CONTENTS[1]

PAGE

ANNUAL MEETING 2
ANNUAL DINNER 15
THE ENGINEER'S PLACE IN INDUSTRY.......... 21
AUTOMOBILE OBLIGATIONS TOWARD HIGHWAY DEVELOPMENT
H W Alden 32
AERONAUTIC PROPELLER DESIGN
F W Caldwell 48
A SUGGESTED RULE FOR RATING RACING CARS
H M Crane 89
RESUME OF BUREAU OF STANDARDS FUEL STUDY
H C Dickinson 111
AIR-TEMPERATURE REGULATION EFFECTS ON FUEL ECONOMY
R E Fielder 175
AUTOMOBILE EXHAUST GASES AND VEHICULAR-TUNNEL VENTILATION
A C Fieldner, A A Straub and G W Jones 185
BODY ENGINEER AND THE AUTOMOTIVE INDUSTRY
Kingston Forbes 217
INVESTIGATIONS OF ROAD SUBGRADES
A T Goldbeck 229
SOME EXPERIMENTS ON THICK WINGS WITH FLAPS
C D Hanscom 248
CAN AUTOMOBILE BODY WEIGHT BE REDUCED?
C A Heergeist 262
VOLATILITY OF INTERNAL-COMBUSTION ENGINE GASOLINE
Frank A Howard 274
FUEL RESEARCH DEVELOPMENTS
C F Kettering 286
NEED FOR RESEARCH ON AUTOMOBILE PARTS
W T Magruder........................ 306

[1] General Index to subjects will be found at the end of the volume.

PAGE

AERIAL TRANSPORTATION AS A BUSINESS PROPOSITION
Glenn L Martin 311
RECENT PROGRESS IN MILITARY AVIATION
Major H S Martin 317
FUEL PROBLEM IN RELATION TO ENGINEERING VIEWPOINT
A L Nelson 325
CHASSIS DESIGN FOR FUEL ECONOMY
A L Putnam 369
A PRINCIPLE OF ENGINE SUSPENSION
S E Slocum 374
COMPRESSION RATIO AND THERMAL EFFICIENCY OF AIRPLANE ENGINES
S W Sparrow........................... 382
TORSIONAL STRENGTH OF MULTIPLE-SPLINED SHAFTS
C W Spicer............................ 391
INTAKE FLOW IN MANIFOLDS AND CYLINDERS
P S Tice 397
AERIAL TRANSPORTATION
Ralph H Upson 407
ECONOMY AND PERFORMANCE DEMANDS
J G Vincent........................... 425
COMMERCIAL AVIATION IN THE EASTERN HEMISPHERE
Edward P Warner...................... 428
HIGHWAY-ROAD CONSTRUCTION
W E Williams 453
NATURE OF FLAME MOVEMENT IN A CLOSED CYLINDER
C A Woodbury, H A Lewis and A T Canby. 465
CHICAGO MEETING AND DINNER.............. 510
RECENT DEVELOPMENT OF ARTILLERY AUTOMOTIVE MATERIEL
Capt J B Haney....................... 514
ENGINEERING ANALYSIS APPLIED TO TRUCK SELLING
N J Ocksreider 528

PAGE

APPLICATION OF STEAM POWER TO AN AUTOMOTIVE TRUCK
L L Scott 535

CARE AND MAINTENANCE OF MOTOR TRUCKS
N J Smith 556

TRACTOR SERVICE REQUIREMENTS
J C Thorpe 570

FARM-POWER MEETING AND DINNER 579

FARM-POWER DINNER 584

CARBURETION OF ALCOHOL
A W Scarratt 587

NEBRASKA TRACTOR TESTS
O W Sjogren 597

COMMERCIAL MOTORBOATS AND THE DIESEL ENGINE
G C Davison 628

GERMAN SUBMARINE DIESEL ENGINE
Lieut Com H C Gibson 641

ALUMINUM PISTONS
Frank Jardine and Ferdinand Jehle 656

CONSEQUENTIAL ADVANTAGES OF WEIGHT REDUCTION
L H Pomeroy 675

PACKARD FUELIZER
L M Woolson 678

UNDERLYING PRINCIPLES OF ELECTRICAL IGNITION
B F Bailey 707

HIGH-SPEED ENGINES OF SMALL PISTON DISPLACEMENT
Louis Chevrolet and C W Van Ranst 729

STATUS OF THE ISOLATED GAS-ELECTRIC GENERATING PLANT
Charles Froesch 749

AUTOMOBILE BODY CONSTRUCTION
P E Stone 785

ANNUAL MEETING

OF THE

SOCIETY OF AUTOMOTIVE ENGINEERS

INC.

