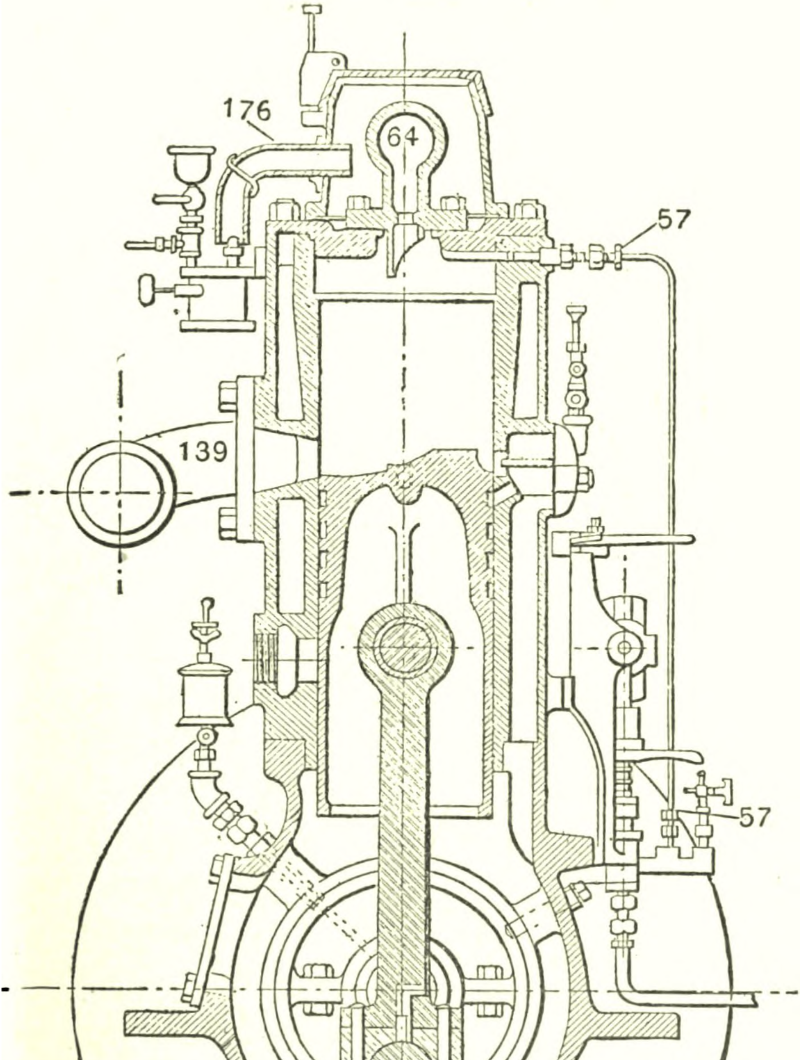

The marine motor

Frank Ward Sterling

THE MARINE MOTOR

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BY

FRANK W. STERLING

ILLUSTRATED

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CHAPTER I

FUEL

GASOLINE

IN the present day of gasoline shortage and in the light of much discussion of the possible use of kerosene as fuel in motor boat engines, the production of gasoline should be of more than passing interest. Because this is the best means of showing the kinship of these two fuels, this production is briefly described.

Production of Gasoline. By far the most important fuels for marine internal combustion engines are derived from petroleum. This important product is found in nearly every part of the globe. The United States and Russia produce most of the petroleum at present. In this country the fields of Pennsylvania, Ohio, Oklahoma, Texas, and California are the best producers.

Contrary to the popular idea, oil is not necessarily found in the vicinity of coal fields, but near salt deposits, the formation of salt and oil being apparently simultaneous. Although still open to dispute, it appears to be fairly well established that petroleum was formed by the decomposition of large masses of organic matter, probably of marine origin, and the subsequent spontaneous distillation of the hydrocarbons from such matter. Some few petroleums seem to be of vegetable origin.

One of the most interesting experiments in support of this organic theory of the origin of petroleum was conducted by Engler. He distilled menhaden (fish) oil between the temperatures of 320° C. at ten atmospheres pressure and 400° C. at four atmospheres pressure, resulting in sixty per cent. of distillate, having a specific gravity of 0.81. The residue contained some unsaponifiable (i.e., could not be converted into soap) fat. Breaking up of the distillate showed the presence of members of the hydrocarbon group from pentane to nonane, and finally, a lighting oil was separated which was indistinguishable from commercial kerosene.

As found in its natural state the composition of petroleum varies with the field of supply, but in every case consists of carbon and hydrogen with a small amount of oxygen and impurities. Its specific gravity (considering only those fields of commercial value) varies from 0.826 found in the Pennsylvania field to 0.956 found in the Baku region. A field in Kaduka, Russia, yields a crude oil with the low specific gravity of 0.65, and in Mexico an oil is obtained with the high specific gravity of 1.06.

Petroleum products are obtained by what is known as fractional distillation. The fractionation is conducted as follows:

The horizontal still shown in Fig. 1 may be charged with 600 barrels of petroleum. A fire is built on the grate and when the oil is sufficiently heated, shown by an even ebullition, superheated steam is introduced to the still, and distillation commences. A temperature of 130° C., to 200° C. is maintained in the still and all the kerosene and less volatile products are distilled off, passing to the deflegmator on the still head, Fig. 2. This acts as a separator, returning any oil which is mechanically carried over to the still, through the pipe *a*. From the deflegmator the distillate passes to a condenser.

As the process progresses, the temperature is raised to 250° C., to 300° C., and at this temperature the lubricating fractions are obtained. These temperatures vary with the petroleum being distilled and with the form of still used. The residue contains cylinder oil and greases. These three fractions are usually

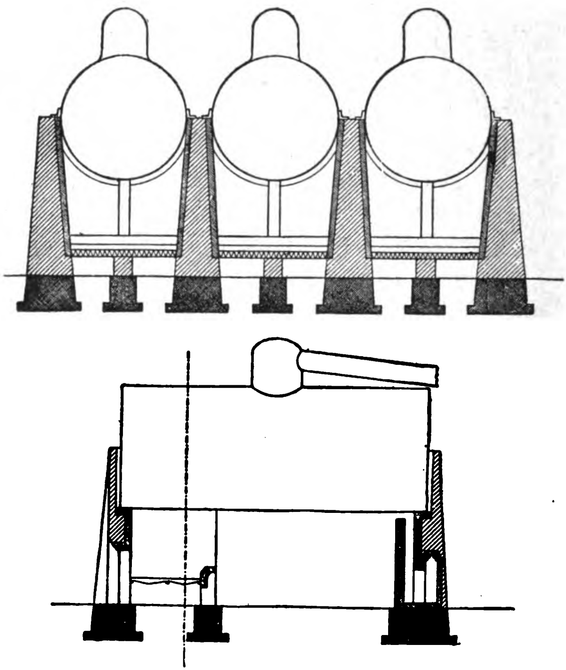

FIG. 1.— American Horizontal Cylindrical Still.

obtained at the first distillation. By the use of superheated steam the high temperatures necessary for distillation are obtained at a lower pressure than would be the case in simple distillation, and the steam carries the vapor away to the condenser as fast as it is generated, the injury to the products resulting from their remaining in contact with the highly heated surface of the still thus being prevented.

To obtain the commercial products a second

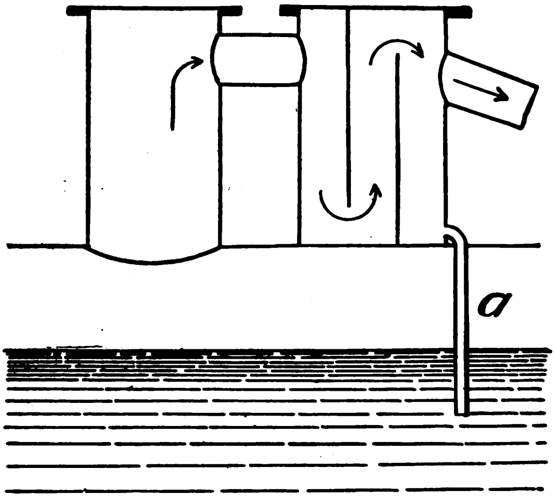

FIG. 2.— Deflegmator.

distillation of these fractions is necessary. Redistillation of the first fraction gives petroleum ether, gasoline, benzine, naphtha, and kerosene. Redistillation of the residue gives cylinder oil, vaseline, and residuum.

The products obtained are not in a market-able condition until mechanically treated to remove impurities. The water present is settled out. In the case of lubricating and heavier oils, steam coils in the settling tanks aid this settling process by temporarily reducing the viscosity (thickness) of the oil. After the water is removed, the distillate is treated with sulphuric acid followed by soda lye. The exact process of this treatment is not fully understood, but the action appears to consist of the removal or decomposition of the aromatic hydrocarbons, acids, phenols, tarry products, sulphur, etc., the acid removing some, while the caustic soda removes the remainder and neutralizes the acid left in the oil.

During the purification process the oil is agitated by a mechanical apparatus or by air blast to aid the chemical action. After settling in tanks the commercial products are ready for delivery. These remarks are of necessity very general as the processes vary in the different refineries. The principles, however, are the same in all cases. Instead of introducing superheated steam into the still, the still may be kept at a low pressure by the "vacuum process" of distillation. In this case the petroleum is distilled under a partial vacuum which is obtained by an ejector form of exhauster, or by designing the still with a long vertical exhaust pipe running downward from the still.

Temperatures at which the Fractions Distill. If the process were carried out in a laboratory to obtain the distillation temperatures of the different petroleum products the results would be somewhat as shown in the table below:

Temp. (Fahr.)	Distillate.		Per cent.	Specific gravity.*	Flash point.* (Fahr.)
113–140°	Petroleum ether		Trace.	.6	...
140–160	Gasoline	commercial gasoline	2	.65	10
160–250	Benzine, naphtha		10	.70	14
250–350	Kerosene, light..		10	.73	50
350	Kerosene, medium		35	.80	150
400	Kerosene, heavy		10	.89	270
482	Lubricating oil		10	.905	315
...	Cylinder oil		5	.915	360
...	Vaseline		2	.925	...
...	Residue		16	...	...
			100		

* Approximately mean values.

The nomenclature applied to the petroleum products throughout the world is so varied as to become confusing, benzine, naphtha, gasoline and kerosene being used indiscriminately. For simplicity we might divide those products used in the internal combustion engine as fuel into (1) commercial gasoline and (2) kerosene and the heavier petroleum distillates.

From the above it is plain that the dividing line between gasoline and kerosene is very indefinite and as far as the consumer is concerned becomes merely a matter of whimsical nomenclature on the part of the producer.

1. COMMERCIAL GASOLINE

All figures relative to the boiling point, specific gravity, composition, etc., must be comparative, for naturally the product varies with the field of production of the original crude oil. Approximately the range of distillation temperatures for commercial gasoline is 115° to 350°. At the lower temperature gasoline is distilled off, then, as the temperature is increased follow benzine, naphtha, and light kerosene in the order named. Commercial gasoline may contain any or all of these fractions. Its specific gravity varies from 0.65 to 0.75, depending upon the proportion of carbon and hydrogen in its composition and it weighs about 5.9 pounds per gallon.

The standard test for commercial gasoline is its specific gravity. Obviously, this criterion is erroneous as the ultimate value of gasoline as a fuel depends upon its volatility. For instance, a high-speed engine needs a light fuel, easily volatilized, while a heavy-duty, slow-speed motor can use a much heavier fuel. Were the entire supply of gasoline derived from one field, fractions obtained at the same temperatures would always have the same composition, and hence the same specific gravity. But, as the world's supply is obtained from many fields in which the compositions vary, it is possible to obtain two gasolines of widely differing specific gravities, which would distill at the same temperature and might be of equal value as fuels. The volatility of two gasolines being equal, the heavier is more efficient due to the presence of a higher percentage of carbon. This might appear paradoxical from the thermal view, but is based upon thermo-chemical considerations.

At present gasoline holds the internal combustion engine field as the most important of the petroleum products. To prepare gasoline for combustion it must be vaporized, and the ease with which this is accomplished gives it a decided advantage over all other liquid fuels. This fuel is vaporized or volatilized by passing air over or through the liquid, or by spraying the liquid into the air by force or suction. This process, called carburetion, will be treated in a later chapter.

2. KEROSENE

The next heavier distillate after gasoline is kerosene. This is given off at 350° F. to 400° F. and has a specific gravity ranging from 0.78 to 0.82. It is safer to handle and stow than gasoline, and being less volatile does not deteriorate so rapidly.

It is not so widely used as an internal combustion engine fuel as is gasoline, for at ordinary temperatures it does not form an explosive mixture with air, and to render it a suitable combustible requires a special treatment, such as introduction into a heated vaporizer, or spraying into a heated cylinder. This will be treated under carburetion. The introduction by one of the popular motor car makers of a carbureter which will handle either gasoline or kerosene may do much to bring it before the layman.

ACTION OF FUEL IN THE CYLINDER

Vaporization. Gasoline in its normal state, as a liquid, is very difficult to ignite and therefore must undergo a preliminary operation before it can be fired and develop power. This is called vaporization or more properly *carbure-*

tion and is treated at length in Chapter 4.

Carburetion consists of atomizing and vaporizing the gasoline and intimately mixing it with air. In this condition it is ready for use in the cylinder.

Compression. The mixture of vaporized gasoline and air that is drawn into the cylinder is at or below atmospheric pressure. At this pressure it will not readily ignite. It must be brought to the temperature of ignition. This is accomplished by *compression.* It is a well known fact that if a gas is compressed its temperature will rise. If an inflammable gas is compressed to a sufficiently high pressure (hence temperature) it will ignite spontaneously. Hence in the use of gasoline in an internal combustion engine there is a high limit to the compression allowed. The fuel is compressed to such a pressure that an electric spark shot through the mixture will readily ignite it. On the other hand, the pressure is kept below that at which the fuel would ignite spontaneously.

Ignition. After the fuel has been compressed in the cylinder to the proper pressure, an electric spark is shot through the mixture, the mixture is ignited and combustion takes place. This combustion is not instantaneous, as is assumed by many, but covers a very appreciable part of a stroke. As the gas burns it expands and forces the piston along its path. Thus is the power developed in the engine.

CHAPTER II

TYPES AND CYCLES

AN internal combustion engine, as the name implies, is one in which, in counterdistinction to the steam engine, combustion of the fuel takes place in the engine itself. A steam engine cannot run without a separate unit, the boiler, for the consumption of fuel and generation of steam, the medium of motive power. Hence in the gas engine vernacular it is called an *external combustion engine*. On the other hand, fuel is fed directly to the cylinder of an internal combustion engine, ignited therein, and the resulting explosion acting on the piston furnishes the motive power.

The internal combustion engine is commonly, though erroneously, called an explosion engine. The action which takes place, and which appears to be an explosion, is in reality a progressive combustion and subsequent expansion of the products of combustion. Some oil engines actually carry the combustion through a considerable part of the stroke. Although the expansion line of an indicator card is necessarily of interest to the manufacturer, the ratio of expansion presents no problem, for the internal combustion engine has no adjustable cut-off and therefore the ratio of expansion is fixed for a given engine by the clearance space and the space swept by the piston during its stroke.

The problem of expansion is replaced by questions of rate of combustion, rate of flame propagation, quantity and quality of fuel, and, most important of all, *compression.*

CYCLES

"A cycle in engineering is any operation or sequence of operations that leaves the conditions the same at the end that they were in the beginning." An internal combustion engine cycle consists of: (1) suction or admission of the charge; (2) compression; (3) ignition, combustion, and expansion; (4) exhaust. The number of strokes necessary to complete this cycle gives a means of cyclic classification as follows: (1) two-stroke cycle; (2) four-stroke cycle. The common terms for these are *two cycle* and *four cycle.* The latter is sometimes called the Beau de Rocha Cycle, or more commonly the Otto Cycle. The two cycle is sometimes called the Clerk Cycle.

A four cycle motor is one that requires four strokes of the piston (two revolutions of the engine) to complete all the actions that comprise one cycle in the cylinder.

A two cycle motor is one that requires two strokes of the piston (one revolution of the engine) to complete all the actions that comprise one cycle in the cylinder.

Four Cycle

Figs. 3 to 6, inclusive, illustrate the four strokes forming a complete cycle in a four cycle engine. The piston is shown near the finish of the stroke in each case.

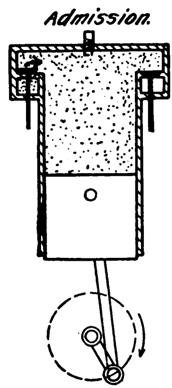

FIG. 3.

Admission. In Fig. 3 the piston has traveled one down stroke. During this stroke the admission valve is open and the vacuum formed by the down stroke of the piston has been filled by the inrush of a fresh charge of combustible mixture. This is called the suction or aspiration stroke. The admission valve closes at the end of this stroke.

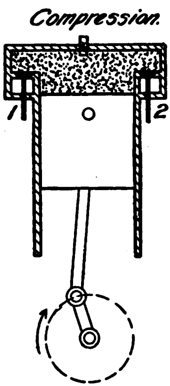

FIG. 4.
1. Admission Valve.
2. Exhaust Valve.

Compression, Fig. 4. During this up stroke both valves are closed and the charge is compressed into a small space at the cylinder end called the "clearance space." The necessity for compression will be shown later.

Ignition, Fig. 5. This third stroke is the power stroke and is variously known as the ignition, combustion, expansion, or explosion stroke. During this stroke both valves are closed. At the beginning of the stroke the charge is ignited and the subsequent expansion furnishes the motive impulse to the piston, driving it to the end of the stroke.

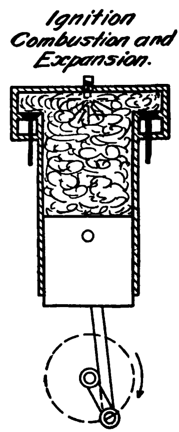

FIG. 5.

Exhaust, Fig. 6. The exhaust valve opens at or near the end of the expansion (ignition) stroke and the up travel of the piston on this fourth (exhaust) stroke forces the gases of combustion out of the cylinder completing the cycle.

As the engine receives only one impulse every four strokes means must be employed to drive the engine throughout the three ineffective strokes. A fly-wheel, which accomplishes this by its inertia, is installed on the main shaft. In the case of multicylinder engines the fly-wheel by its inertia balances the impulses and gives a steady speed.

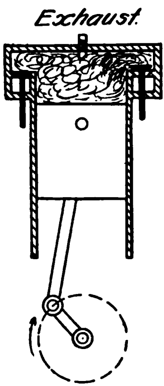

FIG. 6.

Two Cycle

The two cycle engine requires only two strokes or one revolution to complete the cycle. As seen from Fig. 7, the crank case is closed gas tight and a spring loaded admission valve opens to the crank case. Instead of admission and exhaust being regulated by valves, port openings in the cylinder sides are uncovered by the piston at proper points in the stroke and these openings communicate with the fuel supply and the exhaust passage. The piston functions as valves. The port *a*, Fig. 8, connects the crank case and cylinder around the piston, when at the bottom of its stroke. Deflecting plate *b* aids in scavenging the cylinder.

Two circles in the crank case, Fig. 7, illustrate the steps in the cycle. The inner circle indicates operations in the crank case and the outer circle indicates simultaneous periods in the cycle on the top of the piston. Starting from the position shown in Fig. 7, the charge is compressed in the top of the cylinder and has just been ignited. The crank case is full of a fresh charge that has just been drawn through the admission valve. The piston is driven down by the expansion.

