Development and Decline of the British Crosshead Type Marine Propulsion Diesel Engine

Denis Griffiths

A thesis submitted in partial fulfilment of the requirements of Liverpool John Moores University for the degree of Doctor of Philosophy

September 1994

The following Figures/Tables/Appendix have been omitted on request of the University –

Fig. 2.1	pg. 20
Fig. 2.2 & 2.3	pg. 22
Table 2.1	pg. 24
Table 2.2	pg. 25
Fig. 2.4 & 2.5	pg. 30
Table 3.1	pg. 40
Table 3.2	pg. 41
Table 3.3	pg. 43
Table 3.4	pg. 45
Table 3.7	pg. 48
Table 3.8 & 3.9	pg. 49
Table 3.11	pg. 51
Table 4.g.1	pg. 137
Table 5.1	pg. 188
Table 5.2	pg. 189
Fig. 5.1 & 5.2	pg. 191
Fig. 5.3	pg. 192
Fig. 5.4	pg. 193
Table 6.1	pg. 198
Table 6.2	pg. 201

Published papers – Appendix 3

Ph.D. Thesis

Development and Decline of the British Crosshead Marine Diesel Engine

Denis Griffiths

Summary

The Thesis is divided into seven chapters with chapter four comprising nine subchapters which describe the types of crosshead marine diesel engines designed by British companies.

Early application of the diesel engine to marine purposes is covered in chapter 1 and this also looks at the initial interest shown by British companies to this form of propulsion. The following chapter deals with the British attitude to the motorship both in terms of the shipowner and the shipbuilder. The influence of the British coal industry is considered and the evidence offered to show that the coal lobby was influential in obstructing adoption of the diesel engine by British shipowners; this in turn hindered development of British marine diesel engines. Continental owners faced no such opposition.

Economics of motorship operation are covered in chapter 3 and show that, during the 1920s and early 1930s, for most cargo ships of moderate power diesel propulsion was more economical than steam. Diesel machinery cost more than steam plant but the lower operating costs and reduced size, which allowed more cargo to be carried, gave the diesel an economic advantage on many world routes and even in the tramping trades. Evidence is offered to support this.

All British designed crosshead marine diesel engines are discussed individually in terms of technical detail and possible reasons for their failure to make an impact on the market. Only Doxford and Harland & Wolff (H&W) engines were constructed in the post-WWII years and these are covered in some detail.

Work done by other British engine builders in terms of co-operation with overseas designers is also considered together with the apparent unwillingness of British designers to actively licence their designs overseas, or even in Britain.

Reasons for the failure of British crosshead marine diesels, apart from Doxford and H&W, to make any impact on the market are discussed and conclusions drawn. Reasons for abandonments of the H&W engine in the 1960s and Doxford engine in the 1980s are also examined. These show that technical difficulties alone were not responsible for the decline, particularly in the case of the Doxford engine.

Contents

Acknowledgements

The author would like to thank the following for assistance given throughout this research project.

The Royal Society which provided funding for travel by way of a History of Science and Technology award.

Staffs of the libraries of Lloyd's Register of Shipping, the Institution of Mechanical Engineers, the Institute of Marine Engineers, the National Maritime Museum, the Science Museum, the Guildhall Library (London), Liverpool City Library, Hull Library Service and the Mitchell Library (Glasgow).

Staffs of Tyne & Wear Archives (Newcastle), Wirral Archives (Birkenhead), National Maritime Museum Archive (Brass Foundry, Woolwich), Lloyd's Register of Shipping Archive (London), The Ballast Trust (Johnstone, Scotland), Vickers' Archives (via Ron Fitzgerald at Armley Mills, Leeds), and The Maritime Records Centre (Liverpool).

Fred M. Walker (formerly of the NMM, Greenwich), Peter Gee (Chief Engineer Surveyor to Lloyd's Register of Shipping), Jim Grandison and Barbara Jones (Lloyd's Register of Shipping), Dr W. Lind (The Ballast Trust), Dr Johnston Robb (formerly of Scotts of Greenock), Tom Gourley (formerly of Barclay Curle), Dr Finn Orbeck and Bryan Taylor (formerly of Doxfords), David Stables (formerly of Blue Funnel and Doxfords), Willie Falconer and Andy Crawford (formerly of Blue Funnel), Ben Crowdy (formerly of Hawthorn Leslie), Roddie MacLeod and Keith Corlett (Andrew Weir Shipping), Paul Neilsen and N.E. Rasmussen (of B&W), N.W. Fleming (former seagoing engineer), P.J. Humphreys (formerly of Newbury Diesels) and Ron Fitzgerald.

Staff at VSEL (Barrow) and Swan Hunter of Wallsend for attempting to find old records and to Stan Wakefield for advice on wordprocessing packages.

Professor Ben Mills and Professor Mike Lalor, my supervisors, for advice and to various staff in the School of Engineering & Technology Management, particularly the late J.C. Watson, for encouragement and advice.

Chapter I

Introduction

During the 1950s Britain was still a major maritime power, at least in terms of commercial ship operations and shipbuilding, and many of the ships owned by British companies or built in British yards were propelled by diesel engines. Two crosshead diesel engine designs were recognised as being British and both were of the opposed-piston form, the Doxford engine and the Harland & Wolff engine. By the mid-1960s production of the Harland engine had ceased whilst the Doxford was in serious decline, however, diesel propulsion of ships increased during those years at the expense of steam power. European designed engines, particularly Sulzer and Burmeister & Wain, increased their share of the available market whilst Japanese engine builders also made an impact as shipbuilding in that country expanded.

The fact that only two British crosshead engines were available during the post-WWII period gave the impression that, despite Britain's significant share of the shipbuilding market, British engine/ship builders were not really interested in the diesel engine for propulsion purposes. The investigation originated with this belief, the intention being to find reasons why Britain did not embrace the diesel engine for marine propulsion purposes, but it soon became apparent that far from ignoring the diesel a significant number of British engine/ship builders enthusiastically developed designs of their own.

The number of marine crosshead diesel engines designed in Britain exceeded the number of designs produced by any other country but British shipbuilders launched fewer motorships during the critical 1920s than did their European competitors. British shipowners also tended to remain in favour of the older steam reciprocating engine than the newer diesel engine. Of the British crosshead marine diesel designs which evolved during the post-WWI period only the Doxford was a commercial success; the only other successful British design, from Harland & Wolff, did not enter production until after WWII and its period of commercial prosperity lasted less than 20 years.

Despite the failure of British designs to make an impact on the market there was a demand for the diesel engined ship, especially from Scandinavian shipowners and a few enterprising British shipowners. A significant number of British engine/ship builders took licences for European designed engines and some played a very active role in developing those designs. British shipowners still, however, remained firmly wedded to the steam engine.

British designed engines were studied in order to determine possible reasons for their failure to make an impact on the market whilst the general situation regarding shipping operations during the 1920s was also investigated as was the attitude of the British marine industry to the diesel engine. Such investigations were necessary in order to determine reasons for the apparent reluctance of British shipowners to order motor ships when their European competitors favoured the internal combustion engine. Despite the fact that Britain was still the world's leading shipbuilding nation during the 1920s very few home developed diesel engines went into its ships.

During the post-WWII years both the Doxford and H&W engines achieved considerable sales, especially with British shipowners, but both engines went into decline during the 1960s. Although the Doxford remained in production until the 1980s it never regained the share of the available market it had enjoyed during the 1950s. Reasons for the failure of both of these engines were also investigated.

The story of the British crosshead marine diesel engine proved to be more extensive than originally envisaged whilst the failure of the engines as a group owed as much to human aspects as it did to mechanical shortcomings.

Chapter 1.

The Diesel Engine for Marine Purposes.

Credit for introduction of the compression ignition internal combustion engine cycle generally goes to the individual after whom engines operating on such cycles are named, Dr Rudolf Diesel. Diesel's publication of 1893, "Theory and Construction of a Rational Heat Engine", outlined his proposal for an internal combustion engine which would be much more efficient than any operating at that time as his would work on the Carnot cycle: his original patent, No 67207, "Working Processes for Internal Combustion Engines" had been accepted by the German Patent Office on 28 February 1892. High efficiency would require high maximum cylinder temperature and that could only be achieved with high maximum cylinder pressure. Compressing a mixture of fuel together with the cylinder air charge would result in premature self ignition and Diesel concluded that fuel would need to be injected separately at the top of the compression stroke when the temperature of compression would be sufficient to produce ignition.

It was in this idea of compression of an air charge alone being used to instigate ignition that set Diesel's cycle apart from those proposed by others, such as Capitaine, Priestman and Akroyd Stuart, who made use of an uncooled part of the combustion chamber to ignite vaporised hot fuel oil. The use of such an uncooled part to bring about ignition resulted in the description, hot-bulb engine. Stuart lodged his first patent for an oil engine in May 1890 whilst Diesel filed his in 1892 and supporters of both parties have argued ever since as to the merits of each.[1]

Although Diesel considered that his idea was original Emil Capitaine did not and filed a plea of invalidity with the Berlin Patent Office claiming that an engine constructed by himself during the 1880s had employed the same operating processes. The plea was turned down in April 1897.[2] Diesel appears to have been frequently subjected to law-suites or the threat of such over the originality of his patent but it was Capitaine who was the most persistent acting, as Diesel's son put it in his biography of his father, like a permanent Sword of Damocles.[3]

Diesel initially considered maximum pressures as high as 250 bar with power deriving from the combustion of fuel at constant temperature but a later patent resulted when this proved impractical. This second patent (German No 82,168) covered combustion "..*without essential increase in temperature or pressure*" and effectively concerned the method of fuel injection.[4] In 1893 three major engineering concerns, Maschinenfabrik-Augsburg AG (later Maschinenfabrik-Augsburg-Nurnberg {M.A.N.}), Fried. Krupp of Essen, and Sulzer Brothers of Winterthur, Switzerland, took an interest in Diesel's work and each commenced design and testing work on engines using his patents.[5] Licences were also taken by:

F. Dyckhoff Fils, Bar-le-Duc, France (April 1894)
Carels Freres of Ghent, Belgium (April 1894)
Mirrlees, Watson & Yaryan of Glasgow (March 1897)
Adolphus Busch, St. Louis, USA (October 1897)
Burmeister & Wain of Copenhagen (1898)
Marcus Wallenburg, Sweden (January 1898)
{rights later transferred to A/B Diesels-Motorer, Stockholm}
Ludwig Nobel, St. Petersburg, Russia (February 1898)

Not until 1897 did M.A.N. produce an engine which operated successfully on the Diesel cycle (two engines operating under Stuart's patent were working in 1892) whilst Krupp and Sulzer had experimental engines working in 1898. Failures, some of an alarming nature, did occur and it was not until the turn of the century that production manufacture became established. By 1901 licences to build and sell diesel engines had been granted to 31 companies.[6]

Stuart's first patent expired in 1905 and that of Diesel two years later allowing interested parties to make full use of the ideas of both inventors. Many different engines were constructed for land and transport purposes, and although some Diesel cycle engines were constructed many of the early marine engines tended to be of the hot bulb type employing kerosene as fuel. In Britain during the first decade of the 20th century small marine engines were built by Richard Hornsby & Sons, John L. Thornycroft & Co., Gardners Ltd. and Messrs Yarrow & Co: these were for launches and harbour craft but some internal combustion engined gunboats and torpedo boats were also built for the British and other naval forces.[7] These engines were all of the trunk piston type.

As far as ship, as opposed to boat, propulsion was concerned European engine builders were quicker than their British counterparts to see the advantages of the diesel engine; to be really useful, however, a marine engine had to be capable of reversing. Dyckhoff is given credit for the first marine application of the diesel engine, if it can be called that, with the fitting in 1903 of a 25hp horizontally opposed-piston engine to the canal barge **Petit Pierre**. Other installations by a variety of engine builders followed but the major problem lay in getting the vessels to run astern. Initially electric transmissions were employed to allow for such manoeuvring but these were costly and inefficient. Sulzer Brothers was to the fore in the development of the diesel engine and its application to marine propulsion; in 1905 the company introduced the first direct-reversing engine. Other builders followed, a variety of systems being employed for changing valve and fuel timing.[8]

Submarines proved to be ideal craft for propulsion by internal combustion engines and the French engineering concern Schneider & Co. of Le Creusot made rapid progress with diesel engine construction; two-stroke and four-stroke cycle engines were developed. By 1914 the company was able to offer a wide range of engines, the most powerful developing 2,400hp.[9]

M.A.N. built some very powerful submarine engines with encouragement from the German government but mercantile marine engines were also developed. By 1911 a 990hp three-cylinder double-acting engine was under test and being made ready for installation in a ship.[10] The Italian company FIAT (Fabbrica Italiana Automobili Torino) developed a range of two-stroke cycle engines for marine work, a licence being taken by Scotts Shipbuilding & Engineering Co. of Greenock. Although Scotts was concerned with the trunk piston engines for submarine use the FIAT licence also covered a slow speed, two-stroke crosshead engine for mercantile work and Scotts' constructed two 225hp engines of this type for the Royal Fleet Auxiliary tanker **Servitor.**[11]

The first large seagoing vessel fitted with diesel engine propulsion was the Sulzer engined Italian cargo ship **Romagna** (1910); her machinery consisted of two four-cylinder trunk-piston two stroke engines each producing 380bhp at 250rpm. For efficient propulsion of large ships direct drive slow speed engines were required, propeller efficiency being higher at lower rotational speeds. Crosshead type engines allowed for longer piston strokes and lower rotational speeds making the design more suitable for large ship propulsion and the first ocean going motorship with such an engine was the Anglo-Saxon Petroleum Company's 1,210 ton oil tanker **Vulcanus** (1910). A six-cylinder Werkspoor four-stroke engine, developing 650ihp at 168rpm propelled the ship at 8 knots on a daily fuel consumption of 8 tons. Comparisons with a coal fired steamship of similar size showed that the steamer would burn 11 tons of coal per day and require a crew of 30, daily crew (Chinese) costs being £9 0s 7d; **Vulcanus** only required a crew of 16 (European) daily costs being £6 6s 5d. **Vulcanus** remained with her original owners until 1932 covering more than 1 million miles in that time. Anglo-Saxon Petroleum Company, shipping side of the Royal Dutch/Shell group of companies, ordered a further nine Werkspoor engined ships between 1911 and 1915. The four 7,725 ton tankers ordered in 1912 were each fitted with two 2,300ihp engines.[12] Although the company was enthusiastic about diesel engine propulsion it took a great deal of effort to keep the ships working, a major problem being the shortage of experienced motorship engineers. The trials and tribulations of engine room life aboard early motorships was documented by John Lamb, subsequently Engineering Superintendent of Shell Tankers, in his autobiography.[13]

Some British shipbuilders were aware of the possible advantages to be gained by diesel engine propulsion and some took steps to obtain licences. North Eastern Marine (NEM) of Wallsend on Tyne obtained a licence from Werkspoor of Amsterdam in 1912 but the 1914-18 war delayed construction of any engines.[14] The first motorship to cross the Atlantic was **Toiler**, built in 1911 by Swan, Hunter & Wigham Richardson on the river Tyne. This 1,659 gross ton ship was intended for service on the Great Lakes and she was driven by two 180BHP Polar engines designed by A/B Diesels-Motorer of Stockholm with whom Swan Hunter had reached an agreement for engine construction.[15] Although on trials the engines were able to propel the ship at between 7 and 8 knots they were subsequently found to be insufficient for normal service and replaced by a steam plant. A similar ship, **Calgary**, was built the following year but fitted with more powerful Polar engines which served the intended purpose.[16]

In 1913 William Denny and Brothers of Dumbarton took out a licence for construction of Sulzer two-stroke engines but WWI prevented any manufacturing progress from being made.[17] The first Sulzer engines, two small four-cylinder, trunk-piston engines developing 332ihp, were built in 1922 to drive the geared vane wheels used for propelling the experimental 206 ton shallow draft vessel **Meccano**, built for Denny's own account. Work on this pair of engines had actually started when war commenced but that conflict halted further construction.[18] The vane wheel system was devised by the builders specifically for shallow draft vessels, Dennys building many such craft for the Irrawady Flotilla Company.

These Sulzer engines were eventually completed to replace two four-cylinder 302ihp Still (combined Diesel and steam) engines built in 1917 with the approval of the Admiralty. The Still installation included a Yarrow water tube boiler working at 150psi and the engines, of the opposed-piston type, were constructed with the assistance of T.A. Savery & Co of Birmingham. Steam acted upon the backs of the pistons thus increasing power output but it also produced motion for starting ahead and provided all power whilst working in reverse. A solid fuel injection system was fitted. Comparative tests were carried out between the two systems with inconclusive results[19], however, Denny's had no further involvement with the Still system but they continued their association with Sulzer for many years. It was not until 1923 that the first Denny Sulzer crosshead engines put to sea in the tanker **Scottish Borderer**.[20]

The first British owned and built seagoing motorship was Furness, Withy's **Eavestone** (1912). The owner chose the Belgian designed Carels Freres engine which was, in part, constructed by Richardsons, Westgarth of Middlesborough. Although R-W had a licence from Carels they had never built a large crosshead diesel engine before and the licensor arranged to supervise all construction work as well as providing the critical cylinders, pistons and covers from its factory in Ghent. The four-cylinder two-stroke engine developed 800bhp at 95 rpm, sufficient for a service speed of 9 knots.[21] Unfortunately the engine did not prove to be as reliable as anticipated, considerable trouble and delay being experienced. Following a trip to South America the ship had to put into the Azores during January 1913 with engine troubles and remained there until July, repairs necessitating the supply of a complete set of new pistons and cylinder covers. The trouble probably resulted from use of poor quality or incorrect materials as another Carels engined ship, **Fordonian** (1912) had its cast steel cylinder covers replaced by cast iron covers at about the same time.[22] The experience did not, however, deter the owner and Furness,Withy proved to be a champion of the motorship.

As pioneers of British submarine construction Vickers Ltd., of Barrow-in-Furness, was also amongst the first heavy engineering companies to become involved with internal combustion engines. The first Vickers built submarine for the Royal Navy was laid down in 1901 and its success indicated that there was a future in this type of vessel. In conjunction with its associate company Wolseley a powerful petrol engine (600hp) was developed for installation in the "A" type boats and subsequent classes.[23] Dangers of using petrol in confined spaces, together with its high cost, resulted in a demand for machinery capable of burning higher flash point oils. Vickers worked on engines capable of burning heavy oils although it is not certain when such work actually commenced; there is a belief that initial contacts with Rudolf Diesel date back to about 1897/8 but no documentation supporting this survives at Vickers.[24] The first heavy oil engine was installed experimentally in submarine **A.13** during 1908, this being of the Hornsby-Akroyd type[25], but "D" class production boats delivered the same year had Vickers' diesel engines. Blast fuel injection was employed but Vickers had for some time been experimenting with a system of solid fuel injection and its success resulted in adoption for later engines, the earlier "D" class engines being subsequently converted to solid fuel injection.[26] Although these submarine engines were of the four-stroke, trunk-piston type, and were non-reversing, Vickers could justifiably claim to be the leading British marine diesel engine manufacturer in pre-WWI days. The standard "D" class engines developed 100hp per cylinder, the largest engines of the type, having 12 cylinders, were delivered early in WWI.

Reversing engines were specified for the "G" class submarines ordered in 1914 but the reversing requirement was later cancelled. However, work on the reversing system had progressed sufficiently well that Vickers were granted permission to complete the first two engines, installed in **G.13**, on reversing lines.[27] Admiralty support ensured that funding for development work was available and Vickers gained much from that whilst other engine builders had to work strictly in the commercial world. The Admiralty sponsored a single- cylinder experimental two-stroke, reversible, crosshead engine which ran trials during 1913.[28] Running at 140rpm some 1,000ihp could be developed from the 762mm diameter by 914mm stroke cylinder; scavenge air valves were fitted in the cylinder cover, exhaust taking place via ports in the lower part of the cylinder liner. The rotary scavenge blower was independently driven, as was the blast injection compressor, later trials employed solid fuel injection. Vickers intended using the engine as the basis for a high powered mercantile design but the outbreak of WWI interrupted development.[29]

After carefully studying continental practice William Doxford & Sons of Sunderland decided to construct a single-cylinder two-stroke engine in order to obtain operating experience of its own. Reporting on the engine at the end of the trial period ***The Engineer*** made comment upon the relative practices of a company undertaking design and development work itself or obtaining a licence from a continental builder.

"Which of the two is the cheaper method of arriving at a practical result we are unable to venture an opinion, but there is no doubt that the knowledge gained in meeting and overcoming failures is likely to be more valuable than mere knowledge that such difficulties do exist without the practical experience of overcoming them, which is the condition of affairs with firms who seek for immediate success by becoming licensees of already successful builders. It appears to us to be rather on a par with the practical training which an engineer gets by actually going through the shops as compared with what he learns by a course of college training alone."[30]

Although the engine proved capable of exceeding its designed rating and performance there were problems relating to the cylinder cover as well as frame and bearing loadings. Although such difficulties were common to other engines at the time Doxfords decided upon the radical solution of eliminating, as far as possible, the troublesome areas of design. This resulted in adoption of the opposed piston concept (see chapter 4.b), the in-house experience gained from that single cylinder engine probably saving the company a great deal of money by enabling it to bring a reliable engine to the market in a reasonably short time.[31]

On 23 November 1910 Barclay, Curle & Co. signed an agreement with Burmeister & Wain of Copenhagen which gave the Clydeside firm rights for the manufacturing of B&W Diesel motors in Great Britain and Ireland. After building a single cylinder test engine Barclay, Curle then built, and installed without test bed trials, the two 1,250bhp engines for **Jutlandia**. The success of this installation and that of the earlier Danish built **Selandia** prompted the formation of the Atlas Mercantile Company which was to exploit Burmeister & Wain's engine patents in Britain. Barclay, Curle agreed to pay its royalties to Atlas Mercantile and committed itself to having no involvement with any other diesel engines. By way of compensation Barclays were to receive 1 shilling per horsepower of the royalties paid to Atlas by other British licensees. The situation quickly changed and Barclay, Curle agreed to transfer all of its engine rights to Atlas Mercantile which in turn established a new company in Glasgow, The Burmeister & Wain (Diesel System) Oil Engine Company, to undertake construction. Barclays received one tenth of the shares in the new concern which also agreed to purchased the Barclay, Curle diesel engine factory for cost price plus 50%. Atlas transferred all of its rights to the new company.[32]

As it turned out the B&W (Diesel System) Company purchased Harland & Wolff's Lancefield works instead of the Barclay, Curle engine factory and the latter then lost interest in B&W engines. In 1913 Harland & Wolff purchased Barclay, Curle's share in the Glasgow concern and proceeded to establish close links with the licensors in Denmark. During WWI Harlands gradually acquired the remaining shares in the Burmeister & Wain (Diesel System) Oil Engine Company. The Atlas company was liquidated, sole British Empire rights for construction of B&W engines being assigned to its Glasgow based company, and thus to Harland & Wolff, in January 1917.[33] In the meantime Swan, Hunter agreed with its associate company Barclay, Curle to collaborate in the formation of a new engine building concern to be known as the North British Diesel Engine Works.[34] It is generally believed that the 1910 agreement gave Barclay, Curle sole British rights to manufacture B&W engines but in January 1911 Swan, Hunter also received a licence; whether or not this was a sub-licence from Barclay, Curle is not known but it was never cancelled and shortly after the end of WWI Swans' indicated its intention to build B&W engines. Harlands objected indicating that a clause in the original agreement specifically precluded a licensee from manufacturing any other design of diesel engines, Swan, Hunter had a licence from A/B Diesels-Motorer and was by then designing its own "Neptune" engine. The Tyneside concern did not proceed with its intention.[35]

With the establishment of the B&W (Diesel System) Oil Engine Company in Glasgow three engineers, V. Mickelsen, J. Miller and O.E. Jorgensen were transferred from Copenhagen, Jorgensen being General Manager at the works. Following the takeover of B&W manufacturing rights by H&W there appears to have been some conflict between the General Manager and certain of Harlands' customers resulting in Jorgensen leaving the firm during 1915 and being replaced by F.E. Rebbeck.[36] In 1921 engine production transferred to Belfast and all future developments took place there.

References

1. Details of early Akroyd Stuart engines may be found in "*The Early History of Akroyd Stuart's Oil Engine*", by R. Wailes, Transactions Newcomen Soc', vol 48, 1977, pp103-10, whilst comparison between the early work of Stuart and Diesel is covered in "*The Origin and Development of the Heavy-oil Engine*", by A.T. Bowden, Trans' I.Mar.E., vol 48, pt 7, 1936. pp235-8

2. This matter was mentioned by Diesel in a letter of April 1897 to the directors of Mirrlees, Watson and Yaryan, see North East Coast Institute of Engineers & Shipbuilders (NECIES) Presidential Address by Charles Day: Transactions NECIES, vol 127 1934. p200.

3. The biography "*Diesel, Der Mensch, Das Werk, Das Schicksal*" by Eugen Diesel is discussed and quoted in the article, "*Rudolf Diesel*" by A.P. Chalkley; ***The Motor Ship***, vol 18, December 1937. pp314-5

4. L. Cummins, **Diesel's Engine**, Carnot Press, 1993. This book details the early years of diesel engine development with pages 17-72 covering events leading up to the granting of both of Diesel's patents

5. These early years of diesel engine development by M.A.N. and Sulzer are covered in "*Rudolf Diesel and his Association with Sulzer Brothers*" by B. Humm, ***Sulzer Technical Review***, 1/1958.

6. *D.T. Brown*. **A History of the Sulzer Low-speed Marine Diesel Engine.** Sulzer, Winterthur, nd. p5-7

7. A description of early marine I.C. engine applications is given in the article "*Internal Combustion Engines for Marine Purposes*" by Sir John L. Thornycroft; ***Cassiers Magazine***, vol 35 1908-9. pp225-40

8. Brown, **A History of Sulzer Marine Engines**, p9

9. M. Drosne, *"Development of Internal-Combustion Engines for Marine Purposes"*. Proceedings I.Mech.E. 1914. pp537-57

10. "Some Impressions of Continental marine diesel Engine Practice", ***The Engineer***, vol 112, 15th Dec` 1911. pp611-2

11. **Heavy Oil Engines for Marine Propulsion**, Scotts` SB & Eng` Co. 1913. also **Two Hundred and Fifty Years of Shipbuilding**, Scotts` SB & Eng` Co, 1961. p193

12. *"A Century of Oil Trading"* by D.L. Saunders-Davies, ***The Motor Ship***, vol 51, No 597, April 1970. pp30-1

13. John Lamb, **Backward Thinking**, John Lamb Publications & Inventions Ltd., London 1954. pp50-122

14. *"Transition from Steam to Diesel by an Independent Engine Builder"* by G.L. Hunter & G. Yellowley, ***The Motor Ship***, vol 51, No 597, April 1970. pp56-7

15. A.P Chalkley, **Diesel Engines for Land and Marine Work**, Constable & Co, London, 1919. pp233-4

16. J.T. Milton, *"Present Position of Diesel Engines for Marine Purposes"*, Trans` INA, vol 55, April 1914. p85

17. Prof` A.L. Mellanby, *"Clyde Marine Oil Engines"*, Proceedings I.Mech.E, June 1923. p724

18. **The Denny List part III**, compiled by D.J. Lyon. NMM Greenwich, 1975. p711-2

19. W. Denny, *"Comparative Trials of Still and Sulzer Engines Under actual Working Conditions on Board Ship"*, Trans` I.N.A., vol 62, 1920. p286-8

20. **The Denny List**, part III. p737

21. ***The Engineer***, vol 114, 25 october 1912. p433-6

22. J.T. Milton, *"Present Position of Diesel Engines"*, p87

23. Unpublished manuscript *"Naval Construction Works, Barrow-in-Furness, Contribution to Marine Engineering, 1979-1939"*. Vickers-Armstrongs Ltd. no date but probably 1939

24. Private correspondence between Mr R. Fitzgerald (Leeds Industrial Museum) and Mr D.H. Lees and Mr J.D.P Banahan (Vickers Shipbuilding & Engineering Company) dated 25 March 1987 and 15 April 1988 respectively

25. P.M. Rippon, **"Evolution of Engineering in the Royal Navy, vol 1 1827-1939"**, Spellmount Ltd, Tunbridge Wells, 1988. p166

26. W.F. Rabbidge, "*Some Types of Marine Internal Combustion Engines*", Trans' I.Mar.E., vol 39, 1927. p140

27. W.F. Rabbidge, "*Some Barrow Light Weight Oil Engines*", Trans' Barrow Association of Engineers, 1930. p125-34

28. This engine was based upon the Carels design, that company having constructed a similar unit for the French concern Scheider et Cie, of le Creusot during 1907: Cummins L. **Diesel's Engine**, Carnot Press, 1993. pp341, 343 & 544

29. Rabbidge, "*Some Types of Marine Internal Combustion Engines*". pp153-4 also ***Engineering***, vol 119, 26 June 1925. pp176-7

30. ***The Engineer***, vol 15, 14 Feb' 1913. p168: also Sir James McKechnie, "Internal Combustion Engines with large Cylinders", I.C.E. Engineering Conference 1921, reported in ***Engineering***, vol 112, 15 July 1921. pp132-4

31. ***Engineering***, vol 155, 22 Jan 1943. p61

32. Petersen H.F. & Rasmussen N.E. "*The B&W Family part 1*", B&W Engineering, No 4, Feb' 1978, Copenhagen. (Translated by N.E. Rasmussen}

33. C.C. Pounder, "*Milestones In Marine Diesel Engineering*", ***The Motor Ship***, June 1970. pp145-6

34. ***Shipbuilding & Shipping Record***: 18 Sept' 1913, p358; 22 Jan' 1914, p119; 5 March 1914, p311

35. Pounder, "*Milestones in Marine Diesel Engineering*", p145: also letter from B&W Archivist Mr N.E. Rasmussen, Copenhagen. 22 February 1992

36. Correspondence with N.E. Rasmussen of B&W, Copenhagen, dated 22 Feb' 1992

Chapter 2.

British Motorships.

From chapter 1. it may be seen that British ship/engine builders did take an interest in the diesel engine as a means of ship propulsion, however, compared with the size of the British shipbuilding industry before World War I that interest was rather restricted.[1] Some people believe that British builders were wise in their conservative approach to the diesel engine as construction of such machines required a great deal more expertise than the steam reciprocating engine then favoured for most ships. In the words Professor Hawkes, one of the most eminent engineers of the day, "*It was also assumed that the possession of a set of working drawings of an engine was sufficient to ensure success and that any competent engineer with experience of marine steam-engines should be capable of designing and constructing a marine oil-engine. Experience has certainly shown that this is not the case. In my opinion, the development of the marine oil-engine in the years preceding the War suffered largely from its friends*".[2]

During WWI little could be done to progress the British mercantile diesel engine but with the coming of the armistice development work resumed and soon a number of designs were made available to shipowners. Neither the war, nor the coming of peace saw any change in the normal commercial practice whereby the British shipbuilder offered the engine as part of a package; this had been the case for many years with most shipbuilder having their own engine and boiler shops. Due to the fact that most British shipbuilders built their own engines only a few dedicated engine builders became established,[3] and only one, the North British Diesel Engine Works, was dedicated solely to the building of diesel engines to its own design. Most British diesel engine development took place within the confines of shipyards. (see chapter 4)

Although British engineers were generally slower than their continental counterparts to become involved with internal combustion engines operating on the Diesel principle many adopted the idea enthusiastically when its advantages did become obvious. That initial reluctance may simply have been caution but engineers and entrepreneurs of the late Victorian age were imaginative and innovative making such caution difficult to understand. At least one commentator believed that the reason lay in the origin of the invention, "*...I have observed that Englishmen are averse to taking inventions from abroad.*"[4]

For H.E. Yarrow the reason was more practical, "*...I would say it is only because having good plants for turning out steam engines and boilers, they did not like to lay out a good deal of money in new plants before they could clearly see the chance of making it pay.*"[5] The shipbuilder Sir Archibald Denny believed "*...we were prudent and waited to get as much information as we could, but once having been assured that success lay in front of us then there was no hesitation and no lack of energy put into the development.*"[6]

Chapter 1. shows how energetically some concerns did involve themselves in development of the marine diesel engine but in Britain it was the shipbuilder who generally took the lead and hence it was the shipbuilder who dictated development. The diesel engine, like the steam reciprocating engine and steam turbine, was simply a means of propulsion for the shipbuilder's products rather than an end in itself to be sold to others. Shipbuilders did not need to change so long as they could sell steam driven ships to customers. As late as 1924 Messrs Readhead and Sons Ltd, the Tyneside shipbuilders, claimed that owners were not inquiring about diesel engined vessels hence they did not offer them.[7]

The fact is, however, that there was an interest in diesel propulsion as the internal combustion engine was more efficient than the steam engine. The question to be asked is why were British shipowners slower to adopt diesel propulsion and why, in general, were those designs which did evolve in Britain so unsuccessful. During the early 1920s Britain still possessed the world's largest merchant fleet and also constructed more ships than any other nation but being at the forefront of the shipping and shipbuilding industries did not give the country a lead in the designing of effective marine diesel engines; in that area Britain was not successful and in order to determine why it is necessary to consider not just the technical merits of those designs which were produced but also the culture in the British shipping and shipbuilding industries at the time.

Fig 2.1 Change in ship propulsion during the early years of the 20th century (Source: Lloyd`s Register of Shipping Annual Statistics)

Steam propulsion certainly had its advocates particularly as steam generation could be achieved by the burning of coal whereas the diesel engine required oil fuel. Coal not only powered factories but it propelled ships and was a valuable cargo to be carried abroad for driving overseas factories and as ships' bunkers. Mines were inefficient but that did not matter unduly as wages were low and markets at home, in shipping and, to some extent, overseas were protected.[8] Although the diesel engine may have presented a minor threat to coal the burning of oil under steamship boilers was much more significant immediately prior to and during WWI. In the immediate post-war period a number of large liners were converted from coal to oil burning but from about 1925 the tonnage burning oil under boilers remained fairly constant until the outbreak of WWII.(fig 2.1)[9] Growth in diesel tonnage resulted in a reduction in coal fired tonnage thus it was the diesel engine which was the threat to the use of coal at sea from the mid-1920s onwards. Burning oil under boilers was considered to be a waste. The change from coal to oil firing aboard large Atlantic liners had a marked effect on the coal and oil markets and S.B. Freeman of the Blue Funnel Line feared that if the process continued the effect would be "*...still further depressing the price of coal and increasing the cost of oil.*"[10]

During the latter years of WWI an extensive programme of British ship construction had been undertaken to make good losses and that continued with the coming of the armistice. Such tonnage was, generally, steam powered because of the restrictions placed on British diesel engine development during the war. This emergency shipbuilding programme restricted post-war construction by British owners who were able to make use of these, by now, surplus ships and those obtained from Germany as reparations. Throughout the 1920s, and for the early years of the 1930s, the British fleet was essentially getting older with an increasing proportion, being more than five years old.(figs 2.2 & 2.3)[11] Only in Germany was there a rise in shipbuilding during the early years of the 1920s, labour charges there being lower than in Britain or other European shipbuilding countries. In 1925 Furness, Withy & Co., a major British shipowner favouring motorships, placed a five ship order with Deutsche Werf on the grounds of price, the German yard offering to build the ships for £150,000 each whilst British yards tendered £60,000 to £100,000 per ship more.[12]

Fig 2.2: Number of ships (over 1,000 tons) less than 5 years old
Source: Lloyd's Register of Shipping Annual Statistics

Fig 2.3: Percentage of fleets (over 1,000 tons) less than 5 Years Old
Source: Lloyd's Register of Shipping Annual Statistics

If a major British owner was willing to build in Germany on cost grounds it is certain that many overseas, and other British, owners were willing to do the same. British shipbuilding declined and so did the opportunity to sell engines. Labour charges were a major factor in the shipbuilding and marine engine building industries and the relatively high cost of labour, particularly compared with Germany, must have influenced the price of an engine. A 1931 report from the Department of Overseas trade indicates that in many areas of the world British internal combustion engines were uncompetitive in terms of price, particularly with respect to German engines.[13]

The willingness of a shipowner to adopt diesel engine propulsion was influenced by a number of factors including:

i. Cost of the propulsion plant.
ii. Operating costs.
iii. Return on investment
iv. Long term availability of fuel on the routes to be worked.
v. Reliability of the Engine.

i. Cost of Propulsion plant: diesel engines were more expensive than either steam reciprocating or steam turbine plants for the same power output.[14]

ii. Operating costs: Many factors influenced operating costs but of prime importance was the fact that diesel engines burned oil whilst steam plant could be designed for coal or oil firing. In either case steam plant was less efficient than the diesel engine and fuel consumption was greater. [Operating costs will be discussed in more detail in Chapter 3.]

iii. Return on investment was very much a function of operating costs but many owners, particularly from Scandinavia, considered that investment in motorships was worthwhile. Most installations in the immediate post-WWI period were for ships engaged upon liner trades with little consideration being given to tramp ships, a large portion of the British fleet was, at that time engaged in tramping duties. British tramps returning to the UK with imports would often leave again with British coal as a cargo; coal bunkers could be taken at the same time as cargo was loaded hence there was a natural reluctance on the part of such tramp owners to adopt diesel propelled tonnage. The economics did, however, work in favour of the diesel engined tramp compared with other forms of propulsion and this can be seen from table 2.1; costs given are in Danish Krone as the table was prepared for a paper presented in Denmark during 1921 but the comparisons can be appreciated. Bunkers for onward or return journeys would have to be paid for at rates prevailing in local overseas ports and coal might not then be the cheapest fuel. {Coal and oil costs at different world ports during July 1920 are shown in table 2.2} The economics of diesel propulsion were so favourable that in 1923 one British shipbuilder commented "*....within twenty years all tramp ships will be equipped with diesel Machinery.*"[15] [Economics of motorship operation are covered in chapter 3.]

Table 2.2. Cost of Fuel Oil and Coal at Principal Ports, July 1920

Source (Tables 2.1 & 2.2):
E.L. Barfoed, "Motor Tramp Ships", **The Motor Ship**, vol 2, July 1921. p134

iv. Of critical importance to any shipowner was the availability of fuel. Steam engines, reciprocating or turbine, could make use of coal of which Britain had adequate reserves but diesel engines relied upon oil which had to be imported. For most of the time between the two world wars, and particularly during the early 1920s, there was considerable concern that oil reserves would not last and that builders of motorships would need to re-engine there ships. The Naval Architect Sir Westcott Abell offered the view "*Technical opinion of the motor-ship ranges from the optimism of those who visualise a revolution in propulsion - to use an Americanism, the 'Dieselisation' of the sea - to the pessimism of those who calculate that the world's oil supply will be exhausted in ten year's time.*"[16] Concern did exist regarding the availability of oil supplies but oil companies were in the business of selling their products and expanding markets. Oil was also more expensive than coal but during the post WWI period and throughout the 1920s and 1930s there was never any period of price stability in terms of either fuel. Industrial disputes caused periodic coal shortages in Britain but loss of some export markets resulted in abundant stocks at other times. Fuel oil prices were very much set by the large oil companies and it was commonly believed that they artificially fixed prices by restricting supply. Sterry B. Freeman, Engineering Superintendent of Blue Funnel Line, believed that oil virtually sold itself, "*All he (the* *oil industry) may have to do is to hold it for a short time until demand rises to such a level that it is absorbed. The demand has never decreased, but is incessant and increasing.*"[17] The number of bunker stations increased dramatically during the early 1920s. In 1920 there were at least 150 ports with oil bunkering facilities, two-thirds of which could offer the refined oil used for diesel engines.[18] In 1924 S.B. Freeman, whose employers owned both steam and diesel engined vessels, stated, "*Oil for marine purposes has come to stay.*"[19] A report in 1923 indicated that free petroleum resources could last at least 80 to 100 years and then there would be the possibility of obtaining oil from secondary sources such as oil shale and coal.[20] Steamships, even those employing oil firing, required larger engine room crews than motorships and so operating costs tended to be higher.

v. If an engine could not be relied upon to operate without frequent breakdown it was of little use to the shipowner. Early diesel engines were not considered reliable enough for long sea voyages but by the beginning of WWI that reliability was improving. Use of twin screw installations for early motor vessels is often quoted as being necessary in order to safeguard against breakdown and there is some truth in that but for larger ships it was generally the case that sufficient power was not available from one engine and so it was necessary to resort to twin screws.[21] Machine reliability was, and still is, linked with maintenance but in general terms improved reliability comes from improved design brought about through knowledge gained from operating experience, and from the way in which the machine is operated. That situation applied to the early marine diesel engines and by 1924 Sir Westcott Abell had sufficient confidence in them to express the opinion, "*....experience gained in marine transportation with Diesel-engined ships during the last 14 years has been such as to satisfy the requirements of reliability on service, and that the disappearance of the steam engine from overseas trade is largely a matter of time.*"[22] Classifications Societies also had confidence in the diesel engine as can be seen from the requirements for the carriage of spare gear in appendix 1.[23] These indicate no general increase in the type or number of spare gear items which had to be carried; had there been any problems concerning engine reliability problem areas are likely to have been addressed by the need for the carrying of increased spares. Reliability of individual designs influenced the market share of that engine {British engines will be considered in Chapter 4.} but it was the general impression which swayed the shipowner towards or away from diesel propulsion. Unfortunately the operations of early marine diesels tended to go unrecorded but a very interesting paper was written by the superintendent engineer of Rederi A/B Transatlantic who made the maiden voyage aboard the motorship **Yngaren** fitted with the first Doxford opposed-piston engine.[24] Stoppages were for minor items such as the tightening of glands and replacement of fuel valve sprays; during the 33.5 day outward passage to Java there were eight stops totalling 6.73 hours, whilst on the 42 day return voyage from Australia there were nine stops totalling 11.16 hours, no stops were experienced between Java and Australia. In 1923 the chief diesel engine designer at Swan Hunter was confident enough to state, "*..the reliability of oil engines now is considered to be unquestionable.*"[25]

Other factors influenced an owner's decision to install diesel machinery in his ship including that of personal preference, or prejudice. In 1928 Sir William Noble, chairman of the Cairn Line which then owned nine steamers and no motor vessels, commented that the advantages of motorships had been publicised without any mention of problems and that many owners had been induced to "*..push into the fashion*" of motorship building. "*...we may expect the fashion to give another turn of the wheel and a normal increase of world consumption of bunker coal to be resumed.*"[26] The fact that Sir William, as well as being a prominent shipowner and President of the UK Chamber of Shipping, was a director of the Blackwell Colliery Co. may have influenced his preference to coal burning ships. In July 1927 William Ropner, chairman of the Ropner Shipping Co., informed shareholders that the company had ordered eight coal-fired steamers during the past 12 months, "*..and not diesel-engined, or oil burning vessels, in order that the coal industry might benefit.*"[27] At that time Ropners also acted as overseas marketing agents for a number of colliery companies. The directors of other shipping companies, and possibly those of shipbuilders, must have had similar coal interests.

Mr C.W. Cairns, also involved with Cairn Line, also held strong views regarding the battle between coal and oil, "*There are other ways in which coal can help in its fight against oil, such as adoption of good geared-turbine outfits......our marine engine builders might advocate, and shipowners might have the courage to adopt, geared-*

turbine sets down to lower powers..the Diesel engine has got very vocal support whilst those who ought to uphold coal say little...".[28]

Coal, or rather fuel in general, was an important matter as far as the prospective owner was concerned. Availability of supplies, not just cost, had to be considered and an owner would only build a ship if he was certain that its operation would not be hampered by shortage of fuel. Britain had vast stocks of coal and over the years bunker stations had been established in many parts of the world. Indeed the outward cargoes for many tramp ships leaving British ports consisted of coal, much of it to supply local bunker stations. During the 1920s, when most British crosshead diesel engine designs were trying to become established, there was considerable worry about the long term oil supply situation and the price of such supplies. One of the arguments against the diesel engine was its reliance upon imported oil but others argued for the diesel engine on the grounds that its higher efficiency actually save fuel and thereby protected Britain's dwindling stocks of coal. (At the time the extent of Britain's coal reserves was not known no more than was the extent of the world's oil reserves.) Rudolf Diesel recognised this potential advantage, "*Great Britain has the greatest interest in replacing the coal-wasting steam-engine by the more economical diesel engine because she can therewith effect enormous savings in her most valuable treasure - coal, and thus defer the exhaustion of her stock.*"[29]

Of more concern to many than the burning of oil in relatively efficient diesel engines was the waste in converting the boilers of large liners to burn oil. Commenting upon the conversion of **Aquitania** and other liners to oil burning Prof H.E. Armstrong wrote in ***The Times***, "*... such profiteering at the expense of future generations, if not of the present, should not be possible. If we are believers in the internal combustion engine..... it behoves us to economise in the use of oil in every possible way.*"[30] The financier Sir Mackay Edgar commented in similar vein, "*Ships Like the* **Olympic** *and the* **Aquitania** *are now being driven by oil, but I consider this to be the most imprudent way of using up the oil resources of the world*".[31] After returning from America and Mexico, where he had studied the question of oil supply, Lord Pirrie stated that he believed it was wrong to burn oil for the purpose of raising steam. He also stated a belief that the best way of preserving oil reserves was through adoption of the diesel engine rather than burning oil under boilers.[32] He did, however, offer a cautionary note, "*...but today it would be a great responsibility for any shipbuilder to advocate the installation of diesel engines until supplies of diesel oil are assured.*"[33]

The coal situation tended to colour the issue and at times it was almost implied that people were being unpatriotic if they made use of imported fuel. As late as 1930 the national interest card was still being played. In his Presidential Address before the Institute of Marine Engineers that year the shipowner Sir August Cayzer expressed the view that, "*...it will become necessary in the interests of this country that oil suitable for diesel engines and for burning under boilers should be produced from British coal.*" ***The Marine Engineer and Motorship Builder***, in reporting the address commented that it was a view "*with which all of us must be in cordial agreement*".[34]

Protection of the home coal industry may well have been a laudable sentiment but if the burden fell on the shipowner then that interest was not being served correctly as British shipping, owning and building, was also of crucial national importance. To have owners forced from traditional routes because their ships were uncompetitive or to have builders only able to offer uneconomic steam powered tonnage would certainly not have been in the national interest. The coal question cast a shadow over Britain's marine industry during the interwar years and solid fuel protagonists, often in the guise of pro-steam rather than pro-coal, fought hard against any further advance of the marine diesel engine. In Scandinavia there was no indigenous fuel which could be used for oceanic shipping and so owners wanted the most economic form of propulsion. In 1923 having just ordered a large diesel engined liner for service on the north Atlantic Dan Brostrom, owner of the Swedish America Line, commented "*No leading Swedish, Danish or Norwegian shipowner thinks seriously of any other class of vessel than the motor ship - at any rate where cargo liners above 5,000 tons are concerned*".[35] Scandinavian owners concentrated upon diesel powered tonnage as did Scandinavian builders. Fig 2.4 indicates the strength of the Scandinavian diesel powered fleet whilst fig 2.5 illustrates the strength of motor shipbuilding in the region. A strong home market produced plenty of orders and allowed the home based engines, particularly the Danish Burmeister & Wain engines, to thrive.

Fig 2.4 Number of Motorships (over 1,000 tons) owned in various countries
(Source: Lloyd's Register of Shipping Annual Statistics)

Fig 2.5 Number of Motorship completions in different countries
(Source: Lloyd's Register of Shipping Annual Statistics)

In the post WWI period British coal met with competition in overseas and bunker markets resulting in a price reduction, the quality of some British coal also fell as older mines were worked out whilst production costs increased in others with the need for additional cleaning. Depression in the mining industry resulted in industrial action which culminated in the general strike but discussion of that is beyond the scope of this work. A protectionist stance towards coal meant an objection to the diesel engine in one of coal's biggest markets, ship bunkers. In Germany a problem existed in that its pre-war quality mines situated in Upper Silesia had been ceded to Poland after the armistice, France also took control of mines in the west. Only relatively low quality lignite was available in any quantity. In order to obtain foreign exchange Poland virtually dumped coal from Upper Silesia on the international market thereby reducing coal prices and taking much export business from Britain's mines.[36] Germany was forced to make use of low quality brown coal, which it did successfully in land based plants, but this material was not ideal for burning in marine boilers; marine diesel engines were a more reasonable solution. During the immediate post-war period a number of large direct drive engines came into production, designs generally coming from engineering concerns rather than shipbuilders. M.A.N. made progress with its single- and double-acting engine whilst Krupp, A.E.G. and Blohm & Voss undertook the design of high powered diesel engines.[37]

Certain owners may have been vehemently opposed to diesel propulsion but others were equally enthusiastic about its adoption. In 1921 Sir Frederick Lewis expressed the view that "*..the most important development in shipping as an industry is probably the internal combustion engine.*"[38] whilst in 1926, after running several motorship with different types of machinery he confidently stated, "*..the future of marine propulsion lies in the internal combustion engine.*"[39] Lord Inverforth was no less confident, "*I have now the experience of working several motor ships during the past two years, and have not the slightest hesitation in saying that the high-priced motor ships show a decided advantage over steamships.*" The Scandinavian owner Gunnar Knudsen, of A.B. Borgestad, was able to say "*Thanks to the motor ships owned by our company, we hope to be able to promise the shareholders a constant dividend of 10% in the coming years.*"[40]

Sir John Latta was rather confused on the issue. In 1921 he was willing to state, "*I should say that the diesel engine represents the most revolutionary development, and its future possibilities are likely to be far reaching.*"[41] Later the same year he added, "*As far back as 1913 I was quite convinced of the great potential of the motor ship, although its advantages over the steamship are today incomparably greater than they were then...*"[42] In 1926, when his Nitrate Producers Steamship Company still only operated steamers, he advocated coal fired boilers with steam reciprocating engines.[43]

Whilst owners had individual preferences so did designers, consultants and builders. Some British shipbuilders had invested a considerable sum during the immediate prewar years in new machinery to allow construction of steam turbines and gearing, additional cost to enable construction of diesel engines placed an extra burden on already stretched financial resources.[44] Only those builders willing to invest such money could offer diesel propulsion units but if that builder was also to offer an engine to his own design an additional sum had to be invested to cover development costs. Often it was a simpler solution to take a licence from an already established designer and thereby save development costs, however, licence fees had to be paid and these needed to be considered when quoting for an engine. This was particularly so if the licensor also built engines and would, therefore, be likely to quote for a particular installation. British licensees of overseas designs all had to pay a licence fee, usually based upon the engine's power, and so competition would be based upon manufacturing costs but in the case of British designs licensees would also be in competition with the licensor who could quote a lower fee because the licence fee would not need to be paid. Where there might be few orders available the licensee of a British design would always be at a disadvantage compared with the licensor.[45]

In an editorial during 1920 ***The Motor Ship*** took issue with shipbuilders, particularly those on the north-east coast of England and compared their attitude unfavourably with that of Doxfords. "*They do not want the motor ship to progress, because it would mean that they would be driven out of their complacency and forced to deal with something new.*"[46] One shipbuilder responded, "*The shipbuilder holds no brief for the steam engine, the diesel engine, or oil fired boilers. His duty and, on the whole, his practice have been to develop the type that seemed to be most suitable....*"[47] This notwithstanding the editor, Mr A.P. Chalkley, found himself barred from several shipyards whilst sub-contractors were warned not to support the journal with advertising otherwise they risked losing future orders from shipbuilders and shipowners. [48]

During 1925 an intense debate commenced in the columns of ***The Times*** following publication of a paper by the distinguished naval architect Sir John Biles.[49] Biles advocated the steam engine for practically every purpose and his paper compared figures from early diesel installations with predicted costs for the operation of high pressure steam plant which, at that time, had not even been constructed. Lord Bearsted, Chairman of Shell Transport & Trading was the main protagonist on the diesel engine side but he was supported from time to time by others including Lord Invernairn and Sir Fortescue Flannery. Sir John Latta came in on the side of the steam engine. Throughout the month of May many the argument raged in the correspondence columns of that newspaper and, as is generally the case, the dispute came to an inconclusive end, neither side willing to acknowledge the other's case.[50]

The following year Sir John Biles presented another paper before the Institution of Naval Architects[51], making similar claims for steam plant to the detriment of diesel installations. This time a number of people taking part in the discussion, including Sir Archibald Denny, did question the low costs put forward for steam plant and the high costs estimated for the diesel engine. A further paper followed in 1928[52], this time addressing the question of fuel for ships. Again Biles was selective in his choice of figures but drew criticism from some who attempted to counter his argument. S.G. Visker commented that one of his company's vessels, **Bintang**, had been re-engined from triple-expansion steam to a two-stroke Sulzer giving an annual saving of between £4,000 and £5,000. Biles' claim that a diesel engined ship would cost £10,000 per year in maintenance and £2,000 per year in lubricating oil was questioned whilst one individual commented that "*..his Diesel figures appear lacking in foundation.*"[53]

This paper also swelled the correspondence columns of ***The Times*** with A.P. Chalkley playing the main role of advocate on behalf of the diesel engine and Sir John Biles being supported by Sir E.H. Tennyson D'Eyncourt.[54] In replying to one of the contributors of his 1928 I.N.A. paper Biles disclosed the real nature behind his arguments, "*...he {the contributor} may monopolise all the prophesying he likes so long as he helps to increase the use of British coal in place of foreign oil...*".[55] The fight against the diesel engine even went to Parliament with the MP Sir Robert Thomas being reported as saying, "*...the internal-combustion engine has had its day and he was sorry that so much British capital was sunk in it. He believed that the future of propelling power for ships would rest with pulverised coal. That would mean not only an enormous saving in the running of ships but also be of great help to our coal trade*".[56]

With such conflicting views it is little wonder that the shipowner would be confused as to the best propulsion system to install in his ship. Economic matters relating to shipowning must be considered on a long term basis and in respect to worldwide costing as far as fuel is concerned. For a diesel engine to compete with steam plant initial costs and operating costs must be considered, fuel costs are not easy to predict but other operating costs such as engine room staffing and maintenance can be assessed. Depreciation allowance on the initial cost of the engine depends upon that cost and it would only be with large scale production that costs could be kept low. Maintenance costs would depend upon reliability and that also would improve with a large number of engines in service thus allowing development, and subsequent modification, to take place. In general British diesel engine designs were not able to rely on long production runs which would keep unit costs low and allow faults to be recognised and modifications made. There were a number of reasons for this as will be discussed later but the constant battle against other vested interests cannot have helped and was something with which overseas competitors from Switzerland, Denmark and Germany did not have to contend.

References

1. In each of the years from 1900 to the outbreak of WWI British shipyards built about 60% of the world's tonnage. (Information taken from Lloyd's register of Shipping Annual Statistics) The interest in diesel engine propulsion was, therefore, marginal compared with the number of ships built and the number of yards building ships.

2. Prof' C.J. Hawkes, "*The Marine Oil-Engine*", Proceedings I.Mech.E. Jan' 1928. p4

3. These tended to be in the heavy shipbuilding area of the North East of England where the North Eastern Marine Engineering Co., George Clark, and The Wallsend Slipway & Engineering Co. were established. These concerns did not design there own diesel engines but took out licences from others.

4. Comment by Mr A.C. Holzapfel, a continental European who had lived in Britain for 37 years, during discussion of the paper "*Modern Developments in British and Continental Oil Engine Practice*" by E Shackleton, Trans' I.Mar.E., vol 23, 1911-2, p195

5. H. E. Yarrow speaking during the discussion of the paper "*Progress in Marine Propulsion during the Last Ten Years*" by Sir Archibald C. Ross, Trans' NECIES, vol 40, 1923-4. p522

6. Contribution to discussion on Ross' paper, Trans' NECIES, vol 40. p523-4

7. Comment by Sir James Readhead quoted in ***The Motor Ship***, vol 5, April 1924. p3

8. The British coal industry of the period is described in a number of works including C. Barnett, **The Audit of War**, Macmillan, London. (particularly chapter 4) and M.P. Jackson, **The Price of Coal**, Croom Helm, London, 1974

9. Figure derived from data contained in Lloyds Register of Shipping Annual Statistics, 1914-1939. Courtesy of Lloyds Register of Shipping, Information Centre, 71 Fenchurch Street London.

10. S.B. Freeman, "*Fuel Oil for Marine Internal Combustion and Steam Engines*", Trans' NECIES, 1924-5. p93

11. **Lloyd's Register of Shipping Annual Statistics** 1922 to 1939, Courtesy Lloyd's Information Centre

12. ***Lloyds' List Weekly Shipping Summary***, 11th March 1925; NMM Greenwich, London

13. Department of Overseas Trade, **Markets for Internal Combustion Engines**, HMSO, London, 1931. pp 19, 23-4, 32, 35, 43,

14. Cost differences depended upon a number of factors including size and speed but during his Institute of Marine Engineers Presidential Address in 1924 Lord Inverforth, a shipowner with experience operating steamships and motorships, stated that for an 8,000 ton deadweight vessel a diesel engined ship would cost about £25,000 more than a steam engined ship. Transactions I.Mar.E. vol 37, 1925-6. p417: in 1923 report to International Navigation Congress stated initial cost of motorship about 10% to 15% greater than steamship of the same size, quoted ***The Motor Ship***, vol 4, Aug' 1923. p153

15. Sir Alfred Yarrow, quoted in ***The Motor Ship***, vol 4, October 1923. p226

16. Sir W.S. Abell, Presidential Address I.Mar.E.; Trans' I.Mar.E. vol 37, 1924-5.p778

17. Freeman, "*Fuel Oil for Marine Internal Combustion and Steam Engines*", p92: During discussion of this paper Mr A.D. Bruce expressed his belief that the Anglo-Persian Oil Company definitely restricted supplies at certain times, P109.

18. ***The Motor Ship***, vol 1, January 1921. p 294

19. S.B. Freeman, "*Fuel Oil for Marine Internal Combustion and Steam Engines*". p106

20. Report from committee under Sir John Cadman presented to the International Navigation Congress, London, July 1923; quoted in ***The Motor Ship***, vol 4, Aug' 1923. p153

21. P. Belyavin, "*Marine Oil-Engine Installation and Auxiliaries*", Trans' NECIES, vol 39, 1923. p375.

22. Sir Westcott S. Abell, I.Mar. E. Presidential Address, Trans' I.Mar.E., vol 37, 1924-5. p780-1

23. Information in appendix 1. gathered from Lloyd's Rules and Regulations, courtesy of Lloyd's Register of Shipping, Fenchurch Street, London

24. T. Madsen, "*Actual Running Cost of Motorships*", Trans NECIES, vol 38, 1921-2. p549-80

25. Belyavin, "Marine Oil-Engine Installations". p374

26. Quoted in ***The Motor Ship***, vol 9, April 1928. p2

27. Dear I., **The Ropner Story**, Hutchison Benham, London, 1986. p62

28. Mr W.C. Cairns speaking during the discussion of paper on "*The Rational Utilization of Coal*", Trans' NECIES, vol 45, 1928-9. p235

29. Rudolf Diesel, "T*he Diesel Oil-Engine and its Industrial Importance, Particularly for Great Britain*", Trans' I.Mech.E., March 1912. p205

30. Quoted in ***The Motor Ship***, vol 1, July 1920. p92

31. ***The Motor Ship***, vol 1, October 1920. p183

32. ***The Motor Ship***, vol 1, Jan' 1921. p294.

33. ***The Dolphin and Guild Gazette***, (pub by the Imperial Merchant Service Guild, London), vol 2, Sept' 1920- Feb' 1921. p304

34. ***The Marine Engineer & Motorship Builder***, Vol 53, October 1930. p 336

35. Interview with Dan Brostrom reported in ***The Motor Ship***, vol 4, April 1923. p17

36.W.J. Drummond, "*The Rational Utilization of Coal - Coal Used in its Raw State*", Trans' NECIES, vol 45, 1928-9. p211

37. ***The Motor Ship***, vol 1, Feb' 1921. p309; vol 9, Sept' 1928. p222. also **The Motor Ship Reference Book**, Temple Press, London. Year copies 1921 to 1928

38. ***The Motor Ship***, vol 1, Feb' 1921. p340

39. ***The Motor Ship***, vol 7, Sept' 1926. p188

40. ***The Motor Ship***, vol 7, Sept' 1926. p199

41. ***The Motor Ship***, vol 1, Feb' 1921. p340

42. ***The Motor Ship***, vol 2, April 1921. p2

43. ***The Motor Ship***, vol 7, Sept' 1926. p199

44. Discussion on "*The Progress in Marine Propulsion*" by Sir Archibald Ross, Trans' NECIES, vol 40, 1924. Comments by Sir Archibald Denny and D.C Endert (Rotterdam Drydock Co.)

45. Licence fees were often based upon a fixed initial payment followed by a set figure per unit of engine power. In 1924 Doxford required a one off fee of £10,000 plus £1 per SHP. Vickers decided against taking a Doxford licence at that time believing that they could not get manufacturing costs at Barrow low enough to compensate for the royalty payment; Doxfords were laying out their workshops for full engine production. Information provided in report by Vickers Internal Combustion Engine Dept' following a visit to Doxfords in January 1924. Vickers' Doxford files, Barrow.

46. ***The Motor Ship***, vol 1, June 1920.

47. ***The Motor Ship***, vol 1, Aug' 1920.

48. ***The Motor Ship***, vol 51, April 1970. p1

49. Sir John Biles, "*Relative Commercial Efficiency of Internal-Combustion and Steam Engines for High Speed Passenger Vessels*", Trans' I.N.A., vol 67. pp1-26

50. ***The Times***, various dates during May 1925; also ***The Motor Ship***, vol 6, June 1925. p108, gives a summary of the correspondence.

51. Sir John Biles, "*The Relative Commercial Efficiency of Steam Turbine and Diesel Machinery for Cargo Vessels*", Trans' I.N.A., vol 68, 1926. pp207-20

52. Sir John Biles, "*The Present Position of the Question of Fuel For Ships*", Trans' I.N.A., vol 70, 1928. pp1-36

53. Biles, "*Fuel For Ships*". p32

54. A selection of the correspondence, as inconclusive as that published previously, was printed in ***The Motor Ship***, vol 9, June 1928. p94

55. Biles, "*Fuel for Ships*". p35

56. ***The Motor Ship***, vol 10, June 1929. p88

Chapter 3.

Economics and the British Motorship in the 1920s.

For any shipowner intent upon making a profit it was important to minimise the operating costs of his ships and maximise the freight due on cargo they would carry. It mattered not whether that cargo was a bulk commodity such as oil or grain, loose stowed general cargo or even passengers, no more than it mattered whether the ship was engaged upon tramping or liner duties. If it cost less to operate the ship and meet its building costs than the vessel earned in freight dues then a profit was made, how large that profit was depended upon how low the operating costs could be kept.

For ships of a certain size and type there were standard charges which were not governed by the type of machinery, such charges included;

a. Pilotage
b. Harbour dues
c. Freight insurance
d. Agency fees
e. Administration costs

Other costs were influenced by the type of machinery installed as, to some extent, was cargo carrying capacity of the ship. Any ship had to comply with regulations concerning the draught to which it could be loaded and heavy cargo, such as coal or iron ore, would bring the ship down to its maximum draught before hold volumes were full; similarly a light cargo such as grain could completely fill a ship`s hold before the ship was down to its marks. Freight rates charged reflected these differences and applied to steam and motor driven vessels, however, certain installations offered advantages for particular types of cargo in terms of volume and weight savings.

