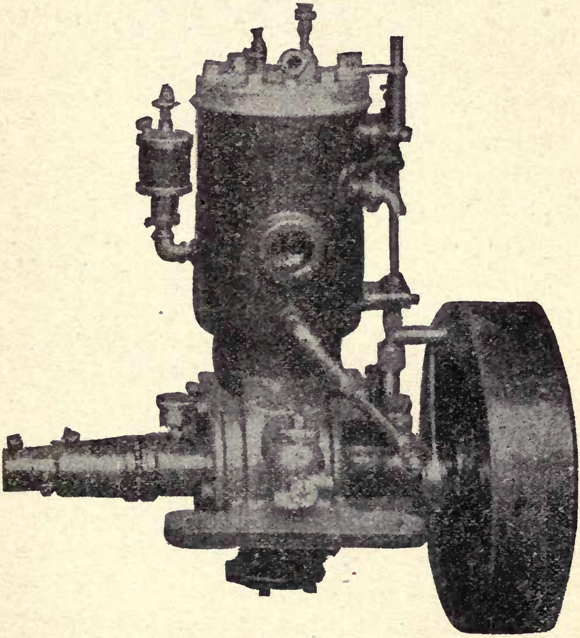

FIG. 44
Single-cylinder, two-cycle Marine Motor.

a condition is of frequent occurrence, or only occasional, and also how long the ignition apparatus will last. If it be found that the engine transmits very little vibration to the boat, it may be presumed that the engine is well balanced.

Another way to tell whether an engine is in good balance is to see if it will run for quite a little time after the ignition current has been cut off. Of two engines, that are of the same size, and equally well lubricated, and which have the same friction resistance, the engine will run the longer after power is shut off that is the better balanced. When resting the hand upon the cylinder head while the engine is running idle, if a knock is perceptible it is a certain sign that it is out of balance.

If the engine is counterbalanced in the flywheel instead of on the crank jaws it gives a twisting movement to the shaft, and the balancing is imperfect. A well-balanced engine should have the counter-weight as nearly opposite the the crank pin as it is possible to place it. In a two-cylinder engine with the crank pins at 180 degrees, or in a three-cylinder engine with the cranks at 120 degrees, a balancing effect is obtained which is much better than that produced by a counter-weight. It is the custom with some builders to put the crank pins on the same side of the shaft for a two-cylinder engine, for the reason that the impulses are better distributed. It is generally admitted that a better mechanical balance is obtained with the crank pins at 180 degrees and in a vertical two-cylinder engine of the four-cycle type with an enclosed crank case, the latter arrangement avoids the pumping action that occurs when the cranks are on the same side of the shaft.

If the counter-weight be in the flywheel, see if it has any side motion when the engine is running, or, in other words, see if the flywheel is out of true sideways. If such is the case, it shows that the crank shaft is too weak for an engine of this kind.

Find out if the bearings give trouble from over heating, and be particular to ask for any experience in this matter. Find out if it is necessary to watch the engine at all times, or whether you may be secure in giving the engine only an occasional glance to see if it is running all right.

Handling Marine Engine with Reverse Lever. In handling the engine when desiring to make a stop, no matter whether equipped with reversing gear or reversing propeller, never stop the engine until the actual stopping point is reached. Many accidents are caused by operators getting excited and stopping the motor when it should have been allowed to run and depend on the reversing mechanism. When the engine has no reversing device and is dependent upon reversing the engine, always make the approach to a landing from the side.