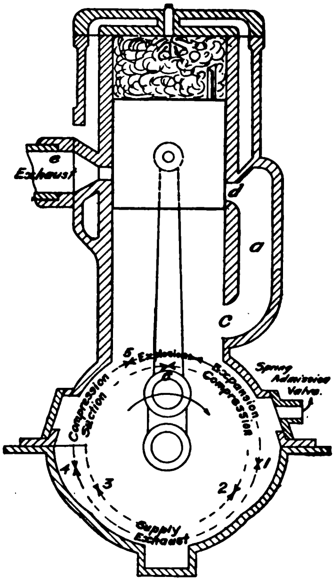

FIG. 7.

The port *d* being covered, the charge in the crank case is compressed on the down stroke. Expansion takes place in the cylinder to the point 1 and when this point is reached by the crank, the exhaust port is uncovered, relieving the pressure.

At the point 2, port *d* is opened allowing communication between the crank case and the cylinder. The compressed charge in the crank case rushes into the cylinder displacing the exhaust gases which escape through the exhaust port *e*, Fig. 8. On the return stroke when the point 3 is reached port *d* is covered by the piston and the up travel of the piston creates a vacuum in the crank case, opens the admission valve, and sucks a fresh charge into the crank case. At the point 4 the exhaust port is covered and from this point to point 5 the fresh charge on top of the piston is compressed. At point 5 ignition takes place, completing the cycle. At 6 the spring loaded admission valve to the crank case closes.

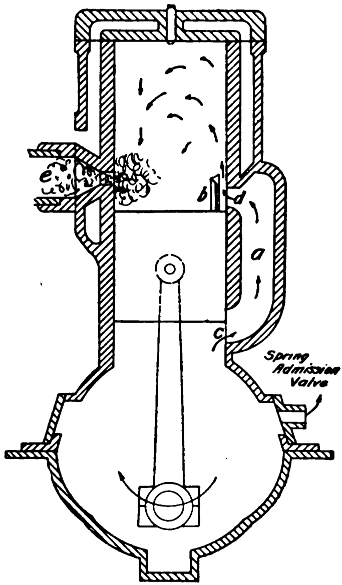

Fig. 8.

As the piston receives an impulse every other stroke, a fly-wheel is employed to drive the piston through the non-impulse stroke. The two cycle is sometimes called a valveless engine on account of the absence of valves.

Advantages and Disadvantages of the Different Cycles

Four Cycle. *Advantages.* Better explosion control; more economical; compression not dependent upon tightness of any parts except valves and piston rings; gas tightness of crank case immaterial.

Disadvantages. Cylinder volume and weight per unit of power greater; multiplicity of parts, especially of valves, valve gear, cams, countershafts, etc., with increased probability of breakdown; loss of power if any of the valves are not gas tight.

Two Cycle. *Advantages.* No valves, valve gear, cams, countershafts, etc., more uniform turning moment and lighter fly-wheel; smaller cylinder volume per unit of power; simplicity and compactness.

Disadvantages. Loss of fresh fuel with exhaust reduces the economy; crank case must be kept gas tight to prevent loss of fuel and compression; fresh fuel entering the cylinder full of hot exhaust gases may cause premature explosion, and if this occurs before the admission port is closed, the crank case charge may explode, causing considerable damage to the engine.

The four cycle engine seems to lose in simplicity by comparison with the two cycle, but it is in far more common use, due to its almost universal use in the automobile.

Although the two cycle engine receives twice as many impulses per revolution as the four cycle, it must not be concluded from this that, for the same cylinder dimensions, the two cycle will develop twice the power. In the four cycle type the impulse due to expansion is carried throughout nearly the entire stroke, whereas, in the two cycle type, the exhaust valve opens much earlier and the impulse only lasts about ⅝ of the stroke, as can be seen from Fig. 7.

COMPRESSION

When a fuel, such as gas, is admitted to the cylinder of an engine, a certain quantity of air is admitted at the same time to furnish the necessary oxygen for combustion. Before combustion this "*mixture,*" as it is called, is *compressed* into a small space (called the "clearance space"). This compression serves to mix the particles of air and fuel more intimately and to raise the temperature of the mixture. The resultant compressed mixture will ignite with more certainty, and will burn more easily than a rarer and colder mixture.

Compression, which immediately precedes ignition, is one of the greatest factors in internal combustion engine efficiency. With a given amount of fuel to be burned if this fuel were not compressed, the cylinder volume would necessarily be increased by the ratio of expansion and would be enormous were the engine non-compression. This was recognized by the inventors of the first efficient gas engine as the underlying principle of success. Thus it is apparent that compression is absolutely necessary. By compressing the mixture into a small space the atoms of the fuel are more intimately mixed with the air present, thus aiding combustion, and they are brought more closely together, thus accelerating flame propagation. Compression heats the mixture, thus aiding ignition and increasing the initial temperature; it also greatly increases the mixture's power of expansion.

By increasing the compression the necessary clearance or compression space is reduced. This reduces the cylinder wall area of radiation and water jacket length and as a direct result the loss of heat by radiation is diminished.

Reducing the clearance space is the equivalent of increasing the stroke. If the compression is too low the fuel may not all burn, due to poor flame propagation, and some gases will not ignite at all unless compressed to a certain pressure.

There is a practical limit to the degree of compression that may be attained. This depends upon the ignition temperature of the fuel. As stated above, compression increases the temperature and, if this is carried too far, premature ignition will result. The following limits of compression in pounds are given by Lücke: carbureted gasoline, high-speed engines, 45-95; carbureted gasoline, slow-speed, well cooled engines, 60-85; kerosene, vaporized, 45-85.

The average small motor is designed to compress the charge to about 60 pounds per square inch under normal conditions.

TYPES

The internal combustion engine is commonly called by a variety of names, none of which are technically correct for all types, for example, *gas engine, explosion engine, heat engine,* etc.

A very common and unscientific method of classifying internal combustion engines depends upon the fuel consumed, thus, gas engine, gasoline engine, oil engine, alcohol engine, alco-vapor engine, etc. This is a common commercial practice.

Two general subdivisions may be made, viz.: (1) single acting engines; (2) double acting engines.

A single acting engine is one which receives the motive impulse on only one side of the piston.

A double acting engine is one which receives a motive impulse on both sides of the piston.

All small high-speed engines are single acting, and, with a few exceptions, only the large, low-speed, heavy-duty motors are made double acting. For the motor boat we are not concerned with the latter type and will assume that all motors that one may be called upon to operate are single acting.

Considered from the motor boat point of view a cyclic classification is most convenient. The engine can be classified as two cycle or four cycle. A lengthy discussion of the relative merits of the two types is unnecessary to the issue at hand — namely, a working knowledge of the typical motor. However, a few words are appropriate at this point.

For large power plants, such as those installed in racing boats, the four cycle engine is almost invariably used. For smaller plants, from one to twenty or twenty-five horse power, the two cycle motor is favored. The reason is obvious; in small units the two cycle motor is fairly economical and very reliable. Its lack of valves and general simplicity appeals strongly to one of limited experience who expects to be his own engineer. The larger plants, such as are found in racing boats, are generally operated by one who has sufficient engineering knowledge so that the multiplicity of parts of a four cycle motor does not confuse. With larger power, hence larger fuel consumption, fuel economy becomes a factor that can not be overlooked. The four cycle motor has the more economical fuel consumption.

The Number of Cylinders is a matter of choice and of design and depends upon the power plant. For small plants single cylinder engines are built from a fraction of a horse power to ten or twelve horse power. These engines are almost invariably two cycle. However, the better practice at ten or more horse power is to use two or more cylinders. Thus, two ten horse power cylinders is a better two cycle design than one twenty horse power cylinder. Three 6⅔ horse power cylinders is better still.

Four cycle plants of over twenty horse power are multicylinder. The power is divided among

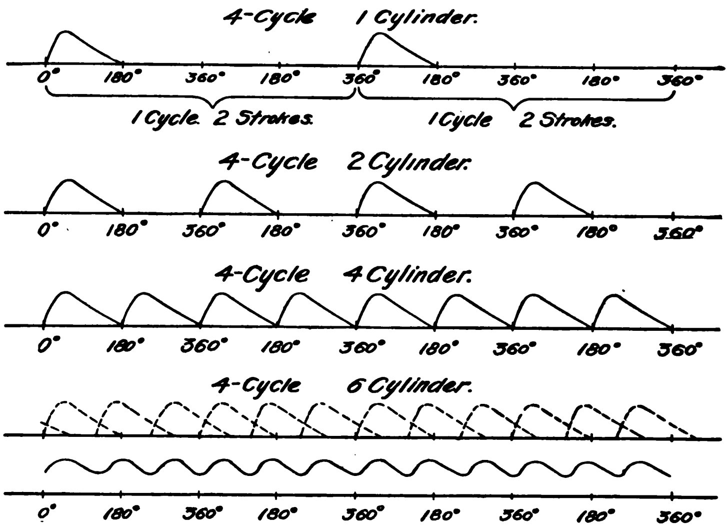

FIG. 9.—Pressure Diagrams Showing the Effect of Multiplying Cylinders.

four or more cylinders as a rule. As stated above, four cycle engines give the better fuel economy, and, although this is of minor importance in very small engines, it becomes a paramount issue with large units.

The diagrams in Fig. 9 show the effect of multiplying the cylinders of an engine. These diagrams are constructed by superposing the indicator cards of each cylinder along a horizontal line of zero pressure. The cards are superposed in their appropriate phase of two successive cycles. The upper line, which represents a one cylinder engine, shows pressure acting through 360° of the crank motion; 1080° of the crank motion is idle or non-effective. As the cylinders are multiplied the useful work area increases and the idle area is decreased until, when the number of cylinders has reached six, the individual cylinder cards overlap and pressure on the crank is continuous.

Long and Short Stroke Motors. The proportion of cylinder diameter ("bore") to stroke is a problem that has caused more discussion and resulted in less uniformity of opinion than any other subject in the internal combustion engine field. Although no distinct line is drawn, a motor that has a stroke exceeding 1½ times the bore is generally spoken of as a "long stroke" motor, and any having a smaller ratio, as a "short stroke" motor. As the advocates of both types lay claim to every conceivable advantage, the subject will not be discussed here other than to say that increasing the stroke increases the expansion and also the loss by radiation due to the longer contact of the gases each stroke with the cylinder walls. It increases the piston speed; and reducing the bore to maintain the same power, it increases the ratio of cylinder wall to cylinder contents, hence increases loss by radiation.

The duty for which the motor is designed, the necessary piston speed, power, weight allowed, and initial compression, must regulate the bore and stroke to a large extent.

Scavenging. Scavenging a cylinder consists of driving out the burnt gases before, or simultaneous with, the entrance of a new charge. This is very imperfect with an ordinary four cycle motor, for, at the instant of admission, *all* the clearance volume is full of burnt gases. Those engines which receive the air and fuel separately can be scavenged thoroughly by admitting the air while the exhaust port is still open and driving out the exhaust gases by this air before the fuel valve opens.

Two cycle engines require thorough scavenging. A study of the cycle shows that upon this depends the volume of fresh mixture that can be taken into the cylinder, and as the two cycle exhausts just past the center of the expansion stroke, instead of at the end as in the four cycle, scavenging is of more importance in the former case. This is generally accomplished by allowing some of the fresh charge to enter while the exhaust port is still open. A proper design of exhaust will aid scavenging by giving the exhaust gases a high speed, causing a tendency toward a partial vacuum in the exhaust line.

CHAPTER III

CONSTRUCTIONAL DETAILS

THE subject of internal combustion engine construction will have to be treated in a very general manner because of the variety of forms of all the parts found in different types. Naturally the design of engine depends upon the service it is intended to perform; thus, the aeroplane engine has been constructed to weigh as little as two pounds per horse power, whereas engines for marine use weigh from 45 to 60 pounds per horse power. With the many types existing it is possible to give only a few general forms of parts.

Cylinder. Cylinders may be cast singly or *en bloc*, that is, in a multicylinder engine each cylinder may be cast as a separate unit, or two or more may be cast in one piece. They are generally classified as: (1) water cooled and (2) air cooled, depending upon the system adopted to prevent overheating of the cylinder. Only water cooled engines are used in motor boats. Fig. 10 shows a water cooled cylinder with the annular space in which water is circulated. Fig. 11 shows an air cooled cylinder. The ribs cast on the outside of this cylinder increase the radiating surface of the cylinder and

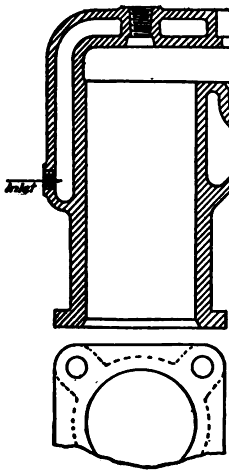

FIG. 10.— Water Cooled, Four Cycle Cylinder.

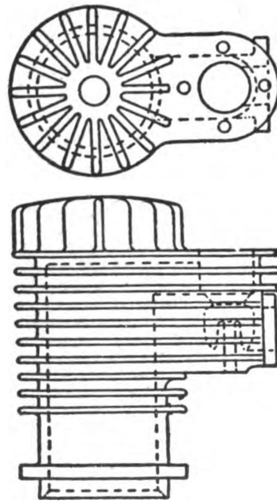

FIG. 11.— Air Cooled, Four Cycle Cylinder.

thus serve the same purpose as the circulating water in the other type.

It should be noted that the annular space and the ribs do not extend the full length of the cylinder, but only cover the upper part. They only extend a little below the compression space which is the hottest part of the cylinder. Fig.

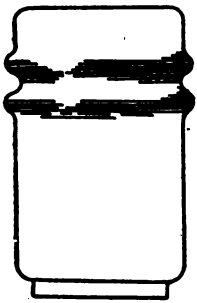

Fig. 12.—Copper Jacketed Cylinder.

12 shows a water cooled cylinder with a copper water jacket fastened and caulked to the cylinder. The corrugations shown allow for the unequal expansion of the copper of the jacket, and, the iron of which the cylinder is cast. This construction is the more expensive of the two and is only used in automobile and aeroplane engines. Fig. 13 illustrates a pair of cylinders cast *en bloc.*

Cylinders are made of close grained, gray cast iron, hardness being the essential requisite. The previous four illustrations portray the four cycle type engine; Fig. 14 shows a general type two cycle cylinder without valves; the piston passing over the port openings acts as a valve. The cylinder is counter bored at the end of the stroke. This prevents the

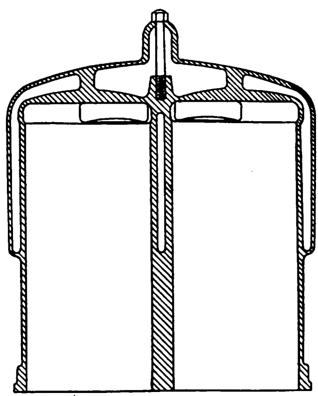

Fig. 13.—Pair of Cylinders Cast *en bloc.*

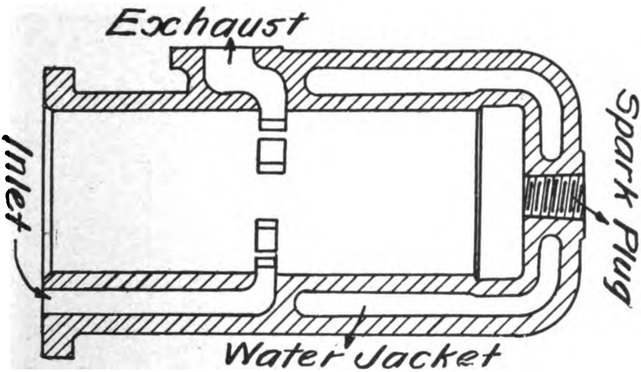

FIG. 14.— Two Cycle Water Cooled Cylinder.

ring from forming a collar at each end of its travel.

Piston. The majority of internal combustion engines are single acting, receiving the impulse on only one end of the piston. The impulse is much more sudden than in the case of a steam engine, and if the piston were constructed disc shape, as in the steam engine, there would be a tendency to cant or dish on explosion stroke. For this reason, and for the purpose of aiding packing, cooling, and guiding generally, the piston is made long and hollow, the length for a good four cycle, high-speed design being about 1½ times the diameter. In this type the length precludes the necessity for connecting rod and guides.

The piston tapers, the explosion end being slightly smaller, say .001 of the diameter, than the opposite end. The reason for this is that

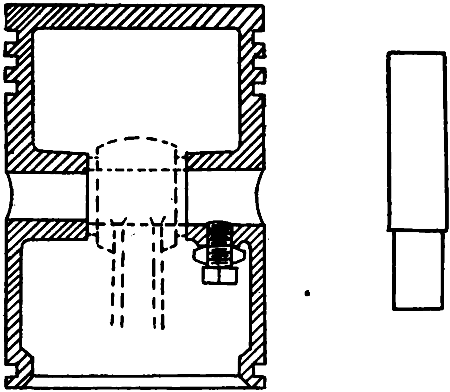

FIG. 15.— Piston, Showing Method of Securing Connecting Rod.

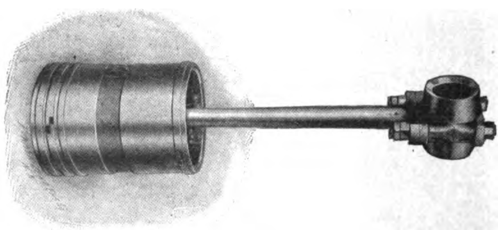

FIG. 16.— Piston with Rings, Connecting Rod and Bearings Assembled.

the explosion end, being in contact with the hot gases, when running, will expand more than the other end. It is fitted with eccentric rings, usually four, which spring into grooves shown in Fig. 15, the lowest ring acting as an oil ring. Fig. 16 shows the piston with rings, connecting rod, and bearings, all assembled.

Figs. 17 and 18 are two types of piston heads for two cycle engines. The dished head, Fig. 17, and the web cast on top of the piston, Fig. 18, serve to deflect the incoming gases, and thus

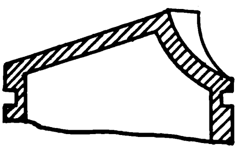

FIG. 17.

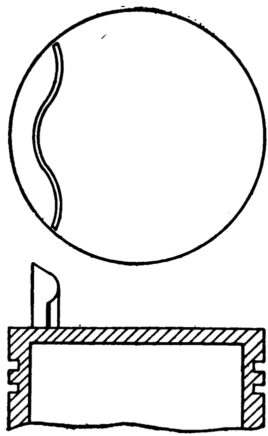

FIG. 18.
Two Cycle Piston Heads.

aid in the work of scavenging the cylinders.

Connecting Rod and Wrist Pin. In all marine engines the piston rod is absent, the piston motion being communicated to the crank by the "connecting rod." At the piston end the rod is connected to the "wrist pin." There are two ways of forming this bearing; first — the one most commonly used — the wrist pin is locked fast to the piston, the rod working on it; and second, the rod is locked fast to the wrist pin and the pin works in the piston as a bearing. Fig. 15 illustrates the first method, a set screw and lock nut being shown in place. Rods are forged or drop forged steel, of I section.

Valves. The most common and best developed at present is the disc, poppet valve shown in Fig. 19. Drop forged valves answer the purpose for all but the heaviest engines, which require valves cast in one piece. The best material must be used in valves, especially the exhaust, as they are subject to the intense heat of explosion, and the exhaust valves receive the full corrosive effect of fast moving, hot exhaust. The smaller valves have a slot in the head to fit a screw driver or tool for regrinding to the seat.

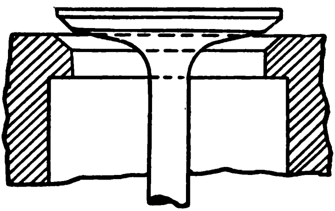

FIG. 19.— Conical Disc, Poppet Valve.

