

SCIENTIFIC AMERICAN

SUPPLEMENT. No 1571

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Scientific American, established 1845.
Scientific American Supplement, Vol. LXI., No. 1571.

NEW YORK, FEBRUARY 10, 1906.

Scientific American Supplement, \$5 a year
Scientific American and Supplement, \$7 a year.

COMPARISON BETWEEN TORPEDO BOAT AND MERCHANT MARINE ENGINES.

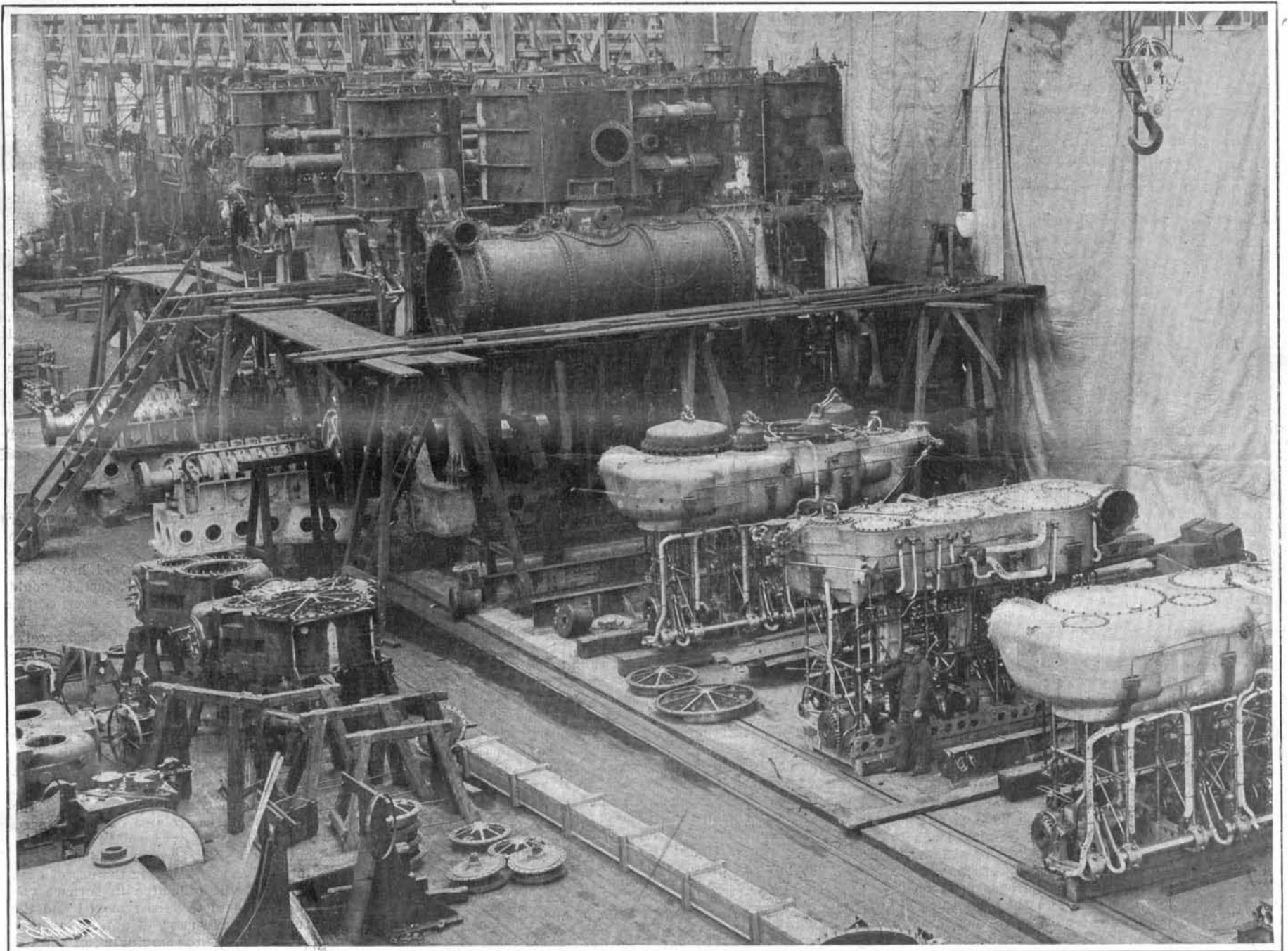
By Dr. ALFRED GRADENWITZ.