For the same ship dimensions the motor vessel allowed for increased cargo capacity compared with steam installations. Fuel oil had a higher calorific value than coal and so less needed to be carried for a particular duty and oil could also be stored in double bottom tanks thus presenting an increased volumetric space for the carriage of cargo. As marine machinery developed during the 1920s there was a tendency towards a size reduction per unit power output but diesel engines were shorter than steam reciprocating engines or turbines of similar power. In general motor ship engine rooms were shorter than those for steam ships with consequent gain in volumetric cargo capacity.[1] (See table 3.1) Engine room height requirements for diesel installations were greater than those for steam turbine plants of similar power; that was, usually, only of significance for passenger ships where additional accommodation could be placed above the engine room. Machinery weight varied with engine type but the diesel installation was not necessarily always heavier than a steam plant of similar power. Water in boilers accounted for considerable weight and it was operating conditions which had to be considered not simply the weight of metal in the engine. As can be seen from table 3.2 there was often little to choose between different plants.

Table 3.1 Comparison of Engine Rooms Lengths

Source: S.B. Freeman, "*Modern Types of Propelling Machinery for Mercantile Use*", Proc` I.Mech.E., vol 122, 1932 and Lloyds Register of Shipping 1930-1

Table 3.2. Comparison of Machinery Weights for 3,500 shp Installations

Source: Le Mesurier & Humphreys, "*Fuel Consumption and Maintenance Costs for Steam & Diesel Engined Vessels*", Trans' NECIES, vol 51, 1934-5

Tonnage measurement rules allowed a deduction of 32% to be made for the machinery space in calculating the net tonnage of a ship provided that the engine room occupied at least 13% of the ship's gross tonnage (Gross tonnage is a volume measurement where 1 gross ton is equal to $100ft^3$ of enclosed space). If the engine room occupied less than 13% of the gross tonnage the allowance was only 1.75 times the actual machinery space, thus there could be a penalty if the engine room was too small. Harbour dues and some other charges were based upon a ship's net tonnage.[2]

Harbour dues were payable for the period of time the vessel stayed within the port confines and for coal burning ships these could be higher than for oil burning ships due to the fact that it took longer to load coal bunkers than to load oil. In addition the ship would often need to go to a special berth to take on coal bunkers whilst the taking of oil from a barge would normally be undertaken whilst the ship was loading or discharging cargo. Costs involved in cleaning a ship after taking coal were not quantifiable in general because this would usually be undertaken by the ship's crew who would need to be removed from other duties.

The size of engine room complement required depended upon engine type but more particularly on the fuel, being burned. Coal required bringing to the boilers, boilers had to be fired and ash removed whilst oil fuel could be handled by pumps and there was no ash for disposal. Coal fired ships required firemen and coal trimmers but steam ships with oil fired boilers also needed firemen to tend the boilers. Even if a diesel engined ship employed steam driven auxiliaries less boiler attention was required and so the number of engine room ratings would be less than for a steamer; when not attending the boiler a rating could be employed on main engine lubrication duties. Diesel engined ships usually carried more engineers than similarly powered steam ships and, where electrically driven auxiliaries were fitted, an electrician. Personnel not only had to be paid wages but they also had to be fed whilst on board; a larger engine room complement resulted in a larger operating bill. The size of engine room complement required could always be open to argument but in general the diesel installation required fewer people than a steamer of similar power.

Comparative operating costs for diesel and steam ships during 1920 are given in Table 3.3, low and high power requirements being considered. No account is made for the savings possible due to reduction in time spent bunkering and the lower costs of bunkering for an oil burning ship, nor are the lower accommodation costs and increased cargo capacity of a diesel engined ship considered.[3] A similar set of comparative figures is given in Table 3.4 but these take into account the freight earning capacities of similar ships. Again no account is taken of a number of factors, including depreciation and interest on loans to purchase the ship, but the figures do show that diesel engined vessels could transport cargo at a lower cost than steamers and so were, potentially, more profitable. Costings in the table assume that ships would always be fully loaded and that fuel costs remained the same at all ports; obviously both assumptions were unlikely to be true but they would have applied to all ships and so the comparative costings remain valid.[4] The reduction in cost per ton mile between 1922 and 1926 reflects the lower bunker prices of 1926 and the decline in labour charges due to recession in the British shipping industry.

Fuel costs varied with the port at which bunkers were taken and also with the time of year. An owner would need to consider carefully both the availability of bunker coal or oil on the ship`s intended route and the possibility of matters changing over the years; there were many unknown factors influencing bunker price and availability. For the tramp operator the situation was even more complex as his ships were not on regular runs and so had to lift bunkers wherever they could. Following the end of WWI more ports were able to offer fuel oil reducing the risk as far as tramp operations were concerned. Table 2.2 (chapter 2) shows the prices of fuel oil and coal at selected world ports during July 1920. This indicates the growing availability of oil and the fact that price differentials did not always favour coal.

Table 3.3. Comparative Figures for the Operating Costs of Diesel and Steam Powered Ships

Source: J. Richardson, "*The Present Position of the Marine Diesel Engine*", Trans' Inst' of Engr's & Shipbuilders in Scotland, 1920

All oil fuels were not the same and diesel engines available in the 1920s generally had to burn a better quality oil than that supplied for boilers, such oil was more costly than boiler oil and it may not have been so readily available. " *....50% more fuel must be carried in the case of the turbine than in oil-engined ships. The oil for an oil-engine will be more expensive than that for the water-tube boiler....*"[5] With regards to adequate supplies of diesel engine fuel being available where and when required and at the right price the situation was far from ideal. As one owner's representative put it, "*The average shipowner is more or less in the hands of the mighty oil trusts, and is therefore now and again liable to disappointments.*"[6] In order to minimise problems brought about by possible shortage of engine grade diesel oil, and to improve economy by allowing the use of cheaper fuels, one British engine builder, William Doxford, carried out full scale trials with boiler grade fuels.[7] The improving oil supply situation minimised the need for burning boiler oils and it was not until the 1940s that real progress was made in the development of marine diesel engines to burn the heavier grades of oil.[8]

Costings, given in tables 3.3 & 3.4, must be considered alongside the earnings of the ship but the shipowner also had to appraise other factors including depreciation on the value of the ship and interest on the finance obtained for construction. Profitability of ship owning during the early years of the 1920s was hit by the world recession and the higher initial costs of the diesel engine caused potential owners to question the building of motorships, or any ships at all, particularly in Britain. Sir Frederick Lewis commented "*...the very heavy initial cost as compared with other types of marine engines, the amount that is necessary to set aside for upkeep and depreciation is to some extent unproved.*"[9] Lewis's comments are significant as he was chairman of Furness Withy which then (1925) owned a number of motorships. In reporting this statement **Brassey's Naval and Shipping Annual** outlined three alternatives facing the shipowner, "*...to build vessels in this country at uneconomic prices, ie prices upon which a return approaching that received from Government securities cannot be obtained, build abroad at lower prices, or to wait until a commercially sound basis is reached.*"[10]

Table 3.4 Comparative Freight Costs for Diesel and Steam Powered Cargo Ships

Source: Brassey's Naval & Shipping Annual, 1921-2 (p443) & 1926 (p526)

With so few motorships in service during the early years of the 1920s there was little practical experience upon which the shipowner could base a decision to adopt diesel propulsion and any owner at that time needed to have real confidence in the engines he was to install. Figures based upon estimates of performance and costings provided some basis upon which to make a decision but there was still a need for the owner to have faith in the diesel engine. Only by the middle of the 1920s had sufficient operating data been obtained to allow shipowners to judge the relative merits of steam and diesel propulsion but, because such information was of commercial value, there was a tendency for an owner to keep his records confidential. One marine engineer commented, "*It is a most regrettable thing that so little reliable information has been published about the actual performance of British-made diesel engines on service.*"[11] An exception to this was Alfred Holt & Co. which owned a large fleet including steam reciprocating, steam turbine and diesel engined ships. The company was recognised "..*as running their vessels on most efficient lines.*"[12] and which also encouraged senior personnel to present papers to learned societies.[13]

As far as Holt's Blue Funnel Line was concerned, diesel engines were an economic proposition compared with older steam reciprocating tonnage and new turbine driven ships. Table 3.5 gives details of different ship classes in the fleet whilst table 3.6 indicates costs for those classes relative to the **Arteus** class ships. For the newer oil-engined **Peisander** and **Orestes** class ships fuel costs were much lower than for the steamers whilst engine upkeep costs also compared very favourably with other classes in the fleet. Spare gear requirements for diesel engines could be higher than for steam plant and that is reflected in the engine stores column, however, the main charge on stores for diesel engines was that of lubricating oil.[14] Obviously the age of ships had an influence upon maintenance costs but the newer **Sarpedon** and **Antenor** class turbine ships were amongst the most costly in the fleet in that respect. In analysing ships of the Blue Funnel fleet L.H. Cripps provided valuable information to the shipping community and it shows that in adopting diesel propulsion for the **Peisander** and **Orestes** class ships the company made a wise decision.[15]

Table 3. 5 Analysis of Some Ships in Blue Funnel Fleet.

Ship Class	Engine Type	Disp't Tons	Fuel	Power SHP	Speed Knots
Arteus (5)	S-S, SR, Sat	13,500	Coal	4,000	13
Keemun (3)	2-S, SR, Sat	18,300	Coal	5,500	12
Lycaon (8)	S-S, SR, Sup	15,000	Coal	4,400	13.5
Nestor (2)	2-S, SR, Sup	26,800	Coal	6,000	13.5
Adrastus (8)	S-S, ST, Sup	15,200	Coal	6,000	14.5
Phemius (1)	S-S, ST, Sup	15,200	Oil	6,000	14.5
Sarpedon (2)	2-S, ST, Sup	19,400	Coal	7,500	15
Antenor (2)	2-S, ST, Sup	19,400	Oil	7,500	15
Peisander (5)	2-S, Diesel	12,600	Oil	3,700	13
Orestes (4)	2-S, Diesel	15,300	Oil	6,600	14.5
Dolius (1) **Medon** (1)	2-S, Still S-S, Diesel	11,400	Oil	2,200	11

( ) number of ships in class: SR Steam Reciprocating: ST Steam Turbine: S-S Single Screw: 2-S Twin Screw: Sat Sat' Steam: Sup Superheated Steam

Table 3.6 Analysis of Some Ships in the Blue Funnel Fleet

Ship Class	Av' Age Years	Relative Cost (Percentage)				Relative Percentage Fuel Cost (7,000 tons of cargo 100 miles at 13.5 knots)
		Ship Upkeep	Ship Stores	Engine Upkeep	Engine Stores	
Arteus	19	100	100	100	100	100
Keemun	28	143	112	105	110	105.3
Lycaon	15	80	100.1	105	112	82.3
Nestor	17	198	88	234	171	94.8
Adrastus	8	75	97	96	112	80.7
Phemius	8	79	99	64	107	102.2
Sarpedon	7	162	131	183	202	95.2
Antenor	5	161	123	134	167	106.8
Peisander	4	56	84	65	161	45.3
Orestes	3	68	92	87	197	47.1
Dolius/Medon	6	49	92	88	162	43.5

Source: Data in tables 3.5 & 3.6 are taken from L.H. Cripps, "*Considerations on Economics of Cargo Liners*",Trans'I.N.A,vol 72, 1930

A major factor in ship economics was initial cost as that had to be covered out of earnings over a number of years. In addition charges on initial cost had to be met and the higher the capital investment the greater those charges. Diesel engines cost more than steam reciprocating plant or steam turbines although the actual price and variation between different installations fluctuated with builder and with time. Relative costs and weights for plants of 2,500shp and 6,000shp are given in table 3.7, the diesel being of Doxford design using electrically driven auxiliaries.[16] This table represents prices in 1926 whilst table 3.8 offers costings two years later for engines in the 3,000shp range; for a 2,500shp Doxford engine with electrical auxiliaries costings taken from table 3.8 give the same price indicated in table 3.7. Although costings of steam plant will have varied with builder the figures given can be taken as typical for the mid-1920s period. By the 1930s the price of diesel machinery had fallen in relation to steam plant as can be seen from table 3.9 which is based upon figures obtained by S.B. Freeman from a number of engine builders.[17]

Table 3.7 Cost of Steam and Diesel Plant (1926)

Source: W.G. Cleghorn, "*Steam versus Diesel Machinery for Cargo Vessels*", Trans' Inst' of Engr's & Shipbuilders in Scotland, vol 70, part 1. 1926

Table 3.8 Comparative Costs of Marine Engines (1928)

Source: A.E. Seaton, **A Manual of Marine Engineering**
Pub. Chas. Griffin. London. 1928

Table 3.9 Relative Costs of Marine Engines (1934)

Source: S.B. Freeman, "*Marine Engineering From a Superintendent's Point of View*", Trans' Lloyd's Register of Shipping Staff Association. 1934-5

The critical time for British marine diesel engine builders was during the early to middle years of the 1920s when so many designs were placed upon the market (see chapter 4) but during that period manufacturing costs were high. Although confident of the future for British marine diesel engines, in 1925 one leading British motor ship owner, Lord Inverforth, complained about its high initial cost, "*The enterprise which has made us second to none as highly skilled mechanics and engineers still predominates, and will lead us to the same degree of perfection in motors as was attained by us in steam. Progressive methods, however, are at the moment handicapped by the unprecedented depression in international trade, and also by reason of the fact that in spite of this state of affairs, the cost of production still remains abnormally high.*"[18] Even the diesel design engineer and manager at Harland & Wolff, F.E.

Rebbeck recognised the problem of cost, "... *it had to contend with the fact that it was an expensive machine to produce, and was therefore handicapped by a relatively high first cost.*" He did, however, believe that the diesel engine's success had ".. *not been the result of its popularity, but rather its inherent capacity for producing low running costs*".[19]

Having analyzed costings and earning for steam and motor ships W.G. Cleghorn indicated that the effect of engine weight on profit was small, a 30% reduction in weight increasing profit by 1% but a 30% reduction in engine cost resulting an a profit increase of 4%. "*This statement is suggestive of the lines along which the diesel engine should be developed, and indicates the desirability of economy in cost rather than weight.*"[20] In responding to Cleghorn's paper the President of the Institution of Engineers and Shipbuilders in Scotland, A.J. Campbell, commented on the point of diesel engine initial cost, "... *I think the remedy is for shipowners to encourage the building of vessels with such machinery, for until they do so by placing orders the economy in first cost will never arise.*"[21]

By the late 1920s production of many of the early British crosshead marine diesel engines had ceased and so costings based upon values obtained at that time were of no benefit to these engine builders, however, they can illustrate the economics of diesel engine operation. Based upon information gathered in 1932 S.B.Freeman was able to determine the payback period for three diesel installations compared with steam plant (tables 3.10 & 3.11) and his figures show that the motor ship was an economic proposition in the moderate and lower power ranges.[22] Such power ranges suited the cargo ship but there were other factors to consider particularly that of fuel.

Table 3.10

Comparison of Initial and Running Costs for Types of 8,500SHP Machinery (1932)

	Oil Engines			**High Pressure Turbines**		
Proposal	1	2	3	4	5	6
Machinery Type	Twin Screw 4SSA Supercharged	Twin Screw 2SDA	Single Screw 2SDA	Twin Screw Coal Fired	Twin Screw Oil Fired	Twin Screw Oil Fired Elect Auxil'
Machinery Cost	£110,500	£105,800	£101,200	£90,500	£89,500	£98,500
Fuel per day (tons)	36.5	36.5	36.5	91.5	65	55
Annual Running Costs	£31,400	£31,200	£30,300	£37,800	£41,400	£33,600

Annual Running Costs comprise Fuel, Stores, Repairs, Wages, and Victualling plus 4% depreciation:
4SSA Four-Stroke Single-Acting, 2SDA Two-Stroke Double-Acting

Table 3.11

Payback Period in Years for Particular Diesel Installations
Compared with Steam Installations as given in Table 3.10

Source: Data in tables 3.10 & 3.11 taken from
S.B. Freeman, "*Modern Types of Propelling Machinery for Mercantile Use*",
Trans' I.Mech.E., vol 122, 1923

From table 3.11 it can be seen that in comparison with type 4 steam plant a type 1 diesel installation would take 3.09 years to repay its higher capital cost from lower operating costs. However, a type 3 diesel installation would only take 0.81 years to repay higher capital costs when compared with a type 6 steam installation.

By 1932 Freeman may have considered that the diesel was ideal for cargo ships in the Blue Funnel fleet but he was well aware that fuel prices were critical to the situation. "*Every oil-engine is tied for satisfactory running and upkeep to a certain fairly narrow range of fuel. The advent of an entirely satisfactory and economical coal-burning engine* *would be of serious consequence to it.*"[23] In 1926 Sir John Latta, no advocate of the motor ship, expressed the shipowner's view quite directly, "*The purpose of building a steamer or diesel vessel is to carry cargo with a view to earning profits.*"[24] Owners had different ideas as to how such profits could be made but it all hinged upon keeping capital repayments and operating costs to a minimum whilst maximising freight earnings.

There was no doubt that during the 1920s the route operated by a ship played an important part in its operating economics, particularly with respect to the type of fuel which could be used. Manchester Liners, part of Sir Frederick Lewis's Furness Withy Group, operated coal fired steamers between Manchester and ports on the east coast of Canada because they were more economical than diesel ships, however, Andrew Weir & Co. considered the diesel powered ship more economical for its world wide routes. On the relatively short UK to Canada route bunkers of inexpensive coal could be obtained on both sides of the Atlantic but for world wide trading greater distances were covered between bunker ports and oil could be obtained at the cheapest ports along the route. At the time both owners were right in their choice of power unit for these particular services.[25]

At higher operating speeds diesel propulsion was more economic due to lower fuel consumption per unit power thus fuel costs, time spent bunkering and space taken by fuel bunkers was less than for a steamer, coal or oil fired. Initial engine cost differentials were also less for higher power plant (see table 3.7) compared with lower powered engines. In 1924 Kerr Line placed six 11 knot motor ships on its round-the-world service from New York in competition with, amongst others, Furness Withy's fleet of 11 knot steamers. In response Furness Withy built five 14 knot diesel engined ships forcing Kerr Line to introduce ships of similar speed in 1926. Such competition on this route, and on the Pacific, was only possible with motor ships due to the distances involved and the economy offered by the diesel engine.[26]

A small, though significant, issue was the cost of insurance on ship and cargo. Early diesel powered vessels were subject to surcharges on insurance rates. During the early 1920s machinery insurance premiums for motor ships could be in the order of 10%

whilst for steamers it was around 3% but by the middle of the decade rates had equalised and one shipowner claimed that some underwriters offered cheaper premiums for motor ships.[27] Only if the high reliability of the diesel had been confirmed would such a situation have existed.

One aspect which did give concern to motor ship operators was the shortage of marine engineers with diesel engine experience, as good engineers were essential to the efficient operation of the diesel engine. Comparing repair costs of diesel engined ships with steamers in the Blue Funnel fleet S.B. Freeman commented "*... the cost of the oil-engine repairs was as low, or lower than that of the steam-driven vessels. The personal factor has much to do with this matter.....The best machinery in the world is not safe in the hands of incompetent or careless engineers.*" [28] The Board of Trade, which controlled the issue of certificates of competency for marine engineers, published regulations concerning such certificates for motor ship engineers in 1916. For a number of reasons introduction of these regulations was delayed until January 1922[29] but following representations from a number of bodies, including shipowners, implementation was again delayed until January 1924. A cause for concern was the increasing number of motor ships but limited availability of certificated motor engineers; a change in the regulations reduced the qualifying service time aboard diesel powered vessels before an engineer could take the examinations for a motor certificate of competency.[30] This scarcity of qualified motor engineers may have had an influence on the part of some shipowners to adopt, or extend, the use of diesel propulsion as it was accepted that motor ships required more skilled engineers than steamers with reciprocating engines.[31]

In view of the conflicting advice being offered from many sides, and the absence of hard facts on diesel engine operation, it is not surprising that the British shipowner appeared reluctant to embrace the motor vessel during the immediate post war years. Certainly some advice was less informed than it might have been particularly with respect to fuel and its availability. A desire to protect a British asset, its coal, may have coloured the judgement of some whilst others may simply have had financial interests in collieries. Even engineers held views which were not always based upon reason, "*A complicating factor for the shipowner is inevitably the conscious or unconscious bias* *of each engineer whom he meets.*"[32] That bias may have been between steam or diesel but even on the diesel side there were many engines from which to choose and each engineer will certainly have believed that his design was the best. As will be seen from chapter 4. British engine builders gave the shipowner ample choice.

References

1. Sir Westcott Abell, I.Mar.E. Presidential Address, Trans' I.Mar.E., vol 37, 1924-5. p783 also Lord Inverforth, I.Mar.E. Presidential Address, Trans' I.Mar.E., vol 39, 1925-6. p418

2. L.J. Le Mesurier and H.S. Humphreys, "*Fuel Consumption and Maintenance Costs of Steam and Diesel-Engined Vessels*", Trans' NECIES, vol 51. 1934-5. p231-2

3. James Richardson, "*The Present Position of the Marine Diesel Engines*", Trans' IESS, 1920.

4. **Brassey's Naval & Shipping Annual**; 1921-2, p443 and 1926, p 526.

5. S.B. Freeman, "*Marine Engines from a Superintendent Engineer's Point of View*", Trans' Lloyd's Register Staff Association, 1934-5. p3.

6. T. Madsen, "*Actual Running Costs of Motorships*", Trans' NECIES, vol 38, 1921-2. p552

7. W.H. Purdie, "*Thirty Year's Development of Opposed-piston Propelling Machinery*", Proceedings I.Mech.E., vol 162, 1950. p453-4. also ***The Motor Ship***, vol 2, January 1922. p362

8. J. Lamb, "*The Burning of Boiler Fuel in Marine Diesel Engines*", Trans' I.Mar.E., vol 60, 1948.

9. Quoted in **Brassey's Naval and Shipping Annual 1925**. p226

10. **Brassey's Naval and Shipping Annual - 1925**. p226

11. Comment by J.H. Narbeth during discussion of W.G. Cleghorn's paper "*Steam versus Diesel machinery for Cargo Vessels*", Trans' Institution of Engineers & Shipbuilders in Scotland, vol 70, part 1, 1926. p77

12. Comment by H.E. Yarrow during discussion of the paper "*Some Considerations of the Economics of Cargo Liners*", by L.H. Cripps. Trans' I.N.A., vol 72, 1930. p252

13. Mr S.B. Freeman, Superintendent Engineer in the 1920s and 1930s, presented many papers during this period to various bodies including I.Mech.E., I.Mar.E., The Diesel Engine Users Association, Lloyd's Register Staff Association and The Liverpool Engineering Society.

14. S.B.Freeman, "*Marine Engines from A Superintendent Engineer's Point of View*", Trans' Lloyd's Register Staff Association, 1934-5. p1

15. L.H. Cripps, "*Some Considerations on the Economics of Cargo Liners*", Trans' I.N.A., vol 72, 1930. p239-47

16. W.G. Cleghorn, "*Steam versus Diesel Machinery for Cargo Vessels*", Trans' IESS, vol 70, part 1, 1926. p 52-3

17. Freeman, "*Marine Engines from Superintendent Engineer's Point of View*", p5.

18. Lord Inverforth, Presidential Address, Trans' I.Mar.E., vol 37, 1925-6. p421-2

19. F.E. Rebbeck, Presidential Address, Trans' I.Mar.E., vol 43, part 8, 1931. p347

20. Cleghorn, "*Steam versus Diesel Machinery*", p61

21. Cleghorn, "*Steam versus Diesels*". p64

22. Freeman, "*Propelling Machinery for Marine Use*", p28

23. Freeman, " *Propelling Machinery for Marine Use*", p15

24. Contribution to the discussion of Cleghorn's paper "*Steam versus Diesel Machinery for Cargo Vessels*".

25. Comment by A. Campbell during discussion of Cleghorn's paper "*Steam versus Diesels*", p83

26. An analysis of these trades and others is given in the paper by A.C. Hardy, "*The Motorship in Relation to World trade Routes*", Trans' I.Mar.E., vol 39, 1927-8. pp528-49

27. Lord Inverforth, I.Mar.E., Presidential Address. p420, also Hardy "*The Motorship in relation to World Trade*", p539

28. S.B. Freeman, "*Propelling Machinery of Marine Use*". p20

29. ***The Motor Ship***, vol 1, Jan' 1921. p1

30. ***The Motor Ship***, vol 2, Nov' 1921. p299

31.Lord Inverforth, I.Mar.E. Presidential Address. p417; F.E. Rebbeck, I.Mar.E. Presidential Address. p347.

32.F.E. Rebbeck, I.Mar.E. Presidential Address. p346

Chapter 4.

British Crosshead Marine Diesel Engines

Many shipbuilders and marine engine builders worked on designs for crosshead marine diesel engines during WWI and the 1920s but not all of these efforts resulted in marketable products. Some companies did produce working engines to their own design whilst others adopted the quicker and easier option of taking a licence for a foreign design. Both ideas had their advocates and in the end much depended upon the personnel within a particular company. Following a decision by Vickers to take out a licence for the M.A.N. design of double-acting engine during the mid-1920s the design engineer of that company, W.F. Rabbidge, commented that the excellence of the engine and not the nationality of the patentee should be given first attention. "*...technical staff of an engineering company must consider the interests of their own shareholders and of the customers of the company rather than their own amour propre as designers*".[1]

The Engineer had other ideas and a 1913 article about the original single-cylinder Doxford engine contained the following. "*...it is therefore all the more creditable that Wm. Doxford and Son. Limited of Sunderland, should have made the venture and successfully constructed a large single-cylinder engine on the Diesel principle to their own designs and wholly without securing the assistance of one of the continental firms by becoming their licensees. Which of the two is the cheaper method of arriving at a practical result we are unable to venture an opinion, but there is no doubt that the knowledge gained in meeting and overcoming failures is likely to be more valuable than the mere knowledge that such difficulties do exist without the practical experience of overcoming them, which is the condition of affairs with firms who seek for immediate success by becoming licensees of already successful builders. It appears to us to be rather on a par with the practical training which an engineer gets by actually going through the shops as compared with what he learns by a course of college training alone.*"[2]

F.E.D. Acland, of the Still Engine Company, looked at the general engineering picture and related this to the diesel engine, "*This country has shown in the past, and still* *shows, that it posses technical and scientific ability second to none; but it often gives scant encouragement to new developments or new principles, until competitors in other lands have proved them of practical utility and profit.*"[3]

That so many British designs did evolve is an indication of that technical ability but reasons for their ultimate failure go further than any scant encouragement they may have been given

References

1. W.F. Rabbidge, "*Some Types of Marine Internal Combustion Engines*", Transaction I.Mar.E., vol 39, 1927. p169

2. ***The Engineer***, vol 115, 14 Feb` 1913. p168

3. F.E.D. Acland, "*A New Prime Mover of High Efficiency and British Origin*", Journal of the Royal Society of Arts, vol 67, No 3,472, 6 June 1919. p463

Chapter 4.a

The Vickers Engine

Through its involvement in submarine development Vickers gained early experience with internal combustion engines, initially with the petrol form and subsequently with those burning heavy oil; the term diesel engine will be used to describe what were generally known as heavy oil engines. A four- stroke trunk piston engine found favour for submarine work and in 1908 the 448kW "D" class design was introduced, this becoming the standard for submarine use until the end of WWI.

The Admiralty became interested in the possibilities of large marine crosshead engines for propulsion of surface ships and was instrumental in the erection of an experimental single-cylinder two-stroke engine which ran trials at Barrow during 1913.[1] Vickers subsequently intended that single-cylinder would form the basis of a future six-cylinder engine capable of developing 4,476 kW.[2] Authorization for construction of this engine, designated No 428, was granted by the Admiralty in 1911 but because of the experimental and secretive nature of the project no information was available at the time and details of the trials were not published until 1921. When running at 140rpm the engine was designed to develop 746kW from its 762mm bore by 914mm cylinder but in full load tests achieved greater output. Details of the 72 hour full load trial were as follows;[3]

Table 4.a.1

Injection Air Press' bar	Fuel Cons' kg/kw.hr	Cyl' Lub' Oil Cons' litres/hr	RPM	Brake Power kW	Indicated Power kW	MEP bar	Mechanical Efficiency %
74.5	0.25	5.9	141	777.2	840	8.56	92.53

Considerable thought went into the design of the engine, particularly with respect to materials, as at that time little was known about the thermal problems of large two-stroke cycle engine cylinders. The cylinder cover was considered to be a critical component in this respect and the original design employed a cast steel cover but this cracked after a period of running. A cure for this trouble was the fitting of a 51mm thick forged steel plate on the lower face of the cover, this being bossed up to 76mm thickness in way of the air inlet valves. This form of cylinder cover construction was patented by Vickers and developed as the standard for subsequent large mercantile engines.

The water-cooled cylinder was supported by two columns which also located the crosshead guides. Scavenging of the cylinder was via four water-cooled valves in the cover, air being supplied by an electrically driven rotary blower. This arrangement of scavenging would have assisted in keeping the cover cool but it meant that exhaust gas had to pass out of the cylinder through ports in the lower part of the liner. The piston was of composite construction, the upper portion being of cast steel and water-cooled, water being supplied and removed by means of the hollow piston rod and telescopic pipes attached to the crosshead. The engine was designed for blast injection of fuel and the main series of trials ran with this arrangement although trouble was experienced with the blast air compressors. In the meantime Vickers had developed a system for solid injection of fuel and the experimental engine was modified to operate with this, air injection fittings being used as far as possible. Results were encouraging with mean cylinder pressures up to 8.625 bar being achieved.[4]

Although the Admiralty had sponsored the experimental engine with a view to diesel propulsion of warships and fleet replenishment tankers, Vickers were optimistic that, on a slightly reduced rating, it would form the basis of a high powered engine for mercantile purposes. The war, however, intervened and mercantile engine development had to wait.[5]

In 1911 the Admiralty decided to build a number of fleet tankers with diesel propulsion engines but problems in procuring the engines and then the outbreak of war prevented the plan from being fully implemented. Orders for propelling machinery were placed with Carels, Sulzer and M.A.N. and strict specifications issued.[6] M.A.N. engines were delivered but fitted in the Monitor **Marshal** Ney instead of the fleet tanker; in service they gave a great deal of trouble. Vickers built sets of eight-cylinder, four-stroke crosshead engines for two fleet tankers but the smaller set, 432mm bore by 686mm stroke and developing 560kW, were fitted in the Monitor **Marshall Soult** instead of the fleet tanker **Trefoil**.

Initial running of the engines in **Marshall Soult** was unsatisfactory due to incorrect propellers but when this problem was overcome the machinery performed well. A similar set of engines was subsequently built for **Trefoil** and these incorporated modifications, mainly to the fuel spray valves, found to be necessary as a result of experience gained from the engines fitted in **Marshall Soult**. The larger engines, 527mm bore by 838mm stroke and developing 932kW were fitted in the replenishment tanker which subsequently entered commercial service as the Anglo-Saxon Petroleum Company's **Marinula**. Naval experience with these fleet tankers and the Monitor showed that a considerable amount of effort was necessary to keep the engines in good working order but the engines performed well without the need for extensive repairs. At the end of the war it was found that refitting costs of the diesel plant was higher than that of equivalent steam plant but this was outweighed by lower fuel and labour costs.[7]

It is interesting to note that in a paper published in 1927 W.F. Rabbidge uses the designation, *Cruiser Type Engine*, for an illustration of a larger engine designed to develop 932kW.[8] This, obviously, indicates an established view amongst those at Vickers that the Admiralty was seriously considering the use of diesel engines for propelling some surface warships. Prior to the outbreak of war several proposals for diesel propulsion were discussed by the Admiralty but the high power requirements and the needs of war mitigated against further consideration. During design work on the Battle Cruiser **Hood** a proposal was made to fit an 895kW, later increased to 2,238kW, diesel engine to the centre shaft with turbines on the wing shafts; another proposal was to fit two sets of 3,357kW diesel engines to each wing shaft and turbines to the centre shaft.[9] Due to the close association between Vickers and the Admiralty it is highly likely that the former concern was involved with some of these proposals.

Trefoil's engines had cylinders supported on cast iron columns which incorporated guide bars, the crankcase being enclosed by light steel plates attached to the columns; the earlier engines fitted in **Marshall Soult** had cylinders supported on turned forged columns. Cylinders were as simple as possible, the design being based upon that of the submarine engines built by Vickers where the top of the cast iron liner was held in a cast steel entablature common to adjacent pairs of liners. The lower part of each liner fitted into a galvanised wrought iron cylinder held by the entablature and sealed against the liner by rubber rings. The space between the liner and iron cylinder formed a cooling jacket. In order to limit engine height due to restricted headroom available in the replenishment tankers no diaphragm was provided between cylinders and crankcase.[10] Pistons were uncooled as it was considered that the low cylinder power would not present problems. A continuous bearing was provided for the crosshead pin but it was not intended to use that aspect of the design in a mercantile engine due to its cost.[11]

Engines fitted in the ship which was to become **Marinula** were of similar design to those of **Trefoil** except that they were of larger dimension, had forged columns supporting cylinders and sea-water cooled pistons. This piston cooling caused problems as water leaking past glands contaminated the crankcase oil. The fact that cooling water from the pistons discharged directly overboard probably contributed to the leakage by increasing pressure in the system, for later engines piston cooling water discharged to the bilge.[12]

These engines all employed the Vickers system of solid fuel injection which performed well during normal service and manoeuvring. Two two-throw reciprocating fuel pumps, driven by spur gearing from the camshaft, pressurized a fuel manifold running the length of the engine, the pressure being 276 bar. Double suction and discharge valves were fitted to each pump, the quantity of fuel delivered being regulated by means of a tappet which held the suction valves off their seats for the desired portion of the pump plunger stroke. A manually operated control lever raised or lowered the fulcrum of a sway beam one end of which was actuated by the plunger and the other attached to the suction valve tappet. Fuel delivery quantity was, therefore, adjusted via the control lever. The fuel manifold supplied cam operated fuel spray valves located in each cylinder cover and when these valves were opened fuel would be sprayed into the cylinder. Each spray had five holes each about 0.5mm diameter and during normal service they lasted about 12 months before requiring replacement. Speed control of the engine was achieved through adjustment of the spray valve bell crank lever pivots thereby varying the period of time the fuel sprays were kept open by the cams.[13]

This solid fuel injection system was retained for the later mercantile engines with but minor modifications. One of these was to have a single control hand lever which rotated the shaft carrying the bell crank lever eccentrics and also adjusted the pump suction valve tappets, thus keeping fuel manifold pressure constant for all engine speeds.[14]

During the war resources were directed to defeat of the enemy but limited research and development was carried out under the enthusiastic leadership of Sir James McKechnie. A mercantile engine became possible when the needs of war eased but the specification had to be based upon different criteria from those of the Admiralty and the mercantile engine differed from the Admiralty crosshead engines in many respects. Simplicity of operation and ease of manufacture were essential with refinements employed in the lightweight submarine and Admiralty crosshead engines being avoided. An early design policy was to aim for minimum lubricating oil consumption resulting in the need for an enclosed crankcase. Hollow cast iron columns of H shape supported the cylinder block whilst long steel bolts, passing through the columns, tied these firmly to the bedplate and took the vertical loads. For the six-cylinder engine fitted to six tankers in the early 1920s there were eight columns and sixteen tie rods. The bedplate was an iron casting made in two pieces. Standard fork type marine crossheads replaced the continuous bearing type as used for the Admiralty engines.[15]

In the basic Vickers' mercantile four-stroke engine large crankcase doors allowed easy access to moving parts whilst a diaphragm prevented contamination of the crankcase by combustion products. Pistons were cooled by seawater but on the six-cylinder 464mm bore engine, subsequently built for Japan, they were uncooled. The Japanese engines had no tie rods, crankcase structure and cylinder blocks being a single casting for groups of three cylinders. Solid fuel injection and a standardised reversing system were common to all Vickers' mercantile engines.[16]

For the engines of **Narragansett** and **Seminole** a bank of lever driven pumps was provided at the back of the engine, the levers being attached to the crosshead of the forward cylinder. This bank consisted of lubricating oil pump, bilge pump and main cooling water pump above which was positioned a booster pump for supplying piston cooling water at 1.38 bar instead of the normal cooling water pressure of 0.69 bar.[17]

Wear at the lever pivots was found to be excessive resulting in erratic operation, particularly critical for the lubricating oil pump, and for subsequent engines electrically driven pumps were offered although there was an option to have pumps operated by the camshaft drive mechanism.[18]

A single camshaft, positioned at cylinder cover height, had cams for air inlet, exhaust, fuel injection and air start valve operation. Two cams were provided for each valve, one for ahead operation and one for astern, followers for all valves apart from air start being located on top of the camshaft. Above the camshaft was the manoeuvring shaft which could be rotated by means of the control lever situated at the engine mid-length. Pivots for air inlet and exhaust valve operating levers were located on the manoeuvring shaft so that when the manoeuvring lever was rotated cam follower rollers would be lifted clear of their respective cams. With the fuel lever in the off position all fuel cam followers would be lifted clear of their cams. The air starting valve follower was kept clear of its cam by means of a spring until starting air was applied. Change of engine rotational direction was achieved through axial movement of the camshaft, the required ahead or astern cams being brought into position under the respective fuel, air inlet, exhaust and air start valve followers. A single reversing lever lifted valve followers clear of their cams and actuated a servo-motor, positioned at engine mid-length, which moved the camshaft axially. Movement of a starting lever admitted compressed air to the cylinders via the cam operated starting valves and when the engine had completed two or three revolutions the starting air lever would be moved to the closed position and the fuel lever operated to bring fuel valve followers in contact with their cams and so admit fuel to the engine. Further movement of the fuel lever allowed for speed control. An interlock prevented application of starting air until the camshaft servo-motor had completed its travel.[19]

Performance of the machinery fitted in **Narragansett** showed great promise; averaged over a 12 month period lubricating oil consumption for all purposes was 68 litres per day whilst daily fuel consumption of 10.08 tonnes compared very favourably with a similarly sized steamer which would have consumed 35.64 tonnes of coal.[20]

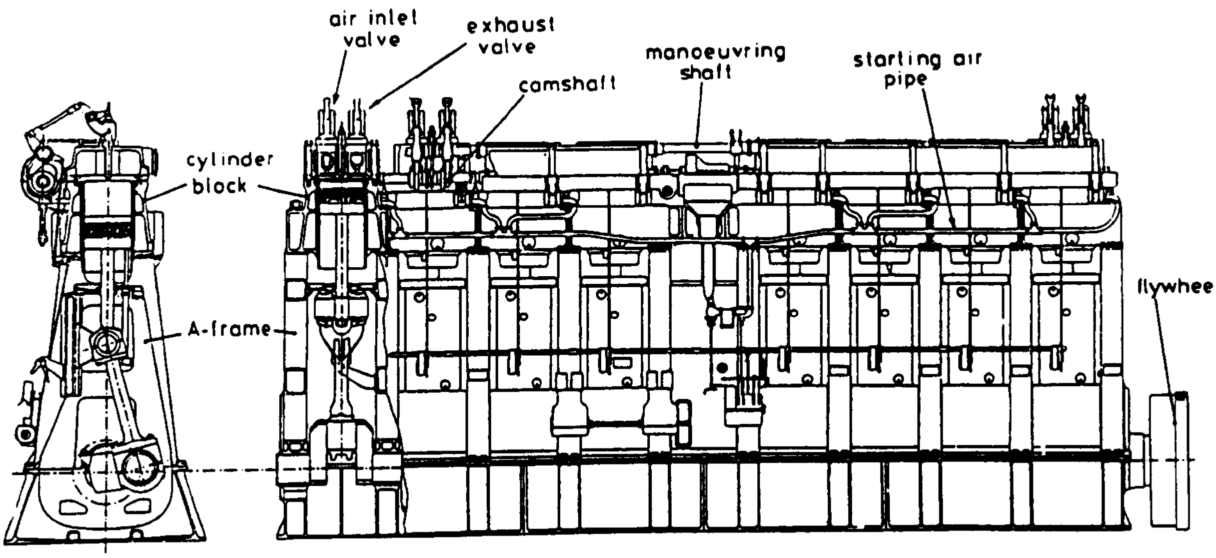


Fig 4.a.1 Eight-Cylinder Vickers Four-Stroke Engine

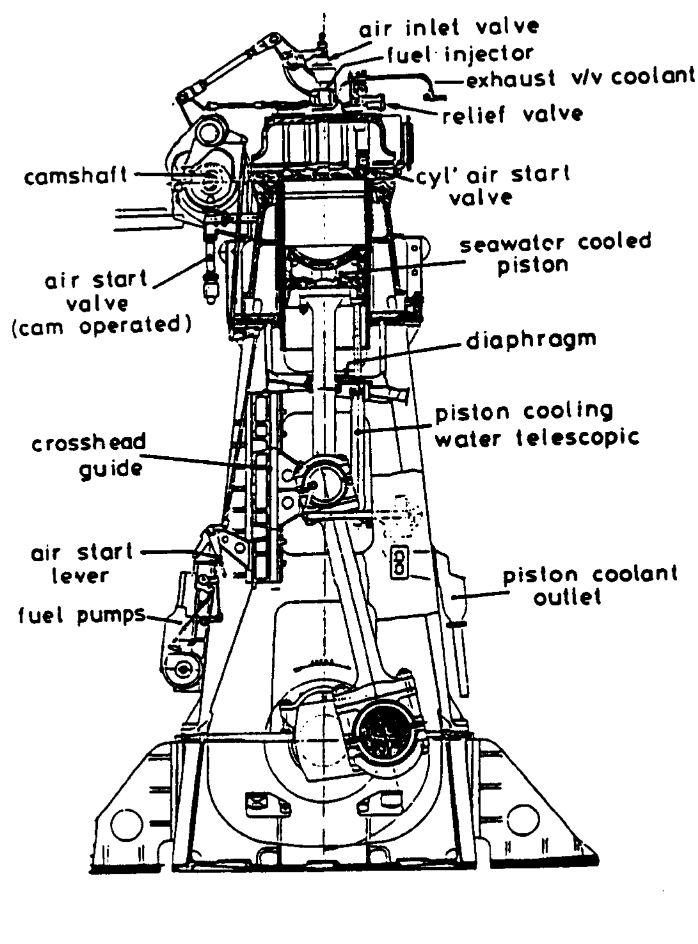


Fig 4.a.2 Section Through Vickers Engine

A larger engine offered greater potential particularly for single screw propulsion and in its eight-cylinder version Vickers probably took its four-stroke design to the limits. Minor changes in design were made but, apart from in cylinder size, the engine was essentially the same as the six-cylinder design. At the launching of **Moveria** a word of caution with respect to high powered diesel engines was offered by Commander Craven, Managing Director of Vickers' at Barrow. "... *a gradual increase in power is desirable..... At the same time my company is actively engaged in the development of a large diesel engine for fast passenger ships.*"[21]

Unfortunately the Vickers crosshead engine got no further and in 1925 a licence was taken out for construction of M.A.N. engines. At the time it was believed that the high power engine had to be double-acting but a considerable amount of time and money would have been required to modify the Vickers engine.

Failure of the original four-stroke single-acting engine to make any real impact on the market would have been influenced by a number of factors including a shortage of orders during the slump of the mid-1920s. Unlike many of its British rivals Vickers did have overseas licensees, La Sociedad Espanola de Construccion Naval, Bilbao and Mitsubishi Shoji Kaisha Ltd of Tokio, but interest is likely to have been in the smaller engines for submarine work than for the larger mercantile engines. Certainly a number of such engines were built under licence in Spain for Spanish submarines.[22]

The mercantile engines themselves were not particularly reliable with three broken crankshafts occurring in the period to 1930 and on four other occasions machinery was so defective that ships had to be towed to port. Casualty reports concerning ships with Vickers engines are indicated in Appendix No 2.

Table 4.a.1

Vickers Engines						
Vessel	**Year**	**Ship Builder**	**Type**	**Cylinder Size(mm)**	**Power kW**	**RPM**
Trefoil *	1917	Vickers	4SSA (two)	8x432x686	560	150
Marinula **	1916	Vickers	4SSA (two)	8x527x838	932	140
Narragansett ***	1920	Vickers	4SSA (two)	6x622x991	933	118
Seminole ****	1921	Vickers	4SSA (two)	6x622x991	933	118
Scottish Minstrel	1922	Vickers	4SSA (two)	6x622x991	933	118
Scottish Standard	1922	Vickers	4SSA (two)	6x622x991	933	118
Scottish Maiden +	1922	Vickers	4SSA (two)	6x622x991	933	118
Scottish Musician	1922	Vickers	4SSA (two)	6x622x991	933	118
Ondo Maru ++	1923	Mitsub' Zosen	4SSA	6x464x686	448	150
Moveria	1924	Vickers	4SSA	8x762x1143	2,014	110
Hayatomo Maru ++	1925	Mitsub' Zosen	4SSA	6x464x686	448	150
Modavia	1927	Vickers	4SSA	8x762x1143	2,014	110

Source: Various editions of **The Motor Ship** and **Lloyd's Register of Shipping**

* Fitted with Admiralty sponsored crosshead engines

** Fitted with Admiralty sponsored Crosshead engine
Sold to Shell Tankers; broken up 1928

*** Broken up 1934

**** Broken up 1936

\+ Re-engined with Werkspoor engines 1939

++ Engine exported

References

1. This engine wasbased upon a Carels' design and was probably constructed, at least in part, by this Belgian concern.
Cummins L., **Diesel's Engine**, Carnot Press, 1993. pp341, 343, 544

2. Eng' Vice-Admiral Sir George Goodwin, "*The Development of Diesel Engines for Naval Purposes*", Trans' I.E.S.S., 1922; Published in ***Engineering***, vol 113, 28 April 1922. pp535-7

3. Sir James McKechnie, "*Internal-Combustion Engines with Large Cylinders*", I.C.E. Engineering Conference, 1921; Published in ***Engineering***, vol 112, 15 July 1921. pp132-4

4. ***Engineering***, vol 119, 26 June 1925. pp796-7

5. W.F. Rabbidge, "*Some Types of Marine I.C. Engines*", Trans' I.Mar.E., vol 39, 1927, p153-4; ***Engineering***, vol 119, 26 June 1925. p796-7

6. Details of the specifications are given in the paper "*The Development of Diesel Engines for Naval Purposes*", by Eng' Vice-Admiral Sir George Goodwin, Trans' I.E.S.S. 1922.

7. Sir George Goodwin, "*Diesel Engines for Naval Purposes*", ***Engineering***, vol 113. p536.

8. Rabbidge, "*Some Types Of Marine I.C. Engines*", fig VI. p155

9. Goodwin, "*Development of Diesel Engines for Naval Purposes*", ***Engineering***, vol 113. p536.

10. C. McTaminey, "*The Solid Injection Engine*", Trans' I.Mar.E., Vol 32, 1920. P162

11. "*Some Notes on the Vickers Diesel Engine*", ***The Engineer***, vol 128, 29 Aug' 1919. pp198-200

12. Rabbidge, "*Some Types Of Marine I.C. Engines*". pp155-6

13. C. McTaminey, "*The Solid Injection Engine*". p161-94

14. Rabbidge, "*Some Types of Marine I.C. Engines*". p148

15. ***The Engineer***, vol 129, 14 May 1920. pp501-2 and vol 132, 15 July 1921. pp55-7

16. ***The Motor Ship***, vol 4, October 1923. pp228-30

17. ***The Motor Ship***, vol 1, June 1920. p66

18. Rabbidge, "*Some Types of Marine I.C. Engines*". p164

19. ***The Engineer***, vol 132, 15 July 1921. pp55-7, also Rabbidge, "*Some Types of Marine I.C. Engines*". p158-65

20. ***The Marine Engineer & Naval Architect***, vol 44, Aug' 1921. p14

21. ***Shipbuilding & Shipping Record***, 16 October 1924. p460-1

22. W.F. Rabbidge, "*Some Barrow Light Weight Oil Engines*", Transactions Barrow Association of Engineers, 1930. p133

Chapter 4.b

North British Diesel Engine Company Engines

Break-up of the Atlas consortium which resulted in Harland & Wolff taking British manufacturing rights in Burmeister & Wain engines also saw formation of the North British Diesel Engine Works (NBDEW) by Barclay Curle and its close associate, Swan Hunter & Wigham Richardson, (see chapter 1.) this company having been established at Whiteinch on Clydeside during 1913 for the sole purpose of building diesel engines. Randolf Smith, formerly Engineering Manager at Barclay Curle, was appointed General Manager of the new company[1] but war intervened and the works became fully engaged in production of military equipment including shells, guns aeroplane engines and diesel engines for submarines.[2]

Although the company produced no engines of its own during WWI design work continued on a four-stroke crosshead engine and with the coming of peace it was possible to approach potential clients. Barclay, Curle had built and engined many ships for the British India Steam Navigation Company (B.I.) and that close association seems to have been used to encourage the ordering of ships with North British four-stroke engines. The closeness of that association is indicated by a 1920 agreement that Barclay Curle would reserve for a period of 10 years two berths at its Whiteinch or Scotstoun yards at which ships for B.I. or P&O might be constructed. B.I. agreed to keep these berths occupied and pay the builder's outlay in materials and wages plus 22.5% of these costs.[3]

The first contract came in July 1919 when B.I. ordered six eight- cylinder four-stroke engines to go in three twin-screw vessels being built in Clydeside yards; **Domala, Durenda** and **Dumana**.[4] Only two other engines of the type were constructed. A smaller four-stroke engine of different design was also available and B.I. installed twin sets in two small vessels being constructed in Bristol; these were the only engines of the type built. The price to be paid for the engines was the actual cost of labour and materials plus 22.5%.[5] Payments to the NBDEW for two sets of large engines and two sets of small engines amounted to £485,583 by the end of April 1922; this was for contracts

27 (**Durenda**), 28 (**Dumana**), 30 (**Dumra**) and 31 (**Dwarka**). Payments for the first installation, **Domala**, were probably made separately to Barclay Curle who built the ship.[6]

Unfortunately there are no other B.I. records available on the matter but the figures indicate that that the cost of the engines was probably on the high side. Three of the ships entered service that year but **Dumana** was not handed over until 1923 and further payments will have been due. (In February 1922 payments of £3,362, £1,557, £3,745 and £2,133 were made on contracts 27, 28, 30 and 31 respectively.) The larger British India ships each had two North British built diesel generators of about 300 bhp plus a smaller 75 bhp emergency generator[7] whilst for the smaller ships two 100 bhp generator units were fitted[8] giving a total installed power for the four ships of 12,880 bhp. Using the amount paid on these contracts to the end of April 1922 gives a cost of £37.7 per horse power. The contracts may have covered other machinery but the figure does compare unfavourably with costings given in table 3.8 and for the price of Fullagar engines as on page 102. Auxiliary diesel engines did tend to cost slightly more than the larger propulsion units, in 1918 Sulzer quoted a price of £9,935 for a 420 bhp engine[9], £23.65 per bhp, but these North British engines do appear to have been rather costly.

The large engines were ordered straight from the drawing board without any experimentation, a pair also being constructed for **Hauraki**, built by Dennys for the Union Steamship Company, in addition to the six built for the B.I. ships.[10] The first engine was to be of a standard type and size, entirely designed by North British staff but employing existing technology and using experience gained from Barclay Curle's involvement with Burmeister & Wain; not surprisingly a four-stroke operating cycle was chosen. British India's specification called for a propulsive power equivalent to that from a 4,500 ihp steam plant and in order to achieve this from two standard eight-cylinder engines separate drive for the blast fuel injection compressors had to be employed. Normal arrangement had blast air compressors driven by the engine they supplied but in the case of the first ship, **Domala**, two 400 bhp six-cylinder auxiliary diesel sets were provided for this purpose, each being able to supply the blast air requirements of both engines.[11]

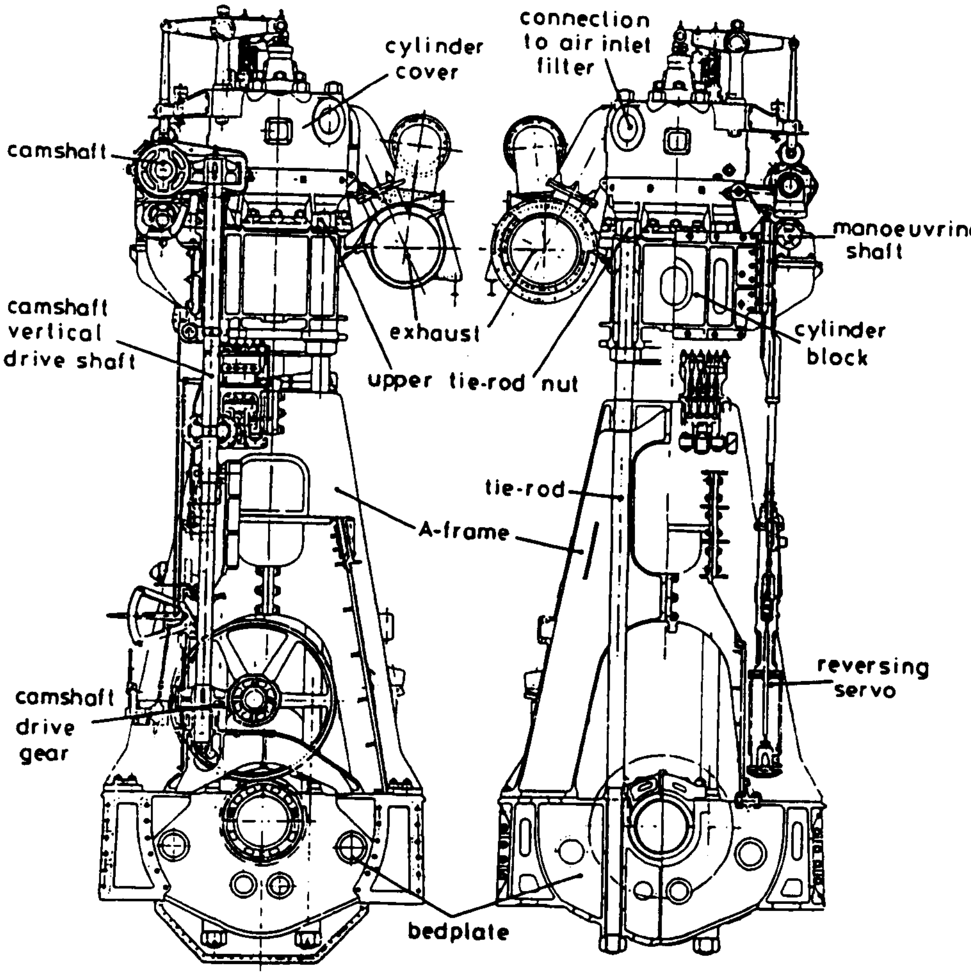


Fig 4.b.1 North British Diesel Engine Works Four-Stroke Engine

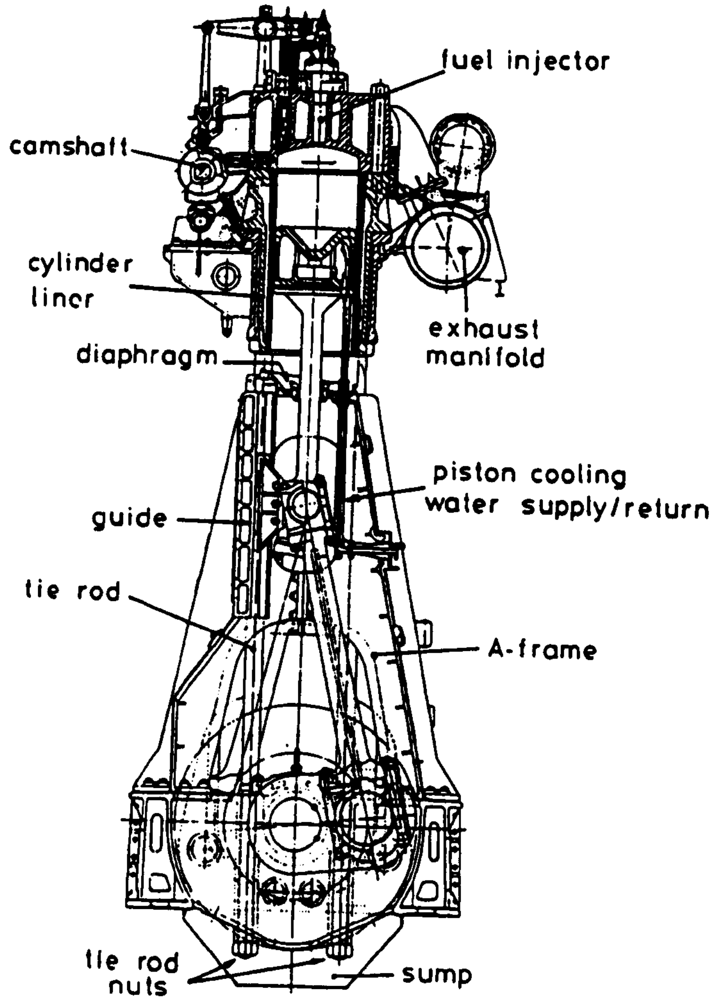


Fig 4.b.2
Section through
NBDEW
4-S Engine

Simplicity through standardization appears to have been the aim in choosing one cylinder size and an eight-cylinder arrangement. Individual cylinder blocks, containing separate liners, fitted in and bolted to cast entablatures which also consisted of individual cast units bolted together. Groups of four cylinders were situated each side of the central camshaft drive system, each group being considered as a separate entity for constructional and installation purposes. The entablature sat upon steel columns which passed from the underside of the bedplate to the top of the entablature, these columns taking combustion loads. Their positioning close to the main crankshaft bearings minimised bending stresses in bedplate transverse girders. Relatively light cast A-frames placed over each main bearing acted to steady the steel columns and provide mounting points for crosshead guides. The bedplate, cast in four sections, comprised two longitudinal box girders joined by transverse girders which supported main bearings. A light sheet iron oil collection tray attached to the lower faces of the bedplate to act as a sump.

Cylinders were open at the bottom but diaphragm plates with simple glands prevented combustion products and waste cylinder oil from leaking into the crankcase. Water cooled cylinder covers contained pockets for air inlet, exhaust, fuel injection, starting air and relief valves. Heads were bolted to their respective cylinder blocks and, by means of a spigot, held the liner in place. Inlet and exhaust valves were positioned far apart in order to allow for cooling water passages and a fuel valve to be positioned between them. Air inlet and exhaust valves were located in cages which bolted to the cover, this being intended to minimise the time taken for valve replacement.

Push rods and rockers operated all valves from a camshaft positioned below cylinder head height, the camshaft being driven from the crankshaft by means of a vertical shaft and gears. An intermediate gear shaft, driven by the camshaft, actually drove the vertical shaft, this arrangement being chosen in order to minimise problems caused by longitudinal movement of the crankshaft. Valves had two cams, ahead and astern, positioned alongside each other on the camshaft, reversal being accomplished by axial movement of that shaft. In order to allow for axial movement, the camshaft was lowered clear of the cam followers by rotating eccentrics which supported camshaft bearings. Rotation of the manoeuvring shaft turned these eccentrics thereby lowering the camshaft but this rotation also caused a quadrant arm to move a grooved drum fitted to the camshaft thus repositioning that shaft axially. Each group of four cylinders had its own control lever and downwards movement of these admitted air to small cylinders fitted at the bottom of the air start valve push rods thus forcing their followers into contact with the cams. Starting air valves would open on those cylinders correctly positioned to receive starting air and the engine would begin to rotate. After a few revolutions the levers were moved upwards, one at a time, cutting off starting air and admitting fuel to the cylinders. Upwards movement of the control levers adjusted opening of fuel pump suction valves and so regulated engine speed.