The requirements for an effective valve are: (1) It must be gas tight without excessive friction; (2) the opening and closure must be instantaneous; (3) it must be accessible for cleaning, grinding, etc.; (4) the gases must not be wire drawn (i.e., made to act with increased speed and reduced pressure due to restriction of the opening). The exhaust valve is generally actuated by cam gear situated on a countershaft that is geared to the main shaft. This is also the better method for actuating the admission valve, although some engines are fitted with spring loaded admission valves that lift automatically on the suction stroke. In some designs a rod and rocking lever actuated by a cam open alternately both admission and exhaust valves of the same cylinders. The Curtiss engine is of this type.

There are a variety of novel valves, such as rotating valves, that have not received general recognition. The Knight motor has two reciprocating sleeves between the piston and the cylinder. These sleeves contain openings that cover and uncover the port openings at the proper points of the cycle and thus act alternately as admission and exhaust valve. The larger exhaust valves are hollow to permit circulation of water for cooling the valve.

Push Rods. Interposed between the valve stem and the cam on the countershaft is a push rod, Fig. 20. As seen in Fig. 21 these push rods are carried in guides that fasten to the engine base. On the lower end is a hard steel roller that bears on a cam giving a minimum friction. In the latest practice for high speed engines the top of the push rod has an adjustable screw that bears on the valve stem so that wear on the end of the rod can be compensated; this tends toward quiet running, and aids valve timing.

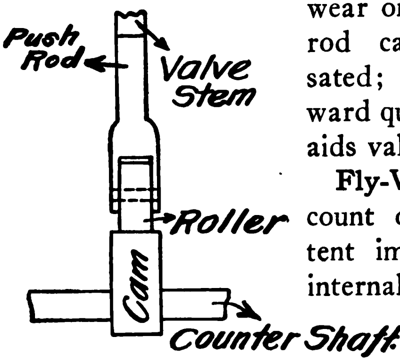

Fig. 20.— Push Rod.

Fly-Wheel. On account of the intermittent impulse given an internal combustion engine shaft, all engines having six or less *working* cylinders require a fly-wheel. By its inertia it tends to give a uniform rotation to the shaft in spite of the non-uniform crank effort. Obviously, the relative size of the fly-wheel required increases with the decrease in the number of working cylinders. The same features govern fly-wheel design whether for internal combustion or other engines, except that more care must be taken in the balance of those used in this particular field.

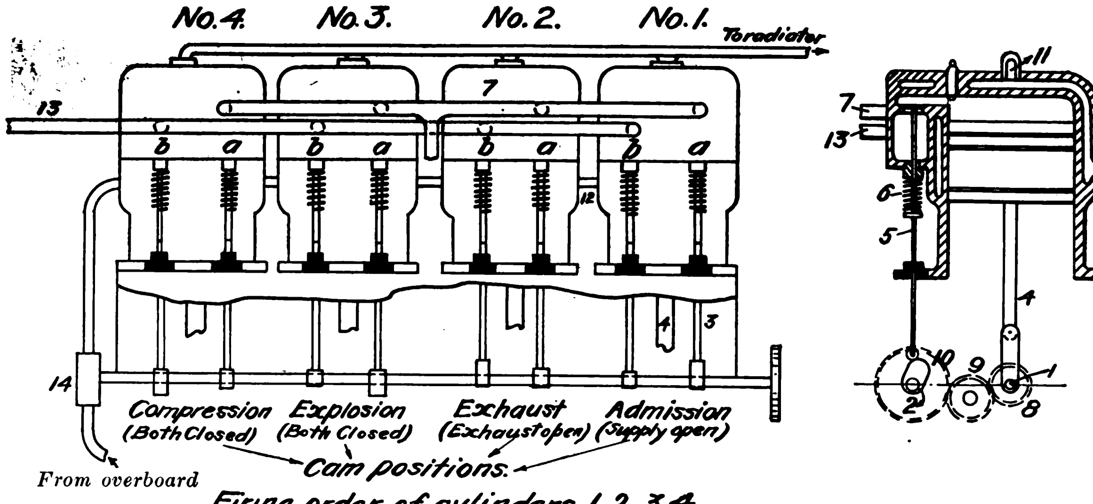

FIG. 21.— Schematic Plan of Four Cylinder, Four Cycle, Gasoline Motor, Showing Fuel and Cooling Systems

1. Main Shaft.
2. Countershaft.
3. Pushrod.
4. Connecting Rod.
5. Valve Stem.
6. Valve Spring.
7. Manifold (Admission).
8. Gear on Crank Shaft.
9. Idle Pinion.
10. Gear on Countershaft.
11. Cooling Water Outlet.
12. Cooling Water Inlet.
13. Exhaust.
14. Circulating Pump.

CHAPTER IV

FUEL SYSTEM, CARBURETION, ETC.

THE FUEL SYSTEM consists of a fuel tank, or source of supply, a strainer for liquid fuel, a carbureter, atomizer, or other agent for converting the fuel to a combustible vapor, and the exhaust, which generally terminates in a muffler. In the case of liquid fuel such as kerosene and gasoline, it is necessary to volatilize them and mix with air before they can be ignited in the cylinder. Fig. 22 illustrates an ordinary gasoline supply system.

The Fuel Tank is generally made of light galvanized iron or copper. It should be of ample capacity, its opening well protected from weather and sea. It must always be borne in mind that a very few drops of water in the system will cause much trouble at the engine. The fuel should always be strained into the tank through chamois or very fine wire mesh to rid it of water and dirt. The tank should be reinforced at all openings and fitted with swash plates if over thirty gallons capacity.

Gasoline Piping is made of copper, seamless drawn. It is connected to the tank at the lowest point thereof. All joints in piping are ground to fit. Care must be exercised against damage and vigilance against leaks. The practice of

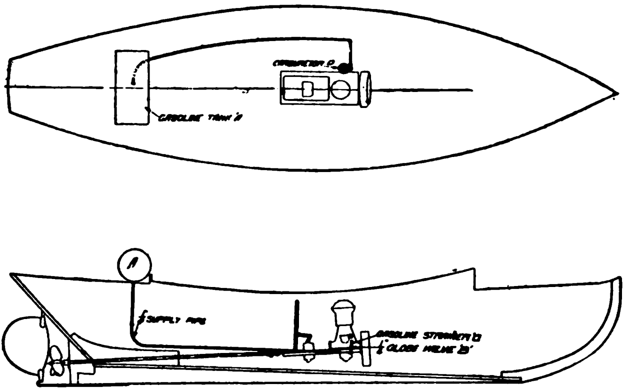

Fig. 22.— Fuel System.

The gasoline tank "A" is always placed so that its botton is above the level of the carbureter "D." The gasoline passes by gravity through the ¼ inch supply pipe, then through a globe valve "B" to the strainer "C," which is always placed next to the carbureter "D." The function of the strainer "C" is to collect all water and sediment that might get into the gasoline, and prevent it getting into carbureter "D." The strainer "C" should be cleaned frequently to prevent clogging. Globe valve "B" should be kept closed when the engine is not in use.

frequently bending the piping to disconnect or remove it is severely condemned. Copper pipe should always be filled with powdered resin or sand before bending it or there will be danger of its kinking and developing leaks. It must be borne in mind that this piping is very frail.

It will clog with dirt very easily and should not be less than ¼ inch in diameter.

A Strainer is inserted in the gasoline pipe line. It is a small receptacle of brass or copper, holding a metal gauze basket through which the gasoline passes on its way to the carbureter. The mesh of this gauze is so fine that, although

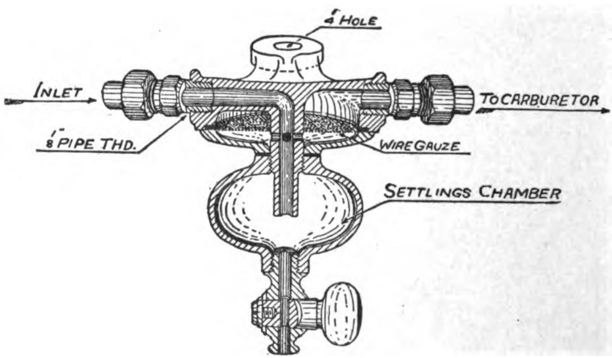

FIG. 22 a.— Cross-section View of Schebler Strainer.

gasoline will pass freely through, water or foreign matter will be retained. The gauze basket is removable for cleaning. Fig. 22a illustrates one type of strainer.

The Carbureter or Mixing Valve is described later under *Carburetion.*

The Manifold. If the engine has more than one cylinder a manifold leads from the carbureter to the various cylinders. This is generally of brass pipe. [See Fig. 21, (7).]

The Muffler. For quiet operation the muffler is an essential part of the exhaust system. Exhausting into the atmosphere at the normal exhaust pressure causes a sharp, disagreeable noise. This is so annoying that many municipalities have passed ordinances requiring that all internal combustion engines be fitted with mufflers.

A muffler is merely an enlargement near the end of the exhaust line to allow a gradual expansion of the exhaust gases to the atmospheric pressure. Although there are a variety of forms, the principle is the same in all. Cast iron is generally used in construction as this best resists the corrosive effect of the hot gases. Some mufflers are fitted with baffles, as in the ejector muffler, and in this case care must be taken in the design to prevent a back pressure in the exhaust as this will reduce the power. A properly designed muffler will reduce the pressure at the muffler exit without reducing the speed of the exhaust from the engine to the muffler. As long as this speed is maintained no back pressure will result. Water spray is often injected into the muffler to help condense the gases.

The Gaspipe Muffler, Fig. 23, consists of two pipes, one within the other, the inner pipe being perforated by a large number of small holes. The exhaust enters from the left and passes through the holes in the inner pipe to the

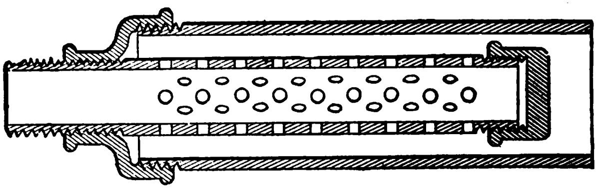

FIG. 23.— Gas Pipe Muffler.

outer *larger* pipe. This expansion and breaking up of the flow of gases reduces the exhaust pressure which causes the distressing noise. The gases exhaust to the atmosphere, at the right in Fig. 23, greatly reduced in pressure.

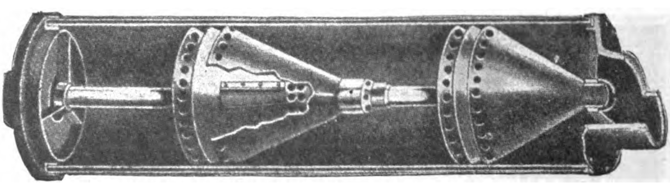

Fig. 23 a.— Ejector Muffler.

The Ejector Muffler, Fig. 23a, is designed, as its name implies, on the principle of an ejector. It consists of three expansion chambers which are formed by conical baffle plates, perforated top and bottom, arranged in two sets. The axial tube, leading through the muffler, is of varying diameter and a part of the gases entering the muffler pass directly into the center chamber and through the second set of cones before the gas which has entered the first chamber has passed through the first set. A portion of the gas is conducted straight through the center pipe to the nozzle at a high velocity which creates a partial vacuum in the third chamber.

The rapid forward movement of the gas

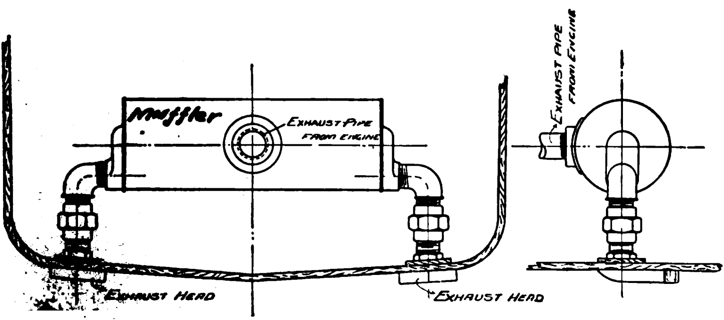

Fig. 24.— Underwater Exhaust.

through the first and second chambers to the third, causes a sudden expansion, removing the heat from the gas and reducing the pressure in the muffler to below that of the atmosphere. This allows the gas to escape without noise and without back pressure. Water may be used in this type and it is very suitable for marine use.

Underwater Exhaust. Fig. 24 illustrates a common form of exhaust below the water line. In this case there are two outlets from the muffler. This form is a little more expensive than that with one outlet, but it is used considerably with the ejector muffler.

CARBURETERS AND CARBURETION

Carburetion is the process of saturating air or gas with a hydrocarbon.

The air or gas that is carbureted is called the *medium.*

The *Carburizer* is the agent (fuel) employed to saturate the air.

A *Carbureter* is an apparatus used to charge air or gas with a volatilized hydrocarbon.

"*The Mixture*" is the term commonly employed in the gas engine field to designate the product of the carbureter when ready for combustion, viz.: the combination of fuel and air.

A "*Rich*" Mixture is one having an excess of fuel, and a "*lean*" mixture is one having an excess of air.

A "*Charge*" is a cylinder full of mixture.

Every fuel requires a certain amount of oxygen for complete oxidation or combustion. This can be supplied by the atmosphere if suitable means are at hand to mix the air and fuel. The various fuels contain different portions of carbon, hydrogen, and other combustibles, therefore will require proportionate amounts of air to attain complete combustion. Excessive air will cool the mixture, greatly reduce the rate of flame propagation, and weaken the ignition if it does not actually prevent it. Its increased volume causes increased loss of heat in the exhaust gases. Too little air will result in incomplete combustion, reducing the efficiency and causing a carbon deposit in the cylinders, etc.

The function of a carbureter or of the mixing valve is to admix the fuel and air to the correct richness, forming a combustible gas or vapor. The rapid advance in the development of the modern internal combustion engine is due in large part to the perfection of satisfactory apparatus to carburet air. Successful working of such an engine is dependent upon the reliability, certainty, and satisfactory working of the carbureting device.

Carburetion of Gasoline may be carried on by three distinct methods, the first two of which have practically fallen into disuse.

a. Surface Carburetion. This, the first method used, consisted of evaporating the liquid hydrocarbon by passing a current of air over the surface of the liquid. The air thus becomes saturated by evaporation from the free surface of the liquid. The method has become obsolete. A uniform mixture could not be obtained.

b. Mechanical Ebullition. By introducing a current of air below the surface of gasoline and allowing it to bubble to the surface a certain amount of the liquid is entrained as mist with the air. This method was abandoned also for practically the same reasons as the former.

c. Spray Carburetion. This is the only practical method now employed to convert gasoline into a combustible vapor. Each suction stroke of the piston creates a vacuum in the cylinder, which vacuum sucks the air into the cylinder through the mixing chamber of the carbureter. This air is at a pressure below the atmosphere. The mixing chamber communicates with the gasoline chamber of the carbureter by a fine nozzle or needle valve. As the air passes over this nozzle a spray of gasoline is sucked through it into the passing air which it saturates. This is made more clear by a study of the carbureter itself.

A good carbureter or mixing valve must fulfill the following requirements: It must be adjustable so that the correct proportion of fuel and air is obtained; this proportion must be maintained at varying speeds; if possible, the location of the spraying nozzle should be near the middle of the air passage; and the apparatus must be simple and compact.

The distinction between a mixing valve and a carbureter will be seen from a description of each. In both cases fuel is drawn through a nozzle into the air which is being sucked into the cylinder. A mixing valve has its nozzle below the source of fuel supply and this nozzle is opened and closed by a valve which is lifted at each aspiration stroke of the piston. A carbureter has its nozzle just above the gasoline level in the gasoline chamber of the carbureter and the fuel is sucked through the nozzle by the air on each aspiration stroke. In either case the flow of gasoline vapor stops when the engine is stopped. A standard type of each is described in this chapter. The writer recommends the use of the carbureter in preference to the mixing valve.

The Carbureter

The Schebler Carbureter, Model D. The Schebler Carbureter is made in a variety of models to suit different requirements. Model D is the standard carbureter and is used for low and medium powers. It is simple, light, and compact. All parts are made of brass. No provision is made for waterjacketing. Fig. 25 illustrates Model D.

Gasoline from the tank enters at G and passes through the float valve H to the gasoline

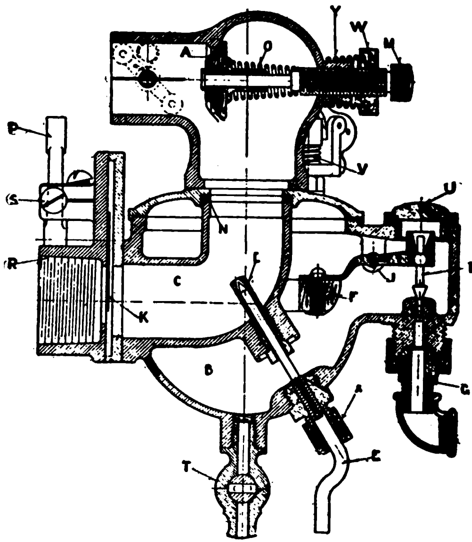

Fig. 25.— Schebler Carbureter, Model D.

or float chamber B. A connects to the atmosphere and R connects to the engine. When running, the engine suction at R draws air in at A, and as this air rushes past the spraying nozzle D, gasoline is drawn from B through D and carburets the air which passes through R to the engine. The amount of opening at D is regulated by the needle valve E. The gasoline in B is maintained at a constant level by the float F as follows: As the gasoline in B is drawn through D and the level in B falls, the float F falls with the gasoline level. This float, through a toggle hinged at J opens the float valve H admitting gasoline to B. As the gasoline level in B rises it lifts the float F until the valve H is closed. This operation is continuous.

The amount of entering air is regulated by the air valve A. When the motor is running at its minimum speed, the air is drawn through an aperture of fixed dimensions. As the speed is increased and consequently the flow of gasoline becomes greater, more air is required, and this additional supply is furnished by the compensating air valve which opens more and more as the speed of the engine increases. The compensating air valve, when once adjusted, admits a regular supply of air in accordance with the speed of the engine.

The amount of air valve lift is regulated by the air valve adjusting screw M. The lock nut W and lock spring Y prevent the screw M from jarring out of adjustment.

The quantity of mixture admitted to the engine is regulated by the throttle disc K which is operated by the lever P. This regulates the engine speed.

The butterfly disc, shown dotted in the air intake, is used when starting. It is habitually open when running. When cranking pull the butterfly disc closed. This causes the mixture to be very rich (cutting off most of the air) and the motor will start easily.

The joint between the carbureter and gasoline piping is made by a ground joint and reversible union so that this joint can be broken without disturbing the carbureter or piping. The joint N is made air tight by a cork gasket.

The Schebler Carbureter, Model L, Figs. 26 and 26a. This, one of the most popular and efficient of the high-speed carbureters, is an automobile type carbureter and is used for high powered motor boat engines. The opening marked "gasoline supply" is connected to the gasoline tank by piping. Gasoline enters here and goes to the annular gasoline chamber. It is maintained at a constant level in this chamber by means of a cork float and a float valve connected to this float. The connection is pivoted so that the valve will rise as the float falls. As the gasoline level drops the cork float on its surface drops and this opens the float valve, allowing gasoline to enter. When the gasoline rises to the proper level the float closes the valve.

The upper end of the carbureter, which contains the throttle disc, is connected to the admission pipe of the engine. On each suction stroke air is sucked through the air passage into the mixing chamber. In its course it passes around the spray nozzle. This nozzle passes through the air passage wall and communicates with the gasoline chamber. Each suction stroke, gasoline is sucked through the spray nozzle and mixes with the air in the mixing chamber. The opening of this spray nozzle can be regulated by a needle valve, Fig. 26a. The carbureter is designed so that the air passage will supply enough air at low speeds. As the speed is increased above this, it is evident that more fuel is sucked through the needle valve and hence more air must be supplied per stroke for combustion.