NEW YORK CITY
JAN. 11-13, 1921

THE GERMAN SUBMARINE DIESEL ENGINE

By Lieut-Com Holbrook C Gibson[1] U S N

The author describes the type, size and general characteristics of the engines with which the German submarines were equipped at the time of the surrender, after having personally inspected 183 of them at that time, and then presents the general details of construction of these engines, inclusive of comments thereon.

The maneuvering gear for such engines receives lengthy consideration and the reliability of engines of this type is commented upon in some detail, the author having confirmed his opinion that the German submarine engine is extremely reliable.

One of the controlling factors in the design is that the Germans had investigated steel casting to the point where the successful production of steel castings was an ordinary process, and the author believes this to have been largely responsible for the success of the German submarine engine.

Much to the surprise of everyone present at the time of surrender, the German submarines came up to their moorings, maneuvering entirely by using their engines. This performance caused much favorable comment. An inspection was made of the various boats and in the majority of cases it was found that the engines were of Machinenfabrik-Ausburg Nürnburg (M.A.N.) four-cycle reversible type. A few other types were found, such as the Vulcan, Bolhm-Voss, Koerting, Benz, Nürnburg two-cycle and Krupp two-cycle but, comparatively speaking, they were very few in number. In our own submarine service, before the war we had heard much about the Krupp two-cycle engine and naturally supposed that this was the best engine in Germany. However, the Krupp interests were so powerful at that time that they had had their engines adopted for the German submarine service. Out of about 183 submarines which I personally inspected at the time of the surrender, there were only five or six boats that had Krupp engines and they were out of repair. These engines also had one serious objection in that the cylinder-heads and some other parts were made of bronze, which metal became very scarce during the war. As soon as the war was well

[1]Submarine Repair Base, League Island Navy Yard, Philadelphia.

under way, the German authorities had to listen to the operating personnel and it became necessary to adopt the M.A.N. four-cycle engine, which can be considered as the standard for the German submarine. However, this type of engine was not a war product, but was a practical proposition as far back as 1912.

During our inspection we found one submarine which was fitted with a pair of M.A.N. four-cycle 800-hp. engines dated 1912. It was about that time that one of our own submarine officers was in Germany. He was shown practically everything in the Ausburg shops except a certain four-cycle engine which was in an enclosure undergoing shop tests. I have reason to believe that this was the engine type which was later adopted for the German submarine service, but it was not until after the war that this four-cycle engine became generally known. Nothing much was heard of it and what one did hear was very vague. Inspections of the German submarine flotilla and various submarine engines and engine plants in Germany revealed that the M.A.N. four-cycle engine predominated. It was being built not only by the Ausburg plant of the M.A.N. company, but at all the other engine plants. The M.A.N. engine is built in the following sizes: 100 hp. at 550 r.p.m.; 300 hp. at 550 r.p.m.; 500 hp. at 500 r.p.m.; 1200 hp. at 450 r.p.m.; 1750 hp. at 380 r.p.m.; and 3000 hp. at 390 r.p.m. The fundamental design of all these engines is the same, but as the size increases certain modifications are necessary. The bedplates are all of cast steel and so are the cylinder jackets. The cylinder-heads and pistons are of the usual material, close-grained cast iron. The crankshafts and connecting-rods are of good quality steel. The M.A.N. engine, with the exception of the 3000-hp. size, is made with six cylinders and an air compressor on the forward end which also carries the fuel pump and a device called the spray air regulator. Everything that is needed to run the engine is located at the forward end, available for the operator.

Regarding the 100-hp. engine, it happened that I went around Kiel harbor in the barge of one of the former German admirals. I noticed that the boat had a quick getaway and high speed. I looked into the engine room and saw that it had a 100-hp. M.A.N. Diesel engine just like the larger ones. This size is a practical proposition; it operated beautifully. This little engine had six cylinders and one three-stage air-compressor on the forward end. The engine was air-starting and had a mechanical reversing-gear through the clutch.

The 300-hp. type of engine had the same general design characteristics as the 100-hp. size. The pistons of the 100 and the 300-hp. engines are not cooled. The 500-hp. size has six cylinders also and has additional features such as air-starting and reversing and two spray valves in each cylinder-head. In other words, it has a twin spray valve for fuel admission. The pistons are oil-cooled in this size.

