THE OILS SECTION OF THE SHIP DEPARTMENT

BY

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Purpose

The purpose of the Oils Section of the Ship Department is to ascertain and co-ordinate technical details of the petroleum fuels and lubricants required for warship equipment and, in conjunction with the Admiralty Oil Laboratory and the oil industry, to provide the Stores and Contracts Departments with the information necessary to ensure that petroleum products are purchased, stored, and handled so that warships receive products of the required quality. Also, equally, it is to inform design departments about the characteristics of oil products that are available or could readily be developed. The section deals with petroleum products: this phrase covers fuels, lubricating oils, hydraulic fluids (including those made of synthetic materials), greases, and a variety of associated products such as temporary protectives, anti-seize compounds, anti-freeze, and oil-spill dispersants. Over the years, naval requirements have been narrowed down, standardized (where

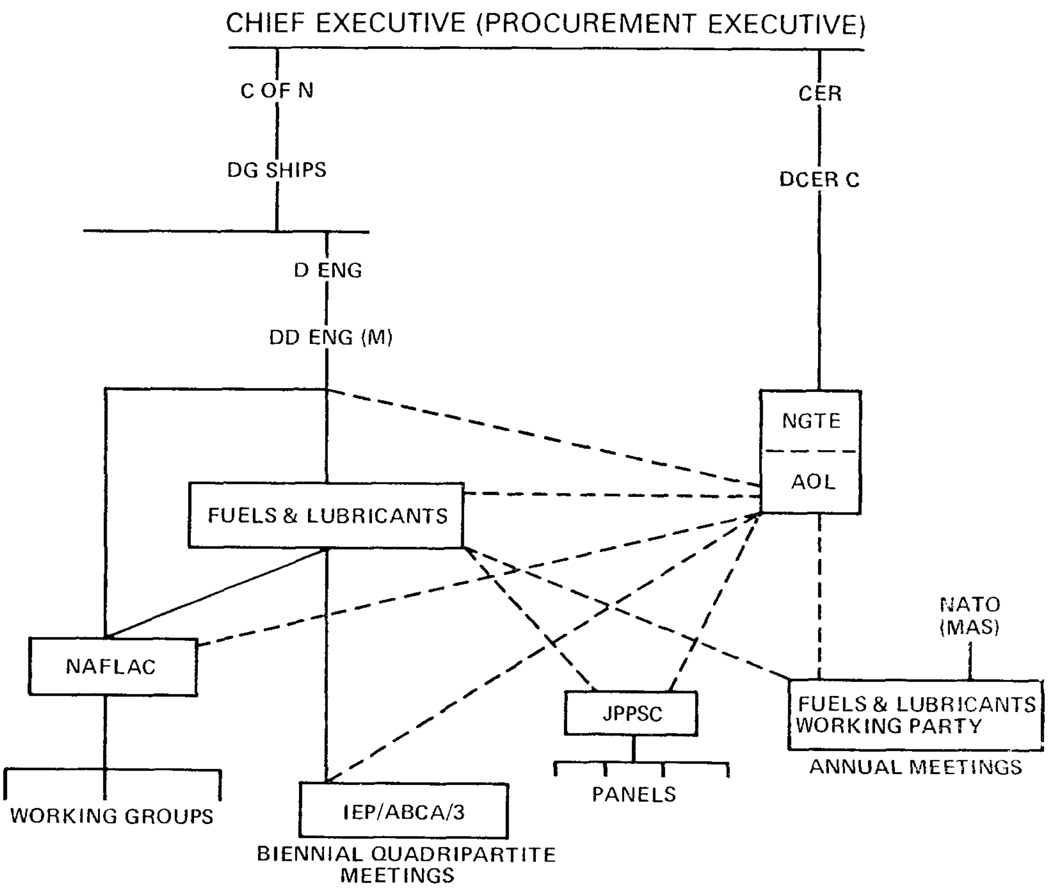

FIG. 1—AUTHORITIES

possible) with other services, and detailed in BR 1336. These standard products, however, do not meet all specialized naval requirements and there are a number of proprietary products which have been identified and approved for naval service, and these are detailed in Appendix V of the *Naval Oils Manual,* BR 3009.

Consultative Arrangements

Development, availability, and standardization of petroleum products is dealt with by consultation and discussion with a number of authorities. These include: the Admiralty Oil Laboratory; the oil industry through the Naval Fuels and Lubricants Advisory Committee (NAFLAC); the other services through the Joint Petroleum Products Committee (JPPSC) of the Defence Engineering Equipment Standardization Committee; NATO navies through the Working Party sponsored by the NATO Military Agency for Standardization; and the American, Canadian, and Australian Navies through an ABCA Information Exchange Project.