A SHORT time ago it so happened that in the workshops of the Germania shipyards at Kiel-Gaarden, two steam-engine sets of the same output were erected side by side, one of which was intended for a torpedo boat, the other for a merchant steamship. The accompany-

ing photograph affords an excellent opportunity of comparing the characteristic features of the two types of engines, while the main data of each are recorded in the following table. Of the three torpedo-boat engines in the foreground of the photograph, each of 3,000 horse-power, two are to be installed in a torpedo boat of 426 tons displacement, giving it a maximum calcula-

tive speed of 30 knots per hour. The two slow-speed engines towering in the background are also of 3,000 normal horse-power each. They will be used in a 13,500-ton freight steamer of 13½ knots speed. The high number of revolutions in the torpedo engine is especially striking as compared with that of the mercantile ship engine, while other features characteristic of the former are the smaller stroke, high piston speed, and above all the exceedingly small weight

of the vessel to vibrating, the intensity of the oscillations being proportional to the speed of revolution. Though the vibration can be decreased by compensatory methods, it is still impossible to obviate it altogether. These vibrations are injurious to a ship, and decrease its length of life at sea. This is of importance in the case of a merchant vessel, which is a more profitable investment the longer it is in service. This is a rule which, in the case of war vessels, while not negli-



TWO SETS OF ENGINES EACH OF 3,000 HORSE-POWER. THE LARGER ENGINES ARE TO BE INSTALLED IN A MERCHANT STEAMER, THE SMALLER IN A TORPEDO BOAT.

ing photograph affords an excellent opportunity of comparing the characteristic features of the two types of engines, while the main data of each are recorded in the following table. Of the three torpedo-boat engines in the foreground of the photograph, each of 3,000 horse-power, two are to be installed in a torpedo boat of 426 tons displacement, giving it a maximum calcula-

and dimensions. The strain on the shaft is obviously very much greater in the torpedo engine than in the other type of the same output.

The question now naturally arises why it is not feasible to supply freight steamers with engines which, while not as light as those of the torpedo boat, would at least approach the present mean weight of the two types shown, or say, 60 to 75 pounds per horse-power, for the lighter the engine is made the larger is the useful weight which the vessel can carry, and correspondingly greater the amount it can earn through its freight charges. This is undoubtedly true, and it points the way along which marine architecture has so far advanced and will continue to advance in the future. Meanwhile, so great a step forward is not possible for reasons of practical utility. The small torpedo boats are high-speed craft, and they must accomplish by means of higher rates of revolution what they are unable to perform because of small propeller surface. The stroke is only 1.64 foot, while that of the merchant-vessel engine driving the larger propeller is nearly three times this figure. As is well known, the movement of reciprocating engines sets the entire body

gible, is by no means decisive. With these it is primarily a question of the performance of a specific purpose, for instance, in a torpedo boat, the development of the highest possible speed. For this reason, the best available resources of the times are employed; all other questions and considerations are subservient to these. This is also true of the original cost of the engines. This is so much greater for the small engines of the torpedo boats, than for the larger ones of the merchant vessel, that the use of such expensive machinery for the latter is precluded by the commercial conditions of to-day.

What was said of the difference in the weights of the two compared engines is correspondingly true of the space requirements. One engine of the merchant vessel requires a space (base area by height) of 9,536,825 cubic feet, the torpedo engine 594,170 cubic feet; in other words, that of the first is sixteen times as great as that of the latter. In the case of the merchant vessel, the smaller the engine space, the greater is the room for cargo. The engines extend from the bottom of the ship to the upper deck. That large slow-moving engines can also be built of less height is demon-

	Merchant Vessel.	Torpedo Boat.
Horse-power of each engine.....	3,000	3,000
Cylinder diam. in inches.....	24.35	1.6
Stroke in inches.....	51.75	32.4
Number of revolutions per minute.....	54.8	47.6
Speed of piston in feet.....	80	20
Steam pressure in pounds per sq. in.....	12.05	350
Diameter of shaft in inches.....	220	19.25
Total weight in pounds.....	15.04	250
Weight per I. H. P. in pounds.....	462,000	7.04
Height in feet.....	154	38,000
Base dimensions in feet.....	23.13	11.9
Strain on shafts, in pounds per sq. in.....	13.5 x 31	8.68
Material of shafts.....	2,980	5.3 x 13.2
	Siemens-Martin steel	6,950
		Special steel.

strated in the case of war vessels, where the engines are located under the armored deck. This arrangement shows that the ventilation of the engine room is also possible under these conditions.

