No. 1

COAL VERSUS OIL FOR THE NAVY

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Coal *versus* oil fuel for the Navy has, as a matter of fact, ceased to exist for some years as a controversial question for the responsible authorities—at any rate since the Great War. It can also be said that all thinking naval executive and engineer officers, and naval architects are agreed that the fuel of to-day must be liquid ; but since this country does not, unfortunately, possess within these islands, any known appreciable source of natural oil, but does possess large quantities of the best steam-raising coal, it is quite natural that those people who earn their livelihood from coal should be bitterly disappointed that their fuel cannot now be made use of in the British Navy, and that misled by the less responsible publicists and supported by even less reputable facts and data, they should from time to time question naval policy and plead for sympathy.

You will gather from these opening remarks, that I am myself in no doubt whatever as to which is the proper fuel to be used to-day, but this condition has not always existed, and I will, therefore, outline how this has come about, and analyse, so far as I can, the relative claims of oil fuel and coal.

I am careful to say " so far as I can," because the subject has four principal headings under which it must be considered, viz. : technical, manning, operational, and supply, and while you will no doubt admit that so far as the technical question is concerned, my opinion should be as good as any other, the other three headings may introduce matters on which a naval engineer is admittedly not necessarily the best and only adviser.

Historical

A number of small auxiliary vessels in the Admiralty service had used steam engines from 1816, but it was not until March 1828, that the name of a steam vessel appeared in the Navy List. This was the " Lightning," of 100 nominal h.p., which was built at Deptford and completed in December, 1823.

At first, only North Country coal was used as fuel, and there was much trouble from smoke, affecting both the cleanliness of the ship and the visibility. In the Baltic campaign, Admiral Napier's flagship, the " Duke of Wellington," used Welsh coal, while the remainder of the ships used North Country coal, "the smoke from which," the Admiral reported, "was so intolerable that, in coming in, the channels could scarcely be distinguished." He also stated that "in going into action with a fleet, or even with batteries, such a smoke would be injurious to the correct performance of evolutions, and that therefore it was a matter of great importance that coals making the least smoke should in future be supplied."

Investigations into the relative values of the various kinds of coal were made, and trials carried out for the Admiralty by Sir Henry de la Beche, the geologist, and Dr. Lyon Playfair, afterwards Lord Playfair, the chemist. Their "Report on the coals suited to the Steam Navy" was published in 1848–49. From this time until it was superseded by oil fuel, Welsh coal was the standard fuel used in the Navy. In 1839, a patent fuel prepared from screen and refuse coal mixed with coal tar, Stockholm tar and Trinidad pitch was used in H.M.S. "Firebrand" during a trip made by some of the Lords of the Admiralty in that ship. It was reported that this fuel showed advantages over the best coal in all respects.

Experiments.—The earliest successful experiments to burn oil fuel in connection with marine boilers of which we have any record were those carried out by Captain Selwyn, R.N., at Woolwich Dockyard in 1867–70, using a steam-spraying system. The fuel used was creosote—at that time a waste product from the distillation of tar for chemical purposes—and it was steam sprayed with very simple appliances over the bricked-over grate of a coal-burning furnace. Very good rates of evaporation were obtained, sometimes nearly double that obtained in the same boiler with coal.

The advantages of oil fuel for naval purposes were, even at that date, clearly appreciated; but special emphasis was laid on the necessity for a fuel heavier than water which would sink clear of the vessel in the event of the tanks being damaged in action, and it appears that the very limited supplies of fuels possessing this quality was the main reason why the matter was allowed to lapse. It is interesting to note that at the same time that Captain Selwyn was making these experiments, another inventor, T. R. Crampton, was carrying out investigations into the use of pulverized fuel, in the belief that his ideas were original, but only to find that his methods had been discussed some fifty years earlier.

Liquid fuel was used in the locomotive boilers of the Great Eastern Railway in 1886, but the earliest marine installation of which I am aware was that fitted in S.S. "Gretzia" by the Wallsend Slipway Company in 1881.