The unit developing 1200 hp. at 450 r.p.m. is exactly the same as the 500-hp. size; it has oil-cooled pistons and some variations in the type of air compressor. There seems to be no standard practice regarding the use of a three or a four-stage air compressor. In a mine-laying cruiser one will find a four-stage air compressor and in another type of boat a three-stage compressor. In the former the compressor is used not only for the engine but for charging the air supply for the ship. That is the only difference in the 1200-hp. type. They are all the same and look as though they had been cut from the same pattern. The 1200-hp. engine can be considered as the German standard, since it was used in a great many vessels; their 800-ton submarine was the standard submarine. A German officer told me that if Germany had con-

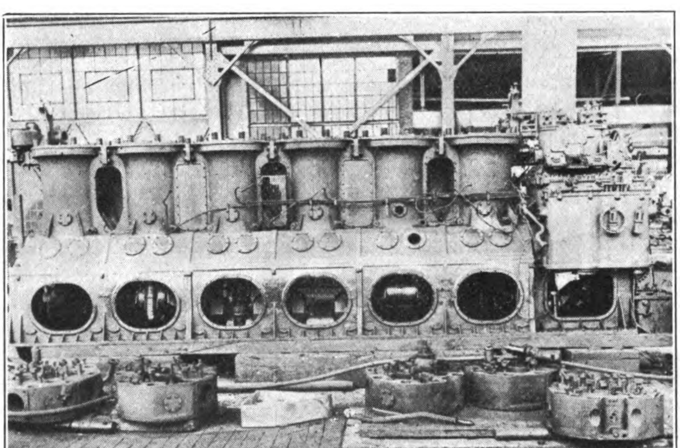

FIG. 1—SIDE VIEW OF A 1200-HP. DIESEL ENGINE SHOWING THE STEEL CONSTRUCTION OF THE BEDPLATE AND THE HOUSING WHICH ARE INTEGRAL UP TO THE BASE OF THE CYLINDER JACKET

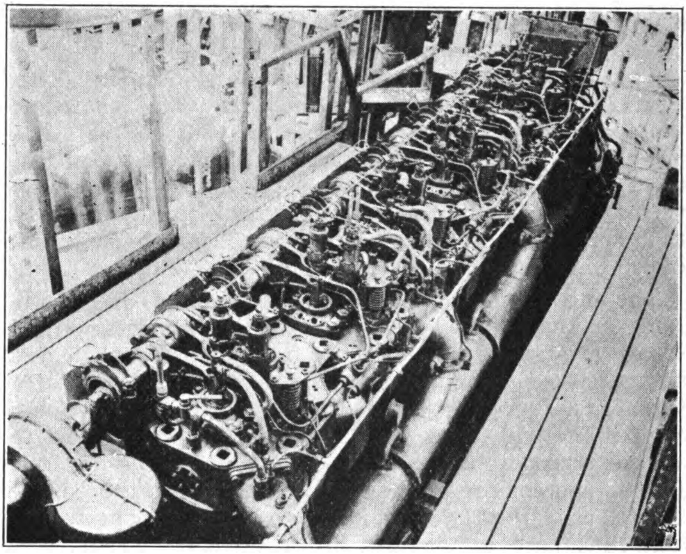

FIG. 2—LOOKING DOWN ON THE 1200-HP. ENGINE

centrated on this 800-ton submarine type, Germany would have won the war. I do not know the total number, but they built 200 or 300 of the 800-ton boats and each was equipped with the 1200-hp. engine.

GENERAL DETAILS OF CONSTRUCTION

Fig. 1 gives a very good idea of the steel construction of a 1200-hp. engine. The bedplate and the housing are integral up to the base of the cylinder jacket. The bedplates are made in sections to take in two cylinders and they are bolted together with many bolts, resulting in a very substantial construction. The joints can be seen in the illustration. There is a small section on the forward end for the air compressor. The cylinder jackets are also bolted to one another and go all the way across on the inside, forming a regular girder construction; the result is a very rigid engine but, where it is bolted together, it is free to expand upward. In other words, the bolts that go through the section are not fitted but are loose, the cylinder jackets being able to expand upward.

Fig. 2 shows the engine viewed from above. The principal feature to be noted is the twin spray valve. In my opinion the idea of the twin spray valve was originated on account of the construction of the cylinder-head. If they had cut one big hole in the cylinder-head for the spray valve in addition to the large inlet-valve opening, the cylinder-head would have been materially weakened. It looks complicated, but really is not and it works beautifully. The satisfactory operation is simply a matter of accurate workmanship and proper lining up of the valves.

