Cormack, William S. (1930) *An economic history of shipbuilding and marine engineering.* PhD thesis.

AN ECONOMIC HISTORY OF SHIPBUILDING AND MARINE ENGINEERING

BY

WILLIAM S. CORMACK.

AN ECONOMIC HISTORY OF SHIPBUILDING AND MARINE ENGINEERING

(with special reference to the West of Scotland).

CORMACK W. S

Vol I

THIS THESIS CONTAINS MICROFILMS THAT COULD NOT BE DIGITISED.

PLEASE CONTACT THE UNIVERSITY IF YOU WISH TO SEE THIS MATERIAL.

CONTENTS.

CONTENTS (Contd.)

CHAPTER I.

Introductory: ORIGINS AND DEVELOPMENT OF THE CLYDE BURGHS.

For upwards of half a century Glasgow has been known the world over as the centre of the shipbuilding and engineering industries of the West of Scotland. Over a similar period the Clyde has held first place among the rivers of the United Kingdom for quantity of ships and engines produced. Regarding quality we need only recollect the phrase "Clyde built" and the significance attached thereto in every corner of the globe where ships sail or engines turn. To those who give the matter superficial consideration only, the pre-eminence of the Clyde Valley in these industries may seem easily explicable. Is not the river and firth ideal for the construction and launch of vessels, large and small? Are not the workers capable, skilled men, with the tradition of engineering invention stretching back a century and a half to the days of James Watt, the father of the steam engine? Was it not on these waters that the first "salt-water" steamboat sailed? Do not the raw materials requisite for the work abound in the area? What further reasons are required in respect to an area that can boast having bred such notable engineers as Watt, Bell, Elder, and David Napier and such enterprising shipbuilders as the Scott family, Wood, Denny, and Robert Napier, to mention only a few names?

Valid and important as all these geographical and human factors may be, we are bound to recognise that economic forces must also have played a part in the establishment and development of the twin industries; and, had these forces been adverse instead of favourable, it is doubtful if the factors enumerated above would have been at all potent. Some of them simply would not have appeared. The shipbuilding industry is not indigenous to the Clyde Valley. The river today is not the river of a hundred years ago. Far from having any natural advantages for shipbuilding, the River Clyde, though possessing an excellent firth, began with a heavy handicap. The following quotation[1] indicates the facts :-

> "The Clyde, which we have accustomed ourselves to call the premier shipbuilding river of the world is perhaps the least endowed by Nature of any to be the mother of great ships. For the better part it is narrow, comparatively shallow, and moderately tortuous, and it does not fill the eye as some others do. Yet its shipbuilders and engineers have accomplished more than others, and Clyde men have been associated with practically every scientific advance in naval architecture in the last century."

The firth, of course, is free from the defects enumerated, being long, wide, and deep, and having numerous sheltered lochs along its shores. Such boatbuilding as was done up to the nineteenth century was confined to those parts. The tendency during the last hundred years has been for the industry to concentrate on the twenty mile stretch between Greenock and Glasgow, with a further concentration latterly towards the city.

As an example of the dependence of the inventor upon economic factors few more striking cases than that of James Watt could be found. Born in Greenock and trained in Glasgow, his invention devised and patented whilst he was living in that city, Watt had to sever family ties and associations and move south to Birmingham to have his engine manufactured. The West of Scotland did not at that time afford facilities for engineering production whereas the

1. From the preface to the marine engineering and shipbuilding section of the British Association handbook, 1901, (Glasgow meeting), by Robert McIntyre.

Warwickshire town was already developed in this respect. Thus a man's birthplace is not necessarily the stage upon which, in later life, he plays his leading part. With the inventor it is not as with the prophet, merely that he "is not without honour save in his own country"; it is that frequently his "country" does not provide the facilities for the practical development and application of his invention. Yet, in later years, Glasgow far excelled Birmingham in the manufacture of steam engines! Nor was it on the waters of the Clyde that the first steamboat paddled its course. Quite apart from the comparatively successful experiments of Symington and Miller on Dalswinton Loch and on the Forth and Clyde Canal, several passenger steamboats, successful alike commercially and technically, were navigating American waters five years before Bell's "Comet" made its momentous appearance on the Scottish river. Yet the "Comet" left a trail, ever widening in scope and increasing in intensity, whereas steamship building in America reached considerable dimensions only during the World War, and thereafter again receded to its former proportions. Other rivers in Britain have had distinguished engineers and shipbuilders associated with their work. The Thames for long was famous for its ships and the names of Maudsley, Brunel, and Woodcroft will be linked with it for all time. But Thames output declined, until today it does not appear among the first fourteen shipbuilding areas of the United Kingdom.

In the chapters which follow an attempt will be made to trace the growth of the shipbuilding and marine engineering industries in the West of Scotland from early times to the present day and, in particular, to examine the economic factors which have influenced its progress, culminating in the position of pre-eminence held by the Clyde today. A brief sketch of the early history of the river and the burghs located on its banks, will form a suitable preface to the more detailed description of the nineteenth century which follows.

The origin of Glasgow may be traced to the bishopric founded, where the city now stands, by Saint Mungo about the year 560. Between 1175 and 1178 it was created a Bishop's Burgh by William, Coeur de Lion. A few years later - between 1189 and 1198 - its citizens were given trading rights from Glasgow Bridge to the Cloch Point, nearly thirty miles down the river. Two adjacent burghs lay claim to recognition at earlier dates. Rutherglen contends that it received from David I the privileges of a free Burgh about 1126, and Renfrew claims to have been elevated to the status of a Royal Burgh in the same reign. It certainly was confirmed as such by charter in 1397. Dumbarton, under its early name of Alclwyd, was the ancient capital of the British Kingdom of Strathclyde, and about 1221 it became a free town. In the latter half of the fifteenth and first half of the sixteenth century Dumbarton was the port and "naval base" of the West of Scotland. In the Lord Treasurer's Accounts and the Exchequer Rolls for that period many payments to the town for repairs to and victualling of naval vessels appear. During the time that James I of Scotland was endeavouring to create a navy - between 1504 and 1507 - a ship was built there. This was probably the first vessel actually constructed at Dumbarton, though reference is made to one having been fitted out in 1487. A "bark" built in 1507 also receives mention. When Mary, Queen of Scots, sailed in 1548 for France, she embarked at that town. Formerly governed by a Superior, Greenock was raised to be a Burgh of Barony in 1635 by virtue of a charter granted by Charles I and confirmed by the Scottish Parliament in 1641. The terms of this charter are disputed and some historians hold that the authentic charter was that granted in 1670 and ratified in 1681. The municipality was established by two charters and an Act of Parliament dated 1751. At the east end of Greenock a separate burgh, Crawfurdsdyke, was created under the seal of Charles II in 1669. Subsequently known by the abbreviated name of Cartsdyke, it was later absorbed into the Burgh of Greenock, though in the sixteenth century it was considered of greater importance than the neighbouring town. The circumstances attending the founding of Port Glasgow will emerge when we come to consider the early trade of Glasgow and the Clyde Burghs.

Up to the middle of the seventeenth century, Glasgow was essentially a trading community. The only industry - if it may be so described - was salmon and herring fishing. The fish were cured locally and shipped for the French market. This in 1420 was the staple trade, William Elphinston being mentioned as its first promoter. The Glasgow coat of arms, visible today on tram cars, omnibuses, public buildings, etc., belonging to the city, is supported by a salmon on either side - a constant reminder[1] to us of the nature of the city's early trade. The earliest reference to Glasgow as a place of trade is to be found in an Order in Council dated Edinburgh, 26th August, 1546. The fishery was carried on also at Renfrew, Dumbarton, and Greenock, and continued to be of importance to these towns right up to the nineteenth century. Manufactures for giving

1. The salmon with rings in their mouths relate to the legend of St. Kentigern but the source of that legend was doubtless the importance of that type of fish to local trade.

employment to the poor at weaving were introduced into Glasgow about 1638 and simultaneously came letter-press printing. From 1630 to 1660 attention was paid to inland commerce and, in consequence, the burgh increased in importance. Commissioner Tucker of the Excise and Customs of Scotland in a report[1] stated that "... with the exception of the collegians, all the inhabitants are traders." It would seem that they went to Ireland with "smiddy coal", bringing back thence barrel hoops, meal, oats, and butter; to France with coal, plaiding, and herring, returning with salt, pepper, raisins, and prunes; to Norway for timber; and to the Scottish Highlands. By 1669 sugar houses had been established in Glasgow, although trade with the American Colonies was not opened to Scottish merchants till the Union of the Parliaments in 1707. Prior to that, the foreign trade of Glasgow was directed mainly to the Netherlands and France. In 1674 a company was formed in the city to carry on the dual business of whale fishing and soap making. Extensive premises at Greenock were occupied in curing fish and boiling blubber, whilst the soap manufactory was situate at the head of Candleriggs Street, Glasgow. Rope making was begun in the city in 1696 and, two years later, an Act of Parliament, designed to encourage this industry by imposing a duty on foreign products of this nature, was passed. Leather tanning and brewing, carried on from early times, became of considerable importance and gave employment to quite a number of Glasgow workmen subsequent to the Union. About the same time Walter Gibson, a fish exporter, commenced the importation of bar iron from Stockholm.[2.]

1. Quoted in "History of Glasgow" (1881) by George McGregor.
2. "History of Glasgow" (1777) by John Gibson.

The foreign trade of Scotland being mainly with the Continent up to 1707, it is only to be expected that the east coast ports were more active than those of the west; but, even so, it soon became apparent that the natural channel of the Clyde was quite inadequate for the extending commerce of the city. "In the beginning of the sixteenth century," wrote Dr. Cleland,[1] "the channel of the river, for about thirteen miles below Glasgow, was so interrupted by fords and shoals as to be barely navigable by small craft. In 1556, by the united exertions of the inhabitants of Glasgow, Renfrew, and Dumbarton, who had entered into an agreement to work on the river for six weeks at a time, with a view to remove the ford at Dumbuck, and some other prominent hirsts, the river was so far improved that small craft were soon brought up to the Broomielaw." The Burgh Records of Glasgow indicate that no harbour existed in 1597, and that the total shipping belonging to the merchants of the city consisted of six vessels totalling 296 tons. These small craft were moored in the centre of the stream, and the cargo was landed by men who waded to and fro between the boat and the river bank. The first year of the new century saw a Customs House erected at the Bridgend. By 1653 the trade of the city had become so great that the river, which it would seem had been allowed to silt up again, was quite incapable of dealing with the large quantities of goods involved. Three years later Commissioner Tucker reported[2] that "no vessels of any size could come within fourteen miles of Glasgow." Shipping belonging to the city but not necessarily sailing from it is recorded, in 1656, to have comprised twelve vessels aggregating 957 tons. The

1. "Enumeration of the Inhabitants of the City of Glasgow, etc." (1832) by James Cleland, LL.D.
2. Quoted by McGregor; op. cit.

merchants had already established a port at Cunningham, Ayrshire, but the transport to and fro by road was costly. The Town Council decided in 1662 to build a quay at the Broomielaw and a year later a weigh house was erected thereon. About 1667 the same body ordered that a book, recording particulars of all vessels arriving at Glasgow, should be kept. Even these improved facilities did not solve the problem of dealing with the ever increasing quantity of imports and exports, so in 1667 offers were made successively to Dumbarton and to Troon to build, at their respective towns, a harbour for Glasgow. Neither burgh was sufficiently enterprising to seize the opportunity of becoming the city's clearing house; the former town expressed the fear that the influx of mariners would raise the price of commodities and at the same time lower the reputation of the place. So in March, 1668, the Town Council of Glasgow purchased thirteen acres of land at Newark, a district lying about four miles to the east of Greenock and, having obtained from Charles II a charter to that effect, they built a harbour and founded the township of Port Glasgow. Shortly after the Revolution in 1688, the Broomielaw harbour, 730 feet long, was constructed at a cost of £1667 sterling. By 1692 the shipping of Glasgow had increased to fifteen vessels of various sizes amounting in all to 1182 tons.[1] In the same year Leith records 1702 tons, a figure which bears out the fact of the superior position held by east coast ports at that period. Ayr, which thirtysix years before, had five vessels aggregating 177 tons, now could not boast a single one; Irvine had only eight small craft, and Dumbarton a single boat of 24 tons. These together with Greenock constituted the

1. "The River Clyde" (1909) by Sir J.D. Marwick.

ports of the west coast. In 1656 the total shipping of Scotland consisted of 93 vessels aggregating 2724 tons. Half-a-century later this had increased to 215 vessels aggregating 14,485 tons.[1] The small share contributed by Glasgow to this total will be noted.

Throughout the eighteenthcentury the trade of the city grew apace and new industries added to its wealth. In 1690 the Merchants' and Trades' House of Glasgow was founded under Royal Charter, confirmed by Act of Parliament on 14th June of the same year. The Hammermen (which Incorporation included the blacksmiths, coppersmiths, silversmiths, jewellers, and saddlers) and the Wrights were two of the fourteen trades which sent deputies. The former sent six representatives, the latter three. London and Bristol had monopolised the West Indies Trade from its inception in 1553 till the beginning of the eighteenth century.[2] After the Union of the Parliaments in 1707 Scottish merchants were allowed to participate in this branch of commerce, and despite the violent opposition of the General Assembly of the Church of Scotland, the Magistrates and Council and the Merchants' and Trades' House of Glasgow to the Union, Scotland benefited greatly by the changed conditions. The following table gives a statistical comparison of Scotland with England immediately before the Union:[3]

	Public revenue.	Customs dut.	Excise Dut.
England	£5,691,803	1,341,559	947,602
Scotland	160,000	34,000	33,500

Exports from Scotland by sea which, just before the Union, amounted to £300,000 per annum had increased to six times this

1. "Caledonia" (6 vols. 1807-24) by George Chalmers, F.R.S.
2. According to Hackluyt's account.
3. "An Estimate of the Comparative Strength of Great Britain, etc." (1804) by George Chalmers, F.R.S.

figure at the beginning of the American War of Independence. According to the Registrar General's London account, shipping on the Scottish register was as follows:[1]

	Vessels	tonnage
25th Dec. 1707 to 25th Dec. 1712	1,123	50,232
Prior to 1707	215	14,485
Increase	908	35,747

Liverpool merchants also entered this trade with the West Indies about the same time and rivalled Bristol for many years until, in the latter half of the century, the Lancashire town completely outstripped the older seaport of the south. Glasgow merchants were not slow to take advantage of the opportunity offered and, despite the jealousy of English merchants which led to law suits, were soon engaged in an extensive trade with Virginia and Maryland. Tobacco, sugar, and rum were imported in ever increasing quantities, the bulk of these being re-exported to France and other Continental countries. By 1735 there were 67 vessels - 47 square rigged and 20 coasters - aggregating 5,600 tons belonging to and trading from the Clyde.[2] Writing in 1727 Daniel Defoe says of the Clyde merchants:[3] "They now send near fifty ships of sail every year to Virginia, New England, and other Colonies in America." As a result of this trade the "tobacco lords" emerged about this time and flourished in the city till the American War of Independence brought the trade to an end. Of the other manufactures which sprang

1. Harlean MSS. No.6209. British Museum.
2. John Gibson, op. cit.
3. "Tour in Scotland" (1727) by Daniel Defoe.

up during the eighteenth century space permits mention only of a few of the more important. By 1725 linens, lawns, and cambrics were being woven in Glasgow and the adjacent Burghs of Paisley, Renfrew, and Kilbarchan where in course of time the work came to be the main occupation of the inhabitants until the manufacture of cotton goods displaced it. The smelting of copper, zinc, and white metal for export was begun in the city in 1747. Delft manufacture was commenced in 1748; flint glass making, dyeing, and chemical works in 1777; turkey red dyeing in 1786 and distilling the same year; and throughout the century the art of type-making and printing of periodicals and books had been extending, culminating in the introduction of stereotyping in 1818 by Mr. Alexander Duncan, the University printer at that time. Tennant's works for the manufacture of bleaching powder were established in the city in 1800 and soon became the most extensive chemical works in Europe.