Propellers for Motor Boats. The propeller wheels used on motor boats are, as a rule, smaller in diameter than employed in steam practice, the reason for this being that the gasoline engine is usually run at a higher rate of speed, and where no reversing gear is used, the engine has to start against the full load of the

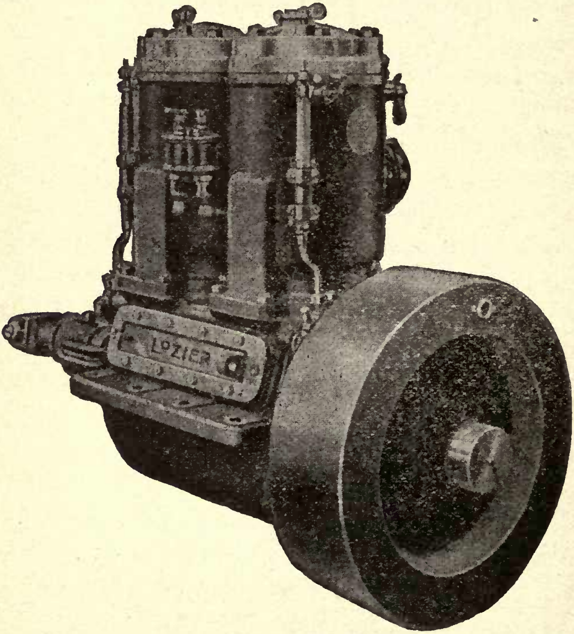

FIG. 45
Two-cylinder, two-cycle Marine Motor.

wheel. Of late, the manufacturers have been using wheels of larger diameter and less pitch, the effect of this being to increase the efficiency of the propeller, making the engine easier to start, decreasing the number of revolutions somewhat, but adding to the speed of the boat. In order to avoid the use of the reversing gears inside the boat, the reversing propeller is used to a large extent. These wheels, although of many different patterns, are all practically of the same principle, the blades being turned by the movement of a sleeve surrounding the propeller shaft, which revolves with the shaft. There are no gears to intermesh or any necessity for slowing down as with the inside reversing mechanism. These propellers will reverse at full speed as they always travel in the same direction, they take hold of the water instantly.

The reversing propeller is necessarily somewhat weak structurally. It being impossible, for mechanical reasons, to design it as a perfectly true screw. It therefore lacks the efficiency of a solid propeller.

The word pitch, as applied to the propeller wheel, refers to it in the same sense as to the pitch of a screw, as the propeller in action should be a perfect screw. The pitch of the propeller designates the number of feet that it would travel in one revolution, supposing it to be a screw. If a propeller wheel is 20 inches in diameter and has 30 inches pitch, it denotes that it will travel 30 inches in each revolution. It is by this means that calculations are made on the speed of the boat. In small motor boats any estimates based on these calculations will, as a rule, prove anything but reliable, as the proportion of beam to length is in all cases excessive in comparison with larger vessels. Of course, as the pitch of the propeller wheel is decreased, a slower screw is had and consequently a more powerful one. For this reason it is becoming the practice of high speed boats to use a wheel of the least possible pitch, and in order to gain on the travel of the screw to increase the number of the revolutions of the propeller.

The form and general design of the propeller have been so extensively experimented with, that the subject is almost worn threadbare, and it is sufficient to say that the true screw propeller will, in all probability, remain as at first the standard of excellence.

Couplings and Thrust Bearings. On the opposite end of the crank shaft from the fly-wheel, is the shaft coupling and thrust bearing. The thrust bearing, which is intended to take up the thrust or push from the propeller, is sometimes made up of a number of balls fitted in a cage between the couplings and the after bearing of the engine, or in a great many cases a groove is turned in the coupling for a ball race, the oposite side being a flat, hardened steel washer. While this is a very neat and effective arrangement, it has been found from actual experience that ball-bearings in marine work are not a success. The older method, and the one still used on large marine engines, is the ring thrust, composed of a shaft with a number of collars turned on it which mesh into a set of babbitt metal rings fastened to the keel and entirely separate from the engine. The necessity of a good thrust bearing, is sadly neglected by the launch owner, as a thrust bearing of good design, if carefully looked after, will in the majority of cases not only keep the engine in much better working order and save a good deal of wear, but in many cases prevent a broken connecting rod.

Gas Engine Design. The builders of gas engines have brought out a great number of different designs in construction.

Out of all this there have been evolved certain constructions that have come to be recognized as standard and followed by most builders.

Cylinders are built in either a vertical or horizontal position.

