The Diesel Engine

The Development of a Remarkable Motor

By Hayner H. Gordon

ANY one who has seen a large triple expansion marine engine in operation has been impressed with the mechanical beauty of the machine. Light and powerful yet easy running, with complicated structure yet mechanically simple, it appears as though this type of engine had at last reached perfection. And yet to-day it stands ready to be replaced by a new type of engine and motive power; a motive power that even a few years ago was largely ridiculed for its unreliability. The gas engine is conquering the land, has conquered the air, and is now beginning to claim the sea for its own.

All internal combustion engines are divisible into two general classes: those in which combustion takes place at constant volume, and those in which combustion takes place at constant pressure; the first being known as the Otto type and the second as the Brayton or Diesel type.

In order to make the difference between these two types clearer, it will be well to follow the cycle of operations in each case. In the Otto four-cycle engine, the piston on the first stroke down draws in the combustible mixture. The up stroke then takes place, compressing the charge to a pressure limited by the ignition temperature of the charge used. This is usually from 60 to 120 pounds per square inch; at the top of this stroke the charge is ignited, and the piston is driven down by the pressure generated by the explosion of the charge. The fourth stroke then follows; the piston rising and the exhaust products passing out through the opened exhaust valve.

In the Diesel cycle the first stroke of the piston draws pure air into the cylinder; the piston then rises, compressing the air to a pressure of 500 or 600 pounds to the square inch, and thereby raising its temperature to about 500 deg. C. This high pressure is obtained by having very small clearance. At the top of the compression stroke an oil valve in the cylinder head is opened, and oil is forced into the cylinder in the form of a fine spray. This is at once ignited from the highly heated air, and continues to burn until the oil is cut off at about one-quarter to one-third of the down stroke of the piston. Expansion follows for the rest of the stroke, and the fourth stroke then takes place as in the Otto cycle.

In the two-cycle engines of either class, the piston uncovers ports at the end of its downward travel, the exhaust products passing out through one set of ports while the new charge is blown into the cylinder under slight pressure through the other ports. The charge of course consists of combustible mixture in the Otto engine, and air in the Diesel engine. Compression and working stroke then follow as in the case of the four-cycle engine.

Three points of superiority of the Diesel engine over the Otto engine will at once be noted. The first of these is the fact that there is no igniter present in the Diesel engine, and that therefore no ignition trouble can take place. Also there will be no trouble from pre-ignition, for there is no fuel in the cylinder during the up stroke of the piston.

The second point is that there is no carburetion or mixture troubles. In an engine of the Otto type, there is always a varying amount of exhaust products present in the mixture at various speeds which necessitates close regulation of the fuel supply. In the Diesel engine, the speed and power of the engine are entirely controlled by regulating the point in the working stroke at which the fuel is cut off. The last point in favor of the Diesel engine is the fact that the change in pressure is not violent as is the case in the Otto engine, but gradually increases during the compression stroke, reaching the maximum at the end of the stroke, and then remaining approximately constant until the fuel cut-off takes place.

The cylinders of the Diesel engine are of small bore with a long stroke. The pistons have to be well fitted in order to retain the high compression. Sometimes as many as ten piston rings are used for this purpose.

The fuels which may be used in the Diesel engine range from the lightest hydrocarbons to the heaviest crude oils. As the fuel must be entirely atomized upon entrance to the cylinder, we find a great many different types of valves for the different grades of oil. The valves are divisible, however, into two general classes: Those which make use of a fuel pump to force the fuel into the cylinder, and those which use compressed air to blow it in. Valves of the first type comprise a small passage through the cylinder head with a needle valve to adjust the nozzle or spray and which opens into the cylinder. Fuel is pumped to this spray valve by a small single acting plunger pump, at a pressure of 750 pounds per square inch, the length of stroke of the pump plunger being generally made adjustable, in order to time the admission of the fuel to the work of the engine.

