AUXILIARY DIESEL ENGINES IN THE GERMAN NAVY ABOUT 1913

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ABSTRACT

This contemporary German document argues the case for diesel generators long before they were used in the Royal Navy, and discusses some of the design and installation aspects.

Introduction

The following document, found in the company archives at VSEL, Barrow and strongly supporting the use of the diesel engine for driving ships' dynamos (d.c. generators), was written in 1913/14. It is reproduced here since much of the content remains relevant today.

There was much comment on the suitability of the diesel engine for shipboard auxiliary drives in the predecessor to this *Journal*, i.e. *Papers on Engineering Subjects*, in particular numbers 1 to 12 written in the nineteen twenties, some of it being decidedly critical. In Germany the internal combustion engine was much more highly regarded—to the extent, in fact, that in the BAYERN Class battleships of 1916, all the main generators were diesel driven. Two ships only of the class were completed, the auxiliary diesel engines intended for the *Sachsen* being diverted to propelling U-boats. It should be noted in addition that although the *Bayern* and her sister ship *Baden* were driven on three shafts by direct drive steam turbines, it had been intended that the centre shaft in the *Sachsen* should be driven by an M.A.N. diesel of 12,000 b.h.p.

In the Royal Navy, of course, the steam turbine driven dynamo was preferred and, with the exception of the TOWN Class cruisers of 1936–39, all generator drives in cruisers and larger warships from the COUNTY Classes through to the DIDO and COLONY Classes, as built, relied entirely upon steam.

I thank Mr J. P. Manson of Vickers Shipbuilding & Engineering Ltd for making a copy of the document available. The translation is contemporary, the translator unknown.

GENERAL CONSIDERATIONS OF THE USE OF DIESEL DRIVEN DYNAMOS ON BOARD SHIP

The idea of making use of the advantages of the diesel engine in large ships was a natural result of the rapid development of diesel engine construction; and of the evolution during recent years, of the high speed diesel engine which has already been largely adopted in the Navy for propelling submarines and similar craft.

The contruction of heavy oil engines for direct propulsion of ships certainly presents some difficult problems, the solution of which can only be regarded as a question of time; although at the present time the existence of these questions does not yet make the installation of such engines in warships admissible.

On the other hand, diesel engines of smaller power, such as could be used for driving auxiliary machinery, have been so far perfected by those firms which have taken part in their development, that their installation in battleships and battle-cruisers involved no great risk. During the last few years, therefore, England and Germany, among other nations, have decided to install diesel engines on board their warships for the purpose of driving auxiliary machinery; of which, the electrical plant can be combined with the greatest advantage with the new prime mover. In Germany a few battleships have already been fitted with diesel engines for driving dynamos, and it is intended that the same principle should be applied to both large and small cruisers in the future.

For some time after the reciprocating engines for driving ships' dynamos had been discarded in German warships on account of the many difficulties which accompanied their use, turbo-dynamo sets were installed exclusively and in general were proved to be sufficiently reliable and economical for the purpose. The recent change of practice, whereby a part of the electrical generating plant is diesel engine driven, has shown that this principle economizes the steam consumption at sea to an extent which offers considerable reserve boiler power; a reserve which would be of great importance when steaming at maximum speed. Furthermore, the use of these diesel engines is welcomed by the staff and crew because it reduces the work of the engine room and boiler staff when the ship is in dock and permits the boiler plant and steam piping to be rapidly inspected, cleaned and overhauled without creating any further disturbance on board.

As soon as the early difficulties, which are unavoidable in the case of any innovation, have been overcome, and the artificer staff have become thoroughly acquainted with those conditions which are peculiar to the diesel engine, and are in a position to diagnose and rectify any possible defects without delay, the popularity of this type of engine will still further increase, on account of the ease with which it can be started and run up to full load independent of the boiler plant, and on account of the efficient ventilation and cooling of the engine room which it brings about in working.