The Head of the Ship Department Oil Section is the Secretary of NAFLAC, a member (and currently Vice-Chairman) of JPPSC, represents the Royal Navy on the NATO Working Party, and is the U.K. Project Officer for the ABCA Information Exchange Project. It is sometimes alleged that these working parties, committees, and visits abroad are an unnecessary expense and also that inadequate support is received from the oil industry. All the consultative organizations mentioned have been in existence for over twenty years (1) and as a result of the good work done during this time it is probably true to say that, if they were to cease to exist, the Navy would 'free wheel' for some time and not notice the difference. However, it is almost

TABLE I—*Naval Fuel and Lubricants Advisory Committee*: *NAFLAC*

	Main Committee
Chairman	— Independent Petroleum Consultant
Members	— Representatives of:
	DG Ships DGW(N) DGST(N) DGDC AOL Universities Merchant Shipping Major U.K. Oil Companies
Secretary	— Head of DG Ships Oils Section
'Managed' by DG Ships	
Reports annually to CFS	
Supported by:	
A 'Bank of Experts' about 80 in No. representative of:	
	Oil Industry Engineering Industry Universities CEGB, NEL, Ricardo, Y-ARD, NAVGRA, etc.
Consulted individually or may form working groups on particular subjects as directed by the Main Committee	
Active in 1977: Turbine and Gear Oil Working Group Diesel Engine Lubricating Oil Working Group Fire and Explosivity Working Group	

TABLE II—*Joint Petroleum Products Sub-committee (1977)*

Chairman	— Head of MQAD Petroleum Division		
Members	— Representatives of:		
		DG Ships AOL	Navy
		MQAD DOrdS DGFVE	Army
		EngD4 MOD(Air) DR(MAT)	Air
		BSI	
Secretary	— from D.Stan		
Reports to	Defence Engineering Equipment Standardization Committee		
Supported by:			
	Fuels Panel		
	Lubricants and Temporary Protectives Panel		
	International Standardization Panel		
	Test Methods Panel		
	Petroleum Handbook (BR 1336) Edit Panel		

certain that, after a very few years, the repercussions would start to become obvious and it would be extremely hard going to restore the position. It is worth having a look at past history to see how all this came about.

History

The Royal Commission on fuel and engines, under the chairmanship of Lord Fisher in 1912 and 1913, which recommended that the Royal Navy should change from coal to oil firing, drew up the specification for the Navy's fuel. It also recommended the measures necessary to ensure supplies which included the Government investment in the Anglo Persian Oil Company (now British Petroleum) and these actions sufficed to ensure that no problems arose over the Navy's fuel until the 1939–45 War. Lubricating oils posed little problem; reciprocating engines had been lubricated for years with either animal or vegetable oils. It is recorded somewhere that the Royal Navy was the largest consumer of olive oil in the world in the Victorian era. Turbine machinery, introduced in the early years of this century, and the early diesel engines were perfectly well lubricated by straight, good quality, mineral lubricating oils, and the Navy very early on assured itself a supply of such an oil from the Pennsylvania oil fields. There may be some older engineer officers who recall the excellent qualities of Special Mineral Lubricating Oil (SMLO) which was used for lubricating virtually everything in the Navy before and during the Second World War.

During the 1939–45 War and immediately after, it became increasingly evident that the Royal Navy was encountering difficulties in obtaining oil fuel and lubricants of the appropriate quality. Factors included changes in supply sources, the increased demands of other users, and the higher quality oil required by more advanced design machinery. The effect on the operation of the Fleet became serious and, in 1950, the Board of Admiralty formed a co-operative body which included representatives of the Admiralty, the oil industry, and independent opinion under an independent chairman (the late Lord Geddes). This committee, entitled The Admiralty Oil Quality Committee, made a number of recommendations in 1951–2; these included

TABLE III—*Milestones*

Year	*Fuel and General*	*Lubricants*
1898	First attempt to burn oil—H.M.S. *Surly*	
1906	A.F.E.S. Haslar opened	
1912	Royal Commission on Fuel and Engines First all oil-burning destroyer Founding of Institute of Petroleum	S.M.L.O.
1915	First all oil-burning battleship (H.M.S. *Queen Elizabeth*)	
1939	H.M.S. *Ajax* burnt pure diesel fuel A.F.E.S. Haslar trials burning pure diesel fuel	Admiralty ICE Oil
1944		OE-30-HD (U.S. ICE oil) 2190T (U.S. turbine oil)
1945		OM-33 (Hydraulic oil)
1949		OMD-110
1950	Admiralty Oil Quality Committee	
1953	AFLAC (later NAFLAC)	OM-100 OMD-111
1954	AOL opened at Brentford	
1956		OMD-110 (Different from 1949 oil) OMD-112
1961	Dieso burning trials in Type 12 frigate	OEP-69
1965	First Dieso Working Party	OMD-113
1966	Admiralty Board approved Dieso burning conversion programme	
1968	Decision to cease design of oil-fired steam ships. AOL moved to Cobham	
1971	Second Dieso Working Party	
1974	Dieso conversion programme complete	
1976	Third Dieso Working Party	

specifications for fuel and lubricants, and quality surveillance standards for the storage of lubricants. Their major recommendations, however, were that there should be established a Royal Navy and Petroleum Industry Advisory Committee to make the knowledge and experience of the industry fully and continuously available to the Admiralty—a naval petroleum technical organization which should include a laboratory with adequate facilities for testing naval fuels and lubricants—and also that there should be annual meetings with the Royal Canadian Navy and the United States Navy. All these recommendations were approved by the Board of Admiralty, hence the existence of NAFLAC, the Admiralty Oil Laboratory, and the ABCA Information Exchange Project.