So far as the Navy is concerned, the question of the use of oil fuel remained more or less in abeyance until 1898, when experimental work was commenced with the types of sprayers then available such as the Holden type of the Great Eastern Railway and the steam pulverizing Rusden & Eeles type, which was in use to a very limited extent in the Mercantile Marine. The results were unsatisfactory, and no substantial progress was made until 1901, when it was realized that the experiments must be transferred to the shore, and various boilers were fitted up at Devonport and Portsmouth for developing oil fuel apparatus and furnaces, both for use with oil alone and with coal. In 1902 an experimental plant was erected at the Gun Boat Yard, Haslar.

Ranging through methods of atomization by steam and air, the experiments with oil culminated in devices for pressure spraying, otherwise called mechanical atomization, and this has remained in essence the system used by the Navy to this day.[1]

Haslar Research Work.—It can be said that the many inventions, details, and improvements, which have been developed from time to time, and have led to the existing fleet appliances for burning oil fuel, have all been produced by naval engineer officers working at the Admiralty Fuel Experimental Station, Haslar, under the direct supervision of the department of the Engineer-in-Chief of the Fleet; the cost of the establishment has been comparatively small, no royalties have been or are being paid,[2] and our system of to-day is, so far as I know, more efficient than any other for the conditions it has to meet. It would indeed be difficult to find any research establishment which has paid, almost without its being noticed, such a handsome dividend.

Early Trials at Sea.—The experimental designs at Haslar, when they reached a certain degree of efficiency, were tried under seagoing conditions in the destroyers "Surly" and "Spiteful."

By this time, in 1903 or thereabouts, the Admiralty was satisfied that supplies of suitable fuel in the desired quantities would be forthcoming, and the devices began to be applied to new construction.

Adoption of Oil Fuel.—From 1904, all the large vessels of new construction programmes were designed to carry and burn a certain amount of oil as well as their coal, and in 1905 coastal torpedo boats Nos. 1 to 32, known in the Navy as "oily wads," and the fast T.B.D's of the "Tribal" class were equipped to burn oil fuel exclusively.

The boilers in the large ships were designed to develop their full power on coal alone, and oil was adopted as a means of enhancing the endurance, both of the fuel and of personnel and, as practice showed, of answering those sudden calls for speed and retaining speeds—the calls to go "all out"—which come at critical times.

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1 Obviously any form of spraying by steam involves a large consumption of fresh water, and would be most undesirable in a ship at sea.

2 An award of £750 was granted to Mr. Melrose, Chief Inspector of Machinery, Royal Navy.

World's Output of Crude Oil.—I have already remarked that about the year 1903 the Admiralty was satisfied that the supplies of oil fuel forthcoming were sufficient to justify advancements in oil-fuel firing. As bearing on this question, the amounts of crude mineral oil produced by the oil wells of the world over the period from 1857 to the present day, for the years enumerated, is shown in the following table :—

In the year—	World's output in Crude Oil in tons.
1857	300
1860	72,700
1870	828,400
1880	4,288,300
1890	10,947,800
1900	21,305,300
1910	46,823,300
1914	58,220,600
1918	71,918,600
1920	98,400,600
1930	201,434,000
1931	195,757,000
1932	186,509,000
Total World's Output to end of 1932:	3,245,038,000 tons.

This table of oil production shows that if oil promised advantages for naval purposes over coal—and it did—we should have been guilty of lunacy if we had remained blind to its future.