For merchant vessels the mentioned disadvantages would be decreased if it should be possible to better the fuel consumption of turbine engines, so that these would become available for slow vessels. Turbine engines produce no vibrations of the ship's hull, and they have smaller space requirements than reciprocating engines of equal output. In that case the engines of a merchant vessel and of a torpedo boat, placed alongside one another, would present no such picture as in the present instance.

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LIQUID FUEL FOR NAVAL AND MARINE USES.*

By Rear-Admiral GEORGE MELVILLE, Former Chief Engineer, United States Navy.

Modification in Boiler Design Required by Liquid Fuel.

BOILER Volume.—Consideration of the mechanics of combustion as applied to liquid fuel appears to show that, for the efficient burning of the latter, it is necessary to provide boilers of greater volume than are now constructed for a given horse-power.

Complete combustion requires that for every atom of carbon, and for every two atoms of hydrogen there shall be at least one atom of oxygen brought in close proximity and then and there subjected to a temperature sufficient for ignition. In other words there must be a thorough mixture and then ignition. It is doubtful if a mere mechanical mixture, however complete, could ever be perfect enough to bring about the desired result. This is well illustrated by contrasting the smoky combustion of black gunpowder, where we have a mechanical mixture, with the combustion of the so-called smokeless powders, in which the mixture is so thorough and minute that similar proportions of oxygen, carbon, and hydrogen occur in each molecule.

In all ordinary cases of combustion, however, where we draw our supply of oxygen from the atmosphere, it is only by virtue of the property of diffusion that a sufficiently intimate mixture is attained. As to the real nature of diffusion, it is known that at ordinary temperatures the particles of oxygen in the air are moving about in every conceivable direction at velocities averaging over 1,600 feet per second. Any one atom, however, moves only an inappreciable distance before being arrested by collision with another atom. So that although the average velocity of the atoms is probably equal to that of a rifle ball, it still takes an appreciable time for a particle to travel even a moderate distance. It is this time element that constitutes the great stumbling block when the attempt is made to burn a large amount of combustible in a small space.

The reason why intense combustion is easily attained with a charcoal fire is that the fuel is solid at the temperature of ignition. Being solid it can present a large surface for the oxygen to act upon, and an atom cannot break away and go up the chimney without first being united with at least one atom of oxygen.

In the combustion of hydrocarbons, on the other hand, we have the following conditions: The fuel is already on its way to the chimney before it is even partially burned. The first effect of the heat is to dissociate the carbon from the hydrogen. Whether or not the latter unites with the oxygen does not affect the soot or smoke question, since the constituents and also the products of combustion of hydrogen are alike transparent colorless gases. But in any case, the carbon, left alone in the form of an impalpable dust, is much less favorably circumstanced than that in a charcoal fire. If it were attached to a hot coal, as in the charcoal fire, so as to be capable of receiving a blast of air, its combustion would be easily accomplished. But instead of this, it is carried along by the current of gases, and unless it is given plenty of time before being cooled it will be left alone as a particle of soot.

An examination of the nature of flaming leads to similar conclusions. The luminous part of a flame is caused by the white-hot particles of carbon. These particles have been robbed of the hydrogen with which they were formerly associated, and they have not yet met the oxygen necessary for complete combustion. This process of finding, or of being found by, the oxygen requires time, and if perchance the temperature falls below that of ignition before the process is completed, the carbon will be deposited as soot or else go on up the stack as smoke along with the excess of oxygen with which it should have been united. Thus an unmistakable symbol of the conditions that are necessary in order to burn a large amount of combustible in a small space is a short flame.

The circumstances which conduce to shortness of flame are:

1. Pure carbon fuel, because the fuel cannot leave the grate or furnace until it is burned to CO at least. In any case it cannot deposit soot, since CO when cooled is a transparent gas.
2. Intimate initial mixture of oxygen with the fuel, since the more intimate the mechanical mixture the less time will it take the gases by the process of diffusion to become perfectly mixed.
3. Initial heating of the air, since the rate of diffusion decreases with temperature.
4. Large surface of fuel presented for impact of the oxygen.