Fig. 3 gives an idea of the mechanism at the forward end. This is the 1750-hp. engine, but it is practically the same except for one additional feature. The fuel pump, air regulator and air compressor are shown. There are three air-coolers and below the coolers are the three separators for the various stages of the air compressor. The wheel shown controls the reversing mechanism which is on the 1200-hp. engine and smaller sizes. It works very easily and one man can handle it without any trouble. This 1750-hp. is the type of engine discovered on the so-called Von Tirpitz super-submarine. These vessels run from 2000 to 2700 tons displacement and were

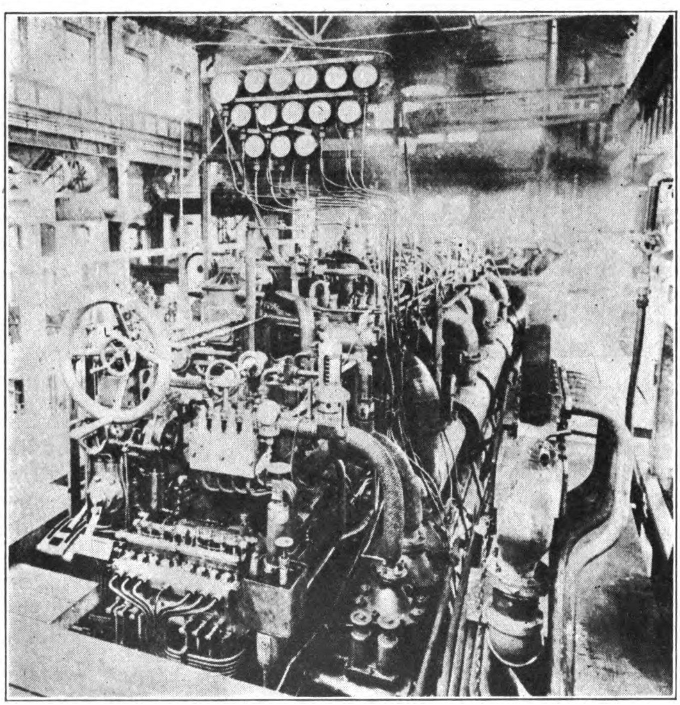

FIG. 3—LOOKING AT THE FORWARD END OF THE 1750-HP. ENGINE

built primarily to operate on the Atlantic Coast of the United States. The engine in the 2000-ton boat is of the 1750-hp. type. As is seen in Fig. 3, it has six cylinders, with air-starting and reversing gear. It has all the earmarks of its predecessors except a few radical departures in design.

Fig. 4 shows the 3000-hp. engine found on the 2700-ton boats which were the largest of the German submarines. It is practically the same as the 1750-hp. engine except that it has 10 cylinders instead of 6. The picture of an average man standing alongside gives an idea of the size of this engine. All of the German engines are

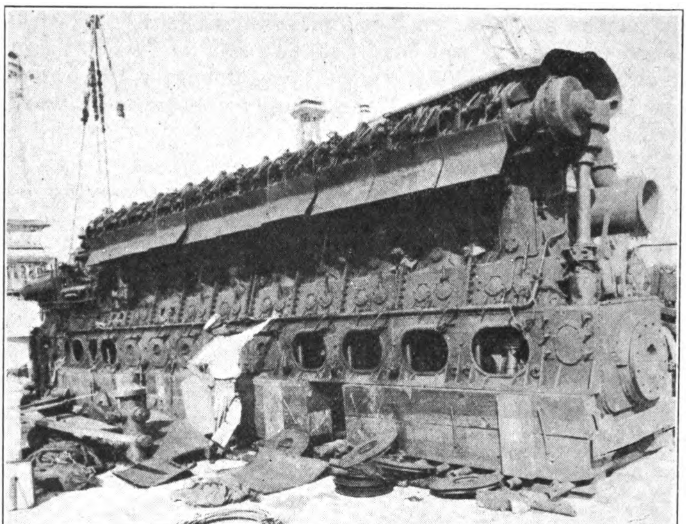

FIG. 4—VIEW OF THE 3000-HP. ENGINE WHICH WEIGHS 14,000 LB.

comparatively light for their horsepower. The 1200-hp. engine, complete with exhaust heads, dependent auxiliaries and everything except miscellaneous piping and the oil cooler, weighs 57,000 lb. The 1750-hp. engine, complete with dependent auxiliaries, flywheel, exhaust heads and the like, weighs exactly 97,530 lb. The 3000-hp. engine weighs 72 net tons, or 144,000 lb. One can see in the illustration how the engine is bolted together; all the bolts fit loosely so that the castings are free to expand upwards, but not fore and aft.