Procurement

Provision of the required kinds of oil to the Royal Navy depends on a number of clearly defined steps. Firstly, the type of oil required must be determined. Ships and equipments ordered to MOD specifications are required to be designed to use fuels and lubricants which are standardized and listed in BR 1336. 'Design-and-build' ships and proprietary commercial equipment, however, usually call for oil products identified by commercial brand names; in most instances a service equivalent can be identified but occasionally a proprietary oil has to be used. The next step is the procurement of the oil and the appropriate quality assurance by oil laboratories to ensure that the specification is being met. The final step is the storage and supply by the Stores Department; this involves regular quality surveillance (with the assistance of AOL) to ensure that the oil product does not deteriorate either in store or in handling. The more straightforward oil products can be supplied by any reputable oil company against the specification with suitable quality assurance procedures. Most of the Navy's lubricating oil and hydraulic fluids, however, involve a qualification or type approval procedure; this requires the provision of candidate oils to the oil laboratory for testing together with details of the oil formulation (the latter being supplied in strict confidence to the laboratory only). If approved, the manufacturer's product is identified by a number which is promulgated to the interested parties, including the Contracts Department. Thus, only oil of the approved formulation is purchased, the manufacturer having agreed that all future supplies will conform to the formulation details of the candidate oil. Each approval normally lasts for four years and re-approval is then required. The

TABLE IV—*Costs of Petroleum Products relative to Steam Turbine Lubricants (OM-100)*

Petroleum Product		*Relative Cost*	*Supplied in Bulk(B)/Cans(C)*
FUELS:			
FFO		0·35	B
DIESO		0·50	B
AVCAT		0·55	B
LUBRICANTS:			
Steam Turbine and Gear Oil	(OM-100)	1·0	B
EP Turbine and Gear Oil	(OEP-69)	1·25	B
Diesel Engine Lubricating Oil	(OMD-113)	1·25	B
Outboard Engine Lubricating Oil	(OMD-45)	3·0	C
HYDRAULIC FLUIDS:			
Mineral Oil	(OM-33)	1·5	C
Emulsifiable Mineral Oil	(OX-30)	2·5	C
Very High Viscosity Index Mineral Oil	(OM-15)	4·0	C
FIRE RESISTANT HYDRAULIC FLUIDS			
Water Glycols	(H.S.271)	2·5	C
Phosphate Esters	(OX-20)	7·5	C
Chlorinated Silicone	(OX-50)	70	C
Perfluorinated Polyether	('Fomblin')	1000	C

oil laboratory also carries out tests to ensure that different manufacturers' supplies to a given specification are compatible with each other. Of course, both technical and logistic changes necessitate periodic additions and improvements to the service range of oils. For naval requirements the new oil and its specification will be developed by co-operative work between AOL, the oil industry, and the equipment designer, with NAFLAC assistance. JPPSC may also be involved particularly where equipment is common to the other services.

Petroleum products are continuously consumed by H.M. ships, some of them in large quantities; the current cost to the Naval Vote is approaching £50m a year. Decisions on petroleum products to be used in warships must take into account not only the cost but also the expected availability of the product during the life of the equipment concerned. Regarding the cost aspect, it is possible to design an equipment which is difficult to lubricate and then put the onus of making the equipment run properly on the oil technologist; it should be recognized, however, that the cost of an oil product will reflect the difficulty of devising the formulation and the availability of special materials to make the finished product; designers should, therefore, take into account the higher cost of more specialized products. Table IV shows the costs of some naval petroleum products relative to the cost of OM100 lubricating oil.

HIGHLIGHTS 1967–1977

Fuels

In 1966, the Dieso Working Party recommended and the Admiralty Board approved that all steam ships with high forcing rate boilers should be converted from FFO to Dieso. In 1967, the Wasp helicopter was permitted to run on Dieso in place of AVCAT except when the ambient temperature was low. In 1968, the decision was made that future surface warships should be propelled by gas turbines or diesel engines. In 1969, the Navy's Dieso specification was tightened in order to make it more suitable for gas turbine and helicopter use; in fact, the fuel supplied did not change because the Dieso provided for many years was much better than the earlier specification required. About this time, many other NATO navies also started to convert their steam ships to burn diesel fuel; unfortunately, not all of them chose the same type of diesel fuel as the Royal Navy (2)(3). This was a subject of considerable discussion in the NATO and ABCA forums; however, by 1972, the other nations began to realize that warship gas turbines and high-speed diesel engines could not use a fuel of lower grade than that of our Dieso specification without significant reduction in time between overhauls and that a higher grade fuel, such as AVCAT, would be expensive and have restricted availability. In 1973, all NATO navies agreed on interchangeable diesel fuel specifications and last year NATO confirmed that this diesel fuel, NATO Code F.76, would be the main propulsion fuel for NATO navies in the future. The stage has now been reached when no FFO is carried in any NATO fleet tanker other than the British ones, and FFO to naval specification is getting increasingly difficult to obtain from commercial sources.

The 2nd and 3rd Dieso Working Parties in 1971 and 1976 made recommendations concerning the remaining FFO-burning ships. Admiralty Board decisions on the latter are awaited.