It is obvious that the diesel-dynamo sets cannot compare favourably in the matter of weight with a turbo-dynamo of equal capacity because the electrical part alone would be much heavier, on account of the lower speed of revolution. If the comparative fuel consumptions and weights of fuel which must be carried be taken into consideration for each case, the balance would come out in favour of the diesel engine, on account of the saving in weight of fuel carried which the economical running of the diesel engine allows; and this would be the case, even if the boiler weight for the turbo-dynamo set be left entirely out of consideration. The boiler plant would hardly be reduced if diesel dynamos were installed, but the amount of bunker coal carried can be considerably reduced for a given radius of action.

The above remarks may show, briefly, that in many directions, the adoption of diesel-dynamos in warships is undoubtedly an advance.

PRINCIPLES OF CONSTRUCTION

When the German Admiralty decided to use diesel engines for the purpose of driving dynamos on board battleships and cruisers, high speed type engines had already been produced by many manufacturers, this being the only practicable type of engine for the purpose, on account of its lightness and compactness; the next consideration was to make the design of these engines suitable in every way for the conditions under which they have to work.

In order to give a definite basis upon which the manufacturers could work, and to enable them to design as far as possible in accordance with Admiralty requirements, a list of particulars was circulated for the guidance of manufacturing firms, containing very exact particulars but still leaving as much latitude as possible to allow for further development.

The leading particulars, as far as they concern constructional details, are given here in brief:

- The capacity of the machines was determined to be, in this instance, ability to maintain an output of 300 kilowatts at 400 rev/min in continuous and unbroken service. The engines must be so designed that they will not be brought to a standstill by a 20% overload applied for a period of 10 seconds, nor be injured by a 15% increase in the number of revolutions per minute.
- Special attention must be paid to the governing of the machines, which must be effective whilst the ship is in any position. It must be reckoned that the ship will roll to an angle of 30° from the horizontal and pitch to an angle of 8° from the horizontal.
- It is also to be reckoned that the ship may have a permanent list of 10° to either side or have a permanent loss of trim fore and aft of 4°.
- The speed of revolution must not alter more than 2% with every alteration in the load equal to one quarter of the full load, nor more than 4% with a sudden change from full load to no load, or vice versa.

It was necessary to impose these conditions, which are difficult to fulfil in the case of a diesel engine, involving, as they do, the use of a much more powerful governor than is theoretically necessary. as well as fuel pumps which work very accurately, on the one hand to meet the heavy demands made on the sensitive power installations on shipboard, and on the other hand to provide a steady light in spite of the frequent variations of the load.

As the nature of the question led to the conclusion that the diesel engines would frequently be required to operate for long periods under light loads, it was feared that when working under these unfavourable conditions they would give bad consumption and emit smoke, and that they would be subjected to unnecessary wear. On this account it was arranged that the number of revolutions per minute should be reduced to 300 when working for a long period under a light load (up to about half load), to ensure the obtaining of a fuller diagram, with consequent better conditions for combustion, and to reduce the wear on the bearings, etc.

This condition also increased the difficulty involved in the design of a governor which would fulfil all the requirements, as, with the introduction of this reduced speed, the governor and the inertia masses together had to provide that the engines retained their normal speed under every possible sudden variation of load which could occur, that they could be started with certainty, and also that they should give a steady light, even with the most sensitive metal filament lamps.

It is required of all the engines that they should run without appreciable vibration or noise, under all working conditions, the exhaust, especially, must be damped as much as possible and as much as the space provided for a silencer will allow.

The following special conditions for the design may be mentioned.

The engine, with its dynamo, must be a complete unit, direct coupled and mounted on a common bedplate, so arranged that the dynamo bed is fastened by means of flanges to the bed of the engine, to ensure a strong connection and to form a single girder, with a flat surface on which it may stand.