The leather air valve shown on the right, Fig. 26, compensates for this as follows: At low speeds the valve is kept on its seat by the spring. As the suction increases it overcomes the tension of this spring and the valve will lift each aspiration stroke an amount dependent upon the speed. The throttle disc acts as an ordinary throttle, but attachments on the throttle shaft further regulate the fuel supply for the speed. As the disc is opened and more air is drawn through the air passage, it becomes

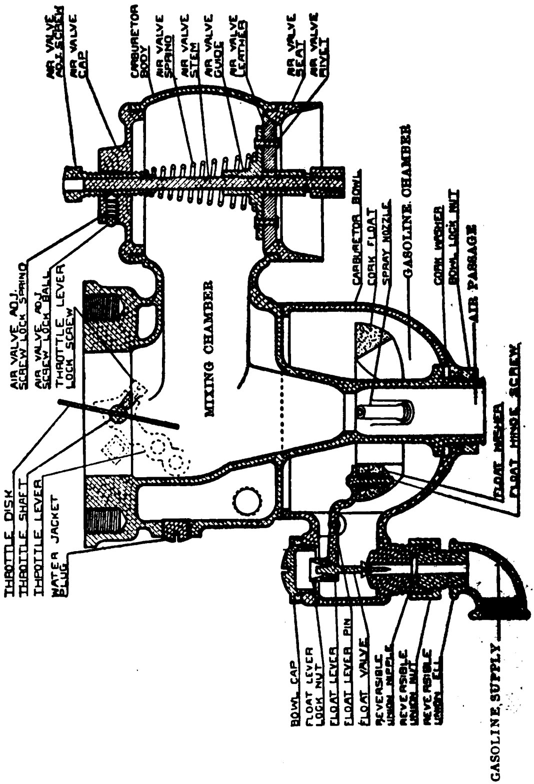

FIG. 26.—Schebler Carbureter.

necessary to provide a larger fuel valve opening to supply the increased demand for fuel. This is accomplished as follows: As the throttle disc is opened the cam on the adjusting cam casting is rotated and bearing on the needle valve roller opens or shuts the needle valve simultaneous with the throttle. The needle valve roller moves the needle valve lever and the

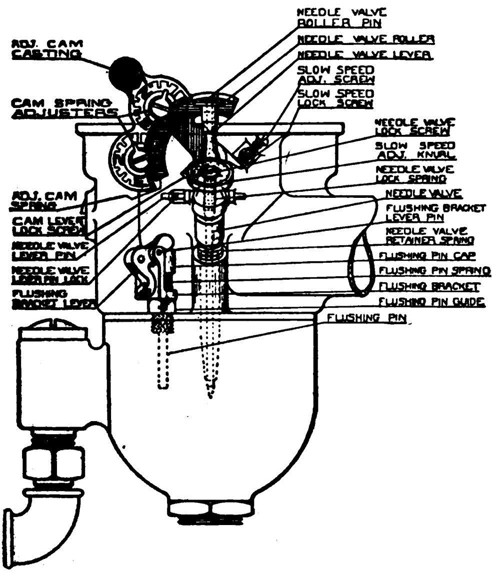

FIG. 26 a.

needle valve about the needle valve lever pin, thus opening and closing the needle valve, Fig. 26a. The cam spring adjusters are used to adjust the cam on the adjusting cam casting so that the needle valve roller pin, and consequently the needle valve, will be opened the proper amount at all speeds. The adjustments are too complicated for a novice to handle. A drain cock, not shown, is generally placed on the bottom of the bowl to drain the gasoline chamber. This prevents the accumulation of water and dirt in the carbureter.

All metal parts are of brass. The end of the spray nozzle is in the center of the column of entering air. This is a point that is overlooked in many otherwise good designs, and tends to maintain a uniform quality mixture for all positions of the carbureter and is of importance in marine practice as well as in motor vehicles.

The heated exhaust water from the cylinder water jacket is led around the mixing chamber of this carbureter to preheat the mixture.

Mixing Valves

The Lunkenheimer Mixing Valve, Fig. 27. Air entrance is effected at 1. Gasoline enters at 3 through the needle valve passage 4. The amount of entering fuel is regulated by the needle valve which is operated by the graduated wheel 5. The mixture leaves for the engine at 2, after passing over the baffle 6 which aids the mixing. On each aspiration (admission) stroke valve 7 lifts, uncovering the needle valve passage. Air is sucked to the upper chamber, drawing gasoline from the needle valve. The

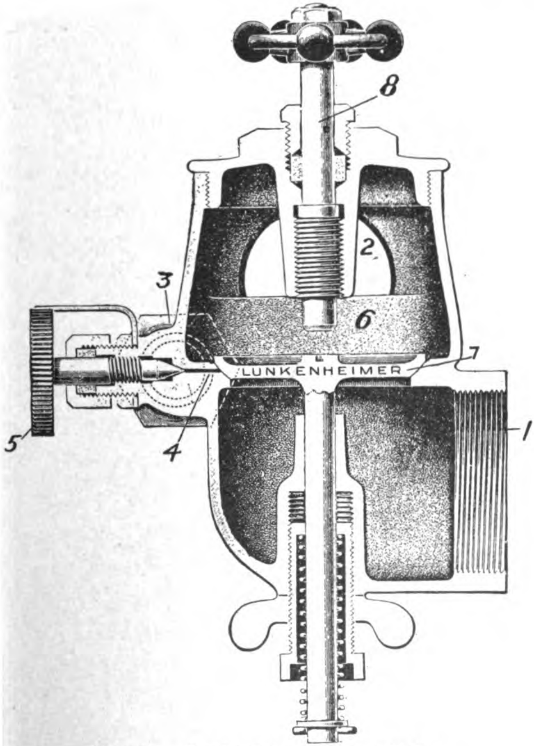

FIG. 27.— Lunkenheimer Mixing Valve.

valve is seated by its spring at the end of the aspiration stroke, and its lift is regulated by the stop 8. Passage 2 contains a throttle.

There are innumerable carbureters and mixing valves on the market and the above are chosen as typical designs.

General. It is advantageous, especially in cold weather, to have the source of air supply warmer than the atmosphere. Many methods are employed, such as having the air suction drawn from the proximity of the exhaust pipe, leading the hot exhaust gases around the admission pipe, or jacketing the carbureter with the exhaust gases or heated exhaust circulating water. 80° F. to 85° F. is the best temperature for admission. The temperature and hygrometric condition (condition as to moisture) of the air supply regulates the relative quantities of air and fuel required in the mixture. It will be necessary to regulate the mixture to meet the varying atmospheric conditions.

Carburetion of Kerosene requires the application of heat to aid vaporization at ordinary temperatures. Therefore, the process consists of two parts, first atomizing the fuel in a similar manner to gasoline carburetion and second, vaporizing this spray by heating. This heat is applied either by jacketing the carbureter or admission pipe, or by heating the air before passing the same through the carbureter. All well designed gasoline carbureters, if jacketed, will carburet kerosene. Many kerosene carbureters start on gasoline and shift to kerosene after the engine is started and well warmed up.

Such a carbureter is shown in Fig. 28. This

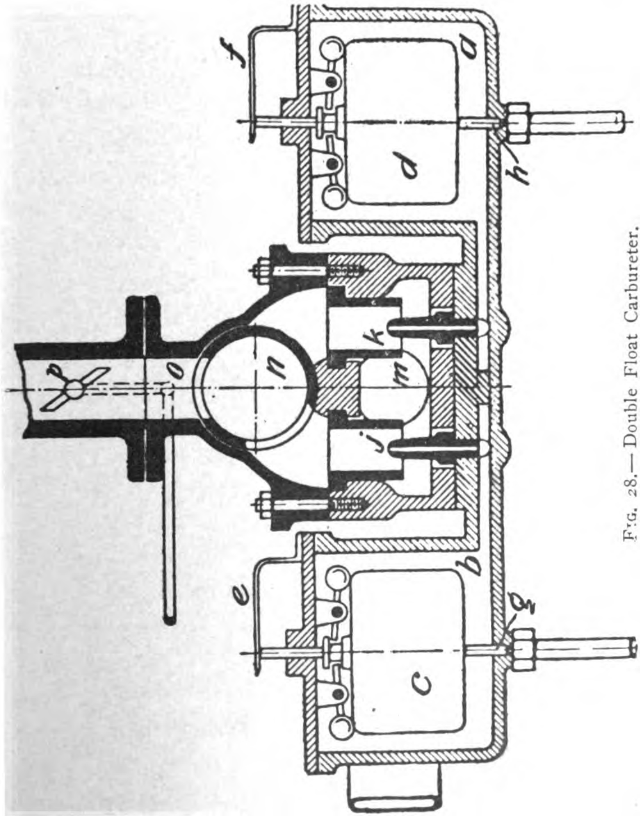

FIG. 28.—Double Float Carbureter.

carbureter, known as the double float type, is constructed to use either gasoline or kerosene thus permitting the start to be made on gasoline (which will volatilize cold) and subsequent running to be done on kerosene. Suppose that compartment *b* is used for gasoline, and *a* for kerosene; *c* and *d* are floats in these chambers that regulate the level of liquid in the chambers by opening and closing the needle valves *g* and *h; e* and *f* are springs that can be used to keep either needle valve (*g* or *h*) closed when the other is in use; *j* and *k* are nozzles communicating with the fuel chambers *b* and *a; m* is the air inlet and *n* is a valve which can be rotated so as to connect the air inlet *m* with the admission pipe *o* by way of either *j* or *k; o* is the admission pipe to the engine and *p* is a throttle. The carbureter is shown with both needle valves closed.

The operation is as follows: Using gasoline to start, push aside the spring *e* allowing the float *c* to operate and admit gasoline to *b*. With the valve *n* in the position shown, the apparatus becomes a simple float valve gasoline carbureter. The air is drawn in through *m* over *j*, sucking up gasoline vapor, through *n* and out at *o*. When the engine is warm and it is desired to shift to kerosene the spring *e* is pushed to the closed position and *f* is pushed aside, allowing the float *d* to operate. The valve *n* is turned so as to connect *m* and *o* by way of *k*. We now have a simple float valve kerosene carbureter, the air being drawn into *m* over *k*, sucking up kerosene and going out by *n* and *o*. This type of carbureter is supplied with *preheated air*.

Check Valve. Two-cycle engines require a check valve between the carbureter and the en-

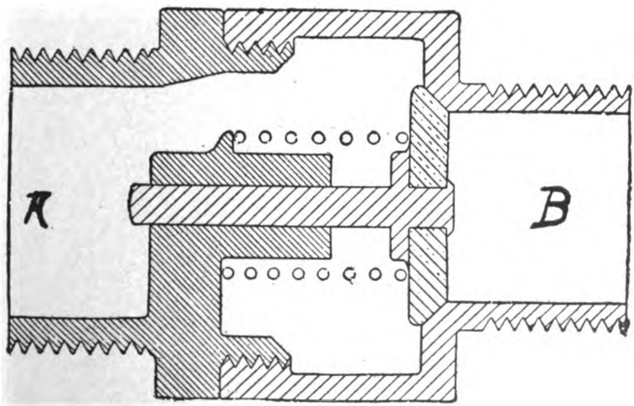

FIG. 28 a.—Check Valve for Use with Carbureter and Two-Cycle Engine.

gine base to cause a proper cycle in the base. The valve shown in Fig. 28a is manufactured by the Wheeler and Schebler Co. The end marked A connects to the engine base and B connects to the carbureter or mixing valves. It functions as follows: On the *engine* compression stroke the valve lifts and admits the mixture to the engine base. On the expansion or ignition stroke the valve is forced closed by pressure in the base. If this valve were not interposed between the base and carbureter the mixture that is drawn into the base on the compression stroke would be forced out of the base through the carbureter to the atmosphere on the following stroke and no mixture would find its way to the cylinder.

CHAPTER V

IGNITION SYSTEM

NEXT to carburetion, the most important feature of internal combustion engine operation is proper ignition. Electrical ignition has come into its own for motor boat work and is now the universal system. The reasons for this are two: its development is near perfection; and it can be easily "timed." "*Timing the spark*" means regulating the point in the stroke at which ignition takes place. For high-speed engines electrical ignition is the only one flexible enough for accurate regulation. It is obvious that with an engine running at 600 revolutions per minute, the stroke being but 1/20 second, it would be extremely difficult mechanically to vary to a nicety the point in the stroke at which ignition will take place.

Ignition is accomplished by shooting a hot electric spark through a compressed charge. Electrical ignition may be subdivided into two classes: (1) make-and-break system; (2) jump spark system.

Generally speaking the make-and-break system is used for small two cycle plants and the jump spark system for four cycle multicylinder plants. The reason for this lies in the fact that in multicylinder plants the spark of all cylinders can be timed together when using the jump spark.

1. **Make-and-Break System.** This system, which is a mechanico-electrical one requiring cam or other gearing to make and break a contact inside the cylinder, is applicable to slow speed engines, and for this special duty has some advantages over the jump spark. A moving contact in the electrical circuit is mechanically made and broken inside the cylinder. At the *break* a spark will leap between the contacts igniting the mixture. This system admits of two methods, depending upon the kind of plug used in the cylinder: (1) wipe spark; (2) the hammer break. By the first method the plug contacts are made to brush together and by the second the contacts are brought together sharply and separated. The wiring for both methods, shown in Fig. 29, is similar. A small coil is employed to step up the current, but no vibrator is used as this would cause a spark to occur at

make as well as break, thus probably igniting the charge prematurely. The circuit shown admits of battery or magneto current.

The difference between the wipe spark and the hammer break lies in the plug (the mechan-

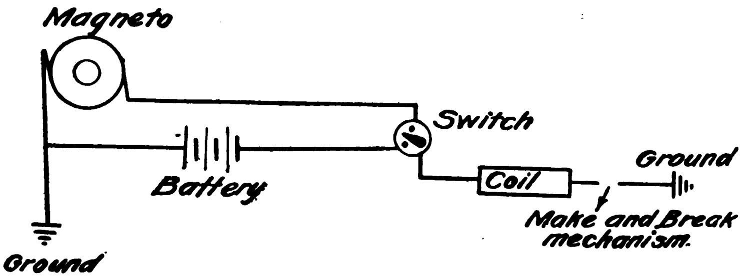

FIG. 29.— Circuit for Make and Break Ignition.

ism) only. The writer prefers the hammer break on the ground of simplicity. The two kinds of plugs are shown in Figs. 30 and 31.

The Wipe Spark mechanism is shown in Fig. 30. The rod *b* oscillates the collar *a* by means of the cam *c* on the countershaft. The collar *a* carries the contact point *d*, grounded to the engine. As the collar *a* oscillates, the point *d* wipes past the spring point *e* completing the circuit. The spring *g* quickly returns the collar to its original position when the cam releases the rod, and the circuit thus being broken a spark will occur between the points *d* and *e*.

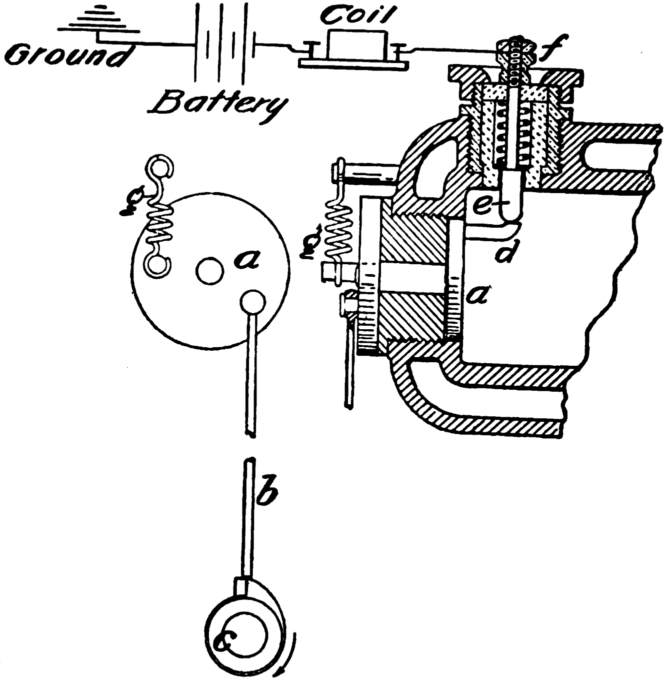

FIG. 30.— Wipe Spark Igniter.

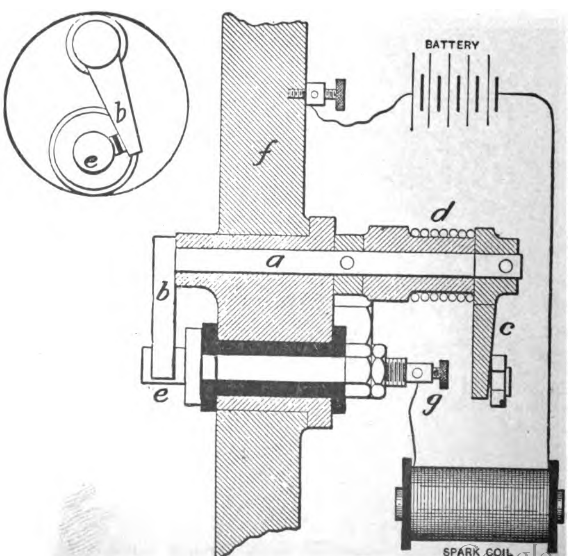

FIG. 31.— Hammer Break.

The source of current is connected to *e* by the terminal *f*. Terminal *f* and point *e* are insulated from the rest of the mechanism. The advantage of the wipe spark over the hammer break lies in the fact that the sliding contact prevents carbon deposits on the points.

The Hammer Break. The principle of the hammer break is shown in Fig. 31. The spindle *a*, carrying the contact *b*, is actuated by cam and rod through the lever *c*; *d* is a spring to keep *b* against the collar *e*; *f* is the cylinder head. Contact *b* is grounded to the cylinder. Contact *e* (which is *inside* the cylinder) is insulated from the cylinder and its terminal *g* is connected to the source of current. When the contacts *e* and *b* are separated mechanically, a spark occurs. The cam or eccentric operating this gear is situated on the main or countershaft of the engine. An eccentric may be used in place of the cam.

Jump Spark. This system requires among other things a spark plug, which is shown in the circuit in Fig. 32. A current of high potential is made to jump across a gap between two terminals of the spark plug. This plug, which is screwed into the cylinder head, has its gap surrounded by the compressed mixture at the moment of ignition. Closing the circuit causes the spark to leap and this ignites the charge. Mica plugs are preferable to porcelain plugs because the latter break easily.

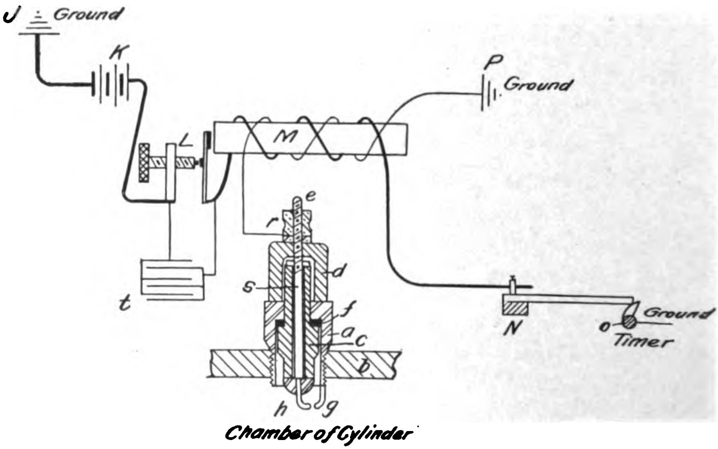

FIG. 32.— Single Cylinder Jump Spark Ignition Showing Details of Spark Plug.