The compressed air fuel admission valve is more largely used than the type just described. This valve usually consists of a hollow plug fitting in the cylinder head of the engine, and containing an inwardly opening check valve in the inner end. The hole in the center of this plug receives the charge of oil under a few pounds pressure, during the compression stroke of the engine, and then high pressure air at 750 pounds is admitted to the chambered plug, and the oil blown into the cylinder of the engine in the form of a fine

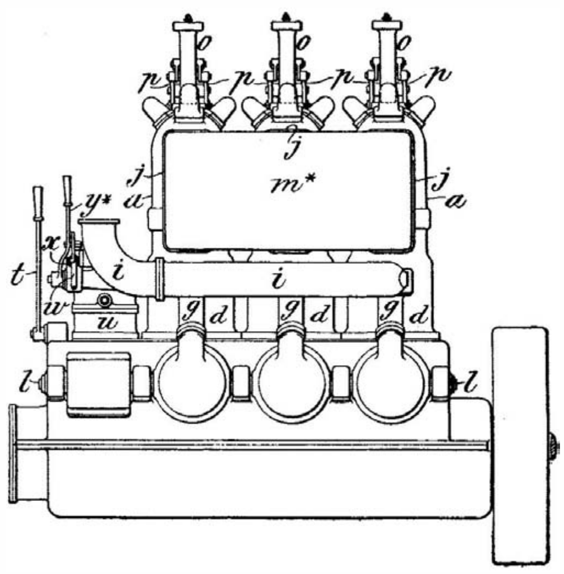

Fig. 1.—Reversing gear dependent upon changing position of cams relatively to the crank shaft.

spray. A valve of this type of course necessitates the use of a separate air compressor, but this is generally needed any way in order to furnish compressed air for starting the engine. In order to start the engine by compressed air, there is an auxiliary starting air inlet valve, which is operated from a cam on the camshaft to admit the high pressure air on a portion of the working stroke of the engine, thereby running it as an ordinary air engine. As soon as the engine picks up speed, the air valves are thrown out of operation by lifting the rockers off the cams or other equivalent method, and the engine picks up its regular cycle.

In addition to being equipped with self starting apparatus, the Diesel motor must also be made reversible, when used for marine purposes. In the case of low

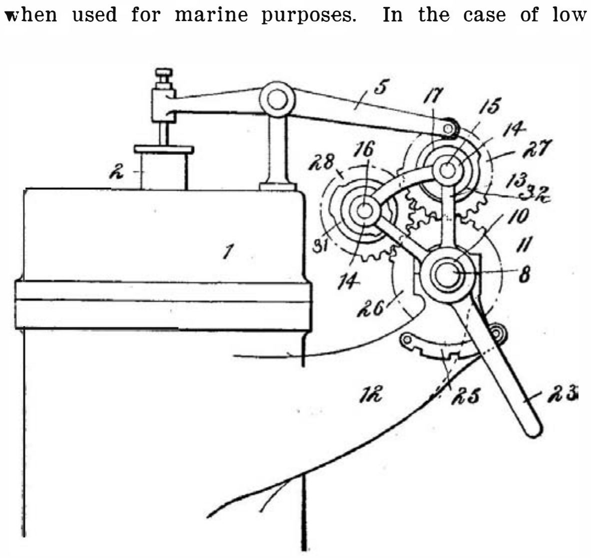

Fig. 2.—Reversing by means of two sets of cams, one for each direction of rotation.

power and small engines, it is possible to use either a reverse clutch or a reversible propeller, but such practice is impossible in engines of a thousand horse-power or over.

There are two methods employed in practice for reversing marine motors. The first is to change the angular position of the cams with respect to the crank shaft, and each other.

Fig. 1 shows a small Diesel marine engine employing this method of reversing. This engine possesses very unusual features in regard to the starting. It is of the two-cycle type, with exhaust ports controlled by the piston, and possesses an air compressing cylinder for each engine cylinder. To start, compressed air from the air tanks is admitted to the pump cylinders, which act to drive the engine until it picks up its cycle. This engine employs two separate cam shafts, one operating the oil valves and the other driving the pumps. The adjustment of the shaft is made by means of sliding spiral gears which drive the cam shafts. These sliding spiral gears are controlled by the longer lever on the left hand end of the engine. The short lever controls the starting air.

The other method is to use two sets of cams, one set being used for each direction of rotation. These cams are sometimes placed on the same cam shaft, which is made longitudinally adjustable under the lifters. A modification makes use of two cam shafts, one for ahead and the other for astern. These shafts may be swung in position under the valve lifters. Such an arrangement is shown in Fig. 2.

The reversing mechanism for the two-cycle engines is not quite so complicated as that for the four-cycle, the only valve mechanism necessary being that for the starting and fuel valves.