The principal claims for the vertical construction are:

Minimum floor space occupied, impulses delivered in the line of the foundation, thus lessening the vibration. Less wear on the piston and cylinder by supporting the weight of the piston on the connecting rod instead of allowing it to lie on one side in the cylinder.

These advantages are met by claims for a horizontal construction in that better lubrication of the piston and cylinder walls is obtained by feeding the oil on top of the piston, so that it will flow by gravity to all parts of the wearing surface.

As both constructions are in demand and both give excellent results in practical use, it becomes a matter of taste with the purchaser, and many manufacturers settle the question by building both the vertical and horizontal types.

In most gas engines the connecting rod is attached directly to the piston thus eliminating the heavy crosshead and piston rod peculiar to the steam engine. As the mass or weight of reciprocating parts is thus greatly reduced the gas engine thereby approaches the ideal engine.

A point in late design is the tendency to multiple-cylinder construction, using two, three, four and sometimes six cylinders. Such constructions are much more expensive to build, but the important advantages of less weight for a given power, constant torque or turning movement, less vibration due to better balance and the increased chances against complete disability are bringing multiple-cylinder engines into general favor.

In an engine with two or more cylinders the principle of operation for each cylinder is the same as for a single-cylinder engine. The cylinders are, however, made to deliver their impulses one after the other, the time between the impulses being made as nearly equal as possible.

Fore-Sight Visible Spark Plug. The great utility of this improved electric sparking device for gas engines has been established by thorough working tests under the most severe conditions. It is especially designed for use with gas engines operating motor vehicles. This type of engine requires a perfect sparking action to meet the exacting requirements of modern service, and must be entirely dependable under the most trying and adverse circumstances.

The vital working parts of a motor vehicle must be perfectly protected against fouling, and at the same time should be quickly accessible for thorough inspection. Ease of operation, personal comfort, and safety must be assured by every successful motor.

The Fore-Sight Visible Spark Plug is constructed on the principle of reduced voltage. An electric current of low voltage will arc or spark instead of following a path of high resistance formed by carbon or other deposits. A low voltage is obtained in this plug without reduced amperage.

An auxiliary sparking gap co-operating with the main ignition gap is so placed as to be visible to the eye and admitting of easy inspection at all times. The working condition of the spark is thus plainly discernible without the removal of the plug from the cylinder. This is a great saving of time as it aids the operator in locating the cause of trouble and prevents useless inspection of parts not affected.

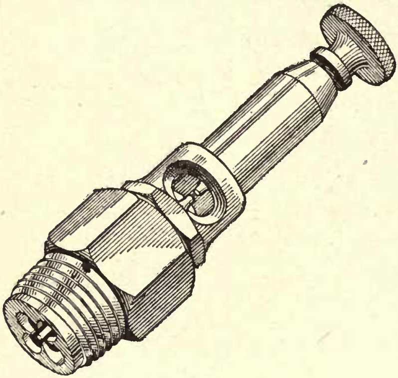

FIG. 46
The Fore-Sight Visible Spark Plug Showing Auxiliary Sparking Gap and Main Multi-Point Ignition Gap.

Road delays are annoying at all times and especially so in emergencies.

Begrimed hands, soiled clothing and a damaged temper could be averted if the driver knew the spark was right without wasting his time in its inspection. The Fore-Sight Visible Spark Plug, Figure 46, shows its condition instantly.

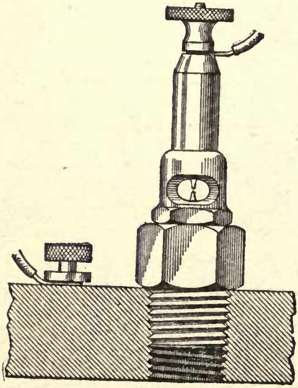

FIG. 47
Outside View of Fore-Sight Visible Spark Plug.

It is accurate, reliable, durable, and should be in use on every motor where time, safety and speed are required.