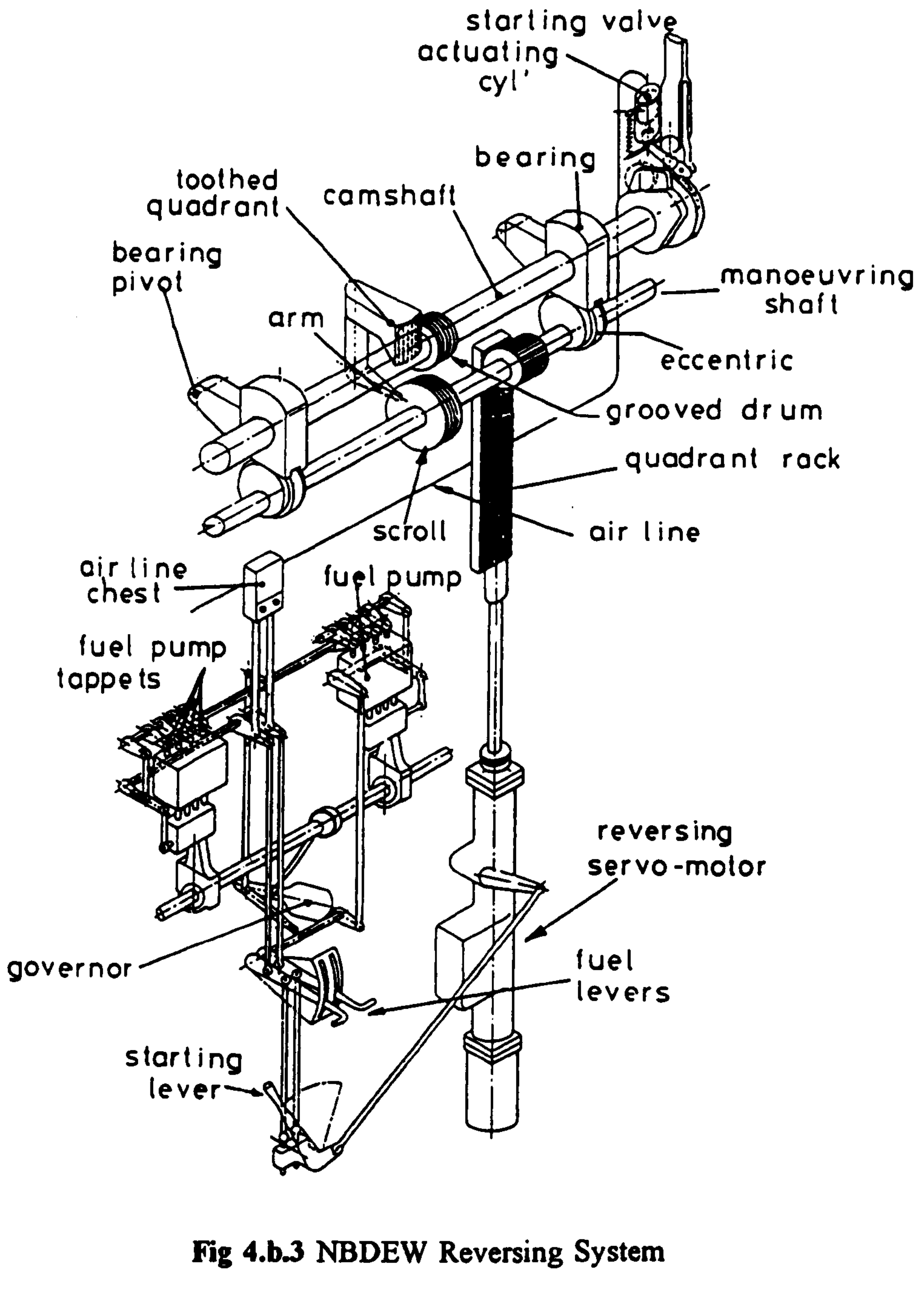


Fig 4.b.3 NBDEW Reversing System

Each cylinder had its own camshaft driven fuel pump, these being arranged together between the two cylinder groups. A hand pump was provided at the manoeuvring platform for operating the reversing servo-motor should that be necessary. Pistons and cylinders were cooled by means of seawater supplied by an electrically driven pump, the use of engine driven pumps being avoided as they would have taken power from the crankshaft.[12]

Shop trial running of the first engines gave a fuel consumption of 0.256kg/kW.hr when burning Anglo-Persian oil having a specific gravity of 0.9.[13]

The smaller engines for **Dwarka** and **Dumra** had no tie rods but the cast iron crankcase structure was of box form and substantial enough to take all loadings; this structure sat on the single piece cast iron bedplate. Cylinder blocks were carried directly on the crankcase with stuffing boxes preventing contamination of the lubricating oil by combustion products, an opening in the lower end of the cylinder block sections giving access to the gland. Construction of cylinders differed from the larger engines although they still consisted of separate liner held in the cylinder block, a cooling jacket being provided. Cylinder block sections carried brackets for supporting the camshaft. Cylinder covers were of similar form to those of the larger engines, inlet and exhaust valves being carried in cages. In the light of experience gained from earlier engines exhaust valves were provided with renewable cast iron faces. Fuel valves had no stuffing-boxes, leakage being minimised by the use of a long, closely fitting cast iron sleeve surrounding the valve spindle. The repacking of glands on blast injection fuel valves was one of the time consuming jobs on many diesel engined ships.[14]

Exhaust valve cages were water cooled, as were liners and cylinder covers, but lubricating oil was employed for cooling the pistons. Oil supply for these came via the main bearings, through holes in the crankshaft to the bottom ends, up a central hole bored in each connecting rod to the crosshead pin. A tube inserted in a larger hole in the piston rod carried oil to the top of the internal piston cavity, return oil flowing downwards through the annular space surrounding the supply tube in the piston rod. Discharge of oil took place from the bottom of the crosshead into a collection trough which led to an observation funnel near the engine control. The large stroke to bore ratio allowed crankshafts to be of the built-up type, there being two sections for each six-cylinder engine. In order to provide a more rigid support for the crosshead pin fork-type top ends were not used. North British provided two separate white metal lined bearing housings which bolted on a platform at the top of the connecting rod and the crosshead pin sat in these, the same arrangement having been used for the larger engines.

By positioning the camshaft close to the top of the engine the use of push rods for operating valves was avoided. The manoeuvring system was simplified, cam followers being lifted clear of their cams whilst the servo-motor moved the camshaft axially to its new position. This reversing procedure could be accomplished by hand if required rather than by means of the McTaggart-Scott servo-motor. Separate controls were provided for each group of three cylinders. The blast air compressor, driven by the crankshaft, had its own crankcase and was positioned at the forward end of the engine.[15]

Only four of these small engines were ever built, these going in the twin screw ships mentioned above. At that time the 750kW output from two engines could easily have been provided on a single screw and it appears likely that twin engines were fitted in order to provide a backup in the event of one engine failing completely. For smaller ships 325kW could easily have been provided by one of a number of more modestly sized trunk piston engines available at that time.[16] It would appear that North British misjudged the market with this engine both in terms of size to power ratio and on confidence grounds as single screw installations were then being widely accepted; construction certainly appeared to be at odds with the claim made at the end of WWI that the company would concentrate upon high powered engines.[17]

In complete contrast to these low powered propulsion units the company also set about developing an engine which would produce high power from minimum size. A common belief during the 1920s, and even in later years, was that high powers could only be achieved by means of double-acting engines[18] and, under the guidance of its design engineer, J.C.M. MacLagan, the North British company set about producing a design. In contrast to the company's earlier products this engine operated on the two-stroke cycle and also in contrast to previous practice a two-cylinder experimental engine was built. Little practical experience existed regarding the double-acting engine and so construction of the experimental unit was probably considered advisable, particularly as MacLagan adopted a very novel approach to the problem of combustion effects on the lower piston rod and gland, he eliminated them.

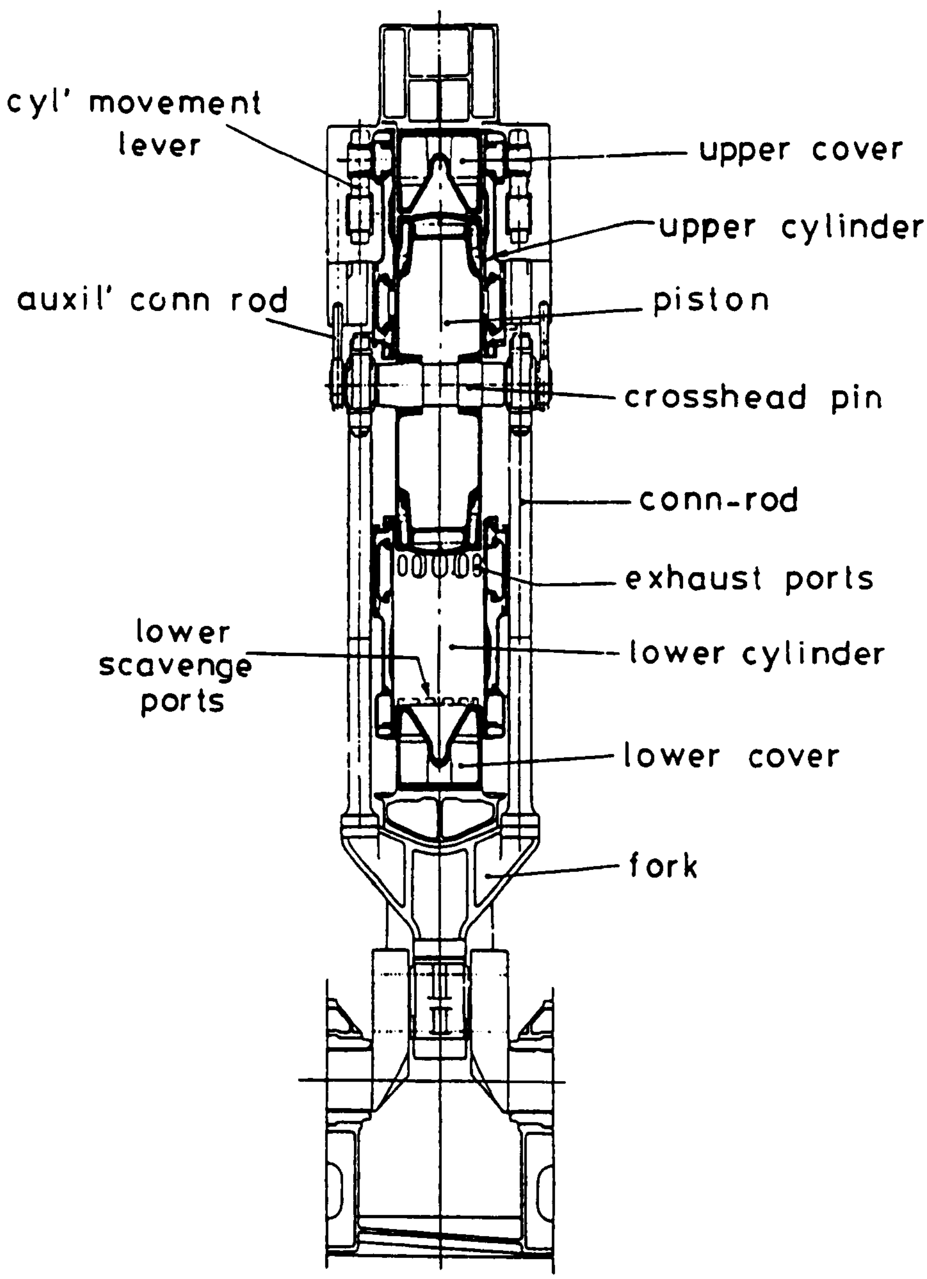


Fig 4.b.4 Section through NBDEW Sliding Cylinder Engine

The experimental unit had cylinders of 292mm bore by 368mm stroke and developed 180kW at 250rpm. When it ran trials during the middle months of 1922 it attracted considerable interest due to its unusual design. Effectively each unit had two separate cylinders, one above the other, and two pistons attached to a common crosshead. Twin connecting rods transmitted power from these pistons to the crankshaft via a forked arrangement on the single bottom end.

Movement of the piston controlled opening and closing of the centrally positioned exhaust ports but scavenge also had to be regulated and MacLagan achieved this by moving the scavenge ports so that they were closed and exposed by their respective fixed cylinder covers; cylinder stroke was about one third of the piston stroke. A connecting rod and lever system attached to the piston crosshead produced movement of the liner thereby regulating scavenge air admission to upper and lower cylinders.

After satisfactory running of the experimental engine at the works a decision was taken to construct a larger engine capable of developing 1,680kW.[19] With trials complete the experimental engine and its coupled generator were installed in a ship, engined by North British, as part of the electrical generating plant in order to provide further operating experience. By 1924 it had been removed.[20]

Rapid progress in the design and manufacture of the prototype engine resulted in it being available for inspection in April 1923[21] and under test on load at the end of the year. Trial running showed that the designed power of 1,492kW at 100rpm could be developed from its three cylinders with a mean effective pressure of 5.175bar. Mechanical efficiency was rather low at 70% and specific fuel consumption on the high side at 0.274kg/kW.hr;[22] low efficiency and high specific fuel consumption were almost certainly due to the additional work and friction involved in moving the cylinder.

The engine operated with blast fuel injection via fuel valves in the cylinder covers, air being supplied by a compressor fitted on the forward end of the crankshaft. Cylinder covers, interchangeable between top and bottom, were dished and contained a single central passageway opened into the cylinder; fuel injector and starting air valves connected with this passageway.

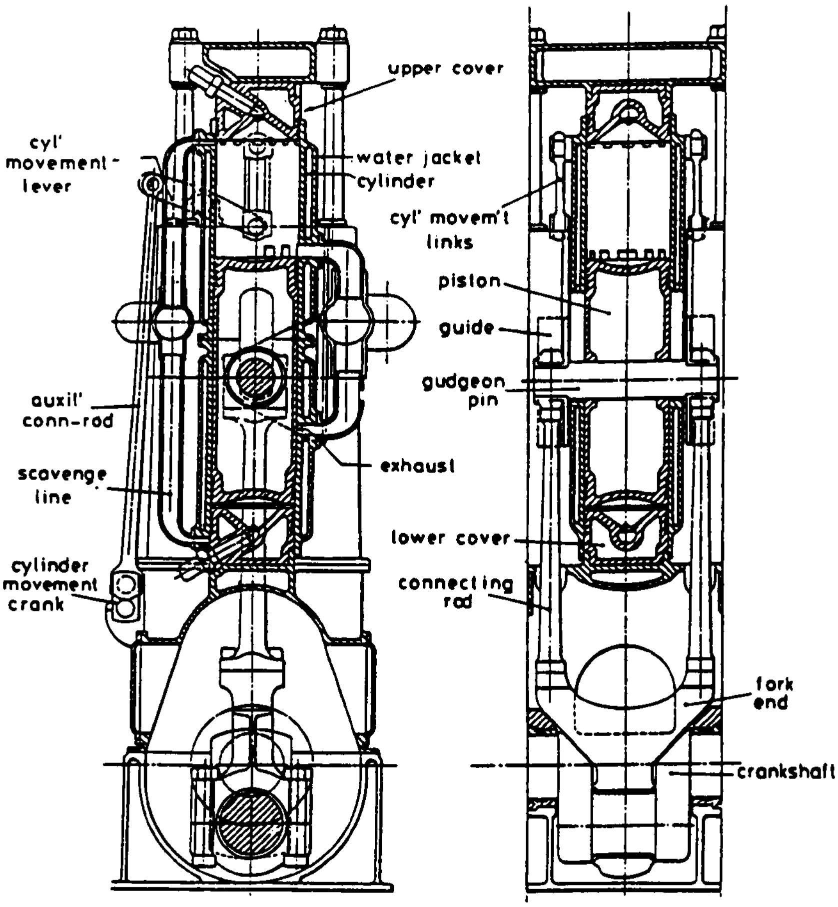


Fig 4.b.5 Section through Cylinder of NBDEW Sliding Cylinder Engine

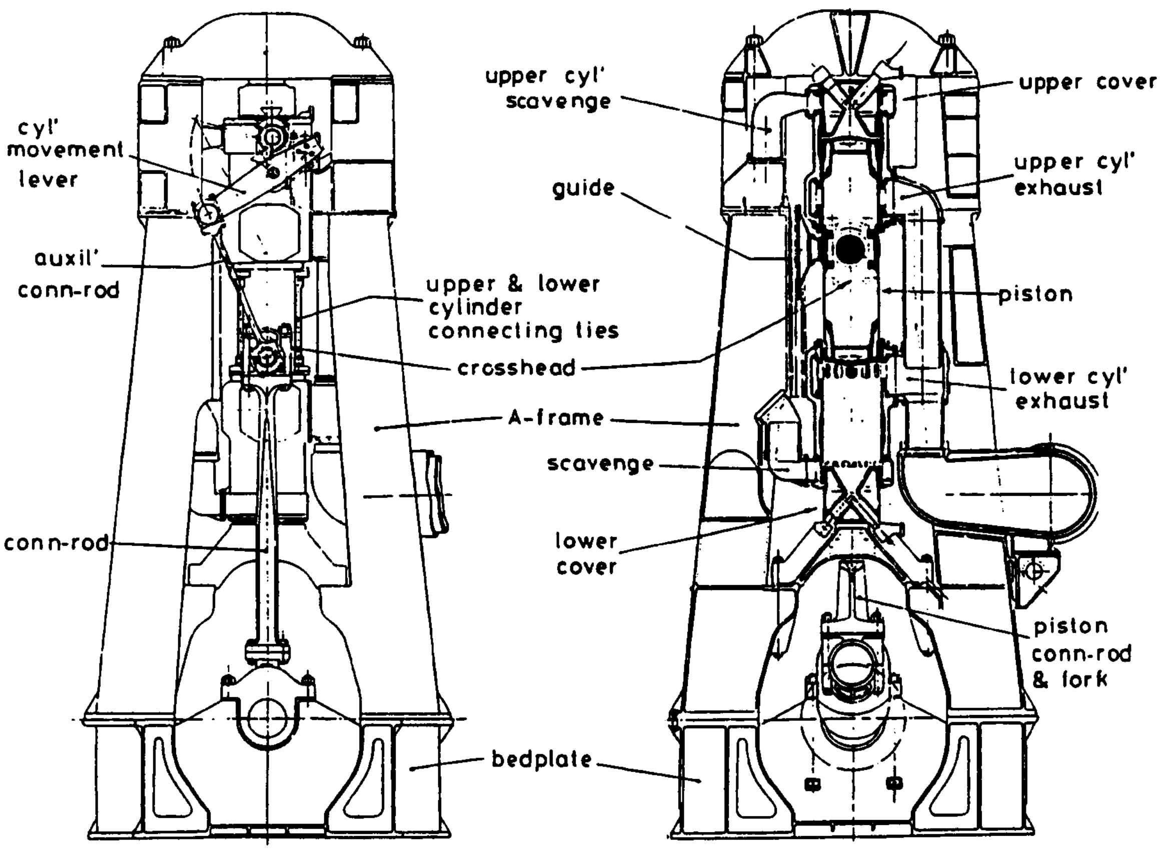


Fig 4.b.6 Transverse Views of Sliding Cylinder Engine

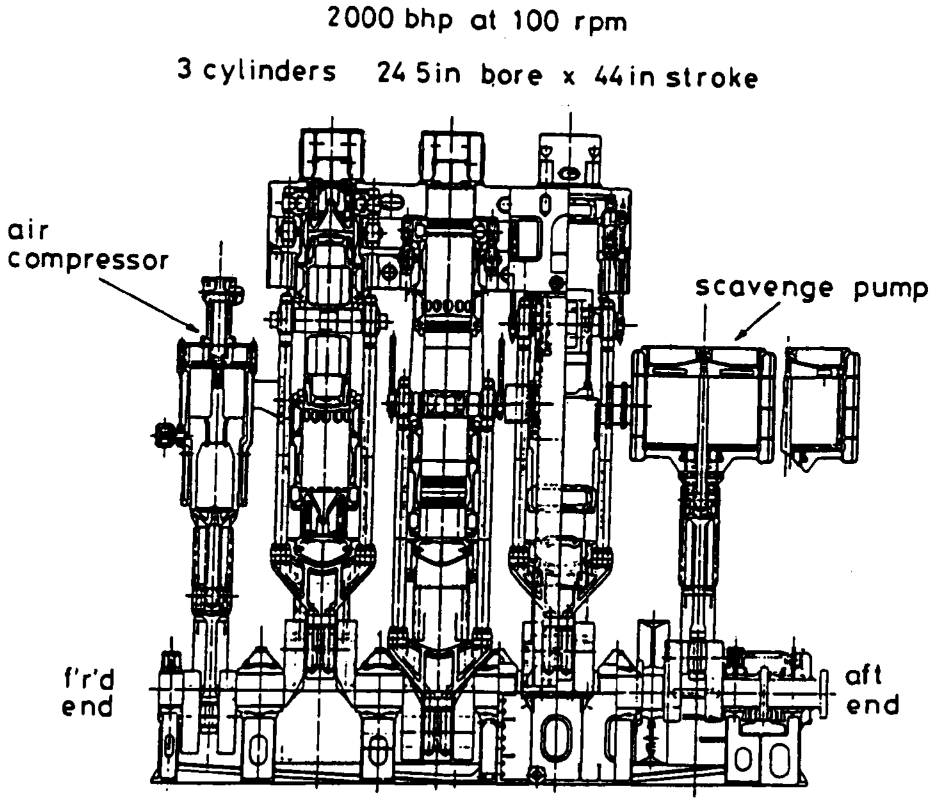


Fig 4.b.7 Section through NBDEW Sliding Cylinder Engine

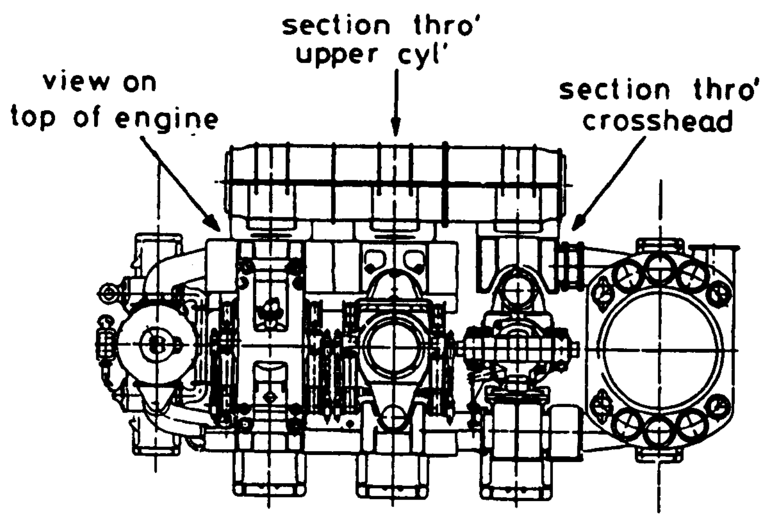


Fig 4.b.8 Plan View of NBDEW Sliding Cylinder Engine

In order to simplify the engine operating system, through elimination of the large main camshaft, the original design had fuel valves of a particular unit actuated partly by the motion of that unit's sliding cylinder and partly by compression pressure in the cylinder. Once the engine was running, either ahead or astern, valve timing would be automatically controlled by movement of the cylinders. The design was arranged so that cylinder movement opened the blast air valve by means of a trigger lever, the blast air then acting upon a plunger which opened the fuel valve. Starting air valves were actuated by action of pilot air supplied from a camshaft driven distibutor. That small camshaft, which also operated fuel pumps was located at the forward end of the engine in front of the controls. Separate ahead and astern cams were provided, the camshaft being moved axially for reversal.[23]

Operating experience with the prototype engine showed that after a period of 210 hours consecutive running the top fuel valves were still satisfactory but bottom valves had a tendency to be sluggish. In view of the need to get the engine operating in its intended ship, **Swanley**, a decision was made to revert to the more normal camshaft operating system for fuel valves.[24] Obviously the problem was considered serious enough to merit installation of a main camshaft system and it must have been due to more than just sluggish operation of valves. In neither of his two papers[25] did the designer make any mention of other reasons but simply indicated that time for experimentation was limited. Experimentation with the cylinder operated valve gear continued into 1925 but without any apparent success.[26]

Scavenge air for the engine came from a double-acting reciprocating pump driven by a crank on the after end of the crankshaft. The hollow engine frames acted as a large air receiver, short pipes with glands allowing distribution of scavenge air to the cylinders. Pistons and cylinders were cooled by fresh water, supply to pistons being via a telescopic pipe system which employed flexible stand pipes; the moving inlet pipe connected with the crosshead and ran inside of the fixed stand or guard pipe, a gimbal arrangement at the bottom of the guard pipe allowing for lateral movement due to piston and guide wear. Water outlet from the pistons was also via a telescopic pipe discharging into a tundish[27]

The prototype engine was installed in the tramp ship **Swanley**, built for the Swanley Shipping Company and managed for the owners by Harris and Dixon Ltd. In view of the experimental nature of the venture it is likely that the engine builders had some financial involvement in the enterprise as a means of obtaining operating publicity for the engine. Initially the engine performed well, the ship's first voyage to Colombo and back being accomplished without any major problems. On the return voyage water leaked into the crankcase and caused emulsification of the oil which in turn resulted in overheating of two top end bearings. After a number of voyages it was decided to replace the flexible piston cooling telescopic system with one of more conventional form employing stuffing boxes and glands.[28]

In 1925 a further sliding cylinder engine was installed, this time in **City of Stockholm**, built for Hopemount Shipping[29], a wholely owned subsidiary of Swan Hunter & Wigham Richardson. This engine was practically identical to the prototype except that a number of pumps which had been independently driven in **Swanley** were now engine driven. Cooling water, sea-water, lubricating oil, dirty fuel oil and purified fuel oil pumps were of the plunger type and driven by means of a beam attached to the crosshead of the air compressor. In order to make use of cheaper boiler fuel in the engine a fuel heating system was installed together with centrifugal separators.[30]

One further engine was built and installed in the Norwegian tanker **Storsten** but this ship ran into difficulties and had to be towed back to the yard of her builder, Barclay Curle, following engine trouble during her trials in July 1926.[31] **City of Stockholm** experienced engine problems the previous month and also had to return to the Clyde for repairs.[32] Problems with the engine resulted in all three ships spending time at Barclay Curle undergoing repairs during the 1926-7 period.[33] All had been re-engined by 1928.

The North British double acting engine was obviously not a success, complexity of the sliding cylinder mechanism and the number of seals necessary to prevent leakage probably contributing to that failure.[34] Swan Hunter acquired full control of the North British Diesel Engine Works in 1922[35] and so had full responsibility for the engines and policy. The chairman informed shareholders that the engine fitted in **Swanley** had performed satisfactorily during the ship's first two voyages but he then went on to state that, "*Several further sets of this type of engine are now under construction...*".[36] This was something of an exaggeration or unfounded optimism but the company certainly had faith in it product.

Table 4.b.1

North British Diesel Engine Company						
Vessel	**Year**	**Ship Builder**	**Type**	**Cylinder Size(mm)**	**Power kW**	**RPM**
Domala	1921	Barclay, Curle & Co	4SSA (two)	8x673x1194	1,675	96
Hauraki	1922	Wm Denny & Co.	4SSA (two)	8x673x1194	1,675	96
Durenda	1922	R. Duncan & Co.	4SSA (two)	8x673x1194	1,675	96
Dumra	1922	C. Hill & Sons Ltd	4SSA (two)	6x381x762	373	165
Dwarka*	1922	C. Hill & Sons Ltd	4SSA (two)	6x381x762	373	165
Dumana	1923	Barclay, Curle & Co	4SSA (two)	8x673x1194	1,675	96
Swanley**	1924	Barclay, Curle & Co	2SDA	3x622x1118	1,492	100
City of Stockholm***	1925	Barclay, Curle & Co	2SDA	3x622x1118	1,492	100
Storsten ****	1926	Barclay, Curle & Co	2SDA	3x622x1118	1,492	100

Source: Various volumes of **The Motor Ship and Lloyd's Register of Shipping**

* Broken up 1937 following grounding in 1935

** Re-engined with Barclay, Curle Doxford 1927

*** Re-engined with SH&WR steam triple expansion 1927

**** Re-engined with Barclay, Curle Doxford 1928

References

1. ***Shipbuilding & Shipping Record***, 18 Sept' 1913. p358; 22 Jan' 1914. p119; 5 March 1914. p311; 25 June 1914. p780

2. Prof' A.L. Mellanby, "*Clyde Marine Oil Engines*", Trans' I.Mech.E., June 1923. p714-6

3. British India Steam Navigation Co. Director's Minute Book No 2, 25 Feb' 1920, p122. Item BIS/1/18, National Maritime Museum, Greenwich

4. B.I. Director's Minute Book No 2, 10 July 1919. p69

5. B.I. Director's Minute Book No 2. 25 Feb' 1920. p121

6. B.I. Director's Minute Book No 2, various pages up to and including p319.

7. ***The Engineer***, vol 132, 29 June 1921. p111

8. ***The Marine Engineer & Naval Architect***, vol 45, May 1922. p206

9. Letter of tender from Sulzer to Townsend Bros. dated 25 Oct' 1918. File No 017/0006/001, Cammell Laird Archives, Wirral Archives, Birkenhead

10. ***The Engineer***, vol 132, 29 July 1921. p109

11. ***The Motor Ship***, vol 2, May 1921. p51-3

12. ***Marine Engineer & Naval Architect***, vol 45, Feb' 1922. pp68-71;
The Motor Ship, vol 2, May 1922. pp51-5; ***The Engineer***, vol 132, 29 July 1921. pp109-11

13. ***The Motor Ship***, vol 2, May 1921. p55

14. ***The Marine Engineer and Naval Architect***, May 1922, vol 45. p206

15. ***The Marine Engineer & Naval Architect***, vol 45, May 1922. p204-7;
The Motor Ship, vol 3, June 1922. p85-7

16. In 1918 a four cylinder Sulzer trunk-piston engine, weighing 36tons, could develop 313kW at 200rpm (see ref No 9).

17. ***The Marine Engineer & Naval Architect***, vol 45, Feb' 1922. p69

18. The editorial in ***The Motor Ship***, vol 1, Oct' 1920. comments on the advantages of double-acting engines for high powers whilst similar remarks are made in many contemporary papers including, W.S. Burn, "*Double-Acting Oil Engines*", Trans' I.Mar.E., vol 38, 1926. p283 and W.F. Rabbidge, "*Some Types of Marine Internal Combustion Engines*", Trans' I.Mar.E., vol 39 1927. p169.

19. ***The Marine Engineer & Naval Architect***, vol 45, Sept' 1922. pp361-5

20. ***The Engineer***, vol 137, 25 April 1924. p434

21. ***The Motor Ship***, vol 4, May 1923. pp42-5

22. ***The Motor Ship***, vol 4, Jan' 1924. p352

23. ***The Motor Ship***, vol 4, Jan' 1924. p353

24. ***The Engineer***, vol 137, 2 May 1924. pp483-4; ***The Motor Ship***, vol 5, Aug' 1924. p158

25. J.C.M. MacLagan, "*The Sliding-Cylinder Double-Acting Two-Cycle Diesel Engine*", Trans' I.Mar.E., vol 36, 1923-3. pp665-746; and "*The Sliding-Cylinder Double-Acting Two-Cycle Diesel Engine*", Proc' IESS, 1924. pp746-801

26. ***The Motor Ship***, vol 6, May 1925. p64

27. ***The Engineer***, vol 137, 2 May 1924. p483; MacLagan, "*Sliding-Cylinder Engine*", Proc' I.Mar.E., p692

28. MacLagan, "*SlidingCylinder Diesel Engine*", I.Mar.E., p735-46

29. ***The Motor Ship***, vol 6, May 1925. pp64-6

30. ***The Motor Ship***, vol 6, May 1925. pp64-6

31. ***Lloyds Weekly Casualty Reports***, 23 July 1926; see appendix 2.

32. ***Lloyds Weekly Casualty Reports***, 11 June 1926.; see appendix 2.

33. ***Lloyds List***, 15 Dec' 1926 (**Swanley**); 9 Feb' 1927 (**Storsten**); 16 Feb' 1927 (**City of Stockholm**); ***Shipbuilder & Shipping Record***, 3 June 1926. p591; 10 June 1926. p621; 24 Feb' 1927. p228; 4 Aug' 1927. p134; also see appendix 2

34. Information supplied by Tom Gourley, former Barclay, Curle Engineering Manager

35. Directors' Report dated 27 Feb' 1923; Item 964/1, Tyne & Wear Archives, Newcastle-upon-Tyne

36. Directors' Report dated 3 March 1925; Item 964/1, Tyne & Wear Archive

Chapter 4.c

The Swan Hunter Neptune Engine

Prior to WWI Swan Hunter & Wigham Richardson licensed the Polar two-stroke cycle diesel engine from A.B. Diesel Motorer of Stockholm, engines being constructed for the ships **Arum** and **Arabis**.[1] Unable to consult with the licensors due to that conflict Swan Hunter designers proceeded to modify the engine according to their own ideas and in 1919 a new engine design was publicised. Styled the "Neptune" engine the basic arrangement followed that of the Swedish licensor but a number of modifications had been included and cylinder dimensions increased; the six cylinder engine was capable of developing 1,120kW at 115 rpm whereas the engine installed in **Arum** could only produce 504kW at 123 rpm.

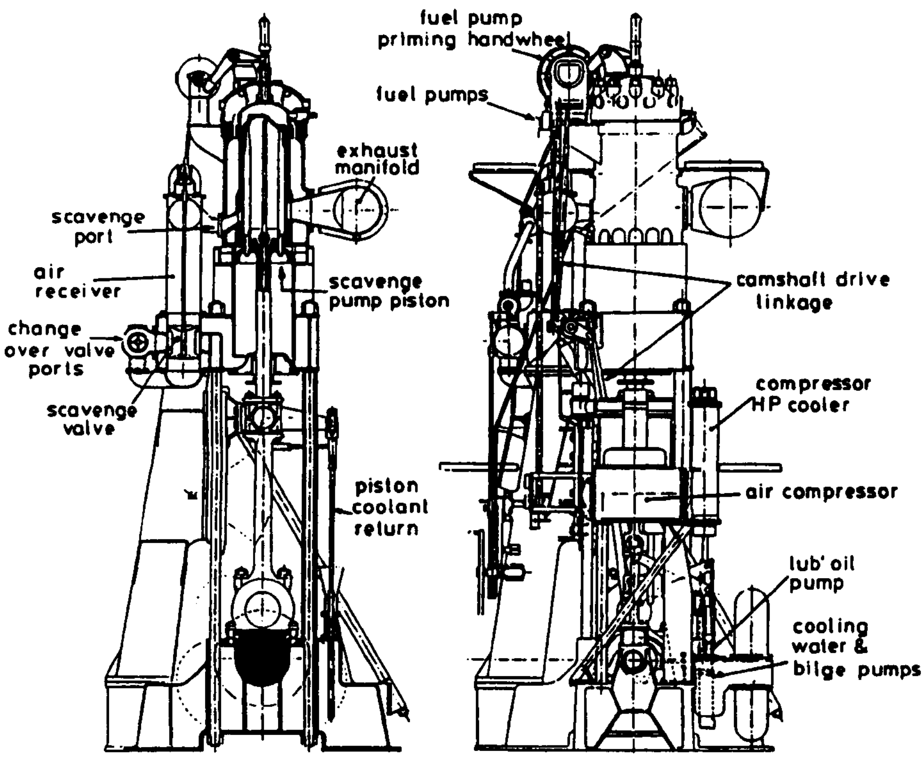


Fig 4.c.1 Original Design of Swan Hunter "Neptune Engine" (1919)

Following the earlier engines the "Neptune" design had scavenge cylinders below power cylinders, the scavenge cylinder blocks being supported upon turned steel columns and cast iron frames, diagonal steel stays providing lateral stiffness to the support structure. Blast air for the injection of fuel was provided by a three stage air compressor driven by the engine crankshaft and positioned at the forward end of the engine. Loop scavenging via ports in the bottom of the cylinder was similar to that employed in the Polar engine but this Swan Hunter variation had a separate liner which fitted into the cylinder block, cooling water circulating in the space between liner and cylinder block. The basic idea was to provide two-cylinder units of standard size which could be combined to give four, six or eight cylinder engines to suit power requirements.[2]

No orders were forthcoming for this engine but development continued under the guidance of Swan Hunter's engine designer Paul Belyavin. He was an advocate of the long stroke engine and "Neptune" engines developed by Swan Hunter tended to have larger stroke to bore ratios than other single piston types; ratios of about 2:1 were used for all Neptune engines and Belyavin believed that a 3:1 stroke to bore ratio would be satisfactory for a two-stroke engine.[3] A much modified engine, designated "Neptune A", ran on test in 1922[4] and a pair were installed in the tanker **Amus** the following year.[5]

"Neptune A" engines were still of the single-acting two-stroke form and employed a scavenge cylinder below each main cylinder. The scavenge piston attached to the lower end of the long skirted combustion piston and was of larger diameter than the combustion piston in order to ensure a sufficiently high scavenge pressure, about 1.25lbs/in^2 (0.1125bar), stroke of both main and scavenge piston, obviously, being the same. A tall engine resulted from this arrangement but the scavenge cylinders could be used for starting purposes. Cam operated scavenge valves at the front of the engine regulated air flow to and from the scavenge pumps, one valve being provided for each adjacent pair of cylinders. With the valve correctly positioned air from atmosphere would flow through ports to the scavenge pump cylinder as the piston moved upwards. With the piston near the top of its stroke the valve would be repositioned thus allowing air from the scavenge cylinder to be discharged into the receiver running the length of the engine; branches from this supplied air to each set of cylinder scavenge ports.

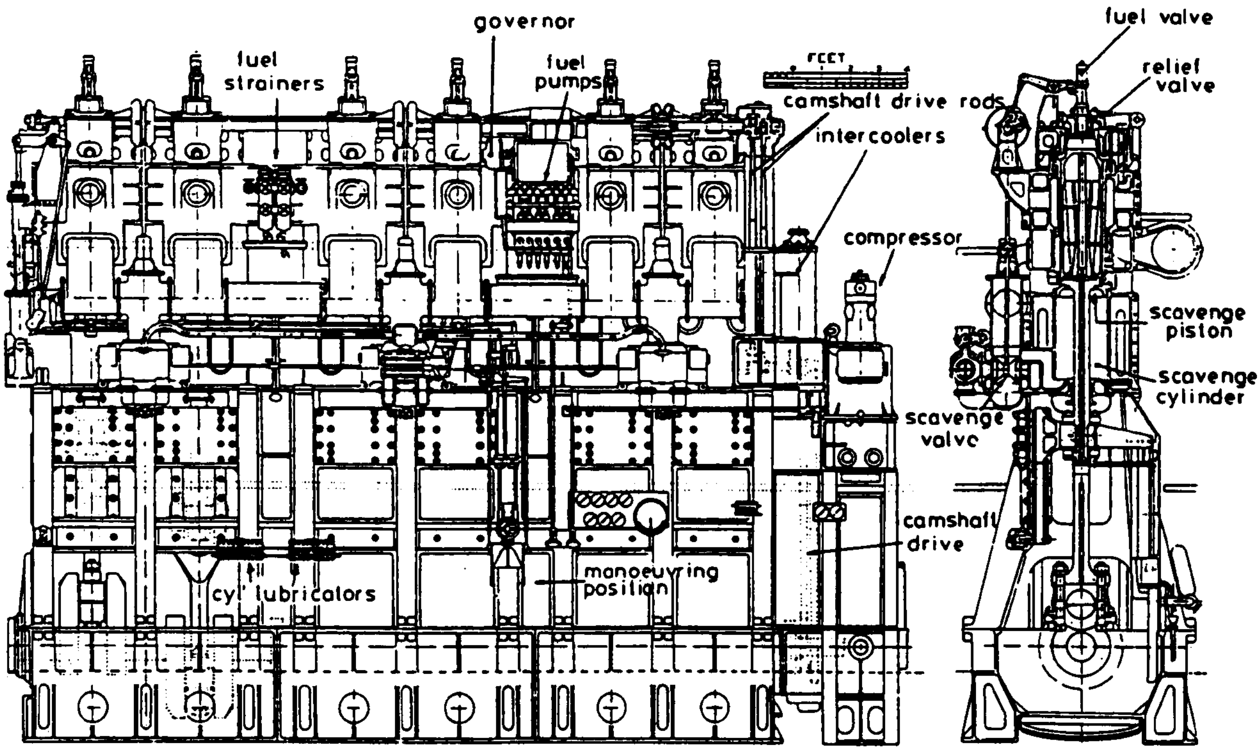


Fig 4.c.2 Swan Hunter "Neptune A" Engine

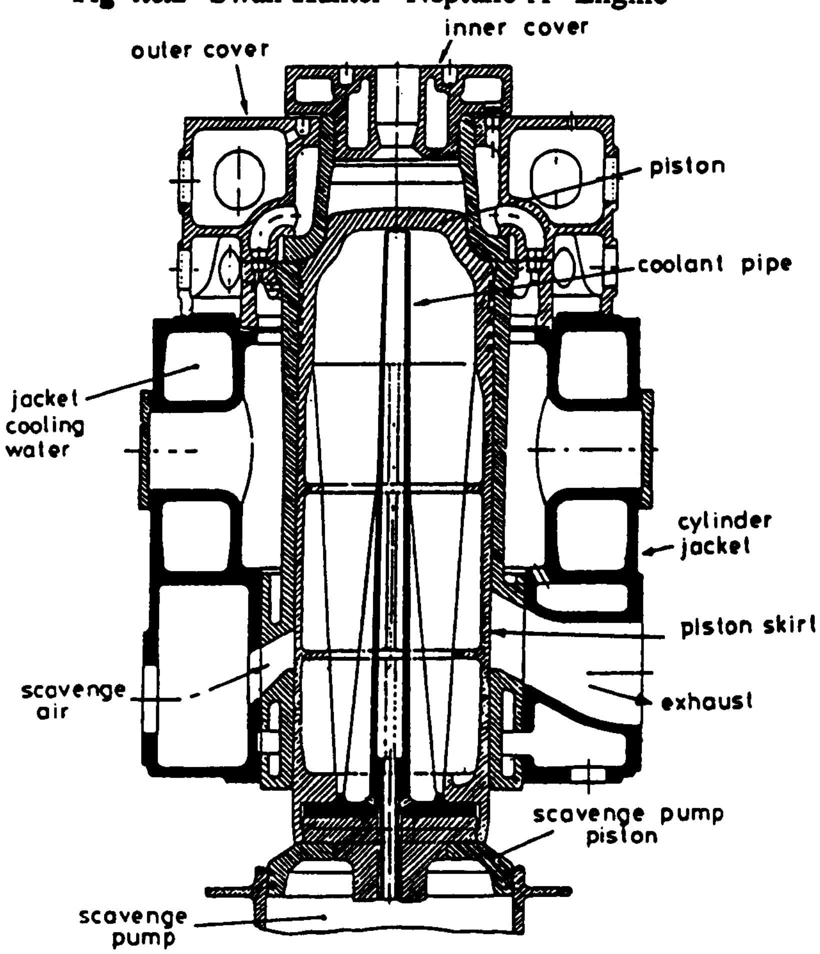


Fig 4.c.3 Cylinder of "Neptune A" Engine showing Scavenge Piston

When starting movement of the starting lever positioned the scavenge valve so that the suction side was closed whilst at the same time opening an air valve which directed starting air into the scavenge cylinder via the scavenge valve. The starting lever also repositioned a change-over valve which vented air from cylinders whose scavenge pistons were moving downwards in order to minimise back pressure on the power piston. This arrangement for starting simplified the cylinder cover and avoided cooling of the cylinder with starting air. Operation of the reversing lever caused air to be supplied to the air cylinder of the servo-motor which, via a bell-crank lever, forced the camshaft axially bringing the desired cams, ahead or astern, under the fuel valve followers. The reversing lever also brought about a 180° rotation of the scavenge valve eccentric thus effectively repositioning the air start system.

Fuel would be applied when firing speed was reached and movement of the air lever back to its normal position would shut off starting air and position the change-over valve to enable scavenge pumps to draw air from the engine room. Fuel valves each had four cams, two ahead and two astern. Main cams were for normal operation but the secondary set gave reduced lift of the fuel valves for slow running. For slow running the camshaft had to be correctly positioned by the servo-motor and this was provided for by the correct amount of movement of the reversing lever. Engine speed could be controlled by means of a handwheel which regulated the period of opening of suction valves on the camshaft driven fuel pumps, the engine operating on blast injection. In addition to hand control fuel pumps were also subject to the action of a centrifugal governor to prevent overspeed.

Piston crowns were symmetrically shaped, cylinder liners having scavenge and exhaust ports cut to provide optimum scavenging. Piston crown shape and the arrangement of the four scavenge ports, positioned directly opposite the exhaust ports, was the result of prolonged tests. Cylinder covers were designed to minimise problems related to thermal expansion, being in three sections, outer cover, liner and inner cover. The liner protected the outer cover from the combustion flame and was free to expand at its upper end, thereby avoiding thermal stress. The inner cylinder cover, which located in the cover liner but was bolted to the outer cover, contained fuel and relief valves. Seawater cooling applied to pistons, liners and cylinder covers. Cylinders were supported in pairs on cast iron columns, long tie bolts connecting the upper part of the cylinder block to the lower face of the bedplate. A three stage fuel injection air compressor was driven by the crankshaft at the forward end of the engine; no provision was made for driving cooling water and lubricating oil pumps.[6]

Although the engine appears to have been reasonably successful only two others of the type were constructed, for the single screw British India ships **Kistna** and **Kola**. These engines had a slightly higher rating due to a small increase in cylinder bore although the stroke remained the same as the engines fitted in **Amus**. Slight modifications to the fuel valve rocking levers allowed adjustment of fuel valves whilst the engine was running.[7]

Designers at Swan Hunter were, obviously, keen to ensure that the company produced engines in which owners could put their trust and to some extent the "Neptune A" achieved that aim. Three installations do not provide sufficient statistical information upon which to base an accurate assessment of reliability but Lloyds Weekly Casualty Reports indicate few engine failures in service (see appendix No 2); **Amus** suffered engine difficulties during the 1927-8 period but the two British India ships were noticeably trouble free. In 1923 Belyavin felt confident enough to comment, *"In the first days of the marine oil engine, its reliability was always suspect and for this reason most of the first motorships were twin screw. ....the reliability of oil engines now is considered to be unquestionable."*[8]

Development work continued and in 1924 the "Neptune B" engine was announced, this being intended as a standard product.[9] The new engine had many features found in the `A` engine but scavenge air was provided by two double-acting lever driven pumps. Abandonment of scavenge cylinders below main pistons reduced engine height, weight and cost, these being the prime reasons for the change, although the new design was also of simpler construction with fewer parts involved in the scavenge air system. The scavenge pump levers also operated reciprocating pumps for cooling water, lubricating oil and bilge duties, a further departure from an advantage claimed for the earlier design. ***The Engineer*** was, however, supportive of the new engine believing that it embodied several conspicuous advantages.[10]

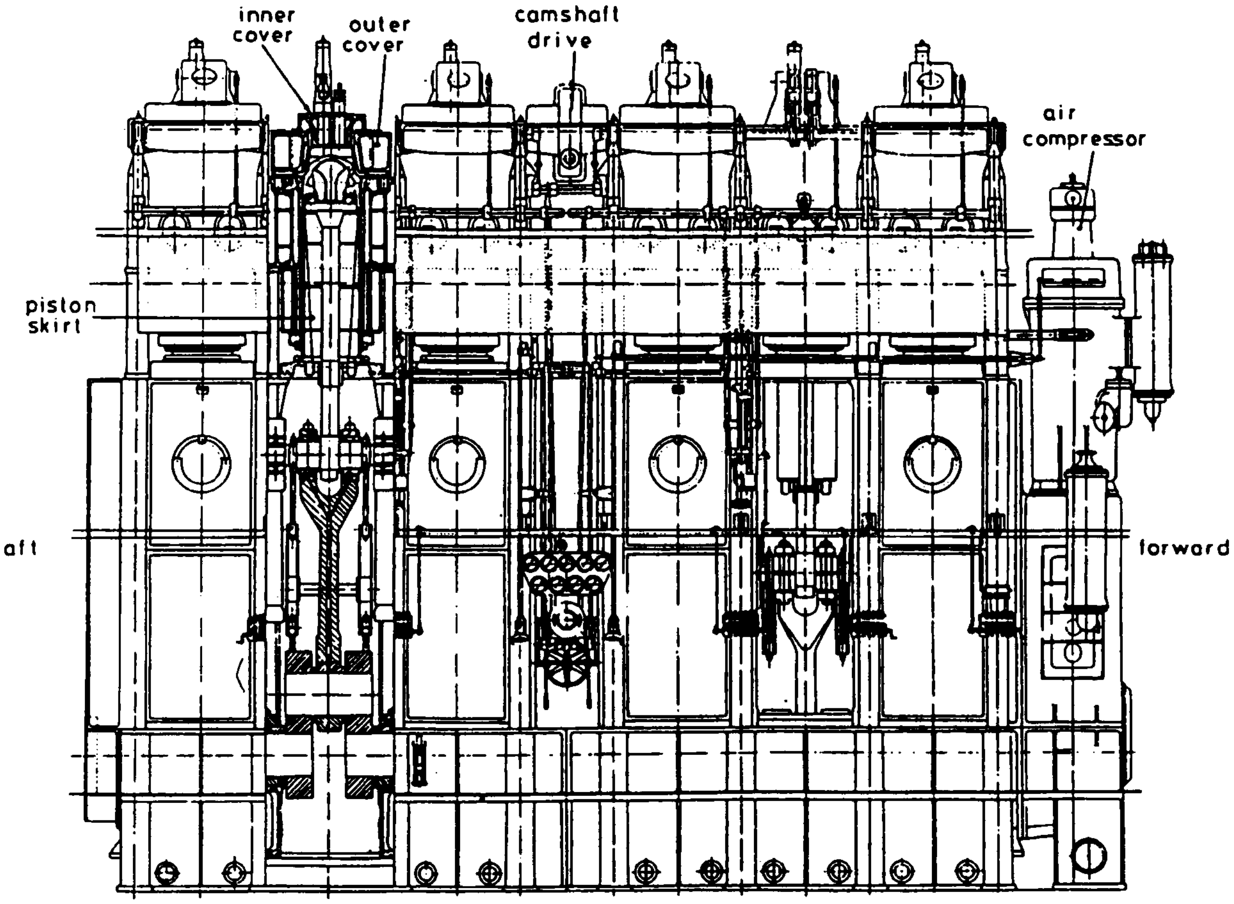


Fig 4.c.4 Swan Hunter "Neptune B" Engine

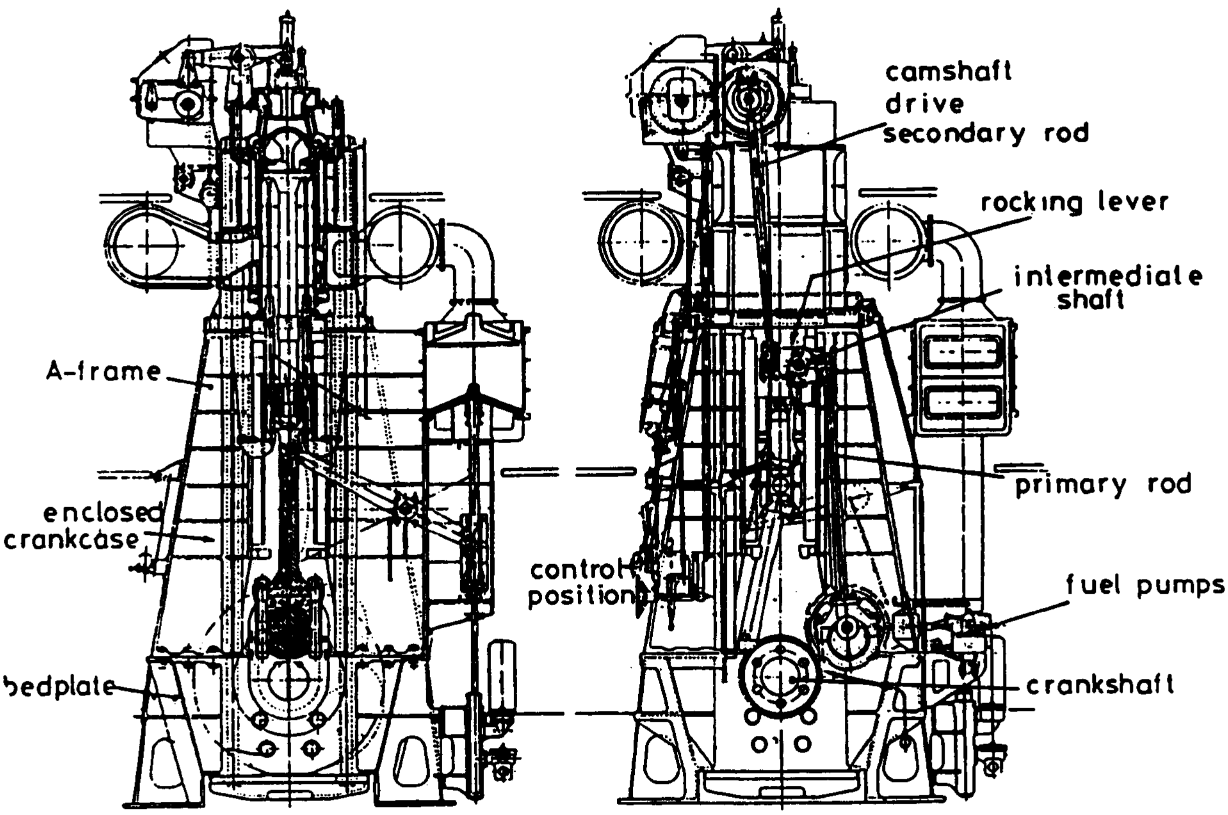


Fig 4.c.5 Section through "Neptune B" Engine showing Scavenge Pump & Camshaft Drives

Pistons had separate heads and skirts, convexity of the short piston head was increased in order to improve cylinder scavenging, the head itself being attached to a long piston rod which bolted to the crosshead pin. A long piston skirt, rigidly bolted to the piston, was provided in order to ensure that exhaust and scavenge ports remained closed until uncovered by the piston head. Seawater piston coolant was supplied to and removed from the piston by means of telescopic pipes. Guide shoes were given a degree of freedom at the crosshead, in order to minimise obliquity effects and so reduce rubbing wear between piston skirt and liner; guide plates were water cooled. Construction of cylinder covers differed in detail from that used for the earlier engines but the basic three part arrangement was retained as it provided for effective cooling and kept thermal stress limited. One change forced on the designers was provision of a hole for an air start valve in the inner cylinder cover, without scavenge pistons at each cylinder an alternative means of starting the engine had to be provided.

Camshaft drive arrangements were redesigned but the drive still utilised an eccentric, intermediate shaft and rods; a second eccentric on the same shaft was used to operate the fuel pumps. Separate ahead and astern cams were provided at each cylinder for fuel injectors and air start valves but, unlike the system for the `A' engine, no axial movement of the camshaft was required for reversal. Each rocker had separate ahead and astern rollers and reversal was achieved by bringing the desired rocker into contact with its particular cam; more linkages were needed but it simplified the actual reversing system.[11]

During the 1920s British Petroleum used its new building policy to try different types of diesel engines and two eight cylinder "Neptune B" engines were ordered for installation in the tankers **British Motorist** and **British Petrol** being constructed by Swan Hunter. These were the largest "Neptune" engines built. Only three other `B' engines were made and one of these went into ship into **Neptunian** owned by Hopemount Shipping, part of the Swan Hunter group of companies.

In subsequent years modification were made to the "Neptune" engines, including the use of fresh water in the pistons and distilled water in the heads; cylinder jackets remained seawater cooled. Operating experience with "Neptune" engines was not outstanding but they did perform better than some engines of the period. The engine fitted in **British Petrol** was replaced following a broken crankshaft but that fitted in her sister, **British Motorist** remained in the ship until she was sunk during 1941. Engine experience aboard **British Motorist** has been described as a nightmare with the situation during starting being particularly hazardous; nobody being allowed at the top of the engine at such times.[12] It was not unknown for parts of valves to come loose from the cylinder covers whilst starting causing possible harm to anybody in the vicinity.[13]

Table 4.c.1

Swan Hunter Neptune Engines

Vessel	Year	Ship Builder	Type	Cylinder Size(mm)	Power kW	RPM
Arnus	1922	SH&WR	2SSA (two)	6x432x889	783	124
Kistna	1924	SH&WR	2SSA	6x445x889	821	125
Kola	1924	SH&WR	2SSA	6x445x889	821	125
British Motorist	1924	SH&WR	2SSA	8x610x1270	2,387	93
Iossifoglu	1924	SH&WR	2SSA	6x572x1143	1,641	100
Silverpine +	1924	SH&WR	2SSA	6x572x1143	1,641	100
Silverlarch +	1924	SH&WR	2SSA	6x572x1143	1,641	100
British Petrol ++	1925	SH&WR	2SSA	8x610x1270	2,387	93
Lenfield	1925	SH&WR	2SSA	4x610x1270	1,120	
Neptunian	1925	SH&WR	2SSA	6x610x1270		
Athelking +++	1925	SH&WR	2SSA	6x572x1143	1,641	100

Source: Various volumes of **The Motor Ship** and **Lloyd's Register of Shipping**

+ Re-engined with R-W Double acting engine 1935

++ Re-engined 1937 with Vickers-MAN Double acting engine following crankshaft failure

+++ Re-engined 1934 with twin Kincaid/B&W engines

The middle years of the 1920s saw British shipbuilding in severe depression and Swan Hunter had very little work in any of its yards or engine works; in 1926 total machinery output for the group amounted to 20,730ihp compared with 90,500 ihp in 1920.[14] Although work was hard to find the company did itself no favours as it maintained two large diesel engine manufacturing plants, Neptune works at Wallsend and the North British Works at Whiteinch, and effectively competed with itself for engine orders through designs produced at both establishments.

References

1.*The Engineer*, vol 117, 29 May 1914. p598

2. *The Engineer*, 21 Nov' 1919. p521

3. P Belyavin, "*Marine Oil-Engine Installation and Auxiliaries*", Trans' NECIES, vol 39, 1023. pp375-6, 408

4. *The Motor Ship*, vol 3, October 1922. p228

5. *The Motor Ship*, vol 4, Dec' 1923. p308

6. *The Motor Ship*, vol 3, Oct' 1922. p228-33; vol 4, Dec' 1923. p308-12

7. *Shipbuilding & Shipping Record*, vol 23, 28 Feb' 1924. p248

8. P. Belyavin, "*Marine Oil-Engine Installation and Auxiliaries*". p375

9. *The Motor Ship*, vol 5, April 1924. p13-5; *Shipbuilding and Shipping Record*, vol 23, 8 May 1924. p541

10. *The Engineer*, vol 137, 31 Oct' 1924. p486

11. *The Motor Ship*, vol 5, April 1924. pp13-5; vol 5, Nov' 1924. pp263-8: *Marine Engineer & Naval Architect*, vol 47, Jan' 1924. pp5-8; *The Marine Engineer & Motorship Builder*, vol 47, June 1924.p 220

12. Private correspondence from former **British Motorist** Engineer Officer Mr N.W. Fleming

13. D. Burrell, "*The Low Speed Diesel in British Shipbuilding up to 1945*", Trans' NECIES,vol 105, pt 1. Nov' 1988. p19-24

14. Swan Hunter Directors' Report dated 1927; Item 964/1, Swan Hunter Archives; Tyne & Wear Archives, Newcastle

Chapter 4.d

The Fullagar Engine

H.F. Fullagar took out his original gas engine patent in 1909[1] and established the Fullagar Engine Company in order to deal with subsequent development. Fullagar died in 1916 following a stroke but his estate applied for and, in 1922, was granted an extension to the two original patents on grounds that World War I had prevented full exploitation of the concept.[2] Although a number of other people had patented designs for opposed-piston engines, notably Professor Junkers (1901) and Oechelhaeuser (1896), Fullagar considered his design to be significantly different from others and there were, evidently, no problems in getting a British patent. Although initially intended to operate on gaseous fuel Fullagar also appreciated the prospects for burning oil and as early as 1913 he commented upon its use for submarine propulsion.[3]

Initially referred to as the "Balanced Engine", due to inherently good balance of rotating and reciprocating parts, by time work commenced upon a four-cylinder experimental unit in 1911 the engine was known by the name of its designer. That 305mm bore by 914mm combined stroke engine, built by W.H. Allen & Sons, developed 410kW at 250rpm when burning town gas and was installed at the Newcastle Electricity Supply Company's South Shore Station in Gateshead during 1913. A 30 hour test conducted by Professor Hopkins showed thermal efficiency to be 30% and mechanical efficiency 80%.[4] Work on a second engine, having six 457mm by 1371mm cylinders, was commenced but due to the war installation in the Weardale Power Station at Spennymoor was delayed until 1917. Burning coke oven gas the engine could develop 1,492kW at 184.5rpm making it the highest powered British gas engine at that time. Problems were experienced but these were mainly concerned with the supply of gas which was of variable quality; however, the engine performed reliably and well, remaining in service until 1937 when the electrical supply frequency was changed.[5]

In 1915 Cammell-Laird reached a provisional agreement with the Balanced Engine Syndicate Ltd, a company established by Fullagar to exploit his patents, for a licence to run for a period of 14 years.[6] This gave Lairds exclusive British rights to construct oil engines for land and marine use and special emphasis was placed upon the development of engines for submarine propulsion. So keen was the Syndicate company to see Fullagar engines used in submarines that it agreed to grant Lairds 1/- (one shilling) per bhp on any submarine engines built under sub-licences provided that Lairds built a submarine engine for testing within 18 months of signing the agreement.[7]

Over the next five years three experimental two-cylinder engines were built as follows:[8]

343mm bore x 762mm combined stroke (experimental engine)

292mm bore x 610mm combined stroke for submarines

152mm bore x 330mm combined stroke for aircraft

The latter was a short lived venture and of no significance here but the experimental engine underwent testing during 1916 and 1917 with representatives from the Admiralty invited to view the trials. Early results are given in table 4.d.1.[9]

Table 4.d.1.

Date	BHP/IHP	Mechanical Efficiency	Scavenge Pump Power	Engine Friction
20/10/16	208/361	57.7%	65hp	88hp
12/11/16	252/340	74%	49hp	39hp

It was believed that the immediate future lay in the construction of submarine engines, hence the invitation to the Admiralty, as the policy adopted by the Wartime Shipping Controller was to build as many ships as was possible with the cheapest and commonest engines, thus effectively precluding diesels.[10] After viewing the experimental engine on test during March 1917 the Admiralty informed Lairds that although results were promising the engine as it stood was not suitable for HM Service.[11] Sir George Carter, Managing Director at Cammell Laird immediately responded indicating that the experimental unit had been constructed to test the Fullagar arrangement and not as a prototype submarine engine; structural parts had been cast and were heavy in order to reduce labour time which was then difficult to procure. The Admiralty was positive and indicated that it would be prepared to order at least two 1,700bhp (1,270kW) engines upon satisfactory testing of a dedicated two-cylinder experimental submarine engine which Lairds then proposed.[12] Constructing and testing the original experimental engine had cost £11,000 and a further £5,000 was required to built a new one.[13]

The new unit had to be totally enclosed in order to meet Admiralty requirements for submarines and it was slightly smaller than the original engine. A 72 hour trial conducted over 19, 20 & 21 Nov' 1918 gave the following average results on Admiralty distillate fuel of 0.9 specific gravity.

Power 293.3 bhp (219kW)
Speed 351.7 rpm
Fuel 0.426 lb/bhp/hr (0.259kg/kW/hr)

A 20 minute overload test was run at 316 bhp (236kW). Further trials took place during 1919 but the Admiralty decided not to pursue the idea of taking two Fullagar submarine engines due to the cessation of hostilities.[14]

Whilst Lairds were involved in this experimental work and the Balanced Engine Syndicate was engaged in erecting the 1,492kW engine at Weardale negotiations continued with regard to the licence. W.L. Hitchens, chairman of Cammel Laird & Co., contacted Merz and McLellan, acting for the Fullagar company and the Balanced Engine Syndicate, during August 1917 suggesting that in view of Fullagar's death they might like to dispose of the patents.[15] In reply Merz & McLellan were not positive and indicated that the Syndicate had spent £20,000 on development of the engine to that date.[16] Obviously with an eye on a possible bargain Sir George Carter responded stating that the patents would soon run out, orders for submarine engines were not likely to be significant and that mercantile orders could not be expected until an engine was shown to operate satisfactorily in service. He offered £6,000 for the land and marine rights to Fullagar engines.[17] Whether this was a serious attempt by Lairds to buy the patent rights or just a way of improving their bargaining position in the licence negotiations is not clear but it did have the effect of bringing those negotiations to a conclusion and appears to have encouraged the patent holders to apply for extensions.

Licence negotiations were completed the following years with the agreement being signed on 2 July 1918. Cammell Laird made a payment of £12,000 to the Fullagar

Engine Company and the Balanced Engine Syndicate for the sole rights to Fullagar oil engines for land and marine purposes with royalties being fixed as follows;[18]

Table 4.d.2

Royalty per BHP	Engine Size, BHP
5/- (25p)	2,000 upwards
6/- (30p)	1,600 - 2,000
7/- (35p)	1,200 - 1,600
8/- (40p)	800 - 1,200
9/- (45p)	400 - 800
10/- (50p)	below 400

Laird's engine followed the basic Fullagar patent and consisted of cylinders arranged in pairs with each upper piston being connected to the lower piston crosshead of its companion unit by means of crossed rods, upper and lower piston strokes were equal. This arrangement dictated that cranks for each pair of cylinders were 180° to each other; subsequent sets of cylinders would have cranks suitably displaced from the first set to provide for an even turning moment With cranks for each pair of cylinders so arranged vertical reciprocating forced were practically balanced, the slight imbalance being due to the fact that the mass on the lower piston assembly was greater than that of the corresponding upper piston. The crossed, or oblique, rods were rigidly connected to crosshead and upper piston unit, guides being provided at the main crosshead and at the upper connection. Spacing of the rods was dictated by the need to clear the cylinder liners and this resulted in a wide main crosshead which was also of high mass due to the need to substantially attach the side rods. The space above each upper piston was organised as a rectangular scavenge pump. The upper piston controlled opening of exhaust ports whilst the lower regulated the scavenge ports.