Now I have seen it argued that the present generation of naval officers is not responsible for the use of oil fuel; that is quite true, but the aim of that statement was to show that some distinguished naval officer, or politician—names have actually been mentioned—drawn into the spider's web of some oil magnate, had combined with Machiavellian cunning to force this unwanted foreign product on the British Navy. It is hardly worth while discussing such suggestions; the truth is, of course, that you cannot stop the march of progress, and the fact is that no single individual or even a small coterie of individuals has been responsible for the introduction of oil fuel for the Navy. Its technical development and use, has, under successive Engineers-in-Chief of the Fleet, and one might say the whole naval engineering personnel at sea, proceeded from day to day. The technique being assured, authority for its adoption and use has, in all the circumstances to be considered, been made, not by one man but successively by a host of men in the governing positions. One might with more truth say that that epoch-making invention, the marine steam turbine, was forced on the Navy by the late Sir Charles Parsons, but even that would not be true—though the credit in this particular case is very rightly his. It was adopted by the governing Board of the Navy, the Admiralty of that day, much to their credit for early perspicuity, acting on the advice of their technical advisers, and not one or two or even a dozen individuals stand alone to extol or blame in such matters. These developments are evolutionary; they can be delayed, they can be hastened; but, if good and right, their preponderating advantages must lead inevitably to their increasing use.

About 1908, destroyer programmes with oil fuel alone having progressed perhaps somewhat quickly, some doubt was felt about the certainty of supply, and it was decided that the twenty vessels of the "Beagle" class, then being designed, should use coal. The disadvantages of coal, already well known in the technical departments, soon became apparent, and in the very next programme coal was finally abandoned. In the "Acorn" class, oil was restored and has continued to be used ever since. After oil had once been tried, coal lasted in destroyers for one programme only—one year's batch—and the following comparison shows the reason: the "Acorn" as compared with the "Beagle" had a superior armament; 20 per cent. less displacement; cost 16 per cent. less; and was 1½ knots faster; moreover she could hold her speed until fuel ran out. Since that date the developments in destroyers with oil fuel have far outstripped those mentioned in the comparison between the "Beagle" and the "Acorn."

It seems that from 1903 onwards the Admiralty were steadily pursuing a policy tending towards 100 per cent. use of oil fuel in the Navy; yet it is not until 1931 that we find a petition being engineered for a return to coal. Was King Coal asleep all those years? But, after all, it must not be supposed that the experiments and improvements in the burning of oil fuel made at Haslar and in the fleet were confined to oil alone. Mechanical stokers were tried, and all the advancements in the handling and burning of coal by the Mercantile Marine and in shore power stations have always been, and are being, watched to see if any of them could be applied with benefit to H.M. ships.

Such is a brief outline of the historical development of fuel since steam became the propulsive agent for naval ships. Now we will pass to a comparison of the technical, manning, and operational features.

Technical.

The caloric value of oil fuel is about 1·3 to 1·4 times that of coal. As measured in British thermal units, oil is about 19,000, while best Welsh steam coal is about 14,500. But, while oil is fairly uniform in quality whatever its geographical origin, it does not deteriorate with storage, and leaves no ash; coal—even Welsh—is not uniform, while the variations in the quality obtained from the various sources of origin all over the world are enormous. Coal does deteriorate slightly with storage, it becomes dusty with handling, and it contains an objectionable amount of ash, though these disadvantages can be mitigated by modern methods of washing and handling.

Bulk.—The space required for stowing one ton of Welsh coal is 40 to 43 cub. ft., whereas one ton of oil fuel averages about 38 cub. ft.; moreover oil bunkers can be safely filled to 95 per cent. full stowage, whereas in coal bunkers there is an appreciable loss from broken stowage—sufficient space having to be allowed under the beams at the crown of the bunkers to provide for ventilation and to permit egress of the coal trimmers.

Pulverized Fuel and Mixtures.—Pulverized fuel cannot be carried in bulk because it is dangerous; but even if it could, it would have to be kept "fluffed," *i.e.*, prevented from packing, and in that condition requires much more space—55 to 60 cub. ft. per ton. Alternatively, if coal is pulverized as it is required for use, on the "hand-to-mouth" system, then much additional machinery, absorbing space and weight, must be installed to do the work.

Mixtures of pulverized fuel and oil, erroneously called "colloidal fuel," have been tried for many years, and while an increased weight per cubic foot of this fuel, as compared to oil alone, can be stowed, no mixtures so far tried have proved really stable or suitable for stowage in and use from warship tanks.