Two factors in the development of Glasgow have already received mention but deserve fuller treatment - the trade with America and the manufacture of cotton cloths; the former because it brought about a renewal of the efforts made during the seventeenth century to improve the river so that vessels engaged in foreign trade might discharge their cargoes and load again in the city, the latter because it was responsible for the introduction of steam power on a large scale into Glasgow. The circumstances attending the commencement of commercial relations between Scotland and America have been dealt with earlier and Table A.1. gives statistics of their growth. In 1724 tobacco to the amount 4,192,576 lbs.was imported into Scotland and of this 3,053,570 lbs. was ~~reexported~~ re-exported the same year. The peak year was 1771 when 47,268,873 lbs.were imported and 45,588,720 lbs.exported. The quantities of sugar and rum imported and re-exported also increased enormously during this period though not to such an extent as tobacco. Glasgow's share of the trade in these commodities for the year 1771 is exhibited below;

	Tobacco (lbs.)		Sugar (lbs.)		Rum (gals.)	
	Imports	Exports	Imports	Exports	Imports	Exports
Scotland	47,268,873	45,588,720	6,734,000		826,741	464,558
Glasgow	46,055,139	43,890,821	5,303,984	3,540,432	179,544	128,887

Glasgow merchants concentrated on tobacco and sugar; the bulk of the remainder of the sugar and much of the rum was discharged at Greenock. So wealthy and powerful did the "tobacco lords" of the city become that the leading master craftsmen in mechanical and other manufactures - the Langs, Martins, Claytons, and Ferries - deferred to them and chiefly through them the farmers general of France received their supplies of the fragrant weed. Glasgow merchants by reason of lower labour costs undersold those of London, Bristol, Liverpool, and Whitehaven; consequently jealousies, which materialised in litigation, were engendered between the rival traders. The names of a number of streets in the centre of the City - Jamaica Street, Virginia Street, Union Street, etc. - serve to remind present day inhabitants of Glasgow of the importance of the West Indian and American commerce two centuries ago.

The outbreak of the American War of Independence in July 1774,[1] interrupted communications and the succeeding years of hostilities gradually brought about a stoppage of supplies, though many vessels risked capture and destruction to obtain the highly valued commodity. The backbone of Scottish trade was broken and, beginning in 1776, depression held sway till 1785. Tables exhibiting various aspects of

1. Fighting did not actually begin till the skirmish at Lexington on 19th April, 1775.

Scottish trade and shipping during the eighteenth century are to be found at the end of the text and are discussed more fully in Appendix 2. All of them emphasize the perilous position in which our country found itself as a result of the misguided foreign policy pursued by George III. At the outbreak of the war American traders owed Glasgow merchants over £1,000,000, a debt which has never been liquidated.[1] For seven years - from 1776 to 1782 - the tonnage entered inwards from and cleared outwards to foreign ports dropped alarmingly. The shipping engaged in foreign trade dropped from 636 vessels aggregating 52,352 tons in 1778 to 524 vessels aggregating 40,530 tons in 1782, whilst respective figures for the total tonnage - foreign, coastal, and fishing - on the Scottish register were 1617 vessels of 94,915 tons and 1431 vessels of 77,997 tons. Not till 1799 did the money value of Scottish exports reach the figure of the previous maximum which had occurred in 1771. Re-exports were affected even more severely than were the total exports. Scotland suffered more than England in all respects. The diminution in tonnage belonging to the United Kingdom between 1778 and 1782 was approximately 86,000 tons on an initial total of 701,000 tons (i.e. 12%) of which Scotland accounted for 17,000 tons on a total of 95,000 tons (i.e. 18%). If instead we take tonnage entered and cleared or the values of imports and exports as a basis for comparison the same conclusion is reached.[2] In further illustration of the detrimental effects of the war on Scottish trade we may cite the following facts:

1. Recent questions in the House of Commons have suggested that this capital sum together with the accrued interest on it should be set off against the British war debt to U.S.A. but the private nature of the former liability renders this course impossible, even if it were desirable - which is doubtful.
2. See Tables A.2. and A.3.

Prior to the American war, Scotland did an extensive export trade with France, Flanders, Holland, Gibraltar, Italy, and Spain. The table below shows the years during which nothing at all was exported to these countries:

Flanders	1773-80	Gibraltar	1778; 1781-82
France	1778-82	Italy	1778; 1781
Holland	1781-82	Spain	1780-82

Normally these countries constituted the chief markets in which Scottish merchants disposed of their Colonial produce and as this diminished to vanishing point so also did Scotland's export trade. Exports to the American Colonies also dropped to zero. A few examples of the diminution of Colonial imports and exports, cited because of their importance in pre-war years, are given in the table below:[1]

Year	Official values in £s sterling.							
	Maryland		New England		North Carolina		Virginia	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
1775	140,644	-	11,587	13,489	25,878	395	348,041	-
76	13,606	-	-	905	74	-	68,172	-
77	-	-	-	-	-	-	830	-
78	1,177	-	-	-	-	-	-	-
79	-	-	-	-	-	-	-	-
1780	-	-	2,200	-	-	-	15,296	-
81	-	-	-	-	-	-	-	-
82	-	-	-	-	-	-	-	-
83	-	2,458	175	2,998	991	7,656	11,175	17,719
84	4,789	11,521	1,248	4,817	2,210	30,611	32,720	161,043

The truth of the statement[2]: "That, by war, the conqueror is rendered almost as unhappy as the conquered: all they

1. Public Record Office MSS. (B.T. 6/185.)

2. "Histoire Philosophique et Politique des Établissemens, et du Commerce des Européens dans les deux Indes." (1770). Tom. VII. (p.310.).

exchange are blood and wounds", was borne out in these years. Not until the war drew to a close in November, 1782, was there any possibility of recovery and the Peace of Paris, by which the American colonies gained their independence, sounded the doom of any hopes which had been cherished that commercial relations previously existing might be resumed. Meantime France had declared war with Great Britain in February, 1778, ostensibly in support of the Colonists claims but doubtless hoping also to wipe out the indignity of the recent Seven Years' War. Spain joined with France in April, 1780, and Holland followed suit in December of the same year. Peace with France and Spain was restored in January, 1783, and with Holland in September of that year. No other course was open to Scottish merchants but to transfer to fresh channels the capital that had been salved from the wreckage and begin anew to build up commerce in commodities different from those which had for so many years formed the bulk of the trade of Scotland.[1]

A new industry - the manufacture of cotton goods by machine power - had sprung up and to this enterprising capitalists of the West of Scotland turned their attention. That this was due in no small measure to the failure of the tobacco trade was recognised by Chalmers when he wrote:[2] "However the foreign trade of Scotland may have been depressed by the colony war, there is reason to believe, that she has thereby added to her domestic manufactures. The commercial capitals, which could no longer be employed abroad, were at length more usefully laid out at home. Instead of promoting

1. In 1783 the Glasgow Chamber of Commerce, the first institution of its kind in the United Kingdom, was founded to aid the development of trade.

2. "An Estimate of the Comparative Strength of Great Britain, etc."

the labour of other countries, these capitals furnished employment to many hands, within the kingdom. And, Scotland has, by those means, extended her valuable manufacture of gauzes; she has augmented the number of her print-fields; she has acquired every branch of the cotton business; and she has greatly increased her linens." Of the last mentioned commodity 2,000,000 yards were manufactured in Scotland in 1728; 12,000,000 yards in 1775; and 21,000,000 yards in 1792, a year of depression. The first mill for spinning cotton had been erected in Birmingham about the year 1741, power being derived from two asses walking in a circle. Manufacture on a larger scale, depending on water power, was begun at Northampton about 1743. John Kay, a weaver of Bury, invented the flying shuttle in 1750. Ten years later Hargreaves adapted to cotton the carding process hitherto applied only to wool. After an interval of seven years the idea of the "spinning jenny" emanated from the same inventive brain, to be superseded in a short time by Arkwright's spinning frame. Crompton's "mule jenny" followed in 1775. Finally, in 1792, William Kelly of Glasgow, manager at that time of the New Lanark mills, took out a patent for operating the mule by machinery. Many other inventions, ingenious and intricate, were applied to this branch of industry and the manufacture of cotton goods soon took a leading place in the nation's wealth producing activities. Meantime, James Watt was perfecting his steam engine and this new prime mover rapidly spread to many industries hitherto dependent upon manual or water power. Its application to cotton spinning was begun in 1785 when Boulton & Watt erected an engine at Messrs Robinson's mill at Papplewick, Nottinghamshire. Spinning and weaving had become an established occupation in and around Glasgow early in the eighteenth century. The first "power" loom in the city was set up by James L. Robertson in a cellar in Argyle Street in 1773; the motive power was supplied by a Newfoundland dog walking inside a revolving drum.[1.] The first actual cotton mill in Scotland was set up at Rothesay about 1778.[2.] Steam power applied to cotton manufacture was introduced into Scotland in 1792 by Messrs William Scott & Co. (afterwards Messrs Tod & Stevenson) in their mill at Springfield, Broomielaw, Glasgow.[3.] Thereafter so rapidly did the use of steam engines for various purposes spread that in 1813 the magistrates induced Parliament to pass an "Act for the Regulation of chimneys, steam engines, and other works within the city and suburbs of Glasgow." Thus, when steam navigation began, engineering shops capable of undertaking the construction of steam engines and mechanics capable of erecting, running, and repairing them were already available in the city. Till 1840 the manufacture of textiles - chiefly cotton goods - remained the principal industry of Glasgow.[4.]

But even at the beginning of the eighteenth century it was apparent to those who took a long view that the commercial prosperity of Glasgow depended on the Clyde being made navigable right up to the city. Even from Port Glasgow the transport of goods by road was expensive. The less costly alternative - to transfer the cargoes to lighters which were[5.] "sailed, rowed, and poled up to Renfrew and then towed up to

1. British Association Handbook for Glasgow meeting (1876) Section on the Textile Industries of Glasgow by James Paton.
2. "Glasgow - Past and Present." Vol.3. (1856) edited by James Pagan.
3. "Historical Account of the Steam Engine" (1825) by James Cleland, LL.D.
4. One variety even went by the name of "Glasgows."
5. "The River Clyde" (1876) by James Deas.

the harbour by either men or horses" - involved excessive handling and delay. Serious steps were therefore taken to accomplish artificially what Nature had left undone. In 1740 an attempt to dredge the Clyde failed. Fifteen years later Smeaton, the famous lighthouse engineer, made a survey and reported that at high water the minimum depth of the river between Dumbarton and Glasgow was 3'-3", while at low water this figure was reduced to 1'-3". He recommended that a weir and lock be built four miles down the river and in 1759 the Corporation, in furtherance of this scheme, obtained an Act of Parliament. Some dissatisfaction having been expressed as to the desirability of this project being pursued, Dr. Wilson made another report, the suggestions contained in which were soon followed up. In view of the improvements effected later it was fortunate that Smeaton's idea was rejected. In 1768 John Golborne, an engineer of Chester, examined the river and made a report. Shortly after, James Watt's advice on the matter was taken[1.] and Golborne's scheme for the erection of jetties was adopted on his recommendation. An Act was passed in 1770, vesting in the Magistrates and Town Council of Glasgow powers to deepen the river and to impose tonnage dues on ships using it. This marks the beginning of the body which later became the Clyde Navigation Trust. Within the next five years Golborne had erected 117 jetties, the purpose of these being to contract the bed of the river and thus deepen it by flood and scour of the tide. By this means vessels of 30 to 40 tons, drawing six feet of water, could come up to the harbour at high tide. Remnants of some of these jetties were still to be seen until recently in the neighbourhood of Scotstoun. In the Treasury Accounts for Scotland[2.]

1. "Annals of Glasgow" Vol.I., pp.290-1; also Clyde Trust Reports (1854).
2. Public Record Office MSS. (T 36/13.)

the first mention of Glasgow as a port appears in 1780, when the following entrances and clearances are recorded:

Year	Foreign (tns.)		Coastal (tns)		Total (tns)	
	In	Out	In	Out	In	Out
1780	181	257	1,630	1,137	1,811	1,394
1784	278	885	10,738	6,159	10,656	7,044

The first vessel "of any size" to arrive at the Broomielaw was a small schooner, the "Triton", in 1780.[1] By 1784, as the figures show, an enormous extension in coasting trade had taken place whilst the increase in outgoings to foreign countries - due partly to the cessation of the American war - was considerable. Thereafter, to the end of the century, the expansion was continuous. In 1792 an extension of 360 feet was made to the harbour. In 1796 1326 vessels aggregating 55980 tons arrived at Glasgow bridge.[2] This gives an average of 42 tons per vessel. Between 1799 and 1806 John Rennie continued the work of deepening the river. Dykes were built joining up the jetties thus contracting further the area available to the incoming tide. In 1806, 1,678 vessels aggregating 80,683 tons (and therefore averaging 48 tons per vessel) came up to the harbour.[2]

Prior to 1818, despite the improvements made, few of the vessels engaged in foreign trade could approach Glasgow; consequently Greenock and Port Glasgow developed in extent and importance. Dumbarton languished till the era of the steamboat. Gradually its early privileges of levying toll on all ships entering the Clyde, of fishing monopoly in the River Leven and the Clyde Lochs, and many others, were filched from it. For a time glassmaking revived the town but this too fell away. The burghs on the south bank on

1. "History of Glasgow" (1882) by Andrew Wallace, Inspector of Poor for Govan.
2. Marwick, op. cit.

the whole prospered exceedingly, though sharing with Glasgow in the temporary depression resulting from the American war. Like Glasgow their early industry was herring fishing. David Loch, a merchant who held the office of General Inspector of Fisheries of Scotland, put on record that in Greenock in 1754 there were about 800 small craft engaged in that work. Each carried four or five men. During the year 1777-8, 23,058 barrels of herring were shipped thence to foreign parts.[1.] In company with other industries of the eighteenth century, herring and cod fishing was subsidised under the general mercantilist policy of the time. Commencing in 1750 bounties were given to herring boats and premiums were paid upon the quantity of herring and cod exported. The tax of 16/8 hitherto imposed on every fishing boat "that wetted her nets, whether herrings were caught or not" was abolished. The portion of these monies which came to Scotland from 1751-82 is shown in the table below:[2.]

Year	Bounties to herring vessels	Premiums on herring & cod exports	Total
1751	£ 223	£ 4,648	£ 4,871
52	452	3,636	4,088
53	778	4,976	5,754
54	605	5,474	6,080
55	117	7,765	7,881
56	117	7,154	7,270
57	250	4,471	4,731
58	454	7,546	8,000
59	454	4,829	5,283
1760	1,387	3,644	5,031
61	1,864	4,808	6,672
62	5,141	3,324	8,464
63	9,229	5,029	14,257
64	12,820	2,987	15,815
65	17,642	5,846	23,489
66	31,191	4,830	36,021
67	31,392	3,893	35,285
1768	£ 23,884	£ 5,403	£ 29,287
69	9,670	4,373	14,043
1770	2,155	7,716	9,870
71	2,085	5,469	7,554
72	11,103	4,070	15,174
73	12,510	6,550	19,061
74	17,025	6,967	23,993
75	19,610	6,062	25,672
76	21,290	8,437	29,727
77	17,592	7,512	25,104
78	16,316	6,160	22,476
79	15,287	5,314	20,601
1780	13,445	5,613	19,059
81	9,675	4,071	13,746
82	10,586	3,830	14,415
Total 32 years	316,366	172,410	488,775

1. "History of Greenock (1921) by Robert M. Smith.
2. Public Record Office MSS. (T. 36/13.). Figures are to the nearest £; hence totals do not always balance.