A Single Cylinder Ignition Circuit is shown in Fig. 32. The spark plug is screwed into the cylinder head *b*. The plug consists of the steel casing *a* which screws into the cylinder head *b* and thus the terminal *g* is grounded at the engine. The other terminal *h* is insulated from the rest of the plug by the porcelain collars *c* and *d*; *f* is a gastight washer of asbestos. These collars and washers are made in a variety of shapes and of different materials, but the principle is the same in all cases.

The system consists of two circuits, a primary and a secondary. Following the primary circuit shown by the heavy lines, it goes from the ground *J* through the battery *K* to the buzzer *L*, through the primary windings of the coil *M* to the terminal *N* of the timer. The timer shaft *O* revolves, and this shaft being grounded, the circuit is completed by the cam on the shaft. The secondary circuit leads from the ground *P* through the secondary winding of the coil *M* to the terminal *r* of the spark plug, then down the spindle *s* to the point *h*. The point *g* being grounded, the circuit is completed by the gap between the two points of the plug.

When the primary circuit is completed by the timer, current flows through the primary windings of the coil. This current induces in the secondary windings a current strong enough to overcome the resistance of the gap. It leaps this gap and ignites the mixture in the cylinder; *t* is a condenser connected across the terminals of the buzzer. Its function is to damp the break spark at *L*.

Magnetos. The foregoing system is shown using battery current. A " high tension " magneto, which is an apparatus similar to a dynamo, may furnish the current. In this case the magneto furnishes the current direct to the plug, the battery and coil being eliminated. If a "low tension" magneto is used, the current must be stepped up in potential by the use of a small coil or "booster." When using the magneto the buzzer is omitted. The function of a buzzer is to break up the spark at the gap into a vibrating series, thus increasing the certainty of ignition.

Multicylinder Ignition, Fig. 33, illustrates four-cylinder engine wiring.

Fig. 33a shows the wiring of the coil. The timer shaft *h* revolves, making contact with the terminals g_1, g_2, g_3, g_4, in succession; *h* is grounded to the engine; *a*, b_1, b_2, b_3, b_4, e_1, e_2, e_3, e_4 are plugs on the outside of the coil box and are connected as shown in Fig. 33a. The plug *a* connects to the battery, *d* to the ground, e_1, e_2, etc., to the spark plugs, and b_1, b_2, etc., to the terminals g_1, g_2, etc., of the timer; k_1, k_2, etc., are the spark plugs; c_1, c_2, etc., are the buzzers.

The shaft *h* being in the position shown, the primary circuit goes from ground *h*, through g_1 to b_1 through vibrator c_1 and primary windings of coil 1 to plug *a*, thence to battery and ground. The secondary circuit 1 leads from

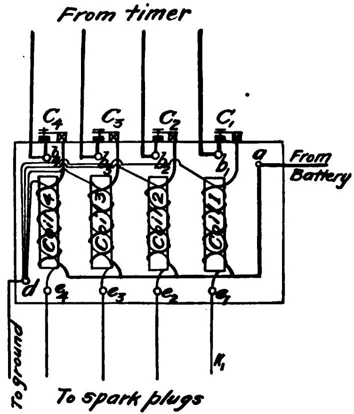

FIG. 33 a.— Wiring of Coil.

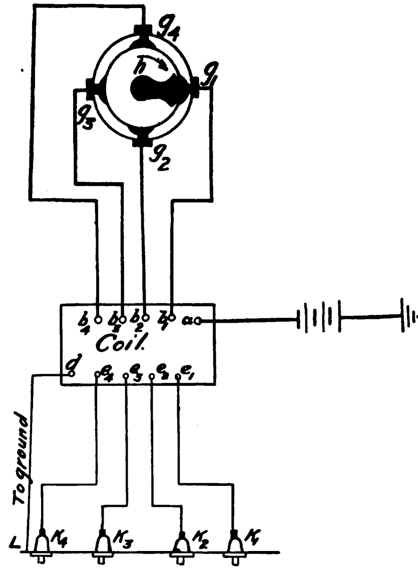

FIG. 33.— Wiring for Four Cylinder Jump Spark Ignition.

ground *L* to plug *d*, through secondary windings of coil 1, where a high tension current is induced, to plug e_1, thence to spark plug k_1. This circuit is similar to the one cylinder circuit described above. When shaft *h* is revolved to make contact with g_2, the current flows through coil 2 to spark plug k_2, etc., and in this manner the cylinders are ignited in rotation.

The Timer. Means must be employed with a multicylinder engine to ignite each cylinder in turn at precisely the proper instant. This is accomplished by the timer. It is interposed in the primary circuit with a terminal for each primary wire from the coil, Fig. 33. There are two general types of timers, the wipe contact and the La Costa or roller contact type.

Splitdorf Timer, Wipe Contact Type. Fig. 34 shows the construction of the Splitdorf wipe contact type timer. The shaft *A*, which is grounded, has secured to it a head which carries the spring point *B*. As the shaft *A*, which is driven by gearing generally from the cam shaft, revolves, the point *B* makes contact with the terminals *C*, *D*, etc., in turn. These terminals are insulated from the collar of the timer *E*. When contact is made with any terminal, the primary circuit corresponding to that terminal is completed and the corresponding cylinder fired. The shaft *A* runs on ball bearings *F*. The collar *E* which carries the several terminals, can be shifted by the lever *G* to advance or retard the spark. The spindle *H* holds the cover on the timer.

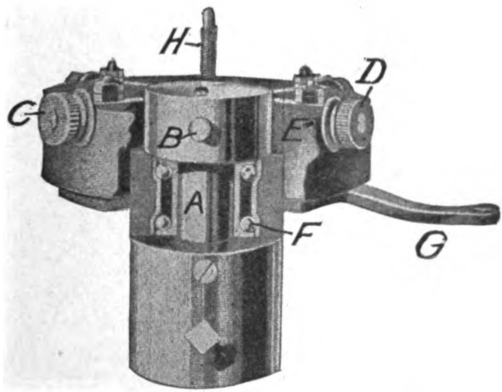

FIG. 34.— Splitdorf Timer, Wipe Contact Type.

Splitdorf Timer, La Costa Type. Fig. 35 illustrates the La Costa type of timer. The shaft *A* which is revolved by gearing from the cam shaft, is grounded, and carries the roller contact *F*. The terminals *B*, *C*, *D*, and *E*, are insulated from the rest of the timer. The primaries for each cylinder lead from the coil to these terminals. As the roller *F* makes contact with the plate *G* of each terminal it completes the primary circuit of the corresponding cylinder, firing each cylinder in turn. The spark can be advanced or retarded by rotating

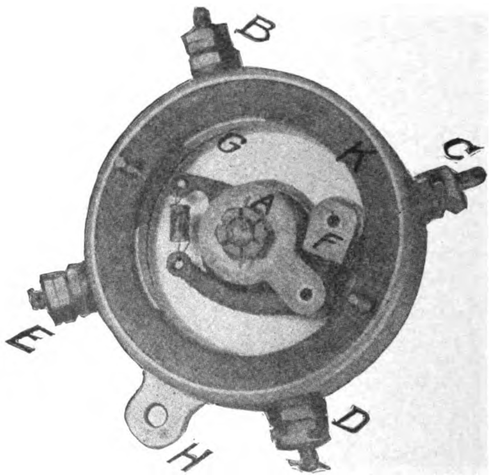

Fig. 35.— Splitdorf Timer, La Costa Type.

the collar carrying the terminals by means of a lever attached to *H*.

Advantages and Disadvantages of the Different Electrical Systems

The make-and-break system is the simpler electrically and less trouble occurs from insulation and short circuits because a low tension current is used throughout. It is mechanically more complex, hence is more suitable for low-speed engines, and hard to adapt to high-speed engines.

General. All contact points and the points of spark plugs are made of a platinum alloy or other heat resisting conductor. The points must be kept clean and free from carbon, as this formation tends to form short circuits across the spark plug gap, thus damping the spark. All connections should be so arranged that they cannot jar loose and the insulation must be protected from heat, oil, and especially water.

Wiring requires special attention. *Any old wire* will *not* do to repair a circuit except temporarily in an emergency. For the primary circuit a good grade of stranded low tension wire must be used. For the secondary circuit a good stranded high tension wire must be obtained. Ordinary lighting wire is a source of constant trouble and should be avoided.

Dual Ignition. By a "dual ignition" system is meant one in which the current is supplied from either a battery or a magneto, or from both, at will. Some systems have a separate set of spark plugs for each source of current supply and in this case the system is in effect two separate systems. The dual ignition system proper, in which current may be obtained through one set of plugs from either battery or magneto, is shown in Fig. 36.

F is a four way switch which operates as follows: Connecting *a* and *b*, the current goes from the dynamo to the primary of the coil direct where it is converted to a high tension

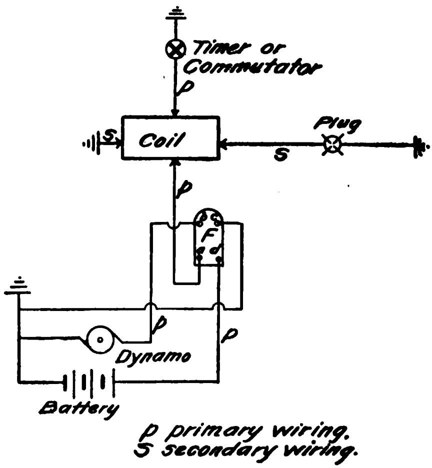

Fig. 36.— Dual Ignition Circuit.

current. Connecting *a* and *d*, the current goes from the battery direct to the primary of the coil. Connecting *c* and *d* the voltage of the battery can be read by a volt-ammeter in the circuit. The secondary circuit *s* is similar to that shown in Figs. 32 and 33.

This should not be confused with double ignition, in which there are two separate circuits and sets of spark plugs, one for the battery and one for the magneto.

There is a tendency in modern practice to have two spark plugs for each cylinder, so as to ignite the charge at two points simultaneously. This is theoretically excellent as it will accelerate flame propagation, but there are several difficulties that are hard to overcome. First, the two sparks must occur at correctly timed instants, otherwise the object of the system would be defeated. Second, if the two spark plugs are situated close together little benefit is derived. The first difficulty has been overcome by several manufacturers of ignition specialties, and where design permitted the installation of two spark plugs widely separated, the author has heard of some remarkable results.

Master Vibrator. A variety of spark coil recently placed on the market is fitted with what is called a master vibrator. In this coil there is one common buzzer for the coils of all cylinders. The system shown in Fig. 33a could be modified as follows: Cut out all the buzzers shown and lead the primary directly from the timer to the coil. Insert a buzzer (master vibrator) in the common primary line from the battery *a*. The advantage of this system lies in the fact that the vibrators give more trouble than any other part of the ignition system, for an arc is constantly present that burns and fouls the vibrator contacts, and obviously one vibrator is easier to keep clean and adjusted than are four.

Advancing and Retarding the Spark. If ignition takes place after the piston has passed the dead center and has started downward on the ignition stroke, the spark is said to be "*retarded.*" It is obvious that the compression is not a maximum and therefore the power developed is lower than the designed power. The later the ignition the lower will be the compression at the point of ignition, combustion will be slower or even incomplete, and the engine will run slower than its designed speed. If the spark is retarded an excessive amount, the engine will tend to overheat.

If ignition takes place when the piston is on the dead center, combustion will not be completed until the piston has traveled a small fraction of its stroke and, as the compression at this point of completed combustion is less than the maximum, the result is, to a minor degree, similar to a retarded spark.

Obviously, some point can be found near the top of the compression stroke, before the ignition stroke has started, such that, if ignition takes place at this point, combustion will be completed at the beginning of the ignition stroke. Here the compression is a maximum, hence the power developed is a maximum. A spark which occurs before this dead center is reached is called an "*advanced spark.*" If the spark is advanced an excessive amount, combustion will be completed before the beginning of the ignition stroke and a back pressure and loss of power results. This is indicated by a knocking sound called a "*spark knock.*"

Small motors generally have their spark fixed at the point of maximum efficiency. Adjustment can be made from time to time to allow for wear of parts, etc., but, after adjustments are made, all parts are secured so that all operations of the motor take place with the spark in the same position. This is called a "fixed spark."

Large motors, especially multicylinder, have an "*adjustable spark.*" By means of an adjustable timer the *point of ignition* can be *varied* in all cylinders simultaneously while the motor is in actual operation. This permits of starting the motor with the spark retarded to avoid back-fires, and then, when started, the spark can be advanced to the proper point for the speed at which the motor is running. Obviously the faster the engine is running the more the spark should be advanced.

CHAPTER VI

COOLING AND LUBRICATION

COOLING THE GASES. One of the measures of efficiency for an internal combustion engine is the effective utilization of the available heat energy. This in turn depends upon the initial and final temperatures of the gases that develop the pressure, if these gases be cooled as far as possible by transforming their heat into work. Experiments have been made along the line of injecting water into the cylinder both before and after ignition of the charge, on the theory that the heat absorbed from the ignited mixture would vaporize the water and reappear as work on the piston in the form of pressure due to adiabatic expansion (i.e., expansion without gaining or losing heat) of the water vapor. Although this reduces the loss of heat in the exhaust, it is open to the objection that it reduces the net effective pressure. It is not in common use.

Cooling the Cylinder. Due to the high heat developed by the combustion of the mixture it becomes necessary to cool the metal of the cylinder walls, pistons, valves, etc. Were this temperature not reduced the result would be leaky valves, deformation, defective alignment, seizing of piston, and oxidation of metal. There are two methods of cooling the cylinder: (1) water cooling; (2) air cooling. Only the former is used for motor boat engines.

The water jacket is shown in Figs. 10 and 14, Chapter III. Water is drawn from overboard through a small inlet pipe and pumped through this water jacket. Here it absorbs heat from the cylinder walls, lowering the cylinder wall temperature, and is discharged overboard. The small pump that operates this system is placed in the inlet pipe line and is operated by an eccentric on the main or countershaft. Water enters the water jacket at the bottom and leaves at the top. Check valves are generally placed on the suction and discharge sides of the pump to make the action more positive.

The pump is designed for the probable working speed because one that would supply sufficient water at a designed high working speed would be deficient at low speed, and one that is designed for a low speed might cool the cylinder to too low a point for efficiency at high speed.

Admission valves are kept cool by the cool entering mixture, and where practical to let this cool mixture impinge on the exhaust valve it aids in maintaining the latter at a safe temperature. The cylinder jackets are carried as near as possible to the valve seats. The temperature of the gases burning in the cylinder of a gasoline engine approaches 2700° F. If no provision were made for carrying away this heat as it is absorbed by the cylinder walls, it is obvious that these walls, and in fact the whole engine, would reach such a temperature that the lubricating oil would be burned up, undue expansion of all parts would take place, and a danger point in the operation of the engine would be quickly reached.

Pounding in the cylinder is often the first indication of an overheated engine. Loss of power, slowing of the engine, and final stoppage are other common signs. When the engine slows due to overheating, throw out the electric switch. If the engine continues to run with the current cut off it is a sure sign of overheating. Cut off the gasoline supply and stop the engine to prevent serious damage. If the engine is continued in use in this condition it may result in the piston seizing, the bearings melting and running, or even more serious damage.

Overheating is generally caused by failure of either the cooling or lubricating system. An excessively retarded spark will cause mild overheating.

LUBRICATION

The external lubrication of an internal combustion engine presents no novel features and requires no comment, but the internal lubrication of the cylinder, piston, etc., is vital to the safety of the engine. A steam cylinder lubricates itself by condensation of steam on the cylinder walls, but due to the intense heat in the cylinder of an internal combustion engine, and due to the high piston speed, it is necessary to have a film of oil between the piston and cylinder walls at all times.

Kind of Oil. The intense heat of the cylinder will tend to evaporate the oil and cause gumming, therefore an oil of high heat test must be used. As this is limited to 600° F. evaporation of the lubricant cannot be eliminated entirely; therefore a thin oil that will not gum upon partial evaporation is necessary. Animal and vegetable oils will decompose under high heat and cause oxidation and a carbon deposit upon the cylinder, not to mention the possible liberation of destructive acid. As partial combustion of the cylinder lubricant is always liable to take place, oil must be used that does not leave any solid residue. Only special grades of mineral oils can be used. These are designated commercially as "gas engine cylinder oils" and come in various grades to suit the varying conditions of speed, load, etc. Oils should be tested carefully for the presence of acid. A good body and low internal friction are very desirable.

The brand of cylinder oil to use depends upon the speed, load, etc. The best guide is the advice of the engine builder. Write the manufacturer of your engine and he will advise you gladly as to the oils and greases best suited to your engine. As he has his reputation at stake you will find his advice correct and unbiased. Two distinct methods of piston and cylinder wall lubrication are employed: (1) splash system; (2) mechanical feed. The splash system is the simpler as it does not require a pump for distributing the oil. The crank case is closed and oil is maintained in the case at such a height that the crank or a small lug on the crank will dip into the oil at each revolution, throwing the oil up on the cylinder walls. The piston spreads the oil over the cylinder wall evenly on the up stroke.

By this system the oil supplied to the cylinder walls is approximately proportional to the speed of the engine. At the same time oil is splashed on all the bearings, or a small pump may draw oil from the case and distribute it to all of the bearings, returning it to the case. This system is used only for engines of medium and low horse-powers. The crank case is fitted with an oil gauge to show the height of oil therein; this height must be kept constant.

Lubricators. The mechanical feed appears in various forms. One is shown in Figs. 37 and 38. The oil is fed by pump or mechanical lubricator into the oil duct to the oil ring around the base of the cylinder, Fig. 37. At each stroke the lower edge of the piston dips into the oil in the oil ring and oil is drawn up the cylinder wall. The lubricator is shown in Fig. 38. A small belt from the main or counter-

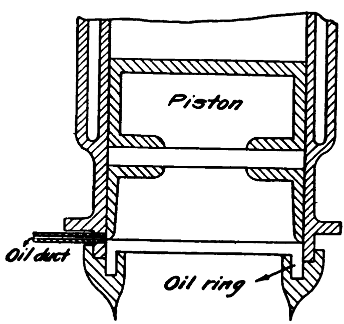

FIG. 37.—Oil Ring.

shaft drives the pulley *a*. This revolves the spindle and crank *b,b,* which carries the loose wire *c*. This wire dips into the oil at every revolution and carries a small amount to the wiper *d,* from which the oil drips to the passage *e*. This passage connects with the oil duct in Fig. 37. As the pulley *a* revolves at a certain relative speed to the main shaft, the oil supplied is proportional to the speed. In Fig. 38 the central bracket which carries the wiper *d* is back clear of the path of spindle and crank *b,b,* as they revolve.

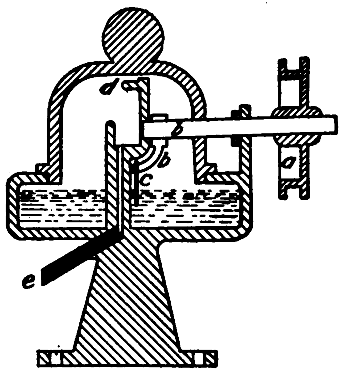

FIG. 38.— Mechanical Lubricator.

External Lubrication while not so vital to the life of the engine is, nevertheless, highly important to its efficient operation. Use only the best oils and greases, preferably those recommended by the maker. All parts that bear or move on other parts must be well lubricated at all times. The reversing gear case must always be well packed with grease. Care must be exercised in selecting this grease, for, if this grease is too thin, it will eventually run out of the case; if it is too thick, it will pack on either side clear of the gears and will be ineffective when backing.