Microbiological Growth in Fuels

Microbiological growth first became evident in aviation fuels about fifteen to twenty years ago (4) but there was then little evidence that these growths occurred in naval diesel fuel. There were two types of growth principally involved: one is the fungus *cladosporium resinae,* the other is a sulphate reducing bacteria. A by-product of the latter is hydrogen sulphide which attacks many metals resistant to other forms of corrosion. As far as naval diesel fuel is concerned, apart from one isolated instance about ten years ago, there were no reports of microbiological growth until about three years ago, since when there has been increasing evidence of the growth of *cladosporium resinae* in shore tanks, R.F.A's., and H.M. ships (5). In extreme cases, the result has been complete blockage of filters. *Cladosporium resinae* utilizes hydrocarbon as a food source but the presence of water is essential for its growth; the normal good housekeeping practice of minimizing water ingress to tanks coupled with the stripping of water bottoms should, therefore, keep the growth under control. Serious problems, however, can arise in ships which have water-displaced fuel systems. A strange thing, however, is that submarines, which have used water-displaced fuel systems for some fifty years, have not reported any of these problems, and from the Type 41 and Type 61 frigates which have been in service for about twenty years with similar arrangements there has been only one report about a year ago.

The aircraft industry developed two methods of combating this growth. The material put in aviation fuel as an icing inhibitor (joint service designation AL31, ethylene glycol monomethyl ether) was found to act as a biostat inhibiting microbiological growth, and this additive is now a standard addition to all aviation fuels. Where severe contamination occurs, a biocide (usually based on boron) can be used to sterilize systems.

Dosing of all ship's supplies of diesel fuel with Fuel System Icing Inhibitor (FSII) has been considered. This would be quite costly and has other snags; firstly, FSII has a low flash point and can reduce the flash point of the final product, possibly to below that which is acceptable for H.M. ships unless the Dieso has a sufficiently high flash point in the first place. Secondly, the dosing must virtually be continuous, and some ships spend long periods away from normal naval sources of fuel and depend on commercial and other NATO navies' sources for their fuel. The alternative (a biocide) also poses problems: apart from the cost, the dose level is critical as there is only a narrow band between the maximum amount that can be permitted which will not cause corrosion of gas turbine blades and the minimum level below which the dose is sub-lethal with the possible development of a strain of growth resistant to the biocide. Because of the serious effect in fuel systems of ships, the Ship Department in conjunction with the Admiralty Materials Laboratory is considering the best means of dealing with these problems.

Lubricating Oils

Steam Turbine and Gear Lubricants

The oil which has provided most of the talking and work in the past year or two has been OEP-69. This was developed to meet the requirement which arose in the 1950's for an extreme pressure (EP) oil to lubricate the highly-rated gearing then being introduced into service. The requirement was a difficult one to meet because, in addition to having an EP capability, the oil also had to be suitable in all respects for use as a steam turbine lubricant in a marine environment. After sea trials of a number of candidate oils provided by different oil manufacturers, one formulation was selected and introduced into service in 1961.

Contrary to expectations, the Merchant Navy did not follow the R.N.'s lead in introducing highly-rated gearing, and as a result only one supplier has seriously sought and received approval. Experience with this oil in service has been generally satisfactory, although there have been some allegations of shortcomings, such as sludging and lacquering. OEP-69 is manufactured by the addition of an EP additive to a high quality turbine oil used in industry and merchant ships. In 1973, the Electricity Generating Industry were finding that the oil in new power stations was not giving the life of twenty or more years they had previously experienced. They specified that the oxidation stability of the oil should be improved. The oil supplier approached the R.N. and asked if we were prepared to accept the additional anti-oxidant additive, which was to be added to the industrial oil, in our OEP-69, as this would be beneficial in terms of cost and availability. Samples of this new formulation were tested at AOL and showed good results against all our specification tests. The results were reported to the Ship Department's Gearing and Oil Sections and it was agreed that the new formulation was acceptable. This new formulation started being supplied to the Navy at the beginning of 1974.

During 1975, the Navy experienced very severe grooving of rotors in way of the oil baffles in the main turbines of Tribal Class frigates and to a lesser extent in some auxiliaries in a number of different classes of ships. In two cases, the rotor was grooved so deeply that renewal was necessary. The investigation carried out by the AOL, the Central Dockyard Laboratory (CDL), and the oil company concerned concluded that the new anti-oxidant additive was the cause of the trouble despite the fact that laboratory tests and the experience of the CEGB had demonstrated that it was effective in prolonging the life of the oil at high temperatures. It appears that oxidation tests had been assumed to control carbon formation, but it is now evident that this is not always the case. The precise mechanism of the carbon formation is still rather obscure but it appears that oil baffle temperatures are particularly high and the oil drainage path is restricted in the Tribal Class main turbines. Tests carried out at the AOL showed that the carbon formed under these conditions from the oil of the modified formulation was harder and more adherent than that formed under the same conditions from OEP-69 of the original formulation. It is thought that this type of carbon builds up and grooves the rotor whereas previously any accumulations of carbon broke off and were carried away in the oil stream. Arrangements were made with the oil company to revert to the original formulation and a programme to change over the ships of the Fleet from the modified formulation to the original formulation was put in hand and should be complete by the middle of 1977. Meanwhile NAFLAC has been asked to devise a specification test to control this characteristic.