As they were not subject to combustion loads forces in the frames were low allowing for relatively light cast iron construction. Inertia forces and couples were practically balanced in each pair of units due to the arrangement of cranks. Fuel injection was by means of air blast at a pressure of about 69 bar and a three stage air compressor was fitted at the forward end of the crankshaft to supply such air and replenish the starting air receivers. Pistons and cylinder jackets were cooled by means of fresh water at a pressure of about 2 bar although on the original 373kW engine fitted in the 500 ton coaster **Fullagar** oil cooling of pistons had been employed.[19]

That original installation of 1920 was considered very much as a floating test bed for the engine and as a training ground for engineers and it did attract a considerable amount of attention from the marine world.[20] Fullagar had considered that "*the minor reactions from the slippers at the ends of the oblique rods*" were less significant than reactions in other reciprocating machinery,[21] however, a correspondent from ***The Motor Ship*** after making the trial voyage aboard **Fullagar** commented "*Whilst observing the behaviour of the engine under way, we formed an opinion that the fore and aft thrust forces produced make themselves felt at the upper part of the cylinders to an extent which would render the necessity of special bracing somewhat desirable.*"[22] This fore' & aft' load on the scavenging piston of a cylinder's adjacent unit was also commented upon by Professor Mellanby in 1923. He considered that approximately one fifth of a piston's vertical load became a sideways thrust in the adjacent scavenge cylinder resulting in appreciable friction and probably accounting for the Fullagar engine's low mechanical efficiency of 73%.[23]

Brocklebank's 5,000 ton **Malia** required higher power and two 746kW four-cylinder Fullagar engines were built by Lairds and fitted during 1923; originally the engine from **Fullagar** and an identical engine were fitted but power was insufficient for the desired speed and they gave considerable trouble when overloaded.[24] It is likely that the lower powered engines were fitted in **Malia** as an interim measure whilst the larger engines were developed as the first 746kW engine was under test at Lairds during April 1921 and **Malia** did not run trials until October that year.[25] During a 24 hour test at its designed rating the engine returned a remarkably good fuel consumption of 0.238kg/kW.hr and a mechanical efficiency of 71.5%, whilst burning Anglo-American diesel oil of 0.92 specific gravity.[26]

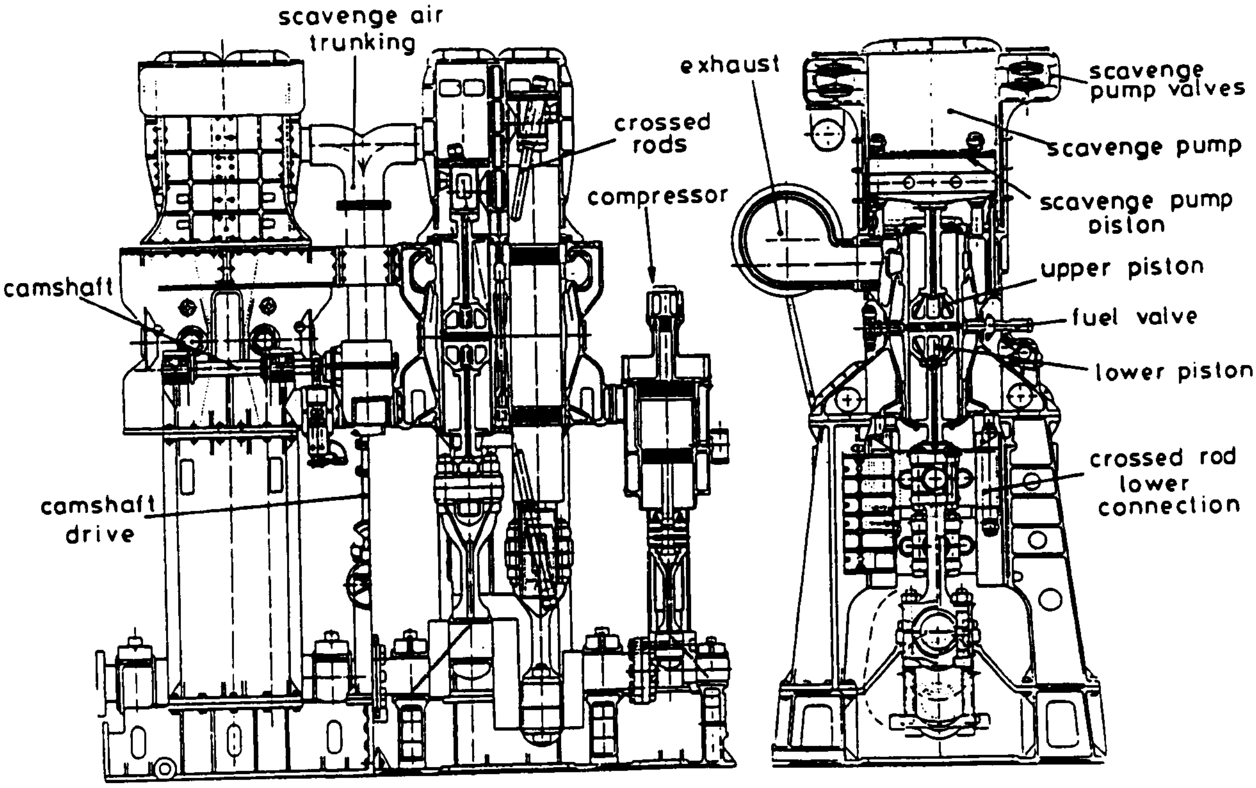


Fig 4.d.1 Four-Cylinder Cammell-Laird Fullagar Engine

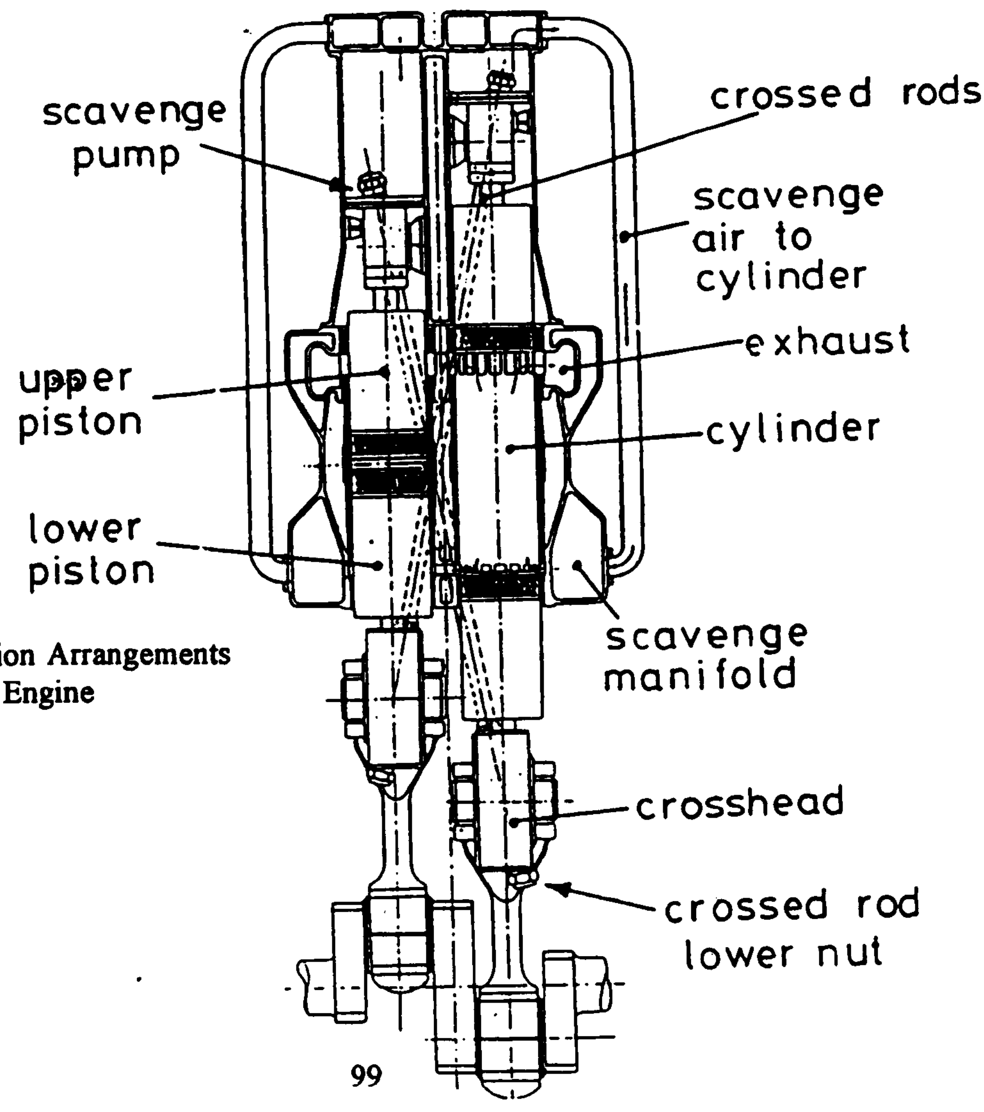


Fig 4.d.2
Piston Connection Arrangements of the Fullagar Engine

These larger engines differed in some details particularly with respect to valve gear and reversing system. In order to minimise the risk of cylinder liner cracking only two holes were bored, one for a fuel valve and the other for a starting air valve; valves were positioned diametrically opposite each other with the fuel valve at the front of the engine. Problems of liner cracking had occurred with the prototype engine and steps to strengthen the liner were taken resulting in a Lairds' patent for liner strengthening.[27] This, however, caused conflict with the Still Engine Company who considered that the liner modifications infringed its earlier patents, No 1750 (1912) and No 133,077 (1917); a royalty of 5/- (25p) per square inch of liner surface was initially claimed for the use of these patents (this would have amounted to half of the total royalty already paid on a complete Fullagar engine).[28] Palmers of Jarrow, a sub-licensee, was singled out for litigation but the Still Company's case was against the Cammell Laird Fullagar engine employing strengthened liners. Lairds argued that its method of strengthening differed from that patented by Still and both parties were willing to have the courts decide the matter with the Birkenhead company going so far as to estimate costs of possible litigation.[29] Eventually the matter was settled with Fullagar engine licensees agreeing to pay £500 in settlement of all claims respecting prior use of patents or alleged infringement and a royalty of sixpence (2.5p) per bhp on future construction.[30]

Change to the use of a single fuel valve resulted in modification of the reversing and control systems, the new arrangement becoming standard for all engines built by Lairds and its licensees from 1921 onwards. A single camshaft, positioned at the front of the engine, was driven from the crankshaft by means of a vertical shaft and a set of spur and bevel gears. Separate sets of ahead and astern cams were fitted for fuel and air start valves of each cylinder, axial camshaft movement by means of a servo-motor achieving reversal. Use of tapered fuel valve cam followers allowed reversal without lifting these clear of the cams. Air starting valve followers were only brought into contact with their cams during starting and they operated the air start valves through levers and push rods which extended to the back of the engine.

When starting the control wheel was rotated causing air start followers to be brought into contact with their cams thus allowing starting air to enter cylinders in the correct sequence, the master air valve being opened by the same operation. After sufficient rotational speed was achieved the handwheel would be turned to its second position which lifted the starting air followers of two cylinders, thus cutting off starting air, and at the same time bringing into operation the fuel valves of those cylinders. Further movement of the handwheel would put all cylinders on fuel; for six-cylinder engines a fourth handwheel position allowed four cylinders to be on fuel with two still on starting air. Adjustment of engine speed was achieved by means of the throttle lever which controlled lift of the fuel pump suction valves and hence regulated fuel supply to the engine. A further lever allowed lift of the fuel valves to be reduced as reduction in blast air quantity as well as fuel quantity was considered to be preferable when the engine was operating below half engine speed. Blast fuel valves were designed so that a single lever, operated by the fuel cam, would open both fuel and air valves simultaneously; the fuel valve discharged fuel into the blast air line slightly upstream of the air valve and pulveriser plate. Although the basic manoeuvring system remained the same some licensees adopted hand wheels instead of levers for control of fuel pump suction valves and fuel valve lift. (Engines subsequently developed for the diesel-electric fruit carriers were unidirectional and so no reversing gear was provided.) Cooling water and lubricating oil pumps were driven by levers from the crosshead of the blast air compressor situated at the forward end of the engine. Cylinder lubricating oil pumps were driven by the camshaft[31]

Early promise shown by the engine encouraged a number of shipbuilders to take out sub-licences from Lairds and by 1924 there were four licensees in Britain and two overseas, far more than for any other British designed engine at that time. One of the overseas licensee, Ateliers et Chantiers de Bretagne, was particularly interested in the potential of the engine for submarine propulsion and encouraged Lairds to provide details of installations to submit to the French Admiralty.[32] There was also considerable interest in the engine from America and in view of the American Shipping Board's desire to convert steam ships to diesel propulsion considerable potential existed. Enquiries came from a number of concerns including Ingersoll-Rand and the Federal Shipbuilding Co. of Newark. During 1922 Lairds appointed R.R. Row of New York as agent on a commission only basis. Row spent a considerable amount of time attempting to get engine orders and dealing with potential licensees and tried, without effect, to interest Lairds in appointing him on salary; in 1924 he found a permanent appointment with Todd Shipbuilding & Eng' Co. and Lairds had no representative in North America.[33] A major obstacle to licensing the engine in he U.S.A. was the Sun Shipbuilding Co. which held rights to the patents taken by Junkers and was unwilling to overlook possible infringement or entertain any exchange of patent rights.[34] In June 1924 Lairds offered Ingersoll-Rand full U.S.A. land and marine rights for $200,000 each provided that the American company would take responsibility for any infringement of Junker patents.[35] This, together with a subsequent lower cost offer, was refused and American interest ceased.

Row did provide a quotation to the Federal S.B. Co. which gives an indication as to the cost of Fullagar engines built by Cammell Laird. His price, including 5% commission, for each of two 1,000 bhp (746kW) four-cylinder engines (470mm bore by 635mm combined stroke) was £19,425, delivered in New York but exclusive of duties; delivery of the first engine being 10 months from the signing of the contract. The price representing about £19.5 per bhp was certainly competitive with other diesel engines at that time as can be seen from table 3.8.[36]

In 1922 Lairds received an order for three fruit carrying ships from the American owned United Fruit Company and offered a diesel-electric drive employing four Fullagar driven generating sets, each on its own bedplate. This owner already had three ships propelled by steam reciprocating engines and one with a turbo-electric drive which had proved effective but a diesel-electric drive offered greater potential for fuel and space saving. It was anticipated that the Fullagar engined ships would burn 13.5 tons of fuel per day compared with 31 tons for the steamers whilst capacity would be increased by 29% compared with the turbo-electric ship. Although the plant was more costly than steam reciprocating or turbine the owners were optimistic that they would achieve the savings they wanted due to this low consumption and increased capacity, together with the need for fewer firemen. There was nothing fundamentally different in the Fullagar engines for these ships except for cylinder size and the fact that no reversing capability was required.[37] The first two ships, **La Playa** and **La Marea**, entered service but the owner appears to have had second thoughts about the installation as steam reciprocating plant was substituted before the third ship, **La Perla**, became operational. The engine sets for that ship were actually under construction at Lairds during September 1923[38] and so the change to steam propulsion must have been for a serious reason. *Lloyds Weekly Casualty Reports* (see appendix 2) do not show any stoppages for the first two ships at that time but there may well have been mechanical problems; alternatively the American dispute concerning the Junker patent may have influenced the owner. Whatever that initial reason the engines were obviously not a success as both ships had been fitted with new machinery by 1930.

The only other marine Fullagar engines constructed were by licensees. Palmers of Jarrow built two tankers for British Petroleum and fitted each with a six cylinder Fullagar engine. David Rowan constructed an engine which William Hamilton & Co fitted in **Baron Dalmeny**, a ship built for their own account and chartered to Hogarths. The other British licensee, John Brown, built two engines which were exported to Japan. There is no evidence that either of the overseas licensees or the other British licensee ever built any Fullagar engines.

The engine fitted in **British Aviator** came under the scrutiny of the Marine Oil-Engine Trials Committee, established by the Institution of Mechanical Engineers and the Institution of Naval Architects in 1922 to carry out tests of oil-engines and oil-engined ships. Five types of engines were investigated, Richardsons-Tosi[39], Scott-Still[40], Doxford[41], Palmer-Fullagar[42], Hawthorn-Werkspoor[43], and the Alfred Holt Hybrid engine[44]. Trials were carried out on the Fullagar engine for **British Aviator** on the test-bed at Palmers and then at sea under normal operating conditions. The series of trials was intended as an information gathering exercise and not as a means of finding the best engine therefore no actual conclusions were drawn from the tests, apart from by individuals during discussion of results. Both on the test-bed and at sea the Fullagar engine performed well giving rise to high expectations, in fact the mechanical efficiency had been unexpectedly high, 80.6% at full torque, resulting in an opinion that the indicator was at fault[45]

That high expectation was short lived and after 1926 no further engines were built. Lairds built its last Fullagar engine in 1924. After 1930 only the Japanese ships retained their original engines indicating major problems with the Fullagar design as far as marine application is concerned.

Table 4.d.3

Fullagar Engines						
Vessel	**Year**	**Ship Builder**	**Type**	**Cylinder Size(mm)**	**Power kW**	**RPM**
Fullagar +	1920	Lairds	2SOP	4x356x1016	375	125
Malia ++	1921	Hamilton	2SOP (two)	4x470x1270	746	115
La Playa +++	1923	Lairds	2SOP (four)	4x356x812	615	250
La Marea ++++	1924	Lairds	2SOP (four)	4x356x812	615	250
Baron Dalmeny **	1924	Hamilton	2SOP	6x470x1270	1,119	115
British Aviator *	1924	Palmers	2SOP	6x584x1829	2,238	90
British Chemist*	1925	Palmers	2SOP	6x584x1829	2,238	90
Florida Maru ***	1925	Kawasaki	2SOP	6X559x1676	1,865	91
Cuba Maru ***	1926	Kawasaki	2SOP	6x559x1676	1,865	91

Source: Various editions of **The Motor Ship** and **Lloyd's register of Shipping**

+ Engine removed 1921; renamed **Caria**

++ Former **Fullagar** engine installed together with another of same size; Larger engines as indicated installed May 1923 Renamed **Daga** 1928; re-engined with Denny Sulzers 1930

+++ Electric drive; re-engine with Fiat engines 1928

++++ Electric drive; 1930 Renamed **Darien** & turbines fitted

* Engines built by Palmers; 1930 re-engined with Doxfords

** Engine built by Rowan; Re-engined Kincaid H&W/B&W 4-S engine 1929

*** Engine built by John Brown

Regarding in-service casualties (appendix 2) the Fullagar engine appears to have been one of the better British types, but there were certainly problems which influenced the engine's reliability even though service casualties may have been avoided. The case of **Malia** is indicative of this and illustrates how poor reliability did not necessarily result in casualty reports. On outward passage to India during October 1925 threads on the No 3 unit starboard engine oblique rod stripped and the ship had to put into Algiers for repairs.[46] A report on the incident by Laird's engineers indicated that oblique rods had a tendency to form indentations into their respective crossheads and this subsequently resulted in hammering; this hammering caused stripping of the threads. At the same time it was discovered that several pistons had suffered breakage of piston head studs, the belief being that this was the result of water hammer in the piston cooling space.[47] The remainder of the voyage appears to have been equally difficult as a report from the Chief Engineer to the managers indicated subsequent piston problems, failed bottom end bolts, fractured main engine driven pump casing and a broken starting air pipe between Calcutta and Suez. He commented, "*I am afraid that something drastic will have to be done before* **Malia** *is fit to make another Calcutta trip...*". The engineers had obviously had enough as five out of the seven had requested to be relieved immediately upon arrival in the U.K.[48] Only the outward bound stop at Algiers was actually reported as a casualty to Lloyds.

Other reasons for the engine failing to make its mark in the marine world included excessive cylinder liner wear and cracking of the badly designed crosshead. Crossheads were massive affairs as they had to incorporate attachment points for the diagonal upper piston rods and this size meant that considerable time was needed for the crosshead to warm up after starting. Guide clearances were, consequentially, excessive at first and that resulted in hammering which caused damage to the guides and leakage at piston cooling connections.[49]

English Electric became interested in the Fullagar engine for land application and in 1920 acquired world oil-engine rights for stationary land applications.[50] A good design was developed and they installed many engines for electrical generation throughout the world[51]; some of these were still operational in the 1960s. Had sufficient time been allowed for development of the marine engine and had sufficient money been spent it is possible that the early problems would have been overcome, the land based engine proved the design's potential.

References

1. Patent No 610 (1909) described the opposed-piston engine arrangement with oblique rods and patent No 6751 (1909) cover combustion chamber design

2. Covering note attached to Patent Nos 6,102 (1909) and 6,102 (1909) in Liverpool City Library

3. H.F. Fullagar, "*A New Type of Internal Combustion Engine*", Trans` IESS, 1913-4. p492

4. Fullagar, "*A New Type of I.C. Engine*". pp 498-500 and W. Ker Wilson, "*The History of the Opposed-Piston Marine Oil-Engine*", Trans` I.Mar.E, vol 63, No 10, 1946. p180

5. Ker Wilson, "*History of Opposed-Piston Engines*", p182

6. Licence agreement in file No 017/0006/001, Cammell-Laird Archives, Wirral Archive.

7. Letter Sir George Carter (Managing Director at Lairds) from the Balanced Engine Syndicate, dated 7 Aug` 1915. File 017/0006/000, Laird Archive.

8. W. Ker Wilson, "*History of the Opposed-Piston Marine Oil Engine*". p182

9. Internal Cammell-Laird Memo to A.L. Bird dated 13 Nov` 1916. File 017/0006/000, Laird Archives

10. Letter from Sir George Carter (Lairds) to Mr Merz, File No 017/0006/000, Laird Archives

11. Letter from R.R. Scott at the Admiralty to Cammell Laird & Co., dated 19 June 1917. File No 017/0006/000. Laird Archives

12. Letters between Cammell Laird and the Admiralty dated 27 Aug` and 4 Oct` 1917. File No 017/0006/000, Laird Archives

13. Letter from Sir G. Carter to Messrs Merz & McLellan, dated 13 Nov` 1917. File 017/0006/000, Laird Archives

14. Letter sent from Cammell Laird to Mr Dupont of Atlieret Chantiers de Bretagne, dated May 1921. File No 017/0006/002, Laird Archives

15. Letter from Hitchens to Merz & McLellan dated 21 Aug` 1917. File No 017/0006/000, Laird Archives

16. Letter to Hitchens from Merz dated 28 Aug 1917, File Not 017/0006/000, Laird Archives

17. Letter from Carter to Merz dated 2 Sept` 1917, File No 017/0006/000, Laird Archives.

18. Licence Agreement Document dated 2 July 1918. File No 017/0006/001, Laird Archives

19. ***The Engineer***, vol 129, 6 Feb' 1920. pp132-3; ***The Motor Ship***, vol 2, June 1921, pp80-4; W.C. MacGibbon, **Marine Diesel Engines**, J. Munro & Co, Glasgow, 1926. pp332-343

20. ***The Motor Ship***, vol 1, August 1920. p140-3

21. Fullagar, "*New Type Of I.C. Engine*", p498

22. ***The Motor Ship***, vol 1, Aug' 1920. p142

23. Prof' A.L. Mellanby, "*Clyde Marine Oil-Engines*", Proc' I.Mech.E., June 1923. p991

24. Ker Wilson, "*History of the Opposed-Piston Engine*", p182

25. ***The Engineer***, vol 132, 7 Oct' 1921. p379

26. Test report for 28/29 April 1921, sent to Mr Dupont on 30 May 1921. File No 017/0006/002, Laird Archives

27. Patent No 177,885 (1921); Outside Jacket formed with Grooves. Cammell Laird, Sir G.J. Carter, D.M. Shannon and L.G. McFarlane

28. Letters between Lairds and the Still Company dated Jan' 1922. File No 017/0006/001 Laird Archives

29. Various letters and memos between 1922 and 1925 contained in File No 017/0006/001 Laird Archives

30. Letter from A.B. Gowan, Managing Director of Palmers) to Cammell Laird dated 8 October 1925; File No 017/0006/001 Laird Archives.

31.***The Motor Ship***, vol 2, June 1921. pp80-4; **The Motor Ship Reference Book for 1925**, Temple Press, 1925. pp34-5; MacGibbon, **Marine Diesel Engines**. pp332-43

32. Letters between Lairds and Monsieur Dupont of Ateliers during May and June 1921; File No 017/0006/002, Laird Archives.

33. Various letters between Lairds and R.R. Row between 1922 and 1924. File 017/0006/000

34. Cable from Row dated 1 June 1924; File No 017/0006/000, Laird Archives

35. Letter to Hitchens dated 5 June 1924; File No 017/0006/000, Laird Archives

36. Copy of a quotation by Row dated 6 May 1924; File No 017/0006/000. Laird Archives

37. ***Shipbuilding and Shipping Record***, vol 22, 18 Aug' 1923. pp481-93

38. Internal Cammell Laird Memo dated Sept' 1923 listing all Fullagar engines then under construction; File No 017/0006/000, Laird Archives

39. 1st Trials Committee Report, I.Mech.E., 1924, vol II

40. 2nd Trials Committee Report, I.Mech.E., 1925, vol I

41. 3rd Trials Committee Report, I.Mech.E., 1926, vol I

42. 4th Trials Committee Report, I.Mech.E., 1926, vol I

43. 5th Trials Committee Report, I.Mech.E., 1926, vol II

44. 6th Trials Committee Report, I.Mech. E., 1931

45. 5th Trials Committee Report, I.Mech.E., 1926. pp1133 & 1154

46. ***Lloyds Weekly Casualty Reports*** 9 Oct' 1925; see appendix 2.

47. Confidential letter from Birkenhead office to London office dated 30 oct' 1925. File No 017/0006/000, Laird Archives.

48. Copy of a letter from D.S. Pinnington, chief engineer of **Malia**, to Messrs A. Goodwin, Hamilton & Adamson Ltd, dated 28 Dec' 1925; File No 017/0006/000, Laird Archives

49. Ker Wilson, "*History of Opposed-Piston Engine*", p184

50. Licence dated 23 oct' 1920; File No 017/0006/001, Laird Archives

51. Ker Wilson, "History of Opposed-Piston Engines", p184 and pp196-7

Chapter 4.e

Scott Engines (Still and Straight Diesel)

The Still engine as devised by W.J. Still was more of a concept than an actual engine although his patents did show details of an engine design[1]. The basic points behind the Still patents were minimising heat loss and maximising power output. Heat recovered from cooling water and exhaust gas could be used for the generation of steam which could then be employed in power production by means of steam cylinders. Advantages of the Still engine were widely publicised at the end of WWI[2] by which time a number of shipbuilders had taken an interest. From the taking out of the original patent Still had worked on his idea, rights to the patents being lodged in the Still Engine Company. That concern obviously believed it had a winning idea but was reluctant to draw any attention to it during the war, "*It has not been advisable during the past four and a half years to allow publication...*".[3] Some experimental work was carried out by Still's company using a gas engine but the war hindered further progress.[4]

One of the earliest expressions of interest came from Dennys of Dumbarton and during the war, with the consent of the Admiralty, it was arranged that an experimental Still installation would be built to fit in the hull of a shallow draught boat **Meccano** initially intended to carry Sulzer engines[5]. The two Still engines were actually built by T.A. Savery of Birmingham under instruction from Dennys because of the pressure of work at the shipbuilders; Yarrows provided the boiler. These engines were of the opposed-piston crosshead type with four cylinders 178mm bore by 380mm combined stroke; the space between the pistons operated on diesel oil whilst steam acted on the back side of each piston. Exhaust ports for the diesel part of the engine were at the lower end of the liner whilst scavenge ports were uncovered by the upper piston. A solid fuel injection system was fitted to each engine and as they started and were manoeuvred on steam no air starting system was required. The boiler worked at a pressure of 10.35bar. Design was in accordance with Still's ideas, water being drawn from the lower part of the boiler and circulated through a heat exchanger, heated by engine exhaust gas, before passing to the engine jacket system. Heat was extracted from the cylinder liners before the fluid, by now a mixture of water and steam, passed back to the boiler.[6] Trials of the

Still installation were carried out and results later compared with those from a Sulzer plant fitted in the same ship in 1922; no view was expressed as to which was the better engine system. No other Still installations were put in hand, even though the licence was retained, and so it can only be concluded that Dennys believed that a straight diesel system was preferable. William Denny became a director of The Still Engine Company and retained that position during the early 1920s.[7]

Scotts' Shipbuilding and Engineering Company of Greenock took an early interest in the marine diesel engine with a FIAT licence being obtained in 1912; engines of trunk piston and crosshead type were offered[8], engines of the former category being intended for submarines and it was that use which primarily interested Scotts in the FIAT licence. Although submarine application was of main concern two large engines were built in 1914 for the fleet tanker **Servitor** but they were the only crosshead FIAT engines constructed by Scotts.[9]

The war limited contact with FIAT but Scotts was keen to maintain its diesel engine interests and so in 1916 an agreement was reached with the Still Engine Company for a licence but it was not until 1919 that construction commenced on an experimental single-cylinder Still engine.[10] Initial intentions were that Scott-Still installations developed from the experimental engine should cover the power range 522kW to 5,220kW with single or twin screws and a reasonable number of cylinders; the specification was, it can be seen, rather open. The single cylinder engine, 559mm bore by 914mm stroke, was intended to develop 261kW when running at 120 rpm, with a capability of producing 298kW on overload. It was considered desirable to work the steam side compounded and so a single cylinder high pressure steam unit, 356mm bore by 559mm stroke, was constructed and coupled to the crankshaft; it was intended that the steam side of a full Still engine would work on the compound principle.[11] In the important respects of heat transfer and recovery the experimental engine followed the Still patents, cylinders and pistons being ribbed in order to maintain strength but provide for optimum heat transfer from cylinder to coolant. Detail design, however, was undertaken by Scotts and several features will have resulted from the efforts of that concern's design team rather than from the Still company. The crosshead pin was supported on a continuous bearing which allowed for a larger bearing surface and low stress in the oil film. Solid fuel injection was used, timing being controlled by a cam, whilst scavenge air came from an electrically driven turbo-blower. In terms of heat recovery the basic Still idea had to be revised as it was considered that the Cochran boiler used as the regenerator would not have sufficient surface area.[12]

The basic Still idea was to utilise heat in the exhaust gas and in cylinder cooling to generate steam; water from a boiler was circulated around a heat exchanger through which engine exhaust gas passed and this water then flowed to the diesel engine cylinder jacket where further heat was obtained. In the cylinder jacket temperatures would be high enough to convert some water into steam and the mixture of steam and water passed back to the boiler. Steam from the boiler would be applied below the combustion piston to produce power and give a double-acting effect, at the same time cooling the piston. Because the cylinder jacket was cooled by water and steam at high temperature improved combustion cylinder efficiency could be expected with less risk of thermal stress. Where necessary oil firing of the boiler could maintain steam production at reduced engine power.[13]

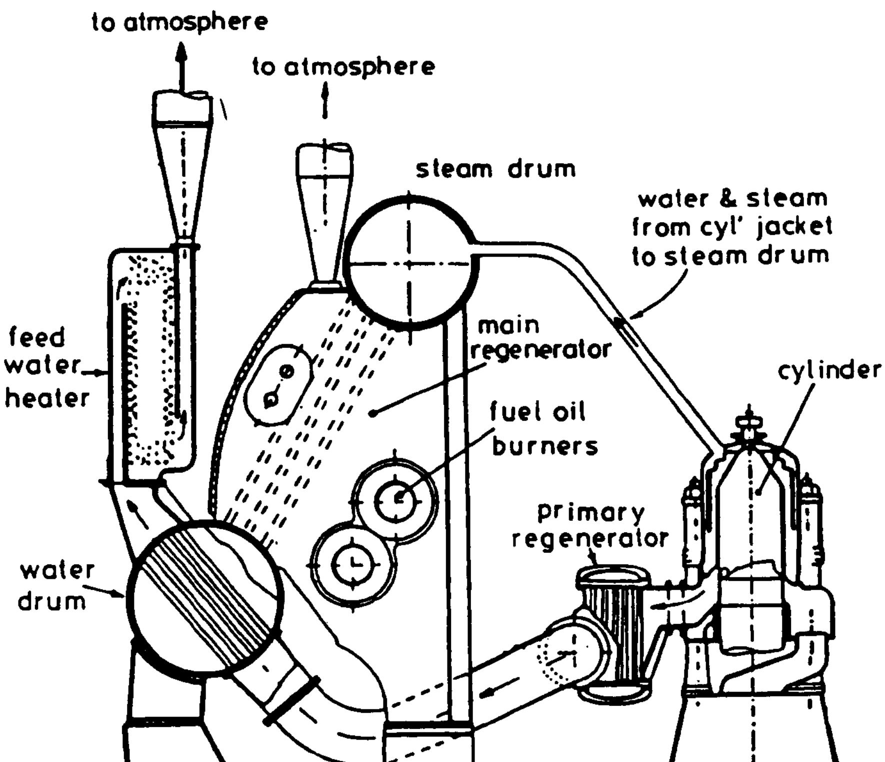


Fig 4.e.1 Arrangement of Still Engine System

Because of the higher temperature of the engine cooling water, about 177°C, it was important that temperature difference between the water and the inner wall of the liner be maintained as small as possible in order to minimise thermal stress and reduce cylinder lubrication problems. This was achieved by using a ribbed thin section liner strengthened by means of mild steel hoops, the arrangement being covered by a Still patent[14]; it was that patent which the Laird Fullagar engine is said to have infringed (see chapter 4.d).

The experimental Scott-Still engine was the subject of extensive testing during 1921 at various loads and using different grades of fuel; results were generally favourable, certainly favourable enough to persuade Scotts to take the idea further.[15] During these tests the internal combustion piston was modified a number of times in order to determine the ideal crown profile for optimum scavenging.[16] There is reason to believe that Scotts' designers were responsible for solid fuel injection being employed as Still himself had doubts about that form of fuel injection. In his paper of 1924 he refers to "*our use of solid injection*" and then goes on to explain his objections to the system.[17] Extensive experimentation was carried out at Scotts with different types of injector and forms of atomizer until the engineers were satisfied that they had the best possible arrangement. These fuel injector tests produced considerable data and some unexpected problems, particularly with respect to detonation.[18]

Successful running of the experimental engine prompted Scotts to consider a full sized installation and Blue Funnel Line (Alfred Holt & Co) agreed to give the engine a try on the understanding that Scotts would replace the Still engine with steam plant if the experiment was not successful.[19] Holts had been customers of Scotts since 1865 and, through its engineering superintendent, S. B. Freeman, was keen to experiment with different types of diesel engine in order to determine the most satisfactory. A typical Alfred Holt cargo steamer, subsequently named **Dolius**, was chosen for the experiment, there being nothing out of the ordinary about the ship apart from its machinery installation; the contract was signed early in 1922[20]. In order to provide sufficient power a twin screw arrangement was chosen, the four-cylinder engines having the same bore and stroke as the single cylinder experimental version. In all major respects the design was the same. Rotary blowers, driven by steam turbines, provided scavenge air, exhaust steam from the cylinders driving the turbines. No starting air system was required as the engine could be started on steam alone, the airless injection fuel system operating when firing speed was reached. As a consequence air compressor and air receiver capacity only had to be provided for the auxiliary diesel engines. Steam inlet and exhaust valves were of the piston type being actuated by hydraulic means from a distributor; a single oil pump supplied sufficient oil to actuate valves on both engines. Following from the scheme adopted for the experimental engine a system of compound working of the steam side was used, the aftermost cylinder taking high pressure steam at about 8.3bar and the other three cylinders employing low pressure steam exhausting from the HP cylinder. The installation was described in detail in the second report of the Marine Oil Engine Trials Committee, as were the results of those trials.[21]

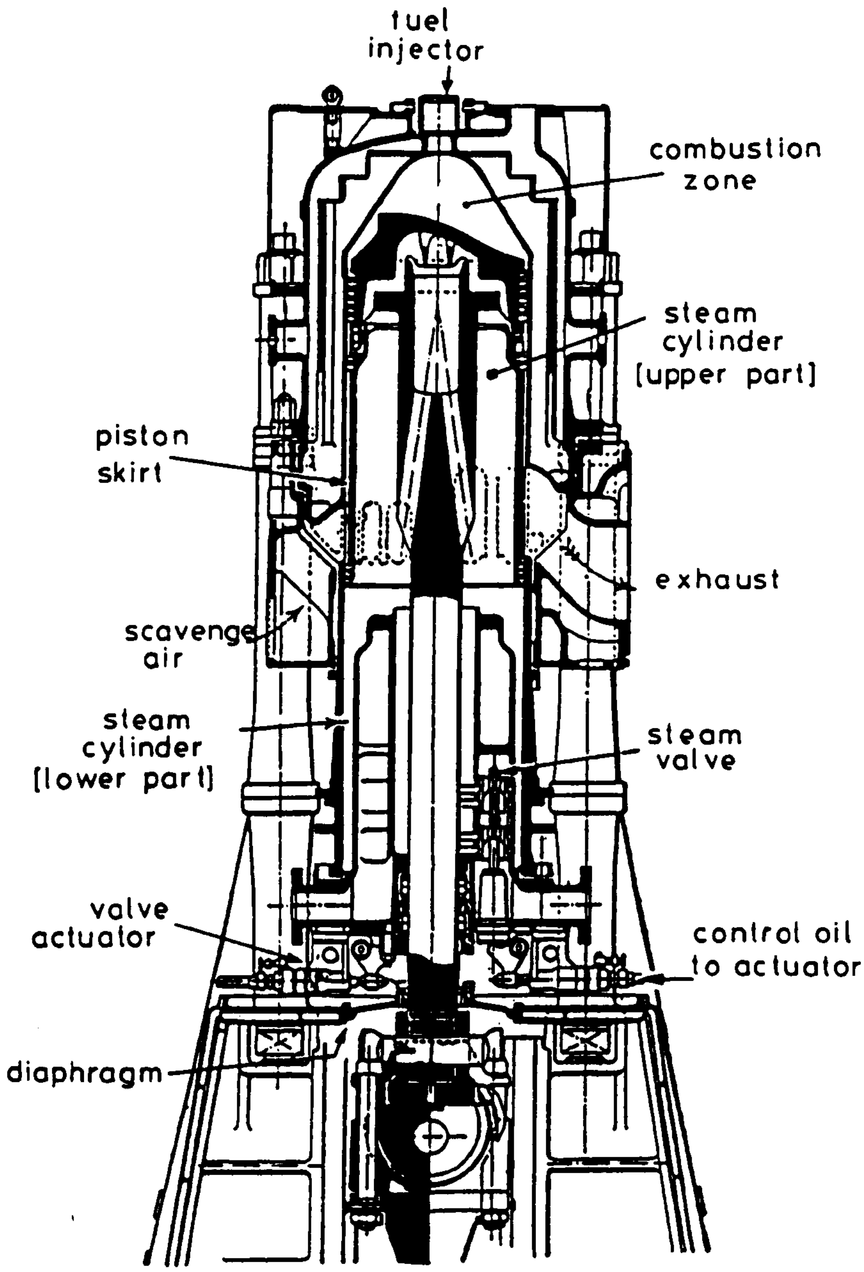


Fig 4.e.2 Arrangement of Cylinder for **Dolius** Scott- Still Engine

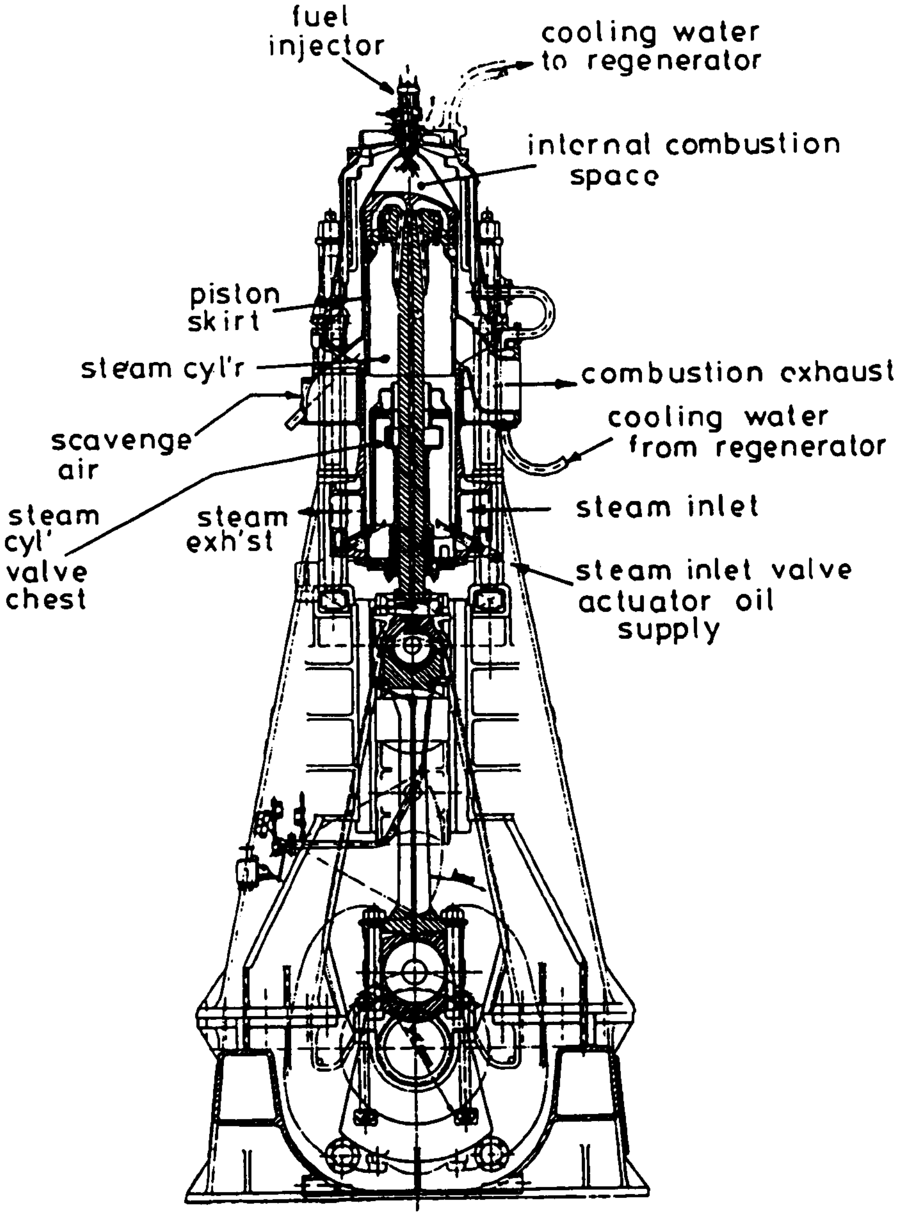


Fig 4.e.3
Section through Cylinder of Dolius Engine

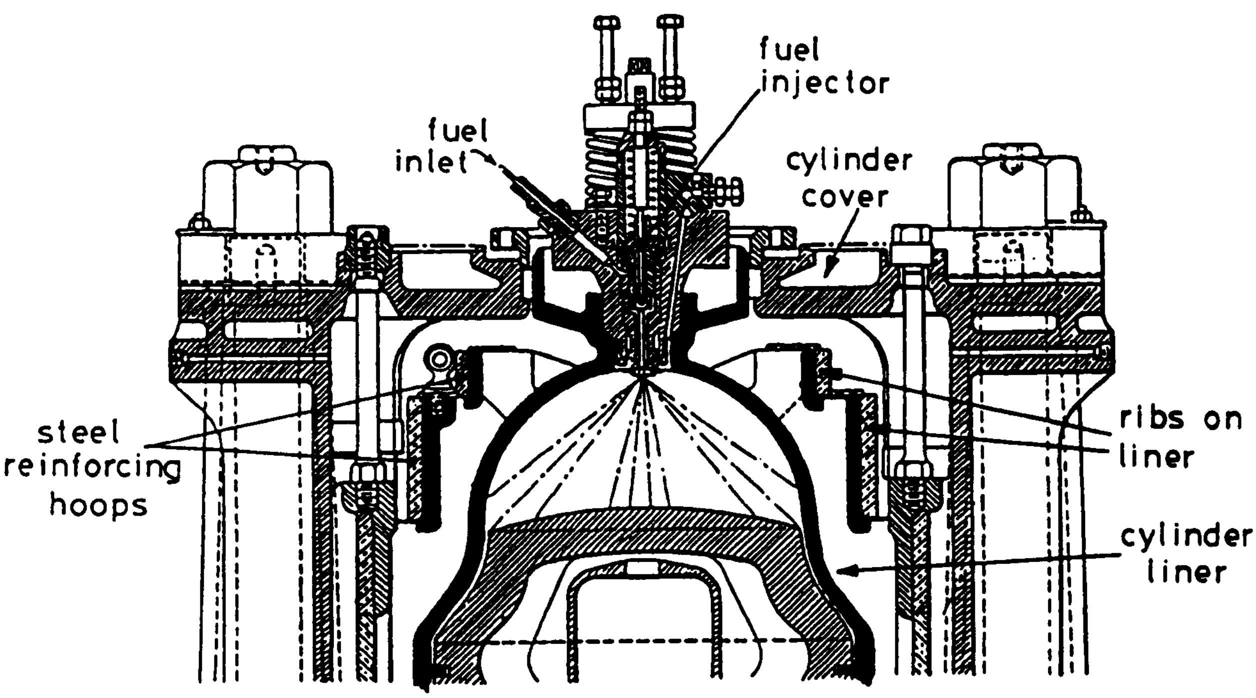


Fig 4.e.4 Cylinder Cover of Dolius Engine

The maiden voyage of **Dolius** took place during April and May 1924, all indications being that the machinery installation was both economic and reliable. Fuel consumption averaged 8.4 tons per day for a speed of 11.45 knots, this figure being good for a ship of 11,370 tons displacement. On the test bed the port engine developed 1,063kW, the specific fuel consumption being 0.217kg/kW.hr which compared very favourably with other diesel engines then in service; at sea, with the ship doing 12 knots, the engines developed a total of 1,816kW for a specific fuel consumption of 0.28kg/kW.hr[22]. Problems did occur in service, but they were not so great as to turn either the engine builder or the owner away from the Still concept and plans were laid for a second ship with more powerful machinery.

The twin screw **Eurybates**, built in 1928, had a different design of Scott-Still engine although the basic Still heat recover system remained. With a view to ensuring reliability and low operating costs separate steam and diesel cylinders were employed, there being five internal combustion cylinders and two steam cylinders to each engine. The internal combustion part of the engine utilised heat recovery features of the Still system but there were a number of important departures from the design used for **Dolius**. With no steam acting below the internal combustion piston a separate water cooling system had to be provided. In order to prevent contact between scavenge and exhaust whilst the piston was near the top of its stroke a rotary valve in the exhaust line was used, this also controlled exhaust timing. Fuel pumps for all five cylinders were positioned on a single block at the back of the engine, drive for these pumps being by means of a gear train from the crankshaft.

The two steam cylinders were double-acting and could be used to start the engine as well as provide power to the crankshaft during normal operations; steam supply pressure was 12.4bar and compounding was not employed. Slide valves controlled steam supply to and exhaust from these cylinders, drive for the valves being by means of long rods actuated by linkages from the crankshaft. The steam generating part of the installation also differed from **Dolius** as exhaust gas from the auxiliary engines was also supplied to the high pressure boiler, operating at a pressure of 12 bar; this boiler could also be oil fired when necessary. Jacket cooling water, at about 1 bar pressure, circulated through a regenerator giving up heat to boiler feed water, this low pressure arrangement being designed to minimise leaks in the jacket system which had been under full boiler pressure in the original design. Cylinder jackets from the auxiliary engines also connected with the regenerator. Turbines driving the scavenge air blowers were supplied with a combination of high pressure steam and exhaust steam from the engine cylinders. The three-cylinder auxiliary engines were of crosshead type and operated on the two-stroke cycle; cylinder bore being 241mm and stroke 381mm. These small engines differed from the propulsion engines and they could be considered as a separate Scott design. Shop trials with the propulsion engines showed that the port engine consumed fuel at the rate of 0.228kg.kW.hr when developing 1,854kW whilst the starboard engine consumed 0.232kg/kW.hr when developing 1,850kW.[23]

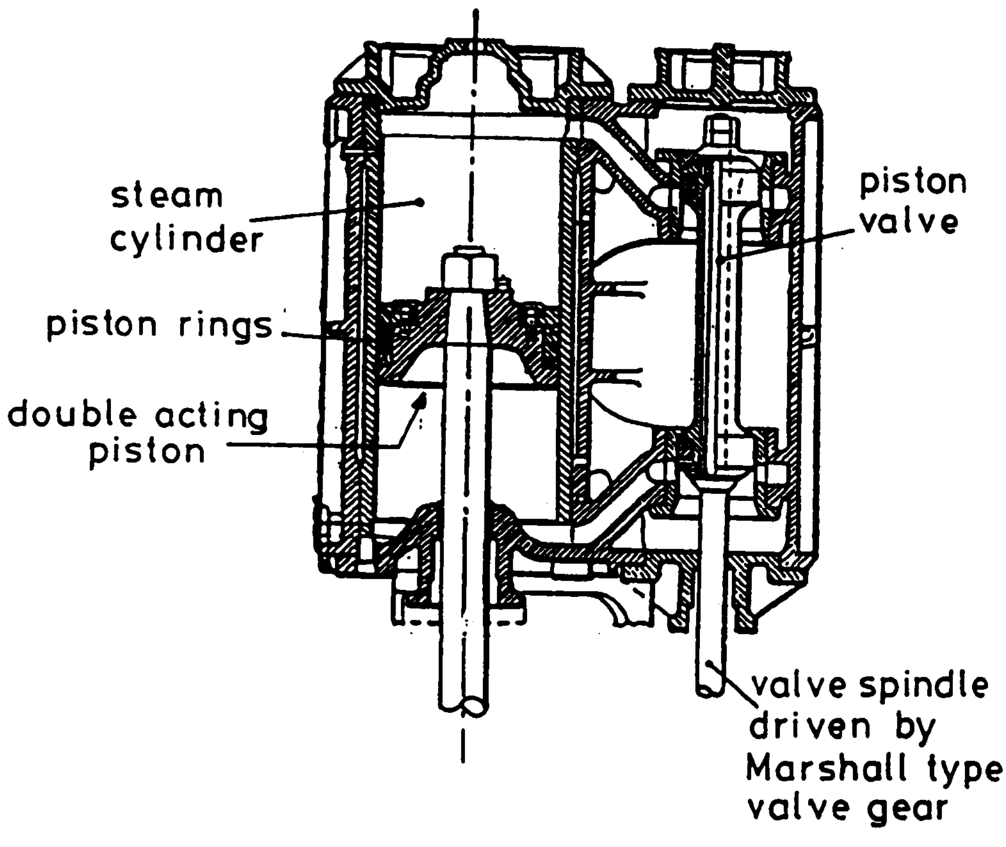


Fig 4.e.5 Steam Cylinder of **Eurybates** Scott-Still Engine

Early service showed economy matching that of **Dolius** but difficulty was experienced maintaining full power without burning fuel in the boiler.[24] **Dolius** was lost during WWII but **Eurybates** survived, however, by the late 1940s a considerable amount of effort was needed to keep her engines in effective order. Piston cracking was an almost constant source of trouble and during one Atlantic crossing towards the end of WWII she cracked all pistons in one of her engines.[25] Burning of pistons was so severe at times that it reduced cylinder compression ratio making ignition of the fuel difficult due to the low cylinder temperature.[26] With completion of war service and after careful consideration of several alternative proposals it was decided to remove the complicated Still heat recovery equipment and replace the two steam cylinders with scavenge pumps. The engines became five cylinder two-stroke diesels of the Scott type with scavenge pumps replacing the steam cylinders as the turbo-blowers were removed with other items of the steam plant. Expectations were for a further 10 to 15 years service and fuel savings of 1,000 tons per year. The Chief Superintendent Engineer also believed that, "*..the ship is now manned by contented engineer officers.*"[27]

Neither Scott-Still engined ship can be really classed as a success in engineering terms although they were relatively economic for the owners. They were not liked by the engineers due to the wide variety of plant on board which needed constant attention.[28] After the war a former Blue Funnel employee wrote his memoirs and made the comment that as **Dolius** was sinking after being torpedoed the engineers in one of the lifeboats all cheered. Blue funnel demanded, and received, a retraction[29] but the fact that the statement could be made indicates that the Scott-Still machinery was not popular.

Diesel parts of the plant fitted in **Eurybates** were effectively engines in their own right and Scotts developed a design along those lines. The Scott family was linked by marriage to the Swire family and these connections were probably used to get the first engine installed in the China Navigation Company's **Anshun**; over the years Scotts had built many ships for that concern which was controlled by the Swire family.[30] Cylinder design was similar to that of the later Scott-Still engine but the stroke was increased. The rotary exhaust valve not only controlled exhaust timing but it also enabled a shorter piston skirt to be used thereby reducing engine height. A pair of double-acting scavenge pumps, rotating at 1.5 times engine speed, was positioned between the two groups of three cylinders. Piston and cylinder construction followed that of the Scott-Still engine, oil cooled pistons being profiled to obtain optimum scavenging of the cylinder. Each cylinder had its own solid injection fuel pump, these being arranged in two groups of three at the back of the six-cylinder engine. A separate forced lubrication system applied to fuel pump cam boxes in order to avoid fuel contamination of the main system. Timed cylinder lubrication was provided.[31]

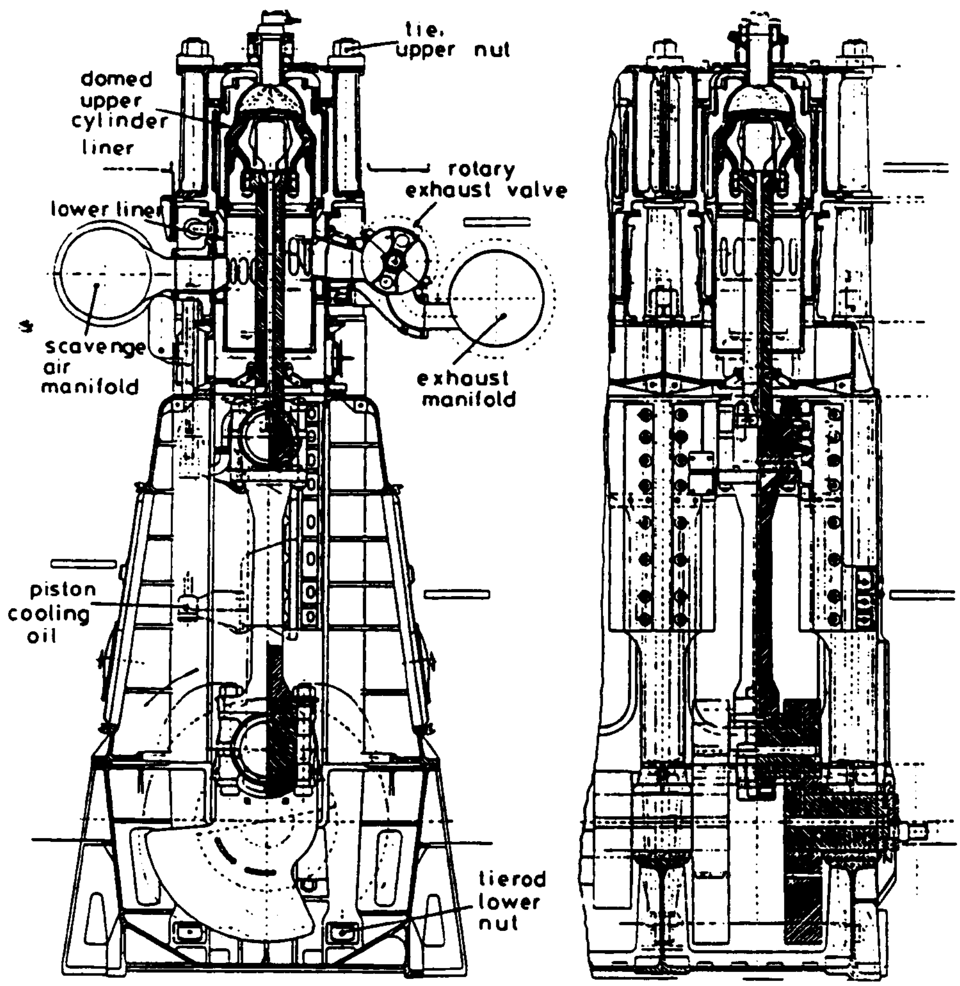


Fig 4.e.6 Section through Scott Two-Stroke Diesel Engine fitted in **Anshun**

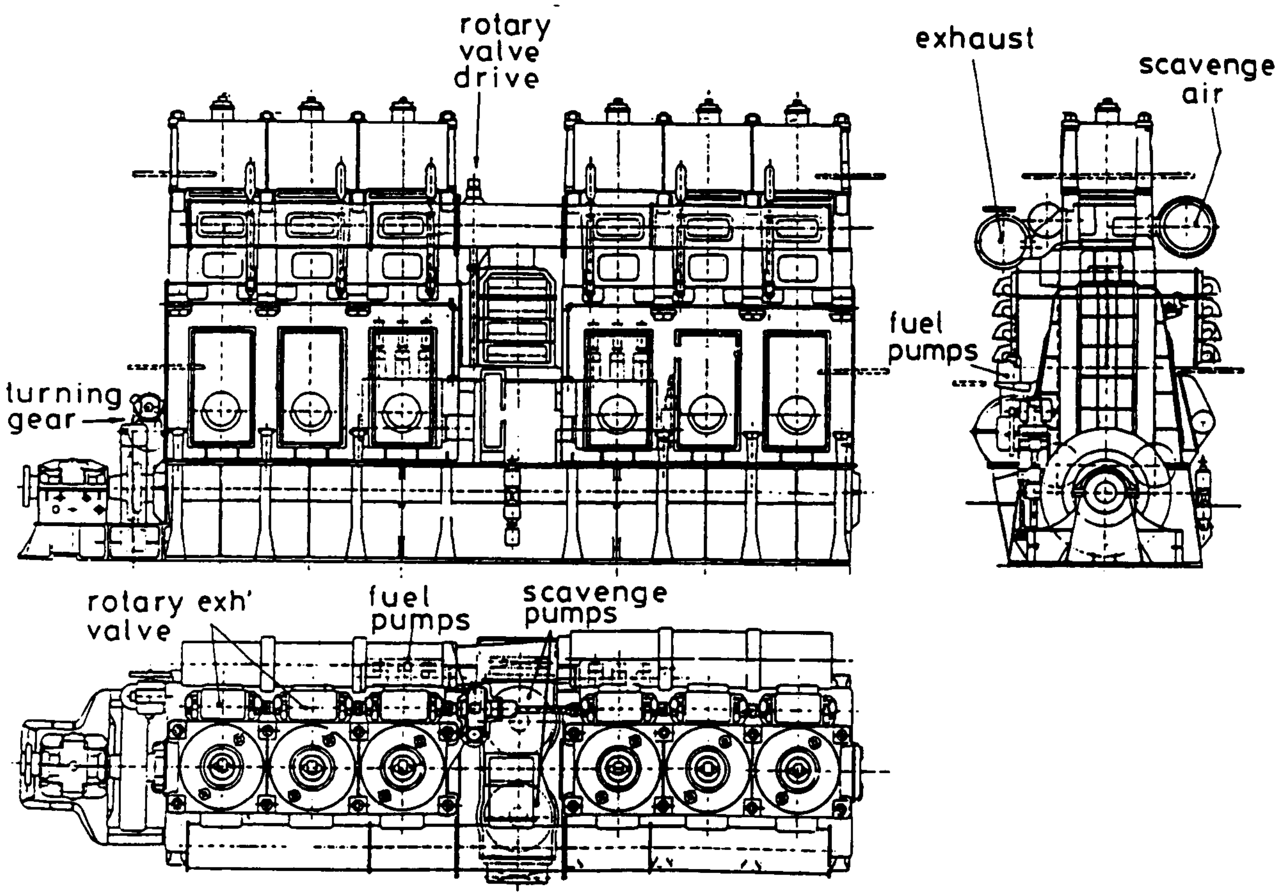


Fig 4.e.7 Arrangement of Scott Diesel Engine Fitted in **Anshun**

A smaller version of the engine was developed a few years later but only two were built, these being placed in China Navigation Company vessels. Minor changes in design included placing the scavenge pumps at the forward end and positioning of scavenge trunking below the cylinders.[32] That the company was willing to develop an independent diesel engine is indicative of the enterprise of what was still a family shipbuilding concern. A considerable amount of money and time was invested in these engines and there must have been some optimism that the market could support another diesel engine. They do not appear to have been unreliable engines as they stayed in each of the ships until they were scrapped, unfortunately there is little service information available as pre-war records were lost during the war and post war records were destroyed when the company rationalised in the 1970s.[33] The fact that only three of the straight diesels were built is not a reflection on the design but is indicative of the strength of Scotts' naval shipbuilding work. From the delivery of **Yunnan** to the outbreak of WWII Scotts launched five merchant ships and 12 for the Admiralty.[34]

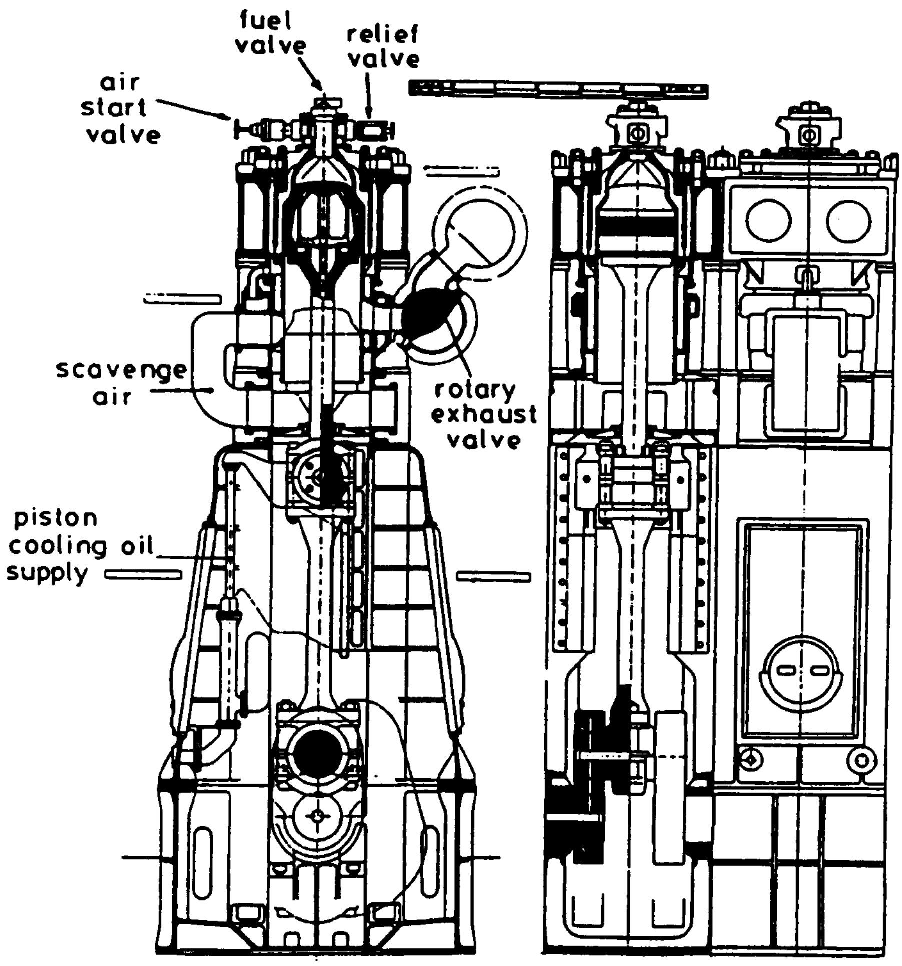


Fig 4.e.8 Modified Scott Two-Stroke Diesel Engine fitted in **Yochow**

Table 4.e.1.