The desirability of supplying a combustion chamber whose volume is at least equal to the volume of the flames seems obvious. In this connection the fact

should not be overlooked that a slight increase in the volume of the combustion space acts in two ways to improve the quality of the combustion. One way—that having to do with the greater time permitted for diffusion—has already been touched upon; but apart from that there are influences at work in consequence of which an increase in the volume of the combustion space actually diminishes the volume of the flames. This is because the temperature of the larger space is higher, and the higher temperature hastens the process of diffusion.

During the process of diffusion heat is being liberated at all points throughout the combustion space. Hence all parts of the space are being traversed by heat rays emanating from every other part of the combustion chamber. It is readily seen that the temperature within this space must under these conditions increase with the volume to an extent limited only by the transparency to radiant heat, and by the temperature of dissociation at which, necessarily, heat ceases to be liberated. Since the transparency of the combustion space is diminished by the presence of solid carbon (for whether black or incandescent it is in any case opaque), it follows that the increase of temperature with a given increase of volume will be less in space filled with luminous flame than in one filled with burning hydrogen or CO.

This question of the proper size of the combustion space is further complicated by the presence and condition of the solid walls of the furnace, whether, for instance, they are themselves incandescent or merely black absorbers of heat. There seems no reasonable doubt, however, that incandescent walls will hasten diffusion and hence shorten flame.

Where it is possible for the diffusion to be completed before combustion begins as in the Bunsen gas burner the difficulties naturally disappear and there is readily attained a very short flame which, moreover, is incapable of depositing soot even on a cold object.

In the case of a liquid fuel which is incapable of vaporization, the diffusion and ignition must occur simultaneously. With such a fuel there is bound to be considerable flaming. Another difficulty, and one from which all solid fuels are free, arises with this sort of fuel from the action of capillarity or surface tension. Thus, no matter how finely the liquid is pulverized, each tiny drop assumes a spherical shape and so presents the least possible surface for the impact of oxygen atoms.

From what has been said it seems clear that a liquid fuel such as crude petroleum requires an ample combustion space, more indeed than does almost any other sort of combustible material.

As to the difficulty arising from the tendency of the gases to follow the path of least resistance and to flow, for instance, with too great velocity at the center of the space and too little at the sides, that can always be checked by means of retarders placed so as to equalize the velocity over the cross section of the current. The difficulty, therefore, reduces itself to the mere trouble of finding out where to place the retarders, and this is obviously a question to be settled by experiment. What is true in this matter of the combustion space is also largely true of the tube space. The process of diffusion, so important to combustion, continues after the combustion is complete, and must have a good deal to do with the rate at which heat is abstracted from the gases by the heating surfaces. As affecting the necessary amount of draft pressure, a tube space short in the direction of flow of the gases and of large cross-sectional area is better than one of small area and long in the direction of flow; but on account of the lesser velocity of flow through the short space the gases within it will be less thoroughly mixed by eddying, and the importance of arranging the heating surfaces so as to permeate all parts of the space will be increased.

A study of the liquid fuel problem from the standpoint of the practical or mechanical rather than the theoretical or chemical feature of combustion would therefore show that when an assured and reasonably cheap supply of such fuel can be obtained, and when steam generators are designed for burning oil exclusively, it will be essential for the efficient and forced burning of such fuel to provide boilers of greater volume than now constructed for designated horse-powers.

Furnace Construction.—Where there is no desire to force the combustion of liquid fuel, the simple cylindrical furnace of the Scotch boiler has been found fairly suitable, particularly if an extension to the front of the furnace is made, so that complete combustion can be effected before the gases pass through the tube.

With the water-tube boiler the problem becomes a more complicated one, at least so far as economy is concerned. Where the gases pass through the tubes, as in the case of the Scotch boiler, the resulting friction is sufficiently great to cause the gases to be abstracted of sufficient heat to produce a comparatively low temperature at the base of the stack. Where the gases pass around the tubes, as in the case of a water-tube boiler, there is but little impeding of the flow, and as a result stack temperatures are comparatively high. When burning oil in bent-tube types of boilers combustion is often only completed near the top rather than near the base of the stack or funnel.

The question of baffling of gases in a water-tube boiler is one of supreme importance, for not only does it concern the economic efficiency but the endurance of the boiler itself. The straight tube water-tube boiler ought, however, to possess special advantage for the burning of oil by reason of the fact that it is possible to secure a combustion chamber of considerable volume, so that complete combustion of the fuel can be effected.