Stowage.—Within reason, oil can be stowed in any compartment, large or small, no matter what shape or where situated in the ship; contiguity to the boilers is not necessary, and the fullest use of all available space can be made without impairment of supply to each and all of the boilers.

Transport to Boilers.—In coal-burning ships the only readily accessible stowage is above the floor plates and abreast the boiler rooms; yet in ships requiring much endurance, a large proportion of the coal must be stowed in bunkers which are not easily accessible or which cannot be worked without increasing the labour necessary to keep up and maintain supply. In the War, for example, many ships carried large quantities of coal in reserve bunkers which it was found impossible to use, and for operational purposes it had no value whatever. Under no circumstances could this coal be transported to satisfy any other rate of steaming, but a low rate.

To supply coal from bunkers to boiler rooms, a number of W.T. doors must be fitted in the bulkheads, and the protective decks must be pierced for scuttles and armoured hatches: all making for weakness and expense in construction and vulnerability under working conditions at sea. With oil fuel these doors, scuttles, etc., are not required, therefore the W.T. subdivision is more efficient, protection is improved, and the strength of the structure increased. Moreover, the bulkheads, decks, etc., forming the boundaries of the fuel tanks remain fully efficient, being always under test; a condition which cannot be assured with the boundaries of coal bunkers. In the latest warships, in which the weight of fuel carried reaches 30 per cent. of the displacement, this advantage is most valuable.

General Effect on Design.—It is almost impossible to design a warship providing for anything approaching an equal supply of coal to each group of boilers, and still more difficult to ensure this state of affairs at the commencement of an action. I may mention my own ship, H.M.S. " Agincourt," as a particularly glaring example, although in fairness it must be said that the ship was not Admiralty designed. She had three boiler rooms—A, B, C; A had 450 tons of coal abreast it; B had about 800 tons; and C, including reserve bunkers, about 2,000 tons.[1] If it had not been possible to carry 600 tons of oil fuel in the double bottoms, and if we had not converted the boilers to take Admiralty oil fuel fittings during the first six months of the War, while remaining at sea, that ship, after a few days out of harbour at high speed, could never have remained in the line with battleships of contemporary Admiralty design.

It might be argued by the technical protagonists of coal—if such people really exist—that modern coal-handling machinery could be devised to bring coal from any part of the ship to the fires, without requiring trimmers; perhaps it could, but how to do so without putting impossible encumbrances on the naval architect, impairing the W.T. subdivision of the ship, and introducing heavy and complicated machinery liable to go wrong at any moment in action, is quite beyond my vision.

Protection.—It has been claimed that coal bunkers provide protection against enemy action, which oil bunkers do not, and the case of a torpedo hitting H.M.S. " Marlborough " at Jutland is quoted as the classical example.[2] As a matter of fact, that torpedo expended most of its energy on a Diesel engine electric generator (much to the gratification of the Engineer Commander, who got a new and better one) and the saving of the ship by coal bunkers is simply not a fact. But in any case the claim, as to coal bunkers, is largely fictitious.

It is necessary, for reasons I have already shown, to start trimming down coal from the upper bunkers as soon as possible after leaving harbour in order to ensure an adequate supply in the immediate vicinity of the boiler rooms for action, and the supposed protection afforded by the coal in them will probably be lost by the time contact with the enemy has been established. It might even be the case that at the critical moment a bunker door might be open and jammed with coal.

These technical questions concerning the stowage of fuel on board, and its transport from the bunkers to the boilers, have been

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[1] These figures are, at this distance of time, approximate.

[2] It has been asserted that the " Marlborough's " speed was only reduced by 2 knots due to the damage caused by this torpedo; according to the Official History, " Naval Operations," Vol. III, p. 412, by 2.30 a.m. on the night after Jutland the " Marlborough's " Division had fallen fully twelve miles astern of station because the flagship could not by then steam more than 12 knots.—EDITOR.

discussed at some length because they affect the naval architect in designing the hull, and because they show the almost crushing superiority of oil over coal from this point of view. Briefly, this superiority in meeting these conditions can all be summed up in the fact that oil fuel is a liquid and coal a solid.