Another problem that has affected many ships using OEP-69 has been the formation of tin oxide on the white-metal bearing surfaces, eventually leading to bearing failures (6). Investigations into the precise cause of this are still continuing and it is too early for any firm conclusions. However, there are indications that tin oxide only forms in the presence of chlorides. There are records of relatively few incidents of tin oxide corrosion in ships using non-EP turbine oils and, in most cases, there is some evidence that salt water was present in the oil; whereas tin oxide corrosion has been recorded for many years in ships using OEP-69, where chlorides are likely to be present since the EP additive is chlorine-based. If the EP additive is shown to be the cause of this corrosion, then the change of formulation being carried out (because of the carbon formation problem just described) will not have any effect on the rate of tin oxide formation.

The solution of this problem is still unclear: frequent examination of all the bearings is being carried out; meanwhile, in conjunction with NAFLAC and NAVGRA, the current requirements for EP oil in the Navy is being examined. It appears that, with improved standards of gear manufacture, the requirements for an EP oil with the high gear-tooth load-carrying capacity of OEP-69 may no longer be necessary. Recently, *Gurkha, Rhyl,* and *Apollo,* which have run for many years on OEP-69, have had their main lubricating oil system changed to OM-100. If these trials and the investigations being carried out on shore should confirm that an oil with a lower load-carrying capability than OEP-69 can be accepted, this opens the way to the use of a different and less aggressive type of additive in our EP oil. Such an oil could bestow great potential benefits: firstly, the avoidance of the tin oxide corrosion problem; secondly, the possibility of using oils that are already available and in use commercially and in some other NATO navies.

Gas Turbine Lubricants

All the Rolls-Royce family of gas turbines used for the propulsion of H.M. ships use the synthetic lubricant OX-38. This lubricant was originally developed for the turbo-prop aircraft turbine. Its high-temperature performance is not adequate for some new designs of aircraft turbines and there is some evidence of marginal performance in industrial applications. OX-26 lubricant is used in many recent aircraft ('Concorde', 'Tristar', 'Tornado', etc.) and usage and availability of OX-38 is expected to decrease. The R.N. may need to change from OX-38 either for technical or logistic reasons and a programme is in hand to clear Olympus, Tyne, and future types of marine gas turbines to use OX-26 if required. Fortuitously, OX-38 gives good corrosion resistance in the marine environment; OX-26, however, does not appear to be so good in this respect and trials will be required to find out if its performance is adequate.

Diesel Engine Lubricants

Diesel engine lubricants exhibit one of the most rapid and greatest changes in lubricating oil technology seen so far this century. This has been necessary to keep pace with development of diesel engines and the enormous growth of the motor car and lorry on our roads. Until near the end of the 1939–45 War, our diesel engines were lubricated with plain mineral lubricating oil; before 1939 SMLO was used for the majority of R.N. diesel engines, as well as for turbines and general lubrication.

During the 1930's, a considerable amount of work was carried out in the United States on the development of detergent lubricating oils for the automotive industry. This included the development of methods of testing these oils. During the latter part of the 1939–45 War, the American forces brought over with them this type of oil for their vehicles and the diesel engines in their ships. Logistic aspects caused the Royal Navy and the other two services to have to depend more and more on American supplies of lubricant. As a result, by the early 1950's the Royal Navy was entirely dependent on diesel engine lubricating oils which were developed and tested in the United States, and over which we had little knowledge and no control because there were no proper means of testing internal combustion engine lubricating oils in this country. This state of affairs was one of the reasons for the setting up of the Admiralty Oil Laboratory (7) equipped with appropriate test engines for testing diesel engine lubricants. The lead given by AOL resulted in the setting up of test engines and laboratories elsewhere in the U.K., permitting the development of specifications for oil suitable for our engines and which could then be manufactured in this country under our own control.

There have been many trials and tribulations during the intervening years and it has been necessary to take into account developments in the United States (both civil and military) and requirements of commercial and domestic users in this country, coupled with the development of the designs of diesel engines. The naval oil OMD-113 has now emerged as the standard diesel engine lubricating oil suitable for all diesel engines used in R.N. service. A programme of upgrading this oil to make it correspond to the Series 3 oils used industrially and the similar oils used in the United States Navy and other NATO navies has just been completed.

Questions are often asked as to why the R.N. uses a specification oil and not one of the many reputable brands of similar oils available on the commercial market; it can often be proved that in certain applications the commercial oil is better, depending on how 'better' is defined. There are good reasons for the R.N. preferring specification oils. Despite what is often alleged, experience shows quite clearly that for large bulk orders the cost of oil to a specification is considerably less (sometimes as little as half) than that of an equivalent branded oil. Also, it must be remembered that, although a branded oil can perform better in a particular application, it may not always be suitable for other applications; and it is logistically desirable for OMD-113 to be equally suitable for orthodox four-stroke engines, large and small, low and highly-rated varieties, as well as for two-stroke engines such as Foden and Deltic where port blocking must be avoided. In addition, the manufacturer can change the formulation of a branded oil without prior notice, with detrimental effect in some applications.