Scott Engines						
Vessel	**Year**	**Ship Builder**	**Type**	**Cylinder Size(mm)**	**Power kW**	**RPM**
Dolius	1924	Scotts	Still (two)	4x559x914	933	120
Eurybates *	1928	Scotts	Still (two)	5x686x1143 2x610x1143	1,865	105
Anshun **	1930	Scotts	2SSA	6x686x1118	2,238	112
Yochow ***	1933	Scotts	2SSA	5x559x914	932	116
Yunnan ****	1934	Scotts	2SSA	5x559x914	932	116

Source: Scott Shipbuilding Records, Ballast trust, Johnston, Scotland

* Steam cylinders replaced by diesels 1947

** Sold by China Navigation Company 1946; broken up 1966 after serious damage to ship.

*** Sold by China Nav' Co. 1960; broken up 1972

**** Sold by China Nav' Co. 1959; broken up 1971

In a paper presented during 1925 J.A. Sim[35] of the Still Engine Company intimated that the Still engine was ideal for use in trawlers as steam would be available in sufficient quantities for the trawl winch whilst slow speed operation using the steam part of the engine would be possible. Sim had in mind the Plenty-Still engine, built by Plenty & Sons of Newbury, which was aimed at coasters and small ships. The company constructed a single cylinder experimental engine during 1925 and due to the need to separate the steam cylinder from the crankcase a crosshead arrangement had to be used, Plenty normally building trunk piston engines. The 370mm bore by 450mm stoke experimental unit developed 112kW at 250rpm, steam pressure at the engine being about 3 bar to 4 bar. Although engine design was influenced by the usual Plenty practice the heat recovery system followed that employed with the Scott-Still engines fitted in **Dolius**. Steam supply to and exhaust from the steam cylinder was via caged poppet valves.[36]

Driving force behind the Plenty-Still engine was H. Kent-Norris (Managing Director at Plenty Diesels)[37] but in 1928 a decision was taken to set up The Plenty-Still Oil Engine Company independent of Plenty & Sons, Ltd. The first and only service Plenty-Still engine was built at Newbury and delivered in January 1928 for the drifter **Larus**.

This engine had three cylinders of bore 280mm and stroke 355mm being capable of developing 224kW at 300rpm. Scavenge air came from an engine driven pump and a form of the standard Scott-Still solid fuel injection was used. During shop trials trouble was experienced with the fuel injectors but the engine could still produce a specific fuel consumption of 0.262kg/kW.hr. **Larus** entered service in 1928 and the engine worked well initially but after a year problems developed and the owners were unwilling to allow time for them to be solved. The engine was removed and returned to Newbury.[38]

Still engines had a short and variable career. The idea was sound in that fuel economy was of paramount importance during the early years of diesel engine application to marine propulsion but as diesel engines became more efficient the advantage of the Still design was lost and its complication became a hinderance not a help.

References

1. Various British patents were taken out by Still, the most important being No 7,146 (1910), No 6,047 (1910), No 25,356 (1910), & No 28,472 (1911)

2. F.E.D. Acland, "*A New Prime Mover of High Efficiency and British Origin*", Journal of the Royal Society of Arts, vol 67, June 1919. p463-82: W.J. Still, "*Type of Still Engine Required for Marine Service*", Trans' NECIES, vol 40, 1924-5. p393-438

3. Acland, "*A New Prime Mover*". p465

4. Acland, "*A New Prime Mover*". p469

5. D.J. Lyon, **The Denny List, part III**, NMM, Greenwich, 1973. ship 1071

6. W. Denny, "*Comparative trials of Still and Sulzer Engines under Actual Working Conditions on Board Ship*", Trans' I.N.A., vol 62, 1920.p286-8

7. Letter headed paper of The Still Engine Company gave a list of directors; letters from Still Company to Cammell Lairds during 1922; File No 017/0006/001, Laird Archives, Wirral Archives, Birkenhead.

8. Advertising pamphlet for Scott- FIAT diesel engines dated 1913; Ballast Trust, Johnstone, Scotland

9. Scotts' of Greenock, **Two Hundred and Fifty Years of Shipbuilding**, Glasgow, 1961. p193

10. Two Hundred & Fifty Years of Shipbuilding, . p90 & p193-4

11. A. Rennie, "*The Still Engine for Marine Propulsion*", Trans' I.E.S.S., vol 65, 1921-2. p415

12. Rennie, "*The Still Engine*". pp412-31

13. Acland, "*A New Prime Mover*". pp466-9

14. F.L. Martineau, "*The Still System of Internal Combustion Engine for Marine Purposes*", Trans' I.Mar.E., vol 34, 1932. p41

15. Rennie, "*The Still Engine*", pp446-52

16. A.I. Nicholson, "*Some Oil Engine Experiments*", Trans' IESS, 1922-3. pp 376-81

17. W.J. Still, "*The Type of Still Engine Required for Marine Service*", Trans' NECIES, vol 40, 1923-4. pp408-9

18. Nicholson, "*Some Oil Engine Experiments*". pp362-76

19. Information supplied by Johnston Robb, former Scotts General Manager(Engineering) and Naval Director

20. ***Engineering***, vol 113, 10th Feb' 1922. p177

21. Second Report Marine Oil-Engine Trials Committee, Proc' I.Mech.E., 1925, vol 1. pp439-542

22. ***The Marine Engineer and Motorship Builder***, June 1924. pp232-3

23. ***The Motor Ship***, vol 8, March 1928, pp455-9

24. A.G. Arnold, "*Diesel Engine Propulsion of Cargo Liners-Development and Maintenance*", Trans' I.Mar.E., vol 62, No 4, 1950. p149-52

25. Information supplied by W.H. Falconer, former Chief Superintendent Engineer of Blue Funnel

26. Comment by David Stables, former Blue Funnel Superintendent Engineer

27. Arnold, "*Diesel Engine Propulsion for Cargo Ships*" . p153

28. Comment by W.H. Falconer, former Blue Funnel Chief Superintendent Engineer

29. Information supplied by David Stables, former Blue Funnel Superintendent Engineer

30. Details of connections between the Swire and Scott families can be found in Marriner & Hyde, **The Senior, John Samuel Swire 1825-98**, Liverpool University Press, 1967.
also information supplied by Charlotte Haviland, archivist to John Swire & Co, London, 1992

31. ***The Motor Ship***, vol 11, December 1930. p390-3; ***The Marine Engineer & Motorship Builder***, vol 53, December 1930. p455-9

32. ***The Motor Ship***, vol 14, Jan' 1934. p376-8

33. Information supplied by Charlotte Haviland, archivist to John Swire & Co, Ltd. 1992

34. Information supplied from Scotts` records; compiled by George Gardiner, The Ballast Trust, Johnston, Scotland

35. J.A. Sim, "*The Economic Application of the Still Engine*", Trans` I.Mar.E., vol 37, 1925. pp677-691

36. ***The Marine Engineer & Motorship Builder***, vol 48, Nov` 1925. p397: vol 49, June 1926. p211-5

37. ***The Marine Engineer***, vol 63, March 1940. p67

38. P.J. Humphreys, **Marine Diesels in Newbury**, published by the author 1989. pp 13-4

Chapter 4.f

The Richardsons Westgarth Double-Acting Engine

In 1912 Richardsons Westgarth (R-W) partly built the Carels engine installed in the pioneer British motorship **Eavestone** but war interrupted further diesel involvement. A Werkspoor licence taken out in 1912 lapsed but Doxford and Beardmore-Tosi licences were obtained after the war. At the 1923 annual meeting of shareholders the Richardsons Westgarth chairman, D.B. Morison, mentioned that development work was taking place on a high powered engine and that £100,000 had been set aside for the work.[1] R-W had Beardmore-Tosi engines under construction and during 1924 engines installed in the Furness, Withy ship **Sycamore** were tested by the Marine Oil-Engine Trials Committee.[2] Even at this stage the Richardsons Westgarth board appears to have realised that the high cost of engine development was better spread amongst a number of interested concerns as in July 1924 an announcement was made concerning the formation of the Internal Combustion Engine Development Company. Partners in the venture were to be R-W, the ship and engine builders Beardmore of Dalmuir, the shipowners Furness Withy, and the Italian engine designers Tosi. Although a large sum of money was involved in the formation of the company its aim was not to earn dividends but to carry out experimental and research work.[3] Apart from this announcement nothing further was heard of the company although development work was undertaken on the Tosi engine, however, that forms no part of the R-W double-acting engine story.

Acting on its own Richardsons Westgarth, through its diesel design engineer W.S. Burn, investigated the possibilities of high power generation from a two-stroke double-acting engine. Burn believed that this type of engine would in the end be lighter, simpler and cheaper than a single-acting design[4] and he received the backing of his directors. A considerable effort must have been expended on design as details of the engine, and a single-cylinder experimental unit, were publicised during May 1926.[5]

This experimental engine was tested extensively during 1926 giving very promising results, it being possible to develop some 597kW from the 680mm bore by 1200mm stroke cylinder when running at 90rpm. The design was publicised and praised by both technical press and engineers.[6] Actually the engine was constructed as a two-cylinder unit but only one of them was a working cylinder, the other containing no parts. The second cylinder, closed in at top and bottom, acted as a receiver for scavenge air supplied by an electrically driven blower.[7] Why the company went to the cost of erecting a structure for two cylinders, only one of which worked, was not explained; a simple container would have been a less costly method of providing a scavenge air receiver. It is possible that a two-cylinder experimental engine was intended but costs mitigated against; alternatively it may have been realised that experimental data could be obtained from a single cylinder just as readily.

Operation of the experimental engine confirmed that a full sized version would have a higher power to weight ratio than a single-acting engine and, using the experimental unit as a basis, R-W indicated that a six-cylinder engine capable of developing 4,960kW would weigh only 345 tonnes.[8] A 24 day trial carried out in September/October 1927 completed the period of experimentation and the company was then in a position to market the design. Using a single cylinder size it was expected that engines would be offered ranging from 1,790kW for three cylinders to 7,460kW with nine cylinders. A 2,240kW four-cylinder prototype engine was planned, design being the same as the experimental engine but with crankshaft driven scavenge pumps instead of the electrically driven blower.[9]

Richardsons Westgarth had orders for Doxford engines and the prototype was delayed but when it did appear there were only three cylinders which developed 933kW. During 1928 the Blythswood Shipbuilding Company received an order for a small tanker and the owner was persuaded to have a three-cylinder version of the R-W double-acting engine installed. This engine was built for the ship and was not a prototype constructed for the purpose of testing and then fitted in a ship.[10] Cylinder dimensions were smaller than for the experimental engine but the basic arrangement was retained. Identical covers were used for upper and lower cylinders, the central section in the lower cover accommodating a gland whilst in the upper cover it held an insert housing the air start valve. Distilled water cooling applied to pistons, covers and liners, the liner temperature being maintained relatively low, about 50^{0}C, in order to minimise lubrication problems. Each cylinder cover was provided with two fuel injectors, there being one fuel pump to each pair of injectors. Fuel pumps were positioned at bottom platform level, their camshaft drive being by means of two horizontal connecting rods attached to cranks on the forward end of the crankshaft. Axial movement of the camshaft allowed for reversal.

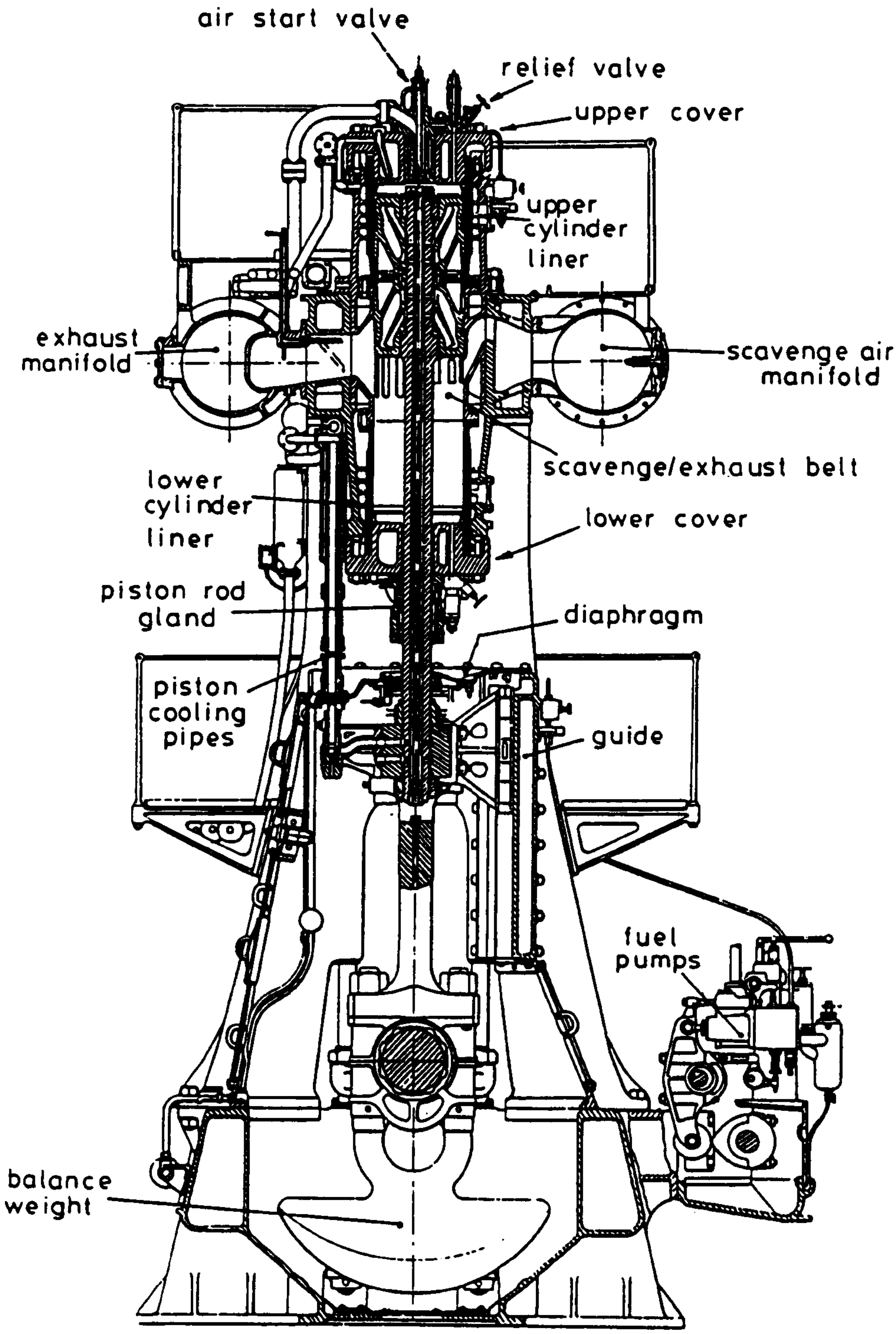


Fig 4.f.1 Section through Richardsons Westgarth Double-Acting Engine

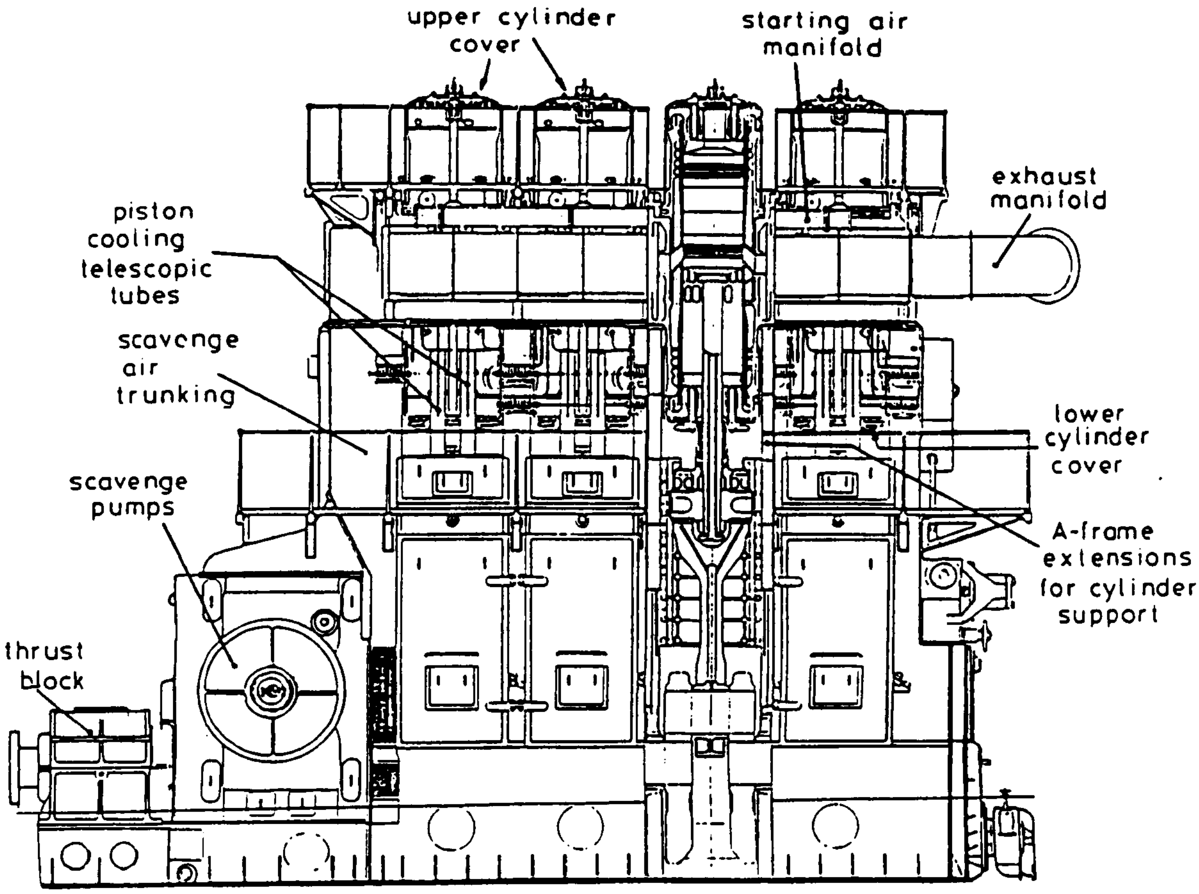


Fig 4.f.2 Layout of Four-Cylinder Richardsons Westgarth D-A Engine

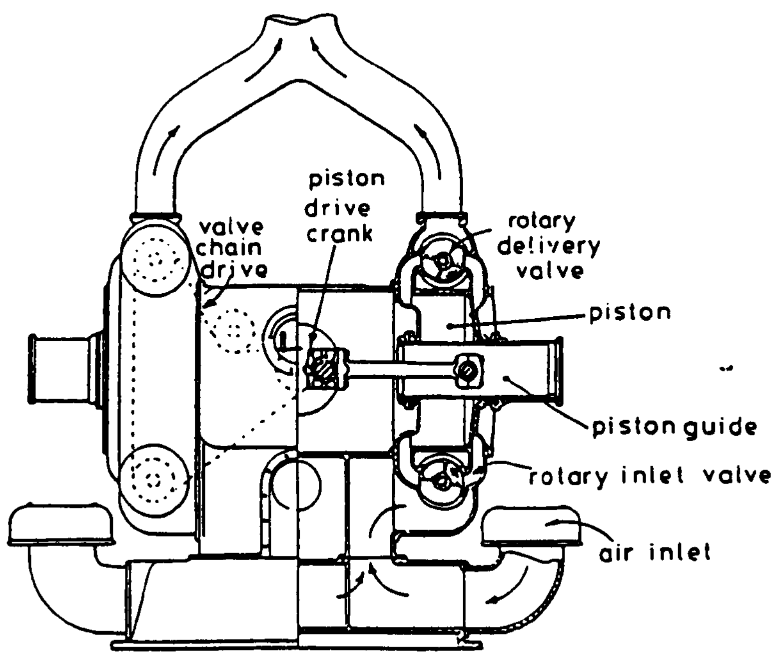


Fig 4.f.3 Richardsons Westgarth Scavenge Pump

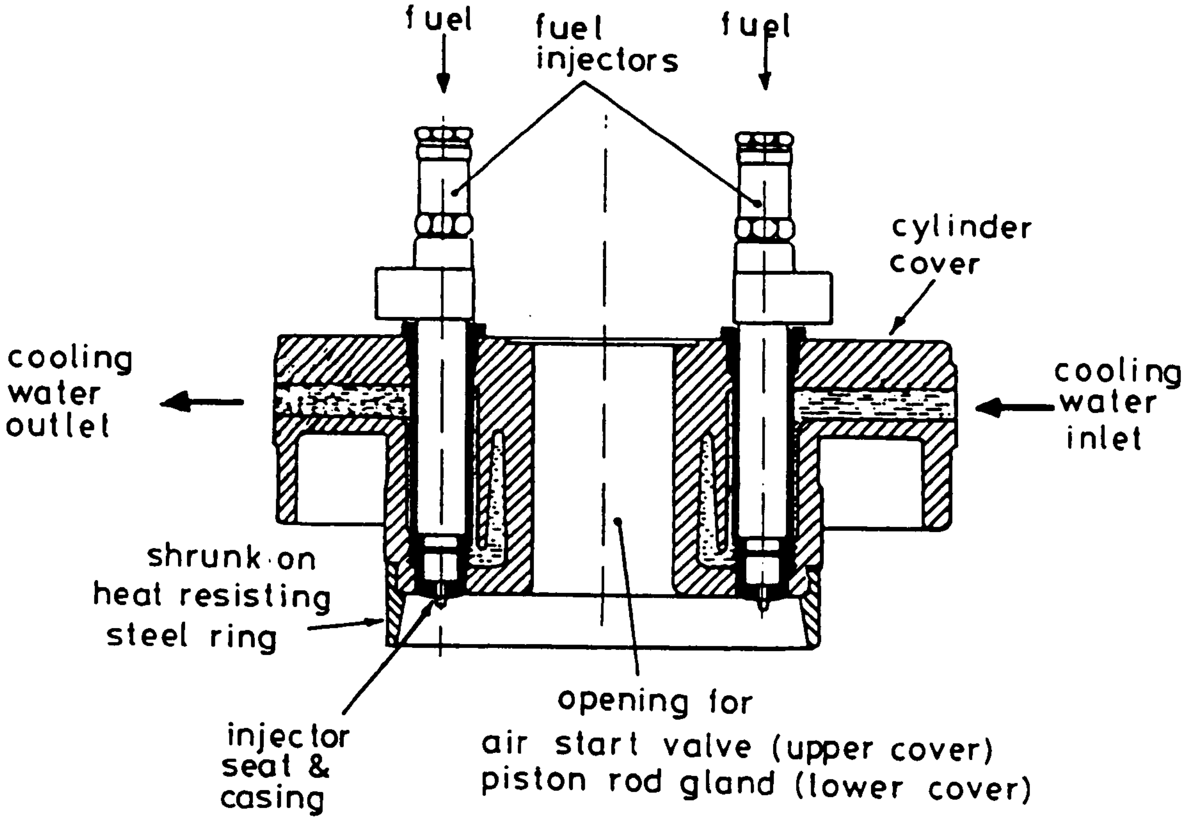


Fig 4.f.4 Richardsons Westgarth D-A Engine Cylinder Cover

A cam and rocker arrangement also applied to the starting air system, rotation of the eccentric shaft on which the rockers were located allowing the cylinder starting valves to be made operational or put out of service. Each valve had separate ahead and astern cams. At starting compressed air was applied to the upper cylinders only and when firing speed had been reached fuel was initially only directed to the lower cylinders as these were not cooled by starting air application; this ensured ready starting of the engine and simplified the starting air arrangements. Scavenge air was provided by a pair of double-acting, horizontally opposed scavenge pumps driven from the crankshaft at three times engine speed by means of helical gearing.

The bedplate was of the flat bottom box girder type with a self contained oil sump. A-frame columns, also of box section, were made in two parts vertically for ease of casting, these being used to locate the guide bars and support the entablature. The guide bars were fitted at the front of the engine whilst pairs of tie bolts passed through holes in the A-frames from the upper face of the entablature to the underside of bedplate transverse girders. Cylinder liners were cast in three sections, upper and lower combustion liners being identical and bolting with the central section of liner. This central section, containing scavenge and exhaust ports, was located in the entablature which accommodated scavenge and exhaust passageways to the respective trunking. Exhaust port bars were water cooled and that entailed a complex casting design which had been the subject of considerable research and experiment.[11]

The engine showed early promise with specific fuel consumption only being 0.2kg/kW.hr during the return passage on **Irania**'s second voyage between Britain and the Black Sea although Burn believed that the general consumption would be around 0.24kg/kW.hr.[12] One problem did occur during the first year and that was fracture of the scavenge pump crankshaft on 21 June 1929. The ship had to be towed to Gibraltar where a temporary repair was executed.[13] The only other major problem was seizure of No 2 piston in August 1929 due to a fault in the cooling system. The ship made port with two cylinders working.[14]

Richardson Westgarth went so far as to advertise a range of double-acting engines, there being four different cylinder sizes available in three-, four-, five- and six-cylinder versions, powers varying from 1,063kW for the smallest three-cylinder engine to 4,476kW for the largest type.[15] Plans had changed slightly from that envisaged when the experimental engine was under test but the company remained optimistic and in 1930 Burn intimated that a high-speed, short-stroke version had been designed and a three-cylinder engine of the type, capable of developing 750kW at 300rpm, was then under construction.[16] Nothing else was reported of this engine and so presumably the project was abandoned before it progressed very far. However, Burn, and presumably the R-W board, still believed in the double-acting concept despite the lack of orders caused by the depression. Faith in the design's technical merit and commercial competitiveness prompted continued experimental work and the single-cylinder experimental engine was re-erected in 1932 and brought up to date. New features included improved fuel injection system, control gear and manoeuvring equipment whilst composite pistons with steel ends were constructed. Oil cooling was introduced for the pistons and a redesigned liner fitted, this allowing for a supercharging effect and air turbulence. These modifications aimed at a reduction in fuel consumption and improved reliability.[17]

The shipping depression certainly made orders difficult to find and it was not until 1935 that any were forthcoming. Two Silver Line ships, **Silverpine** and **Silverlarch**, fitted with Swan Hunter Neptune engines and previously employed on liner routes across the Pacific, had been laid up in 1930, high fuel consumption and maintenance costs mitigating against their use as tramps.[18] In 1934 it was decided to modernise the ships and fit more economical propulsion units, the compact size, low weight and high power output of the R-W double-acting engine made it an ideal choice particularly as the builders were "*....prepared to agree a very rigid form of contract .... in view of the experimental nature of the engine.*"[19]

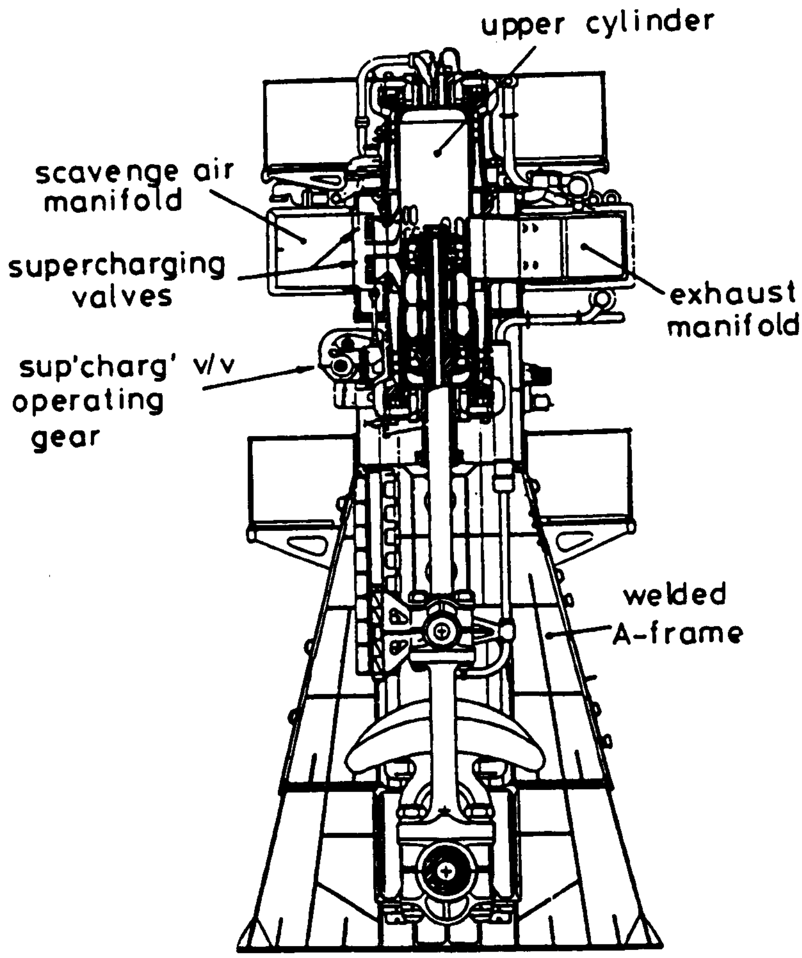


Fig 4.f.5 1930s Richardsons Westgarth D-A Engine with Welded Frames and Supercharging Valve

The new engines had four cylinders but the basic arrangement was the same as that for the earlier engine, modifications to pistons, liner, fuel system and control gear being included. Welding of bedplate and frames reduced cost and weight.[20] Protection for the piston rod was provided by a shrunk on ring of Hadfield's Era steel whilst a sleeve of the same material offered protection to the liner in the combustion space. Liners and covers were salt water cooled, water being circulated by an impeller pump chain driven from the crankshaft; the pump also supplied seawater to the lubricating oil cooler.[21]

Despite the success of these new engines no further orders were forthcoming, however, development work continued; Burn and his employers appear to have been perpetual optimists. In 1938 Richardsons Westgarth amalgamated with The North Eastern Marine Engineering Company (N.E.M.) and further development on the engine entrusted to N.E.M.[22] A 2,240kW three-cylinder design was offered in 1941, this being of standardised dimensions, 699mm bore and 1,200mm stroke.[23] Again no orders were forthcoming despite the urgency of wartime ship construction, or maybe because of the urgency of wartime needs. Late in WWII the final two engines were built. These had five cylinders of the same dimensions as the engines fitted in **Silverpine** and **Silverlarch** and so could develop proportionately more power. Pistons remained oil cooled but jackets and cylinder covers reverted to distilled water cooling. Fuel pumps were modified to incorporate N.E.M. ideas and injectors of C.A.V. standard pattern were used. Apart from these features and a new design of piston which had no exposed nuts there was little to distinguish the engine from the 1935 product.[24]

Table 4.f.1

Richardsons Westgarth Engines

Vessel	Year	Ship Builder	Type	Cylinder Size(mm)	Power kW	RPM
Irania	1929	Blythswood S.B. Co	2SDA	3x546x965	933	90
Silverpine	1924	re-engined 1935	2SDA	4x699x1200	2,984	110
Silverlarch	1924	re-engined 1935	2SDA	4x699x1200	2,984	110
Empire Chancellor	1945	J. Laing & Sons	2SDA	5x699x1200	3,357	105
Empire Inventor	1945	J. Laing & Sons	2SDA	5x699x1200	3,357	105

Source: Various editions of **The Motor Ship** and **Lloyd's Register of Shipping**

All engines built after that fitted in **Irania** had the same cylinder dimensions whilst those offered fitted into a limited range of dimensions thus allowing for the advantages of standardisation. Unfortunately the rate of ordering was insufficient to profit from this. Over the years some redesign had taken place but they were of parts rather than the engine concept and the company held faith in that double-acting idea. The engine did have a good power to weight ratio and was comparatively short for the power it developed. Although no figures for cost are available there is reason to believe that costings would have been competitive, the company being keen to establish the engine as can be seen from its rigid agreement with Silver Line. In the end Richardsons Westgarth double-acting two-stroke engine had little impact upon the market despite the time and money which were obviously spent over the years. With no licensees and a relatively small shipbuilding base to support the engine it stood very little realistic chance in the highly competitive marine engine building market which existed between the wars.

References

1. ***Shipbuilder and Shipping Record***, vol 21, 31 May 1923. p693

2. First Trial Report, Marine Oil-Engine Trials Committee, Proc` I.Mar.E, 1924, vol II, pp863-94

3. ***Lloyds List Weekly Shipping Summary***, 9 July 1924.

4. W.S. Burn, "*High Powered Engines*", Trans` NECIES, 1926. p325

5. ***The Marine Engineer & Motorship Builder***, vol 49, May 1926. pp165-70

6. W.S. Burn, "*High Powered Oil Engines*", Trans` NECIES, vol 42, 1925-6. p325-69; W.S. Burn, "*Double-Acting Engines*", Trans` I.Mar.E., vol 38, 1926. p281-325

7. ***The Motor Ship***, Oct` 1927, vol 8. p262

8. ***The Marine Engineer & Motorship Builder***, vol 49, May 1926. p165

9. ***The Motor Ship***, vol 8, Oct` 1927. pp262-3

10. ***The Motor Ship***, vol 9, March 1929. p467

11. W.S. Burn, "*Development and Performance of the Richardson-Westgarth Oil Engine*"`, Trans` NECIES, 1929. p29-68; ***The Engineer***, vol 147, 8 March 1929. p274-6

12. Burn "Developments & Performance of the R-W Engine", p60 and log extract, plate I

13. Lloyds Weekly Casualty Reports, 29 June 1929; also Burn *"Development & Performance of the R-W Engine"*. p34

14. Lloyds Weekly Casualty Reports, 22 Aug' 1929; Burn *"Development & Performance of the R-W Engine"*. p34-5

15. ***The Marine Engineer & Motorship Builder***, vol 52, March 1929. p110

16.Paper by Burn *"The Trend in Design of Double-Acting Two-Stroke Oil Engines"* read at the 2nd World Power Conference in 1930, reported in ***The Marine Engineer & Motorship Builder***, vol 53, Sept' 1930. pp333-6

17. W.S. Burn, *"Some Developments in British Oil Engine Design"*, Trans' I.Mar.E., vol 45, part 5, 1933. p147-8

18. R.C. Thompson, *"Modernizing the Motor Vessels* ***Silverpine*** *and* ***Silverlarch****"*, Trans' NECIES, 1936. p215

19. Thompson, *"Modernizing* ***Silverpine*** *and* ***Silverlarch****"*. p 219-20

20. ***The Motor Ship***, vol 16, July 1935. p127

21. ***The Marine Engineer***, July 1936. p183-93.

22. ***The Engineer***, vol 179, 11 May 1945. p369

23. ***The Motor Ship***, vol 21, January 1941. p314-5

24. ***The Engineer***, vol 179, 11 May 1945. pp369-70;
The Motor Ship, vol 26, May 1945. pp53-7

Chapter 4.g

The Alfred Holt Engine

The idea of a standard marine diesel engine attracted support from some people in the marine industry very soon after WWI when the internal combustion engine started making real inroads in terms of ship propulsion. At the start of the 20th century the triple-expansion steam reciprocating engine was essentially a standardised product which varied little from builder to builder. For some people the same should have been true for the diesel engine as that would then bring economy of scale in terms of production and security in the obtaining of spares.[1] Others believed that each builder should adopt his own ideas as that would lead to competition and improvement, a "universal" engine would be a compromise with little prospects of improvement due to the absence of competition.[2]

Blue Funnel Line took a considerable interest in the types of engines used for propelling its ships and actively pursued improvements in performance and economy. Within that concern there was a keen interest in the idea of a "universal" engine provided that it would meet company requirements. One of the directors, Lawrence Holt, and the Chief Engineering Superintendent, S.B. Freeman, both spoke in favour of such an engine. During the 1920s B&W and Werkspoor engines were favoured by Blue Funnel for diesel propulsion of its ships but the engineering department was not prepared to accept what engine builders provided without question. Using what were considered to be the best ideas from engines already in the fleet, and others from elsewhere, an engine design was developed at Blue Funnel's head office in Water Street, Liverpool; the design became known in the company as the "Water Street Engine".[3]

This four-stroke single-acting engine generally followed North Eastern Marine - Werkspoor practice but it was supercharged on the Buchi system. Use of separate cylinder liners and square form of cylinder head were B&W ideas, as was oil cooling for pistons. Air injection of fuel was adopted despite the fact that airless injection was by that time, 1930, becoming accepted practice.[4] The engine cannot really be classed as a British design as it simply made use of standard items already in use and actually designed for overseas engines, but its introduction does indicate ingenuity and the search for an ideal propulsion unit. Only eight engines were built, these going into four standard Blue Funnel cargo liners, but that was a larger number than some British designs. Description is not necessary as individual parts were of overseas design but the "Water Street" engine is included as the concept was British and it was an idea which no other organisation, shipbuilder, engine builder or ship owner, adopted.

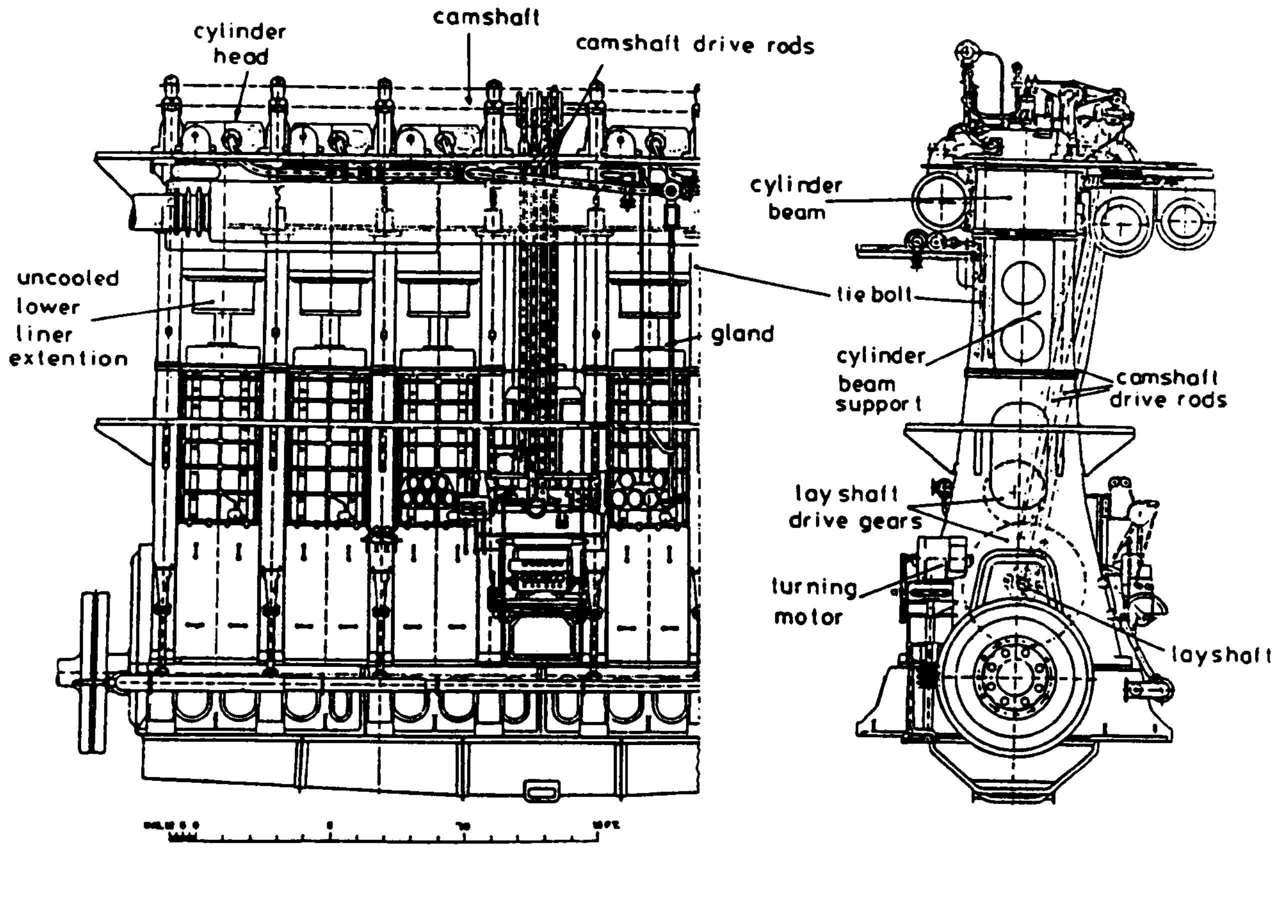


Fig 4.g.1 Alfred Holt "Water Street" Engine

North Eastern Marine built the engines for **Maron** but the others were constructed by Scotts at Greenock. These engines attracted considerable attention in the shipping and engineering community because of their novelty, particularly with respect to supercharging, and prior to installation **Maron's** port engine was put under test by Prof' Hawkes of Armstrong College, Newcastle.[5] **Polyphemus** was the subject of the sixth trial of the Marine Oil-Engine Trials Committee.[6] Both tests were for finding information rather than forming judgements as to the merits of particular engines, but overall the conclusion was favourable. In service they performed well being reliable and economic. Tentative plans were made to convert the engines to solid fuel injection, which would have improved performance, but delays in making the decision and the coming of WWII prevented that action being taken. All four ships fitted with these engines became casualties of war and the experiment ceased, however, the venture was considered to be a success.[7] The fact that no other engines of the type were constructed for Blue Funnel was not a reflection on the design nor the concept but was due to a number of factors. The deep shipping depression of the 1930s had a serious effect on the fortunes of Alfred Holt & Co., bringing it close to bankruptcy, and no new ships could be contemplated for a number of years.[8] After that there was the problem that non-standard engines do not fit easily in a large fleet.

Table 4.g.1.

Source: The Motor Ship vol 10, 1930; Proc' I.Mech.E. vol 121, 1931.

During post-war years Blue Funnel adopted a universal engine of sorts in that for many years it almost exclusively installed opposed-piston engines of the type developed by

Harland & Wolff. Even then design details were insisted upon and many items applied only to engines built for Alfred Holt and Company. At Kincaids, who had a B&W sub-licence from Harlands, there were separate drawings used for the "Holt" engines.[9,10]

References

1. ***The Motor Ship***, vol 2, August 1921. p148

2. Comments by D. Kemp, manager of the engine department at Palmers Shipbuilding & Iron Co. reported in ***The Motor Ship***, vol 7, May 1926. p38

3. A.G. Arnold, "*Diesel Engine Propulsion for Cargo Liners - Development and Maintenance*", Trans' I.Mar.E., vol 62, No 4, 1950. p149

4. Arnold, "*Diesel Engine Propulsion*". p153-4

5. ***Engineering***, vol 129, 28 Feb' 1930. p 280-3; ***The Motor Ship***, vol 10, March 1930. p495-9

6. Proceeding I.Mech.E, vol 121, Nov' 1931. p183-309

7. A.G. Arnold, "*Diesel Engine Propulsion*". p154

8. F.E. Hyde, **Blue Funnel - A History of Alfred Holt & Co.**, University of Liverpool Press

9. Information supplied by Andy Crawford, former Kincaid apprentice and Blue Funnel superintendent engineer.

10. Details of these Blue Funnel variations may be found in Arnold's paper "*Diesel Engine Propulsion of Cargo Liners*"

Chapter 4.h

Harland & Wolff Engines

As discussed in chapter 1, Harland and Wolff became sole British Empire licensees for B&W engines during 1917 and moved engine development work from the Clyde to Belfast in 1921; the story of the Harland & Wolff (H&W) marine diesel engine is a Belfast affair and closely linked with Burmeister and Wain of Copenhagen. Harland & Wolff had a keen interest in diesel engines before the links with B&W, licences for Krupp and M.A.N. engines having previously been taken whilst a six-cylinder crosshead Sulzer had been purchased in order to provide electrical power for the Queen's Island site in Belfast.[1] It was, however, the links with B&W which evolved over the years into what has been described as ".. *a partnership of equals*", particularly with respect to developments in the 1930s.[2] How equal that partnership really was is difficult to define as B&W was the licensor and Harlands the licensee but there was a considerable involvement on the part of Harlands in development of the opposed-piston, generally known as the coverless, engine.

Without doubt Harland & Wolff contributed to the success of the Burmeister & Wain engines not least by the fact that the company was such a successful shipbuilder. Successive chairmen, Lord Pirrie and Lord Kylsant, were both enthusiastic supporters of the diesel engine with Kylsant particularly furthering the cause by having diesel machinery installed in many of the Royal Mail Group ships constructed during the 1920-30 years of depression.[3] Direct involvement by Harlands in B&W engine matters came in the early 1920s after H.H. Blache, B&W's Technical Director, proposed a double-acting four-stroke engine as a means of developing the high powers needed for propelling large passenger liners. Lord Pirrie was attracted by the idea and agreed to divide the expenses involved in constructing a single-cylinder experimental engine of 840mm bore and 1500mm stroke.[4] The actual cost to Harland & Wolff was £16,000 and the engine was running in Copenhagen by 1923.[5]

The people in Belfast did more than contribute funding as F.E Rebbeck, General Manager of the engine building concern and subsequently chairman of Harland &

Wolff, lodged many patents, often in collaboration with V. Mickelsen, the Chief Engine Designer who had originally come from B&W in Copenhagen. These patents were for items claimed to improve the basic engines as designed in Copenhagen[6] but were not taken for general production. Ideas finding more favour involved airless injection and these were patented in the names of Rebbeck and G.L. Kirk[7]. During the 1920s Harland & Wolff initiated a series of airless injection experiments using engines installed aboard the Pacific Steam Navigation Company's vessels **Lautaro** and **Lagarto** engined by H&W at Finnieston in 1915 and 1917 respectively.[8] From these experiments a solid injection system was developed employing multiple pumps and mechanically operated spill valves, this arrangement being fitted to engines in a number of ships including the passenger liner **Reina del Pacifico** in 1931. In the words of Cuthbert Coulson Pounder, then Chief Draughtsman and subsequently Chief Technical Engineer at Harlands, "*But, true to practice, as soon as Burmeisters introduced an airless injection system, in 1931, H&W discarded their own arrangement and fell into line*".[9]

The views of Pounder are interesting as when he was appointed Chief Technical Engineer in 1933 he express the view that Harland & Wolff was, "*completely dependent upon B&W to the most insignificant detail.*"[10] This would indicate that despite the development work undertaken by the engineering staff at Belfast it was the licensor which controlled all matters relating to engine design; Pounder would have known how little influence Harlands had over engine design matters having entered the drawing office as a draughtsman in 1916.

Despite the fact that B&W controlled design matters Harland & Wolff did make an impact upon the engines in relation to their size and power; construction techniques had to be developed in order to enable these larger engines to be built and that also meant considerable work for the drawing office. With respect to the double-acting four-stroke engine Pounder stated, "*Within six years we had built engines more powerful and of longer stroke than those of our licensor.... In 1926 we pressure-charged, on the Buchi system, our four-stroke single-acting engines. Later we developed our own under-piston pressure-charged arrangements for these four-stroke engines. In neither of these developments were our licensors interested.*"[11]

The four-stroke double-acting engine brought diesel propulsion to the large passenger ships but there were problems, not least in terms of the engine's specific size and weight. Increased power for no increase in size or weight could be obtained from a two-stroke double-acting engine but development of such a power unit was rather forced upon B&W by a shipowner. The East Asiatic Company was a frequent customer for B&W ships and engines but the managing director, H.N. Andersen, suggested to H.H. Blache that B&W should take a licence for the recently introduced M.A.N. two-stroke double-acting engine. Blache was not impressed by this idea and responded that B&W would design and build an engine of that type and within two weeks East Asiatic placed an order for the single-screw vessel **Amerika** (1930), thus the B&W two-stroke double-acting engine was born. Design work was undertaken in Copenhagen with little input from Belfast, Blache being primarily responsible for many of the novel features including the use of piston valves rather than poppet valves. Initially a chain driven lay shaft was provided for operating these valves but after early experience a crankshaft eccentric drive was employed.[12] These engines proved to be extremely popular and were used extensively for propelling Belfast built ships including many passenger liners of the 1930s. Without doubt the links that Harlands had with major shipping companies and the confidence those companies had in H&W as a builder of quality ships and engines did much to popularize the B&W two-stoke double-acting engine.

Although Belfast had no part in designing the engine originally there was an input with respect to developments resulting from early operating experience. A meeting of senior engineers from B&W and H&W was held in Copenhagen during November 1937 to discuss criticisms from engine operators, these criticisms included overhauling problems, difficulties relating to cylinder covers and high initial cost. Pounder and his team held the view that problems relating to the cylinder covers could be overcome by eliminating them altogether and making the exhaust pistons of the same diameter as the cylinder. This would result in an increased power from the exhaust piston producing a higher first cost but reduction in exhaust piston stroke to 400mm from 600mm would minimise stress difficulties. B&W agreed to redesign the single-cylinder experimental engine they were then working on in the light of Harland's proposals and further agreed to construct a six-cylinder engine incorporating the ideas from Belfast.[13]

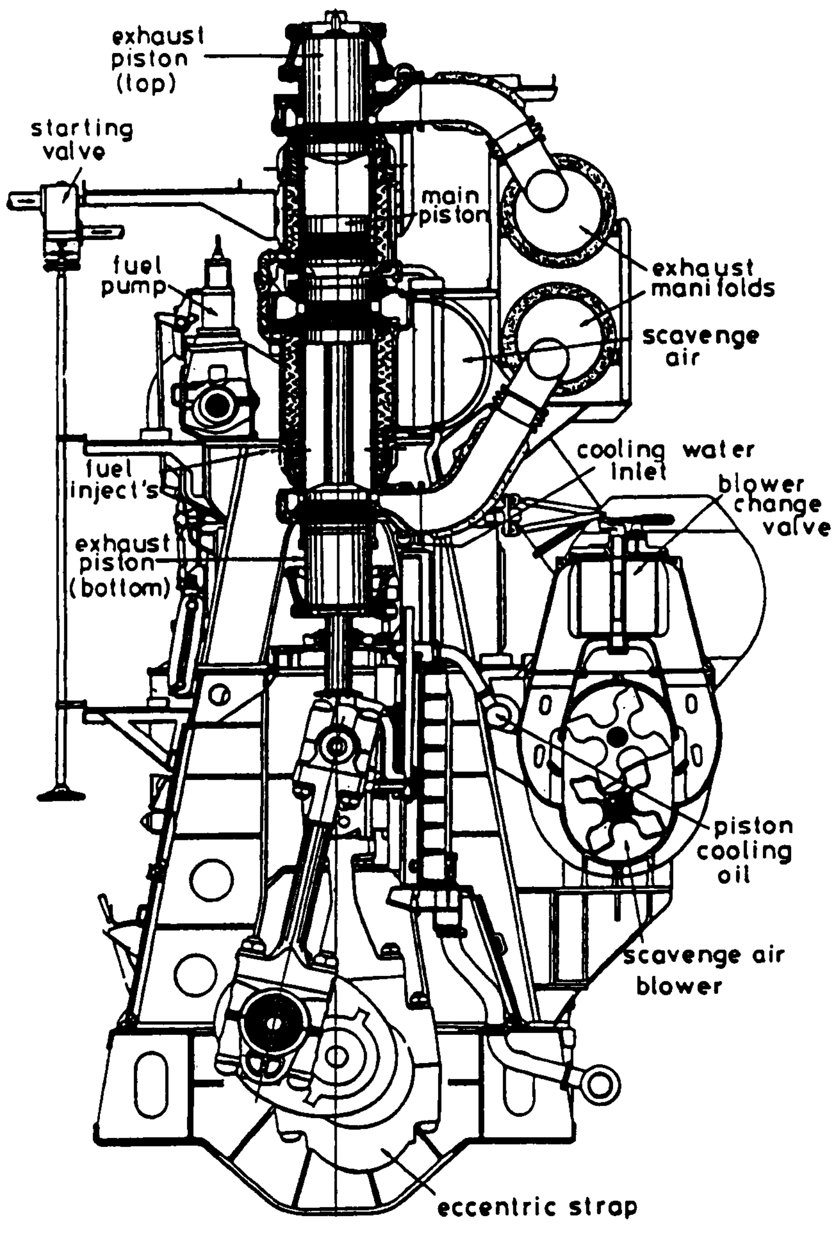


Fig 4.h.1 B&W Two-Stroke Opposed-Piston Double-Acting Engine

Harland & Wolff built the first of the modified two-stroke double-acting engines, also known as the coverless or opposed piston type, during 1944 and the last of the type in 1949. The main problems with the design, as with all double-acters, centred around the lower cylinder, particularly the piston rod and stuffing box; one engineering superintendent claimed that 85% of engine maintenance costs were for the bottom end of the cylinder.[14] Problems of this nature obviously forced consideration of a single-acting engine and whilst B&W concentrated their efforts towards a single-acting two-stroke engine with an exhaust valve positioned centrally in the cylinder cover Harland's engineers looked at developing an opposed-piston single-acting engine. The war somewhat forced the issue as communications with B&W engineers in occupied Denmark was not possible and so Harland & Wolff was very much on its own if it wished to make progress. The war did restrict matters, however, as permission for the construction of a prototype engine would not be forthcoming during the conflict and production was confined to existing designs. The first of Harland's single-acting two-stroke engines were built straight from the drawing board without experimentation.[15]

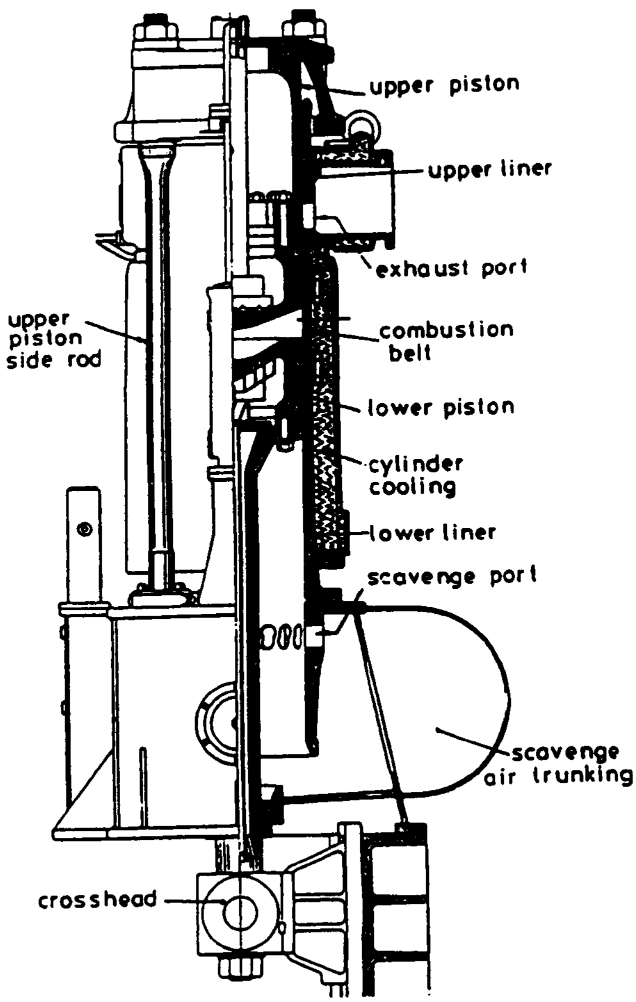


Fig 4.h.2 Cylinder of Harland & Wolff Opposed Piston Engine

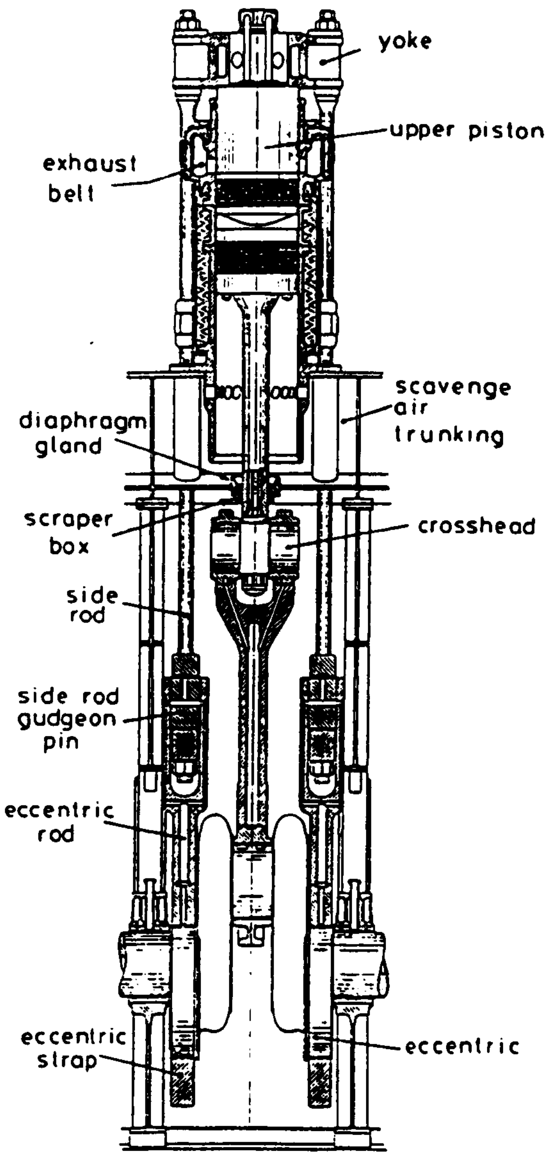


Fig 4.h.3 Section through Cylinder of H&W Opposed Piston Engine

In 1939 a patent was lodged by Rebbeck and Mickelsen for piston driving arrangements of a two-stroke single-acting opposed-piston engine, the lower piston being of the trunk type whilst the upper connected with its eccentrics via crossheads.[16] A further patent, in the names of Pounder and Rebbeck, was taken in 1941 for an alternative arrangement connecting the upper piston to its crossheads.[17] The system devised by B&W employed a yoke and two side rods but Pounder and Rebbeck proposed a square block at the piston with the use of four side rods, two for each crosshead; this allowed for closer spacing of cylinder centres with a consequent reduction in engine length and weight. The arrangement was generally adopted. Whilst the opposed-piston double-acting engine can be attributed to B&W there is no doubt that the single-acting version was very much a product of Belfast and this is accepted by people from B&W, although the general view seems to be that it was a case of simply using the upper cylinder portion of the double-acting engine.[18]

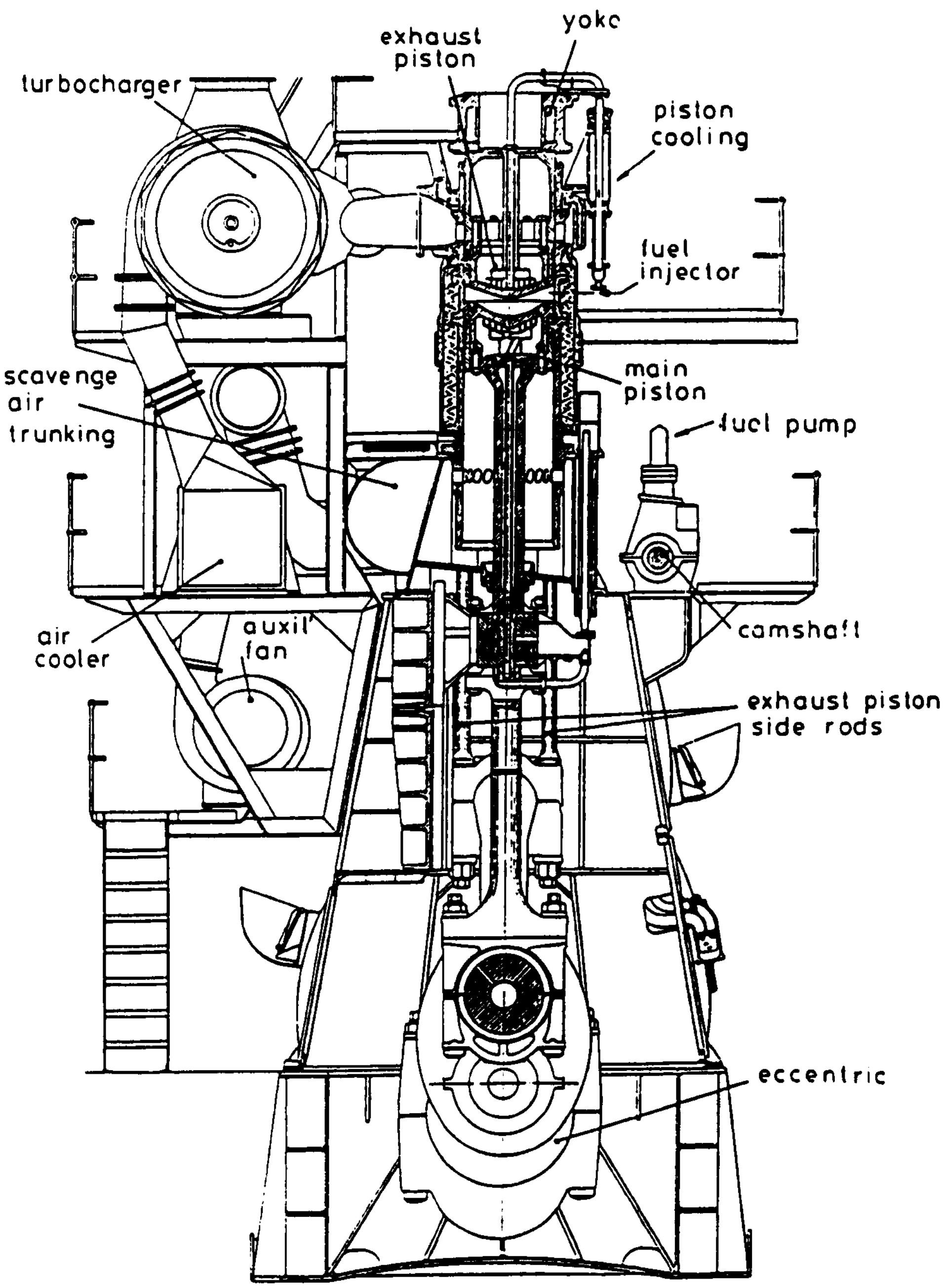


Fig 4.h.4 Turbo-charged H&W Opposed-Piston Engine

Pounder became an advocate of the opposed-piston engine and believed that most British shipowners, having had considerable experience of Doxford engines, preferred that type.[19] The first of these Harland engines entered service in 1949, having been constructed by the sub-licensee J.G. Kincaid & Co, and many were built over the next 15 years with certain owners, notably Blue Funnel Line and Bank Line, being particular enthusiasts. Two cylinder sizes were designed, 620mm bore by 1870mm combined stroke and 750mm bore by 2000mm combined stroke.[20] The Norwegian B&W licensee, A/S Akers Mek. Verksted, Oslo, also adopted the Harland opposed-piston format and designed an engine having a 500mm bore with 1500mm combined stroke. Akers built a number of the 500mm bore engines and a six cylinder version was built by B&W in Copenhagen; the only other engines of the type built in Copenhagen were two five-cylinder and one seven-cylinder engines of 750mm bore and 2300mm combined stroke.[21] This longer stroke version must have been a B&W development as it did not figure in the Harland scheme, the combined stroke was greater than for any of these engines built elsewhere. As part of the licensing agreement H&W had to declare all inventions and developments to B&W, who then had full use of these ideas and could pass them to other licensees.[22] Apart from the few engines built in Copenhagen only Akers and the sub-licensee, Kincaids, undertook to construct any single-acting opposed-piston engines.