The fall exhibited in the year 1769 was due to the fact that the bounties to Scottish vessels were paid out of a special fund. In 1766, to the consternation of the Scottish herring fishers, it was announced that this fund was overdrawn. In 1771 the matter was remedied; the bounty was made a charge on the national revenue - as the English bounty had all along been - and was guaranteed at 30/- per ton for the next seven years. Vessels of the Greenland whale fishery were also subsidised as follows :

1733-40	-	20/- per ton
1740-50	-	30/- per ton
1750-70	-	40/- per ton

At the maximum point, touched in 1755-6, some sixteen Scottish vessels aggregating 4964 tons were engaged in this activity.[1] The vessels engaged in foreign trade from Greenock aggregated approximately 14,000 tons, while in addition about one hundred "busses" of 50 tons each, carried on the fishing industry. Sir John Shaw, the Superior of Greenock made unsuccessful applications in 1696 and again in 1700 to the Scottish Parliament for public aid to build a harbour at Greenock. Undaunted by these rebuffs the inhabitants raised a fund by means of a special tax of 1/4 per sack of malt brewed into ale. The harbour was begun in 1707 and completed three years later. It covered an area of ten Scotch acres[2] and cost £5,555, which sum was completely paid off by 1740. In 1759 Greenock obtained legislative sanction to improve the harbour. Further statutes to the same end were passed in 1789, 1801, 1803, 1810 and 1817. Finally the whole harbour was rebuilt at a cost of £119,000. A dry dock was constructed by Scott's shipbuilding company in 1785 at a cost of £4,000. Some

1. "Annals of Commerce", Vol.III. (1805) by David Macpherson.
2. Equivalent to 12½ imperial acres.

forty years later a public graving dock of larger dimensions was completed at a cost of £20,000.

Port Glasgow too was extending. By 1672 it had a dry dock capable of accommodating at the same time two 500 ton ships. A spacious harbour having three piers provided facilities for the discharge of cargoes. The table below gives the tonnage entered at and cleared from the harbours of Greenock and Port Glasgow at five-yearly intervals from 1761-84. For comparison the statistics of an Ayrshire port and of two East Coast ports are given. Figures for 1775 are also given to show the maximum reached prior to the depression brought about by the American War.[1]

Year	Greenock		Port Glasgow		Irvine		Leith		Bo'ness	
	In	Out	In	Out	In	Out	In	Out	In	Out
1761	11436	15284	13547	16434	4,628	6,542	10,540	4,080	2,972	3,868
1766	13529	13307	13907	14132	10,979	11,164	17,425	6,820	6,092	7,097
1771	20880	17198	19526	27713	7,563	12,775	14,490	7,200	6,216	8,273
1775	26025	18037	19825	19817	14,454	14,362	18,000	6,750	9,051	18,033
1776	15577	14504	11818	13520	14,051	14,731	14,850	6,300	8,199	20,582
1781	10768	12325	8193	9964	13,737	16,694	10,392	3,567	12,378	9,809
1784	16426	15383	8231	9011	18,263	20,409	30,304	7,063	19,261	16,434

The parallel progress of the two Clyde burghs will be noted; also the fact that the depression affected Glasgow's port at an earlier date and more severely than its neighbour. The East Coast ports were much less affected than those of the West and recovered more quickly. The following table shows the number of vessels and total tonnage on the registers of Port Glasgow, Greenock, and Scotland, classified according to the trade in which they were engaged - foreign, coastal, or fishing. Though it must not be assumed that all the tonnage added was built in Britain, much of it being

1. Public Record Office MSS. (T.36/13).

prizes of war, the table illustrates the recovery after the minimum of 1782, and indicates also the beginning of Port Glasgow's subsequent decline as a shipping centre, due to the deepening of the Clyde which enabled vessels, in ever increasing numbers and ever larger in capacity, to come right up to Glasgow, there to discharge and embark their cargoes.[1] Fishing too declined there, but Greenock shows an all round increase.

Year	Place of Registry	Foreign		Coastal		Fishing		Total	
		No.	Tons	No.	Tons	No.	Tons	No.	Tons
1781	Port Glasgow	70	6,266	16	664	25	1,224	111	8,154
	Greenock	113	9,683	37	1,093	83	2,691	233	15,467
	Scotland	524	42,113	682	28,050	241	10,531	1,447	80,694
1782	Port Glasgow	87	7,295	28	1,055	18	755	133	9,105
	Greenock	117	9,088	30	711	57	1,878	204	11,677
	Scotland	524	40,529	700	27,614	217	9,981	1,441	78,024
1783	Port Glasgow	72	5,956	31	1,628	16	705	119	8,289
	Greenock	116	9,105	23	503	106	2,919	245	12,527
	Scotland	556	42,138	647	27,523	262	10,473	1,465	80,134
1784	Port Glasgow	66	6,180	24	1,304	33	1,482	123	8,966
	Greenock	137	11,466	36	910	124	1,369	297	13,745
	Scotland	643	50,386	709	31,542	297	10,421	1,649	92,349
1785	Port Glasgow	117	8,562	37	1,786	18	669	172	11,017
	Greenock	168	14,472	40	928	92	2,135	300	17,535
	Scotland	785	60,356	790	36,371	252	11,252	1827	107,980
1800	Port Glasgow	51	8,837	29	2,117	7	218	87	11,172
	Greenock	204	26,707	165	9,546	187	7,954	556	44,206
	Scotland	687	81,907	1,169	66,133	559	23,688	2,415	171,728
1810	Port Glasgow	65	12,646	39	2,624	1	18	105	15,288
	Greenock	181	32,508	110	7,468	69	2,911	360	42,887
	Scotland					271	12,910		
1818	Port Glasgow	66	11,242	14	962	-	-	80	12,204
	Greenock	171	34,296	99	6,310	68	2,774	338	43,380
	Scotland	1,016	140,429	1,676	104,162	337	18,010	3,029	262,601

1. For 1781-85; "Annals of Glasgow" (1816) by James Cleland, LL.D. For 1800, 1810, 1818; "Caledonia" (6 vols. 1807-24) by George Chalmers, F.R.S. Note that for the period 1781-85 ships going to Ireland are included as foreign trade vessels. This practice continued presumably till 1800 when the Union of the Parliaments took place. Also, for the same period (1781-85) ships owned in Dumbarton are included in the Port Glasgow register.

This brings the historical summary to the close of the eighteenth century, and it only remains to indicate the extent of the growth of Glasgow by citing the population figures at intervals throughout the preceding two hundred years:[1]

Year	Population
1610	7,644
1614	about 8,000
1660	14,678
1688	11,948
1708	12,766
1712	13,832
1740	17,034
1743	18,366
1755	23,546
1763	28,300
1780	42,832
1785	45,889
1791	66,578
1801	83,769

The striking increase is that during the latter half of the eighteenth century, particularly the closing twenty years of it. This is the period when Glasgow became a manufacturing as well as a commercial city. A new era opens with the nineteenth century - the era of iron and steam - but before proceeding to consider this it will be necessary to survey the shipbuilding activities of the epoch when wood was unchallenged as the material of construction and sail had no rival on the seas.

1. For 1610 to 1712; also 1743; Post Office Directory for Glasgow (1803). For 1740; also 1755 to 1801; "Statistical Account of Glasgow" (1803) by James Cleland, LL.D.
Note: Figures for 1755-1801 include population of suburbs.

CHAPTER II.

SHIPPING AND SHIPBUILDING IN THE EIGHTEENTH CENTURY.

The modern shipbuilding industry of the Clyde - as will be argued more fully later - cannot be regarded simply as the development of the boat building activities existing there prior to the nineteenth century. The technique and requirements of work in iron are vastly different from those called for in constructional work in timber. The latter would today be classed as carpentry, the former as the job of a shipwright or an engineer. The difference in construction between a steamship and a sailing vessel is much less marked, both modes of propulsion being incorporated in ocean going vessels up to the eighties of last century. Now, whilst it is true that the upper reaches of the river were innavigable in early times, the firth was eminently suited alike to the acquisition of the art of seamanship and to the practice of the craft of boatbuilding. It cannot be doubted that a bias existed towards activities relating to the sea and that the lower reaches of the Clyde possessed topographical features which endowed it with the potentialities of a shipbuilding area. But the development of this industry, which took place during the nineteenth century, implies economic factors also. Had these not been present it is fairly certain that the favourable natural features of the firth would not have been sufficient to make Glasgow and the

Clyde the famous shipbuilding and engineering centre that it is today.

The nature and extent of early boatbuilding was just such as one would expect to find on the shores of any sheet of water situated near a centre of population and giving easy access to the sea. The Treasury Accounts make mention of a payment in 1512 for the building of a galley at Glasgow.[1.] If it were actually built - mention of payment made is no guarantee of that! - it must have been extremely small; perhaps the materials for outfitting were sent from Glasgow. Writing of Scottish shipping in the sixteenth century Miss Grant says[2.]; "There was at times a considerable mercantile Navy, but how far the Scots built and how far they bought their ships remains a matter for conjecture." During the war with the Dutch in the reign of Charles II a 60 ton privateering vessel, the "Lion of Glasgow", was fitted out on the Clyde. In 1684 Walter Gibson, a merchant of Greenock, was endeavouring by public advertisement to induce persons to emigrate to the Bermudas, Carolina, New Providence, and the Carriby Islands, the ships being due to sail from the Clyde on 20th February of that year.[3.] This, it will be noted, was prior to the Union of the Parliaments and the opening to Scottish merchants of the Colonial trade which accompanied that constitutional change, and provides evidence that enterprising persons were already endeavouring to break down the barriers that existed. The first authenticated Atlantic crossing by a vessel from Greenock was undertaken two years later, to convey to Carolina some twentytwo persons

1. "The River Clyde and the Clyde Burghs" (1909) by Sir J.D. Marwick.

2. "The Social and Economic Development of Scotland before 1603". (1930) by I.F. Grant.

3. "Bannatyne Miscellany". This seems to have been the vessel referred to by Daniel Weir in his "History of the Town of Greenock" (1829) as being the first to cross the Atlantic from Greenock.

under sentence of transportation "for attending conventicles and being disaffected to the Government."[1] Thus, even at this early date, the area seems to have harboured opponents to the existing system; a feature which, in more recent times - not altogether justifiably - has brought it notoriety! Part of the Darien expedition was fitted out at Cartsdyke in 1697 and the first locally built vessel to engage directly in the Colonial trade was one of 60 tons burthen launched at the same town in 1716.[2] Prior to this, many of the vessels engaged in the Colonial trade were chartered from the merchants of Whitehaven, Cumberland. During the American war Glasgow fitted out fourteen privateering vessels, the hulls of which would be built elsewhere; in fact it is not quite clear whether the city supplied the actual materials or whether the citizens simply accepted responsibility for raising the necessary finance.

Only one firm - that founded by John Scott[3] of Greenock in 1711 - has continued for over two centuries in uninterrupted development, through all the varying phases of ship design and construction. For over fifty years this firm confined its activities to building herring busses and small craft, but in 1765 their first square rigged vessel was begun. It was constructed to the order of owners in Hull and it is claimed to be the first built in Scotland for owners beyond the Border. In 1791, John Scott (a grandson of the founder of the firm) was responsible for building the largest ship of the year, the "Brunswick", 600 tons carpenter's measure (1,000 tons d.w.) for trade with Nova Scotia, and three years later the "Caledonia" - claimed to

1. "Historical Sketches of the Town and Harbour of Greenock" (1879) Dugald Campbell.
2. "History of Glasgow" (1795) by Andrew Brown. Weir's history gives 1719 as the date.
3. A member of the Incorporation of Hammermen; associated with the father of James Watt.

be the largest of its year - 650 tons c.m. for the carriage of timber, masts, etc. to Government dockyards.[1] The firm acquired the Greenock foundry in 1790 and were thus able to manufacture their own fittings. When in 1825 they began the construction of steam engines, they were experienced in the art of casting iron and were well equipped to take a leading place in the new industry. Daniel Weir in 1829 was able to write in his "History of the Town of Greenock"; "The building yard of Messrs Scott and Sons[2] is allowed to be the most complete in Britain, excepting those which belong to the Crown."

Since the Clyde shipbuilding industry was devoted to the production of wooden and sailing vessels for many years after steam and iron had begun to supersede the older forms, a brief account of the technique of such work and the type of ships built is necessary. Very few improvements either in constructional methods or in type of vessel were made during the seventeenth and eighteenth centuries. The first letters patent dealing with these matters is dated 17th January, 1618, and excepting improvements to sheathing and pumps the next seems to have been issued in 1810. Advances in the preserving of timber were made. At the beginning of the eighteenth century the practice was to char the inner surface of the log while the outer surface was kept wet. This was superseded by "stoving", a process involving the application of heat to the planks whilst these rested upon wet sand. Subsequent to 1736, the timber was steamed and impregnated with some liquid having the property of preventing deterioration. Creosote proved very effective but had the disadvantage of rendering the wood extremely inflammable. Alternatively solutions of

1. "Two Centuries of Shipbuilding." (1920).
2. The firm became John Scott and Sons in 1802.

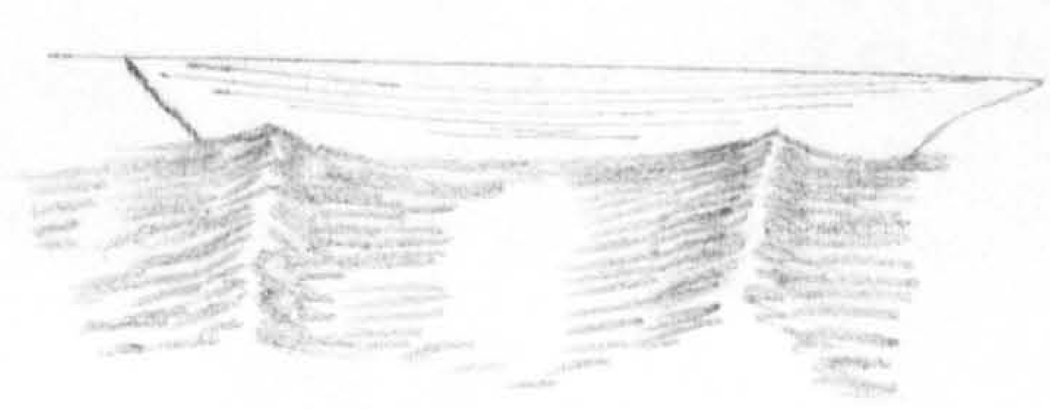
zinc chloride, copper sulphate, or corrosive sublimate were used. Copper sheathing was first applied to warships in 1761; prior to this, sheet lead had been used from the time of Charles II onward. Muntz metal had also been tried as an anti-fouling device. Early English ships were built of native oak. Timber for the large vessel built by Scott in 1764 was obtained from the forests at Hamilton, Lanarkshire. But the supply from home sources was a diminishing one and in the latter half of the eighteenth century large quantities of fir were imported from Baltic countries. Before 1803 imports of timber from our American Colonies were small, but subsequently the Colonial trade expanded whilst imports from Northern Europe declined. Porter in his "Progress of the Nation" gives the following data;

From 1788 to 1802 the imports of timber from Europe totalled approximately 3,000,000 loads, whilst 19,429 loads came from the American Colonies during the same period. In 1803 the imports from the west were 10,113 loads and thereafter the amount increased steadily year by year, whilst the imports from Europe diminished relatively as a result of the Napoleonic wars and the preference in customs duties given to our Colonies. Thus in 1846 the figures were;

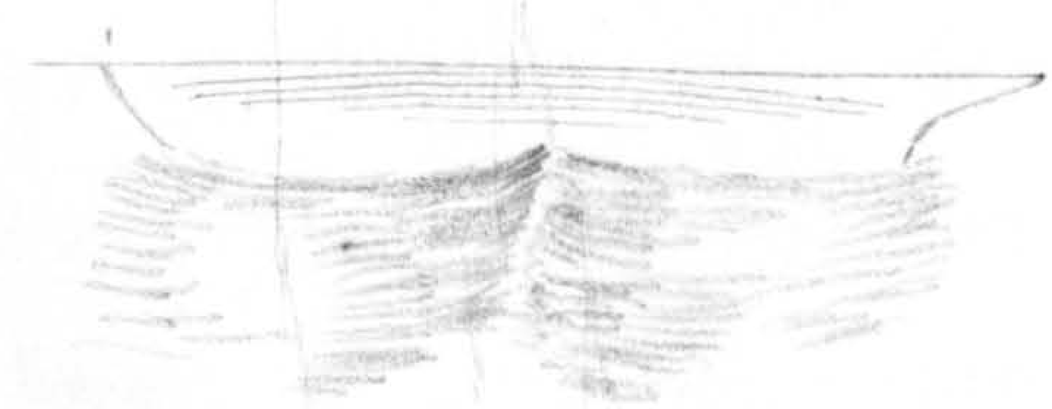
from American Colonies	-	1,214,442 loads
from foreign countries	-	810,497 loads
Total imports of timber	-	2,024,939 loads

A load comprised 50 cubic feet. Clyde shipbuilders seem to have obtained their supplies mainly from the New World. Small quantities were obtained from local sources and a fraction of the imports came from Norway. Stakes which mark the site of the enclosures into which the logs were floated are still to be seen on the south bank of the River Clyde between Langbank and Port Glasgow and serve as a reminder of the extensive trade in timber conducted locally a century ago.