Fuelling Ship.—Another advantage, arising from the same fact, is to be seen in fuelling ships. Fittings required for refuelling with oil are merely pipes, filters, and valves; and they involve much less disturbance to the hull structure than those required for coaling. The rate of refuelling can be considered as two to three times the rate of coaling, and that with practically no effort on the part of the personnel. Ships can also be stored and ammunition embarked at the same time. As soon as these operations are performed, the ship is ready for sea, without having to be cleaned, and without a fatigued personnel.

Effects on Design of Machinery.—In the design of the machinery, no actual advantage accrues to the main propelling steam turbines, from the use of oil fuel, but when we come to the boilers and boiler rooms, the advantages are most marked. The human element sets a limit to the size of fire grate which can be adopted, since, if the length of the great is increased beyond about 7 ft. 6 in., the fires cannot be efficiently served and cleaned. The length of oil-fired boilers is only limited by the necessity to ensure that the particles of oil and air, necessary for its combustion, can reach the extreme end of the combustion chamber. Modern oil-fired boilers can be made up to a length of 20 ft. and more if necessary. For high-powered ships, therefore, the use of coal involves a large number of small boilers, whereas with oil, the same output can be obtained from a small number of large units; an arrangement which results in a considerable saving in the weight and space required for the machinery. It also permits of a more favourable W.T. sub-division of the hull with consequent improvement in immunity from under-water attack, both to hull and machinery.

Coal-fired boilers necessitate the installation of machinery and gear for getting rid of ashes; they require relatively more fan engine power; and the general effect on machinery design is to add greatly to the weight and space required.

Manning.

The engine-room complement of a large ship is decided chiefly by the number of men required to steam the ship continuously at high power, working in three watches; it follows that this complement for a large coal-fired ship is from three to four times that of an oil-fired ship, power for power. For example, H.M.S. "Tiger," 108,000 s.h.p., coal and oil—E.R. complement 600; H.M.S. "Hood," 144,000 s.h.p., oil only—E.R. complement 300. In a modern

8-in. gun cruiser an increase of at least 250 men on existing complement would be required, if coal were used instead of oil. Accommodation, provisions, drinking and washing water have to be provided for this increase of complement—all absorbing additional weight and space which could and should be devoted to items of military importance.

This matter of additional accommodation, etc., is most vital to the problem of design, for it is already very difficult to find space for all the men required for fighting the ship. But, supposing for the moment that it were possible to convert the Navy as it exists to-day to an all-coal one, it would necessitate an increase of personnel of some 15,000 men. Incidentally, it would cost about thirty million pounds.

Operational.

Under the heading of "Operational" I am including all those operations at sea under steam, both technical and military (for lack of a better term) which are affected by the fuel carried and used. It is impossible to separate technical and military considerations in this case.

Oil fuel ships can steam continuously at, say, 90 to 100 per cent. of their maximum power until all the fuel on board, wherever stowed, is expended, without any noticeably increased effort on the part of the personnel. There is little fouling of the combustion spaces in the boilers; no fires to be cleaned; no ashes to be drawn and discharged overboard; and no calls have to be made for assistance from the upper-deck complement.

Speed.—As an example of maintaining high speed we lately had H.M.S. "Achilles" leaving Gibraltar one day and arriving in England the next. Again, H.M.S. "Suffolk," on receiving the signal that H.M.S. "Petersfield" was in trouble, and although she had one boiler out of eight empty and open for cleaning, arrived at the scene of the accident, 360–370 miles away, in about 13 hours.

Endurance.—One of the special features desired in our ships is that they should have great endurance because of the extent of our Empire and the great length of our trade routes. Now, while it would be unfair to compare performances of modern oil-fired ships with ships of the past burning coal, it can be said on the indisputable authority, both of naval engineers and of naval architects, that in any modern design, with displacement, armament, speed, the same in each case, the endurance on oil could be more than doubled, while the complement of engine-room ratings could be more than halved.