The Foresight Visible Spark Plug is constructed only of the very best material. Its parts are simple and accurately fitted by skilled mechanics. It is absolutely closed to dirt or water and works perfectly under conditions that would put the ordinary plug out of business. It will run longer without exhaustion than any other plug on the market. It never misses a spark and is instantly visible to the eye of the driver by simply raising the hood. See Figures 47 and 48.

Its sparking center is interchangeable and can be renewed at any time at the cost of a few cents.

Figure 49 shows our Multi-Point spark plug. It is turned to show the Multi-Point sparking gap.

It is made of the same fine material and good workmanship, and excepting the secondary spark is identical with the Fore-Sight.

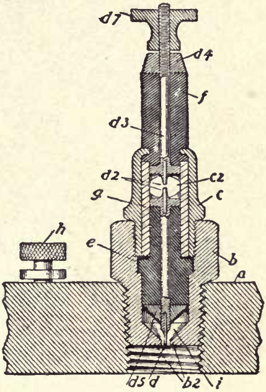

FIG. 48

Sectional View of Fore-Sight Visible Spark Plug

EXPLANATION

a—Cylinder Wall.
b—Hollow Plug. Engaged into wall *a*.
*h*2—Ignition points.
c—Tubular socket engaged into plug *b*.
*c*2—Sight opening to sparking gap.
d—Platinum point in ignition gap.
*d*2—Platinum point in auxiliary gap.
*d*3—Terminal member.
*d*4-5-6—Washers.
*d*7—Nut adjusting circuit wire to terminal.
e-*f*—Insulating bushings.
g—Glass or transparent mica tube.
h—Binding post connecting circuit wire.
i—Open space to prevent carbonization.

This Plug is far superior to any closed plug on the market.

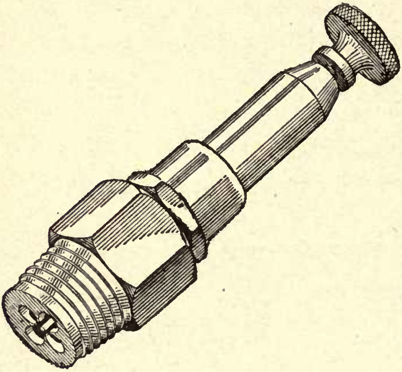

FIG. 49
Multi-Point Spark Plug Showing Multi-Point Sparking Points

It is of better material and workmanship.

It is fitted with a deeply milled set screw for circuit wire at top, easily turned with fingers, without pliers.

It is absolutely dirt and water proof and perfectly insulated.

Its platinum pins last longer than in any other plug.

Its Multi-Points absolutely guarantee a spark, a positive spark that will not stop until the driver wills it.

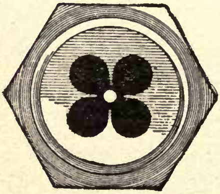

FIG. 50

It is safe, reliable economical, and costs no more than a single point plug that soon becomes foul and worthless.

Figure 50 shows an enlarged end view of the Ignition Gap of our Fore-Sight and Multi-Point spark plugs. Note the several spark points.

This very important feature merits the special attention of every owner and operator of a Motor. It is the heart of the vehicle and its life spark must be positive and constant.

A great percentage of road delays is caused by "heart failure." Most plugs in use are of single point ignition and, being easily fouled by corrosion, a short circuit and consequent stop is inevitable.

With our Multi-Point sparking gap, ignition is constant and sure. There is no corrosion of the platinum pin and the points being thin, the temperature rises just high enough to vaporate the oil, instead of forming obstructive carbon deposits.

The Multi-Point sparking center is interchangeable in the Fore-Sight Visible Spark and is the only interchangeable spark center that can be so cheaply renewed.

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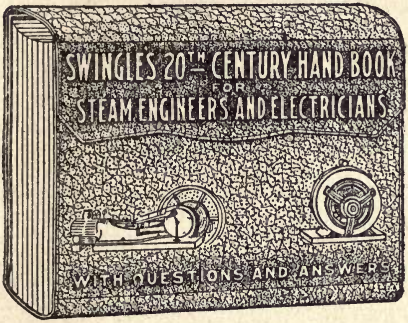

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