Some radical departures are made in the construction of the pistons of the 1750-hp. engine. Fig. 5 shows the six pistons removed. From a casual glance one would

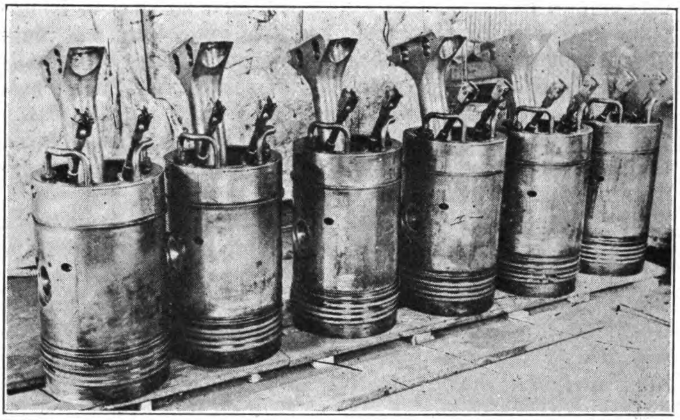

FIG. 5—THE PISTONS OF THE 1750-HP. ENGINE REMOVED

think they were exactly the same as those of the 1200-hp. engine. However, when we commenced to clean them up and looked on the inside, we noticed a row of bolts. When these were taken out we discovered that they released the piston-head. The pistons are a radical departure in design from their predecessors in other engines. Fig. 6 shows one of them taken apart; the trunk of the piston, with the flange at the top; the piston-head, looking inside; and the cover that goes up inside of the piston to make it a closed cavity so that the oil cannot escape. The piston-head is a very fine piece of work. It is a block of semi-steel, machined inside and out. The cavities are for the cooling oil which comes in at the side, works its way around through these grooves and finally into the

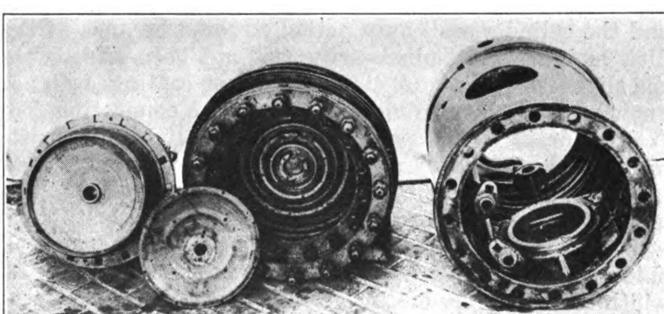

FIG. 6—ONE OF THE DIESEL ENGINE PISTONS TAKEN APART

center and out. Locknuts are provided so that it is impossible for the inside cover-plate to get adrift. A plate goes on over the oil grooves. Some of the groove walls are made thicker than others to provide for the screws which hold the cover-plate on. The bolts that hold the piston-head to the flange of the piston are riveted through and they are all locked with lock-pins and locknuts so that the whole is a unit and cannot come adrift. This design of piston is one of the important departures from former practice. To my mind, it is the most interesting. The cooling-oil pipes are shown which carry the oil in at the periphery and out at the center. The Germans apparently were experimenting more or less with this type of piston, for we discovered that the pistons in the engines of the submarine U-140 were slightly different from those of the U-127, although the engine was exactly the same to all appearances. The pistons described were taken from the engine of the U-127 and are apparently of later design.

Another interesting feature about the piston is that on the former engines the pistons were straight from the bottom of the working rings to the bottom of the piston. On this type of piston we found that the skirt was relieved all the way down for a space about 6 in. wide and parallel to the wrist-pin ends. The diameter of the piston is 21 in.

Fig. 7 shows the construction of the connecting-rod and the wrist-pin bearings which is the same throughout all the engines that have cooled pistons. It shows how they provide additional bearing area for the wrist-pin bearings which are subjected to much heat and heavy pressure. The Germans apparently had no trouble with these bearings, for we have had cases where the piston and the cylinder wall have actually scored because of the dirt, and the wrist-pin bearing has not been affected in the slightest degree. A steel forging or casting, I do not know which, goes through the eye of the connecting-rod. It is made in two halves. The upper half of the wrist-pin bearing is shown partly taken out. The lower half has lips or projections to hold the shell in place. The upper half has one small lip and is slipped in last. The wrist-pin bearing is made the extreme width that can be obtained from the inside of the piston; almost double the width of the eye of the connecting-rod is obtained. Naturally, the wrist-pin pressures are very much reduced in this way. The bearing metal, instead of being a bronze bushing, is of comparatively thin babbit metal. They have a fitted distance-piece, measured by micrometers, between the upper half of the bearing and the eye of the connecting-rod. The connecting-rod is drilled out to make it light and when oil is forced to the wrist-pin, this big hole or cavity fills with oil; the inertia of this oil column tends to pull the oil from the wrist-pin and run that part dry. Instead of putting in a check-valve at the foot of the connecting-rod to prevent this, they