At the end of the eighteenth century, ships were built up of a series of ribs running transversely. These were connected by the outside planking and ceiling. There was nothing in the nature of filling between the ribs; hence the structure suffered from hogging and sagging stresses. Heavy seas soon strained the planking and caused serious leaks. French designers introduced oblique riders to give strength; towards the same end the ceiling and outside planking was laid diagonally. The Sepping system, introduced in 1810, consisted in connecting the beams by longitudinal timbers and making use of other stiffening members; a trussed framework gave additional resistance to strain and the deck planks were laid diagonally. Rarely did the life of an eighteenth century ship exceed twelve to fifteen years. Those of soft wood - American pine, Norwegian fir, etc. - had an existence even more brief. For their "A.1." classification Lloyd's allowed only English oak, African oak, live American Oak, morra and greenheart of British Guiana, teak and saul of India, and iron bark of Australia.



Sketch to illustrate sagging.



Sketch to illustrate hogging.

Many variations in build and rig were to be found in these early days. Types that are now merely names, known and understood by few-brigantines, snows, galliots, gabbarts, sloops, schooners, etc. - were common to most ports. Three leading types deserve special mention, viz. the East Indiaman, the West Indiaman, and the clipper. The first mentioned type emerged about 1772. They were bluff-bowed, heavy sterned vessels, slow and steady. Designed for fighting as well as for carrying goods and passengers, their registered tonnage exceeded their actual cargo-carrying capacity, whilst they required crews twice the numerical strength of those common to West Indiamen of the same nominal tonnage. A further reason for the cumbrous and expensive design of this type was that these vessels had to be capable of withstanding the typhoons prevailing at certain seasons in the Indian Ocean. But even when allowance has been made for all these circumstances the East Indiaman does seem to have been constructed upon lines all too generous, no expense being spared in its building and equipment. Perhaps the profitable nature of the monopoly of trade with India and with China enjoyed for many years by the East India Company that owned these vessels, explains the fact that as late as the year 1813 such ships cost £40 per ton as against the £25 per ton commonly paid by other shipowners. Even at this period, owing probably to lower labour costs, ships could be built more cheaply on the Clyde than at London or Bristol, but there existed against Scotland a prejudice, justifiable or otherwise. Most of the East India Company's vessels were built on the South Coast of England, though later a number of them came from India, teak being the material used. The reason for this was that in 1772 an Act of Parliament[1] was passed prohibiting the East India Company from building any new vessels in Britain until their fleet was reduced to less than 45,000 tons. They were however allowed to have ships built in India or the

1. 12. Geo. III. c. 54.

Colonies. This seemingly foolish discouragement of British shipbuilding was an attempt to conserve the much depleted timber supplies of the country.

The West Indiaman type, which came into being early in the nineteenth century, was designed on improved lines and had a carrying capacity in excess of nominal tonnage; but it was badly proportioned for speed, the length being only four times the breadth. Faulty design and defective material were fruitful sources of extensive loss of life and property at sea; in coarse weather the West Indiaman was rather unmanageable. Ships belonging to America entered into keen competition with British ships on the western ocean about this time and, for a period, outnumbered those of all other nations trading on these routes. The American vessels were designed for speed, the ratio of length to breadth being five or six to one, a nearer approach than had hitherto been made to what is now known to be correct stream line form. Capstans and winches replaced manual labour for heavy heaving and lifting and, proportionately to their tonnage, these vessels were lightly rigged. They may be regarded as forerunners of the nineteenth century clippers and, as early as 1788, they entered into competition with the ships of the East India Company in the China trade. Not till the termination in 1814 of that Company's monopoly, which had been in existence for 214 years, does there seem to have been in Britain sufficient inducement to make any really striking advance in ship design. The blame for this state of affairs cannot wholly be laid upon the Company which, from 1668 onwards, adopted a settled policy of freighting ships specially constructed for their trade. Encouragement was given to shipowners to build vessels for the purpose; but whether this encouragement took the form of monetary premiums or merely that a satisfactory performance on one voyage was recognised as a claim to re-employment, is not clear.[1] The China trade was in the hands of the same Company till 1834.

Another factor making for improvement in ship design and management was the relaxation of the English Navigation Acts which was begun tentatively in 1794. These legislative measures dated back to the early years of the reign of Richard II. The chief of them, however, had been passed by the Rump Parliament under Cromwell in 1650 and were later confirmed by Charles II. As a result of Cromwell's Act Britain lost the Greenland, Iceland, and Baltic trade in which she had previously shared. Protected interests naturally laid the blame for the increase in American shipping and the decline of British shipping on the action taken to relax these Acts. Acheson in his "Encroachments of America" gave the following figures showing the number and tonnage of British ships engaged in direct trade with U.S.A. entered at and cleared from British ports;

Year	Inwards		Outwards	
	No.	Tons	No.	Tons
1786	216	36,875	213	39,651
1806	53	11,347	39	8,731

He seems to take no account of the significance of the years chosen; the former being four years after the cessation of hostilities with America and marking a revival in trade following on the depression which lasted till 1785, the latter in the middle of a war which had engaged our ships and men for the best part of the preceding

1. "A Calendar of the Court Minutes, etc. of the East India Company." Vol. 7. (dealing with period 1668-70), edited by Ethel B. Sainsbury.

thirteen years. If tonnage on the register be taken as an index, the United Kingdom and Scotland with it had advanced considerably in the period 1786-1806 as the following table shows:

Year	Scotland		United Kingdom	
	No.	Tons	No.	Tons
1786	1,936	129,318	10,331	932,000
1806	(1805) 2,581	210,295	19,315	2,079,914

Included in the United Kingdom figure for 1806 are 2,564 vessels totalling 342,248 tons captured as prizes. But even allowing for this fact and taking no account of war losses, the advance was very considerable.

The facts regarding this period, as now seen, were that the influences tending to remove trade restrictions, whilst adversely affecting shipping interests for the time being by reducing freight rates[1.] in what seemed to be a calamitous manner, had the effect of revealing the need for more efficient ships. Given this fairer opportunity, Clyde builders were not slow to demonstrate their ability to satisfy the need. Prior to the American war, almost all large vessels (according to Daniel Weir's account) were built in America. Certainly the whale fishing company of Glasgow mentioned above[2.] were compelled to have two ships, one of 700 tons and the other of 400 tons, constructed at Belfast "for want of carpenters in our then fallen state."[3.] Thus the "great progress" in shipbuilding, which Brown in his "History of Glasgow" alleges to have taken place subsequent to the first Clyde built vessel engaging in the

1. From India to Britain freights dropped from £32. 10/- per ton in 1773 to £10 per ton in 1830.

2. p.6

3. "History of Glasgow" (1777) by George Gibson.

American trade,[1] cannot have continued for any length of time. We do know that in 1769 our North American Colonies built 389 vessels aggregating some 20,000 tons, a figure exceeding the total output of the United Kingdom for that year.[2] The first square rigged vessel to be launched on the Clyde was one by Peter Love of Greenock in 1764; Another by Walter McKirdy followed later in the same year. Both were for the West Indian trade. In 1776, a year that may be regarded as representative of the time, 18 vessels totalling 1073 tons were launched in Greenock. The largest was one of 77 tons. From 1783-93 there were launched at Port Glasgow and registered there 51 vessels aggregating 6,192 tons. This figure must be regarded as a minimum of actual construction, for it was quite customary to register at Greenock ships built in the neighbouring burgh. But the necessity for larger vessels than those which hitherto had been used in the transport of tobacco and the export of manufactured goods was felt when the import in large quantities of the bulky raw cotton began. The advantage of having these vessels built locally was also evident. Thus by the end of the century ships of 500 tons burthen were being launched from Greenock yards. In the early years of the nineteenth century East Indiamen of 700 to 800 tons and West Indiamen up to 300 tons were being built there. When trade with India was thrown open to all, Clyde merchants immediately seized the opportunity. In 1816 the first voyage from Greenock to India was made by the "Earl of Buckinghamshire", a ship of 600 tons burthen. The economy of using large vessels in trade with such a

1. In 1716.

2. "Two Centuries of Shipbuilding and Engineering". (1920).

distant country was at once recognised and soon vessels of 1500 tons were on the stocks.

New shipyards were opened up and old ones enlarged. In 1796 Messrs Steel and Carswell began business at the Bay of Quick, Greenock, on a spot occupied by building yards for upwards of fifty years previously. Robert Steel & Co. followed in 1816 and by 1828, in addition to a number of steamboats, had launched 30 square rigged and 14 fore and aft rigged vessels. Messrs R. & A. Carswell opened up in 1816, to be followed a year later by William Simon & Co. In the succeeding twelve years the latter firm were responsible for 13 square rigged, 5 fore-and-aft rigged vessels, and 3 large steamboats - in all 5220 tons.[1] John Wood of Port Glasgow - famous as the builder of the "Comet" and other early steamboats - and James Maclachlan of Dumbarton, the forerunner of William Denny & Co. may also be mentioned as two of the better known shipbuilders of this period of Clyde history. Owing to the limitations imposed by the river channel, Glasgow progressed but slowly in shipbuilding. At the beginning of the nineteenth century vessels of greater draught than six feet could not come up to the city; hence the ships built there were few and of small size. Complete figures for tonnage launched on the Clyde are not available for years earlier than 1863[2] and for the very early period with which we are at present concerned statistics are scanty. As giving some information which will enable us to compare the relative importance of various

1. "History of Greenock" (1829) by Daniel Weir.

2. As will be shown later, shipbuilding did not become an important industry on the river till the second half of the nineteenth century.

Scottish ports in boat building activities we may however cite the following data compiled from a register of the ships belonging to Scotland in 1820.

The total dealt with comprised 2,851 vessels aggregating 273,453 tons. These figures approximate closely to those given by Chalmers in his "Caledonia", viz., 3,133 vessels totalling 288,770 tons, so that we may take it that the Association of Underwriters and Brokers of Glasgow responsible for the aforementioned register had made a fairly complete survey of Scottish shipping. The following table shows the distribution of the fleet in respect to ports of registration;

Port	No. of Vessels	Tonnage	% of total tonnage	Aver. Tons / Vessel
Glasgow	89	6,842	3	76.9
Port Glasgow	118	18,511	7	156.9
Greenock	338	44,107	16	130.5
Other Clyde ports	320	22,224	8	69.6
Other Scottish ports	1,986	181,769	66	91.5
Total	2,851	273,453	100	95.9

Of all Scottish ports Aberdeen had the largest tonnage on its register; Greenock was second and Leith third. This marks the relative and temporary decline of the West following upon the collapse of the American Colonial trade, accentuated by the depression which resulted at the close of the Napoleonic Wars. The average size of Glasgow's ships was well below the Scottish average. The leading place taken by Port Glasgow as regards the average size of its vessels was due to the fact that towards the end of the nineteenth century the fishing fleet of that town, which consisted of vessels of small tonnage, diminished to vanishing point[1] whilst that of Greenock increased. The foreign trade of the West was still conducted from the ports on the Firth of Clyde. To detail the tonnage of the various types of vessel comprising the Scottish fleet would digress too far from the main thread of the subject. The composition of the fleet according to the trade pursued - foreign, coastal, or fishing - is dealt with in the appendix to this chapter; all are included in the figures given above and below.

As to the origin of the vessels on this register, the oldest of these was one built at Irvine in 1765 and several built as recently as 1820 are on the list. Clearly the figures do not include all the vessels built between these dates, but only those extant and on the Scottish register in the latter year. But since few vessels were built in Scotland for owners elsewhere in the period under consideration and since there is no reason to suppose that vessels built at any particular port were more liable to removal from the register by loss or sale than those of any other port, the figures will give fairly accurately a basis for comparison. The next table therefore summarises the origin of the ships on the register:

Origin of Vessels	No. of Vessels	Tonnage	% of total tonnage	Average tons/vessel
Prizes	162	19,596	7	120.9
British built, but not in Scotland	407	57,516	21	141.0
Foreign built	48	11,947	5	249.2
Total	617	89,059	33	144.2
Built on the Clyde	468	42,213	15	90.2
Built on the Forth	611	46,704	17	76.4
Built elsewhere in Scotland	1,155	95,477	35	82.7
Total	2,234	184,394	67	82.5
Total built outside Scotland	617	89,059	33	144.2
Total built in Scotland	2,234	184,394	67	82.5
Grand Total	2,851	273,453	100	95.9

1. See table p.23 above.

Thus, Scotland imported from abroad a twentieth part of her ships. These were mostly large vessels, largest of all being one of 599 tons built at Montreal. Slightly more than one fifth of the total originated in England, Ireland, Wales, the Channel Islands, and the Isle of Man, ships representative of each of those areas being found on the register. These again were mainly vessels of large tonnage. If therefore we include prizes taken in the wars, we find that one third of the Scottish fleet was of non-Scottish origin. The Forth was a more important ship-building river than the Clyde. Places such as Limekilns, Charlestown, and Kennetpans on the north bank of the Forth and Borrowstounness (Bo'ness) and Blackness on the south, that today are mere villages of no consequence in shipbuilding, were at that time launching quite a number of boats every year. The combined output of Clyde and Forth equalled the rest of Scotland. The fact that the average tonnage per vessel launched on the Clyde exceeded the general average of those built in Scotland, was due to the port of Greenock which, as is shown below, was responsible for the majority of large vessels launhhed in Scotland. The following table shows the origin of all vessels of 400 tons and over.