The Harland & Wolff opposed-piston engine had its problems particularly with respect to the joints on the three piece cylinder liner. These difficulties became apparent when turbo-charging was applied during the mid-1950s and the solution lay in adopting an arrangement used by B&W for the earlier double-acting engines; this entailed holding the central combustion belt rigidly between upper and lower liner sections by means of alloy-steel studs. Other early problems with the engine involved cracking of eccentric straps and white metal bearings but attention to material quality soon minimised these troubles.[23] Application of turbo-charging improved engine performance and specific output whilst the application of gas compression fuel pumps simplified engine construction in that it eliminated the need for a camshaft to drive the fuel pumps.[24] Gas compression pumps were offered as an alternative to the standard camshaft driven pumps and some owners, particularly Blue Funnel Line, preferred this arrangement.[25]

Harlands adhered to the opposed-piston engine until the 1960s but with Pounder's retirement in 1964 production came to an end, and the engine building system reverted to the arrangement of the 1920s with Harland & Wolff building B&W designs. The end of opposed-piston construction did not cease abruptly with Pounder's retirement the two neatly coincided. Pounder was certainly a strong personality who could impose his ideas on those around him but he was also a good engineer.[26] As late as 1962 he still believed in the H&W opposed-piston engine and when asked by P. Jackson of Doxford if Harlands were going to forsake the design for the poppet valve engine he "*... gave a categorical negative reply.*"[27] B&W saw the matter differently, believing that its two-stroke poppet valve engine was superior to, and more marketable than, the Harland opposed-piston engine. During 1961 a London office was opened in order to promote the B&W poppet valve engine against rising competition from Sulzer, the attitude adopted by B&W illustrating the nature of the relationship which then existed between Copenhagen and Belfast. "*Neither Sir Frederick Rebbeck nor Mr Pounder liked this idea, but they were presented with it as a fait accompli.*"[28]

By the early 1960s the marine world had changed considerably and Britain was no longer the major shipbuilder she once had been. Harland had a monopoly on B&W engine construction in Britain and the Commonwealth either through its own engine shops or by means of the sub-licence granted to Kincaids but that situation was no longer satisfactory as far as B&W was concerned and on several occasions they had attempted to renegotiate the licence agreement. In 1966 successful negotiations were concluded and a date set for expiry of the sole licensee agreement; from January 1978 Harland & Wolff took a non-exclusive licence to build B&W engines.[29]

Harland & Wolff did have an influence in the marine diesel engine world both by virtue of the opposed-piston engine designed in Belfast and due to the influence that Pounder, and other H&W engineers, exercised in Copenhagen. Being simply a licensee did at times appear to irritate Pounder, "*The weight and value of the continuous contribution which Harland & Wolff have made over the years to the development of the marine oil engine have no equal in Britain. But because we are licensees of another firm, everything we do is perforce associated, in the minds of outsiders, with that licence.*"[30]

References

1. C.C. Pounder, "*Some Notable Belfast Built Engines*", Transactions Belfast Association of Engineers, vol 57, 1948. p31

2. Prof' Sir Bernard Crossland, "*Harland & Wolff - Burmeister and Wain Diesel Engines and the Influence of C.C. Pounder on the Development of the Two-Stroke Marine Diesel Engine*", Trans' I.Mar.E., vol 98, paper 19, 1986. p9

3. Details of the Royal Mail Group and the problems surrounding its breakup are covered in Green & Moss, **A Business of National Importance**, Methuen, 1982; also Moss & Hume, **Shipbuilders to the World**, The Black Staff Press, 1986, particularly chapters 8, 9 and 10

4. H.H. Blache, "*Stages in the Design of the Large Burmeister & Wain Marine Diesel Engine*", Proceedings I.Mech.E., vol 164, 1951. p235

5. C.C. Pounder, "*The Marine Oil Engine: A Chapter in Its Evolution*", Trans' NECIES, vol 74, 1957. p43

6. Patents for Rebbeck & Mickelsen include No 167729 (1920) Double-acting engine piston; No 166791 (1920) Scavenge pump valve chest; No 205394 (1923) Double-acting engine valve arrangement

7. Patents No 261598 (1927) Fuel pump, and No 312573 (1929) Airless injection system

8. Pounder, "*Belfast-Built Engines*". p37

9. C.C. Pounder, "*Milestones in Marine Diesel Engineering*", ***The Motor Ship***, vol 50, June 1970. p146

10. Crossland, "*Harland & Wolff - Burmeister & Wain Marine Diesel Engines*". p2

11. C.C. Pounder. Institute of Marine Engineers Presidential Address, Trans' I.Mar.E. 1961

12. Blache, "*Stages in Design of Large B&W Marine Engines*". p236

13. C.C. Pounder, "*Report of visit to Copenhagen, November 1937*" in Pounder's private papers; Quoted Crossland "*Harland & Wolff - Burmeister & Wain Marine Diesel Engines*". p9

14. Pounder, "*The Marine Oil Engine; A Chapter in its Evolution*". p44

15. Pounder, "*Milestones in Marine Diesel Engineering*". p148

16. Patent No 508464 (1939)

17. Patent No 534167 (1941)

18. S. Hansen (formerly chief designer, B&W) in the discussion of Crossland "*Harland & Wolff - Burmeister & Wain Marine Diesel Engines*". p14-5

19. Comments by S. Hansen & J. Berring during discussion of Crossland "*Harland & Wolff - Burmeister & Wain Marine Diesel Engines*". pp15 & 19

20. Pounder, "*The Marine Oil Engine; A Chapter in its Evolution*". p45

21. Correspondence from N.E. Rasmussen, B&W Archivist/Historian, dated 22 Feb` 1992

22. Pounder, Presidential Address, I.Mar.E. 1961

23. Details of the problems and their solutions are given by Crossland, "*Harland & Wolff - Burmeister & Wain Marine Diesel Engines*". p11

24. C.C. Pounder, "*The Harland and Wolff Pressure Charged Two-stroke Single-acting Engine*", Trans` I.Mar.E., vol 69, 1957. pp161-211 with pages 166-8 being devoted to the fuel system

25. A.G. Arnold, "*Some Experiences in Vessels Equipped with Two-stroke Cycle Harland and Wolff Opposed Piston Diesel Engines Using Boiler Oil*", Trans` I.Mar.E., vol 68, 1956. pp201-45

26. Comments by S. Hansen, J.N. MacKenzie, J. Berring, et al during discussion of Crossland "*Harland & Wolff - Burmeister & Wain Marine Diesel Engines*". pp14-9

27. P. Jackson, "*The Doxford Direct Drive Diesel Engine*", Trans` I.Mar.E., vol 74, 1962. p484

28. Comment by J. Berring who was in charge of the London office, Crossland, "*Harland & Wolff - Burmeister & Wain Marine Diesel Engines*". p20

29. Letter from N.E. Rasmussen dated 22 Feb` 1992

30. C.C. Pounder, Presidential Address, I.Mar.E. 1961

Chapter 4.j

The Doxford Engine

The Early Years

The shipbuilding firm of William Doxford & Sons commenced operation with a small Wearside yard at Coxgreen in 1840 and over the next seventy years produced a variety of high quality naval and merchant vessels. The company had an innovative approach to shipbuilding and marine engineering being responsible for the famous turret-deck steamers and early oil burning steam driven torpedo boats. Even in 1906 the company was aware of the potential of the internal combustion engine for ship propulsion and over the following two years investigations were carried out.[1]

Initially thoughts were towards a gas engine but the project was abandoned in 1908 when it became evident that there would be considerable difficulty in designing a gas producer unit for marine purposes. Use of oil fuel was the next step and in 1910 a single cylinder experimental engine was constructed. This 495mm bore by 940mm stroke engine operated on the two-stroke cycle with valve scavenging of the cylinder and blast injection of fuel, being able to develop 187kW at 130rpm.[2] Intended as a single unit of a proposed four-cylinder engine the experimental engine performed well but towards the end of the trial period in 1912 problems became evident with the cylinder cover, frames and main bearing. Similar troubles were experienced with other conventional engines of the period and Doxford engineers decided to abandon the design and adopt a more radical approach.[3]

Opposed piston engines were not new, a number of gas engine designs having been evolved, and the Doxford engineers under the guidance of Karl Otto Keller turned to an arrangement developed by Professor Junkers. Doxford acknowledged Junkers' work in its licence document, making reference to a 1920 Indenture which allowed the granting of sub-licences for marine and land opposed-piston engines.[4]

The first experimental Doxford opposed-piston engine, designed in 1913, had a bore of 500mm and combined stroke of 1500mm. Capable of developing 336kW at 130rpm this single-cylinder engine initially operated with air injection of fuel but following seizure of the engine driven air injection compressor in 1916 a decision was taken to adopt airless fuel injection. Airless fuel injection required more time for fuel combustion and this was achieved by advancing injection timing and reducing compression pressure to prevent pre-ignition. Experimentation eventually produced a satisfactory compromise which gave 21bar compression pressure and 42bar combustion pressure. This engine operated on a dual combustion cycle not the Diesel constant pressure combustion cycle.[5]

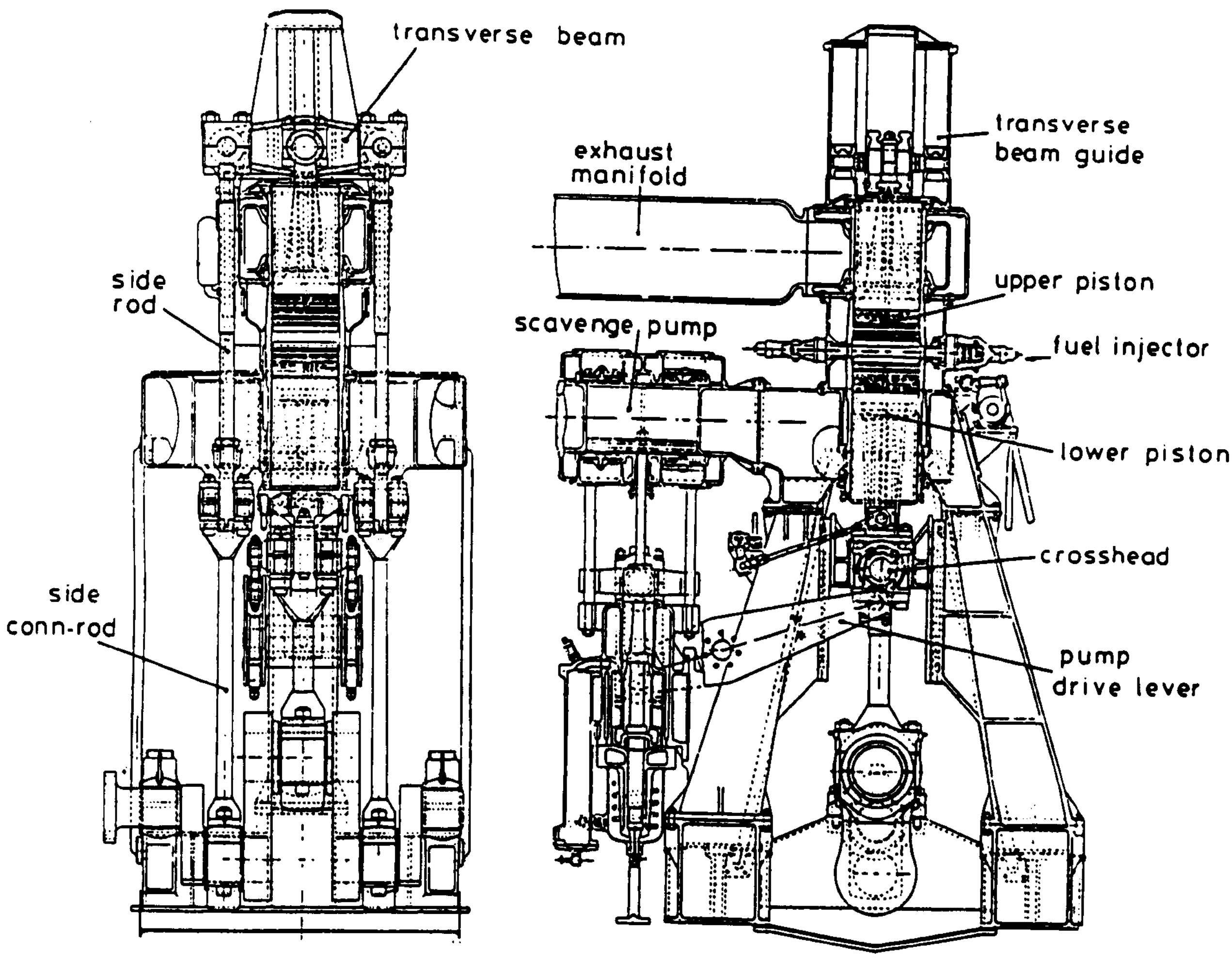


Fig 4.j.1 Section through the Doxford Single-Cylinder Experimental Engine

Progress was hampered by the 1914/1918 war but some experimental work was undertaken including construction of a single-cylinder high speed opposed-piston engine. This 370mm bore by 720mm combined stroke unit developed 298kW at 360rpm and attracted interest from the Admiralty as a potential submarine engine. Further work was undertaken by the Admiralty, including the use of aluminium pistons, but with the coming of peace the project was abandoned.[6,7] It is interesting to note that during the second world conflict the idea of an opposed-piston submarine engine was again raised. In January 1945 the Vickers board approved finance for construction of an experimental single-cylinder two-stroke engine following an indication that the Admiralty might be considering a new submarine prime mover. A proposal for a Doxford engine was schemed and Doxford's views were sought[8] but the project got no further.

During WWI limited design work was possible but with the coming of peace work on a prototype engine could begin and Doxford wasted no time in building the engine. The 2,238kW developed from four cylinders at 77rpm represented a higher cylinder output than most other marine internal combustion engine at that time. Modifications had been made in view of lessons learned from the experimental engine but the main features, including use of solid fuel injection, remained the same. Pistons comprised an outer cast iron body carrying the rings and an inner steel portion which formed the flat topped crown. In order to minimise thermal stress cylinder liners were only 25mm thick, strengthening being provided by means of steel shrink rings. Two fuel valves were positioned in the central combustion chamber, diametrically opposite each other and at slightly different heights. Valves were directed so that their fan shaped fuel sprays just cleared both pistons. Distilled water was used for cooling cylinder liners and pistons, most other engines of the period used seawater cooling. Scavenge air came from a crankshaft driven double-acting pump positioned at the middle of the engine.[9]

Experimental work prior to construction of the prototype had cost Doxford some £100,000 a considerable sum in those days particularly for a single private company.[10] The prototype engine found its way into the Swedish vessel **Yngaren** having originally been intended for a ship ordered by Grindon Steamship Company, a concern with which Doxford was associated.[11]

Growth in the 1920s

Five engines of the type fitted in **Yngaren** were built between 1919 and 1924, one being the subject of extensive trials during 1924-5. Carried out under the supervision of the Marine Oil-Engine Trials Committee appointed by the Institution of Mechanical Engineers and the Institution of Naval Architects these trials of the Furness Withy vessel **Pacific Trader**[12] did much to establish the Doxford reputation. The relatively high output power on a single shaft, use of airless or solid fuel injection and reliability of those early engines attracted the interest of British shipbuilders. Several approached Doxford for licences and a number were granted. At that time Doxford did not seek licences but were quite willing to grant on application and no limit was put on the number which would be granted. Terms, however, were considered to be on the high side by at least one potential licensee, Vickers of Barrow: an initial payment of £10,000 plus a royalty of £1 per brake horse power.[13]

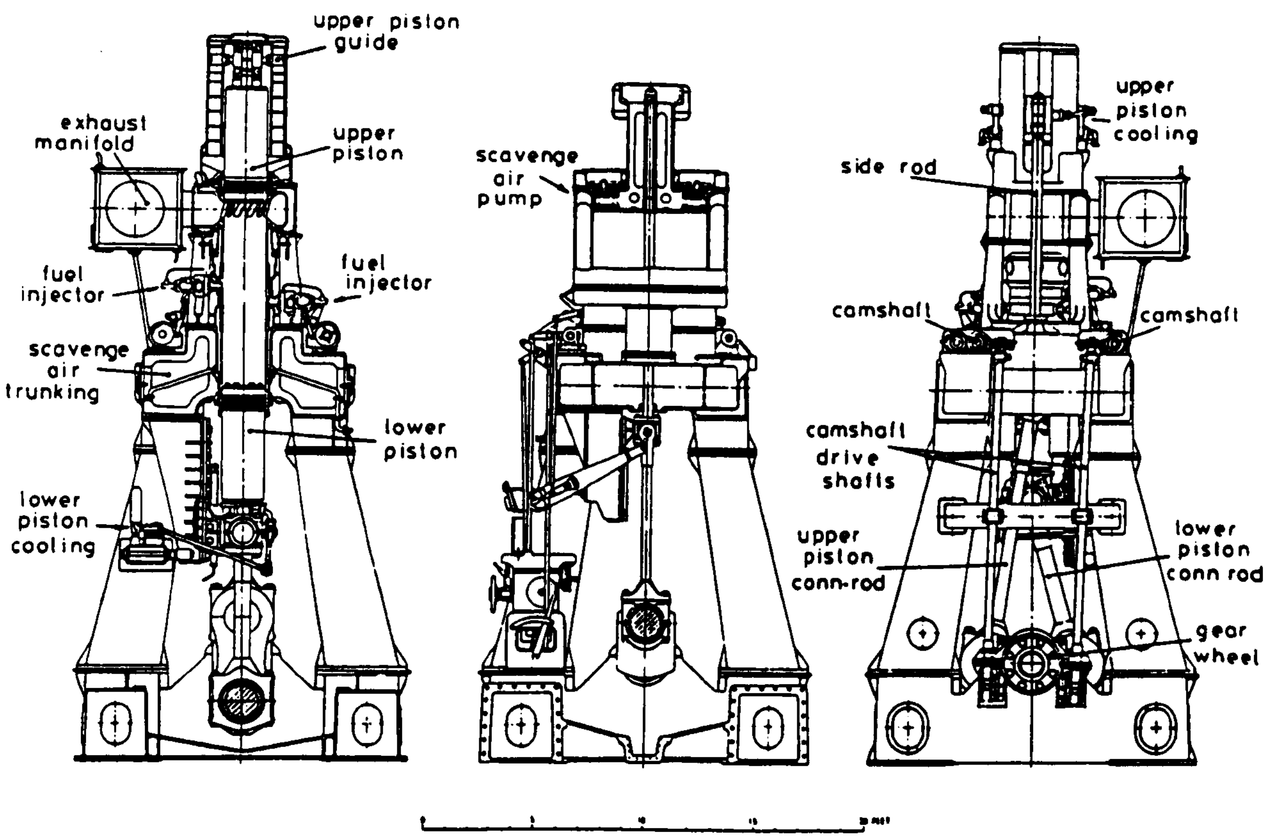


Fig 4.j.2 Section through the First Doxford Engine showing the Scavenge Pump and Camshaft drives

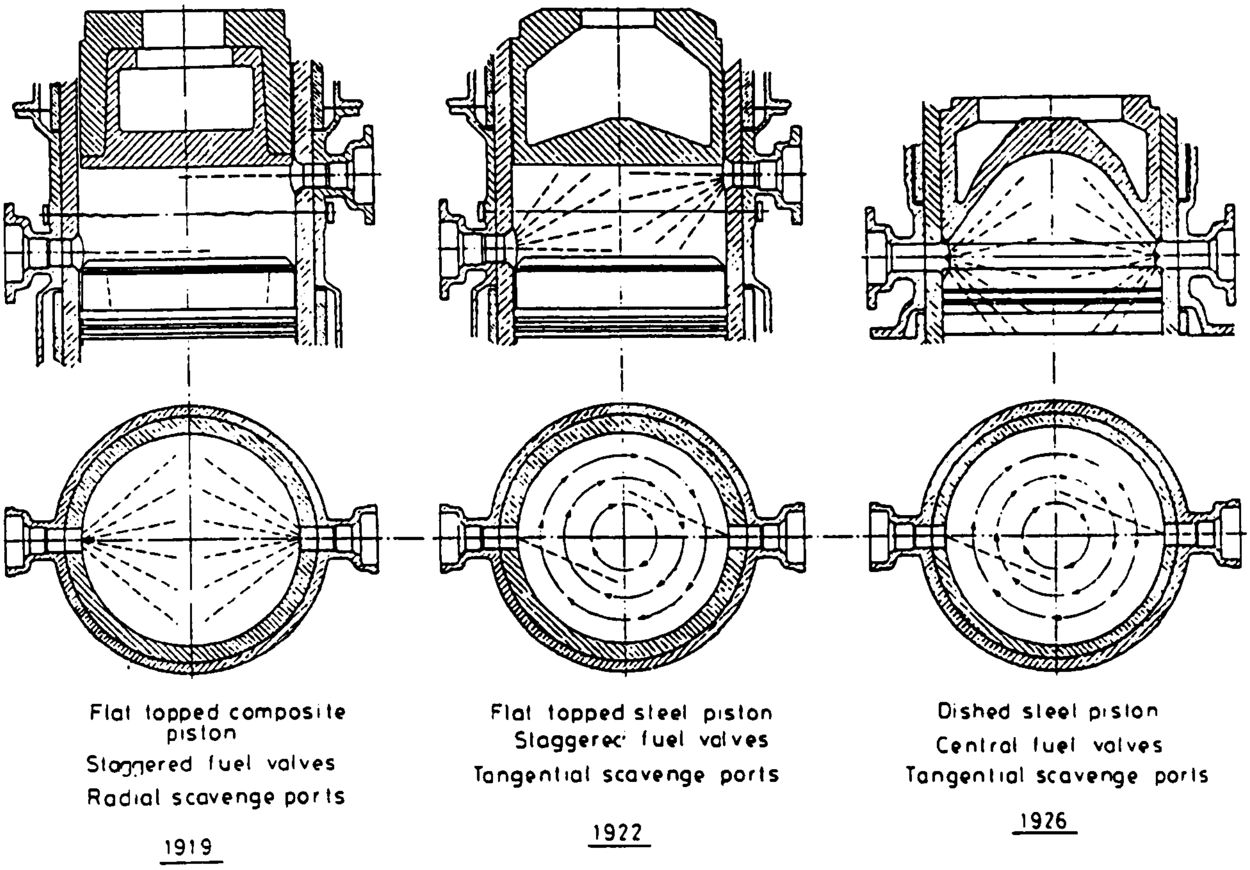


Fig 4.j.3 Development of Doxford Pistons

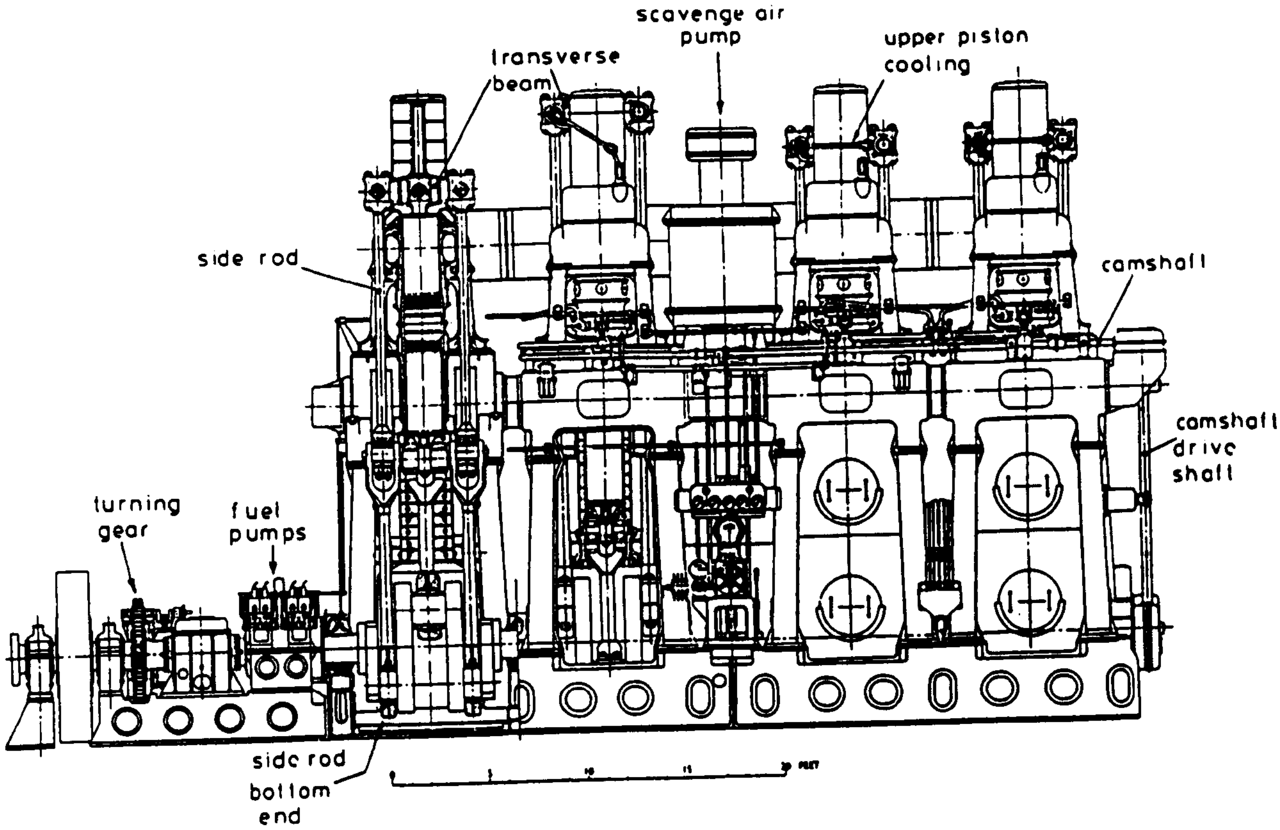


Fig 4.j.4 Early Four-Cylinder Doxford with Crank Driven Scavenge Pump

Between 1924 and 1927 several new cylinder sizes were introduced and some modifications made including the use of dished pistons to give a spherical combustion chamber. Designs on offer included a 540mm bore three-cylinder engine developing 1,313kW and a four- cylinder engine developing 3,730kW. The oil engine still suffered criticism with respect to vibration and Doxfords failed to win a passenger ship engine contract on those grounds. In 1926 a decision was taken to design a balanced engine which would avoid such criticism and allow entry into the developing diesel powered passenger ship market. In order to balance primary inertia piston forces a differential stroke was introduced: up until that time top and bottom pistons had equal strokes. Other changes included adjustments in weights of reciprocating parts, boring of centre crankpins to balance rotating masses and change in the firing order to obtain secondary balance.[14] Complex analysis was required but so successful was the new design that it was immediately chosen for the quadruple screw luxury liner **Bermuda**. At this time the designation LB (long stroke, balanced) was applied to the engine.

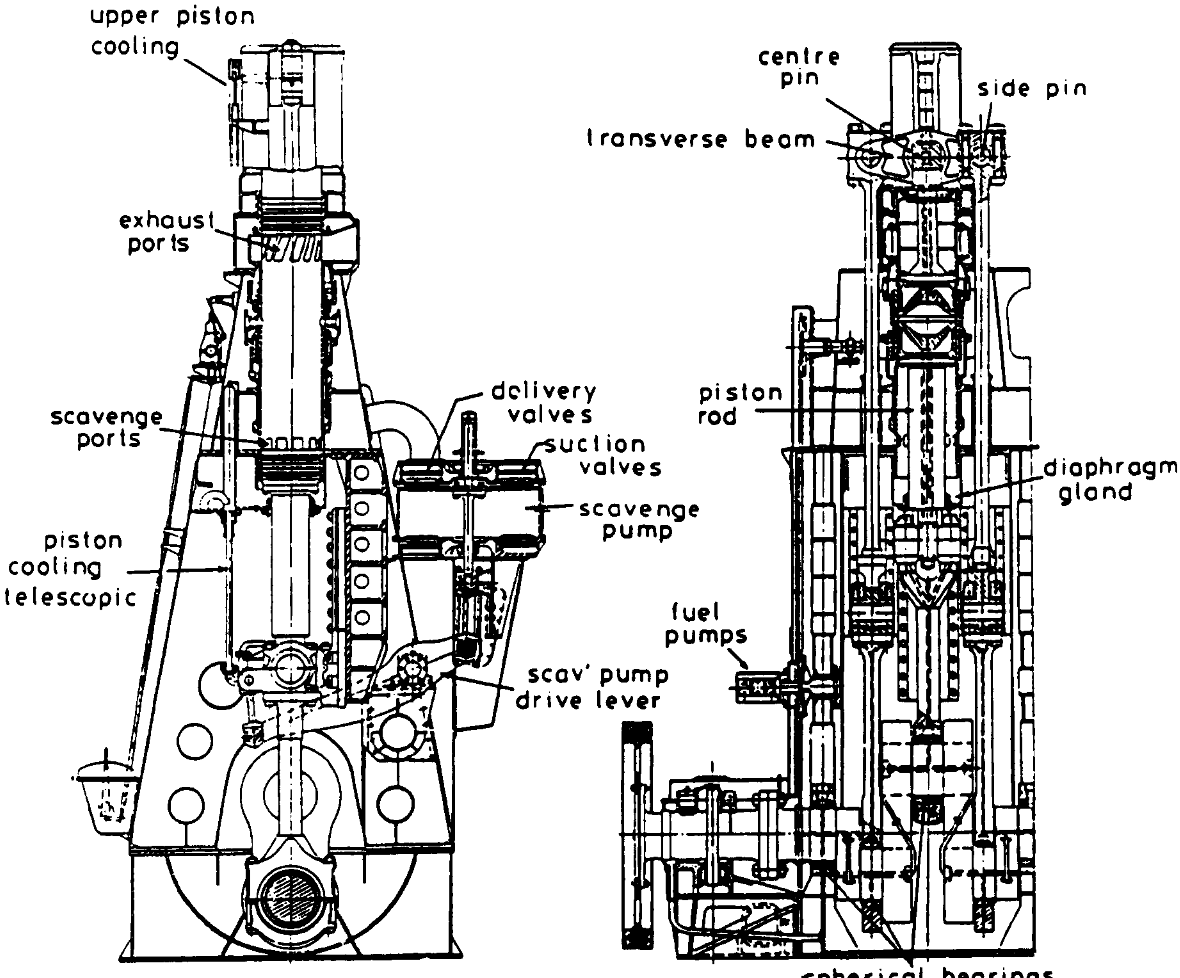


Fig 4.j.5 Section through Balanced Doxford Engine with Lever Driven Scavenge Pump

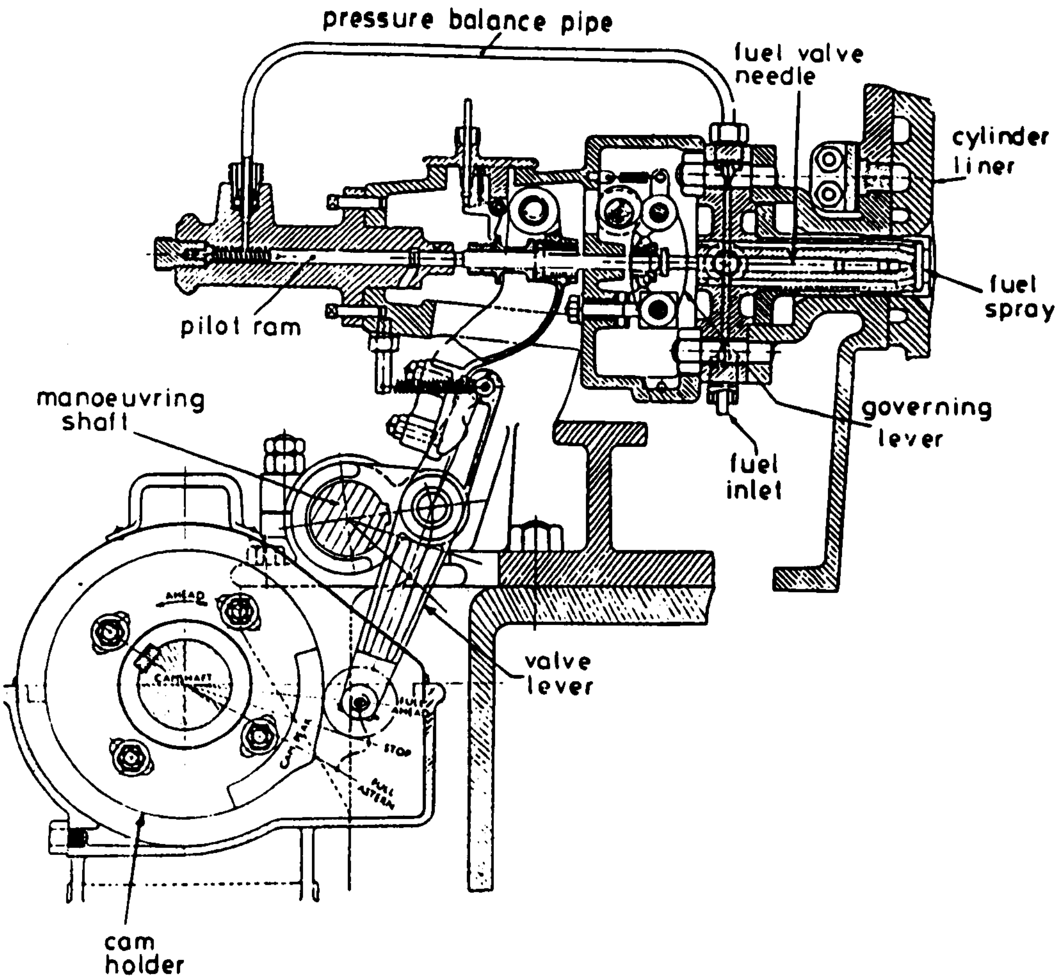


Fig 4.j.6 Doxford Mechanically Operated Fuel Valve - as modified in 1920s

In 1928 torsional vibration problems became evident in two twin screw ships fitted with large balanced engines. All new designs were subject to detailed analysis so that critical speeds could be avoided, however, torsional fatigue cracks were discovered in one of the crankshafts after only 2.5 round trips to Australia. No other engines had experienced such problems and analysis had indicated that there should not have been a problem at the operating speed of 98rpm. It was soon determined that changing the firing order to produce the balanced engine had created a critical speed at the operating speed. The solution involved removal of the heavy flywheel from the after end of the crankshaft and fitting light flywheels to each end of the crankshaft. In later years the flywheel at the forward end developed into the well known Doxford-Bibby detuner.[15]

During 1928 thought turned to the lower power market and a three-cylinder 400mm bore engine was designed for both marine and land application. A lever driven scavenge pump provided combustion air, the drive coming from the main crosshead of the centre cylinder. Cooling water and lubricating oil pumps were driven from a crosshead attached to the scavenge pump rod. One of these small three-cylinder engines was exhibited at the North East Coast Exhibition during 1929[16] and was then used for experimental work before being fitted in the concrete vessel **Lady Wolmer** during 1942. The other engine was fitted in the small tanker **Freshmoor** in 1929. These were not the smallest engines built by Doxford as in 1921 a number of two-cylinder 70kW generating sets running at 320rpm were constructed. Upper and lower piston stokes actually differed, a novelty at the time, the upper being 220mm and the lower 280mm for a bore of 200mm. Although initial results were promising the project was abandoned because of problems involved in manufacturing large propelling engines and small auxiliary engines with the same plant; there was also severe competition from four-stroke medium speed engines.[17]

One factor mitigating against the oil engine was the type of fuel it burned. Boilers could burn heavy grade residual oil from the refinery process, commonly known as boiler oil, but the oil engine required refined lighter oil which involved higher cost. Doxfords carried out many trials involving the burning of boiler oil in its engines and a number of shipping companies co-operated with these investigations. Centrifugal separation of fuel was introduced and fuel sprays were modified in order to reduce the formation of carbon deposits on the sprays. In 1921 Furness Withy encouraged Doxfords to undertake boiler oil tests with the engine to be installed in its ship **Dominion Miller** it being the intention to run the ship on heavier grades of fuel.[18] During the 1920s a number of Doxford engined ships operated successfully on a mixture of diesel and boiler grade fuels but the price differential between grades became so small that the practice was abandoned.[19]

Doxford Development in the 1930s

A number of British shipbuilders took licences from Doxfords during the 1920s but the only overseas interest came from the Sun Shipbuilding & Dry Dock Co. of Pennsylvania, USA and Lindholmen Motala A/B of Gothenburg, Sweden. British licensees were Barclay Curle, and Fairfields on the Clyde, Richardsons Westgarth of Hartlepool, and Workman Clark of Belfast. Barclay Curle built two engines to replace failed North British sliding cylinder engines but the only really active licensee during the 1920s was Sun, much of its output going to re-engine former steamships. The depression in shipbuilding during the early 1930s limited prospects but improved trading saw John Brown, David Rowan, Alexander Stephens and Swan Hunter take licences later that decade.

Doxfords the marine engine builders was owned by Doxfords the shipbuilders but the fact that practical engineers had control of engine matters enabled progress to be made independently of shipbuilding. The needs of Doxfords the shipbuilders were, naturally, important and the recession in shipping had an effect on both sides of the business. It became clear that a low speed, low powered and highly fuel efficient ship could make inroads into the tramp shipping market which had previously been the domain of the steam reciprocating engine. The Doxford "Economy" ship was developed. Initially the three-cylinder 520mm bore engine was fitted to this standard design ship but with the subsequent trend towards higher speeds the 560mm bore engine was substituted. Later in the decade, and during WWII three- and four-cylinder versions of the 600mm bore engines were used. By employing a lever driven scavenge pump at the back of the engine instead of a crankshaft driven unit length of the 520mm bore three-cylinder engine was only 7.9m. The lever also actuated cooling water and lubricating oil pumps thereby avoiding the need for other pumps to be operated at sea.

First of the "Economy" ships was **Sutherland** in 1935. For a deadweight capacity of 9,400 tonnes she could maintain a speed of 10.5 knots on less than 6.5 tonnes of fuel and 30 litres of lubricating oil per day. With a bunker capacity for 790 tonnes of fuel a Doxford "Economy" ship could travel 48,000km without the need to take bunkers.[20]

Part of the programme which resulted in the economy ship was waste heat recovery by means of steam generation and in 1929 investigations commenced. The efficient uniflow scavenging of Doxford engines required a lower scavenge air supply than other types of engine thus the exhaust temperature remained higher as it was not cooled by excess air. Experiments indicated that the excess air supply could be reduced from the 30% level, other engines used about 60% excess air, to around 20% or even 10%. A reduction in excess air supply to 20% of that required for cylinder combustion also allowed for a reduction in scavenge pump size. With the exhaust temperature raised to 375°C it was possible to generate 0.6kg of steam per kW engine power at a pressure of about 10bar.[21]

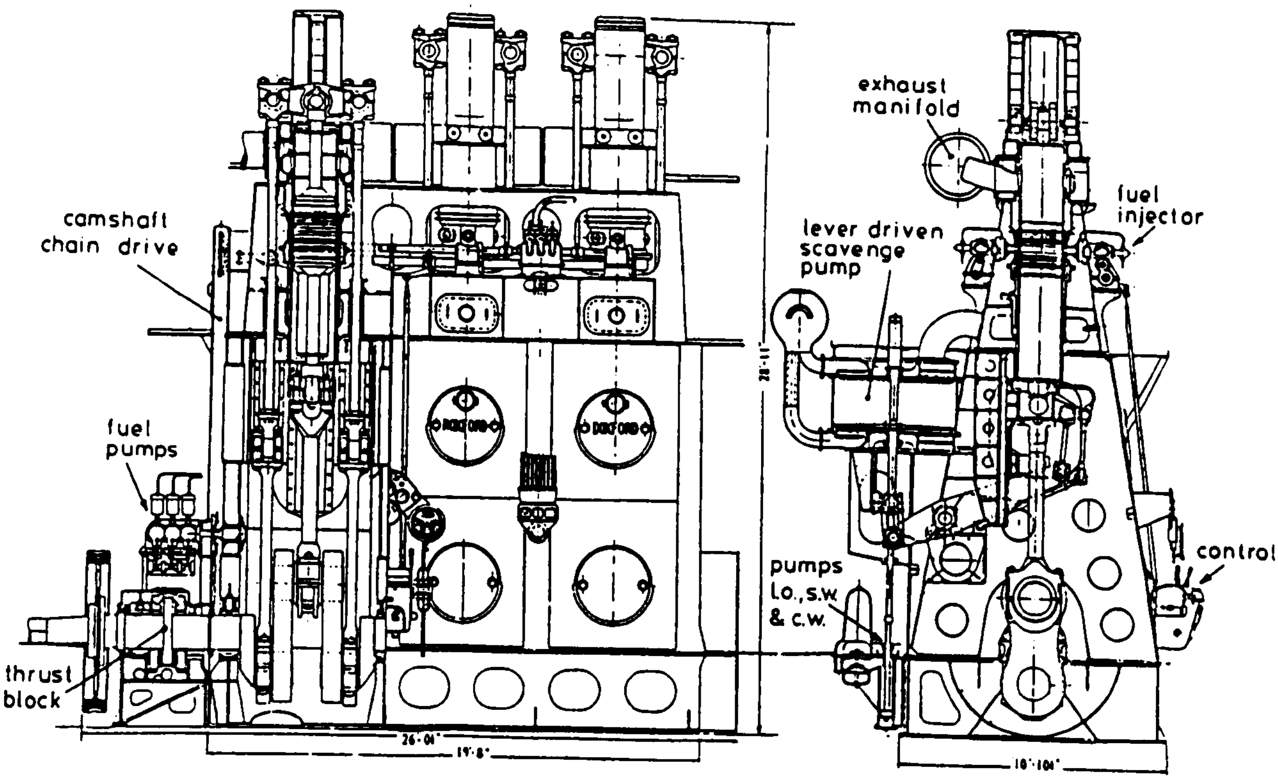


Fig 4.j.7 Three-Cylinder Doxford Engine with Lever Driven Scavenge Pump

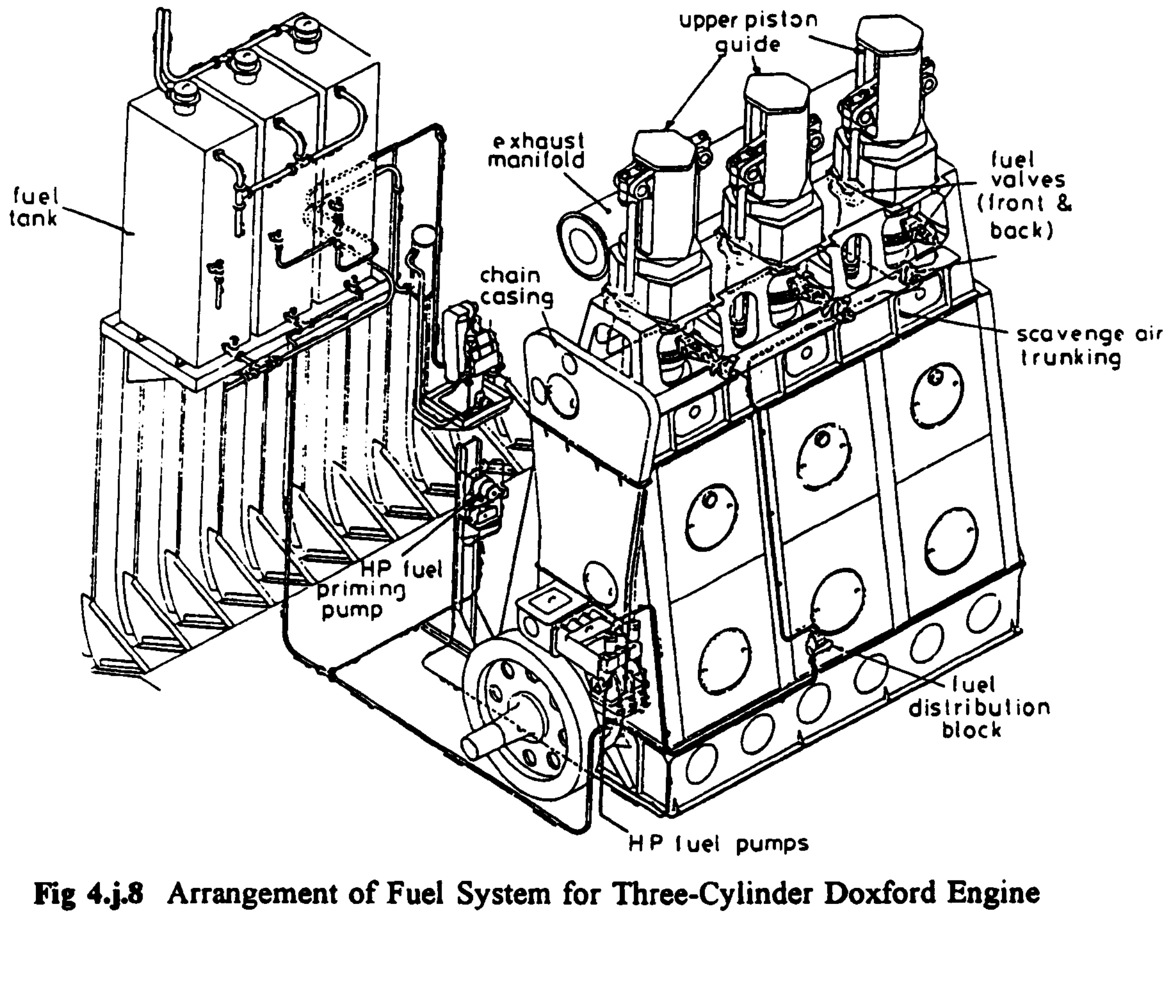


Fig 4.j.8 Arrangement of Fuel System for Three-Cylinder Doxford Engine

Upper and lower pistons were both cooled by water supplied to and taken from the pistons via swinging link arrangements. A simplified system using rubber hoses was introduced for upper pistons during the 1930s and that remained standard until development of the "P" type engine in the 1960s. Corrosion in the cooling water system with subsequent leakage at the swinging links had been a problem with the very first engines but the Doxford Works Chemist, Ernest Armstrong, devised a solution which alleviated the problem. Bichromate of potash in distilled water worked well provided that no seawater entered the cooling water system.[22] Preventing leakage of seawater into the engine cooling system was always a problem and as late as 1952 questions on the matter were still being asked at Doxford licensees' meetings.[23]

During the 1930s Doxfords began to make use of electric welding for the construction of engine frames and bedplates thus reducing weight significantly. Initially only frames were of welded construction, a saving in weight of some 25% being claimed for the small three- cylinder engine,[24] but the success achieved prompted Doxford designers to extend the process to bedplate construction. Specific weight for welded engines fell to 113kg/kW for a single screw ship and 85kg/kW for a twin screw installation; for engines having cast frames and bedplates specific weights per engine were around 155kg/kW.[25]

Introduction of a five-cylinder engine during 1935 and proposed construction of a six-cylinder engine prompted further study on torsional vibration and it became evident that some form of vibration suppressor would be required. In collaboration with James Bibby the Doxford-Bibby detuning wheel was developed[26] and this became a standard feature on the forward end of Doxford engines until development of the "J" range in the 1960s.

A major advance in engine power came with the engining of the liner **Dominion Monarch** with four five-cylinder engines during 1939. Two engines were built by Doxfords and the other pair by Swan, Hunter & Wigham, Richardson, who also built the ship. Each engine was rated 4,850kW at 123rpm, the 725mm diameter cylinder being the largest built to that time and the ship the highest powered motorship in the British fleet.

War and Postwar Glory Years

The needs of war restricted development work at Sunderland but Doxford engines played an important part in the survival of Britain. Their high power to size ratio allowed for increased cargo space compared with steam powered ships, there was no tell-tale smoke cloud as the engine exhaust was clear, and engines could be built quickly by a large group of licensees to meet the demands of hull constructors. The three-cylinder engine proved to be very popular for driving standard ships as developed by Doxford and other shipbuilders.

In America the Sun Shipbuilding & Dry Dock Company continued to build Doxford engines but did not follow exactly the British pattern. In fact Doxford allowed its licensees a considerable degree of leeway in terms of engine construction as it did not object to design modifications being made. Drawings issued by Doxford were for guidance and not production, individual licensees prepared production drawings from these to suit their own manufacturing facilities. It was not until 1959 that strict conditions with respect to modifications were enforced as part of new licensing arrangements.[27] In 1925 Sun constructed a pair of 560kW engines on a common bedplate for Henry Ford's yacht **Sialia**. Each four-cylinder engine, 330mm bore by 432mm + 560mm stroke, drove its own propeller but the form of construction allowed for a very compact design.[28]

In 1939 Sun commenced production of the largest bore Doxford engines ever built. Engines of 813mm bore were constructed in four- and five-cylinder versions, Canadian Vickers building three four-cylinder engines by special arrangement in 1946. These Canadian built Sun engines retained the older camshaft drive arrangement incorporating vertical shaft and bevel gear, British and American built engines employed a chain drive from the crankshaft; oil sumps of the Canadian engines also had straight sides and flat bottoms instead of sloping sides.[29] A major Sun innovation was the use of the rotary scavenge blower instead of the reciprocating scavenge pump, drive being by means of a chain from the crankshaft. Two such blowers applied to the four-cylinder 813mm bore engines of 1939,[30] however, the arrangement proved unsatisfactory and later engines reverted to crank driven scavenge pumps.[31] In 1941 Sun constructed geared installations for four C3 class standard passenger/cargo ships, there being two six-cylinder 3,170kW engines running at 180rpm geared to a single propeller shaft. Cylinders were of 533mm bore by 1524mm combined stroke, air was supplied by separate electrically driven blowers and facilities were provided for the burning of boiler grade oil.[32,33]

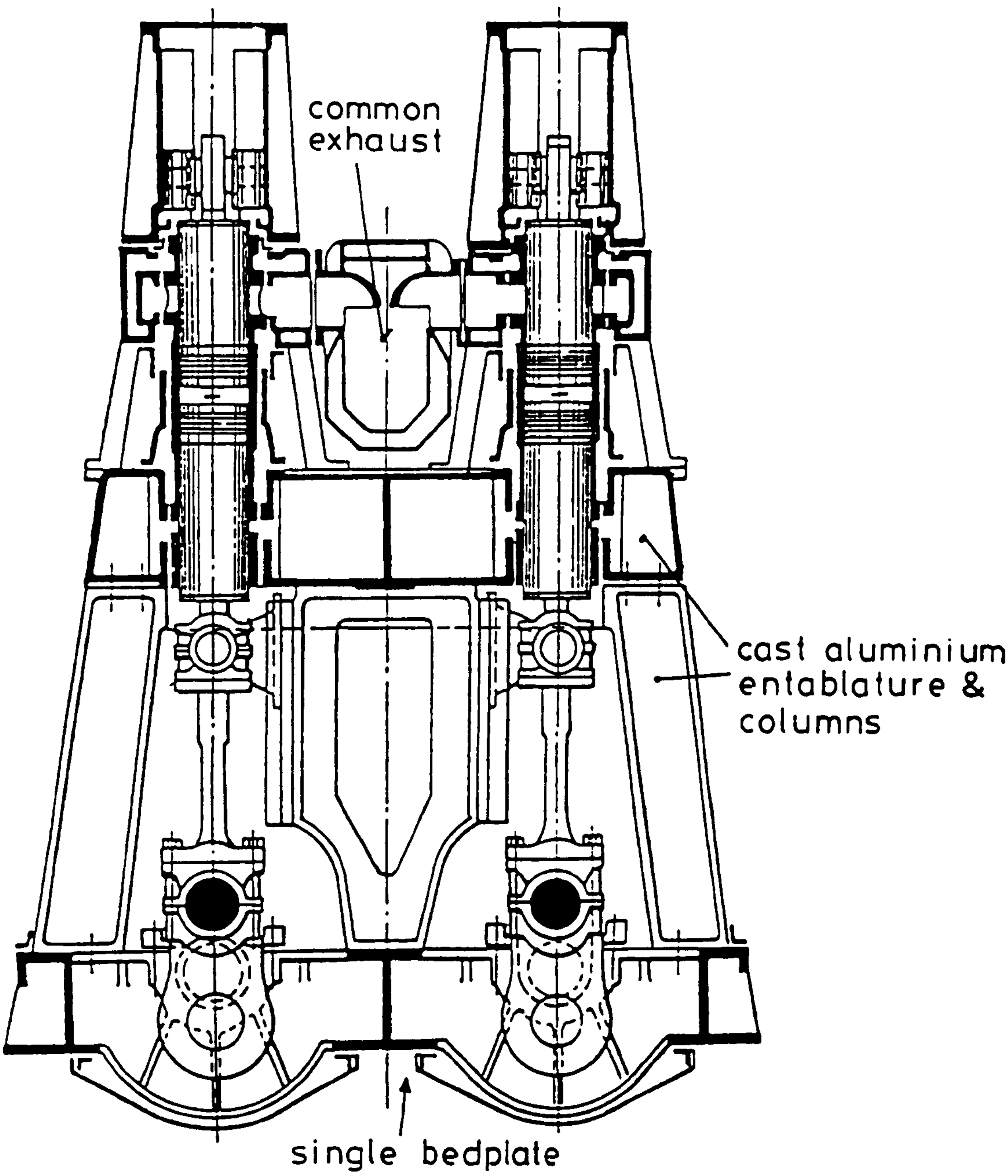


Fig 4.j.9 **Twin Sun-Doxford Engines as fitted in the Yacht Sialia**

During the conflict additional licensees joined the fold, including Vickers-Armstrong in 1943. In 1945 an approach was made by two continental engine builders, Wilton-Fijenoord of Holland and Eriksbergs of Sweden, concerning the possibility of licences and Doxfords took the trouble to find the reactions of existing licensees to the granting of such. Opinion was that if a licence was refuse these builders would seek one elsewhere but if one was granted it was likely to enhance British and Doxford prestige abroad.[34] That attitude did not extend to German engine builders as a licensees' meeting in May 1953 disapproved of granting a licence to a manufacturer from that country.[35] During the 1953-4 period Dr J. Ramsay Gebbie, Deputy Chairman and Managing Director, firmly refused licence applications from engine builders in Japan, Poland and Jugoslavia.[36] At the time there may have been a desire to protect existing licensees but the engine was extremely popular, over 50% of British built large motorships were being fitted with Doxford engines during the 1950s, and overseas builders would have extended market share. In retrospect the attitude appears to have been very short sighted as these countries were expanding their shipbuilding industries which could only have served to help Doxfords. Certainly the royalties would have assisted in financing future development work and it is highly likely that benefit would have derived from links with a Japanese engine builder. The attitude was parochial in the extreme.

Doxford engines were extremely popular but towards the end of the war problems existed as crankshaft production could not match the demand for engines. Crankshafts were built-up from separate main crankpins, main webs and forged "dog leg" pieces which formed main journals, side webs and side pins. These "dog leg" pieces were obtained from specialist forges and extensive discussions took place between Doxfords, their licensees and Forgemasters with respect to the bottleneck being caused by the failure of the forging industry to meet the engine builders' requirements. Only when the needs of military production eased and rebuilding of damaged steelworks was in hand did the situation ease and sufficient crankshaft forgings became available to meet demand.[37] That, however, was not expected to be before the second half of 1946.[38]

Before WWII Doxfords had obtained crankshafts either complete or as rough forgings from European countries including Germany and Czechoslovakia[39] but during the war and in the years that followed such sources were unavailable. Without doubt the problem concerning crankshaft production limited engine output but the same situation will have applied to the construction of all large diesel engines. During 1945 the Vickers' engine works at Barrow was fully engaged in Doxford construction for vessels building in its own yards but the Scotswood works had spare capacity. This could not be effectively used, however, due to the bottleneck in crankshaft production.[40]

With the coming of peace Doxfords decided that regular meetings of licensees would promote open discussion of problems and allow information to be disseminated. The first Technical Meeting of Licensees was held at the company's offices in Sunderland on 11th & 12 May 1948, being attended by representatives from all British licensees, apart from Barclay, Curle, together with technical personnel from Wilton-Fijenoord of Holland and the Ordnance Factory of Melbourne, Australia.[41] These meetings became regular events until the end of the 1950s.

Doxford Licensees

(as at November 1956)

British

Company	Location
Ailsa Shipbuilding Co. Ltd	Troon, Ayrshire
Barclay, Curle & Co. Ltd.	Whiteinch, Glasgow
John Brown & Co. (Clydebank) Ltd.	Clydebank, Scotland
Fairfield Shipbuilding & Eng' Co. Ltd.	Govan, Glasgow
William Gray & Co. Ltd.	West Harlepool
Hawthorn, Leslie (Engineers) Ltd.	Newcastle-on-Tyne
John Lewis & Sons. Ltd.	Aberdeen
Richardsons, Westgarth & Co. Ltd.	Wallsend-on-Tyne
David Rowan & Co. Ltd.	Glasgow
Scotts' Shipbuilding & Eng'g Co. Ltd.	Greenock, Scotland
Alexander Stephen & Co. Ltd.	Linthouse, Glasgow
Vickers-Armstrongs Ltd.	Barrow-in-Furness
Wallsend Slipway & Eng'g Co. Ltd.	Wallsend-on-Tyne

Overseas

Company	Location
Ansaldo S.A.	Genoa, Italy
Canadian Vickers Ltd.	Montreal, Canada
Commonwealth Government Engine Works	Melbourne, Australia
Eriksberg Mekaniska Verkstads A/B	Gothenburg, Sweden
Marinens Hovedverft	Horton, Norway
Nederlandsche Dok En Scheepsbouw Maatschappij	Amsterdam, Holland
A/S Rosenberg Mekaniske Verksted	Stavanger, Norway
Societe des Chantiers et Ateliers de Provence	Marseilles, France
Sun Shipbuilding Co	Chester, Pennsylvania, USA
Taikoo Dockyard & Eng'g Co.	Hong Kong
Wilton-Fijenoord N.V.	Schiedam, Holland

{Information taken from The Motor Ship Reference Book for 1957; Temple Press. London}

An early problem discussed was that of corrosion in engine crankcases especially when burning boiler grade fuels. Most licensees considered that a diaphragm was necessary to prevent combustion products scraped off the liner from entering the crankcase and one reported that two major customers were not prepared to place further orders unless diaphragms were fitted. Gebbie held the view that corrosion was due to water leakage from the lower piston cooling pipes and did not believe that a diaphragm was necessary.[42] Adoption of oil cooling for lower pistons prevented any water contamination and a diaphragm arrangement was designed into new engines producing the designation "LBD" (D for diaphragm).

Problems still existed for older engines, particularly when burning boiler oils, and Doxfords designed a conversion system but it was expensive. One of the licensees, North Eastern Marine Engineering Co., developed an alternative conversion package which was simpler and cheaper, only requiring a smaller diameter piston skirt and new gland.[43]

Two major changes of the late 1940s were the increasing tendency towards the use of lower grade boiler fuel with its higher viscosity and increased levels of sulphur, and supercharging as a means of increasing specific engine output. A great many fuel trials were carried out on test engines and the single-cylinder 670mm bore experimental engine constructed in 1950. Shipping companies, particularly British Petroleum and Shell, encouraged the development of heavy oil systems but there were problems related to cylinder liner wear which could be two or three times that experienced with diesel oil.[44] Doxfords decided that a new fuel system was required for use with boiler grade fuels and devised two different arrangements which were extensively tested. One arrangement employed individual cylinder pumps driven by compression of air in the particular cylinder but licensees preferred the arrangement based upon the former common rail system. Heavy mechanically operated fuel valves were replaced by small hydraulically actuated C.A.V. type injectors, fuel injection timing being regulated by cam operated timing blocks. Accumulator bottles in the fuel manifold at each cylinder maintained fuel pressure during injection, engine driven fuel pumps supplying the common rail as in the earlier system. A major advantage of this system was that it made use of standard proprietary items which could be readily obtained.[45] The system only required a single camshaft compared with the two, needed to operate front and back fuel valves, fitted on earlier engines.

Accompanying the new fuel system was a new and simplified air start and reversing system. Again camshaft operated valves were replaced by much lighter components. Pilot air operated starting valves required an air distributor and use of that device simplified the reversing system. The Doxford engine of the early 1950s was able to burn lower quality fuels and, in some areas, easier to overhaul but in one respect it still lagged behind its major competitors. Doxfords was slow to adopt turbo-charging.