With the limitations of weight and space incumbent on all modern naval designs, the rate of forcing of the boilers is necessarily very high—with coal-fired boilers the consumption of coal per square foot of fire-grate must be large in order to keep the boiler dimensions and weight within reasonable limits. At these high rates, the consumption of fuel is bound to be inefficient and relatively large quantities of unburned or only partially consumed fuel are carried away up the funnel in solid form, to the annoyance and disadvantage of the personnel and fittings on deck. In addition, the boiler heating surfaces become foul and the gas spaces between the tubes choked with soot and ash, with the result that heat transmission is impaired, efficiency still further reduced, and the already dirty fires are required to burn even more coal than before if the output of steam is to be maintained.

Actually, as between the two fuels and with the latest improvements, combustion with oil almost attains that which is theoretically possible, and it is under perfect control all the time. With coal the limitations are most serious; one has only to read the Admiralty regulations in the Steam Manual of the all-coal-fired ship days to realize this. A full power trial then consisted of 8 hours at 100 per cent. F.P. and 16 hours at 60 per cent. Sixty per cent. was the maximum power obtainable until the coal was finished and, speaking from considerable experience, it can be said that even this low percentage of power depended very largely on the organization, the skill, and the endurance of the engineering personnel with, in many cases, frequent calls for deck assistance to bring the coal in distant bunkers to the vicinity of the various stokeholds.

Is this enormous handicap with all its effects on the qualities of the ship to be accepted lightly? I know of no naval engineer officer who has experienced service under both conditions who would think twice about the matter.

Flexibility.—Changes of speed, and without making smoke, are easily obtainable with oil-firing; with coal, comparatively large increases of speed must await the thickening up of the fires, while subsequent decreases involve ample time for burning down the fires, and, of course, uneconomical expenditure of fuel.

A modern destroyer at sea with all boilers alight can increase from, say, 15 to 30 knots, just as fast as the ship can gather way, and go on increasing to full power and speed all within 10 to 15 minutes.

I have seen it argued that this characteristic is not one required of destroyers in war time; but it most certainly is, and I imagine the matter is one which can safely be left to the opinion of those officers who have commanded destroyers.

Smoke.—Owing to incomplete combustion, it is impossible in naval designs, for reasons already stated, to avoid the production of a certain amount of smoke with coal-fired boilers, more especially at high rates of forcing and large changes of speed. In oil-fired ships, the combustion of the fuel is under complete control and production of smoke can be entirely eliminated.

From the point of view of visual signalling and the handling of the fleet, the advantage of being able to work with a clear funnel is obvious. Moreover, with oil, the making of smoke is under control and can be utilized for smoke screens for tactical reasons. Control of smoke is of high tactical and gunnery importance, and in this respect coal-burning ships are at a very definite disadvantage.

Changes of Trim.—I have already mentioned the advantages of oil fuel to ship design—stowage and ease of supply to the boilers in adequate quantity to meet all demands ; but there is another, an operational advantage, and one that under certain circumstances both in war and peace may be considerable. In case of damage to the ship from enemy action or from accident, such as collision or grounding, rapid changes of heel, trim, and buoyancy can be made by transferring oil from one part of the ship to another. This is not possible with coal.

Personnel.—An argument which has been advanced in favour of coal, but which would scarcely be worth mentioning were it not put forward in all seriousness, is that coaling ship was an operation which brought untold good to the Navy because it built up the spirit and physique of officers and men, and provided the finest means of selecting petty officers and of testing the quality of junior executive officers—nothing is said about the infinitely more exacting work of the engineering personnel in the bunkers—and, further, that the use of coal produced a type of British stokers, engineers, and seamen who were to a modern fleet what old-fashioned sailors were to the fleets which our ancestors commanded. Not, their parents, nor their upbringing, be it noted, but coal was alleged to be responsible for this fine personnel !

This form of argument has been used, on the introduction of some new armament or appliance, by every " die-hard " ever since the days of bows and arrows, and there is only one answer to it ! !