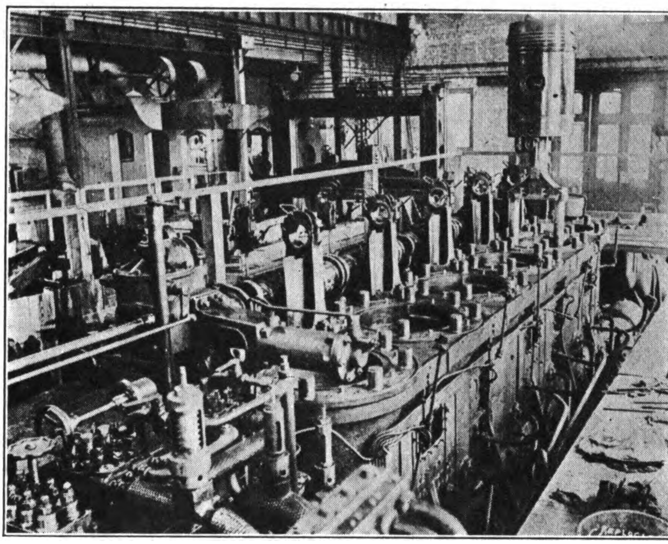

FIG. 7—THE CONSTRUCTION OF THE CONNECTING-ROD AND THE WRIST-PIN BEARINGS WHICH IS THE SAME FOR ALL ENGINES HAVING COOLED PISTONS

have put in a pipe with a screw plate and screwed the pipe into the wrist-pin bearing. The connecting-rod is not filled up with oil and they do not have the difficulty that we sometimes encounter. It is a very simple scheme and there is nothing to go wrong. Another interesting feature in this engine is that the after bearing is of a larger size than the other main bearings of the engine. This bearing is 12.375 in. in diameter; the other bearings are 11.223 in. in diameter. This is done to provide support for the clutch.

MANEUVERING GEAR

Fig. 8 shows an engine having the same maneuvering gear as the 1200-hp. engine; it has the same handwheel for operating the valve gear. This wheel works through a series of bellcranks and levers and raises the valves clear of the camshaft; the camshaft moves sufficiently to bring another set of cams in line and, to complete the operation, the valve gear is lowered on the new set of cams. On the 1200-hp. engine this was done manually and, while it could be operated readily by the average man, it was a hard task to do this several times per minute in answering the engine-room signals. On the 1750-hp. engine this reversing gear can be operated in this way, but it is really all that one very strong man can do; so, in addition to the manually operated gear, a gear is installed which operates by air and also by oil. It is a small box that has four valves in it and by turning a small handwheel in one direction the proper valves are depressed admitting air to a ram. There is an interlocking device on the front of the engine so that when the power-operated maneuvering gear is used the hand gear is thrown out. It is interlocked. When this handwheel is turned, the ram goes over in about 2 sec. and the engine is then ready to operate in the other direction. In case the air pressure fails, there is a small oil-pump provided and the ram can be pumped over with oil pressure. The operating gear shown had not been used in two years and we tried it today to see if it would work, as it was the only thing on the engine that we did not take apart. We found that it operated very satisfactorily, as if it were put together only yesterday. Another interesting feature on this type of engine, which is simple but apparently very necessary, is a stop-valve on the circulating water supply which is operated by the starting levers of the main engine. It is a sluice valve in the header which supplies water for the working cylinder jackets. It is arranged so that when the operating levers are brought to the stop position the water is cut off from the working cylinders, and it is impossible to supply water to them until the engine is started again. From reading a confidential German instruction pamphlet, I noticed that they lay stress on the fact that cold water must not be put into the engine when it is shut down. The water must be turned off the minute the engine stops. But with this engine, even when using independent electric auxiliaries, it is impossible to damage the engine by pumping cold water into it after the gear has been brought to the stop position. That is a refinement and I suppose it is very necessary. I am also of the opinion that this may have something to do with the air-starting of the engine. In other words, it is not possible to put water on the working cylinders until after the engine has started firing. Consequently, when starting with air, the cylinders are not being cooled with cold water.

One other point in the operating gear that does not appear in the older engines is interesting. There are three indicators on the dial of the operating gear, marked *Voraus, Tachstellung,* and *Zurick.* The *Voraus* and *Zurick* mean ahead and astern, and *Tachstellung* means