There is a considerable degree of 'advertising' about the attributes of advanced diesel engine lubricants; these higher qualities are normally achieved by the addition of more and costly additives and there is experience to show that some additives can have unfortunate side effects; there is, therefore, no merit in putting in an additive which one does not need. It must be remembered that additives are not put there to improve the 'oiliness' of the oil but to improve things like the thermal stability, detergency, corrosion protection, viscosity index, and other features; also, the cumulative effect of too many additives will reduce the percentage of lubricating oil in the final product. A diesel engine lubricating oil such as OMD-113 contains over 10 per cent. of additives leaving less than 90 per cent. of lubricating oil. As an illustration of this, the author recalls at a NATO meeting the United States Navy representative describing efforts to achieve an 'improved' lubricating oil (not in this instance for diesel engines) saying that they had put in additives to prevent corrosion, oxidation, foaming, wear of gear teeth, and to improve the viscosity index and vapour space inhibition; the result was an oil which had so much additive and so little oil that it did not lubricate!

It appears in recent years that the development and use of higher-power diesel engines, particularly for propulsion purposes, has resulted in problems at low powers and low speeds due to carboning or lacquering up in the cylinder head and valve area. The NAFLAC Diesel Engine Lub. Oil Working Group has applied itself to this problem, as have others working in this field. However, it appears that changes to diesel engine lubricating oils can only provide a very limited solution to this problem and some engineering or operating change may be necessary when this problem is met.

Air-compressor Lubricants

For many years naval air compressors have been satisfactorily lubricated using the conventional oils carried on board for steam turbines or diesel engines. Industry, however, has suffered a number of serious explosions in air systems attributed to the carry-over and carboning-up of oil from air compressors; this has resulted in efforts to develop a special more suitable oil. Recently the Royal Navy has been worried by the quality of compressed air provided for breathing purposes, in particular the carbon monoxide content which seems to be related to the degree of carboning-up inside the air compressor; also the degree of oil carry-over is not regarded with favour. It is possible that the oil being developed for industrial air compressors may be helpful to the Royal Navy in avoiding these problems. Consideration is therefore being given to carrying out a comparative trial with the commercial oils recently put on the market.

Hydraulic Fluids

The principal development during the last ten years arose out of the introduction into service of submarines that had part of their hydraulic systems outside the pressure hull resulting occasionally in severe water contamination of the hydraulic system. In order to flush out the water, use was made of a proprietary emulsifiable oil made in this country under licence from America. After a repeated number of such incidents, it was decided to try leaving the emulsifiable oil in the system as the working fluid—on the principle 'if you can't beat them, join them'. The result of these trials was very satisfactory and consequently all the submarines in question had their working fluid changed over to this emulsifiable oil, known by its proprietary name PR1192. Any ingress of water forms an emulsion with the oil and the amount of water in the emulsion can be measured on board so that when it reaches a stated percentage the oil is changed at the next opportunity. As the water forms a water-in-oil emulsion, the metal surfaces of the system are protected from the water and corrosion is thereby prevented from occurring, provided the emulsion remains stable. The possibility of problems arising due to the use of a proprietary product made by a single manufacturer was recognized, and two years ago a specification was drawn up to permit other manufacturers to tender for supplies of this oil (now given the joint services designation OX-30). At present it is only used in submarines but there is no reason why it should not be used in other systems where ingress of water creates a repeated problem. The characteristics of the oil are virtually the same as OM-33 except that it has this property of being emulsifiable.

Fire Resistant Lubricants and Hydraulic Fluids

Arising from some rather serious fires over the past few years in which lubricating oils and hydraulic fluids were involved, consideration has been given to the introduction of suitable fire-resistant fluids. Such products have often been given generic names such as 'non-flammable' but the use of such a phrase is seriously resisted because in the right conditions almost all these fluids will burn. It is also necessary to ensure that the selected fluid does not produce toxic fumes when heated. These may be acceptable in a large building ashore but not in the confined spaces of a warship or particularly a submarine. NAFLAC carried out a survey recently of fire-resistant lubricants which might be suitable for ships' main steam turbines and gears. The conclusions were that no product is currently available on the market which will meet the requirements. The few fluids that showed promise required considerable development and their cost could be expected to be many times the relative cost of a straight mineral oil such as OM-100. As the present cost of turbine oil is somewhere between £100 and £150 a ton and as we use something like 2000 tons a year, clearly the additional cost to the tax payer would require some justification.

A fire-resistant hydraulic fluid in place of OM-33 is more possible and considerable work is continuing in this field under the direction of Central Hydraulics Authority (RN). A large number of potential products have been examined at AOL, and the experience of other people in the field (such as the National Coal Board and Industry) have been considered. For some years, the Navy has used one proprietary fluid (HS 271) to a limited extent. Trials have been carried out at AEL with this fluid, and it has recently been put into the stabilizer system of a DLG (which had previously run on mineral oil) to see how it performs in service. The two types of fire-resistant fluids which look promising are an aqueous polyglycol, the type being used in the DLG trial, and a water-in-oil emulsion used by the National Coal Board. It should be noted that both these types of fluid depend on having a minimum quantity of water in the total fluid, otherwise the fluid ceases to be fire resistant; thus, if the fluid leaks onto a hot surface including one that is lagged, the water content will boil away leaving a flammable residue and spontaneous ignition can occur. The lubricating properties of these alternative fluids are not so good as mineral oils and the tests currently being carried out are principally to find out whether the wear rates of hydraulic equipment become too great to be acceptable. Other types of fire-resistant fluid have also been investigated. There are a number made from different types of synthetic oil; the best known are phosphate esters. These are not attractive on the score of cost, toxicity, and non-compatibility with existing system materials.