Origin of Vessels	No. of Vessels	Tonnage	% of total tonnage	Average tons/vessel
British built but not in Scotland	4	1,802	18	450.5
Foreign built	6	2,857	29	476.2
Built in Scotland:				
Greenock	9	3,956	40	439.6
Aberdeen	2	949	9	474.5
Peterhead	1	400	4	400.0
Total	22	9964	100	452.5

Greenock was the only seaport of the West of Scotland at which ships of this size were being built.[1] An analysis

1. The register records only 10 vessels built at Glasgow, the largest being one of 96 tons in 1807.

of the ships built in the West of Scotland, excluding those of 1820 for which the figures are incomplete, shows the following distribution among towns on the river and firth:

Towns	Tonnage
Greenock	19,483
Port Glasgow	6,510
Ayr	3,990
Irvine	3,142
Dumbarton	2,482
Saltcoats	2,356
Bowling	818
Troon	672
Other Clyde ports	544
Total	41,794

Summing up, then, we see that the Clyde's contribution to Scottish shipbuilding at this time was relatively small. In the West of Scotland the industry was unimportant, Greenock being the only town having an output at all significant. The manufacture of textiles was the largest single source of wealth to Glasgow and the surrounding towns at this time. The coming of the steamboat in 1812, however, marks the beginning of the trend - later to develop in such a striking manner - towards the establishment of the Clyde as the leading shipbuilding and engineering river of the kingdom. The Scottish shipping register which has been examined above, bears the names and particulars of only ten steamboats, and it is interesting to note that the only two rivers contributing these vessels were the Clyde and the Forth. Of the total of 740 tons the former river supplied 7 vessels aggregating 491 tons and the latter 3 of 249 tons. It may here be remarked that many of the steamboats built on the Clyde in the period 1812-20 had already found their way to England, Ireland and even as far afield as the Continent. For comparison with the Scottish figures given above, it should be noted here that in 1803 some 1,194 vessels of 118,238 tons were built and registered in Britain, a total which in 1808 had fallen to 455 vessels aggregating 46,859 tons.

CHAPTER III.

IRON AND EARLY IRON SHIPS.

The discovery of iron and its use in the manufacture of small articles goes beyond the period of written history. Its use as a constructional material was possible only after the introduction of puddling and rolling processes by Henry Cort in 1783. Prior to this copper and cast iron were the only metals available for the manufacture of boilers. Occasionally hammered iron plates were made. By 1786 rolled iron plates were in use for an early form of haystack boiler and shortly after were applied to the construction of small vessels. This practice was not adopted widely till more than half a century later although the process of rolling had reached a fairly satisfactory technique by 1830. Nails, screws, hooks and some of the fittings for sailing vessels were made of iron. The art of working cast iron seems to have been commenced in Scotland as early as 1686 when an Act giving John Meikle a monopoly of the manufacture of this metal for nineteen years was passed by the Scottish Parliament. The first Scottish furnace was established at Goatfield, Argyllshire, about 1750, the second at Bunawe in the same county about the same time.[1] Charcoal from the woods in the vicinity

1. "Principal manufactures of the West of Scotland." Handbook of British Association meeting at Glasgow in September, 1876. Section on the iron and steel industries by St.John V. Day, A.M.I.C.E.

supplied the fuel[1] and this seems to have been the determining factor in the location of the furnaces, situated as they were far from any source of iron ore which had to be transported from Ulverston, in Cumberland. In 1788 the combined output of these two furnaces was 400 tons. That at Bunawe was still operating 125 years after its commencement and producing 800 tons per annum. Meanwhile, in 1760 the first large ironworks in Scotland had been erected by John Smeaton to the order of Messrs Roebuck, Cadell & Co. at Carron, near Falkirk. The company was incorporated by Royal Charter in 1773. This firm was the first to produce malleable iron in Scotland; it also led the way in the use of pit coal reduced to coke as fuel and clayband ironstone as ore.[2] The first "carronade" - a species of cannon, alleged by some to have been invented by Patrick Miller of Dalswinton[3], a pioneer of steam navigation - was produced in 1779, and this type of weapon was soon in use against French men-of-war. The total Scottish output of pig iron in 1788 was about 1500 tons[4] from the eight furnaces then in blast.[5]

Prior to the establishment of these iron smelting works, bar iron had been imported from abroad and worked up by blacksmiths; any smelting performed was on a very small scale by tinkers. As early as 1734 a slitting mill, situate below Partick bridge on the outskirts of Glasgow,

1. Although Abraham Darby had in 1713 successfully used coal which had been reduced to coke to smelt iron at Colebrook Dale.

2. Claim to the latter distinction is also made for the Wilsontown works.

3. Others say it was the invention of Lieut.-Gen. Robert Melville.

4. St.John V. Day, op. cit.

5. As stated by Thomas Barclay, an iron broker of Glasgow. See "Glasgow Past and Present", Vol.I. (1851), edited by James Pagan.

was manufacturing nails, adzes, hoes, spades, and shovels. Later this industry removed to premises at Smithfield, Broomielaw. In 1766 a file cutting works was begun at Strathbungo, the grinding for which was performed by a water driven mill at Partick. Skilled workmen were brought from Sheffield, but the enterprise failed for lack of "capital and abilities."[1.] It was taken over by David Fleming & Co. whose premises were at that time situated on the banks of the Molendinar Burn.[2.] This firm was successful and is today one of the leading tool making establishments of the city. Ships' anchors were being forged in Glasgow in 1773 and the iron consumed annually in the city for articles of household utility was about 500 tons. When worked up in this form, the metal was valued at about £46 per ton[3.] at a time when home produced pig iron ranged up to £7.10/- per ton and that from Russia and Sweden cost from £17 to £18.10/-[4.] at the Cramond works in Scotland.[5.] The year 1786 witnessed the erection of the Clyde Iron Works at Tollcross near Glasgow. These were owned by Messrs Edington & Co. and, when running at full output, consumed some 30,000 tons of coal per annum. Employment for 400 to 500 workmen, including mechanics and labourers, was provided. Both cast and wrought iron were manufactured; cannon were cast and bored; cannon balls and bombs were also made. By 1789 cast iron articles and nails were

1. Brown, op. cit.
2. The stream is now extinct. It flowed through the ~~district~~ district now called Townhead; see p.103 note 1.
3. Gibson, op.cit.
4. This figure included £2.16/- per ton customs duty and 8/- to 15/- for freight.
5. St.John V. Day, op.cit.

being shipped from Glasgow, the exports of such materials amounting in 1795 to twentytwo tons, and throughout the Napoleonic Wars the export iron trade of the city benefited considerably. Of the seventeen furnaces operating in Scotland in 1796, eight were situate in the Clyde area and of these eight, three were blast furnaces in which the blast was supplied by steam engines[1] and the remaining five air furnaces with no forced blast. In this area there were also two cupolas producing cast iron and three boring mills but no bar iron furnaces. Production of pig iron averaged 20 tons per week per furnace, valued at £6.10/- per ton.[2] The boring mills were of two types; one for boring cylinders, pipes, and other parts of engines and machines; the other for guns, mortars, and carronades. Judged by weight the material was doubled in value by boring or, to put it another way, the process of boring[3] cost more than the whole process of smelting and casting.

Writing in 1795 Andrew Brown, a historian of Glasgow, made the following prophetic declaration; "Notwithstanding the gloom of electrical prejudice that has hitherto obscured the promising infancy of the iron trade in Scotland, it is with pleasure we state its gigantic strides towards appearing in the eyes of all as a future permanent source of real internal wealth." The course of events fulfilled the prophecy more fully than Brown could have imagined; for, scarcely had the new century begun, when David Mushet, an employee of the Clyde Iron works, discovered blackband

1. John Wilkinson was first to introduce the steam engine for this purpose.
2. Brown, <u>op. cit</u>.
3. The art of turning metal was introduced into England by John Hanbury early in the eighteenth century. See "History of the Iron Trade." (1854) by Harry Scrivenor.

ironstone in large quantities in the vicinity of the River Calder[1]. This consists of protoxide of iron combined with sufficient carbonaceous matter to render calcination easy. Of the calcined ore 50% to 70% is iron and the discovery of extensive deposits of this ironstone in various districts of mid-Scotland was responsible more than any other circumstance for the growth and progress of the iron industry in Scotland. Next in importance, came the application of the hot blast initiated by James B. Neilson, a Glasgow engineer, in 1828. He conceived the idea of heating the air blast which was driven into the smelting furnace to a temperature of 300°F. The coal required to heat the air was but a small fraction of that saved by the use of the hot blast. By 1833 the process was so well developed that raw coal could be used instead of coke and the blast temperature had been raised to 600°F. In the process of coking, the coal lost 55% of its weight; so that the use of coal in the raw state, first successfully tried by Mr, Dixon of the Calder Iron Works in 1831, enabled substantial reduction to be realised in the fuel consumpt per ton of ore smelted. The following data illustrate this point:

Year	Type of Furnace	Coal to smelt 1 ton of ore
1829	Cold blast	8 tons 1¼ cwt.
1830	Blast at 300°F	5 tons 11¼ cwt.
1833	Blast at 600°F	2 tons 13¼ cwt.

At the latter date therefore one third of the coal previously used could produce the same quantity of cast iron and that of better quality.[2] The following table shows the

1. In the Parish of Monkland.
2. Output at the Clyde Iron Works:

		Iron (tns.)	Coal used (tns.)
1829	3 furnaces	111	888
1830	3 "	162	836
1833	4 "	245	554

production of iron in Britain prior to the application of the hot blast:

Year	England & Wales			Scotland		
	Total no. of furnaces	Out of blast	Output in tons	Total no. of furnaces	Out of blast	Output, in tons
1740	59		17,350			
1788	77		61,300	8		7,000
1796	104		108,973	17		16,086
1806	206	60	234,966	11	0	23,240
1823	237		417,566	22		24,500

The use of coal to heat the blast was finally dispensed with, the heat of the waste gases from the furnaces being used for this purpose.[1]

Dr. Cleland points out[2] that Glasgow is equidistant from the Atlantic Ocean on the west and the North Sea on the east, being some 26 miles from each. Communication to the east was by means of the Monkland and Forth and Clyde Canals. The Garnkirk and Airdrie railway was also under construction at this time. "With these advantages for obtaining the materials, and sending the manufactured article to market", he proceeds, "Glasgow must become the seat of a great iron manufacture. She has already large establishments for the manufacture of steam engines and machinery, and for making the machines employed in the processes of cotton spinning, flax spinning, and wool spinning. In these works everything belonging to, or connected with, the millwright or engineer departments of the manufacture is also fabricated. Having those important and valuable portions of the manufacture already established,

1. Cowper stoves consisting of two chambers filled with chequer brickwork, the hot gases being passed through one whilst the air blast goes through the other, are now used. Every half hour or so the currents are changed over.
2. "Enumeration of the Inhabitants of Glasgow" (1832) by James Cleland, LL.D.

and with the advantages which the district possesses for carrying on the trade, there is every reason to expect its rapid growth, and its extension to every article of the iron manufacture." The omission of any reference to the building either of sailing ships or of steamboats or to the manufacture of marine engines as local industries is significant of the meagre contribution made by these activities to the commercial position of Glasgow, of which Dr. Cleland in his census report was making a detailed examination. However the foundations were being laid in the general engineering trades and the production of iron for local consumption and for export extended rapidly in Central and Western Scotland. Ten iron works were operating in Scotland in 1832, four of them being in the immediate vicinity of Glasgow and the others, though more distant, were all within 40 miles of the city.[1.] These four had a combined output of 31,000 tons per annum out of a Scottish total of 55,000 tons.

The output per furnace increased steadily, due to improvements in technique of working and to the adoption of larger units. Pagan[2.] gave the following figures for output per furnace at various dates:

1805	-	25 tons per week
25	-	33 " " "
35	-	62 " " "
43	-	107 " " "
46	-	110 " " "

By 1836 another establishment had been opened at Coatbridge and Scottish production had increased to 110,240 tons per annum. Exports too had risen from 2,862 tons to 23,792 tons per annum over the same period. Twentytwo new

1. Excepting that at Bunawe which, though it continued to operate for over a century and a quarter from the date of its commencement, maintained only the negligible output of about 800 tons per annum throughout the whole of its existence.
2. "Sketch of the History of Glasgow", (1847) by James Pagan.

furnaces were under construction at the latter date. In another passage Cleland wrote:[1] "Although the cotton manufacture has hitherto been the staple trade of this city and neighbourhood for a long period, the iron manufacture, in its various branches, would appear to be the one which Nature points out as likely to furnish the most advantageous employment of the labour and capital of the district, from the inexhaustible stores of the materials for the making of iron with which it abounds. The local situation of Glasgow, too, is peculiarly favourable for the cheap conveyance of the bulky and heavy articles of this manufacture to every quarter of the world." Subsequent to 1836 the iron industry in Scotland made rapid strides. Contemporary writers express astonishment at the enormous increase in output which took place in the ensuing quarter century; some gave voice to fears that the expansion was too rapid to be permanent, and it was true that from time to time stocks of iron on hand mounted to very large figures. The following table continues that begun on p.47 :

Year	England & Wales			Scotland		
	Total no. of furnaces	Out of blast	Output in tons	Total no. of furnaces	Out of blast	Output in tons
1830	333		615917	27		37,500
1833				31		44,000
1836						110,240
1839	323 in blast		1,051,021	54 in blast		196,960
1842				62		276,250
1852	511	127	1,926,000	144	31	775,000
1861				122		1,040,000

1. Cleland, op. cit. (1832).

The effect of the introduction of the hot blast is seen in the leap from 44,000 tons in 1833 to 110,000 tons in 1836. The decade 1842-52 covers the great boom in railway construction and that doubtless accounted for a considerable fraction of the annual output. Prior to 1846 few iron vessels were built. From 1846-51 the output was moderate, averaging for the Clyde some 13,000 tons per annum, almost wholly steamships. From 1852 onwards, until replaced by mild steel some 30 years later, iron became established as the material for ship construction. For the ten years 1852-61 the output of iron ships on the Clyde averaged 57,000 tons per annum. Exports of pig iron from Scotland had increased steadily until in 1861 they exceeded 150,000 tons.

In the brief account of the iron industry just given, sufficient has been recorded to relate it to the subject which is the special concern of this history. The pig iron of course had to be smelted again whether the final product was of cast or of malleable iron. Originally the product was worked up to its final state in the one establishment, but as time went on the economy of specialisation became manifest and three types of works developed; iron smelting, iron founding (usually part of an engineering works and accompanied by the casting of other metals), and iron rolling (including plates, bars, and sections of all kinds). The iron industry developed quite apart from shipbuilding and was well equipped to meet the demand from that quarter when it came. It cannot be said that the application of iron to shipbuilding was at any time hindered by inability of the former industry to supply the requirements of the latter, and naturally iron production and engineering were always closely allied.

The possibility of making vessels of iron came in 1783 with Cort's discovery of the technique of rolling plates. The use of plates hammered out by hand from iron bars was obviously too expensive for anything but very small articles. A vague record exists[1] of a small iron passenger boat having been built on the River Foss, Yorkshire, in 1777. No particulars of the vessel are given nor is the outcome of the experiment mentioned. The first authentic account we have concerns a small lighter constructed by John Wilkinson in 1787, and launched on 6th July of that year. One of the progressive and original ideas which this ironfounder applied to his craft has already been noted above. A news paragraph on 28th July of that year gave details of this small vessel built at Bradley Forge, Birmingham.[2] It was 70' x 6'8½"; the plates were $^5/_{16}$" thick and, as countersinking had not yet been invented, the rivets were of the round headed type; stem and stern posts were of timber and the gunwale was likewise lined with wood. The beams were elm planks and the whole structure weighed 8 tons. The deadweight load carried was 32 tons and unloaded the vessel drew only 8" or 9" of water. Appropriately enough it was named the "Trial", and plied a local canal with minerals. The first iron vessel to be launched in salt water was one completed on the Mersey in August, 1815. The plates were supplied by Joshua Horton's works near Birmingham, and the vessel was fitted up by Roger Hunter and F.J. Humble in Liverpool. It was used by its owner, Thomas Jevons, as a pleasure boat. He himself in April, 1818, lodged at the

1. Article on the "Ship; section II." Encyclopaedia Britannica (11th edn.).

2. "Iron Ship-building" (1858) by John Grantham.

Patent Office a caveat with reference to a self-righting iron lifeboat[1.] which he had invented. This was constructed by the builder who had made his pleasure boat. Concerning the latter it may be mentioned that it was found one morning sunk - deliberately, it was alleged - beside the quay where it had been lying.