Graphite. After an exhaustive test of deflocculated (powdered) graphite the writer favored its use in oil for internal lubrication of high speed engines. It is questionable whether it is worth while in the average motor boat engine of small or medium horse power. There is no doubt that it adds to the life of the oil. Graphite is a great natural lubricant.

Mixing Oil and Gasoline. In small engines it is the practice of many to mix the oil intended for internal lubrication with the gasoline, allowing it to find its way to the cylinder walls in this manner. It is practical, but the writer does not favor its use. With correct design an independent oiling system is much more positive and quite as economical. It can be checked and regulated by the operator.

CHAPTER VII

OPERATION

STARTING THE MOTOR. Small motors may be started by hand by giving a few turns to the fly-wheel or to a crank fitted to the crank-shaft, but the large engines require an auxiliary starting mechanism. Some engines are so fitted that they may be run by compressed air for a few revolutions until the first explosion is obtained. Another method is to introduce a charge of mixture into a cylinder by a pump and then to fire this charge by the igniter or a detonator. This method is not commonly used with marine engines. Some of the larger marine motors are fitted with electric starters.

If no self starter is fitted, retard the spark, if adjustable, so that ignition will occur after the crank passes the dead center. See that the ignition circuit, oiling gear, and cooling water are in order and turned on. Open the throttle and fuel valve to carbureter, if installed, prime the cylinders and open the relief cocks on the cylinders if necessary. Give the engine a few turns by the fly-wheel, if small, or the starting device, if large, and if everything is in order, the engine will start. Opening the relief cocks relieves the compression and makes cranking easy; on the other hand, relieving the compression makes the ignition more difficult. The behavior of the engine at hand will govern this point.

After the engine is started, adjust the ignition to the proper lead, close the relief cocks, if open, see that the oil and water are working properly, and adjust the mixture if necessary. These general instructions may be modified for different types of engines. If an engine is to stop for only a few moments, the ignition circuit may be broken, if of the jump spark type with battery and coil. The few revolutions due to inertia after the spark is cut off will leave the cylinders charged with mixture. By again closing the ignition circuit a spark will jump in the cylinder that has its piston in the firing position, and, if the mixture is still in combustible form, the engine will start without cranking. This is called "starting on spark."

In very cold weather the engine is particularly liable to balk when starting cold. Probably the first thing done by all motorists when an engine refuses to start at the first trial is to prime the engine. If this priming is done with warm gasoline success will often result, saving much hard cranking. A small squirt can carried in an inner pocket will keep gasoline warm enough for the purpose. It is an excellent "wrinkle."

Stopping the Motor. To stop the engine, close the throttle, break the ignition circuit, and close the fuel valve. If exposed to freezing weather, drain engine jackets and connecting pipes. Although it has been recommended that the oil supply be shut off before the engine is stopped in order that the surplus oil may be carried out with the exhaust, the author is not in agreement. If the oil supply is properly regulated, there will not be enough surplus to cause serious clogging in the cylinders or valves, whereas the serious results that might occur if the engine were started without turning on the oil supply (as might easily happen if other than the regular hand started the engine) are obvious. Wrecks from this cause are not infrequent. In modern practice, especially where the splash system is used, the oil supply is left turned on at all times. This does not apply to heavy duty motors having special feed systems.

If the engine has been behaving badly and does not stop when the circuit is switched off, it has overheated. In this case shut off the fuel supply, let the engine cool off, and seek the trouble.

Reversing. There are three methods of reversing the direction of the motor boat: (1) reversing the direction of rotation of the motor; (2) reversing the pitch of the propeller; and (3) reversing the direction of rotation of the propeller by means of gearing.

The first method is readily employed with small two cycle motors. To be effective the spark should be adjustable. It involves momentary stoppage of the engine, and not being as positive as the other two, does not find as much favor. The writer does not recommend it. Cheapness is its only virtue. Momentary stoppage in close waters may easily end in collision. The second and third methods are in common use with both two and four cycle engines.

(1) *Reversing the Direction of Rotation of the Engine.* If the spark is adjustable, place it in the neutral position, switch off the current and crank the motor in reverse direction. Then advance the spark to the proper point. It is apparent that this is hardly a desirable method for making a boat landing or working around crowded waters. If the spark is

"fixed" then the adjustment for ahead direction (*advanced*) will be retarded for the reverse direction, and reduced power and probably overheating will result. This method is undesirable from an engineering viewpoint. It has simplicity (absence of reversing mechanism) and hence cheapness to recommend it for very small units of one or two horse power, because in this case the cost of reversing gear would be a large proportion of the total power unit cost.

(2) *Reversing the Pitch of the Propeller.* This method of reversing the direction of the motor boat is accomplished by shifting the blades on the propeller hub so that with the same direction of rotation of the engine the *effective* direction of the screw is reversed. In other words, the screw, if originally a right-handed one, becomes lefthanded. By means of a lever in the boat and mechanism running along the propeller shaft the blades are turned on their axis through an angle on the propeller hub so that the screw tends to drive the boat in the reverse direction. The principal objection to this method is that it necessitates parts under water and inaccessible. Accessibility is an advantage much underrated by the novice.

(3) *Reversing Gear.* The third and last method for reversing the boat is to interpose

gearing between the engine shaft and the propeller shaft, so that by means of gearing the propeller can be made to go ahead or reverse while the engine maintains its ahead direction. Such gearing is shown in Fig. 39. *G* is the

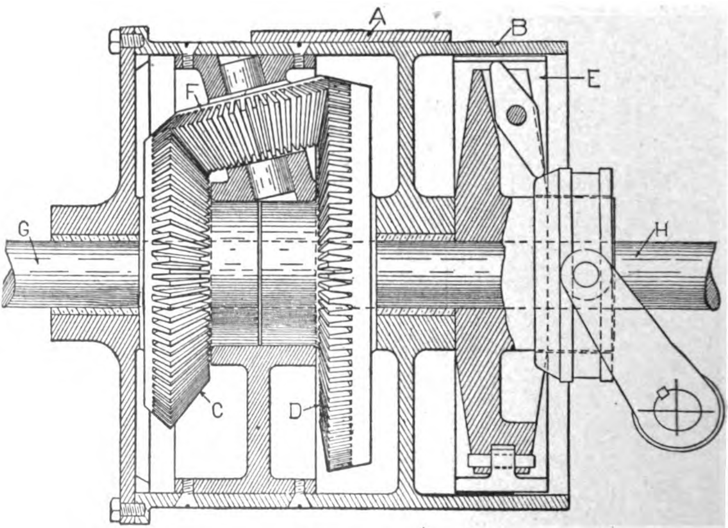

Fig. 39.— Reversing Gear.

engine crank shaft carrying the bevel wheel *C*. *H* is the propeller shaft which carries the bevel wheel *D*. *F* is a pinion which is carried in bearings cast to the casing *B*, and meshing with the bevel wheels *C* and *D*. *A* and *E* are friction collars operated by the reversing lever through a clutch in such a manner that either can be locked to the casing *B*, the other being simultaneously unlocked. *A* is made fast to the bed plate or other stationary part of the engine or boat. *E* is firmly fixed to the propeller shaft *H*.

The operation is as follows: When going ahead the casing *B* is free to rotate, the friction band *A* being unlocked. At the same time the friction band *E* is locked to the casing so that it will revolve with the casing. This locks all the spur wheels, and the casing will now revolve with the engine crank shaft driving the propeller shaft as it is also locked to the casing. To reverse, throw the clutch to the right, releasing the friction band *E*. At the same time the friction band *A* is locked making the casing stationary. Rotation of the engine shaft is communicated through the pinion *F*, which now has a stationary bearing, to the spur wheel on the propeller shaft *H*. The gears reduce the speed on reverse direction. These are three pinions like *F* spaced at equal intervals around the casing.

Laying Up the Motor. If the motor is to be laid up for any long period, drain the cooling system; there is generally a pet cock low in the system for this purpose. The line should be broken at a low point and drained, being careful to break a joint on the right side of a valve so that the hull will not be open to overboard. If to be left in the water during freezing weather, pack the overboard suction and discharge pipes about with sawdust or something to keep the water therein from freezing. Empty the gasoline tank and drain the line of all gasoline. If practical blow out all gasoline vapor. Leave the oil in the engine crankpit and pack reversing gear and grease cup. Force grease and oil through all bearings, and, if practical, vaseline cylinders, pistons, and all accessible parts. Remove all electrical gear and store it indoors. Turn over the motor occasionally, about once a week to keep it oiled and free from dust.

Before using the motor, after any protracted laying up, inspect it carefully to see that all working parts, especially internal, are clean, free from dust and carbon, and well lubricated; that the gasoline system is clean and free from dirt and water; and that the ignition system is in first class shape, free from grounds, short circuits, carbon, etc.

CHAPTER VIII

MOTOR TROUBLES AND THEIR REMEDIES

IN years past the early gasoline engines gained considerable ill repute through ignorance of operators and faults due to bad design. In time the terms "balky" and "cranky" were applied to motors, and, no doubt, they could be justly applied to the early engines. Faulty design can cause trouble that might baffle an expert operator.

However, the design of a modern gasoline engine built by a reputable firm can be relied upon as dependable and free from trouble making. Most builders to-day seek to make their motors foolproof.

Bearing the above in mind, the operator, when in trouble, should no longer shift the burden by dubbing his motor "balky." Ignorance on the part of the operator is the sole cause and should be so acknowledged. Because the operator encounters a fault new to his experience is no indication that it is peculiar to the engine. The most peculiar behavior on the part of a motor probably has a simple and logical explanation.

Experience on the part of the operator will solve all the so called "balks" of the engine. After considerable experience an operator will encounter trouble new to him, but in every case by systematic searching and a little logical thought the remedy can be found. Troubles are generally located by a system of elimination. The operator will recognize most of these at once by the behavior of the engine. If the fault is out of the common, elimination is the simplest method. Examine each system, fuel, ignition, cooling, and lubrication, in turn, going from one end to the other. *Haphazard searching is futile.*

If the trouble is of an eccentric nature, such as would worry a good operator, it will generally be due to an adjustment that has jarred loose. The endeavor of builders to give the public good service has resulted in many cases in these builders establishing a corps of "trouble hunters," whose sole work is to examine and adjust so called "balky" motors for their customers. The operator will always find the manufacturer his best friend. Letters are cheerfully answered and help extended. The builder's best advertisement is a *successful* engine. The more common faults, methods of locating, and remedies follow.

Failure to Start. Should the motor fail to start, the trouble can only be found by a man conversant with the interrelation of the parts of the machine and their relative functions, and "trouble hunting" resolves itself into an investigation of the different integral systems of the motor. Of course, many causes of non-starting are apparent from the behavior of the engine, and an experienced hand will generally have little trouble in finding the defect. However, occasionally a defect will baffle even an expert until he has thoroughly overhauled and analyzed the motor.

When investigating non-starting, divide the work as follows:

1. Ignition system.
2. Fuel system.

Non-starting Due to Faulty Ignition. First look to the spark. It may be too feeble to ignite the mixture or may not occur at all. Unscrew the spark plug and lay it on the cylinder head so that the points are clear. Turn over the engine and the spark can be observed at the gap. If a feeble spark or no spark is found, test all contacts and switches to see that they are tight. If all is found in order, test the battery by a pocket voltmeter. If this is found in order, look at the plug. This may be too foul for the spark to bridge, the points may be too far apart, or the insulation may be defective or broken.

If the plug, battery, contacts, and switches are found in order, the trouble must lie in the wiring. This can be tested section by section with a testing magneto, a testing set, or by disconnecting from the plug and touching the wire quickly to the cylinder head. If the whole circuit does not give a spark disconnect another section and touch the remainder to the cylinder head or other part. By thus shortcircuiting the circuit the section at fault can finally be located.

If a good spark is present at the plug, then it may be taking place at the wrong part of the cycle, due to the timer being out of adjustment. This discrepancy is made good by so adjusting the timer that the spark will occur at or just beyond the end of the compression stroke. If the spark is strong enough for ignition and properly timed, then the trouble will be found under the second head.

Non-starting Due to Fuel Supply. The tank may be empty or the fuel valve closed. Although this sounds childish, many operators have wasted much valuable time trying to start under these conditions. The feed pipe may be clogged. Often waste or other foreign matter find their way into the feed pipes through the tank. The throttle or air valve may be stuck. Defective adjustment of the fuel or air valves may result in a non-combustible mixture. The carbureter may be out of order. A leaky needle valve, resulting in a flooded carbureter, is a frequent source of trouble. The compression may be defective, due to leaky or broken piston rings or valves. This is evidenced by the small resistance encountered when cranking the engine. A broken valve stem or loose valve cam, which does not show at once, may cause a valve to become inoperative. In a new installation the tank may be too low to supply a gravity feed, or the lead of feed pipe may be bad.

Back-Firing. This, one of the commonest of the defects, consists of explosions in the passages outside of the cylinder. They may be located in the exhaust pipes or passages, or in the inlet passage between the carbureter and inlet valve. In the case of exhaust passage explosions, the ignition may be too late. Combustion is incomplete when the exhaust valve opens, and some of the unburnt charge finds its way to the exhaust passage where it explodes. A mixture which burns so slowly that combustion is incomplete when the exhaust valve opens will have the same effect as late ignition.

Back-firing in the admission passage is more perplexing. A leaky, broken or badly timed admission valve may transmit the combustion within the cylinder to the fresh charge in the admission passage, causing a back-fire there. Another, and very common, cause for this form of back-firing is a too thin mixture. A very lean mixture burns slowly, and the combustion may continue throughout the exhaust stroke until the inlet valve opens, thus exploding the mixture in the inlet passage. A very rich mixture might act in the same manner, but it is more likely to cause a back-fire in the exhaust passage. A loose valve cam may cause back-firing by timing an admission or exhaust valve improperly. A leaky gasket on the admission pipe or manifold will cause a lean mixture, hence an admission pipe back-fire or a carbureter explosion.

Misfiring. There are two distinct classes of misfiring, continuous and intermittent. *Continuous misfiring* of one cylinder of a multicylinder engine is a simple problem. The trouble is almost certain to be in the ignition system, because the operation of the other cylinders indicates that the fuel supply is operative as far as the admission valve of the defective cylinder, and were trouble located in the valves of the defective cylinder it would generally be accompanied by back-firing. The manifold gasket of the defective cylinder may be leaking, rendering the mixture in this cylinder too weak to explode.

If the valves are functioning correctly, and the gasket is tight, then the ignition system must be overhauled. The system is operative as far as the coil because, if it were defective in the battery or the primary line to the coil, all the cylinders would fail to fire. Among the defects that might cause misfiring in one cylinder are foul or defective plug, broken wire or bad contacts, or improperly adjusted coil vibrator, if fitted. These are all easily found by simple electrical tests.

Intermittent Misfiring may be caused by improper mixture, weak battery, poorly adjusted coil, broken wires or connections that are in contact intermittently due to the vibration of the engine, dirty sparking device, admission valve, if automatic, not working freely, exhaust valve not closing every cycle, leaky valves and poor compression, or water in the gasoline.

Carbureter Explosions have the same origin as admission pipe back-firing.

Muffler Explosions have the same origin as exhaust pipe back-firing.

Weak Explosions are due to late ignition, weak battery, poor quality of mixture, insufficient compression, or loss of compression due to leaky or broken piston rings or valves. Overheating may give weak explosions and attendant loss of power due to the dissociation of the mixture to its elements.

Overheating may be occasioned by one of three defects, excess friction due to poor adjustment of bearings, etc., defective circulating water supply, or failure of the lubricating system. The water supply may fail totally or partially due to pump break down, clogging of the pipes, valve closed in the line, or sediment on the cylinder walls. When the water supply fails the temperature quickly rises high enough to burn the oil and damage ensues, the piston rings and cylinder walls wear, and the piston will ultimately seize. Failure of the oil supply if not discovered early results in the same serious trouble. Serious overheating is attended by loss of power and this is an early warning signal to an experienced man. A spark excessively retarded may cause overheating.

Knocking may be due to mechanical trouble such as a loose bearing, etc., or to explosive defects. Under the latter head there are two classes of knocks, "gas knocks" and "spark knocks." A gas knock is caused by too rich a mixture or by opening the throttle too quickly. It is an infrequent phenomenon. A spark knock is caused by advancing the spark too far. A slight preignition occurs, and though it is not early enough to cause reversal of the engine rotation, it puts undue stress on the engine parts and causes a "tiny" thump. Carbon deposits will cause knocking in the cylinder. Near the end of the compression stroke these become incandescent and premature ignition then takes place.

Crank Chamber Explosions in a two cycle engine are caused by a thin mixture or a retarded spark. In either case combustion is not complete when the admission port is uncovered and the burning gases come in contact with the fresh charge in the admission pipe, igniting them. The explosion transmitted through this pipe to the crank chamber may be a source of much annoyance, for frequently the crank case cover gasket is blown out and must be replaced to keep the case gas tight.

A Smoky Exhaust indicates too rich a mixture or an excess of lubricating oil. In the latter case the exhaust is black or dark brown, burnt oil vapor being present. In the former case the exhaust is generally hazy and lighter and carries the pungent smell of unburnt fuel.

Lost Compression may be due to improper lubrication. An important point that is often overlooked is that the film of oil between the piston ring and cylinder forms a packing, and if this is not perfect, the gas will leak by on the compression stroke. This is technically known as "blowing." Other and more frequent causes of loss of compression are overheating, leaky or broken valves or rings, leaky spark plug gaskets and relief cocks, and scored or worn cylinder walls.

Premature Ignition may be produced by advancing the spark too far, too high compression, overheating, overloading the engine, or by carbon deposits on the piston or cylinder heads becoming incandescent. The remedies are obvious. Carbon deposits must be removed periodically. This is generally done by scraping, although there are several reliable solutions on the market for this purpose.

Carbureter Defects are common and numerous. The needle valve may leak and flood the gasoline chamber. This will cause a very rich mixture, and can be remedied by grinding the valve. The air valve or throttle may become stuck. The auxiliary air valve spring may not be properly adjusted to give the correct mixture at high speeds. Water may accumulate in the float chamber, if present in the gasoline. A drain cock is generally provided to avoid this difficulty. The spray nozzle may clog if there is dirt in the gasoline. Gasoline should be thoroughly strained through chamois before putting it into the tank. This will remove all dirt and water, if carefully done. A thorough knowledge of the carbureter is essential for successful operation of any internal combustion engine.