Scotch marine boilers, on account of their contracted volume of furnace, produce difficulties in the introduction of oil, and by reason of the small cubical space permissible for combustion purposes it is requisite that careful study should be given to the disposition of the brick work in, or surrounding a furnace. It is, of course, quite possible to spray the oil at once into the metallic fire box or furnace of the Scotch boiler, the flame impinging on the cold surfaces of the steel plates; but although this is often done, yet it cannot in any case be recommended as good practice. For successful combustion of oil it is requisite that the issuing oil spray should not too early in its progress of combustion strike the chilled or comparatively cold surfaces of the metal work. Carefully designed oil-burning furnaces require that the furnaces should be either partially or wholly bricked around.

The fact of heated brickwork is in itself a very great advantage in aiding combustion, and of still greater use in insuring perfect continuity of the heat supply, especially when burners tend to act in gusts, as they often do under improper action of the pumps, or where there is dirt or water in the oil supply.

The brickwork surrounding the interior of the Scotch furnace ought not to constitute a serious loss in thermal effect, because the brick itself early becomes incandescent and transmits a large portion of its heat directly to the metal in a steady and continuous flow.

Various forms of brick construction may be used in the cylindrical furnace. For example, the furnace may be lined throughout and the brick work also extended well into the combustion chamber in order to protect the back connection from the direct impact of flame. The burner may be fitted in the middle of the fire door, spraying directly into the furnace and utilizing the whole volume of the latter for combustion. Again, the combustion chamber may be bricked, the bridge wall left in place, the standard forms of grate bars left intact, and the top of the bars paved with fire brick, having interstices between the bricks. The furnace, however, should not be lined, in order to retain the maximum volume. By this plan, the oil burning installation can be readily removed and the furnace prepared for the use of coal. Again, the furnace may be fitted with a small wagon top arch at the usual location of the bridge wall, and, behind the arch, space be left for a combustion chamber. The latter and the furnace should be lined with fire-brick, excepting over the arch in order to avoid checking the gas flow there. This plan insures an intimate mixture of flame and gases but shortens the active length of the furnace. The latter disadvantage may be met by extending the front of the furnace by a projecting casting, suitably lined. Other modifications in furnace design are essential in the use of mechanical burners, when compressed air or steam is not employed and the air for combustion requires to be fed in heated, rotating currents.

Water-tube boilers have usually somewhat greater volume in their fire boxes than the furnaces of the Scotch boilers, consequently the opportunities are greater to arrange the brick work to suit the peculiar conditions required by oil fuel. With most of these boilers it is quite customary to put the burners into the fire doors or the spaces which would have been occupied by fire doors. As a matter of fact, it would often be better to put the burner at the back of the boiler and fire toward the front of the furnace, as by this means the larger end of the furnace would receive the gases of combustion at the point where the greatest expansion was taking place.

Owing to the fact that all the gages, fittings and connections are on the front of the boiler, it becomes an advantage to have the burner also, therefore, located on the front rather than on the back, where it would be practically inaccessible.

As with Scotch boilers, various modifications of furnace construction are possible or desirable. The grate bars may be removed and the burners fitted in the front to spray into the entire volume of the furnace. Again, the burners may spray over a paved grate, set with fire brick having openings for air. The advantage of this is the fitness of the furnace for the use of coal, also its disadvantage is the reduction in furnace volume. Again, the grate bars may be removed and the bottom of the furnace constructed of a thin layer of brick work, so arranged that the impinging of the hot gases and the effects of radiation cause the floor to be heated to a considerable temperature. The air entering for combustion and passing under this floor is quickly heated, thus increasing the efficiency of the furnace. Many other modifications are possible. The furnace may be fitted with a flat arch or a series of wagon top arches, with or without a combustion chamber behind the arch. A hot-air floor may be added, the front of the furnace extended as noted for Scotch boilers, and, if necessary, special spiralized air-heating devices fitted.

Equipment for Oil Fuel.

Strainers.—The majority of the crude oils having been obtained from wells driven into the earth, of necessity carry in the body of the oil, more or less intimately mixed, certain small proportions of water, as well as more or less sand or grit. The heavier and more viscous the oil, the greater the tendency there is to hold in suspension these deleterious substances.

In general it can be assumed that no crude oil is perfectly clean. Therefore in the installation of any oil-burning plant special provision should be made for straining out all sand and foreign matter. Arrangements should always be provided for catching the water as it slowly settles to the bottom of the tanks or bunkers.

* Paper presented before the Congress of the Permanent International Association of Navigation Congresses.