Similar experiments were being conducted in Scotland. In 1816 Sir John Robinson of Edinburgh designed a small iron passenger boat, the "Vulcan". Work upon it was commenced during October, 1818, by Thomas Wilson, at Faskine, near Coatbridge on the Monkland Canal some five or six miles from Glasgow. The launch took place on 14th May, 1819, and the vessel began to ply with passengers on the canal four months later. It measured 61' x 11' x 4'6" and, like all iron vessels hitherto built, its motive power was a horse! The origin of the oak tree in the acorn is surely not more surprising than the fact that our modern steel shipbuilding industry should have developed from a few horse drawn canal barges built about a century ago.[2.] Yet the superiority of iron over wood in point of endurance could have had no better exponent than the "Vulcan", for in 1875 it was still in service carrying minerals on the canal where first it floated. All the early steamboats were of wood, but in 1821 a departure from this practice was made by an English ironfounder, Aaron Manby of Horsely Iron Works, Tipton, Staffordshire. The "Aaron Manby", as the vessel was called, was a small steamboat, 120' long driven by an 80 H.P. engine. It was brought in sections

1. For a description see "Kaleidoscope", Vol. III, p.105.

2. A parallel development may be observed in railways which began with horse drawn trucks on rails.

to London and erected in the Surrey Commercial Docks. Mr. C. Manby, F.R.S. (a son of the builder), in 1820 had taken out a patent for steamboats in France and, with Captain (later Admiral Sir Charles) Napier as partner, a company was formed. With cargo on board the vessel steamed from London to Havre and then up the Seine to Paris, thus establishing the double distinction of being the first iron steamer and the first iron vessel of any kind to put to sea. Not till 1855 was it broken up, and during the first eight years of its activities the hull required no repairs although the vessel had gone aground repeatedly. The next to be built by Manby was the "Marquis Wellesley", named after the Lord Lieutenant of Ireland. Begun in 1823 she crossed to Ireland in 1825 and thereafter plied the River Shannon. She was similar in construction to Patrick Miller's early steamboat[1] having twin keels and a central paddle wheel. Subsequently many similar vessels were made both at Horsely and at Charenton, near Paris, where Manby's ironworks were situated. Not till 1827 was the first iron steamboat built in the West of Scotland by David Napier. She was named the "Aglaia" and was only 30 tons burthen. Plying Loch Eck, she facilitated the overland journey from Glasgow (via Dunoon by steamer) to Inverary.

In this age of steel it occasions surprise to learn that shipowners for so long should have failed to realise the superiority of iron over wood for shipbuilding purposes. Sixty years after the first iron vessel had floated, timber was still commonly in use; in fact, only from 1847 onwards do we find iron displacing it to any considerable extent. The reasons for this deserve some attention. Firstly, the

1. See p. 92 below.

principles of floatation were not understood[1] and the few who did grasp and apply them were regarded as persons of weak intellect, credulous beyond words. Their assertions were to be accepted only with the customary grain of salt and their experiments, true perhaps on a small scale, proved nothing. It was "against Nature" that iron should float.[2] One would think that the success of the "Trial" would have disposed of this fallacy, but it did not. Secondly, even after the principle had been well established, the ability of iron to satisfy the exigencies of salt water navigation, was called in question. The sceptics averred that if an iron ship ran aground, an occurrence all too frequent at that time, its bottom would be ripped open or its hull shattered by heavy seas, much more readily than the more flexible timber vessels. As little was known then of strengths of materials or of the stresses to which ships were subject, this error of judgment is more pardonable than the first. The contention received striking disproof when, in 1834, the "Garry Owen", an iron ship, was driven ashore during a heavy gale encountered on her maiden voyage. She was refloated and found to be uninjured whilst wooden craft, victims of the same storm, were completely wrecked. Thirteen years later the durability of iron was demonstrated even more conclusively when the "Great Britain", the largest ship of her time, was stranded Dundrum Bay, Ireland. After lying for eleven months with

1. Even today the average person, without scientific training, gives a most unsatisfactory explanation of why steel vessels float - shades of Archimedes!

2. Compare this with the statements current some twenty years ago when "heavier than air" machines were being tried out.

bottom holed and exposed to the fury of the Irish Sea, she was salved and found to be unstrained.[1] The weakness of the wooden ship was emphasized with tragic force in the early days of Atlantic rivalry. In January, 1856, the wooden steamship "Pacific" belonging to the American owned Collins Line and the Clyde built "Persia", the first iron Cunarder, started off from Liverpool in close succession. Both vessels struck an ice floe. The former sank with a loss of over 400 lives; the latter survived the repeated blows of the floating ice and arrived undamaged.

Naval authorities declared that iron would not meet the stringent requirements of men-of-war. If damaged by shell fire, emergency repairs to an iron hull would be much more difficult to execute than would the patching of a timber ship. It was also imagined that the iron plating when struck would splinter with disastrous results to the crew. On the very first occasion upon which an iron ship came into action both contentions were disproven. This happened during the first China War.[2] Captain Hull, commander of the "Nemesis"[3], the vessel in question, in 1848 gave evidence before the Committee on Naval Estimates to the effect that his ship was struck fourteen times. The holes made were clean; no flying splinters were experienced; and temporary repairs were executed with dispatch. But so convinced were the Admiralty that timber was superior to iron that, even so late as 1861, out of a totalvote of

1. For an account of the salving see the pamphlet published in 1847 under the title: "Extracts from letters of Capt. Claxton R.N. to I.K. Brunel and the Directors of the Great Western S.S. Co. re the protection of the 'Great Britain' in the winter of 1846-47 and its salving in the summer of 1847."

2. 1839-43.

3. An iron steamer of 660 tons built in 1839 by Laird of Birkenhead for the East India Co.

£3,849,471 for ships and stores no less than £949,371 was for timber.[1.] One disadvantage of the iron hull was discovered by experience; the keel became fouled with barnacles more readily than did the copper or muntz metal sheathing of the timber hulled vessel especially in tropical waters. Such fouling retarded speed, but, on the other hand, sheathing was an expensive process applied only to first class vessels; and the difficulty was in some measure overcome by painting the iron hull with an anti-fouling compound which served at the same time to diminish corrosion. Dry docking and cleaning was necessary at intervals alike for iron[2.] and for wooden vessels. The fifth objection to iron was the most serious of all and the only one that had a substantial foundation in fact. It was found that the huge mass of iron composing the hull deflected the compass. When the "Tayleur", bound from Liverpool to Melbourne, was wrecked near Dublin during a fog in January, 1854, with the loss of 334 lives, the disaster was attributed to compass deviation. This excuse doubtless did service in accounting for many accidents due to entirely different causes; but the case cited did much to revive the prejudice, gradually dying out, against iron ships. Sir G.B. Airy conducted experiments on the matter with the "Rainbow" at Deptford, and with the "Ironsides" at Liverpool. During 1839 he read to the Royal Society a paper concerning the magnetic disturbance due to iron hulls and specified the corrections to be applied to compass readings. Further experimentation led to an almost complete solution to the difficulty. The

1. Hansard Parliamentary Reports. Vol.III. (1861).

2. Iron ships required cleaning every six months.

placing of two large iron balls, one on either side of the compass - a noticeable feature of the binnacle - was found to give effective protection. Most vessels require to have their compasses corrected at intervals but the modern gyro compass, being independent of magnetic force, eliminates entirely the trouble of deflection. A further discouragement to the use of iron was the fact that for many years maritime underwriters maintained higher premiums for iron than for timber ships.

Against the objections enumerated above must be set the advantages of iron over wood. These, without a doubt, outweighed the disadvantages, a fact which accounts for the slow but steady progress made by those who pinned their faith to iron. So much stronger is iron than wood[2.] that, although it is more dense, the total weight of an iron vessel is less than one of wood of the same size. Thus for the same displacement a greater deadweight can be carried. Further, owing to the thickness of timber required for the hull, beams, and framing of a wooden ship, the iron vessel has a greater internal capacity for the same external dimensions. Before the Select Committee on Steam Navigation to India in 1834, Mr. Macgregor Laird of Birkenhead, one of the pioneers of iron shipbuilding, stated; "A strong iron vessel will weigh less than half a similar wooden one and will therefore draw less water. Capacity for storage will be greater, the sides being not more than 4" thick, including strong iron frames, while wood will be 12" thick. The

1. Average ultimate tensile strengths of various materials are as follow;

timber	6 tons per sq. in.
malleable iron	20 " " " "
Basic Bessemer steel	26 " " " "
open hearth mild steel	30 " " " "
crucible cast steel	40 " " " "

average weight of an iron steamship is 6 cwt. per registered ton, while that of a wooden one is 20 cwt. per registered ton." Mr. J.G. Lawrie in a paper read before the Scottish Shipbuilders' Association in 1862, made the following comparisons:[1] "The internal capacity of a timber ship is 82% of its external volume, while that of an iron ship is 89%. The weight of a timber ship is 20 cwt. per ton of internal capacity while that of an iron ship is 15 cwt. per ton. An illustration may be taken as follows: An iron ship of 1,000 tons internal measurement will carry 1,500 tons dw. + 775 tons lw. giving a displacement of 2,275 tons. A wooden ship of 1,000 tons internal measurement will carry 1,473 tons dw, + 1,000 tons lw. giving a displacement of 2,473 tons." These comparisons may be rendered in another way: if the cargo carrying capacity and strength of a wooden and of an iron ship is the same, the wooden ship unladen is 1 1/3 times the weight of the iron one; or alternatively, if the vessels unladen are equal in weight, the iron ship can carry 1 1/3 times the weight of cargo carried by the wooden vessel.

In the early days of iron ships the first costs of these exceeded initial costs of wooden ships. But as the output of iron increased its price fell and simultaneously timber was becoming scarce and therefore dear.[2] About 1846 an iron ship cost £25 per registered ton and a timber ship £20 per registered ton.[3] The shortage of English oak

1. "Proceedings of the Scottish Shipbuilders' Association", Vol.III. (1862-3). The discrepancy between the figures here given and those given previously by Laird is due partly to the changes in construction which had taken place in the interval and partly to the changes which had taken place in 1835 and 1854 in the method of calculating tonnage (for which see Appendix 4).
2. In "Ancient and Modern Ships" (1906), Sir G.C.V. Holmes gives the price per load (50 cu.ft.) of English oak at various periods as follows:

in reign of James I.	£1. 7/-
after 1600	2. 15/-
" 1815	7. 7/-
" 1833	6. 0/-
2nd half of 18th cent.	6. 18/-

Continued -

2. (contd.):

No account has been taken of changes in the value of money.

3. "Practical Mechanics' and Engineers' Magazine" for February, 1846.

caused many vessels to be built in India instead of in Britain. Canada and U.S.A. had almost unlimited quantities of pinewood and though the soft nature of this timber rendered depreciation of the vessel rapid, it was sufficiently cheap to warrant frequent replacement. So long as the wooden ship retained its place in ocean navigation, America proved a serious rival to Britain in trade on the high seas. Dr. Strang in 1852 gave the following data for Clyde built vessels, averaging all sizes, without engines, boilers, or furnishings:[1.] iron ships, £12 per ton; wooden ships £14 per ton. A circular issued by James Hodgson, a consulting engineer of Liverpool, dated 23rd February, 1854, gave £13. 10/- and £16. 10/- as the respective costs. He also pointed out that for depreciation 5% must be allowed for wooden vessels and only 2% for iron.[2.] Grantham in his treatise on iron shipbuilding wrote: "The usual calculation for a timber built steamer is that the expense of repairs will, in ten or twelve years, have equalled the first cost. In a well built iron steamer repairs to the iron work will not, I believe, have become necessary within that period, provided the vessel has not been injured by accidents; and it is frequently more expensive to keep in repair the copper sheathing alone of a wooden vessel, than to effect the whole repairs in the hull of an iron vessel." He also avers that iron ships at the time of writing (1858) were cheaper than English built coppered wooden ships. But even if iron vessels had a greater prime cost than wooden ones, the margin was more than covered by the economy of

1. Paper read before the Statistical Section of the British Association meeting at Belfast 7th September, 1852.

2. Both percentages seem very low.

space, increased length of life, and lower depreciation obtained. Corrosion of iron is external and can be prevented, or at least greatly minimised, by painting; dry rot and insects may attack the whole mass of timber. Seasoning and steaming took a long time to accomplish and bending into the required curves often involved considerable difficulty. Frequently builders had to wait for weeks until the plank acquired the proper set.

But the decisive factors which made the replacement of wood by iron inevitable were; first, the ever increasing size of ships which was necessary if the maximum economy in transport over long distances were to be achieved; and second, the introduction of the screw propeller to replace paddles. The limit of length for wooden ships is about 300'. The largest wooden sailing ship ever built was the "Great Republic", 335' x 53', constructed at Boston, U.S.A., in 1853.[1.] Iron alone could give the strength and stability necessary to resist the stresses to which large vessels are subjected. As regards the second factor, iron can easily be made to take any shape required; it possesses much greater local strength as well as general strength than does wood; and with it very great local strength can be provided in comparatively small bulk. Two pieces can readily be united by welding or by riveting with comparatively little loss of strength. The replacement of paddles by the screw propeller sealed the fate of the wooden steamship. Wooden hulls could not withstand the vibration occasioned by the propeller. Not only were iron plates capable of taking this stress, but the propeller boss could be made as heavy as was necessary, a specific instance of the need for local

1. "The Sailing Ship." (1926) by Romola and R.C. Anderson.

strength. All the difficulties attending the use of iron were overcome in course of time, but the prejudice against it prevailed for many decades after its qualities as a constructional material for ships had been amply proven.[1.] Much of the opposition was simply the inherent conservatism which prefers the known to the unknown; timber merchants, of course, defended their special interests.[2.] Not until mild steel was beginning to displace iron, had iron completely displaced wood. Thus, in a paper to the Institute of Naval Architects,[3.] Dr. Thearle said; "The proportion of the sailing carrying trade performed by wooden vessels continued to be considerable for nearly twenty years after 1861. The writer of this paper found abundant occupation in the survey of wooden mercantile vessels, even up to 1,200 tons register, between the years 1876 and 1880, and it may be said with perfect truth that never were wooden vessels built so strongly nor so durably as when the time came for the building of them to practically cease altogether." Wood had ceased to be used for steamships many years before this, but for a long time iron was thought to be unsuitable for large sailing vessels. Finally, even for this type, iron was adopted, one great advantage being that it was a home product whilst timber had to be imported from Canada, Georgia, Burmah, or Oregon, according to the kind desired.

Reference has already been made[4.] to the reluctance of

1. "Milestones", a play by Arnold Bennett, has as the central theme this early prejudice against iron and the later prejudice against mild steel when it replaced iron.

2. For instance it was alleged that, to preserve its flavour, tea must be carried in wooden hulls.

3. "Fifty Years' development in Mercantile Ship Construction"; a paper by S.T.P. Thearle, D.Sc., chief ship surveyor to Lloyds Registry. See the Transactions of the Institute of Naval Architects, Vol. 53, pt. II. (1911).

4. See p.57 above.

underwriters to lower their insurance premiums for iron ships and in this matter it cannot be said that Lloyd's, the well-known marine underwriters, were at all helpful in popularising the use of iron. Not till 1855 did they issue rules for such vessels. From 1837, when an iron ship first came under their survey, till 1855 all such were registered under the rules applicable to wooden ships. When Lloyds did see fit to give a special classification the triumph of iron was assured. Composite ships in which the beams and framing were of iron whilst the planking was timber, were introduced as a definite type when, in 1839, the "Tubal Cain" (787 tons) was built at Liverpool. The idea originated with William Watson of Dublin, and about 1843 he took out a patent for it. Another patent on the same lines was taken out by Mr. Jordan of Liverpool. It was a logical development of the practice, begun early in the nineteenth century, of making the beam knees and diagonal riders in wooden ships of iron. In 1867 Lloyd's issued special rules for this type but, apart from the period when the clipper ship flourished,[1] it did not succeed in gaining public favour. Though less liable than iron ships to fouling of the keel, composite ships were more expensive to build and were subject to rapid deterioration owing to galvanic action. A few are still built but their tonnage is a negligible fraction of the total. A few composite ships having iron shelled hulls with timber stiffenings were built, but these were not successful. Wooden ships are now constructed only for very special purposes, such as polar exploration, where perfect accuracy

1. See p. 141 below.

of the compass is required. The last wooden vessel of any considerable size built on the Clyde was the "Canadian", by Scott of Greenock in 1859.