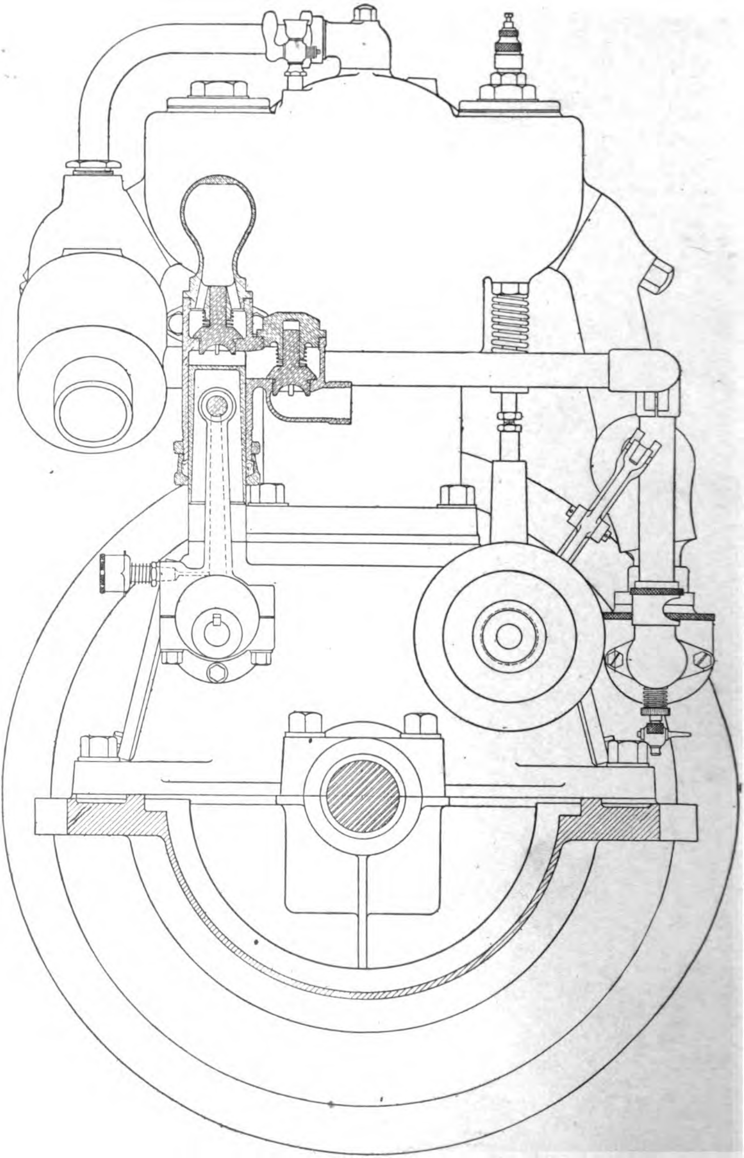

FIG. 40.— Sterling Engine.

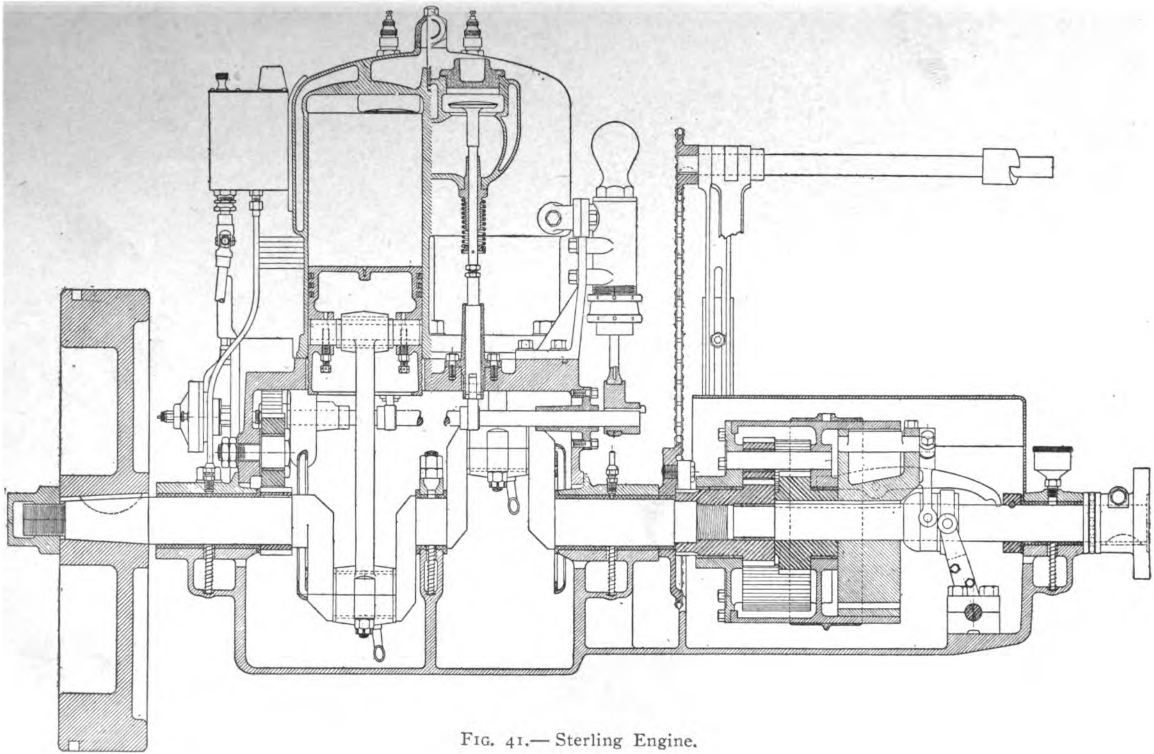

Fig. 41.— Sterling Engine.

CHAPTER IX

ENGINES

THIS chapter is devoted to the descriptions of several four cycle and two cycle engines. The engines chosen as examples are arbitrarily picked from a large field, not for any inherent superiority, but because they typify good design.

Four Cycle Engines

THE STERLING GASOLINE MARINE ENGINE

An example of excellent marine gasoline engine is shown in Figs. 40 and 41. The plates are self explanatory. These engines are built in sizes ranging from 8 to 240 horse-power.

The cylinders are cast of special hard, close-grained, gray iron, the cylinder proper being chilled to present a very hard surface (Fig. 42). The admission and exhaust valves are located on opposite sides of the cylinder and are all mechanically operated and are interchange-

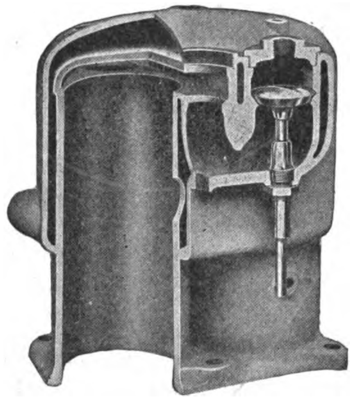

Fig. 42.—Cylinders and Valves.

able. Valve seats are entirely surrounded by water jackets, and the inlet and exhaust passages are large and free from sharp bends. Valve caps admit of easy access to the valves for inspection. The large valve is a good feature of the design. The valve stem guides are exceptionally long, preventing leakage of the exhaust, and also preventing the incoming charge from sucking air past the inlet valve stem and thus impoverishing the mixture.

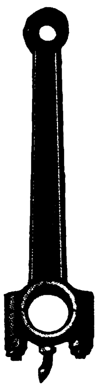

Fig. 43.—Connecting Rod.

The connecting rods, Fig. 43, are of drop forged steel, "I" section. The upper end is provided with a phosphor bronze bushing, which actuates on a hardened steel wrist pin. The lower end has a scoop to dip into the crank case oil.

The crank shaft, Fig. 44, is made of carbon steel. All bearings are

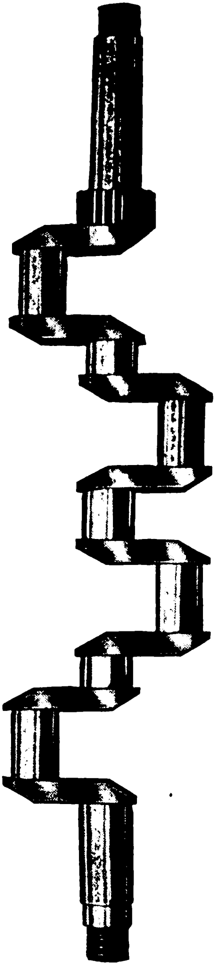

Fig. 44.—Crank Shaft; Three Point Suspension.

ground to size within .0005 inch in diameter and .002 inch in length. The forward end is turned taper and has a key-way cut for attaching the fly-wheel. The crank shaft has three main bearings and this is known as "three point suspension."

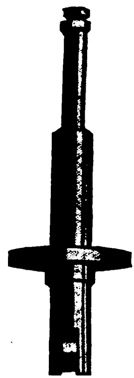

Fig. 45.—Push Rod.

The push rods, Fig. 45, which operate the valves are of steel. The lower end receives the hardened steel roller which bears directly on the cam. These rods are fitted with adjustable screws which admit of adjustment of the valves without disturbing any other parts. Push rod guides are of hard bronze, supporting the push rod nearly its entire length. This guide is secured to the engine base by stud bolts.

The water circulating pump is of the large plunger type and expansion joints are used on the water connections. The exhaust manifold is water-jacketed its full length.

The lubrication system is mechanical. Oil is pumped from the reservoir through the tubes to the oil rings and the cam gears, and from there flows to the base, maintaining the necessary level of oil for the splash system that is used for the cylinders.

The lower base is divided into pockets by partitions between the connection rods. This maintains a constant level of oil regardless of the pitching of the boat. Without these partitions all the oil would run to the end of the engine that is temporarily lowest. The crank pins are lubricated by oil which enters the scoop and passes through a duct in the connecting rod cap.

Ignition is by the jump spark system.

DETAILS OF 20TH CENTURY ENGINE

The 20th Century gasoline marine engine is of the four cycle type. It is illustrated in Figs. 46 and 47, which are self explanatory. Figs. 48 and 49 show some of the constructional details.

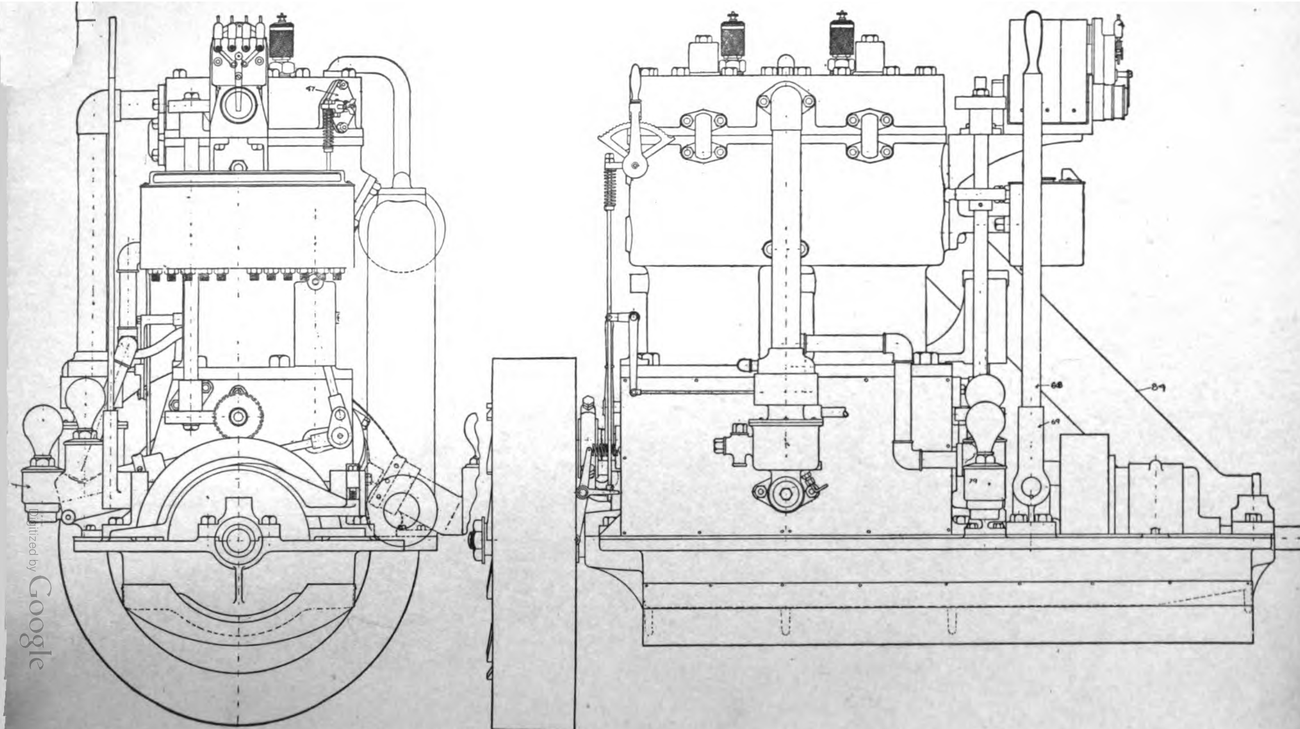

FIG. 46.— 20th Century Engine.

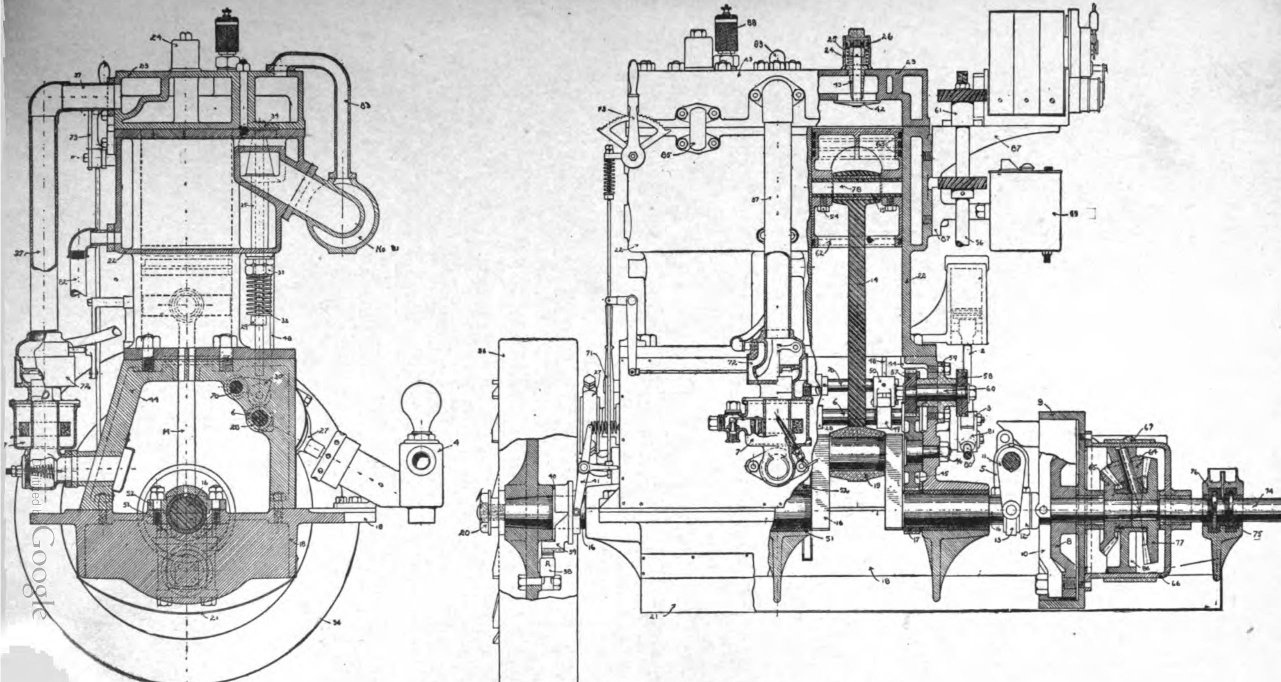

FIG. 47.— 20th Century Engine, Cross Section.

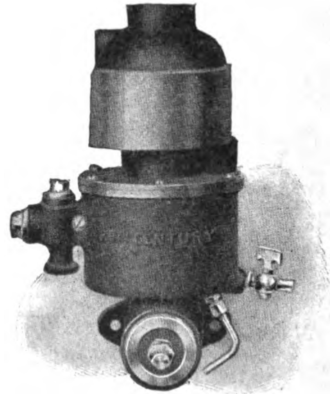

FIG. 48.— Carbureter.

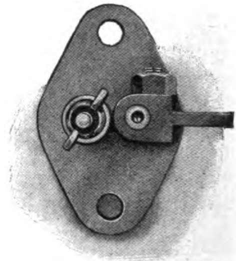

FIG. 49.— Igniter.

Two Cycle

THE GRAY, MODEL U, MARINE MOTOR

The Gray Motor is made in units of from 3 to 50 horse power, from 1 to 6 cylinders, both two-cycle and four-cycle. It is one of the most popular marine power plants. The Model U engine is an example of good one cylinder, two-cycle design. Fig. 50 shows a cross section of this engine.

The piston is at the end of its explosion stroke. When in the position shown fresh mixture is passing from the crank case through the *by-pass* to the *cylinder* while exhaust gas is discharged from the *cylinder* through the *exhaust* port. As the piston moves upward it covers the *exhaust* and *by-pass* and, near the end of its

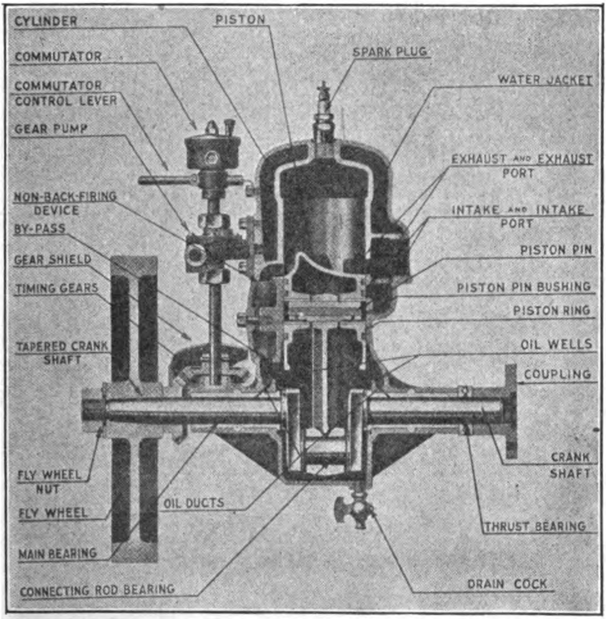

FIG. 50.—Part Sectional View Showing Arrangement of Parts in Gray Marine Motor, Model U.

stroke, uncovers the *intake port* admitting a fresh charge to the crank case.

The *commutator*, or timer, and the circulating *pump* are driven by a vertical shaft geared off the main shaft by *timing gears.* A unique feature of this engine is a gauze screen in the by-pass which acts as a *non-back-firing device.*

Some of the good features in the Gray design are sturdiness, ample main bearings with interchangeable white nickel babbit bushings, ample water jacket, and excellent equipment.

THE MIETZ AND WEISS MARINE OIL ENGINE

The Mietz and Weiss marine oil engine operates on kerosene, fuel, or crude oil; the fuel is injected directly into the cylinder. The manufacturers claim a consumption of one pint of oil per horse-power hour under full load and a decrease in consumption in almost direct proportion to the decrease in load plus the idle consumption (amount required to overcome friction). It is a form of two cycle engine receiving one impulse every revolution.

Fig. 51 shows a cross section of the engine. The piston is of the trunk pattern fitted with cast iron packing rings. The cylinders are amply water-jacketed; the circulation is by a rotary pump driven by gear from the main shaft. Circulating water enters the base of the jacket,

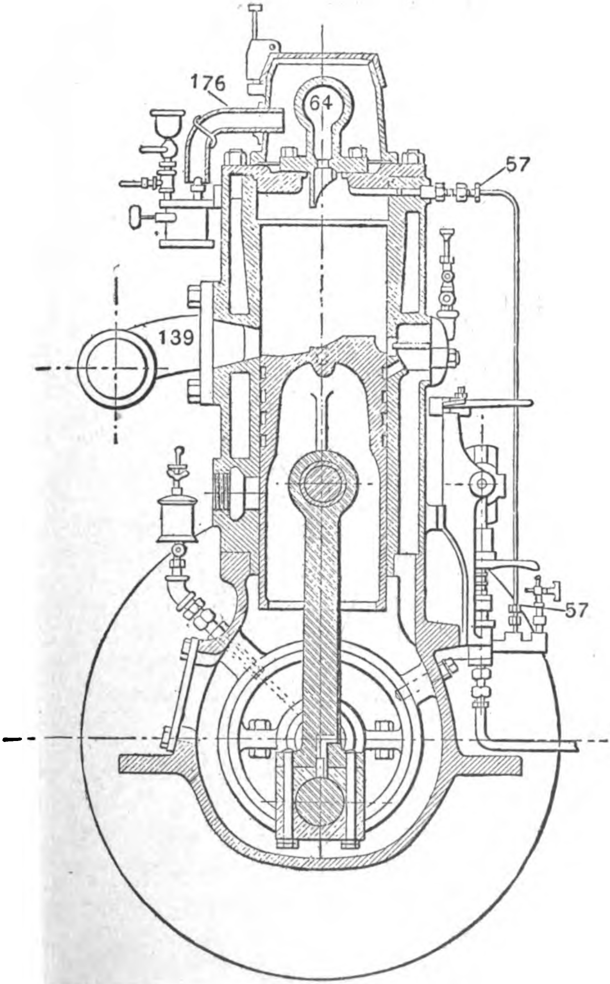

FIG. 51.— Mietz and Weiss Kerosene Engine.

is forced up to the top and is led into the exhaust pipe to prevent overheating of the latter. This is a common marine practice.