Probably the one feature of the Diesel motor which is causing its introduction into the marine field more than anything else, is its efficiency. Tests have been made on large engines of this type which show the almost remarkable figures of 0.38 pound of fuel used per brake horse-power hour. This is for crude oil. The marine engines of this type now in use average from 0.40 to 0.44 pound of fuel per brake horse-power hour while running under full load. When we compare these figures with those of the best triple expansion marine engines, which burn 1.46 pounds of coal per brake horse-power hour, we at once see the great advantage of the Diesel engine. In round figures, the Diesel engine will drive a ship just as fast and just as far on 100 tons of fuel, as a steam engine would on 350 tons of coal. Moreover, the liquid fuel may be stored in tanks placed in the double bottom of the ship; thereby giving space formerly occupied by the boilers and coal bunkers, over to passenger and cargo space. The earning power of the ship is thereby increased; the engine room space needed for an oil engine is just about the same as the engine room needed for the steam engine equipment.

The accessories needed for the Diesel engine require about the same space as the condenser and pumps of the steam engine.

The construction of the marine oil engine seems to follow along the standard lines laid down by steam engine practice; all the large oil engines so far constructed have a short piston and use flat guides, and a cross head with the ordinary open construction. It has been stated that it is poor practice to use the trunk piston, on account of the slight longitudinal movement of the crank shaft as the thrust bearings wear. With flat guides this slight play would make no difference, and the open construction also renders inspection easier.

The air pump for obtaining air for starting, and for fuel injection purposes, is generally obtained from a three-stage air compressor, which is driven from the cross heads of the three cylinders, air being cooled between the compressor stages. The circulation pumps are also driven from the main engine; but an auxiliary air compressor and auxiliary circulation pumps driven by smaller oil engines are provided for breakdown purposes. The bilge and fire pumps are either electrically driven, or driven by a separate engine, and electric current for light and power purposes is provided by direct-coupled generators driven by oil engines.

The oil engines in use at the present time—and building—comprise both two and four-cycle single and double acting. Each type has many good features of its own and it is almost too early to state which is the better; the construction of the two-cycle, double-acting engine is complicated, but the number of cylinders is reduced for a given power. On the other hand, in an engine with eight cylinders, one cylinder may not become inoperative without affecting the power of the engine to a very great extent.

It is safe to say that the development of the oil engine in this new rôle will proceed rapidly. With several German firms building large vessels equipped with oil engines, with the report that the German Admiralty is building a cruiser to be equipped with two six-cylinder engines each of 6,000 horse-power, and with several Glasgow firms building vessels similarly equipped, we shall soon see the oil engine given ample trials.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Revival of the Merchant Marine

To the Editor of the SCIENTIFIC AMERICAN:

I write to express my high appreciation of the great interest which since April 1st you have been manifesting in the upbuilding of the American merchant marine.

Everything published on this subject, either in your editorial or your correspondence columns, is greedily devoured by this writer, who for the past twelve years has made a special study of ship subsidy, mail subsidy, postal subvention, preferential duties, free ships, and every other measure suggested by human ingenuity for restoring that branch of our merchant marine engaged in the foreign or deep-sea trade to the proud position it formerly occupied.

The greatest difficulty in doing this seems to be in getting people living in the interior of the continent, remote from the seaboard, to take an interest in or to inform themselves on such matters.

The writer bids you Godspeed in the work you propose to undertake. JAMES G. MCBRIDE.

Canton, Miss.

One Man Who Saw the Meteor Train

To the Editor of the SCIENTIFIC AMERICAN:

Regarding the letter on your page 275 *re* "Meteor Train," I was one of a party of about a dozen at Mamaroneck, New York, who saw the appearance substantially as described by Mr. Pfarre.

Philadelphia, Pa. EDWARD T. CHILD.

Lessons of the Gordon Bennett Flying Race

To the Editor of the SCIENTIFIC AMERICAN:

With reference to the above subject in your issue of August 19th, will you kindly permit a few supplementary remarks in concurrence with Mr. Grover Loening's views thereon? Your contributor lays particular stress upon the difficulty experienced by such able exponents as Weymann and Leblanc in turning sharply at each pylon, and emphasizes on the other hand the facility and also marvelous "banking" performed by Ogilvie on the "Baby Wright."

Now it is certainly correct that this feat is difficult at all times with such superficial area out of all proportion in the case of the 60 square feet surface of the clipped Blériot, but it is also equally certain that the centrifugal force generated by the single tractor-screw is a factor not to be overlooked. That of the Nieuport was 7 feet diameter, the Blériot 8½ feet, while the twin propellers of the Wright are 8½ feet each, the last however revolving in opposite directions and thus counteracting centrifugal action magnified in the monoplanes. Consequently, the Wright—or its equivalent, a monoplane with twin propellers—is able to "bank" acutely in negotiating turns which would necessitate wide curves with the single-screw type or an alternative loss of stability and disaster. A still further point of importance with monoplanes driven by twin screws is the greater velocity attainable over the biplane similarly propelled, with furthermore the facility to forge against stronger winds—a real desideratum.