Supply.

Now we come to an important question which I believe really forms the basis of all the arguments for coal and of all agitation against oil, and that is the question of supply. It is contended that while our supplies of oil could all be cut off at source, the supplies of home-produced fuel are always available.[1] Putting aside for the moment those cranks who will not listen at all to any of the reasoned arguments on the coal *versus* oil question, it is quite natural that many people who are deeply concerned for the Navy and the safety of this Empire, should ask whether we can keep going under all the possible circumstances of war and requirements for the adequate

[1] The supply of Welsh coal—a supply limited to a single source—has been curtailed both during and since the War by general strikes.

defence of the Empire. In this matter of supply, the whole question of oil *versus* coal is most involved, because modern transport of almost all kinds, and in all the three Services, depends on adequate supplies of liquid fuel.

It would be a most serious impeachment of our controlling authorities—and that includes others besides the Board of Admiralty —if they had not been the very first to realize the importance of this question, and to make a proper provision.[2] It may well be that risks have been taken, and yet those risks have received careful and proper discussion and have been found in all the circumstances to be justifiable. It is quite obvious that none of us here knows quite enough to discuss the matter properly. I certainly do not pretend to myself, nor, I imagine, would it be altogether in the public interest to give all the facts in connection with arrangements for supply of oil in war. But this at least can be said, we are not dependent entirely on supplies from any one country, or from any one part of the world, and it is as ridiculous to say that our supply of oil is liable to be cut off at its source at any time without a shot being fired to defend it, as to say the same of any other raw materials, such as food.

Reserves of oil can be and, I have no doubt, are being built up as the responsible authorities may judge necessary. In some respects it is easier to build up reserves of oil at distant fuelling bases than it is to build up reserves of coal—a fuel much more liable to deterioration and much more of which for the same performance would be required: over 40 per cent. more tonnage is required to carry the same useful quantity of coal than for oil; in point of fact the position is far worse than that, because oil can be carried in the double bottoms and in tanks other than bunkers, and in those of ships other than pure colliers or oilers.

Another point that is often forgotten is that there can be no certainty nor, I hope, probability that future wars will be fought entirely in Home waters and, quite apart from the difficulties of transport mentioned above, there can be little doubt that in most parts of the world, it is now easier to get oil fuel than good Welsh coal.

The one disadvantage of having to transport oil in large quantities to these islands is fully recognized, and without exception everybody concerned would much prefer to use a home-produced fuel, were it possible to do so.

I have not referred to a point which has been raised occasionally —that the Navy could use coal in peace time and turn over to oil in war time. It is really not worth arguing about; of course, it could be done, but not if you want an efficient Navy.

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[2] The question of the possibility of home-produced liquid fuels is beyond the purpose of this lecture.

Summary.

To summarize : the following are, briefly, the advantages obtained from the use of oil :—

Increased endurance for a given weight of fuel—approximately up to the ratio of 2 to 1 ;

Longer periods at sea without having to return to harbour ;

Increased power and speed for a given weight of machinery ;

Alternatively, equal power on a reduced weight and space of machinery, permitting the difference in weight and space to be devoted to other military requirements, viz., armour protection, armament, etc. ;

Increased flexibility ;

Reduced complement ;

Short time required in harbour to replenish with fuel and stores, and ability to go to sea at once without a fatigued personnel ;

Full power can be maintained as long as fuel lasts, instead of only 60 per cent. ;

Absence of smoke and ability to control smoke for tactical purposes ;

Transfer of fuel for correction of heel and trim in event of damage ;

Transport to distant fuelling stations more easy and less of it required in store ;

No deterioration in storage.

In conclusion, it can be stated that on a limited displacement it would be impossible to design a coal-burning ship having the same military characteristics as a ship burning oil.

It has been customary to state from time to time that were we to revert to coal, we should be accepting a handicap which could not now be undertaken without the gravest prejudice to the strength of the fleet and its operational efficiency ; but do not let us play with this question, the fact is we should render the fleet useless for the defence of our Empire.