In 1949 people at Doxfords still held the view that supercharging was a long term proposition and that the immediate solution to higher powers was a larger bore. Several licensees, including North Eastern Marine and Wilton-Fijenoord, believed that the future lay in supercharging.[46] A six-cylinder 750mm bore engine was designed and put into service during 1951. The engine proved to be a success in that it could develop 6,600kW on a single shaft making it ideal for large tankers then being constructed, however, in 1955 disaster struck when crankshaft failure occurred in five engines over a short period of time; other failures subsequently occurred but no Doxford built engine failed in this way.[47] Doxfords acted with great urgency calling meetings of interested parties and having investigations carried out by Lloyds and other bodies. Reports were acted upon and recommendations issued to licensees concerning the modification of engines already in service or under construction.[48] Axial vibration and incorrect crankshaft alignment were considered to be two of the main reasons for failure and in 1960 two of Doxford's senior personnel produced a paper detailing the problems and solutions.[49] However, the damage was done with the result that certain shipowners and licensees turned their attention to other engines. One shipowner insisted that the crankshafts for two ships under construction be replaced by ones conforming to the new recommendations.[50] As far as one leading Doxford engineer was concerned the limit of the normally aspirated Doxford engine appeared to have been reached in the 75LB6 engine.[51]

In addition to the 670mm bore single-cylinder engine Doxfords decided that a large bore (800mm) experimental engine should be built in order test the possibilities of high power development. By early 1949 drawings for the engine were well advanced but it was evident that the engine could not be operational for at least two years[52] and a year later it was decided to hold the large experimental engine in abeyance and investigate the use of supercharging as a means of developing higher powers. A number of licensees were particularly keen on very high powers through the supercharging of the 725mm and 750mm bore engines then in production and approval was given for construction of an experimental three-cylinder 600mm bore supercharged engine.[53]

Brown-Boveri became involved in the investigations and anticipated a power increase of 40% to 50% compared with a normally aspirated engine of the same size.[54] The engine was operational by March 1952 when extensive testing commenced. Power increases of 50% were obtained and licensees requested that plans be made for turbo-charging other engines in the range, particularly the six-cylinder 700mm bore engine, to give 7,460kW.[55] Agreement was reached with British Petroleum for installation of the experimental engine in its motor tanker **British Escort** during 1954 and trials over the next year proved the installation to be a success, although the three-cylinder form was not particularly suited to turbo-charging. Turbo-charging required large exhaust and air inlet ports for maximum performance but enlarging the ports would have produced "dead bands" in which starting air could not have been applied. In order to prevent the latter problem the engine had smaller ports than turbo-charging required and so operated below maximum rating.[56] Doxfords quickly set about supercharging its range of engines with Brown-Boveri turbo-chargers and a new era for the Doxford engine began.

Initially Doxford turbo-charged engines retained their scavenge pumps, working in series with the turbo-chargers, in order to supply combustion air when starting or at low loads. They also offered safeguard against turbocharger failure but were both costly and increased engine weight. Trials carried out in 1958 on the engine fitted in the Ropner tanker **Thirlby** indicated that satisfactory operation could be obtained without scavenge pumps, combustion air when starting, at low loads and during emergencies being provided by electrically driven blowers.[57] Retention of scavenge pumps for so long indicates a conservatism not shown by major competitors like Sulzer and B&W.

The Final Phase

In 1947 Doxford appointed Percy Jackson to set up and head a department devoted to research and development. Work on the burning of heavy oils and turbo-charging was carried out by Jackson's team but during the mid-1950s it became apparent that power potential limits of the "LB" engine had been reached, particularly with respect to the crankshaft. Plans for another single-cylinder experimental engine were revived but with complete redesign of many features. In order to develop higher powers without risk of torsional vibrations a stiffer crankshaft was required. Reduction in upper piston stroke reduced side rod crank throw thereby allowing for overlap between side crankpins and main journals which in turn increased stiffness. The stiffer crankshaft enabled spherical bearings to be replaced by plain bearings, spherical bearings having been used on all Doxford opposed-piston engines from the first design in order to allow for crankshaft flexibility. A three piece cylinder liner was introduced and the upper piston guides eliminated because of the reduced upper piston stroke and increased rigidity of running gear connections. This single-cylinder engine survives at South Tyneside College of Technology.

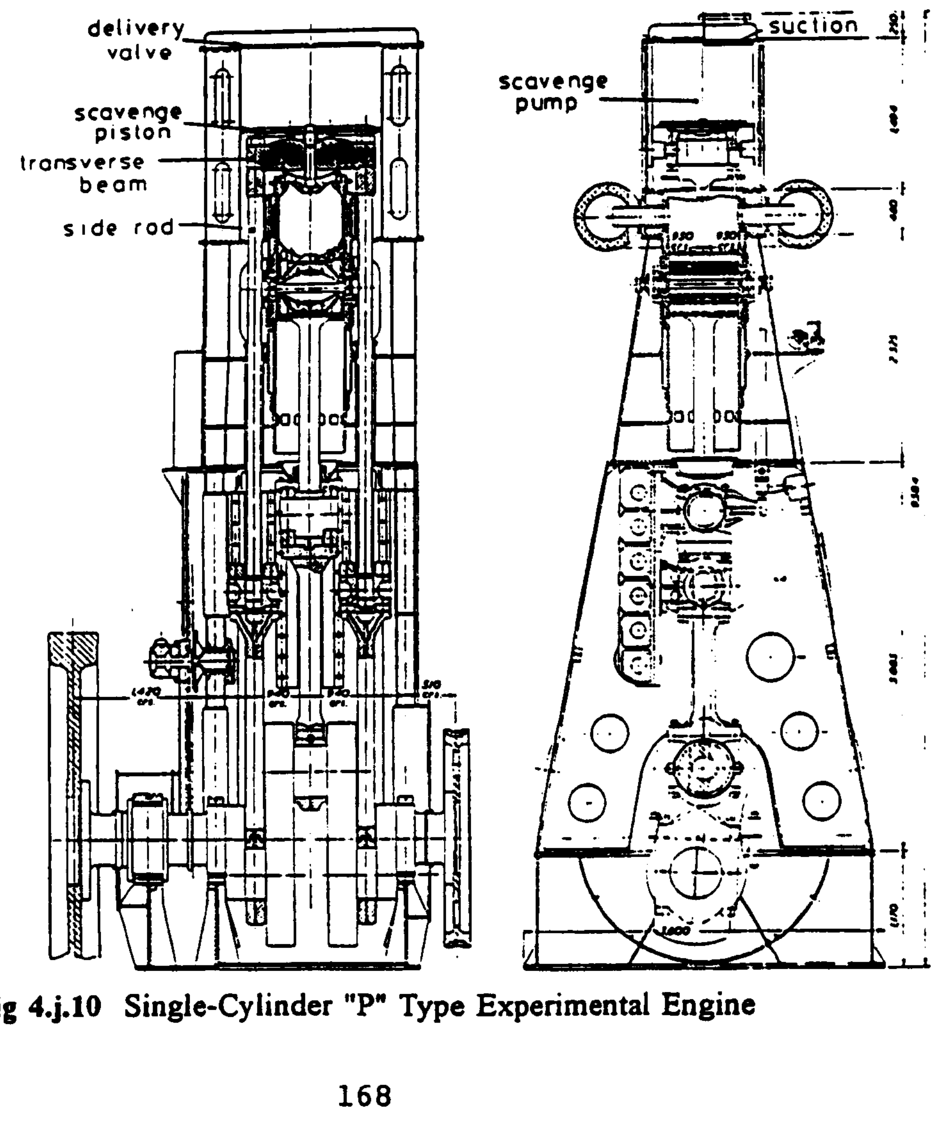


Fig 4.j.10 Single-Cylinder "P" Type Experimental Engine

Operation of the single-cylinder experimental engine proved satisfactory and a new engine developed, the "P" type. The six-cylinder 670mm bore prototype, designed to develop 7,460kW, was both shorter and lighter than an "LBD" engine of the same power. After extensive shop testing it was installed in the tanker **Montana** during 1961. Both turbo-charged and normally aspirated "P" type engines were offered but it was only the turbocharged version, operating on the pulse system, which attracted any interest. A considerable amount of design work went into the new engine which held Doxford's hopes for the future.[58] In October 1960 it was announced that a further £333,000 would be spent from reserves in developing the "P" engine, some £750,000 having been spent to that date on the project.[59]

Publicity material issued at the time indicated that turbocharged versions would also be offered with bores of 560mm and 850mm but these were quickly cancelled.[60] There was no demand for the smaller bore and within months of the proposal being made it was realised that a 770mm diameter crankshaft would be required for the larger engine in order to avoid torsional vibration problems. This would have been prohibitively expensive and heavy.[61] The new engine had reached the end of the road as soon as it entered service. Problems in service did not encourage sales, high cylinder wear rates were experienced with the engine fitted in **Montana** whilst the second engine, fitted in **Tudor Prince**, experienced fractures in the side rod bottom end bearing caps.[62] Only two licensees, Hawthorn, Leslie and Societe des Chantiers et Ateliers de Provence, built any "P" type engines.

The crankshaft was the problem but an opposed piston design presented difficulties in terms of crankshaft construction and a number of alternative methods of connecting the upper piston were considered. Lever systems and arrangements similar to that of the Fullagar engine were appraised and discounted as impractical.[63] Increased crankshaft stiffness was obtained by adopting an idea proposed by K.O. Keller in 1931; machining side rod webs in circular form would allow them to act as main journals and would increase crankshaft stiffness with an accompanying reduction in engine length, weight and cost.[64] The "J" type engine was born.

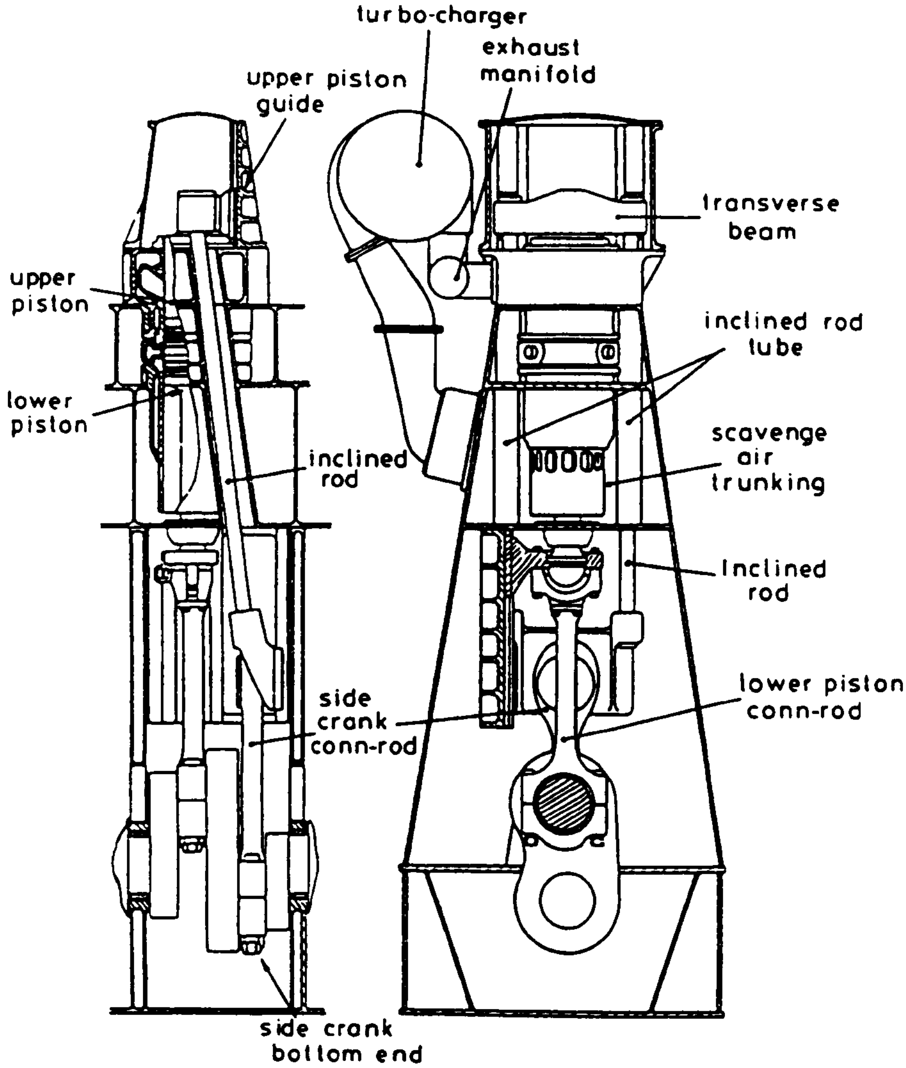


Fig 4.j.11 Fullagar Type Arrangement Proposed for Doxford Engine

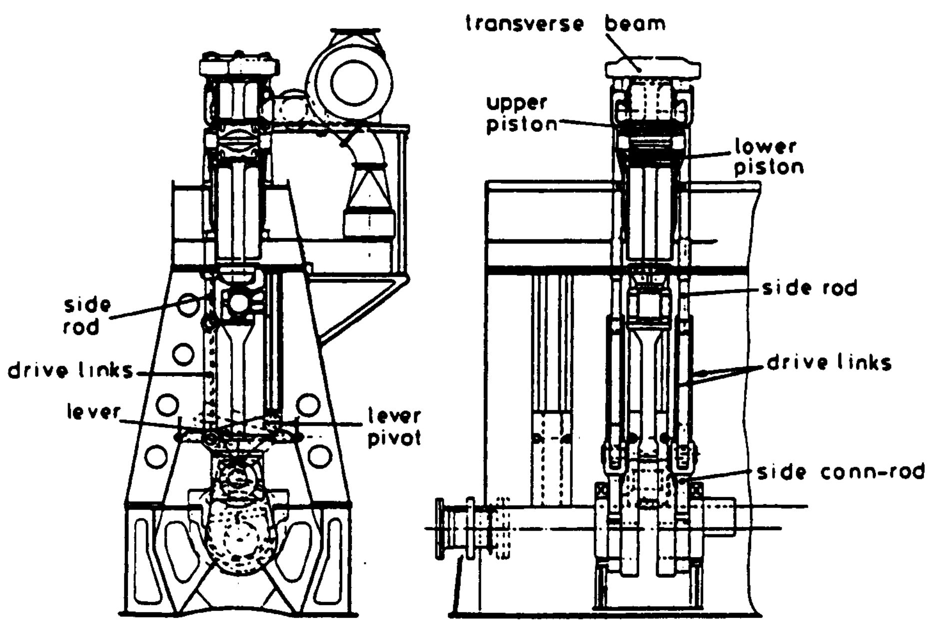


Fig 4.j.12 Lever System Proposed for Doxford Top Piston Connection

Many standard Doxford features such as the fuel system and air start system found their way onto the "J" engine, there was no point changing systems which functioned effectively. Improvements were made to pistons, liners and their cooling, and to the cylinder lubrication arrangements but it was the crankshaft which was the major change. In order to allow side webs to act as main journals the stroke of the upper piston had to be reduced to about 30% of the lower piston stroke. The high stroke to bore ratio was a major advantage of the opposed piston design in terms of cylinder power production and this change diminished that advantage over single piston engines. Trends towards long strokes in single piston designs resulted in power per cylinder of the "J" engine being little higher than that obtained from other contemporary slow speed designs. As with earlier opposed piston designs the "J" engine still had the advantage of balance over its competitors. Doxford engines required more bearings than single piston designs and the use of thin shell bearings was aimed at easing maintenance workloads. Initially the centre connecting rod top end bearing employed two shells and a support pad but this was quickly changed to a continuous bearing.[65] Engines were offered with 580mm, 670mm and 760mm bores with between four and nine cylinders depending upon bore, power range being between 4,476kW and 18,650kw.[66]

No single-cylinder engine was built, Doxford going straight to construction of a nine-cylinder 760mm bore engine which was installed in the tanker **North Sands**. Doxfords had the ship built in order that the engine would be seen to work at sea, design and construction being well documented at the time.[67] Performance in service was good and there was interest from shipowners, particularly those with Doxford engines already in their fleets, but only one licensee, Hawthorn, Leslie built "J" type engines. Vickers did express an interest and sent people to Sunderland in order to investigate costs involved in manufacture. On the assumption that they would eventually be quoting for "J" engines Vickers arranged to have price estimators visit Doxfords; at least two other licensees, Fairfields and Wallsend Slipway had undertaken similar exercises.[68] Licensees were, obviously, interested in the engine but there appears to have been a reluctance on the part of former shipowner clients to become involved again. Doxford engines were, or at least had been, profitable to the licensees, in the 1950s Hawthorn, Leslie (Engineers) Ltd. were making a profit of 25% on turnover building, on average, one

Doxford each month.[69] Doxfords continued development work on the "J" engine and a major improvement came with adoption of constant pressure turbo-charging in 1978,[70] but again this was too late.

In 1969, at the instigation of Hawthorn, Leslie (Engineers) Ltd. who wished to have a more active role in the engine design process after having been licensees for many years, a research company was formed with the aim of developing an opposed piston engine which could be operated at higher speeds.[71] Multiple geared or single electrical generating units could be devised making use of the inherent balance of the opposed piston engine. A four-cylinder prototype "Seahorse" engine was built and commenced tests during 1971.[72] A number of Doxford engineers had reservations about the engine including David Stables, General Manager and a director at Doxfords, who was of the opinion that existing resources could not support development of a completely new engine. However, the largely non-engineering board decided to proceed with the engine.[73]

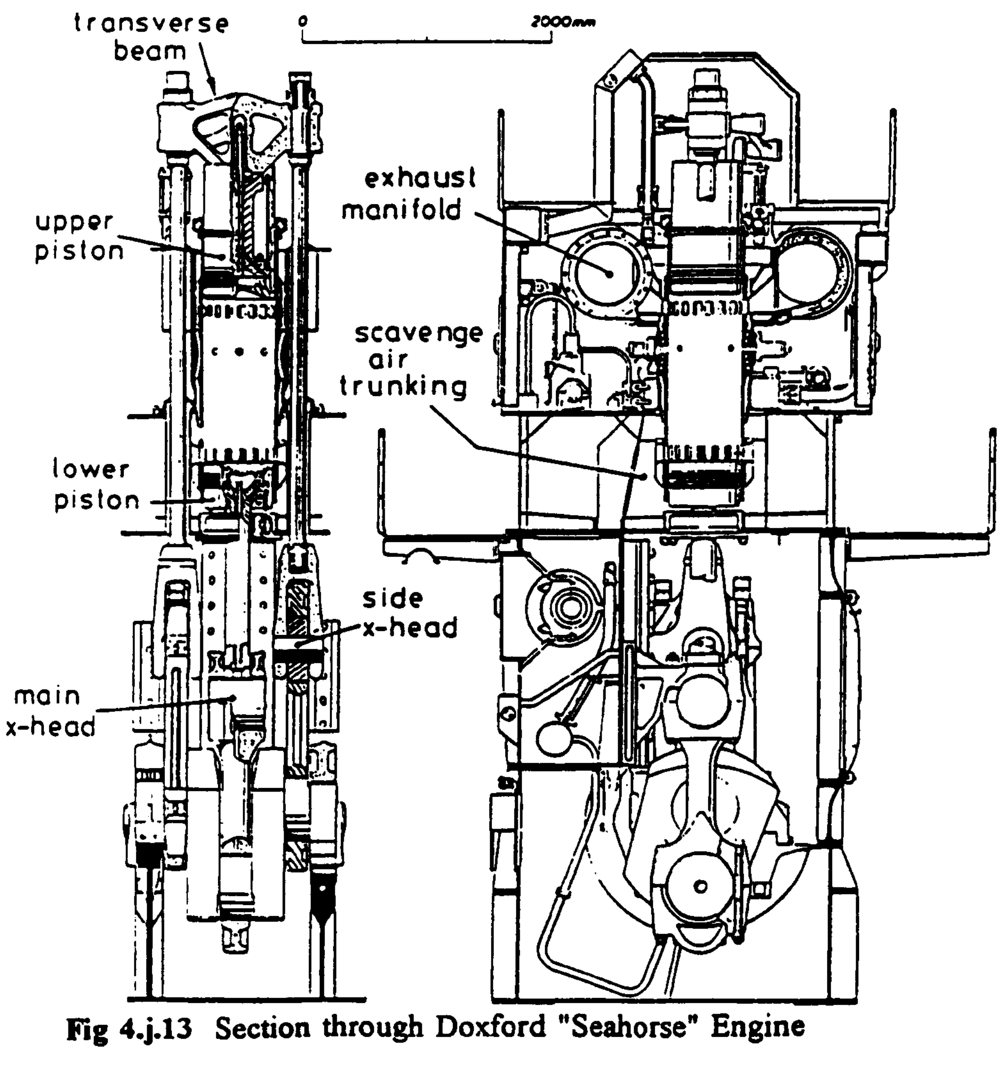


Fig 4.j.13 Section through Doxford "Seahorse" Engine

There was great hope for the "Seahorse" both in the marine field and for industrial applications[74] but development costs were high and the initial breakthrough of a land or marine order never came. E.P. Crowdy, a director of Doxford Hawthorn Research Services Ltd, went on a world sales tour and believed that many orders would have been forthcoming had there been an engine in commercial service. There were internal shipyard pressures against the engine as more profit could be made from a vessel with a "J" type engine than from a ship having a "Seahorse" installation. One shipowner with a large Doxford engined fleet was willing to take two "Seahorse" engines but the Doxford shipyard persuaded him to take a "J" engine instead.[75] In fact the engine had major troubles including excessive cylinder scuffing and operation of the mechanical supercharger with its 75:1 gearbox. By 1973 the "Seahorse" was looked upon as a "money-pit" and Court Line, the new owners of the Sunderland Shipbuilding Group of which Doxfords was then a part, was unwilling to sanction further expenditure. In 1974 Court Line virtually handed the "Seahorse" over to Hawthorn Leslie, who did not pursue development, and Court Line soon afterwards went bankrupt itself.[76] Doxfords had to be rescued by the government.

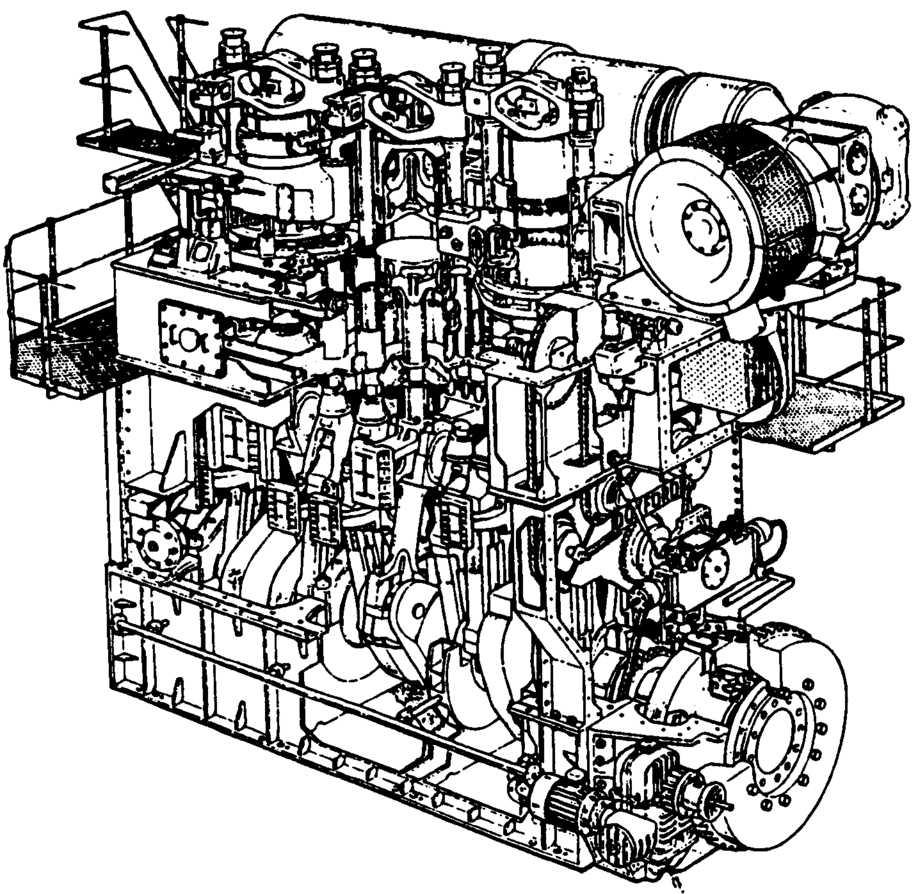


Fig 4.j.14 Sectional Drawing of the "58JS3" Doxford Engine

Some of the knowledge gained from the "Seahorse" project was used to develop the 58JS engine for the lower power market occupied by medium speed engines.[77] Three-cylinder versions of this design were built to drive small container ships[78] but by time early problems had been solved B&W and Sulzer also had small engines available.

Table 4.j.1

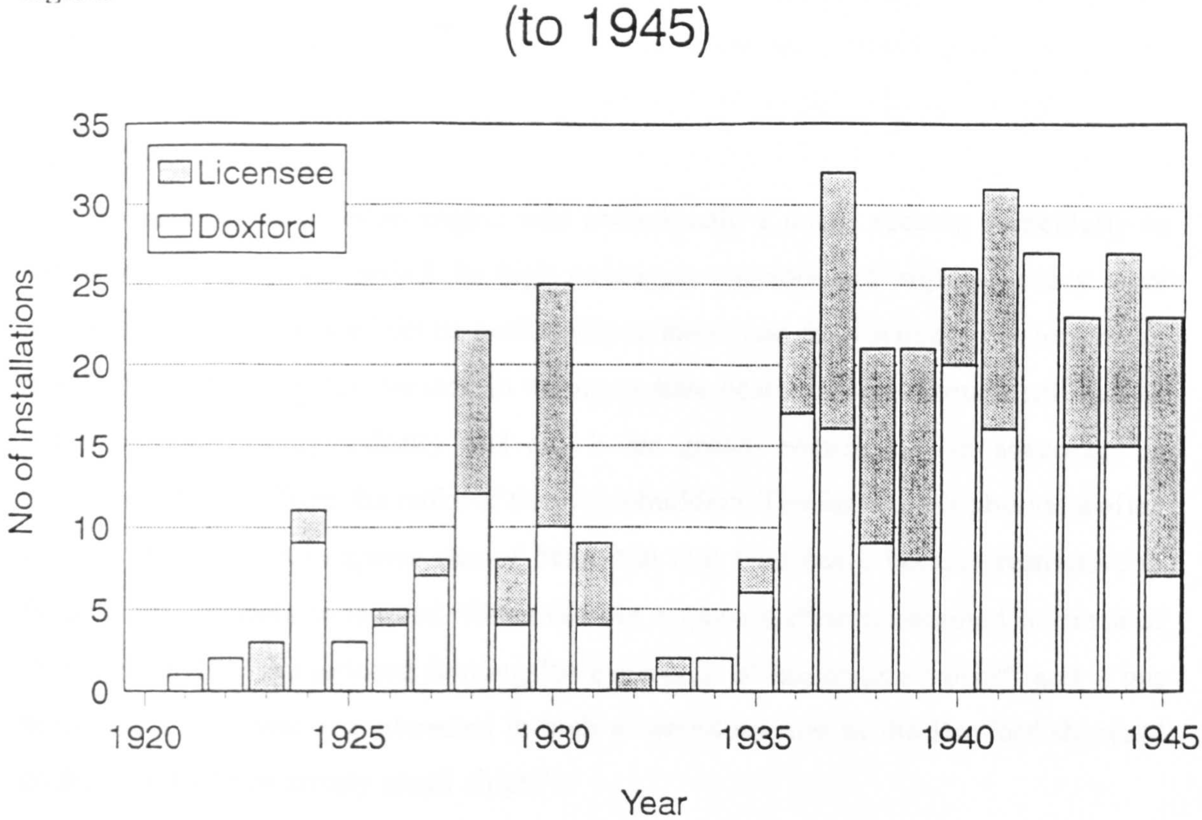
Doxford Engine Development							
Year	**Cyl'r Power** ***kW***	**Bore** ***mm***	**Stroke** ***mm***	**No cyls**	**RPM**	**S.F.C.** ***kg/kW/hr***	**Comment**
1919	504	580	1160+1160	4	77	0.268	Prototype eng'
1924	541	580	1160+1160	4	87	0.250	Uprated prototype
1926	522	600	760+1040	4	110	0.232	Balanced eng'
1928	200 274	400 400	540+760 540+760	3 3	145 200	0.216 0.220	Marine Industrial
1928	615	600	980+1340	4	98	0.237	
1931	881	700	880+1220	4	120	0.230	
1933	541	600	980+1340	4	92		Welded struct'
1935	448	520	880+1200	3	115	0.212	Economy eng'
1935	448	560	700+980	5	115	0.216	1st 5 cyl' eng'
1938	970	725	950+1300	5	123	0.219	**Dominion Monarch**
1939	1119	813	1016+1397	4	94	0.210 *	Sun Doxford
1949	274	440	620+820	3	145	0.224	Trawler Eng'
1951	1057	750	2500	6	110		
1952	933	600	2320	3	125	0.207	Exp' T/C eng'
1959	1300	700	2320	6	120		No scav' pumps
1961	1243	670	720+1380	6	120		"P" type
1965	1865	760	520+1660	9	119	0.219	"J" type
1971	1865	580	420+880	4	300	0.201**	Seahorse
1978	1350	580	340+880	3	220	0.201	58JS3

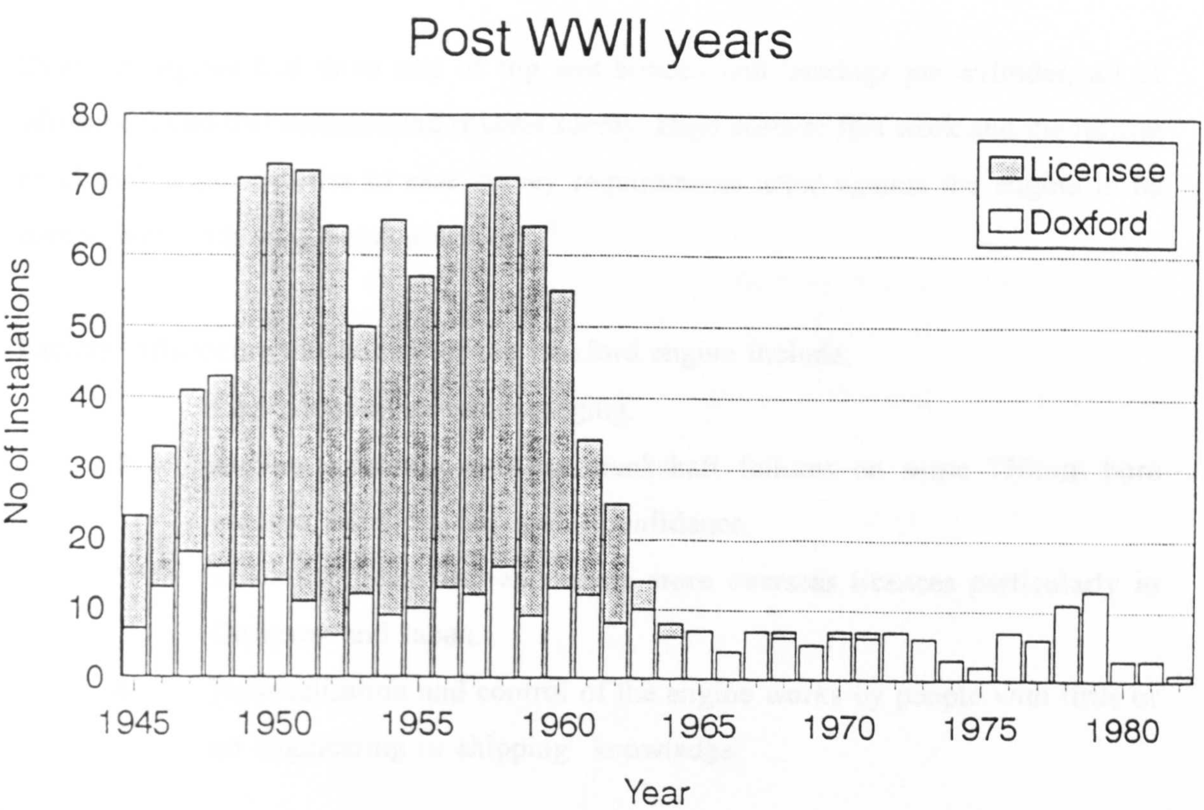
* Consumption figure calculated using shaft output power and electrical power generated using waste heat.
** Projected consumption

{Information in table 4.j.1 taken from various technical papers, ***The Motor Ship*** for various dates and Doxford publicity brochures}

Fig 4.j.15 Doxford Installations (Some installations twin screw)

Information taken from Doxford records in the Tyne & Wear Archives, Newcastle, various editions of ***The Motor Ship*** and D. Burrell, "*The Low Speed Diesel Engine in British Shipbuilding up to 1945*", Trans' NECIES, vol 105, pt 1, 1988. pp22-3.
Note: Information for 1942 does not differentiate between Doxford & licensee built engines





Nationalisation saw Doxfords become part of British Shipbuilders and it was under that cloak that a final opposed-piston engine design was devised. In conjunction with International Power Engineering of Copenhagen project BS42-100 was started in 1982 with the intention of designing a 420mm bore by 1000mm combined stroke engine. Unfortunately with the departure of Robert Atkinson as Chairman of British Shipbuilders the project faded.[79]

Epilogue

The Doxford opposed piston engine was undoubtedly a major success particularly in the immediate post-war period. Its high power per cylinder and high efficiency were important to shipowners whilst its availability in three- and four-cylinder versions made it popular with tramp ship owners. In the immediate post war years Britain still had an extensive shipbuilding industry and any home grown engine had an advantage in attracting licensees from the ranks of these shipbuilders. The fact that shipbuilders often constructed their own engines was of benefit at that time but it became restrictive as far as Doxfords were concerned. When Gebbie, a naval architect, became Chairman of Doxfords in 1957 he reduced funding for expansion of the engine works[80] and it has been said that he was not interested in high powered engines as the Doxford shipyard could only build relatively small ships.[81]

Doxford engines had three sets of top and bottom end bearings per cylinder, all of which required maintenance and routine survey. High costs of this work and the refusal of classification societies to ease survey requirements acted against the engine in its competition with single piston designs.[82]

Factors influencing the decline of the Doxford engine include;

1. Late adoption of turbocharging.
2. Engine problems, such as crankshaft failures on some 750mm bore engines, resulting in loss of confidence.
3. Failure to grant and encourage more overseas licences particularly in Germany and Japan.
4. Nationalisation and control of the engine works by people with little or no engineering or shipping knowledge.

5. Decline of the British shipbuilding and shipowning industries.
6. Development of higher cylinder powers with single piston Sulzer and B&W designs.

A further aspect was probably the attitude of people at Doxford as the company always seemed to have a poor relationship with its licensees believing that any engine problem was the fault of the licensee or the operator of the engine, never the fault of the design.[83]

Some have contended that the opposed piston concept had reached the end of its development[84], but for others it still had potential in certain areas of the marine market.[85]

The argument is now academic as by the end of the 1980s there was no real British commercial shipbuilding industry for which engines could be built. Doxford's decline mirrored British shipbuilding decline because there was insufficient involvement with overseas engine builders. Without an extensive array of licensees insufficient royalties were earned to fund further development. Had a German or Japanese partner been sought in the early 1950s the story might have been different.

References

Key

Vickers	Vickers files of Doxford correspondence; VSEL, Barrow
Licensees	Minutes of Doxford Licensees Technical Meetings; Scotts of Greenock Archives, held at the Ballast Trust, Johnstone, Glasgow.

1. J.W. Smith & T.S. Holden, **Where Ships are Born**, T. Reed & Co, Sunderland, 1953. p62-4, p154

2. *The Engineer*, vol 115, 14 Feb' 1913. p168

3. *The Engineer*, vol 155, 22 Jan' 1843. p61

4. Doxford Sub-Licence agreement as used in 1924: Vickers

5. *Engineering*, vol 155, 22 Jan' 1943. p62

6. W. Ker Wilson, "*The History of the Opposed-Piston Marine Oil Engine*", Trans' I.Mar.E., vol 58, 1946, pp189-92

7. C.J. Hawkes, "*Some Experimental Work in Connection with Diesel Engines*"; Transactions Inst' of Naval Architects, vol 62, 1920. pp283-4: R. Beeman, "*Further Experimental Work on Diesel Engines*"; Trans' Inst' of Naval Architects, vol 66, 1924. pp119-22

8. Internal Memo, Vickers I.C. Engine Department, 15 Jan' 1945: Vickers

9. ***The Engineer***, vol 131, 17 June 1921. pp633-5

10. W.H. Purdie, "*Thirty Years' Development of Opposed-piston Propelling Machinery*", Proc' Inst' of Mechanical Engineers, vol 162, 1950. p447; ***Engineering***, vol 155, 22 Jan' 1943. p63

11. D. Burrell, **Furness Withy 1891-1991**, World Ship Society, Kendal, 1992. p91

12. "*Marine Oil-Engine Trials Committee Third Report,*" Tran's Inst' of Mechanical Engineers, Jan' 1926, vol I. pp99-213

13. Report from Vickers I.C. Engine Department following visit to Doxfords, dated 1 Feb' 1924; Vickers

14. W. Ker Wilson, "*Oil Engine Dynamics with Special Reference to the Opposed Piston Engine*"; Trans' I.Mar.E., vol 58, 1946. pp77-8

15. ***Engineering***, vol 155, 5 March 1943. pp181-2

16. ***The Engineer***, vol 147, 24 May 1929. pp570-1

17. ***Engineering***, vol 155, 12 March 1943. p201

18. ***The Motor Ship***, vol 2, January 1922. p362.

19. W.H. Purdie, "*Thirty Years Development*". p464

20. ***The Motor Ship***, vol 15, Jan' 1936, pp362-4

21. W. Ker Wilson, "*History of the Opposed-Piston Engine*", Trans'I.Mar.E., vol 58, 1946. p198

22. W.H. Purdie, "*Thirty Years Development*". p450

23. 10th Doxford Licensee's Technical Meeting, Minute No 166: Licensees

24. ***The Motor Ship***, vol 14, Jan' 1935. p335

25. W. Ker Wilson, "*History of the Opposed-Piston Engine*". p198.

26. W.H. Purdie, "*Thirty Years Development*". p460

27. 17th Doxford Licensees Technical Meeting. Licensees

28. W. Ker Wilson, "*Oil Engine Dynamics*". p84

29. ***The Motor Ship***, vol 27, June 1946. pp112-4: vol 28, April 1947. p13

30. ***The Motor Ship***, vol 20, Nov' 1939. p267: vol 24, June 1943. pp76-7

31. ***The Motor Ship***, vol 42, Jan' 1942. pp324-5

32. ***Engineering***, vol 155, 12 March 1943. p202:
The Motor Ship, vol 24, June 1943. pp76-7

33. ***The Motor Ship***, vol 42, Sept' 1942. pp173-9

34. Report on Doxford Licensee meeting held on 18 July 1945: Vickers

35. Minutes of First Doxford Special Policy Meeting, 26 May 1953: Licensees

36. A. Storey, "*Final Years of the Doxford*", Trans' North East Coast Institute of Engineers & Shipbuilders (NECIES), vol 105, pt2, Nov' 1988. p66

37. The problems concerning crankshaft production are illustrated by correspondence in the Vickers Ltd Doxford files for various dates between Nov' 1944 and October 1945. Vickers

38. Letter from E.R. Micklem of Vickers to A. Belch, Secretary of the Shipbuilding Conference dated 14 July 1945. Vickers

39. Minutes of Meeting Between Doxford, licensees and Forgemasters, 16 October 1945. Vickers

40. Letter from Micklem to Belch 14 July 1945. Vickers

41. 1st Doxford Licensees Technical Meeting, 11th/12th May 1948. Licensees

42. Minutes of Second Doxford Special Policy Meeting, 22 Oct' 1953. Licensees

43. ***The Motor Ship***, vol 44, April 1963. p34

44. 10th Doxford Licensees' Technical Meeting, 1 April 1952, Minute No 168. Licensees

45. 9th Doxford Licensees Technical Meeting, 30 Oct' 1951. Minute No 153. Licensees

46. 4th Doxford Licensees' Technical Meeting, 14 June 1948. Minute No 94. Licensees

47. Conversation with David Stables former Doxford Managing Director, 3 Feb' 1994

48. Letters and reports in Vickers' Doxford file 27 Dec' 1955 to 16 Aug' 1956. Vickers

49. R. Atkinson & P. Jackson, "*Some Crankshaft Failures; investigations, causes and remedies*". Trans' I.Mar.E., vol 72, No 2, 1960. pp269-304

50. Letter from Vickers to Doxford dated 16 Aug' 1956. Vickers

51. B. Taylor, "*The Rise & Fall of the Doxford Engine: Some Personal Views*", Trans' NECIES, vol 105, part 2, 1989. p64

52. 3rd Doxford Licensees' Technical Meeting, 2 Feb' 1949. Minute No 63. Licensees

53. 6th Doxford Licensees' Technical Meeting, 25 May 1950. Minutes No 100 & 101. Licensees

54. 7th Doxford Licensees Technical Meeting, 24 Oct' 1950. Minute No 119. Licensees

55. 10th Doxford Licensees' Technical Meeting, 1 April 1952. Minute No 170. Licensees

56. P. Jackson, "*Two Decades of Research & Development on the Doxford Engine*", Trans' NECIES, 1963. p49

57. ***The Motor Ship***, vol 40, June 1959. p102-3

58. P Jackson, "*The Future Doxford Marine Oil Engine*", Trans' I.Mar.E., vol 73, No 7, 1961. pp197-242

59. ***The Motor Ship***, vol 41, Oct' 1960. p302

60. Doxford publicity brochure for "P" type engine issued 1961

61. P Jackson, "*The Doxford J Type Opposed Piston Marine Oil Engine - Testing Experiences*", Trans' I.Mar.E., vol 77, 1965. pp89-90

62. P. Jackson, "*The Doxford Direct Drive Diesel Engine,*" Trans' I.Mar.E., vol 74, 1962. pp463-6

63. P. Jackson, "*Doxford J Type Engine*", pp90-1

64. ***The Motor Ship***, vol 51, April 1970. p49

65. B. Taylor, "*Development of the Doxford J-type Engine*", Inst' of Marine Eng'rs International Marine & Shipping Conference, June 1969.

66. Doxford "J" engine publicity brochure

67. P. Jackson, "*Doxford J Type Engine*". p89-91

68. Letters from Vickers to Doxfords, 3rd & 15th March 1965, Vickers

69. E.P. Crowdy, "*Final Years of the Doxford*", Trans' NECIES, vol 105, part 2. 1989. p66

70. F. Orbeck, "*Development of the Doxford Engine from 1960*", Trans' I.Mar.E., vol 102, pt 1, 1990. pp40-1

71. Conversations with E.P. Crowdy, Director & Technical Manager, Hawthorn, Leslie (Engineers) Ltd: December 1992.

72. J.F. Butler & E.P. Crowdy, "*The Doxford Seahorse Engine*", Trans' I.Mar.E., vol 84, pt 3, 1972. pp73-115

73. Conversation with David Stables, 3 Feb' 1994

74. J.F. Butler & E.P. Crowdy, "*Industrial Applications of the Doxford Seahorse Engine*", Diesel Engineers & Users Assoc', publication No 350. Feb' 1972

75. Conversations with E.P. Crowdy, December 1992.

76. Conversation with David Stables, 3 Feb' 1994

77. Orbeck, "*Development fo the Doxford Engine*". p41

78. ***The Motor Ship***, Doxford 58JS3 Supplement, February 1979

79. F. Orbeck, "*Development of the Doxford Engine*". p42-3

80. A. Storey, "*Final Years of the Doxford*". p66

81. Conversations with E.P. Crowdy, December 1992

82. Conversations with B. Taylor, former Chief Engineer, Doxford Engine Works: Dec' 1992

83. Conversation with David Stables, 2 Feb' 1994

84. A.F. Harrold, "*Development of Merchant Ship Propulsion Machinery Over the Past 25 Years*", Trans' I.Mar.E., vol 101, pt 1, 1989. p8

85. Orbeck, "*Development of the Doxford Engine*", p51

Chapter 5.

British Engine Builders and the Diesel

Although a significant number of British shipbuilders/engine builders did make the necessary investment and develop their own crosshead diesel engines a much larger number did not. In many cases there were good reasons for adopting the policy of wait and see, particularly before the outbreak of World War I, but it tended to put the company in the realm of a follower in technology and not a leader. To some extent that is what most British shipbuilders had always been as they simply constructed ships for the general market leaving the large concerns to make the advances; most of those advances came through the construction of passenger liners and warships but orders for such vessels went to only a small proportion of British shipbuilders.[1] Certainly not all British shipbuilders built their own steam engines and even fewer decided to build diesels. In 1925 only 20 British shipbuilders built, or held a licence to build, crosshead marine diesel engines[2] whilst there were some 686 building berths over 250ft long[3] these being operated by about 90 firms in some 100 shipyards.[4]

It has been proposed that those companies who took licences rather than adopt the path of independent development did so because of the high cost of development and experimental works together with a desire to produce engines for the market as soon as possible.[5] There would certainly be economic merit in such action in the immediate post-WWI years particularly as many continental engine designs had been able to progress whilst Britain had been engaged in the conflict and development work was, of necessity, restricted. Sulzer engines were preferred by most British licensees during the 1920s seven licences being taken, Harlands held a B&W licence, North Eastern Marine and Hawthorn Leslie held licences from Werkspoor whilst Beardmore took a licence for the Italian Tosi engine and Richardsons Westgarth held a sub-licence from Beardmore.[6] It would, however, be incorrect to presume that because an engine builder held a licence he was not involved in any innovation or development work, many were.

During the early 1920s double-acting engines were looked upon as being the obvious choice for high power generation and many concerns expended considerable time and energy in producing designs for such machinery. Three Sulzer licencees, Alexander Stephen & Sons of Govan,[7] the Fairfield Shipbuilding & Engineering Co.,[8] also of Govan, and the Wallsend Slipway & Engineering Co. of Wallsend on Tyne[9] were granted patents for double-acting crosshead engines during the 1920s. Swan Hunter also patented such an engine[10] and followed this with a succession of patents covering details of the design. None of these engines appears to have progressed to the experimental stage but the number of patents taken does illustrate that some of the larger British shipbuilders were forward looking and even licensees perceived possible advantages in designs of their own. Mickelsen and Rebbeck of Harland & Wolff filed a patent for a two-stroke double-acting engine[11] in 1922 but again this appears to have progressed no further than a paper design.

Despite, or maybe because of, their work on four-stroke engines Vickers also considered opposed-piston two-stroke designs and a number of different arrangements were outlined in patents filed in 1919.[12] Each patent offered a number of designs but they all involved levers and linkages for connecting the pistons with the crankshaft and were certainly more complex than the Fullagar or Doxford arrangements; they also contained more bearings than the double-acting design put into service by the North British Diesel Engine Works. Designers not associated with any of the large engine builders often produced engine designs of their own and one which attracted attention during 1924 was an offering from W.D. McLaren. This individual had spoken during discussion of MacLagan's 1924 paper on the sliding-cylinder engine[13] and later that year he presented a paper[14] before the same Institution concerning a two-stroke engine of his own design. This was effectively an opposed-piston double-acting engine based upon the Junkers tandem arrangement and although the paper was sympathetically received many speakers commented upon the complexity of the arrangement and the height of the engine. By the early 1920s it appears to have been generally accepted that the basic designs of engine then in service, whether two-stroke or four-stroke, single piston or opposed-piston, were all that were needed and Sir Westcott Abell commented that in the future the aim should be, "*...to devote considerable attention to obtaining the maximum simplicity, gaining thereby in reliability and ease of maintenance*".[15] This was the intention of those concerns with designs already on the market and even of engine builders who licensed overseas designs.

Sulzer appear to have given licensees little scope for "improving" the product and that would have suited some engine builders as they could manufacture the engine from complete drawings supplied by the designer without the cost involved in modifying existing designs or redrawing individual components. The cost of a licence involved an initial payment to cover drawings and technical advice plus additional royalties based upon the number of engines constructed. In 1935 the board of Hawthorn Leslie decided to take a Sulzer licence instead of one for the Doxford engine on the grounds that the Sulzer royalty payments were lower than those required by Doxford despite the initial payment being higher.[16] In 1924 Vickers had decided against taking a Doxford licence because of what was considered to be a high royalty charge of £1 per bhp.[17] The Hawthorn Leslie board's decision followed a 1934 review of marine diesel engine development by one of the company's senior engineers, P.B. Johnson. Concluding his report Johnson stressed that *"Owners nearly always specify that the engine must be a make....already tried out in service"*[18] and during the difficult marine climate of the 1930s it was considered prudent to licence a design rather than suffer the delay and unquantifiable costs of designing an engine of their own. That sort of argument would equally have applied to shipbuilders/engine builders during the 1920s

Hawthorn Leslie had been early licensees of the Dutch Werkspoor company, a licence having been taken in February 1920; that licence allowed H-L to build Werkspoor engines and sell them anywhere in the world, the initial payment of 21,000 guilders (about £2,386 at that time) bringing a complete set of dimensioned working drawings and permission to send up to three engineers to be trained at the Werkspoor factory; an equal payment was due when the first ship was engined and a third when orders reached 3,000bhp.[19] Werkspoor reserved the right to issue four additional British licences, one already being held by the North Eastern Marine Engineering Company (NEM), this having been granted in 1912.[20]

Hawthorn Leslie were very much licensees and do not appear to have contributed much to the development of the Werkspoor engine. The situation during the early 1920s was a difficult one for British shipbuilders in general with few orders available on which to make any profit. Two sets of twin diesel engines were ordered from H-L but both sets had been cancelled by May 1921 and it was not until 1925 that the company had its first Werkspoor engines at sea. These were fitted in the twin screw vessel **Cape York** which was the subject of the fifth Marine Oil-Engine Trials Committee report.[21] The company actually made a loss on this engining of £30,608[22] which illustrates the sorry state of the British shipbuilding and marine engineering industry at that time.

NEM supplied twin engines for one ship during each of the years 1921, 1922, 1924 and 1925,. the engines being strictly to Werkspoor drawings.[23] The close relationship between licensor and this licensee resulted in agreement during the early years of the 1920s to jointly develop a double-acting engine and to this end NEM funded the construction of a single-cylinder experimental double-acting four-stroke engine to a design produced by Werkspoor. This 800mm bore by 1400mm stroke unit could develop 560kW when running at 95rpm. and it performed well during a 20 day continuous trial conducted in May 1924.[24] Successful running of the experimental engine resulted in orders being obtained for full scale installations and the first of these came from Alfred Holt & Co. for a six-cylinder 4,400kW engine to be installed in the cargo ship **Stentor** built by Caledon at Dundee. Much of the detail design work was carried out by NEM and the engine can be considered as a collaborative venture between that organisation and the licensee.[25] Unfortunately the engine was not a success and the ship had to be re-engined with a single-acting B&W four-stroke during 1930.[26]

NEM had more success with the application of turbo-charging to marine diesel engines, indeed the company was one of the first to recognise the advantages of such an arrangement. Considerable interest was generated by a paper read by Dr Alfred Buchi before the Institute of Marine Engineers during 1928[27] and NEM convinced the owners of the vessel **Raby Castle** to modify the Werkspoor engine in the ship so that it would operate on the Buchi system of turbo-charging. Fitting the Brown-Boveri built turbo-charger to the eight-cylinder four-stroke engine produced a 25% increase in power.[28] **Raby Castle** was the first ocean going vessel to operate under continuous super-charging and although NEM did not develop the system the company was to the fore in its application indicating a degree of foresight not shown by some other British marine engine builders, particularly Doxford. Success of the installation prompted its use in the "Water Street" engine (see chapter 4.g). Depression in the shipping industry during the 1930s meant that orders were difficult to find and only three other turbo-charged engines were built at Wallsend before the outbreak of World War II; these went into **Imperial Transport** (1931), **Athelfoam** (1931) and **Hylton** (1936).[29] The engine fitted in **Hylton** was described as "*...the latest type of North Eastern engine....to be standardised for cargo ships of a certain size and speed*", the major change from earlier installations being the use of solid fuel injection.[30] No further orders were forthcoming and after the war the building of Doxford engines commenced; NEM became part of the Richardsons Westgarth group in 1938 and the licence granted to R-W was modified to include other companies in the group.

William Beardmore & Co. of Dalmuir reached an agreement with Franco Tosi of Legano, Italy, this being closer to a collaborative venture than the granting of a construction licence. Although Beardmore followed the basic crosshead Tosi four-stroke engine pattern a number of modifications were made including design of a new reversing system which became standard for all British built Tosi engines.[31] The first two Beardmore engines went into the MacAndrew Line vessels **Pinzon** (1922) and **Pizarro** (1923) and both performed well in service initially. A sub-licence was granted to Richardsons Westgarth of Hartlepool and this concern also made minor modifications to the basic design before building any engines.[32] Two engines were built by R-W for the Furness Withy ship **Sycamore** (1923) machinery and vessel being the subject of trials conducted by the Institution of Mechanical Engineers and Institute of Naval Architects.[33] A similar set of engines were built for Furness, Withy's **Tramore** (1924) with another pair for the cargo ship **Silurian** (1924).

The six cylinder engines of built for **Sycamore** developed some 930kW each but all concerned believed that a more powerful unit was required and in 1924 G.F. Tosi, a partner in the Italian parent company, announced that Tosi, Beardmore and Richardsons Westgarth were working together on the development of a large double-acting engine capable of developing 750kW per cylinder. The expectation was that engines of up to ten cylinders would be built.[34]

Lloyds List announced the venture as, "*...the formation of the Internal Combustion Engine Development Co by Richardsons Westgarth, Beardmore, Furness Withy and Tosi of Italy: it has been decided to build two large diesel engines, one by R-W at*

Hartlepool and the other by Beardmore at Dalmuir. A very large sum is involved in the formation of the company, capital supplied principally by engineering firms but also by FW&Co. No subscription by the public as the object is not to earn dividends but to carry out experimental and research work."[35] This would indicate progressive attitude on the part of these engine builders and the shipowner (Furness, Withy); the engineering concerns may not have been involved in originating the Tosi design but they were certainly willing to make a financial investment in order to ensure future progress.

Results of the efforts did not live up to expectation as only two of these double-acting engines were constructed and these were of smaller size than that anticipated by G.F. Tosi. The only effective way of bringing the engine to the notice of potential customers was via practical operation at sea and so Beardmore decided to install a pair of the engines in **Wulsty Castle**, a ship owned by the company; these engines had three-cylinders of 510mm bore and 620mm stroke and could develop some 675kW at 250rpm.[36] This vessel was engined by Beardmore in 1918 being fitted with a turbo-electric system constructed under licence from the Swedish Ljungstrom Marine Turbine Company but this installation had proved unsatisfactory, Beardmores claiming that the problems were due to the ship's engineers. The steam plant remained unsatisfactory and **Wulsty Castle** was laid-up until taken to the Vulcan shipyard at Stettin, Germany for re-engining with the pair of engines driving a single propeller shaft through gearing and Vulcan fluid clutches.

Prior to construction of the double-acting engines for **Wulsty Castle** a single-cylinder experimental unit was built by Vulcan-Werke at Hamburg and extensively tested; the experimental engine had the same cylinder dimensions as the production engines.[37] Vulcan built the engines and transmission system as part of the agreement in which Beardmore acquired British rights to the Vulcan hydraulic clutch.[38] The installation was not a success and no further engines of the type were built. .

Beardmore continued development of the single-acting Tosi engine and in 1927 applied supercharging as a means of increasing power. The supercharger consisted of a Weir steam turbine driving a rotary blower, it being possible to operate the engine supercharged or naturally aspirated. Three ships, **Itape** (1927), **Itanage** (1928) and **Itaquice** (1928) were built for Brazilian owners and each was fitted with two six-cylinder supercharged engines, 660m bore by 1100mm stroke, developing 1380kW (1231kW when naturally aspirated).[39] The engines appear to have been successful for they were still in the ships at the end of their lives, two ships remaining in service until the 1960s.[40] Beardmore involved itself in the development of a trunk-piston semi-diesel engine, the Beardmore-Speedwell, which had no more success than the company's other diesel engines.[41] The yard closed in 1930, a victim of the cutback in naval orders and of the general decline in British shipbuilding due to overseas competition.

At the outbreak of WWII only the Doxford engine could be considered as British as, strictly speaking, the Harland & Wolff opposed-piston engine had not then been developed. The optimism shown by many builders during the 1920s had not been realised and those who had not already done so were forced to take licences for engines designed by others. By 1924 some British designs had attracted licensees although in most cases few of these actually built any engines.

Table 5.1 Licensees of British Designed Engines during 1924

Source; The Motor Ship Reference Book for 1925, Temple Press. London

Table 5.2 List of Licences Granted by Major European Crosshead Engine Designers

( ) Licensees in Designer's Own Country   * Sub-licence granted by U.K. sole licensee

Source: The Motor Ship Reference Books for 1925, 1927, 1931, 1935 and 1939, Temple Press, London

By 1930 only Doxford licensees were building engines and the number of licensees increased steadily over the years reaching a peak during the 1950s as shown in chapter 4.j. Overseas engine builders, however, appear to have been more active in seeking licensees both in Britain and other countries as shown by Table 5.2.

The British market was, obviously, an attractive one for oversees designers simply because Britain built more ships than any other country and not all were for the domestic owners; even if British shipping companies could not be persuaded to adopt diesel propulsion most continental owners were much more agreeable. By 1930 the four major continental designers had become well established with Sulzer having the dominant share, particularly in Britain. It was not easy for other people to break into the market and few even tried as development of large marine diesel engines was a costly business which most British designers had, by then, learned. One who did try, however, was the Dane O.E. Jorgensen who had been general manager of the B&W (Diesel System) Oil Engine Company when it was first established in Glasgow (see chapter 1). After leaving that organisation Jorgensen worked with the Worthington company in America as designer of its two-stroke double-acting engine and then left to establish his own company. The new two-stroke double-acting engine he designed bore strong similarities to the Worthington engine and a licence was taken by Earle's Shipbuilding & Engineering Company of Hull.[42] A four-cylinder engine was constructed and underwent testing during 1930[43] but despite media attention no buyers were forthcoming. The depression then afflicting the British shipbuilding industry may well have been influential in that matter as Earles suffered badly and the company was purchased by National Shipbuilders Security in 1933 and shut down.[44]

British engine builders were active throughout the interwar years and many motorships were constructed in Britain as can be seen from fig 5.1; the wide variation in annual construction indicates the vagaries of the market and the depth of the shipbuilding depression in the early 1930s. What is also evident from fig 5.1 is that Britain's share of motorship construction was relatively low compared with the rest of the world.

Fig 5.1 British Motorship Completions
Source: Lloyd's Register of Shipping Annual Statistics

Fig 5.2 Motorship launchings compared with steamship launchings
Source: Lloyd's Register Annual Statistics

Fig 5.3 British Owned Motorship
Source: Lloyd's Register of Shipping Annual Statistics

Fig 5.2 shows that British yards launched more steamships over 1,000 tons than motorships, often two steamers for each diesel powered vessel, whilst overseas yards favoured the motorship. Although the number of British owned motor vessels rose steadily during the inter-war years, apart from the deep depression years of the early 1930s, the share of the world's motorship fleet remained much the same. (fig 5.3) Whilst this indicates steady construction it takes no account of the fact that the British fleets was declining[45] and that construction of ships in British yards was also falling due to competition from continental builders. Continental builders did not construct British designed marine diesel engines but they did attract orders from British shipowners when price and other conditions were right.[46]

In Britain the Doxford engine quickly became the most popular of the home designed engines and during the 1930s there was virtually no home designed competition. With respect to licensed designs the B&W engine was the most popular despite the fact that only two firms built the engines, holders of the licence Harland & Wolf and the sub-licensee Kincaids. Success of the type during the interwar years was not only due to the quality of the B&W design but also to the fact that most ships in the Royal Mail Group fleets were built and engined by Harlands; both concerns being in the empire established by Lord Kylsant.

Fig 5.4 British Motorship Installations in the inter-war years by engine type
Source: The Motor Ship for years 1920 to 1939

British engine designers did have an influence on overseas engines in terms of ideas incorporated in those engines. It took some time for continental builders to adopt solid injection of fuel although Vickers and Doxford had proved the effectiveness of such an arrangement prior to 1920. Similarly British engineers took the lead in the use of heavy fuel for burning in marine diesel engines; Doxford experimented with the burning of boiler oil during the early 1920s[47] whilst the Shell Tanker Company, under the guidance of its Chief Engineering Superintendent John Lamb, carried out extensive development work during the immediate post-WWII period in order to enable engines in the company's fleet to burn heavier grades of fuel. So successful was Lamb's work that by 1956 some 500 ships worldwide had diesel engines capable burning heavy residual fuel.[48]

The British Admiralty carried out detailed investigations on many engines, and even developed its own, with a view to finding the ideal submarine engine. Although experimental engines of the Doxford and Fullagar types were investigated (see chapters 4.j and 4.d) it became obvious that the future of the submarine engine lay with the trunk-piston type rather than the crosshead or even opposed-piston form. For one engineer, W.F. Rabbidge of Vickers, the involvement of the Admiralty in diesel engine development was a grave mistake and in 1943 he wrote a scathing article criticising that organisation for wasting the lead which Vickers, and others, had given the British engine building industry. One complaint concerned the establishment of the Admiralty Engineering Laboratory during WWI with its panel of advisers which did not include anybody from Vickers despite that company's expertise in airless injection. Rabbidge further complained that papers published by people from the Admiralty gave away valuable secrets concerning airless injection which the Germans, and others, quickly copied.[49] Why Rabbidge felt compelled to write such an article is difficult to imagine unless he believed that the Admiralty was somehow responsible for the British marine diesel engine industry losing its way. Certainly with the end of WWI there was no longer the pressing need for submarine engines and experimental or development work was reduced.[50] Whilst Rabbidge may have felt aggrieved that a lead was thrown away he had earlier expressed views that the excellence of the design rather than its nationality should be of prime importance.[51] It is possible he supposed that an excellent Vickers engine could have been developed had the Admiralty invested the funds.

References

1. E.H. Lorenz, **Economic Decline in Britain**, Clarendon Press, Oxford, 1991. pp26-8

2. **The Motor Ship Reference Book for 1925**, Temple Press, London, 1926. pp118-9

3. L. Jones, **Shipbuilding in Britain**, University of Wales press, Cardiff, 1957. pp122-3

4. Lorentz, **Economic Decline in Britain**. p29; Table 2.2 shows that in 1920 there were 109 shipbuilding firms with 126 yards but by 1930 this had fallen to 60 firms with 80 yards.

5. Prof' C.J. Hawkes, "*The Marine Oil-Engine*", Proceedings I.Mech.E., Jan' 1928. p4

6. Information for the year 1925 from **The Motor Ship Reference Book for 1925**

7. Patent No 198255 of 1923

8. Patent No 244355 of 1924

9. Patent No 213802 of 1924

10. Patent No 205443 of 1923

11. Patent application No 33671/22 (accepted as 205,394 of 1923)

12. Patent No 164679 of 1919 and patent No 165861 of 1919

13. J.C.M. MacLagan, "*The Sliding Cylinder Double-Acting Two-Cycle Diesel Engine*", Proc' I.E.S.S., 1924. pp 807-10

14. W.D. McLaren, "*The Further Development of Large Power Diesel Engines*", Proc' I.E.S.S., 1924-5. pp195-233

15. Comment by Sir Wescott Abell during his I.Mar.E. Presidential Address; Trans' I.Mar.E., vol 37, 1924-5. p792

16. J.F. Clarke, **Power on Land & Sea**, Hawthorn Leslie, Newcastle, nd. p88

17. Report from Vickers I.C. Engine Department following a visit to Doxford, dated 1924. Vickers Archives.

18. Clarke, **Power on Land & Sea**. p88

19. Clarke, **Power on Land & Sea**. p86

20. ***The Motor Ship***, vol 51, No 597, April 1970. p57

21. "*Sixth marine Oil Engine Trials Committee Report*", Proc' I.Mech.E., 1926, vol II. p1059

22. Clarke, **Power on Land & Sea**. p87

23. **The Motor Ship**, vol 51, No 597, April 1970. p57

24. Lugt & Hunter, "*A New Type of Double-Acting Diesel Engine for Marine Purposes*", Trans' I.N.A., vol 66, 1924. pp361-70; also ***The Motor Ship***, vol 51, No 597, April 1970. p36

25. ***Engineering***, vol 121, 28 May 1926. pp634-5

26. Contribution by W. Falconer to discussion of D. Griffiths, "*The British Crosshead marine Diesel Engine between the Wars*", Trans' I.Mar.E., 1994.