This condition is of importance, inasmuch as there is no such reliable foundation on board ship, as there is in the case of a stationary diesel plant; therefore, the machines must posses great internal stiffness in order to avoid serious accidents or breakdowns, especially shaft fractures. The bedplates must, therefore, be sufficiently stiffly constructed to allow the forces which are developed to be taken up in the machine as far as possible, and to ensure that the main bearings retain their alignment.

In addition to this they must be so divided that the sizes of the separate parts do not exceed certain prescribed dimensions, in order that any necessary repairs do not involve disturbances of the ship, such as removal of large sections of the decks. For the 300 kilowatt engine which is under consideration, six cylinders were prescribed, this number giving frequent ignitions and favourable conditions of balance, with comparatively small rotating masses; that is, it permits the attainment of very even running. With this arrangement, the dynamo rotor itself usually possesses sufficient flywheel energy, which is an advantage in consideration of the limited space available. Considerations of available space on board a warship further demand that the engines be built as compactly as possible, naturally without sacraficing accessibility and ease of inspection.

In addition to space consideration, the question of weight plays an important part. The engines must therefore be built as lightly as is compatible with strength and economy.

Weight must be saved chiefly by means of suitable construction and by the use of high class materials, as, for instance, steel or bronze castings, in place of the cast iron which would usually be adopted in consideration of cost. At the same time, all the parts of the engine must be so strongly constructed that they will be subject to no dangerous stresses, even under unusual loads, as for instance, through sudden changes from no load to full load and vice versa. Aluminium and aluminium alloys must not be used for the purpose of saving weight; on the other hand, these materials are totally excluded from use on board ship for any engine parts which must carry load, on account of their unreliability and their low powers of resistance, especially against damp sea air.

Especial care must be paid, naturally, to all those details which are necessary to ensure safe running and control of the engine. Every cylinder must be fitted with a safety valve, a precaution which was not favoured at first by the firms which are engaged in building diesel engines, but has since proved its value; the principal objection raised against the adoption of safety valves by the firms in question was the fear that they would always leak, and would consequently give rise to difficulties in the working of the engine. This objection has since proved to be without foundation, whereas even a comparatively small safety valve is sufficient to guard against excessive pressures such as would be caused by a hung up starting valve when starting, and such as sometimes arise in ordinary running. Further safety devices which are an absolute necessity are the non-return valves which must be fitted in the fuel, injection air and cylinder lubricating oil piping; these are for the purpose of preventing the hot highly compressed ignition air from blowing back into the piping should the fuel valve, for instance, be not quite tight, and thus preventing explosions in the piping in question. The compressed air piping is a source of danger if sufficient care be not taken that it be kept as far as possible free from oil. To this end, the lubricating oil pumps must be provided with a device which prevents too great a quantity of oil from being delivered, especially to the compressor cylinders. The compressed air must also be freed from oil by means of amply dimensioned oil traps, both between the stages of compression and in the high pressure pipe line. These oil traps can be combined conveniently with the intercooler, but many firms of wide experience keep them separated.

The diesel engine must be as simple as possible in all particulars, accessible and under easy observation. It must be so constructed that it can be dismantled and re-erected easily, without special space being reserved for this purpose on board.

Diesel engines of the same type and size, which are delivered for installation on one ship, must be exactly identical with one another, so that spare or replace parts can be fitted without being especially worked up; this refers most particularly to the parts which wear most quickly, as, for instance, bearing bushes; such parts must be so designed that they can be easily fitted or adjusted. The bearings and their lubrication system must be so arranged that they do not overheat if the engine should be permanently out of level, that is, if the ship should have a permanent list in any direction.

Forced lubrication to all bearings has proved suitable for the purpose of keeping the amount of wear within reasonable bounds in high speed engines of the type under discussion. It makes it necessary, however, to provide a completely enclosed crank case, in order to prevent the escape of lubricating oil vapour into the engine room. The closed crank case must be suitably ventilated.

The spring-loaded governor, the requirements of which have been enunciated already, must act with certainty within the prescribed limits of revolution, even when the ship is rolling violently.