It is really extraordinary to note at the present moment the continuous copying universally of the Wrights' patent warping system, either flagrantly emulating the bending of the rear marginal tips in conjunction with the foot-operated vertical rudder, or the virtual reproduction of the same by means of ailerons—a system which although copied from nature is by no means the most powerful in controlling lateral stability by the bird. That perfect aviator among other methods demonstrates to us that by warping, or rather *depressing*, the outer half of one wing and correspondingly elevating the other, he obviates all danger of law litigation by encroaching on the Wright patent!

Well might Mr. Grover Loening in his able article refer to the emphasizing for the need of the "variable surface" monoplane shown by the Gordon Bennett race. Not only will greater speed be accomplished by the adoption of the bird-like wing, but so will inherent or natural stability be automatically secured in tumultuous winds by means of flexible construction in addition to this urgent need for variable surface. Therefore, the lessons demonstrated not only by the Gordon Bennett flying race, but by daily flights throughout the globe, for the production and evolution of the ideal mechanical flying machine, may be succinctly summarized in the following requirements: (1) The improvement of the car or fuselage in finer stream-line Nieuport form; (2) twin propellers of large diameter to thus engage a larger volume of air or "disk area," and rotating in opposite directions to minimize undue centrifugal force; (3) constructing the main planes flexible with small camber, high aspect ratio, and single-surfaced; (4) by superior lateral control other than that employed in the biplane of the Wrights and assured by the graduating of main spars toward the tips; (5) by variable surfacing of main planes or wings to insure higher speeds and susceptibility to encounter safely higher wind velocities by such diminution and augmentation of the supporting area; (6) the discarding of the vertical rudder acting in conjunction with the main planes for steering in the horizontal plane; (7) the need for compactly folding the wings against the side of a car when not in use or descent on water; (8) and the means for increasing or decreasing the angle of incidence of the main planes to suit the requirements of flight conditions. All the above essential features are by no means impossible to reproduce in one design, and will decidedly enable a monoplane to ascend and descend from water, and in due course to fly across the Atlantic.

London, England. EDGAR E. WILSON.

The Proposed Safety Stop Locomotive Throttle

To the Editor of the SCIENTIFIC AMERICAN:

In the correspondence department of your issue dated August 19th, on page 167, I noticed an article by Aubrey D. Beidelman, of Braintree, Mass., headed: "The Bridgeport Railroad Wreck."

In the last paragraph of his communication he offers the suggestion that the throttle and brake valve handle be provided with means to automatically bring them to positions that would shut off the steam and apply the brakes in the event of the engineer's becoming incapacitated from any cause. To quote from his article, "it would be necessary for the engineer to exert some little pressure on them" to prevent their action in this manner.

He questions if a device of this kind would be inconvenient. To my mind it would be insufferably so. In traversing a rolling country it is necessary for the engineman to frequently change the position of the reverse lever, requiring the use of at least one and usually both hands. It is at times necessary for him to use the injector on his side of the engine, due to the inability of the injector on the fireman's side to deliver sufficient water to the boiler.

It is not an unheard of thing for an engineman to find it necessary to fill the lubricator while on the road.

All these things take time; and while he was attending to them, the steam would be shut off and the brakes applied, causing a considerable and undesirable reduction in speed.

In addition to his physical duties, he has to keep in mind the orders he has received, which govern his movements with respect to other trains that may be on the road, their meeting and passing points, and what time he has in which to make a given point before another train. This would be extremely difficult for a man under the continuous physical strain that would be required to maintain these two levers in running position, especially in the case of the throttle, as he would have to exert considerable force to hold it open against a device that would have any value as a positive closing mechanism.

The conditions under which an engineman works at present are not what might be termed restful. There is continual jar and pound, as a locomotive compared to a coach rides about as easily as a hay wagon compared to a limousine.

If in addition to this a man were compelled to maintain a steady and unremitting pressure for a period of from three to seven hours, the average length of a passenger run, it would be almost if not quite beyond human endurance.

Los Angeles, Cal. J. B. WELLS.

Irrigation Supplementing Water Power

A New Joint Use for Our Canals.