Greases

The most interesting change in this field has been the replacement of the grease XG-310, the old 'non-floating' grease, by XG-286. XG-310 gained its non-floating property, which was really its sole attribute, by the addition of a heavy barium sulphate filler and this did nothing to improve the lubricating properties of the grease—for which there was no commercial use. Many years ago it had been established by discussion between design departments that the non-floating characteristic was no longer necessary; however, pressure of other work prevented AOL from developing an alternative grease specification. In 1973, the sole remaining supplier of this grease declined to go on making it. As a stop-gap, a grease that had been specially developed to protect the chassis of buses running on motorways in winter time when there was salt on the road was introduced. Tests showed that this grease was very effective in sea-water conditions. A specification was written with this grease in mind, and a number of manufacturers are able to provide grease to this specification (DGS 327). The grease is a far better lubricant than XG-310, has enhanced corrosion protection, and adheres better to metal surfaces.

XG-274, the R.N. rolling-bearing and multi-purpose grease, suffers from oil bleeding and hence hardening if subjected to pressure in long pipes or grease passages. This is partly due to the poor oil retention characteristics of lithium-based soaps, but has also been attributed to the thin oil used. The specification was revised and re-issued last year as a Defence Standard 91-28/1, and now requires a much thicker oil.

Bearings in recent design electric motors appear to run hotter and investigations are in hand to see if there is a more suitable grease than XG-274 or XG-344 now specified. There are some new greases available commercially; they are costly, not made in this country, and their suitability for a marine environment is not proven.

Safety

The Oils Section is also responsible for BR 1754, the Safety Regulations for Storing and Handling Petroleum Oils, Lubricants, and certain other Hazardous Stores in H.M. ships, and with the assistance of the Admiralty Oil Laboratory and NAFLAC provides advice on all aspects concerning safety when storing and handling petroleum products.

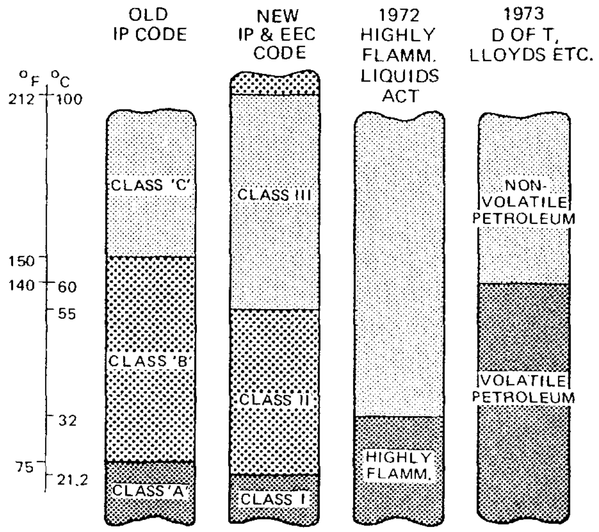

FIG. 2—CLASSIFICATIONS OF PETROLEUM PRODUCTS AND HAZARDOUS LIQUIDS

Problems are beginning to arise in framing the rules for BR 1754. This arises because the BR is based on the U.K. classification of flammability expressed in a long-standing Institute of Petroleum code of practice involving Class 'A', highly-flammable liquids with a flash point less than 73°F; Class 'B', flammable liquids with flash points between 73°F and 150°F; and Class 'C', combustible products with a flash point in excess of 150°F. These classifications are quoted in the Transport of Dangerous Goods Regulations and in the Petroleum Consolidation Act 1928; these regulations are still extant.

In 1972 however, the Highly Flammable Liquids and Liquid Petroleum Gases Regulations became law; these state that in all premises subject to the Factories Acts all liquids with a flash point of less than 32°C (approximately 90°F) are to be classified Highly Flammable. These regulations appear to cover H.M. dockyards and possibly H.M. ships when under dockyard control. However, the current European model code used by the EEC requires the demarcation between highly flammable and flammable to be 21°C and the demarcation between flammable and combustible to be 55°C. This code is now being adopted by the Institute of Petroleum in lieu of their previous code and the U.K. is committed to harmonize its legislation with the EEC in due course. On top of this, the Marine Classification Society rules (such as Lloyds, Bureau Veritas, etc.), the Merchant Shipping Construction and Survey rules, the International Oil Tanker Terminal Safety Group guide, and the Inter-Government Maritime Consulting Organization all apply the criterion that the point of demarcation between petroleum products which are relatively safe and those which are relatively hazardous (i.e. the demarcation between flammable and combustible) is 60°C/140°F. This merchant shipping classification is now adopted by many NATO navies. The R.N. has not yet decided to follow suit.