Returning to the history of a few of the earliest iron vessels, and their builders, mention must be made of John Neilson of Oakbank, Glasgow, who in 1831 constructed the first iron steamboat to ply on the Clyde. As the building yard was situated at the Old Basin, Hamilton Hill, near Port Dundas[1.] on the Forth and Clyde Canal, some two miles from the Clyde, the boat had to be conveyed on lorries to be launched at the Broomielaw. She was named the "Fairie Queen" and carried passengers on the Largs route. In 1832 Messrs Wingate & Co. launched their first iron vessel, a lighter for the Glasgow and Paisley Canal.[2.] The first iron steamer from a Clyde shipbuilding yard was the "Vale of Leven", launched in 1835 by a firm recently founded, Messrs Tod and Macgregor[3.] Four vessels, at least two of which were for the Forth and Clyde Canal, were built in Manchester in 1831. They were navigated from Manchester to Liverpool, thence by sea to Greenock, and thereafter by canal to Port Dundas. On the Mersey, William Laird who in 1824 had established the Birkenhead Iron Works, was a convinced believer in the iron ship. In 1829 a 60 ton lighter was launched and thereafter a number of similar small iron vessels for service on Irish canals. Since iron had given

1. Named after the Governor of the Forth and Clyde Canal Co., Lord Dundas.

2. Now non-existent but commemorated in the name of a railway station; Paisley (Canal).

3. Later taken over by Messrs D. & W. Henderson of Pointhouse Yard.

every satisfaction with river steamers he was convinced it would be equally serviceable for sea going vessels. In 1832 Laird & Co. built the "Elburkah",(70' x 13' x 6'6"; 55 tons), to go as consort to the "Quorra" on an expedition led by Macgregor Laird up the River Niger. Though the plates composing the hull were only ⅛" thick the ship gave every satisfaction. Other iron steamships by Laird were the "John Randolph" (250 tons) for Savannah in 1833, and the "Garry Owen" in 1834 for service on the Shannon. The latter had the distinction of being the first iron steamer with a regular arrangement of water-tight bulkheads, an invention of C.W.Williams. For the Mexican Government, which was evidently more enterprising than our own,[1.] Messrs Laird in 1837 built an iron frigate. Two years later the British Admiralty ordered a small non-combatant iron steamer, but not till 1843 was the first fighting vessel launched for the Royal Navy. From the Clyde the first iron sea going steamship was the "Iron Duke" (393 tons), launched in 1840. The first from the Tyne was the "Prince Albert" two years later. A few iron ships were also being built at intervals at Toulon in France, on the Baltic seaboard, and at Constantinople.

Thus the Clyde and the Mersey were the rivers upon which the pioneer work in iron shipbuilding was done. "To the Clyde builders", says William Fairbairn, F.R.S.,[2.] "may be referred some of our most important constructions, and there is probably no part of the United Kingdom where

1. In 1834-5 the Admiralty was urged to experiment with iron for ships of war. They delayed for several years, conducted some tests of doubtful validity at Woolwich and then went back to the "wooden walls."

2. "Treatise on Iron Ship Building" (1865) by William Fairbairn, F.R.S.

greater energy and enterprise in this branch of industry is displayed." Quite early, Clyde builders began to specialise in steam vessels and thus, subsequent to 1845,[1.] they constructed comparatively few vessels of wood. Referring to iron shipbuilding John Grantham wrote:[2.] "The science which had been thus established, was pursued most actively in the Clyde, the Thames, the Mersey, and latterly in the Tyne." A famous Tyne shipbuilder, in a paper to the Institute of Engineers and Shipbuilders in Scotland,[3.] paid a tribute to the Clyde as the nursery of craftsmanship in iron: "The earliest iron shipbuilders on the Tyne and Wear, and most of their workmen", he remarked, "came from Scotland." The effect of screw propulsion in compelling the adoption of iron for the hulls of steamships is illustrated by the following statistics: between 1839 and 1847 one of the largest Clyde firms built 34 wooden steamboats;[4.] from 1846 to 1852 total Clyde production of vessels of this type, built almost wholly at Greenock and Port Glasgow, comprised only 14 vessels.[5.] Subsequent to the latter date Dr. Strang neglects wooden vessels and gives statistics for iron only, a fact in itself significant. The same writer gives an indication of respective costs during the period 1846-52:[6.]

1. The time of the introduction of screw propulsion which, as noted previously, necessitated iron hulls.

2. "Iron Ship-building" (1858) by John Grantham.

3. "Sixty Years of Merchant Shipbuilding on the North-East Coast"; a paper by Dr. G.B. Hunter and E.W. De Russett in the Proceedings of the Institute of Engineers and Shipbuilders in Scotland, Vol.52 (1908-9).

4. "Glasgow and the Clyde" (1876) by Robert Gillespie.

5. Paper to the Statistical Section of the British Association meeting at Belfast on 7th September, 1852, by John Strang, LL.D.

6. Detailed statistics of output during this period are given in Tables B3 and B4.

wooden hulls averaged £14 per ton; iron hulls £12 per ton; furnishings varied from £6 to £15 - with an average of £8 - per ton; and engines cost £25 to £50 - averaging £35 - per H.P.

The value of the Clyde output for seven years was therefore as follows:

	£
wooden hulls, 18,331 tons @ £14 per ton	256,634
iron hulls, 129,273 tons @ £12 per ton	1,551,276
furnishings for 147,604 tons @ £8. per ton	1,180,832
engines and boilers, 47,766 H.P. @ £35 per H.P.	1,661,810
	4,650,552

Hence the average annual wealth created by the Clyde shipbuilding industry was £664,364. Details of the cost of one vessel, a steamship of 604 tons and 320 N.H.P., are given as follow:

	£
Wooden hull	7,852
Joiner and smith work	1,953
Upholstery	754
Plumbing work	318
Painting and cabinetmaking	273
Sails, rope, and rigging	354
Copper sheathing	363
Carving and gilding	907
Other accounts	563
Engine and boiler, 320 N.H.P. @ £42 per N.H.P.	13,440
	26,777
Silver plate, crockery, linen and furnishings of stewards' department	2,233
	29,000

The hull therefore cost £13 per ton, the furnishings £9 per ton, and the stewards' department £3 per ton. Whilst the Clyde builders specialised in iron vessels builders in other parts of Britain - for example, on the Thames and the Wear - were still producing large numbers of wooden ships every year. [redacted]

Evidence of the fact that even in 1854 wood still predominated is to be found in a somewhat casual remark by Scrivenor:[1] "To pass through the Liverpool Docks, which extend for some miles filled with ships, and see the anchors, chain cables, and parts of the rigging, made of iron, and occasionally an iron ship, anyone with common observation must be struck with the advantages possessed by this country in having an abundant and cheap supply of this most essential material." Thereafter iron ships became more common but many years elapsed ere they formed the major part of the registered tonnage of the United Kingdom.[2] Of our own area McCulloch in his "Dictionary of Commerce"[3] says: "Within the last dozen years the building of iron steamships has been immensely extended on the Tyne and the Clyde, especially the latter, which has become the grand seat of this branch of industry. In 1853-4 no fewer than 266 vessels were built or contracted for on the Clyde." Of these part were steam and part sail, engines for the former aggregating 29,000 N.H.P. The striking extension of iron shipbuilding at this time[4] is displayed in the following table,[5] which shows vessels launched in the United Kingdom:

Year	Iron Ships		Wooden Ships	
	No.	Tons	No.	Tons
1851	55	15,826	617	133,811
1862	219	106,497	740	115,955

1. Scrivenor, op. cit.
2. In 1854 there were 26,859 vessels aggregating 4,248,750 tons on the register, only a small fraction of which were iron.
3. 1859 edn.
4. Reasons for this will be suggested in Chapter IX, when we come to survey the periodic fluctuations in shipbuilding.
5. Paper on: "The Construction of Iron Ships", by John Vernon; Proceedings of the Institute of Mechanical Engineers (1863).

Thus, in eleven years whilst the tonnage of iron vessels launched increased by 570%,that of wooden vessels decreased by 13%. Of the iron tonnage of 1851, Clyde output accounted for almost thewhole, but only for 66% in 1862.[1] Of the total for 1851 Scotland's share was 136 vessels of 30,100 tons,[2] being 20% of the United Kingdom output. In 1860 only 30% of the tonnage added to the register was iron. Two years later the proportion had increased to almost 50% and by the end of the decade it was over 90%. The following table[3] shows the ships under construction at the end of 1871:

Type	Sail		Steam	
	No.	Tons	No.	Tons
Iron	23	14,698	421	379,675
Wood	249	32,064	16	1,121
Composite	-	-	1	100
Total	272	46,762	438	380,896

Thus of the total tonnage only 8.4% was wood, and the tonnage of wooden steamships was negligible. Complete figures, separating the various types of vessels, for the Clyde are not available till 1866. Though that year falls in the period of the "clipper ship", wooden and composite vessels accounted for only 10% of the tonnage launched on the Clyde and from 1875 onwards they disappear almost completely.

1. As a matter of fact Dr. Strang's figures for Clyde output of iron vessels for 1851 is 41 vessels of 25,322 tons. As his returns are well authenticated the United Kingdom figure of 55 vessels aggregating 15,826 tons must either be incomplete or else calculated upon a different tonnage basis.

2. Accepting Dr. Strang's figures, the tonnage launched on the Clyde constituted 92% of the whole Scottish output or 18% of the United Kingdom output.

3. Paper on; "Tonnage Statistics for the Decade 1860-70", by John Glover; Journal of the Royal Statistical Society; Vol.35. (1872).

Before closing this chapter reference must be made to the use of iron for the manufacture of ships' rigging, masts, etc. The difficulties attending the importation of hemp for ropes in the period 1808-14 caused attention to be directed towards the possibility of obtaining a substitute. In 1808 Mr. Slater, a surgeon of the Royal Navy, took out a patent for iron cables,[1.] but did not carry his idea into practice. Three years later Captain Brown, engaged in the West Indian merchant service first used chain cables for the anchor of a 400 ton ship. Rigging, he found, could also be made of chain. The lower masts of the ill-fated "Tayleur"[2.] were of iron and about 1853 Mr. Clare of Liverpool patented a form of iron masts and yards in which the iron was covered with a veneer of wood. These were lighter and stronger than those made wholly of wood and were not any more costly. The deck also came to be made of iron plates, sometimes covered with wood and sometimes left bare.

Progress was also being made in the use of machinery to replace hand labour. Woodworking machinery advanced more rapidly than that for use with metal. Before 1850 engineering shops contained very few machines, those in the main being limited to the self-acting lathe, the horizontal planing machine, the vertical borer, and the simple slotting machine. If the degree of accuracy achieved today was unattainable at that time, a standard of

1. Really iron chains which are not to be confused with the much more modern wire rope.

2. See p. 58 above.

manual skill and craftsmanship higher than is necessary now, was essential.[1] As late as 1860, shipyard machinery was quite crude; the chief machines in use were those for bending, shearing, punching, drilling and countersinking, and riveting. The shearing machine could take cuts 4" to 6" long through a plate 1" thick. William Fairbairn, F.R.S., of Manchester was the first person to apply steam power to the operation of riveting. A later patent by Messrs Garforth of Dunkenfield, concerned a machine capable of putting in 6 rivets per minute as compared with the 3 minutes per rivet necessary when the work was done by hand.

That the Clyde has for the past half-century held premier place among the shipbuilding and engineering areas of this country is due in no small measure to the faith and foresight of those pioneers who, in the early days when steam power and iron hulls were still novelties, set to work with skill and determination to assure the triumph of the iron steamship. Dealing with a material produced locally, whose peculiarities were understood and whose properties were appreciated by few persons at the time, Clyde shipbuilders were well ahead of others when the superiority of iron came to be recognised generally. The technique of iron working had been developed to a high level of perfection and the advantage thereby achieved was maintained when mild steel displaced iron, a transition much more rapid

1. At the beginning of the century the chief tools were hammer, chisel, and file. A few simple machines existed. Crucible cast steel had been produced experimentally in 1740 and commercially in 1770 by Benjamin Huntsman at Handsworth, near Sheffield. Milling cutters originated in France about 1782 but were of a very simple type. The invention of the guide screw lathe is credited to Henry Maudslay, the famous London engineer, during the last decade of the eighteenth century.

than the change from timber to iron. The comparative position of the three countries in 1871 is strikingly illustrated by the following table[1] showing the number of yards engaged in the building of iron ships and their personnel:

Country	No. of yards	Males employed (under 18 years)	Males employed (over 18 years)	Total males employed
Scotland	30	2,279	21,696	23,975
England & Wales	48	2,743	17,717	20,460
Ireland	5	335	2,816	3,151
U.K.	83	5,357	42,229	47,586

Scottish yards though fewer in number than those of England and Wales, employed more workers. Fully 50% of all persons employed in iron shipyards in the United Kingdom were engaged in Scottish establishments and of these the vast majority found employment on the Clyde. Proportionately to the total number of employed persons in the respective countries, there were about eight times as many workers engaged on iron shipbuilding in Scotland as in England. The preeminent position reached half-a-century ago was greatly to the advantage of Clyde industry when competition with other rivers of Britain and with Continental countries became keener. The Clyde gained a reputation world-wide in extent for fine workmanship, sound naval architecture, and engineering skill. The trade mark, "Clyde built", signified the best that the world could produce in ships.

1. "Industrial Classes and Statistics" (1877) by Geo. P. Bevan.

CHAPTER IV.

THE COMING OF THE STEAM ENGINE.

The earliest experiments with steam are shrouded in uncertainty. Accounts of them which have come down to us are adorned with the romance bestowed by the passage of time, but possess little real historic validity. The first to which a reasonable degree of accuracy can be ascribed is that recorded by the Marquis of Worcester in a collection entitled "A Century of Inventions", dated 1663, being an account of one hundred experiments performed by himself. No.68 tells of water being raised by steam on what today would be termed the pulsometer principle. Uncertainty prevails as to whether or not he tried out his idea with an engine larger than model size. In 1693 Marmaduke Hudson took out a patent for a pumping engine. The patent operated for 19 years, but though the engine was said to be quite efficient, there is scant record of its practical application. Six years later Thomas Savery patented a steam pump also on the pulsometer principle. It was useful only in situations where the combined suction and lift did not exceed a height of 35 ft. With greater heights the back pressure of the water was so large that the boiler was in danger of bursting. Although described by the inventor as "the miner's friend", the pump was of little use in coal mines and was shunned by mineowners.[1] D.F.J. Arago alleges[2] that "with one solitary exception none of them ordered his engines." Savery's engine was adopted to some extent for raising water at country houses of the gentry. It was enormously improved by Thomas Newcomen,[3] a blacksmith of Dartmouth, Devonshire, in collaboration with John Cawley, a glazier from the same district. Although it operated upon entirely different principles Newcomen's engine infringed Savery's patent specification and had therefore to be produced in conjunction with the earlier inventor. Cawley's part in the improvements is not quite clear and the engine went by the name of his partner Newcomen. Before Savery's time the steam was produced by a fire directly below the working vessel. Savery introduced a separate boiler and added also some parts of valve mechanism. His pump, as already noted, operated on what is now known as the pulsometer principle. Two vessels were arranged to fill and empty alternately, the steam pressing directly on the surface of the water. When one vessel had been discharged by this means, a cock was turned so that the steam pressure was applied to the water in the other vessel. Meantime the condensation occurring in the evacuated vessel created a partial vacuum in it and thus induced it again to fill with water. In Savery's day the cock was turned by hand.