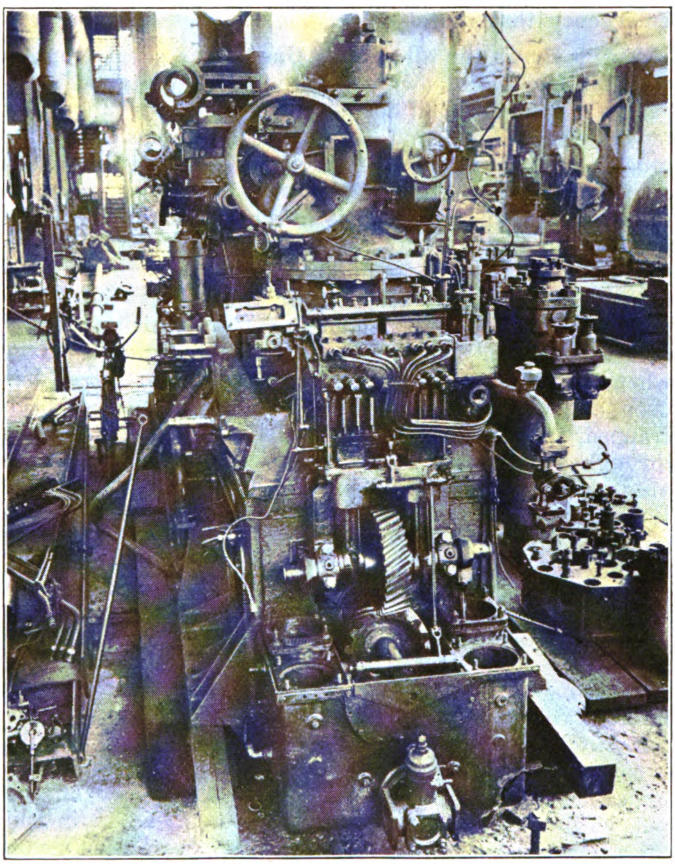

FIG. 8—THE MANEUVERING GEAR OF THE 1750-HP. ENGINE WHICH IS TYPICAL OF ALL THE GERMAN SUBMARINE ENGINES

diving position. I have been trying to discover a real reason for this third setting and, so far as I can determine, the diving position means the position in which the engine control is placed when the boat dives. It is just the same as the neutral position of the engine, midway between ahead and astern. I think it is one of the refinements that was developed during the war. In case a submarine comes to the surface, the commanding officer is able to maneuver the ship to the best possible advantage. It might also be used in an emergency case, to avoid ramming. If the commanding officer had the controls in the *Tachstellung* position, he would then be in the best possible maneuvering position for any emergency that might arise.

Fig. 9 shows the oil-pump. One of the great troubles we have had in our own service is to build a good lubricating oil-pump. I do not necessarily mean a pump that never breaks down, but sometimes oil-pumps make too much noise. This pump is the same kind that is used on all the German engines. It is very simple and consists of two gears, one of which is fitted with a cylinder with grooves cut in it. So far as I can make out, the idea is that in an ordinary gear pump a certain amount of oil is trapped between the teeth after the oil has been discharged, creating a tremendous pressure which naturally makes it pound. The pump shown is designed so that, when the teeth are in a certain position after the oil has been delivered and a certain amount of oil has been trapped, the holes come into position and the oil passes through the groove. This pump is very smooth-running and is almost noiseless. I took one apart on a 1200-hp. engine which had been operating for 25,000 miles, but the original toolmarks were still on it and all we did was to put it together again. It is apparently a very satisfactory design of pump and very efficient.

Fig. 10 shows the main engine clutch on a German submarine. It is necessary to have a clutch between the main engines and the electric motors so that when the boat dives the engines can be disconnected. This clutch is typical of the German design and is very simple. It consists of two truncated cones. The cones slide on a spider, operated by springs. There is a sleeve on the end, with bellcranks to force the truncated cones in and out against the outside casing. The travel is very small, only ½ in. The angle of the cones is 28 deg. The cones are made of cast iron and the outer rings are steel. They

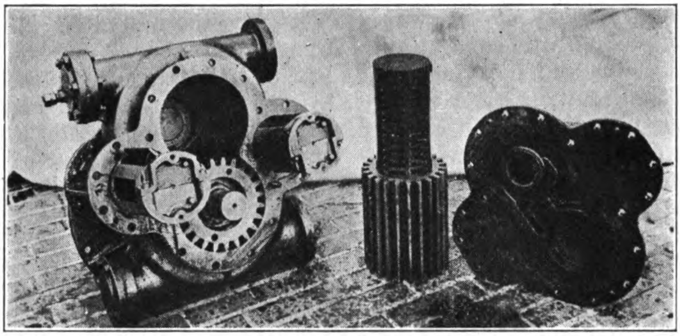

Fig. 9—The Oil-Pump Disassembled into Its Various Parts

are forced in and out by means of a pneumatic piston which is controlled by a small valve. This control enables extremely rapid engagement and withdrawal of the clutch.