27. A. Buchi "*Turbo-charging of Internal Combustion Engines, especially Diesel Engines*", Trans' I.Mar.E., vol 40, 1928.

28. ***Engineering***, 5th October 1928; ***The Motor Ship*** vol 51, No 597, April 1970. p58

29. ***The Motor Ship***, various dates to include

30. ***The Motor Ship***, vol 17, Feb' 1937. p422

31. ***The Engineer***, 11 Nov' 1921. p509

32. ***The Motor Ship***, vol 4, Aug' 1923, p156

33. "*First Marine Oil-Engine Trials Committee Report*", Proc' I.Mech.E., 1924, vol II. p863-986

34. G.F. Tosi, "*Large Internal Combustion Engines*", Trans' First World Power Conference, London, 1924. p107

35. ***Lloyds List***, 9 July 1924

36. ***The Marine Engineer & Motorship Builder***, vol 49, Dec' 1926. p465

37. ***Engineering***, vol 123, 28 Jan' 1927. pp102-6

38. A.C. Hardy, **A History of Motorshipping**, Whitehall Technical Press, london, 1955. pp 92 & 218

39. ***Shipbuilding & Shipping Record***, 24 May 1928. pp614-20

40. I. Johnston, **Beardmore Built**, Clydebank District Libraries and Museums Department, 1993. p159

41. Hume & Moss, **Beardmore: The History of a Scottish Industrial Giant**, Heinemann, London, 1979. p183

42. O.E. Jorgensen, "*Low Cost Motorships*", Trans' I.Mar.E., vol 43, part 5, 1931. pp204-5

43. ***Engineering***, vol 130, 29 Aug` 1930. pp260-3 and 5 Sept` 1930. pp307-8 also ***The Engineer***, vol 50, 29 Aug` 1930. pp233-5

44.L. Jones, **Shipbuilding In Britain**, University of Wales Press, 1957. p137

45. Lloyds Register of Shipping Annual Statistics (1927-8 p3 and 1938-9 p3) show that whilst the British fleets account for 41.6% of world tonnage in 1914 it had fallen to 30.3% in 1927 and 26.4% in 1938

46. Furness Withy constructed five motorships in Germany during the 1920s with German built B&W engines; price and delivery being the reason for placing the order there. ***Lloyd's List***, 11 March 1925

47. The second Doxford Engined Motor ships **Dominion Miller** ran trials with boiler grade fuel in 1922 and the ship had tank heating installed in order to allow the burning of such fuel; ***The Motor Ship***, vol 2, Jan` 1922. p362

48. ***The Motor Ship***, vol 51, No 597, April 1970. p33

49. ***The Motor Ship***, July 1943

50. This is evident from the Admiralty's dealings with Cammell Laird over the experimental Fullagar engine (see chapter 4.d) and in the papers C.J. Hawkes, "*Some Experimental Work in Connection with Diesel Engines*", Trans I.N.A., vol 62, 1920. pp266-85 and R. Beeman, "*Further Experimental Work on Diesel Engines*", Trans` I.N.A., vol 66, 1924. pp114-33

51. W.F. Rabbidge, "*Some Types of Marine Internal Combustion Engines*", Trans` I.Mar.E., vol 39, 1927. p169

Chapter 6.

Epilogue

It can be seen from chapter 4 that far from ignoring the diesel engine many British engine builders were enthusiastic enough about its prospects to invest considerable sums of money in developing their own designs. Companies such as Harland & Wolff, North Eastern Marine and Beardmore invested money through partnerships with overseas licensors whilst several others developed paper engines which got no further than patents. British shipowners were conservative compared with many of their overseas competitors but a number did see that diesel propulsion had advantages. Furness Withy, Bank Line and Blue Funnel were early British enthusiasts of the internal combustion engine and by 1934 they had extensive fleets with that form of propulsion. However, despite Britain's premier position in world shipping other countries took an early lead in the owning of motorships and maintained that over the years.

Table 6.1
Tonnage and Numbers of Motorships owned by Different Companies in 1934 & 1939

Source: ***The Motor Ship***, vol 14, March 1934. p412 and vol 19, Jan' 1939. p392

Where a shipping company possessed a large fleet the superintendent engineer's department would have been extensive and usually under the control of a strong personality; Blue Funnel had S.B. Freeman in control and Furness Withy had E.W. Harvey. These major British motor ship owning companies were, at that time, also under the management of enthusiastic people who had the foresight to see the economic advantages of diesel propulsion; the Holt family still retained control of Blue Funnel, Frederick Lewis was chairman of Furness Withy and Lord Inverforth was chairman of Andrew Weir & Co, owners of Bank Line. Enthusiastic shipowners they may have been but they were businessmen who were intent upon making maximum profit from their ventures. Lord Inverforth knew that the form of ship propulsion adopted had an important bearing upon a ship's profitability, *"I have, nevertheless, always studied with great care the economic aspects of shipowning, and in this connection it is a most obvious fact that the question of motive power is of outstanding importance."*[1]

If these people could see the advantages of the motorship the question is why did other British shipowners appear unaware of them? Certainly large companies tended to have well informed people holding high management positions at board level and at engineering superintendent level. Freeman presented many papers on technical matters over the years[2] whilst Lord Inverforth was President of the Institute of Marine Engineers and Frederick Lewis was a member of the committee of Lloyd's Register and knighted for his services to the marine industry. Other major shipping companies would also have been controlled by influential and educated people but the major portion of the British fleet during the 1920s comprised tramp ships owned by small concerns. Prior to the outbreak of World War I British companies owned 90% of the world's tramp ships and that situation changed little in the immediate post war period.[3] Small companies often had little technical backup and relied upon the shipbuilder for advice regarding propulsion machinery; if that builder did not construct diesel engines, or knew little about them, it is not likely that he could offer advice favourable to that type of plant. Many yards, particularly the smaller yards, specialised in tramp ship tonnage but during the 1920s and 1930s there was little or no standardisation of design and outfitting, tramp and general cargo ships were "one offs" or of a small class to suit the owner's requirements.[4] Builders, generally, built strictly to order although some large yards, including Swan, Hunter, built ships as speculative ventures in order to keep the shipyard working.[5]

It was in the area of tramp ships that the diesel engine could have made an impact but the destination and duration of the voyage, particularly if carrying coal as an outward cargo from Britain, were influential and assisted the owner in making the decision to fit his ships with coal fired steam reciprocating engines.[6] Chapter 2 shows that others held different views whilst table 2.1 illustrates the economics of diesel engined tramp ships compared with other forms of propulsion. If tramp ship owners did hear the message regarding diesel engines they took little notice but it is also likely that they were not adequately informed. Shipbuilders had responsibility for that as the shipbuilder would have been in a position to advise his client even if that client initially stipulated a particular type of engine. As has already been shown, during the 1920s not all British shipbuilders constructed their own propulsion plants whilst only a few built diesel engines either under licence or to their own design. If the shipbuilder only constructed steam plant it would have been in his own interest to recommend that type of machinery, or as a minimum not dissuade the shipowner from wanting it installed. If the yard built no propulsion plant then there could still have been a preference for steam plant as the yard workers would have already been familiar with installation procedures for that type of plant. In addition the yard owners might well have believed that there would be fewer complaints from the owner during the guarantee period with a tried, and outdated, coal fired steam plant compared with the relatively new diesel engine.

British tramp ship owners stayed firmly wedded to the reciprocating steam engine and coal firing. In 1937 there were 102 British registered tramp companies which owned two or more ships and these concerns owned 715 steam powered vessels and only 77 motor ships.[7] Although by that time any change in preference towards the diesel engine would have been too late to help most British designed engines the figures are presented to show that a major part of the British fleet, and one which was almost entirely built in Britain, remained the preserve of steam. During the 1920s when diesel engine builders were seeking orders practically all new tramp ship contracts would have stipulated steam power. Other parts of the British fleet reflected a similar adherence to steam.

Shipbuilding output varied during the 1920s reflecting the fluctuating demand for new tonnage but there is little evidence to suggest that overseas owners were deserting their traditional British suppliers.

Table 6.2 British Shipbuilding Output Compared with Rest of the World

Source: Lloyd's Register of Shipping Annual Statistics

With its share of the market holding up reasonably well during the 1920s builders would not have felt inclined to change their ideas with respect to propulsion. However, during the next decade the situation changed and the shipping recession hit British shipbuilders and shipowners very hard.[8] Again by time the 1930s dawned the fate of most early British marine crosshead diesel engines had long since been decided. In 1933 one British engineer, W.S. Burn of Richardsons Westgarth, stated that he believed decline in the nation's shipbuilding to be due to adherence to steam. "*Meantime by far the greatest number of vessels built abroad continue to be fitted with oil engines, and one wonders whether the decline of British shipbuilding has not been caused to some extent by undue adherence to what is internationally today an unpopular, one might almost say obsolete, type*".[9]

Correlli Barnett has shown that British shipbuilding was actually in decline even when its order books appeared healthy, that decline being due to poor management culminating in a condoning of demarcation practices by the workforce. Barnett expresses the opinion that the idea of the "practical man" (the skilled manual worker upon whose labour the shipyards thrived during the latter part of the 19th century and early years of the 20th century) even extended to shipyard managers. He states that these "practical men" in management lacked the skills of production planning and cost control, together with other vital talents needed of a mid-20th century shipyard manager, and so they held on to former practices.[10] If such people were reluctant to embrace modern ship construction methods it is certain that they were also hesitant in adopting, or recommending, the idea of diesel propulsion. Earlier chapters have shown this to be the case in certain instances but not in all, some shipyards did embrace the diesel engine so enthusiastically that they invested considerable sums of money in developing designs of their own. Even in such instances it is possible to see the guiding hand of the "practical manager" with his minimal technical education.

Behind almost all of the British marine crosshead diesel engine designs was an individual, or at most a small team, providing the driving force for a particular project. That is the way good engineering projects develop but it would appear that in certain instances the strength of the personality dictated the pace and investment rather than the engineering merits of the design. Doxford was fortunate in having Keller as the guiding light but he was also favoured by having the support of R.P. Doxford at board level. In later years the engine's reputation ensured its survival until major redesign was needed in the 1960s. At Harland & Wolff the strong hand of Rebbeck ensured satisfactory relations with B&W but the personality, and engineering skill, of Pounder ensured that a good design was produced during the difficult wartime period when contacts with the licensee in Denmark were impossible. With Pounder's retirement production of the Harland opposed-piston engine also ceased. There were other reasons behind the decision to abandon the Harland opposed-piston engine but Pounder was certainly the individual responsible for its survival. (see chapter 4.h)

Regarding the failures the most outstanding is probably the North British sliding-cylinder engine developed by MacLagan; without doubt it was a disaster which should never have been put into service but it was, three times. Swan Hunter, parent company of the NBDEW, was also actively engaged upon the development of a two-stroke marine diesel engine and was effectively in competition with itself at times when the market for ships, let alone diesel engines, was very restricted. The Swan Hunter annual report for 1923 stated that most ships built yielded no profit due to depression in the shipbuilding industry[11] and yet the year before the company had acquired the remaining shares in the NBDEW which it did not already own.[12] Design engineer responsible for the Swan Hunter "Neptune" engine was Paul Belyavin a Russian emigre about whom little is known except that he had a number of diesel engine patents to his name.

In terms of patents D.M. Shannon was also prolific, most being for developments of the Fullagar engine in conjunction with Sir G.J. Carter, Managing Director at Cammell-Laird. Carter was an engineer and would have been influential in obtaining finance from the Laird's board, he was certainly to the fore in negotiations with the Fullagar company concerning licence arrangements and with the Admiralty regarding submarine application of the engine.[13] Failure of the Fullagar marine engine saw Shannon depart to act as UK agent for FIAT whilst Carter stayed at Lairds.

Most persistent of engine designers was W.S. Burn of Richardsons Westgarth; he appears to have persuaded his employers to invest a small fortune over the years in developing his double-acting engine with little reward in terms of orders. The company certainly appears to have been keen on marine diesel engine development in view of the licences it held; prior to WWI Carels and Werkspoor licences were taken and allowed to lapse whilst after the war Beardmore-Tosi and Doxford licences were acquired, only the Doxford licence proved to be of any use. The R-W board seemed to be incapable of making a good decision in terms of an engine licence whilst its perseverance with the Burn engine is indicative of poor management.

The Still engine is an example of a sound idea in principle failing to make the grade in practice. Whilst the concept of fuel saving was admirable during the wartime and immediate post-WWI years the advances in marine diesel engines which followed the armistice should have warned people that progress was leaving the Still engine behind. Why Scotts decided to pursue the idea and invest a considerable sum of money in the venture is difficult to imagine. It would appear to be a case of poor engineering judgement but the initial decision to take a licence was made during the war when the future was unknown with respect to fuel oil supplies and other engine developments.

As a group the British engines were probably no worse than their foreign counterparts at similar stages of development[14] but any development requires money and that can only be made available if there are sufficient orders for existing engines. Vickers realised very quickly that its four-stroke engine had no future but the company was unwilling, or unable, to provide the funds for development of other crosshead designs; it took a licence for the M.A.N. engine. (see chapter 4.a)

Despite the recession in shipbuilding during the early 1920s there were orders to be had and many of these were motorships as may be seen from figures 2.5 and 5.1. In Britain, however, the diesel engine was certainly less well favoured than the steam engine for ship propulsion as shown by fig 5.2. Certainly the aggressive stance taken by the coal lobby did not help the cause but the British diesel engine industry did not appear to sell itself as well as it might have done. The 1920's attitude of Doxfords to the granting of licences (see chapter 4.j) was probably typical of the period and the fact that so few British engines attracted licensees could be attributable as much to lethargy on the part of management as to a poor product. A 1931 Department of Overseas Trade report into the Markets for Internal Combustion Engines[15] made rather gloomy reading in terms of British achievement overseas. Although the report covered all internal combustion engines and not just large marine diesels the message was plain, Britain did not market its products as effectively as did its competitors. Commenting upon the prospects for large marine engine sales to the Netherlands the report stated, "*The sale of British internal combustion engines cannot be undertaken without a local agent....... but here again the commitment of the yards undertaking the building of the hull and other interests of the prospective owners play such a part that constant and close attention is required to obtain an order.*"[16] Even when British engine builders concerned themselves sufficiently with overseas orders to provide the necessary close attention it appears to have been offered without real dedication. Cammell-Laird did appoint a representative to promote its Fullagar engine in the USA but he was an agent working on commission only and the company would not entertain his being made a salaried employee.[17]

During the 1920s there was a case for coal, and hence steam, on certain routes but the pro-coal lobby used such instances to distort the global marine propulsion situation. Diesel engine builders offered figures of their own to back their engines. Information reaching the shipowner was confusing as each party needed to put the opposing power source in the least favourable light in order to attempt to gain the advantage. This situation existed in Britain and not in continental Europe where coal appears to have had less of an influence. Shipbuilders and engineers were certainly biased towards a particular propulsion system and even an engine type, thus making advice to a prospective owner somewhat doubtful. However, many owners relied upon the advice from shipbuilders or their consultant/superintending engineers. F.E. Rebbeck of Harlands was in no doubt on that matter, "*A complicating factor for the shipowner is inevitably the conscious or unconscious bias of each engineer whom he consults.*"[18] A major enthusiast for steam was Sir John Biles but it can be said that he was "economical with the truth" respecting the real existing economics of diesel and steam plant during presentation of his 1925, 1926 and 1928 papers to the Institute of Naval Architects. (see chapter 2)

Whilst many of the factors discussed above were responsible for the failure of most British diesel engines to break into the 1920 marine market subsequent decline and demise of the Doxford engine may also be attributable in some respects to poor management. Being closely linked to the Doxford shipyard restricted growth particularly when the engine side of the business was controlled by an individual, Ramsay Gebbie, who was a shipbuilder not a marine engineer. Unwillingness to licence the engine to some foreign concerns in developing shipbuilding areas was poor management as was a 1957 decision to reduce finance and restrict expansion of the engine building side of the company.[19] The investment of a very large sum in development of the "Seahorse" engine to the detriment of the established "J" engine was also considered by some to be a waste of resources.[20] There were many factors influencing the eventual demise of the Doxford engine including decline of the British shipbuilding and shipowning industries which had supported this "home" product. However, being closely linked to Doxfords the shipbuilders during the post-war period did prove to be restricting and the fact that the Geddes report into the British shipbuilding industry recommended that large diesel engine development and construction be separated from shipbuilding[21] gives weight to the argument that Doxford engines would have been better served as an independent organisation.

If Doxford engines was restricted by being closely associated with Doxford shipbuilders during the post-WWII period it does not necessarily mean that is was similarly restricted during the pre-war period. Close links between shipbuilder and engine builder were certainly necessary to obtain orders for new engine designs and it is probable that most of the engines developed by British shipyards during the WWI years and early 1920s would not have been commercial propositions without those links. Engines were costly to develop but there were too few orders to make them commercial propositions for one yard alone, only licensing could repay the expenditure involved.

Had more British owners opted for diesel engine propulsion rather than being swayed by the steam lobby the situation might have been different.

References

1. Presidential Address Inst' of Marine Engineers, Trans' I.Mar.E., 1925-6. p413

2. A number of these have been referenced in other chapters but a number of others were also presented to organisations such as The Liverpool Engineering Society (of which he was president during the 1920s), Lloyd's Register Staff Association and The Diesel Engine Users Association

3. Lorenz E.H., **Economic Decline in Britain**, Clarendon Press, 1991. p27

4. Elbaum B. & Lazonick W., **The Decline of the British Economy**, Clarendon Press. 1986. p110

5. During the 1920s Swan Hunter built a number of motorships for its own account and these were likely to have been constructed in order to keep its yards working and provide working platforms for its engines. **Neptunian** with a Neptune 'B' engine was owned by Hopemount Shipping (part of the Swan Hunter Group) as was **City of Stockholm** with its North British Sliding-Cylinder engine.

6. Comments by G.J. Innes during discussion of Cleghorn, "*Steam Versus Diesel Machinery for Cargo Vessels*", Trans' I.E.S.S., vol 70, 1926. pp67-8 and Sir John Latta, ***The Motor Ship***, vol 7, Sept' 1927. p199

7. From the **Shipping World Yearbook** for 1937, Quoted in Thomas P.N., **British Ocean Tramps vol 1**, Waine Research Publications, 1992. p150

8. British shipbuilding between the wars and its decline is discussed in Jones L. **Shipbuilding in Britain**, University of Wales Press, 1957 and Barnett C., **The Audit of War**, MacMillan, 1986 chapter 6.

9. W.S. Burn, "*Some Developments in British Oil Engine Design*", Trans' I.Mar.E., vol 45, part 5, 1933. p144

10. Barnett, **The Audit of War**. pp109-11

11. Swan Hunter Directors' Report dated 3 March 1924; item 964/1; Swan Hunter Archives, Tyne & Wear Archives. Newcastle

12. Swan Hunter Directors' Report dated 27 Feb' 1923; item 964/1; Swan Hunter Archives

13. Correspondence in Laird Archives, file 017/0006/000 particularly during 1917: Laird Archives, Birkenhead Town Hall

14. Appendix 2 gives casualty reports for ships fitted with British crosshead engines (apart from the Doxford) during the 1920s; casualty figures are not, in general, worse than for other types of diesel engine of the period. Steam powered ships of the period also had similar casualty figures, often due to boiler troubles.

15. Department of Overseas Trade, **Markets for Internal Combustion Engines**, HMSO, 1931

16. **Markets for Internal Combustion Engines**, HMSO. p 17

17. See chapter 4.d and reference 33 in that chapter

18. F.E. Rebbeck, Presidential Address, I.Mar.E., vol 43, part 8, 1931. p346

19. Comment by A. Storey former General Manager and director of Doxford Engines; A. Storey & E.P. Crowdy, "*The Final Years of the Doxford Engine*", Trans' NECIES, vol 105, part 2, 1989. p66

20. Comments by David Stables during a conversation on 3 Feb' 1994

21. Report of Shipbuilding Enquiry Committee 1965-1966, chairman R.M. Geddes. HMSO, 1966. Chapter 11, conclusions 44-9

Chapter 7.

Conclusions

The attitude of people who controlled the British shipping industry had an influence on other national and international industries but the converse is also true as many people with outside interests imposed them on the shipping industry. This study has concerned the British crosshead marine diesel engine but it could not be treated in isolation from the industry it was intended to serve, namely commercial shipping. Without ships there was no need for such engines and any decision to install a particular type of propulsion plant in a ship was influenced by a number of factors as already discussed. Generally decisions with respect to plant were, during the critical years of the 1920s, based upon confused information and some outright untruths. The commercial world is a hard environment and orders had to be won by competing; unfortunately most British shipbuilders/engine builders of the period appear to have been unwilling to compete as aggressively as those from other nations. The British coal lobby supported steam in its internal competition with the diesel engine builders, competition not encountered to the same extent by overseas diesel engines.

Conclusions drawn from the study are:

1. British engine builders did invest in diesel engines for marine propulsion even though they came late to the scene due to World War I.

2. There was considerable innovation shown by such engine builders in their designs and enthusiasm for the development of new ideas.

3. British engine builders had a scientific approach to the large marine diesel engine and undertook considerable experimental work, including the construction and testing of experimental engines before beginning prototype production.

4. British crosshead marine diesel engines, as a group, failed to make an impact on the shipping world for a number of reasons.

a. They were generally developed by shipbuilders who had other interests which usually had priority for funds when finance was scarce.

b. Licensees were, generally, not actively sought thus limiting the potential market only to customers of that shipyard.

c. The market was further reduced in Britain due to the advocates of steam propulsion, some of whom produced distorted figures putting the diesel engine in a bad light.

d. The British coal industry suffered loss of export orders in the immediate post-WWI period and aggressively fought to retain its share of the bunker market; as diesel engines used oil the coal industry supported steam propulsion of ships.

e. Recession in shipbuilding during the 1920s and early 1930s reduced the output of British yards, although they retained their relative share of orders available, thereby reducing the number of hulls into which diesel engines could be fitted.

f. Lack of orders reduced income from engine building, and licensees when they existed, thus restricting funds for future development. New engines were not produced to overcome early troubles and to meet overseas competition..

g. With few engines of any particular British type in service potential clients were unable to fully assess the merits of the design and tended to go for engines with a larger client base. Shipowners new to diesels would generally opt for an engine which had a proven record in service.

5. There were too many British engine designs for the available British market during the critical years of the early 1920s.

6. Shipyard managers did not study the market for their engines and invested unwisely in designs which had little chance of success. Without a chain of licensees no engine could succeed; even if all products of a shipyard were fitted with that company's own diesel engines. Management was generally poor at making sound commercial decisions and was influenced too much by advice from engineers who believed strongly in their designs.

7. The Doxford engine suffered from its association with the shipbuilding side of the business during the post-WWII years although it had relied partly upon this association during the 1920s in order to establish the engine's reputation.

8. Poor management at Doxfords in the post-WWII years resulted in;

    a. The engine falling behind its competitors in terms of power output and performance.

    b. Poor relations with licensees which had an adverse effect on quality and the licensee's attitude when negotiating with clients.

    {Some licensees (including Scotts & Vickers Armstrong) took Sulzer licences as a consequence of these difficulties.}

9. Restricting the granting of licences meant that Doxfords relied heavily upon British shipbuilders and shipowners; decline in both of these industries reduced income from engine building and licence fees thus restricting finance for future development.

10. Investment of limited funds in the wrong engine, the "Seahorse", for which a market had not been defined instead of developing the "J" engine which had a proven reputation. Over optimism on the part of some engineers at Doxford and

Hawthorn-Leslie persuaded management to make incorrect investment decisions; management was not equipped to make commercial assessments of highly technical subjects.

11. The Doxford engine had serious technical limitations and could not compete with single-piston designs during the 1980s. It had reached the limit of its development and the end of its natural technical life but there could have been a niche market in the lower power ranges had these areas been exploited; however, decline of the British shipbuilding industry removed that possible market.

12. There was no lack of technical expertise or innovation concerning British designed crosshead marine diesel engines but there were problems concerning the management of companies involved in their development and construction. Managers did not have the technical judgement to assess projects in terms of commercial viability in a shrinking market. Shipyard managers were either unwilling, or unable, to accept that their core business was the building of ships and they did not need to design and make the propulsion plant as well. This was a hangover from the early days of steam powered ships. diesel engines were often treated as part of the ship which the shipbuilder made and not a engineering items in their own right; ie products which could be exploited commercially through licensees. Managers failed to recognise the true nature of the industry with which they were involved; shipbuilding and marine diesel engine design/development were different and not interlinked apart from the fact that the ship needed an engine. Even Doxfords confused the shipbuilding and engine building sides of the company, to the detriment of engine building, until it was too late to matter.

Future work is required into the effect of the coal lobby on the British shipbuilding industry and the relationship between the advocates of coal and British shipbuilders/shipowners during the 1920s.

The attitudes of shipyard managers during the 1920s to the shipbuilding and engine sides of their industries is also worthy of further study as is the influence of the Admiralty on diesel engine builders during WWI.

The study unearthed a problem which occurred during the latter year of WWII and the immediate post-war years with respect to the shortage of forgings for Doxford crankshafts. This is also likely to have affected licensed engine construction, limiting production in the same way as it limited construction of Doxford engines. This warrants further investigation as it is likely that this restriction of diesel engine construction during the immediate post-war period allowed less efficient steam turbine plant to be constructed for installation in British built ships.

Appendix No 1

Spare Gear Requirements for Motor Ships
as required by Lloyd's Register of Shipping

Drawn from various editions of
Lloyd's Register Rules & Regulations for the Construction of Steel Ships

(Volumes located at Lloyd's Register of Shipping, 71 Fenchurch Street, London)

Lloyd's Rules & Regulations

Spare Gear Requirements for Motor Ships

First requirements listed in the 1914-15 Rules & Regulations and these remained identical until new regulations were published in 1926-7.

Spare Gear: Articles mentioned in the following list will be required to be carried.

1. 1 Cylinder cover complete for the main engines, with all valves, valve seats, springs, etc. fitted to it.

2. In addition, one complete set of valves, valve seats, springs, etc., for one cylinder of the main and auxiliary Diesel engines, and fuel needle valves for half the number of cylinders of each engine.

3. 1 piston complete, with all piston rings, studs, and nuts for the main engine.

4. In addition, one set of piston rings for one piston of the main and of the auxiliary Diesel engines.

5. 1 complete set of main skew wheels for one main engine.

6. 2 connecting rods, or piston-rod, top-end bolts and nuts, both for the main and for the auxiliary Diesel engines.

7. 2 connecting rod bottom-end bolts and nuts, both for the main and for the auxiliary Diesel engines.

8. 2 main bearing bolts and nuts, both for the main and auxiliary Diesel engines.

9. 1 set of coupling bolts for the crankshaft.

10. 1 set of coupling bolts for the intermediate shaft.

11. 1 complete set of piston rings for each piston of the main and auxiliary compressors.

12. 1 half set of valves for the main and for the auxiliary compressors.

13. 1 fuel pump complete for the main engine, or a complete set of all working parts.

14. 1 fuel pump for the auxiliary Diesel engine, or a complete set of all working parts.

15. 1 set of valves for the daily fuel supply pump.

16. 1 set of valves for the water circulating pump.

17. 1 set of valves for one bilge pump.

18. 1 set of valves for the scavenge pump where lift valves are used.

19. A quantity of assorted nuts and bolts, including one set of cylinder cover studs and nuts.

20. Lengths of pipes suitable for the fuel delivery and blast pipes to the cylinders, and the air delivery from the compressors to the receivers, with unions and flanges suitable for each.

Spare gear requirements were modified in the 1926-7 edition of Lloyd's Rules and Regulations. Spare gear requirements for air compressors and bilge pumps being listed separately.

For the main engine the requirements were as follows.

a. 1 cylinder cover of each design used complete with all valves, casings, springs and other fittings, and in addition one complete set of valves for one cylinder with all springs and other fittings.

b. Fuel needle valves for half the number of cylinders on each engine.

c. 1 cylinder liner where engines are of the opposed-piston type.

d. 1 piston complete with all rings. studs and nuts, and in addition one set of piston rings for one piston.

e. Telescopic cooling pipes for one piston where these are used.

f. 1 set of skew wheels for the camshaft drive of one engine where these are used.

g. 1 set of studs and nuts for one cylinder cover of each design.

h. 2 crosshead bearing bolts and nuts or 1 gudgeon pin where trunk pistons are used.

j. 2 crankpin bearing bolts and nuts.

k. 1 set of bolts for one crankshaft coupling.

m. 1 set of bolts for one intermediate shaft coupling

Changes in the above requirements.

1928-29. Same as 1926-7 but item **c.** removed

1933-34. Same as 1928-29 but item **P.** as follows added:

p. 2 main bearing bolts and nuts.

1935-36. Same as 1933-34 but with items **r, s, t, u, v, w, x, & y.** added and items **f, k, & m** removed.

r. 1 complete cylinder liner.

s. 1 set of wheels for the camshaft drive of one engine or six separate links with pins and rollers where a chain drive is used for camshafts or scavenge blowers.

t. 1 set of rubber rings for liner joints.

u. 1 complete crankpin bearing.

v. 1 set of top end bearings.

w. 1 set of packing for one piston rod for double-acting engines.

x. 1 set of pads for each hand for one face of Michell thrust block.

y. 1 set of coupling bolts of each size used.

1937-38. Same as 1935-6 but with item z added.

z. 1 piston rod for double-acting engines

Appendix No 2

Main engine casualties reported for ships fitted with British crosshead marine diesel engines during the 1920s (apart from Doxford engines)

Drawn from various editions **Lloyd's Weekly Casualty Reports**

(Volumes of Lloyds Weekly Casualty Returns located at the Guildhall Library, London)

Note: Casualties were reported when an incident delayed a ship on passage or prevented it from commencing a voyage. Not all engine failures were reported as casualties and not all casualty reports could be classed as major engine problems. These reports do, however, give an idea as to the reliability of the engines concerned.

Lloyd's Weekly Casualty Reports

12th Dec' 1921.
Scottish Maiden. Barrow; Dec' 5th 1921. British Motor Vessel **Scottish Maiden** (McKay master) left here on 3rd Dec' but returned next day owing to engine trouble

13th Dec' 1922.
Marinula. Rotterdam, 13th Dec'. Steamer{sic} **Marinula** arrived off Waterburg with damage to machinery; towed in by tugs and assisted to Rotterdam.

12th March 1923.
Durenda. London, 8th March; Motor vessel **Durenda** put into Gibraltar for small repairs to air compressor.

19th March 1923.
Durenda. Gibraltar, 10th March; British Motor Vessel **Durenda** left at 5.45pm today; repairs to motor engines

5th November 1923.
Scottish Musician. Rotterdam, 27th Oct'; British Motor Vessel **Scottish Musician** which left here on 25th October put back this morning on account of engine trouble.

17th Dec' 1923.
Scottish Minstrel. Queenstown, 10th Dec'; Motor tanker **Scottish Minstrel,** Manchester for Galveston, put into Queenstown today with evaporator out of order.

14th Jan' 1924.
Marinula. New York, 9th Jan'; British Motor Vessel **Marinula** from Carteret has engines broken down, anchored off Staten Island.

28th Jan' 1924.
Domala. Port Said, 24th Jan'; British Motor Vessel **Domala** delayed by damage to dynamo, sailing Saturday 26th Jan'.

11th Feb' 1924.
Hauraki. San Francisco, 2nd Feb'; British Motor Vessel **Hauraki** put in for repairs, starboard engine disabled; valves pulverised, fuel oil changed, sails today.

18th Feb' 1924.
Domala. Plymouth, 9th Feb'; Motor Vessel **Domala** detained owing to motor trouble. London, 10th Feb': Telegram from Plymouth dated 10th Feb' states British Motor Vessel **Domala** left Plymouth for Harve after completing repairs.

24th March 1924.
Domala. Gravesend, 16th March; Motor Vessel **Domala** for Karachi anchored below here yesterday with defective machinery.
Gravesend, 17th March; Motor Vessel **Domala** proceeded on voyage at 5.30pm yesterday.

31st March 1924.
Narragansett. New York, 26th March; British Motor Vessel **Narragansett**, New York for Rotterdam, anchored off Staten Island, has engine trouble.

7th April 1924.
Narragansett. New York, 27th March; British Motor Vessel **Narragansett** repaired and proceeding.

28th April 1924.
Scottish Minstrel. Charleston 19th April; Wireless message from Motor Vessel **Scottish Minstrel** reports due to arrive on 19th April with machinery deranged.
Charleston, 22nd April; Motor Vessel **Scottish Minstrel**, think it advisable to be surveyed by surveyor to Lloyd's Register, lubricating machinery in bad order, bearings burnt out, will advise later cost of temporary repairs to vessel to proceed.

5th May 1924.
Scottish Minstrel. Charleston, 24th April; Motor Vessel **Scottish Minstrel** survey by surveyor to Lloyd's Register, engine in bad condition generally.
Charleston, 30th April; Motor Vessel **Scottish Minstrel** sailed 30th April

10th June 1924.
Domala. Gibraltar, 30th May; British Motor vessel **Domala** put in with defective machinery.

22nd Aug' 1924.
Scottish Musician. Gibraltar, 14th Aug'; British Motor Vessel **Scottish Musician** put in with damage to engines.
Gibraltar, 14th Aug'; Motor Vessel **Scottish Musician**, dry docked, surveyor recommended opening up port engine.
Gibraltar, 18th Aug'; Motor Vessel **Scottish Musician**, piston rod bent slightly, one piston stud loose, foot connecting rod bent; dockyard affecting permanent repairs, hope to be completed by Wednesday 20th Aug'.

17th Oct' 1924.
Dolius. Amsterdam 10th Oct'; Motor Vessel **Dolius**, Java for Harve and Rotterdam is proceeding at reduced speed owing to a defect in the machinery.

28th Nov' 1924.
Scottish Maiden. Rotterdam, 21st Nov'; Motor Vessel **Scottish Maiden** arrived with machinery damaged towed by three tugs.

6th Feb' 1925.
Silverpine. Ponta Delgada, 1st Feb'; British Motor Vessel **Silverpine** put in with defective machinery.

8th May 1925.
Scottish Standard. London 5th May; The owners of the Motor Vessel **Scottish Standard** have received the following wireless message from the master dated 2nd May, port engine crankshaft broken at crank No 2 web running on four cylinders 90 revolutions since 11.0am Friday 1st May, all well at present, 1680 miles off Land's End, weather rough.

12th June 1925.
Iossifoglu. Yokohama, 8th June; Information received states British Motor Vessel **Iossifoglu** adrift 150 miles south west of Yokohama, engines broken down, tug being sent.
Yokohama 8th June; British Motor Vessel **Iossifoglu**, cannot get tug immediately endeavouring to arrange dispatch of two steam trawlers to fix for towage.
Yokohama, 9th June; Motor Vessel **Iossifoglu** stopped 80 hours leaking piston service and other engine troubles; message received from master states now passing Mikurajima maintaining 4 knots and states not necessary to detain trawlers.

19th June 1925.
Iossifoglu. Kobe 10th June; British Motor Vessel **Iossifoglu** arrived Yokohama this morning

19th June 1925.
British Motorist. Gibraltar, 15th June; British Motor Vessel **British Motorist** has put in for repairs to motor engines.

24th July 1925.
Silverpine. Manila, 15th July; British Motor Vessel **Silverpine** lat 21N Long 121E engines working badly, heavy weather, wants a tug; ship's agent endeavouring to obtain further particulars.
20th July, Manila; **Silverpine** repairing here, repairs will be permanent and will be effected in ten days. Ship proceeded at 2.5 knots to Manila.

2nd Oct' 1925.
Silverpine. Perim, 28th Sept'; British Motor Vessel **Silverpine** which passed Perim yesterday has put back on account of piston stud trouble, holding survey and repairing here, estimate about four days.

9th Oct' 1925.
Silverpine. Perim, 1st Oct'; Motor Vessel **Silverpine** several minor repairs to engine, mechanical parts also leaking boiler tubes, expected to complete repairs end of the week.
Perim, 5th Oct'; **Silverpine**, repairs completed, survey has been held, certificate of seaworthiness has been given.

9th Oct' 1925.
Malia. London, Following telegram from master of Motor Vessel **Malia** dated 28th Sept', oblique rod threads stripped effecting repairs but doubtful if permanent, radio instructions to Malta.
Telegram from owners; If engineers have any doubt about ability prior to the repair of the oblique rod proceed malta and telegraph us also Lambert Bros. Malta to arrange

with dockyard for permanent repairs.
Telegram from master; repairs to oblique rod a failure, starboard engine out of commission, making for Algiers.
Algiers, Motor Vessel **Malia** arrived; London to Calcutta; put in with defective machinery detention will occupy about four days.
Algiers, 30th Sept`; Motor Vessel **Malia** damaged confined to stripping from thread of one of the diagonal rods of the starboard motor, having thread recut and new nut made, expense will be slight.

19th Feb` 1926.
Silverlarch. Weedy Island, 2nd Feb`; British Motor Vessel **Silverlarch** from new York is anchored off Duck Creek, has engine trouble.

26th Feb` 1926.
Silverlarch. New York, Feb` 18th; Motor Vessel **Silverlarch** satisfactory dock trials held in Baltimore 17th Feb`. Left in ballast for Newcastle.

26 Feb` 1926.
Marinula. Ponta Delgada, 17th Feb`; British Steamer {sic} [Motor Vessel] **Marinula** put in with port side engine crank broken.

1st April 1926.
British Motorist. Ferol, 24th March; British Motor Vessel **British Motorist** from Abadan bound Swansea put in with damaged engines.

16th April 1926.
Dolius. Land`s End Wireless Station, 12th April; Following from Motor Vessel **Dolius** anchored Falmouth Bay, vertical drive shaft operating steam end on starboard engine fractured. Repairing.

16th April
Dwarka. Durban, 10th April; British Motor Vessel **Dwarka** which sailed on 6th April developed engine trouble and returned 7th April; main engine compressor liner slack, repairs being executed; sailing 11th.

30th April 1926.
Seminole. Seaforth Wireless Station, 27th April; Motor Vessel **Seminole** reports engine stopped since 8.37 last night. No 1 main bearing hot, clearing same and hope to be away by midnight.

21st May 1926.
Silverpine. Honolulu, 8th May; British Motor Vessel **Silverpine** arrived here today with motor trouble.
Honolulu, 8th May; Motor Vessel **Silverpine** three liners cracked, overheating; must replace, also supply spares; Neptune engine works, change fresh to sea water; Surveying estimate ready tomorrow.

21st May 1926.
British Aviator. Falmouth, 14th May; British Motor Vessel **British Aviator**, Abadan for Swansea, arrived yesterday to effect slight repairs to machinery.

4th June 1926.
Athelking. Colombo, 5th May; Motor Vessel **Athelking** having sustained damage to engines when manoeuvring at Surabaya has been surveyed here and has effected repairs; the vessel left for Liverpool on 2nd May.

11th June 1926
City of Stockholm. Glasgow, 7th June; Motor Vessel **City of Stockholm** outward for Persian Gulf via Liverpool sailed Tail of the Bank Saturday June 5th pm but returned to Gourock Bay on Saturday evening with machinery trouble - repairers now on board. Glasgow June 8th; Motor Vessel **City of Stockholm** sailed from Gourock after repairs at 7.30am today.

9th July 1926.
Seminole. New York, 2nd July; Motor Vessel **Seminole** anchored of Ambrose Channel with black ball in rigging, proceeding today.

23rd July 1926.
Storsten. Glasgow, 13th July; New Diesel oil tanker **Storsten** had trouble while running trails in firth of Clyde today and was towed back to Tail of the Bank and is now towed back to builder's wharf Glasgow; trials will be delayed for a week.

3rd Sept' 1926.
British Aviator. London 31st Aug'; The owners of the British Motor Vessel **British Aviator** which left Swansea on 27th Aug' for Abadan state that the vessel put back to Swansea on 28th Aug' for slight engine repairs.

17th Sept' 1926.
Narragansett. Galveston 13th Sept'; British Motor Vessel **Narragansett** arrived with one engine disabled.

24th Sept' 1926.
Narragansett. Galveston 14th Sept'; British Motor Vessel **Narragansett** arrived today.

24th Sept' 1926.
Swanley. Falmouth 16th Sept'; British Motor Vessel **Swanley**, Rotterdam for Table Bay, arrived today with No 3 engine fired {sic} liner "found" and piston badly torn.

1st Oct' 1926.
Athelking. Grimsby Wireless Station, 26th Sept'; Motor Vessel **Athelking** returned Humber with machinery defects at 7.55pm:
Cullercoats Wireless Station, 27th Sept'; Motor Vessel **Athelking** anchored off Humber 1.0am. Note British Motor Vessel **Athelking** left Hull 26th Sept' for Port Said.

15th Oct' 1926.
Silverlarch. Colombo, 7th Oct'; British Motor Vessel **Silverlarch** put back on account of minor defects in machinery, sails tomorrow.

17th Nov' 1926.
Swanley. Barry, 13th Dec'; Motor Vessel **Swanley** from Dalagoa Bay delayed with engine trouble.

3rd Dec` 1926.
Iossifoglu.Honolulu 29th Nov`; British Motor Vessel **Iossifoglu** arrived with engines out of order, surveying: Honolulu 29th Nov`; Motor Vessel **Iossifoglu** intermediate pressure piston broken {sic}, new piston imperative, repairs will require about 9 days.

14th Jan` 1927.
Swanley. Barry, 11th Jan`; Motor Vessel **Swanley** previously reported left here today in tow for Greenock.

21st Jan` 1927.
Swanley. Fishguard Wireless Station, 13th Jan`; Following received from British Motor Vessel **Swanley**. Midnight, broke adrift from tug, drifting north east 2 miles, hope to connect again daylight, plenty of room for drift. Tug standing by. Strong westerly gale. Position lat 53 30 N long 5 35 W.
London 12th Jan`. A radio message from the Motor Vessel **Swanley** via Seaforth, 13th Jan` 10.45am states connected with tug proceeding anchorage Point Lynas to await improvement in weather.
London 17th Jan`; Motor Vessel **Swanley** arrived off Greenock 4.0pm on 16th Jan`, proceeding Gareloch tomorrow.

28th Jan` 1927.
Narragansett. Hull 19th Jan`; British Motor Vessel **Narragansett** from Baton Rouge, oil and motor spirit, reports that her starboard main circulating pump, valve chest and pump chamber burst on 8th Jan` in the north Atlantic.

11th Feb` 1927.
Storsten. Lands End Wireless Station, 5th Feb`; Following received from Norwegian Motor Vessel **Storsten** at 2.15pm. **Storsten** from Rouen bound Glasgow 160 miles distant engine broken down only four cylinders [sic] working.
Lands End Wireless Station 6th Feb`; Tug **Willem Barendsz** signalled by wireless 6th Feb` 7.38am searching for **Storsten**, in Brest.
Glasgow, 8th Feb`; Norwegian Motor Vessel **Storsten** outwards from Rouen to New Orleans, light, put back to Clyde with machinery defect, proceeding Glasgow for repairs; Barclay Curle & Co carrying on same; vessel arrived Tail of the Bank this morning.

18th Feb` 1927.
City of Stockholm. London 9th Feb`; The No 1 top cylinder liner of the British Motor Vessel **City of Stockholm**, Calcutta for Boston, general cargo, fractured on 13th Jan` in lat` 38 39 30 N long 58 18 50 W.

11th March 1927.
British Aviator. Swansea 3rd March; Tank Motor Vessel **British Aviator**, Swansea for Abadan, put back yesterday through engine trouble.

11th March 1927.
British Chemist. Malta 8th March; British Motor Vessel **British Chemist** put in with Nos 3 and 4 liners gone, No 6 leaking.

1st April 1927.
Baron Dalmeny. Barry 25th March; Motor Vessel **Baron Dalmeny**, loaded ready for sea, reported delayed with engine trouble.

1st April 1927.
Silverpine. Kobe, 23rd March; British Motor Vessel **Silverpine** towed in here by a tug with cylinder cover blown off, very badly fractured.

14th April 1927.
Dolius. Rotterdam, 11th April; British Motor Vessel **Dolius** arrived with defective machinery, tug assisted.

29th April 1927.
Scottish Standard. Falmouth 25th April; British Motor Vessel **Scottish Standard**, Tampico for Rotterdam, arrived today with motor engine trouble.

6th May 1927.
Scottish Standard. Rotterdam 26th April; Tugs **Roode Zee** and **Seine** have left Nieuwe Waterweg for Falmouth to tow the disabled Motor Vessel **Scottish Standard** from that port to Rotterdam.
Falmouth, 28th April; British Motor Vessel **Scottish Standard** left here 27th April for Rotterdam in tow of tug **Roode Zee**.
St. Catherine's Point, 28th April; Motor Vessel **Scottish Standard** passed east today in tow of Dutch tugs **Roode Zee** and **Seine**
Maassluis, 30th April; British Motor Vessel **Scottish Standard** arrived Nieuwe Waterweg yesterday in tow of tugs **Roode Zee** and **Seine**.

20th May 1927.
Durenda. Naples, 11th May; Motor Vessel **Durenda** arrived here on 8th May from Melbourne with her port engine vertical timing shaft broken. Survey has been held and the shaft is being temporarily repaired. A new shaft will be fitted at Gibraltar.

10th June 1927.
Storsten. Rotterdam, 2nd June; Norwegian Motor Vessel **Storsten** towed in here by three tugs, machinery disabled.

7th Oct' 1927.
British Aviator. Malta, 1st Oct'; British Motor Vessel **British Aviator** put in for engine repairs.

7th Oct' 1927.
Silverpine. Manila, 23rd Aug'; Motor Vessel **Silverpine** arrived at Cebu on 14th Aug' owing to dynamo trouble.
Manila, 27th Aug'; Motor Vessel **Silverpine** sailed on 20th Aug' for Panama.

14th Oct' 1927.
Arnus. Rotterdam, 4th Oct'; On leaving wharf Vlaardingen on 2nd Oct' Spanish Motor Vessel **Arnus** grounded owing to a defect in her motors but floated at high water and proceeded her motors having meanwhile been repaired.

Porta, 10th Oct`; Spanish Motor Vessel **Arnus** arrived today engines working badly.

21st Oct` 1927.
Iossifoglu. Yokohama, 14th Oct`; British Motor Vessel **Iossifoglu** after being adrift off Sunosaki owing to engine disabled towed in here by a tug noon 12th Oct`.

21st Oct` 1927.
Marinula. Rotterdam 15th Oct`; British Motor Vessel **Marinula** entered with assistance of two tugs, machinery out of order.

28th Oct` 1927.
Arnus. Malta, 20th Oct`. Spanish Motor Vessel **Arnus** sailed for St. Kitts today.

4th Nov` 1927.
Lenfield. Lisbon, 26th Oct`; British Motor Vessel **Lenfield** put in with machinery slightly damaged.

18th Nov` 1927.
Baron Dalmeny. Plymouth, 10th Nov`; Motor Vessel **Baron Dalmeny** from Karachi arrived here today for engine repairs.

16th Dec` 1927.
Iossifoglu. San Francisco, 7th Dec`; Motor Vessel **Iossifoglu** towed in from off Bar 6th Dec` with engines disabled. Surveyed. Damage principally scavenger pump No 2 cylinder, also bearings rocking beam broken, necessary open engines for inspection and cleaning. Estimated complete repairs 13th Dec`.
San Francisco, 9th Dec`; Motor Vessel **Iossifoglu** account apparently overboard discharge being left open overnight 8th Dec` engine room flooded to about 15ft.before water controlled by shore pumps. Engine room dry this morning and surveyors have made necessary recommendations; repairs should be complete by 15th Dec`; costs later.
San Francisco, 12th Dec`; Motor Vessel **Iossifoglu** classification society surveyor recommending new liners all cylinders, will require about 20 days to make and fit.

6th Jan` 1928.
Arnus. Fishguard Wireless Station, 30th Dec` 1927; Tug **Zwarte Zee** signalled at 5.08am today 50 miles south west of Fishguard bound for Motor Vessel **Arnus**.
London, 2nd Jan`; L.Smidt & Co. Internationale Sleepdienst, from Rotterdam on the date of 30th powered tug **Zwarte Zee** took the Spanish Motor Vessel **Arnus** yesterday in the Irish Sea off Tuskar the vessel had motor trouble and the tug is now towing her to Liverpool.

13th Jan` 1928.
Silverpine. Honolulu, 7th Jan`; British Motor Vessel **Silverpine** arrived today with engines out of order.
Honolulu, 8th Jan`; Motor Vessel **Silverpine** arrived on 7th Jan`, surveyors report pump levers, bolts, brasses, jackets damaged by heavy weather. Suction air chamber broken, replacing, checking pump levers for truth. Estimated time 4 days.

20th Jan` 1928.
Silverpine. Honolulu, 13th Jan`; Motor Vessel **Silverpine** repairs have been completed

and vessel sailed today.

20th Jan' 1928.
Iossifoglu. San Francisco, 12th Jan'; Motor Vessel **Iossifoglu** repairs completed and the vessel sailed this afternoon.

27th Jan' 1928.
Silverlarch. San Francisco, 3rd Jan'; Motor vessel **Silverlarch** having sustained damage to hull and machinery during heavy weather from 23rd Oct' to 28th Nov' last while on the voyage from the Philippine Islands to San Francisco and Los Angeles was surveyed at Los Angeles on 5th Dec' and subsequent dates and repairs to hull amounting to $1,565 and to machinery amounting to $4,617 were effected.

30th March 1928.
Silverpine. Colombo, 23rd March; British Motor Vessel **Silverpine** returned to port with main engine piston rings slack, survey now being held. Will probably be delayed 5 days.

13th April 1928.
Silverpine. Colombo, 4th April; British Motor Vessel **Silverpine** towed out of port and anchored awaiting engine trials.

20th April 1928.
Silverpine. Calcutta, 16th April; British Motor Vessel **Silverpine** arrived Diamond Harbour, mechanical breakdown, has been towed Budge Budge.

25th May 1928.
Durenda. Perth, Western Australia, 23rd April; Motor Vessel **Durenda**, Liverpool for Port Adelaide, general, arrived at Fremantle on 21st April to effect repairs to two cracked cylinders in the starboard engine and one in the port engine, it is expected that the repairs will be completed tonight and the vessel will resume her voyage early tomorrow morning.

20th July 1928.
Baron Dalmeny. Ponta Delgada, 13th July; British Motor Vessel **Baron Dalmeny** arrived yesterday with machinery damaged.

17th Aug' 1928.
British Petrol. Aden, 14th Aug'; British Motor Vessel **British Petrol** damage to engines, high pressure compressor, proceeding at reduced speed to Abadan using auxiliary compressor.

2nd Nov' 1928.
Dolius. Liverpool, 30th Oct'; Motor Vessel **Dolius** reports slight engine trouble off Skerries on 29th Oct'.

2nd Nov' 1928.
Neptunian. North Shields, 23rd Oct'; Motor Vessel **Neptunian** arrived 10.40pm apparently put back and passed up river to Wallsend.

7th Dec' 1928.
Scottish Musician. Falmouth, 30th Nov'; British Motor Vessel **Scottish Musician** returned from Falmouth Bay today for adjustment to engines.

4th Jan' 1929.
Durenda. Colombo 31st Dec'1928; British Motor Vessel **Durenda** Liverpool to Brisbane put in on 28th Dec', minor repairs to port engine, sails today.

22nd Feb' 1929.
Scottish Maiden. London, 19th Feb'; The owners of the Motor Vessel **Scottish Maiden** received the following wireless message from the master of the vessel 18th Feb'; 390 west of Fayal, strong westerly gale No 5 port bottom end bolt broken, sole plate broken back and front, No 7 column broken at back, connecting rod bent, guide shoe broken, now proceeding Falmouth running port engine on five cylinders, taking every precaution.

1st March 1929.
Scottish Maiden. London, 23rd Feb'; The owners of the Motor Vessel **Scottish Maiden** have received the following radio message from the master; **Scottish Maiden** noon 21st Feb' lat 40 51 N long 27 58 W.
Lands End Wireless Station, 26th Feb'; Motor Vessel **Scottish Maiden** signalled that at 8.20am today 210 miles south west bound Falmouth.

8th March 1929.
Scottish Maiden. Newton Wireless Station, 28th Feb'; Motor Vessel **Scottish Maiden** signalled at 1.29pm bound Hebburn 8 miles west.
Tynemouth, 3rd March; British Motor Vessel **Scottish Maiden** outward bound from Avonmouth to Tampico arrived Tyne 7.15am today and proceeded to Palmers, Hebburn.

15th March 1929.
Scottish Maiden. Newcastle upon Tyne, 7th March; The work of repairing the Motor Vessel **Scottish Maiden** which has arrived in the Tyne will be carried out by Palmers Shipbuilding & Iron Co. Ltd. The vessel cracked a bedplate on a voyage to Tampico from Avonmouth and had to put back, it will be necessary to fit a new bedplate.

21st June 1929.
Athelking. Algiers, 13th June; British Tank Motor Vessel **Athelking**, Java for Liverpool, cargo molasses, put in with defective machinery, principally compressors and scavenger pumps. Surveyor to Lloyds Register called in.
Algiers, 14th June; British Motor Vessel **Athelking** repairs being executed.
Algiers, 16th June; British Motor Vessel **Athelking** repairs completed vessel sails 11.0pm today.

28th June 1929.
Irania. Malta, 21st June; Motor Vessel **Irania** in want of assistance.
Gibraltar, 23rd June; Motor Vessel **Irania**, following is copy of telegram received from salvage team. Midnight June 23rd **Irania**, ballast, in tow lat 36 15 N long 0 56 W. Proceeding Gibraltar crankshaft broken.
Gibraltar, 24th June; **Irania** arrived today in tow, survey now being held.

5th July 1929.
Irania. Gibraltar 25th June; Motor Vessel **Irania** broken auxiliary crankshaft being sent to dockyard for repair as may be recommended by Lloyds Register surveyor and builders representative who arrives today.
Gibraltar, 28th June; Motor Vessel **Irania** repairs proceeding probably ready next week. Later, now moored at Admiralty wharf to facilitate repairs.

12th July 1929.
Irania. Gibraltar, 3rd July; Motor Vessel **Irania** is now lying in Admiralty wet dock probably ready on Friday 5th July.
Gibraltar, 8th July; Motor Vessel **Irania** sailed yesterday 7.0pm.

19th July 1929.
Swanley. San Francisco; British Motor Vessel **Swanley** arrived on 11th July with machinery damaged, cost of repairs $4,700.
San Francisco, 15th July; Motor Vessel **Swanley** classification surveyor recommends whole engine requires opening. ***(Ship now has Doxford replacement engine)***

22nd Aug` 1929.
Irania. London, 19th Aug`; The middle cylinder of the British Motor vessel **Irania** cracked on 28th July in the Mediterranean the vessel which was on voyage from Constanza for Harve with oil proceeded on two cylinders to Harve thence to Falmouth for repairs.

11th Oct` 1929.
Narragansett. Harve, 8th Oct`; British Tank Motor Vessel **Narragansett** from Galveston lies in the roads with machinery damage, will repair before entering port.

18th Oct` 1929.
Dumra. Kilindini, 21st Sept`; Motor Vessel **Dumra** completed repairs on 18th Sept` left today for Mikindani, the damage was due to the breakage of the connecting rod of the engine driving the port side generator resulted in damage to the cylinder liner, connecting rod, exhaust pipe, new parts have been made and fitted.

15th Nov` 1929.
British Chemist. Malta, 7th Nov`; British Motor Vessel **British Chemist** slight defects in machinery repairs being executed by crew, detention will probably not be serious.

29th Nov` 1929.
British Chemist. Grangemouth, 26th Nov`; ***Report of severe explosion on board.***
20th Dec` 1929; report **British Chemist** being towed to Tynemouth (arrived on 15th Nov`)
(Note; Ship repaired and fitted with Doxford engines)

22nd Nov` 1929.
La Marea. Belfast, 18th Nov`; Motor Vessel **La Marea** Garston for Belfast for overhaul wirelessed this morning that she was 5 miles south of Southrock, Co Down and required assistance of a tug. The tug **Audacious** accordingly proceeded to her at 7.15 and should reach steamer[sic] about 10 o`clock.
18th Nov`; Motor Vessel **La Marea** was duly picked up by tug **Audacious** in the

position given in the report earlier.

20th Dec` 1929.
Silverlarch. Manila, 17th Dec`; British Motor Vessel **Silverlarch** Singapore for San Francisco reports having inferior fuel oil vessel's position 400 miles east of Manila, returning to Manila but reports finding difficult to make progress.

27th Dec` 1929.
Silverlarch. Manila, 19th Dec`; British Motor Vessel **Silverlarch** anchored off Suluan Island off south coast of Samar with machinery out of order; owners agent contracted with steamer **Salvager** for towage service not salvage service to Manila 2500 pesos daily.

30th Jan` 1930.
Silverlarch. Manila, 26th Dec` 1929; British Motor Vessel **Silverlarch** from Calcutta arrived here today.

14th Feb` 1930.
Silverlarch. Manila, 3rd Jan`; Motor Vessel **Silverlarch** arrived here on 25th Dec` in tow of the steamer **Salvager** with engines out of commission, repairs to several cylinders have been effected here, donkey boiler(s) were also giving trouble and leaking badly and it was found that the firebricks at the back of the furnaces had been destroyed and the flame jets were playing on the unprotected plates of the boiler. Repairs have been effected. The question of the quality of the oil was gone into and tests were made and showed the oil to be quite satisfactory, surveyor concluded that the trouble arose from the presence of water in the tanks.
{Note the **Silverlarch** has since left Manila, 8th Jan`}

23rd May 1930.
Irania. London, 19th May; The cylinder liner of the British Motor Vessel **Irania** cracked on 11th May in the Bristol Channel. The vessel which was bound to Saltend, Hull from Swansea with benzene put back to Swansea for repairs and afterwards proceeded.

20th June 1930.
Neptunian. Seattle, 15th June; British Motor Vessel **Neptunian** crankshaft balance weight auxiliary compressor carried away wrecking motor. Arrangement being made for obtaining competitive tenders for repairs.
Seattle. 16th June; Motor Vessel **Neptunian** surveyed damage apparently caused by balance weight bolts slacking back and breaking.

15th Aug` 1930.
Hauraki. Adelaide, 9th Aug`; British Motor Vessel **Hauraki** 4425 tons net Sydney for Adelaide arrived 8th Aug` and reports damage to port engine.

12th Sept` 1930.
Narragansett. New Orleans, 5th Sept`; British Tank Motor Vessel **Narragansett** proceeding up river tug assisting, it is reported that starboard crankshaft is broken.

3rd Oct' 1930.
Irania. Istanbul, 20th Sept'; Motor Tanker **Irania** West Hartlepool for Tuapse in ballast experienced trouble with main motors between 30th Aug' and 15th Sept'. She was surveyed here on 17th Sept' and it was found that the necessary permanent repairs had been effected at sea and the vessel was granted a certificate of seaworthiness and she proceeded on 18th Sept' .

10th Oct' 1930.
Lenfield. St. Catherine's Point, 4th Oct'; Following received from Niton Wireless Station; Following SOS received from British Motor Vessel **Lenfield** at 1.21pm GMT, **Lenfield** at 1.15pm GMT position N 30 W (true) 15 miles from Casquets requires assistance engine trouble, engine stopped, need tow.
Weymouth, 6th Oct'; Motor Vessel **Lenfield** inside of engine and lubricating oil system terrible mess due to water in oil and using fuel oil for lubricating, impossible examine until all clean; engineer states does not consider engine damaged to prevent proceeding Hull, my surveyor recommends cleaning lubricating system and effecting repairs to auxiliary engines, a good number of pipes to be cleaned and made good, oil suction and discharge strainers cleaned and a new nest of tubes be supplied and fitted to one oil cooler; towage Lloyds salvage agreement.

17th Oct' 1930.
Storsten. Glasgow, 9th Oct'; Norwegian Motor Tanker **Storsten** outward bound anchored Tail of the Bank with engine trouble, repairs will take about 3 days.
(Note; Ship now has Doxford engine)
24th Oct 1930.
Lenfield. Portland, 16th oct'; Motor vessel **Lenfield** sailed at 2.0pm today for Hull after effecting repairs to machinery.

31st Oct' 1930.
British Aviator. Colombo, 27th Oct'; British Motor Vessel **British Aviator** arrived today scavenger pistons fractured, temporary repairs will be effected; vessel sails tomorrow.

Table Cas.1 Engine Casualties between 1920 and 1930.

Engine Type	No of Installations	No of Ship Years	No of Casualties	Casualties per Ship Year	Tows Required	Broken Crank Shafts
Vickers	9	78	20	0.256	4	3
Swan Hunter	11	64	27	0.422	6	-
North British 4-S, S-A	6	48	11	0.229	-	-
North British 2-S, D-A	3	7	8	1.14	3	-
Fullagar	6	36	12	0.333	1	-
Scott-Still	2	8	4	0.5	1	-
Richardsons, Westgarth	1	1	4	4.0	1	-

Analysis of casualties reported in Lloyd's Weekly Casualty Reports for European ships having engines in each category. Casualties are as reported for main propulsion engines only and concern each incident not each report (an incident may have produced a number of reports if a tow and/or repairs was reported in separate weekly editions). A casualty is defined as one which delays the ship for a significant time during its passage, delays its departure from port, requires an unscheduled call at a port for repairs or necessitates towage. Not all engine incidents would have been reported if they only produced a short delay, eg short stops at sea to change fuel valves, tighten glands, etc.

Appendix No 3

Refereed Publications resulting from research detailed in the Thesis.

1. **The British crosshead marine diesel engine between the wars;**
   Trans' I.Mar.E. vol 106, part 2, 1994. pp105-129

2. Accepted for publication by The Newcomen Society in the 1994-5 Transactions
   The Doxford Engine; its development and decline

3. Accepted for publication by The Society for Nautical Research in ***The Mariner's Mirror*** during 1995; **British Shipping and the Diesel Engine; the early years**

4. Accepted for publication by The Newcomen Society in the 1995-6 Transactions
   Britain and the Crosshead Marine Diesel Engine