It can be seen therefore that under current legislation petroleum products being transported on land and then handled in H.M. dockyard, in a R.F.A., or H.M. ship could have different classifications in each place. For H.M. ships in commission, the philosophy is that the R.N. should generally follow those practices prevailing in the Merchant Shipping Regulations. However, some differences may be necessitated by military considerations; these include enemy action, closing down for NBCD, and the high standards of training and discipline of personnel. These considerations sometimes lead to relaxation and sometimes to strengthening of the Merchant Shipping Regulations. It cannot be stressed too much that the regulations detailed in BR 1754 are specifically applicable to H.M. ships only and, except where stated otherwise, cover storage and handling only; precautions when *using* petroleum products are generally covered elsewhere, e.g. equipment manuals.

The introduction of GRP construction initiated a research programme into potential hazards arising from electrostatic charge generation in fuel filling systems. This work has been under way for three years at Southampton

University. The test rig has one GRP and one metal tank complete with filling system similar in size to the new MCMV fuel tanks. Considerable electrostatic voltages are built up under certain conditions, not all predictable, and this confirms the wisdom of retaining a high minimum flash point for naval fuels. The NAFLAC Fire and Explosion Working Group is watching progress and has suggested that opportunity be taken to measure the flammability of the mist formed when filling fuel tanks, a subject which lacks much hard facts.

Future Availability of Petroleum Products

Overlying the work of the Section is the question about which a torrent of words have been written and spoken during the last four years: How long are oils of the type we want likely to continue to be made available in quantity? The answer very much depends on who one consults on the matter (8). In an absolute sense, opinions vary between somewhere near the end of this century to the middle of the next; but there is the confusing factor, however, of international politics where, regardless of the amount of oil available in the ground, a major oil producing nation or a group such as OPEC could deny the rest of the world supplies of oil for political reasons. The dependence of the world on oil is now so great that a very small upset in the supply and demand balance can have very alarming effects. A shortfall of as little as 5 per cent. in supplies can result in near panic in the developed countries in respect of heating oil, aviation and motor fuels, and the supplies of the more difficult lubricating oils. A surplus on the other hand can result in oil apparently running out of the oil companies' ears and cheap petrol being offered at every other garage. There is no doubt, however, that as time goes on supplies of oil will get more difficult and this could occur during the lifetime of ships now building and being designed. The world consumption rate continues to rise steeply; the total quantity of oil reserves is finite even though the exact figures are not known, and calculations show that at the projected demand rate even a major reappraisal of available reserves would make very little difference to the date when shortages become acute. A search for alternative power sources should be encouraged and, as far as lubricating oils and hydraulic fluids are concerned, designers would be well advised to ensure that their equipment does not require special petroleum products which, inevitably, will become more difficult and expensive to obtain.

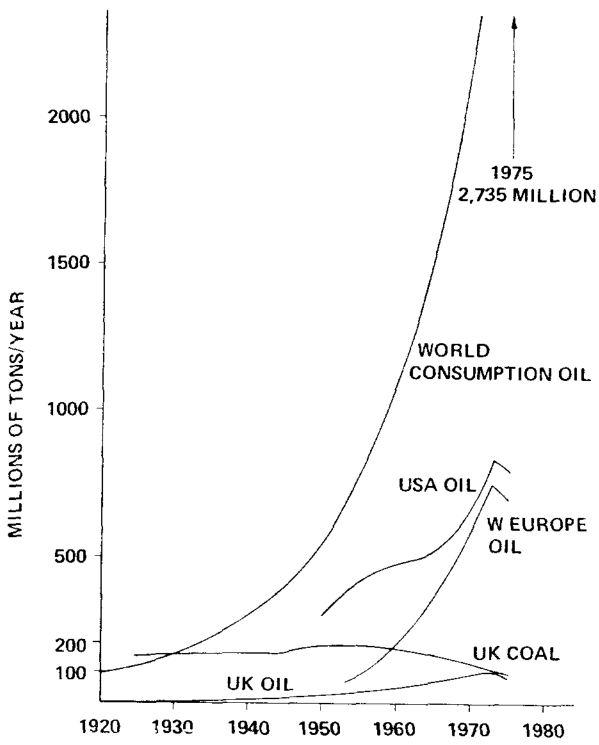

FIG. 3—FUEL CONSUMPTIONS

Conclusion

To end on a personal note: the author has enjoyed the ten years in this job and scarcely a day has gone by without him learning something new or strange. One thing he has learnt is that one should not jump to conclusions. By way of illustration: very many years ago, the Egyptian railways found that the consumption of axle grease was halved by the addition of castor oil. Attempts to reflect this saving elsewhere failed. It was later revealed that the purpose of the castor oil was to discourage the local employees from eating the grease! (9).

Acknowledgement

Finally, the author would like to acknowledge the very considerable assistance received over the years from the Institute of Petroleum through its many publications and, above all, from the Superintendent, Admiralty Oil Laboratory, and his staff. The Royal Navy is very fortunate in the service it receives from the Admiralty Oil Laboratory. Neither the other services nor industry have such comprehensive and relevant expertise to call upon. D.G. Ships' very small oil section and AOL work together extremely closely; in fact, one can almost be regarded as an extension of the other. Most of the work described in this article was either carried out at AOL or would have been much less effective without AOL's assistance.

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Postscript

As this article was going to press it was announced that, under the rationalization programme for Research and Development Establishments, AOL Cobham was to come under the administration of the National Gas Turbine Establishment and to be renamed NGTE Cobham on 1st April 1977, and also that the microbiological section of the AML has been transferred to CDL, Portsmouth.