Fuel is supplied by a pump which is regulated by a governor so that the amount of fuel supplied is a function of the speed and load. The fuel enters the cylinder by the pipe 57 and encounters the hot bulb 64, which vaporizes and ignites it. Waste gases pass out at the exhaust 139. When the engine is to be started cold the bulb must be heated to dull red heat by an external burner 176. The details of this arrangement are shown in Fig. 52. After the first explosion the bulb will retain its heat and the ignition is by a combination of compression and hot bulb.

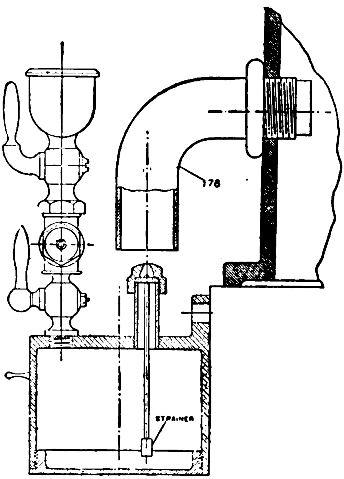

FIG. 52.—Sectional View of Starting Lamp Showing Burner and Blowpipe.

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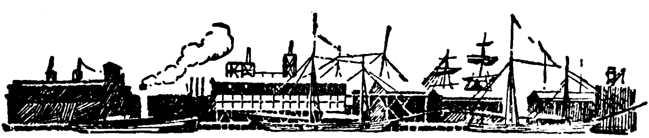

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11. OUTDOOR SIGNALLING, by Elbert Wells. Mr. Wells has perfected a method of signalling by means of wig-wag, light, smoke, or whistle which is as simple as it is effective. The fundamental principle can be learned in ten minutes and its application is far easier than that of any other code now in use. It permits also the use of cipher and can be adapted to almost any imaginable conditions of weather, light, or topography.

12. TRACKS AND TRACKING, by Josef Brunner. After twenty years of patient study and practical experience, Mr. Brunner can, from his intimate knowledge, speak with authority on this subject. "Tracks and Tracking" shows how to follow intelligently even the most intricate animal or bird tracks. It teaches how to interpret tracks of wild game and decipher the many tell-tale signs of the chase that would otherwise pass unnoticed. It proves how it is possible to tell from the footprints the name, sex, speed, direction, whether and how wounded, and many other things about wild animals and birds. All material has been gathered first hand; the drawings and half-tones from photographs form an important part of the work.

13. WING AND TRAP-SHOOTING, by Charles Askins. Contains a full discussion of the various methods, such as snap-shooting, swing and half-swing, discusses the flight of birds with reference to the gunner's problem of lead and range and makes special application of the various points to the different birds commonly shot in this country. A chapter is included on trap shooting and the book closes with a forceful and common-sense presentation of the etiquette of the field.

14. PROFITABLE BREEDS OF POULTRY, by Arthur S. Wheeler. Mr. Wheeler discusses from personal experience the best-known general purpose breeds. Advice is given from the standpoint of the man who desires results in eggs and stock rather than in specimens for exhibition. In addition to a careful analysis of stock—good and bad—and some conclusions regarding housing and management, the author writes in detail regarding Plymouth Rocks, Wyandottes, Orpingtons, Rhode Island Reds, Mediterraneans and the Cornish.

15. RIFLES AND RIFLE SHOOTING, by Charles Askins. A practical manual describing various makes and mechanisms, in addition to discussing in detail the range and limitations in the use of the rifle. Treats on the every style and make of rifle as well as their use. Every type of rifle is discussed so that the book is complete in every detail.

16. SPORTING FIREARMS, by Horace Kephart. This book is the result of painstaking tests and experiments. Practically nothing is taken for granted. Part I deals with the rifle, and Part II with the shotgun. The man seeking guidance in the selection and use of small firearms, as well as the advanced student of the subject, will receive an unusual amount of assistance from this work. The chapter headings are: Rifles and Ammunition—The Flight of Bullets—Killing Power—Rifle Mechanism and Materials—Rifle Sights—Triggers and Stocks—Care of Rifle—Shot Patterns and Penetration—Gauges and Weights—Mechanism and Build of Shotguns.

17. THE YACHTSMAN'S HANDBOOK, by Herbert L. Stone. The author and compiler of this work is the editor of "Yachting." He treats in simple language of the many problems confronting the amateur sailor and motor boatman. Handling ground tackle, handling lines, taking soundings, the use of the lead line, care and use of sails, yachting etiquette, are all given careful attention. Some light is thrown upon the operation of the gasoline motor, and suggestions are made for the avoidance of engine troubles.

18. SCOTTISH AND IRISH TERRIERS, by Williams Haynes. This is a companion book to "The Airedale," and deals with the history and development of both breeds. For the owner of the dog, valuable information is given as to the use of the terriers, their treatment in health, their treatment when sick, the principles of dog breeding, and dog shows and rules.

19. NAVIGATION FOR THE AMATEUR, by Capt. E. T. Morton. A short treatise on the simpler methods of finding position at sea by the observation of the sun's altitude and the use of the sextant and chronometer. It is arranged especially for yachtsmen and amateurs who wish to know the simpler formulae for the necessary navigation involved in taking a boat anywhere off shore. Illustrated with drawings. Chapter headings: Fundamental Terms—Time—The Sumner Line—The Day's Work, Equal Altitude, and Ex-Meridian Sights—Hints on Taking Observations.

20. OUTDOOR PHOTOGRAPHY, by Julian A. Dimock. A solution of all the problems in camera work out-of-doors. The various subjects dealt with are: The Camera—Lens and Plates—Light and Exposure—Development—Prints and Printing—Composition—Landscapes—Figure Work—Speed Photography—The Leaping Tarpon—Sea Pictures—In the Good Old Winter Time—Wild Life.

21. PACKING AND PORTAGING, by Dillon Wallace. Mr. Wallace has brought together in one volume all the valuable information on the different ways of making and carrying the different kinds of packs. The ground covered ranges from man-packing to horse-packing, from the use of the tump line to throwing the diamond hitch.

22. THE BULL TERRIER, by Williams Haynes. This is a companion book to "The Airedale" and "Scottish and Irish Terriers" by the same author. Its greatest usefulness is as a guide to the dog owner who wishes to be his own kennel manager. A full account of the development of the breed is given with a description of best types and standards. Recommendations for the care of the dog in health or sickness are included. The chapter heads cover such matters as:—The Bull Terrier's History—Training the Bull Terrier—The Terrier in Health—Kenneling—Diseases.

23. THE FOX TERRIER, by Williams Haynes. As in his other books on the terrier, Mr. Haynes takes up the origin and history of the breed, its types and standards, and the more exclusive representatives down to the present time. Training the Fox Terrier—His Care and Kenneling in Sickness and Health—and the Various Uses to Which He Can Be Put—are among the phases handled.

24. SUBURBAN GARDENS, by Grace Tabor. Illustrated with diagrams. The author regards the house and grounds as a complete unit and shows how the best results may be obtained by carrying the reader in detail through the various phases of designing the garden, with the levels and contours necessary, laying out the walks and paths, planning and placing the arbors, summer houses, seats, etc., and selecting and placing trees, shrubs, vines and flowers. Ideal plans for plots of various sizes are appended, as well as suggestions for correcting mistakes that have been made through "starting wrong."

25. FISHING WITH FLOATING FLIES, by Samuel G. Camp. This is an art that is comparatively new in this country although English anglers have used the dry fly for generations. Mr. Camp has given the matter special study and is one of the few American anglers who really understands the matter from the selection of the outfit to the landing of the fish. His book takes up the process in that order, namely—How to Outfit for Dry Fly Fishing—How, Where, and When to Cast—The Selection and Use of Floating Flies—Dry Fly Fishing for Brook, Brown and Rainbow Trout—Hooking, Playing and Landing—Practical Hints on Dry Fly Fishing.

26. THE GASOLINE MOTOR, by Harold Whiting Slauson. Deals with the practical problems of motor operation. The standpoint is that of the man who wishes to know how and why gasoline generates power and something about the various types. Describes in detail the different parts of motors and the faults to which they are liable. Also gives full directions as to repair and upkeep. Various chapters deal with Types of Motors—Valves — Bearings — Ignition — Carburetors — Lubrication— Fuel — Two Cycle Motors.

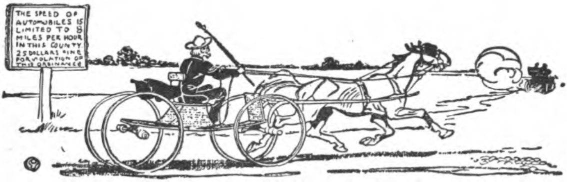
27. **ICE BOATING, by H. L. Stone.** Illustrated with diagrams. Here have been brought together all the available information on the organization and history of ice-boating, the building of the various types of ice yachts, from the small 15 footer to the 600-foot racer, together with detailed plans and specifications. Full information is also given to meet the needs of those who wish to be able to build and sail their own boats but are handicapped by the lack of proper knowledge as to just the points described in this volume.

28. **MODERN GOLF, by Harold H. Hilton.** Mr. Hilton is the only man who has ever held the amateur championship of Great Britain and the United States in the same year. In addition to this, he has, for years, been recognized as one of the most intelligent, steady players of the game in England. This book is a product of his advanced thought and experience and gives the reader sound advice, not so much on the mere swinging of the clubs as in the actual playing of the game, with all the factors that enter into it. He discusses the use of wooden clubs, the choice of clubs, the art of approaching, tournament play as a distinct thing in itself, and kindred subjects.

29. **INTENSIVE FARMING, by L. C. Corbett.** A discussion of the meaning, method and value of intensive methods in agriculture. This book is designed for the convenience of practical farmers who find themselves under the necessity of making a living out of high-priced land.

30. **PRACTICAL DOG BREEDING, by Williams Haynes.** This is a companion volume to PRACTICAL DOG KEEPING, described below. It goes at length into the fundamental questions of breeding, such as selection of types on both sides, the perpetuation of desirable, and the elimination of undesirable, qualities, the value of prepotency in building up a desired breed, etc. The arguments are illustrated with instances of what has been accomplished, both good and bad, in the case of well-known breeds.

31. **PRACTICAL DOG KEEPING, by Williams Haynes.** Mr. Haynes is well known to the readers of the OUTING HANDBOOKS as the author of books on the terriers. His new book is somewhat more ambitious in that it carries him into the general field of selection of breeds, the buying and selling of dogs, the care of dogs in kennels, handling in bench shows and field trials, and at considerable length into such subjects as food and feeding, exercise and grooming, disease, etc.



32. **PRACTICAL TREE PLANTING, by C. R. Pettis.** The author, who is the New York State Forester, takes up the general subject of reforesting, covering nature's method and the practical methods of broadcast seed-sowing, seed spot planting, nursery practice, etc. The various species are described and their adaptability to varying conditions indicated. Results of reforesting are shown and instructions are given for the planting of windbreaks and shade trees.

33. **AMATEUR RODMAKING, by Perry D. Frazer. Illustrated.** A practical manual for all those who want to make their own rod and fittings. It contains a review of fishing rod history, a discussion of materials, a list of the tools needed, description of the method to be followed in making all kinds of rods, including fly-casting, bait-fishing, salmon, etc., with full instructions for winding, varnishing, etc.

34. **PISTOL AND REVOLVER SHOOTING, by A. L. A. Himmelwright.** A new and revised edition of a work that has already achieved prominence as an accepted authority on the use of the hand gun. Full instructions are given in the use of both revolver and target pistol, including shooting position, grip, position of arm, etc. The book is thoroughly illustrated with diagrams and photographs and includes the rules of the United States Revolver Association and a list of the records made both here and abroad.

35. **PIGEON RAISING, by Alice MacLeod.** This is a book for both fancier and market breeder. Full descriptions are given of the construction of houses, the care of the birds, preparation for market, and shipment. Descriptions of the various breeds with their markings and characteristics are given. Illustrated with photographs and diagrams.

36. **FISHING TACKLE, by Perry D. Frazer. Illustrated.** The subtitle is descriptive. "Hints for Beginners in the Selection, Care, and Use of Rods, Reels, Lines, etc." It tells all the fisherman needs to know about making and overhauling his tackle during the closed season and gives full instructions for tournament casting and fly-casting. Chapters are included on cases and holders for the care of tackle when not in use.

37. AUTOMOBILE OPERATION, by A. L. Brennan, Jr. Illustrated. Tells the plain truth about the little things that every motorist wants to know about his own car. Do you want to cure ignition troubles? Overhaul and adjust your carbureter? Keep your transmission in order? Get the maximum wear out of your tires? Do any other of the hundred and one things that are necessary for the greatest use and enjoyment of your car? Then you will find this book useful.

38. THE FOX HOUND, by Roger D. Williams. Author of "Horse and Hound". Illustrated. The author is the foremost authority on fox hunting and foxhounds in America. For years he has kept the foxhound studbook, and is the final source of information on all disputed points relating to this breed. His book discusses types, methods of training, kenneling, diseases and all the other practical points relating to the use and care of the hound. An appendix is added containing the rules and regulations of hound field trials.

39. SALT WATER GAME FISHING, by Charles F. Holder. Mr. Holder covers the whole field of his subject devoting a chapter each to such fish as the tuna, the tarpon, amber-jack, the sail fish, the yellow-tail, the king fish, the barracuda, the sea bass and the small game fishes of Florida, Porto Rico, the Pacific Coast, Hawaii, and the Philippines. The habits and habitats of the fish are described, together with the methods and tackle for taking them. The book concludes with an account of the development and rules of the American Sea Angling Clubs. Illustrated.

40. WINTER CAMPING, by Warwick S. Carpenter. A book that meets the increasing interest in outdoor life in the cold weather. Mr. Carpenter discusses such subjects as shelter equipment, clothing, food, snowshoeing, skiing, and winter hunting, wild life in winter woods, care of frost bite, etc. It is based on much actual experience in winter camping and is fully illustrated with working photographs.

41. LEARNING TO SWIM, by L. DeB. Handley. Illustrated. Mr. Handley takes up the problem from the standpoint of the person of any sex or age who cannot swim a stroke. Step by step he unfolds the various stages, floating, the side stroke, the crawl, the trudgeon, the breast stroke, swimming on the back, etc., concluding with a chapter on speed swimming and training for racing. It covers the whole field of natation in a clear, simple manner, with photographs showing each stroke in detail.

42. BOAT AND CANOE BUILDING, by Victor Slocum. All of us like to think we could build a boat if we had to. Mr. Slocum tells us how to do it. Designs are given for the various types of canoes as well as full descriptions for preparing the material and putting it together. Small dories and lapstreak boats are also included

43. PRACTICAL PROSPECTING, by Charles Johnson Post. Illustrated. Did you ever wonder what ore-bearing rock looked like? Did you ever want to know how to test it for the various minerals? Would you be interested in learning how to put together a rough and ready outfit that would do all the work of the more expensive kits? This book covers all these points and more. It is a valuable companion for a walking trip through the hills. It tells you not only where minerals are found and how, but also where you need not expect to find them.

44. BOXING, by D. C. Hutchison. Practical instruction for men who wish to learn the first steps in the manly art. Mr. Hutchison writes from long personal experience as an amateur boxer and as a trainer of other amateurs. His instructions are accompanied with full diagrams showing the approved blows and guards. He also gives full directions for training for condition without danger of going stale from overtraining. It is essentially a book for the amateur who boxes for sport and exercise.

45. TENNIS TACTICS, by Raymond D. Little. Out of his store of experience as a successful tennis player, Mr. Little has written this practical guide for those who wish to know how real tennis is played. He tells the reader when and how to take the net, discusses the relative merits of the back-court and volleying game and how their proper balance may be achieved; analyzes and appraises the twist service, shows the fundamental necessities of successful doubles play.

46. THE AUXILIARY YACHT, by H. L. Stone. Combines information on the installation of power in a boat that was not designed especially for it with the features desirable in designing a boat for this double use. Deals with the peculiar properties of the auxiliary, its advantages and disadvantages, the handling of the boat under sail and power, etc. Does not go into detail on engine construction but gives the approximate power needed for different boats and the calculations necessary to find this figure.

47. TAXIDERMY, by Leon L. Pray. Illustrated with diagrams. Being a practical taxidermist, the author at once goes into the question of selection of tools and materials for the various stages of skinning, stuffing and mounting. The subjects whose handling is described are, for the most part, the every-day ones, such as ordinary birds, small mammals, etc., although adequate instructions are included for mounting big game specimens, as well as the preliminary care of skins in hot climates. Full diagrams accompany the text.

48. THE CANOE—ITS SELECTION, CARE AND USE, by Robert E. Pinkerton. Illustrated with photographs. With proper use the canoe is one of the safests crafts that floats. Mr. Pinkerton tells how that state of safety may be obtained. He gives full instructions for the selection of the right canoe for each particular purpose or set of conditions. Then he tells how it should be used in order to secure the maximum of safety, comfort and usefulness. His own lesson was learned among the Indians of Canada, where paddling is a high art, and the use of the canoe almost as much a matter of course as the wearing of moccasins.

49. HORSE PACKING, by Charles J. Post. Illustrated with diagrams. This is a complete description of the hitches, knots, and apparatus used in making and carrying loads of various kinds on horseback. Its basis is the methods followed in the West and in the American Army. The diagrams are full and detailed, giving the various hitches and knots at each of the important stages so that even the novice can follow and use them. It is the only book ever published on this subject of which this could be said. Full description is given of the ideal pack animal, as well as a catalogue of the diseases and injuries to which such animals are subject.

50. RAINY DAY IN CAMP, by C. H. Claudy. Illustrated. What do you do when you are stormbound in the camp and time hangs heavy on your hands? This book gives a long list of games that you can play and the rules that govern them. It also describes various improvised indoor occupations appropriate to camp life. If you have it in your duffle bag you need not fear the approach of threatening clouds.

51. WALKING OUTFITS, by C. P. Fordyce. Illustrated. Every year the adherents of "hiking" in this country grow in numbers and enthusiasm. It is an old art and a valuable one. But something more than a pair of legs is necessary to make the walking trip a success. You must wear the right shoes and the right clothes. You must carry with you the right kind of sleeping and cooking outfit. Mr. Fordyce gives the concentrated experience of many years on highway and trail.

52. LEARNING TO SKATE. by J. F. Verne. Illustrated. Half the fun of skating is in knowing how to do if with the least effort. Nothing is so easy when you know how—or so hard when you don't. This book describes the process in detail from the first day on the ice to the highest development of speed and fancy skating. The author is familiar with the latest developments in Europe where figure skating has been carried to a much higher point than in America.

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