To the Editor of the SCIENTIFIC AMERICAN:

In order to get at the power to be obtained from waterfalls, a height of 10 available feet is taken as a convenient basis to calculate any power from.

One cubic foot of water, weight 62½ pounds, falling 10 feet produces 625 foot pounds. Requirement for one horse-power, 33,000 pounds divided by 625, gives 52.8 cubic feet, required, for one theoretical horse-power, per minute.

But as wheel efficiency is seldom over 75 per cent, we add one-third to 52.8 or 70.4 cubic feet of water, which is sufficient to cover 844 square feet, or one-fifty-second of an acre. So that the amount of water required to produce one horse-power 52 minutes would cover one acre one inch deep, if none was wasted. But as the waste is considerable, let us assume that it requires two hours to cover one acre one inch, or in ten hours the water required to yield one horse-power would cover five acres one inch deep.

Now, as power can be generated, even in small units, for not over 20 cents per horse-power for ten hours, and in large units for much less, we have one inch of water costing four cents per acre, when for some crops it would be worth easily fifty times that, and others much more, as this water is warm rain water, and far superior to well water for irrigation purposes.

In view of the above statements, can we not safely conclude that our canals, or at least such sections of them as are favorably located, should be maintained for irrigation, which as explained below, may also reduce their value for water powers but little?

In many cases the canal is so located that all the water to be spared can naturally flow onto the lands, while in some cases a ditch to the next lock may be required to get the water high enough.

The very favorable results of some small irrigating experiments in our section, I think, will fully justify our valuable experiment stations in examining available located lands, and in preparing necessary information as to suitable crops, fertilizers, sand mixing to lighten heavy soils, etc. That may enable the great increase in crops due to irrigating to be fully realized.

Now, if the power man, who is usually short of power, either for manufacturing or to sell electrically, will arrange his water wheels, etc., so as to give him the full power of the fall for say the best six months of the year, and will put in engines enough to develop the same amount of power, to be used when there is not water enough for all needed, which if for lighting will be less when water is lowest, he can have water power for all his needs for six months or more, and for nearly all the rest of the time part of the water, in fact most of it. Where the water is used only for ten hours for power, the irrigating can be done at night, as in the West. So that the power man can be in a better position, after the first cost of engine installment is paid, than if entirely dependent on the water power, as he will not only have increased power, but also power that can absolutely be depended on.

I trust that the above will be, in some way, a suggestion that will be a benefit to the community and the State in making use of its canals.

Dayton, O. J. H. STEVENS.

Automatic Stability in Aeroplanes—A Suggestion

To the Editor of the SCIENTIFIC AMERICAN:

Would you allow me to express through your valuable paper my opinion on the possible solution of the automatic lateral stability in flying machines?

The many devices designed and tried out to maintain automatic stability have as yet not met with the success which would be desirous. All further progress and the commercialization of aerial navigation depend upon the appearance of such a device. A suggestion of my own may lead to a possible solution of this problem. I describe my idea with a view of encouraging constructors of flying machines to experiment in this direction.

My automatic lateral stabilizer consists of fins, constructed of a light framework of wood or metal covered with a suitable fabric. These fins are hinged under the surface, at the extreme ends of the plane (wing tips) and can swing to both sides. When swinging inward such a fin can move until it lies flat under the surface, but toward the outward it is prevented by a strap from swinging farther than 45 degrees.

The function of the device may be conceived to be as follows:

When the plane is in motion, and as long as it is not influenced by a force caused by a side wind, the fins will be retained in a vertical position. But when the wind strikes the plane at an angle to the direction of motion, the fin nearest to the side from which the wind is coming will be laid flat under the surface of the plane. At the same time the fin on the opposite side swings outward to an angle of 45 degrees to the plane, and will present a resistance corresponding to the natural resistance on the windward side.

This arrangement seemingly works well when straight flights are made, and even in turning it seems likely to do all the banking required; but to straighten out the aeroplane after or at the termination of the turn, it may be found necessary to have recourse to the operation of ailerons. Even if this device needs at times to be supplemented by ailerons, it would do much to relieve the operator of an aeroplane of the continuous strain which the attendance of a lever mechanism to operate the lateral and the longitudinal stability means.

One of the main requirements would be to have the size of the fins in the right proportion to the plane which it serves as equalizer.

Such a device could be used on aeroplanes of all constructions, and to simplify the attachment of these fins the last five or six ribs on both sides should flatten out gradually, so as to make the extreme ends of the plane nearly flat.

Chicago, Ill. EWALD STEINHAUS.