In the case of a breakage or loosening of a connection in the governor mechanism, the engine must stop automatically. The governor and all the shafts, cams, etc., which form part of the valve and control gear, must be provided with positive and accurate actuating mechanism and driven in such a manner as to cause no disturbing noise; and these parts must be protected so as to remove the possibility of accident or injury to the engine room staff; but at the same time, all governor or other gear which may have to be adjusted while running must be easily accessible. The fuel pumps must be fitted as near as possible to the governor, in order to obtain the most exact influence of the governor action.

All auxiliaries which are necessary for the running of the engine, must be directly coupled to it, in order to make the plant independent of other machines and to facilitate its control.

The cylinders, cylinder covers, compressors, etc., and, if necessary, the bearings are cooled with sea water; the quantity of cooling water supplied must be liberal, in order to prevent excessive temperature rises, and the consequent precipitation of salt and other impurities. The cooling water jackets must be provided with inspection doors, large enough to permit any solid deposits to be removed without difficulty. Special care must be given to the run of the cooling water passages, that the water may circulate freely, without forming dead corners (still water). It is advisable to carry the water directly, by means of special tubes, to those parts which are especially dangerous. Care must be taken that the materials which come into contact with sea water are chosen with a view to their power of resisting its injurious action. Those parts of the cylinder walls which are in contact with sea water must be coated with a resisting composition having good heat-conducting properties. It is scarcely necessary to mention that those metals which will form galvanic elements, that is, different metals which have different galvano-electric tensions, must be avoided as far as possible in the cooling jackets; failure to observe this general condition has often been the cause of most unpleasant consequences after the engine has been running for a comparatively short time.

It is also not necessary to state expressly, that ample means must be provided at the lowest point of all pipelines and cooling jackets for the purpose of draining.

As a rule the diesel engines are started by means of air which is compressed in the compressor cylinders, and stored in special starting air bottles. The starting air battery must be proportioned to allow the engine to be started ten times in succession. Special care must be given to the construction of the air bottles, that the internal high pressure may be the cause of no accidents; but definite conditions cannot be laid down until experience has been gained over several years. In the mean time, the following requirements must be fulfilled. The bottles must be seamless, with hemispherical ends, or with ends of hemispherical internal form. Bottles up to two metres in length must have an opening at one end, and bottles over two metres long must have an opening at each end, to allow examination of the interiors for the purpose of discovering whether any rusting or pitting has taken place. This examination is a most important precautionary measure; the diameter of the inspection holes must be equal to half the internal diameter of the bottle and at least 80 millimetres.

The insides of the bottles must receive a coat of red oxide for the purpose of rust prevention, and, to the same end, suitable arrangements must be made for drainage. Safety valves and reducing valves must be provided and adjusted to the normal starting air pressure. The piping must be provided with stop valves and with a relieving device so that it may be kept under atmospheric pressure when running.

It is unnecessary to provide reserve starting air compressors or cooling water circulating pumps, as the general installation of the ship provides for this. If, through the inattention of the staff, the starting air pressure in both batteries should be allowed to drop, air can be taken from the torpedo compressed air system, through connections which are made for this purpose; should the water circulating pump break down, the sea water necessary for cooling purposes can be taken from the fire mains, which are always under pressure, in the same manner that the cooling water is often taken from the mains when the engines are on the test bed in the Works. In any case, all possible care must be taken to avoid engine stoppages of any length, through defects in the auxiliaries. This refers especially to the sea water filters, which require frequent cleaning, especially in the muddy water which is found in the North Sea on the German coast.

It would be outside the scope of this article, to go more closely into the multifarious regulations for the installation of the plant in the ship, regulations which deal chiefly with the arrangement and the sizes of the piping, the subject of this article being the design of the diesel engines themselves, concluding with a report of the test results. Possibly there will be an opportunity, later, of describing the particular conditions which govern the installation on board, together with the experiences which have been gained during a long period of marine practice.