Reliability

I have confirmed my opinion that the German submarine engine is extremely reliable. Some thorough tests were made on a 1200-hp. engine without any trouble or breakage. This was an old engine which had been horribly abused. It was overhauled, put in operation, and ran without much trouble. A former German submarine, the U-111, was operating last winter with some of our submarines. It had a green crew and none of them knew

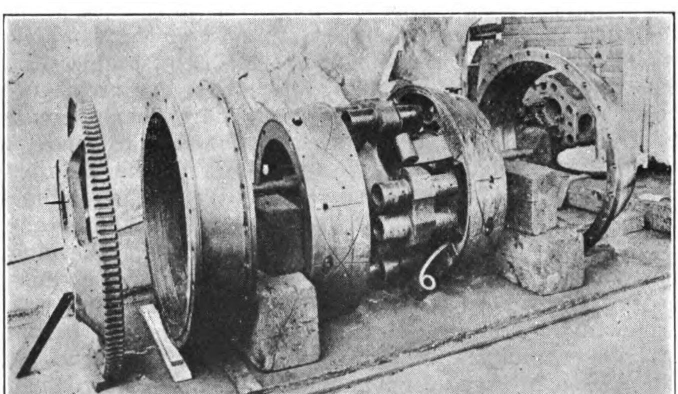

Fig. 10—The Main Clutch of the Diesel Submarine Engine

anything about the engine. The vessel operated all winter until it came to the League Island Navy Yard for docking and painting preparatory to some speed trials. I talked with the commanding officer, and told him his engine was not adjusted properly, but in spite of this it was running very well and was misleading on account of such satisfactory operation. I persuaded him to allow the gang of men I had used on previous engine tests to tune the engine up for him. It was found that everything possible on the engine was wrong; it was all out of adjustment. The gang cleaned the engine parts, set the valves, ground them in tight and set the parts according to the data we had collected on this 1200-hp. engine on test. The vessel went out burning up its fuel perfectly. She developed over 17 knots, while on the previous trial she could not make 14 knots. This demonstrates that the German submarine engine is reliable and can run even if the personnel are not highly trained. That is a condition we must meet in submarine service.

The submarine Diesel engine is not an ordinary Diesel engine, mainly because the requirements are so exacting. The submarine demands everything of an engine that is difficult to get. The space and the weight are limited; the service and treatment are very severe. The requirements of a submarine Diesel engine might be considered as a quest of the absolute. It must be entirely free from imperfections both in design and workmanship. The Germans spared nothing on the submarine campaign to win the war, and I think the results have shown themselves in the development of the M. A. N. four-cycle engine. Many people who have seen it state that it is complicated. I feel now, since I am more or less familiar with it, that such statements are made by people who have not given careful thought to what the engine is supposed to do. To bring this point out more clearly, I will take for example, a little device on the forward end of the engine which is used to stop it from the conning tower or the bridge of the vessel. We had a similar device on our gasoline boats in the early days. This consisted of a little switch in the conning tower by which the ignition-system circuit on the gasoline engine could be broken in case of emergency. The same idea was proposed for the Diesel engine, but we had a better interior communication signal on the later boats and we did not see any need for it; submarine officers stated that it simply made the engine more complicated. But if we stop and think for a moment, it becomes very apparent that with a larger-sized boat having larger compartments and a big induction valve supplying air to the engine room, when crash diving it is necessary to stop the engines from the bridge to be sure that they are stopped before the main induction valve of the boat is closed. What would happen if the man in the engine room was slow in obeying the signal? Suppose he did not get the signal or was not at his post at the time the signal came through and the induction valve was closed. A vacuum would be produced inside the hull which might kill everybody aboard and cause the loss of the boat. One may not be able to understand at once the reason for everything on a German submarine Diesel engine, but if careful study is made, a very good reason will be found for all of the so-called complications on these engines.

One of the controlling factors in the design of this German engine is the steel castings. I think this is true not only of the German Diesel engine but also of the motorboat engine. The Germans have investigated steel casting to the point where making steel castings is an ordinary, every-day job. I think that has much to do with the success of the German engine, for they have made beautiful steel castings. In this country we have found it difficult to get the steel castings made properly, but after many efforts we are now making a steel casting for the 1200-hp. engine in the League Island Navy Yard with electric furnaces. We employ a 3-ton electric furnace and have done some experimenting which indicates that the trick is in the coring. The steel is poured into the mold and the minute that the metal has set the mold is broken down to get the casting out. The cores are destroyed so that the casting cannot shrink on a stiff hard core. In some of the difficult castings the core is made so that it will crush and, so far, the results have been satisfactory. It is a job that the steel manufacturers of the United States did not want to attempt. But it was felt in the Submarine Service that it was necessary to learn how to make good steel-castings. It must be borne in mind that the German engine is a good type, and the information to the world is three years old. It is not only the United States that has this steel-casting information, all the other nations have it. The Germans pour steel like we pour brass and make no fuss over it. We do not want to be satisfied with copying; we must lead.