1. See: "Annals of Coal Mining"; first series (1898) by Robert L. Galloway.

2. "Life of James Watt" (1839) by D.F.J. Arago.

3. For life of Newcomen (1663-1729) and his work on the steam engine see "Transactions of the Newcomen Society", Vol.IV., p.113.

Newcomen introduced a cylinder with a piston under which steam was admitted. The top of the cylinder was open to the atmosphere, there being no cover; hence the descriptive name, "atmospheric engine". When the piston had reached its full height water was poured on the top of it. The supply steam having been cut off, the steam below the piston was thus condensed. It was a painfully slow operation, resulting in only a few strokes per minute.[1] Atmospheric pressure, aided by the weight of the piston itself, then caused the latter to go down. This downward stroke only was used to eject the water from the pump cylinder below. Power was therefore derived indirectly from the steam. Some of the advantages of Newcomen's engine over Savery's earlier machine were that a lower steam pressure could be used, a saving of fuel effected and, by using a steam cylinder of large diameter and a pump cylinder of small diameter, any required degree of pressure could be brought to bear upon the water. The suction and lift height of 35 ft. had seriously restricted the possible use of the earlier engine. Since no such consideration entered into the operation of the Newcomen type it could be used for the deepest mines and accordingly soon became popular. It was offered to the public in 1705 but the first to be used in a coal mine was that erected at a Staffordshire pit in 1712. A short time only could have elapsed till it was in use in Scotland, for the claim is made that the second to be erected in our country was put down at a pit at Stevenston, Ayrshire, in 1719.[2] Another,

1. Seven or eight per minute was quite common.
2. Article by N.M. Scott on "Documents relating to Coal Mining in the Saltcoats district in the first quarter of the eighteenth century"; Scottish Historical Review, Vol. 19, (1922). See also; "Genealogical Account of Ayrshire Families", Vol.I. (1823) by George Robertson.

under Savery's patent, is known to have been operating at Edmonstone, Midlothian, in 1725.[1]

Dr. Denis Papin, F.R.S., a Frenchman, was in England about the time when Savery took out his patent. Papin too had been experimenting with heated water in closed vessels and had actually devised a means of thus "digesting" animal bones. In the course of his experimentation he doubtless discovered a great deal about the force and elasticity of steam. Having returned to France he published in 1707 an account of his work and claimed to have invented a steam engine independently of the others, a claim admitted by the people of his own nation, but regarded with suspicion in England. He did suggest an improvement which was later incorporated in Newcomen's type of engine, viz. to spray water underneath the piston into the cylinder and thus hasten the process of condensation. Newcomen was responsible for the large beam, a prominent feature of the atmospheric engine. He also introduced snifter valves and improved the mechanism of the cocks. The idea of packing the piston and its rod to prevent the escape of steam was due to the German inventor, Otto Guericke whose name is more widely known in connection with the air pump. In 1717 Henry Beighton eliminated a number of imperfections by simplifying the beam and valve mechanism and making them one unit. John Smeaton, F.R.S., the famous structural and lighthouse engineer, redesigned the proportions of many parts of the engine. Passing over, for the moment, the achievements of James Watt, there remains to be mentioned the name of Edward Cartwright who in 1798 introduced metal piston rings.

1. "General View of the Coal Trade in Scotland (1812) by Robert Bald.

Newcomen's engine, though serviceable, was very inefficient mechanically and thermodynamically. The packing of the piston and rod was poor and so, on the upstroke, a large quantity of steam escaped. The spraying of water into the cylinder and the condensation taking place in it, involved a reduction of temperature of the cylinder and its contents after each stroke. The incoming steam had to give up much of its heat merely to raise the temperature of the cylinder walls again, a dead loss so far as the work done by the engine was concerned. The ponderous beam with the chain to the piston and counterpoise weights, by which the engine was connected up to the machine to be operated, added considerably to the inefficiency already existing by reason of the heat losses. To James Watt belongs the credit of producing the first modern steam engine. He more than any other inventor paved the way for the improvements and refinements that characterise the twentieth century product and make it still the most reliable of all prime movers.

James Watt was born at Greenock on 19th January, 1736. His father had a ship chandlery business in the town and so young James early in life became familiar with matters pertaining to ships and the instruments used in navigation. The fact that his paternal uncle John was a land surveyor may also have influenced the choice of his career. Having received a good education at local schools, he came to Glasgow at the age of 18 to pursue an apprenticeship as a mathematical instrument maker. He remained there for a year and then went to London to gain further experience at his trade, returning to Glasgow in October, 1756. His intention was to open a shop there, but this was vetoed by the corporation of master craftsmen of the city. However, in 1757 he was appointed instrument maker to the University and continued in this capacity for the ensuing six years. In 1759 he again visited London, on this occasion with the object of obtaining orders for the business which, in partnership with John Craig, he started that year. Their shop was situated in the Saltmarket and among other articles displayed for sale was the map of the survey of the Clyde made by his uncle in 1734.[1] Watt left his College workshop in 1763 to occupy premises at the delftworks, Broomielaw, but maintained the shop at Saltmarket. In addition to instrument making he continued the pottery business at the delftworks. It was at this time that the ~~first~~ steam engine first came under his notice. He had been given the model used in the University Natural Philosophy class to repair.[2] It was of the Newcomen type and set him thinking upon the problem of how to avoid heat losses in the steam engine. The idea of the separate condenser emerged in May, 1765, though the first engine incorporating it was not constructed till four years later. Meantime, to earn a living, Watt had taken up surveying, chiefly in connection with waterways, natural and artificial. In company with Robert Mackell of Falkirk, he made a survey on behalf of the Carron Coy. for the proposed Forth and Clyde Canal. The route by Loch Lomond which they suggested was not the one finally adopted. Later surveys carried out by him included the Monkland Canal[3] route (1769-72), the Crinan Canal and the Inverness or Caledonian Canal (1773).[4]

1. "Extracts from the Burgh Records of Glasgow, 1718-38". (1909) by Robert Renwick.
2. This model is still kept at Glasgow University.
3. Constructed expressly for the purpose of carrying to Glasgow coal from the Coatbridge area.
4. This project was actually carried through by Telford in 1801.

His survey of the Clyde, begun in 1769, deserves notice. Golborne's earlier survey was confirmed and his plan for jetties[1] adopted in preference to Smeaton's proposal to build a lock on the river four miles below Glasgow. Watt also surveyed the site for the dry dock at Port Glasgow.

During the time that he was instrument maker to the University, Watt became acquainted with Dr. Black, Professor of Anatomy and Chemistry, and through him got into communication with Dr. Roebuck, one of the founders of the Carron Iron Works. In 1767 Roebuck took up Watt's invention and a small engine (18" dia. cylinder) was made at Carron. The cylinder was of tin and the engine was erected at Kinneil, near Bo'ness in 1769. Unfortunately it could not be made to work satisfactorily. Just about the same time Roebuck found himself in financial difficulties[2] and his interest in the engine was transferred to a friend, Matthew Boulton of Birmingham. At Soho, Birmingham, Boulton in 1765 had erected a workshop where fancy buttons, watch chains, clocks, etc. were manufactured. Watt had been shown over the premises there in 1768 and it was then that the idea had first been mooted of adding to these activities the erection of Watt's engines. The first patent was taken out on 5th January, 1769, nor was it merely a patent for the actual engine (though drawings of this were submitted); principles relating to the working of the engine were patented too and this caused much litigation later. Dr. Small, partner to Boulton, was responsible for the drawing up of the patent specification, the validity of which was called in question

1. See p. 18 above.

2. Owing to the failure of his extensive undertaking; the Borrowstounness Coal & Salt Works.

by rival inventors. Eight items were included, the first two of which marked a striking advance on engines existing at the time. A separate vessel, the condenser, was introduced and thus it became possible to maintain the cylinder approximately at steam temperature. The third item provided for an important condenser auxiliary, the air pump, by means of which a vacuum was maintained in the condenser. Only a relatively small drop in temperature was necessary in the condensation of the steam. Another item specified that the cylinder should have a cover, thus converting the engine from the atmospheric to the direct acting type; that is to say, power was derived directly from steam acting on the top side of the piston and not from the pressure of the atmosphere as in the Newcomen type. Provision was also made for reciprocating action, for alterations to the boiler, and for improved piston and gland packing. Watt was the first to use a stuffing box to maintain the piston rod steam tight at the point where it emerges from the cylinder.

Meantime the first engine remained at Kinneil. Being busily engaged on civil engineering work, Watt could not give it attention. Finally, in 1773, the engine was sent to Soho, and in May of the following year Watt gave up his work in Scotland and proceeded to Birmingham. There on 1st June, 1775, he entered into partnership with Boulton and the famous firm began. Just before Watt went south, John Wilkinson the iron founder[1.] had made his improved cylinder boring machine, without the service of which it is doubtful if Watt's engine could have been made to work satisfactorily. As it happened the engine was in running order by the end of 1774.

1. "John Wilkinson, Ironmaster" (1914) by H.W. Dickinson.

By training, James Watt was not an engineer, but by the experience he gained in partnership with Boulton he soon became one, as his later inventions show. He was the first to consider and experiment upon steam volumes in a systematic manner. By the year 1776 two of his engines were at work, one in Staffordshire and the other in Shropshire. A year later the connexion with the Cornwall mines began. Meantime Watt had obtained a ten years' extension of his first patent. The Bill was presented to Parliament on 9th March, 1775, and received the Royal Assent two months later. His action was hotly resented by others who wished to improve upon the engine. But already Watt himself was busy with ideas towards the same end. An experimental engine incorporating the expansive use of steam was erected at Soho in 1777. Four years later his second group of patents was issued. Five different methods of transforming reciprocating motion into rotary motion were described. As the idea of the crank had already been anticipated (rather unfairly, it was alleged)[1.] by Matthew Wasborough, Watt could not patent his improved crank with balance weights. Four of the suggested methods were less suitable than the crank, but the fifth was the famous "sun and planet" motion.[2.]

By 1782 the experiments on the expansive use of steam had proved sufficiently satisfactory to justify the application for another patent. This contained four items of extreme importance in the development of the steam engine.

1. Though James Watt did not claim to have originated the idea.

2. Still much used in certain types of machinery though not in connection with steam engines. The device was really due to William Murdoch, but was patented in Watt's name.

Hitherto the supply of steam to an engine had been admitted during the complete stroke. The first item of the 1782 patent described a means of cutting off the steam supply when the piston had travelled a fraction (say three quarters) of its stroke, the remainder being completed by the expansive force of the steam.[1.] Further, the engine was made to be double acting, steam being admitted alternately to the top and bottom sides of the piston. By this means almost twice the power could be developed by the same size of engine. The third item explained the principle of compound expansion, involving the use of two cylinders for one engine, so that the drop in steam pressure might be dealt with in two stages. The exhaust of the first (or H.P.) cylinder became the inlet steam of the second (or L.P.) cylinder. Higher initial steam pressure, which would have involved too great a drop for a single cylinder, could now be used, thus increasing the thermal efficiency of the engine. Fourthly, the mechanical efficiency was increased by the substitution of a toothed rack and sector for the chain previously in use. This acted simultaneously as a guide for the piston rod and as a means of transmitting the power. The fifth item in the patent was the steam wheel or rotative engine, the precursor of the modern turbine. As early as 1774 an experimental engine of this type had been laid down at the works, but it proved unsuccessful in practice.

A fresh patent in 1784 described one of Watt's most ingenious devices, the parallel motion, rendered necessary by the double acting engine. Royalty payments for engines operating in the Cornish mines were paid in proportion to the number of strokes made by the engine, so it was desirable

1. See Appendix 5 for indicator diagrams.

that some accurate record should be taken of these. Hence the second item of the 1784 patent, a stroke counter. Other inventions emanating from his fertile brain within the next few years included the barometer or float to indicate condenser vacuum; the indicator, which draws to scale diagrams showing the work done in the cylinder at each instant during the stroke of an engine;[1.] a mercury steam gauge; a steam tilt-hammer; a smoke consuming boiler; a paste for steam jointing; and a combination of the ball governor and throttle valve[2.] for use on the rotary engine. He also conceived the idea of applying his engine to road carriages and one of his leading assistants, William Murdoch,[3.] made a model driven by an oscillating cylinder engine. Although Murdoch succeeded in making the model run along the parsonage avenue at Redruth in 1784, nothing more came of the experiment, and Watt had really little faith in the feasibility of steam locomotion by land or sea.[4.] In 1799 Murdoch took out a patent covering four important items.[5.] The first was a worm and wheel for boring steam cylinders. The second described how the steam jacket and cylinder could be cast in one piece, whilst the third was the "D" slide valve for admitting steam to the cylinder; also a cylindrical valve for the same purpose. Item 4 was an improved rotary engine.

1. See Appendix 5.
2. Watt did not invent these but only combined the use of them and applied them to the steam engine.
3. Taken on as a workman at Soho in 1777, he soon displayed remarkable ability and carried out many important commissions for the firm. He is best known as the man who first applied coal gas as an illuminant. He also invented some pneumatic machinery.
4. See article by Percy A. Hillhouse, B.Sc., in the "Comet" Centenary book issued in 1912 by Glasgow Corporation in connection with the centenary celebrations.
5. "Men of Invention and Industry - William Murdock" (1884) by Samuel Smiles, LL.D.

Watt's improved engine was much in demand for clearing coal mines and tin mines of water, and for driving the machinery in cotton factories, ironworks, etc. The firm of Boulton and Watt prospered financially, always having on hand sufficient orders to keep them fully employed. It is interesting to note that when their enterprise began, organisation of industry had not reached the stage of carrying through from beginning to end the manufacture and erection of engines. The different parts of these were made in different workshops and only brought together at the site, there to be erected under the surveillance of the firm which had undertaken to supply the engine. Boulton and Watt had begun in this way as consulting engineers, sending out specifications and drawings and seeing that the engine was properly erected. Only the valves and valve boxes were made at Soho in the beginning, but by 1800 complete engines were being manufactured there. Few inventors during their lifetime command the recognition and honour (not to mention the commercial success) which Watt received. The scientific world paid him its greatest homage by electing him a Fellow of the Royal Society in 1785. The partnership of Boulton and Watt came to an end in 1800 and Watt retired from active participation in the engineering world to enjoy a well earned rest till his death at Heathfield, Staffordshire, on 25th August, 1819. It seems strange that, with his genius and capacity, Watt should have exhibited on several occasions a lack of insight into the practical applications of the steam engine. During his association with Roebuck he erected at Carron Iron Works a large atmospheric engine the power of which, instead of being applied directly to the machinery, was used to pump water back up into a reservoir so that it might again be used on the water wheels which drove the machinery! In 1790 he declined to co-operate in Patrick Miller's steamboat experiments[1] and in 1801 wrote to Henry Bell a pessimistic letter regarding the latter's steam navigation project. In March, 1802, Symington's steamboat, the "Charlotte Dundas", performed successful trials on the Forth and Clyde Canal; and a year later Robert Fulton purchased one of Watt's engines for his steamboat venture in America.[2] Watt also lived to see the steam engine applied to land locomotion; in 1814 George Stephenson's "Puffing Billy" was working at Killingworth Colliery. Two years later Richard Trevithick, who had been refused employment at Soho some twentythree years before owing to his association with Edward Bull,[3] after experimenting with models for upwards of ten years, successfully constructed and drove a locomotive. Shortly after Watt's death, in 1825, Burstall and Hill built the first practicable steam road carriage. Two years later Goldsworthy Gurney repeated this success and drove his carriage in and around London for two years. The year 1825 also saw the opening of the Stockton and Darlington railroad and, four years later, Stephenson's "Rocket" locomotive made its appearance before a large and sceptical audience.

It is almost superfluous to add that James Watt's success inspired much jealousy amongst rival inventors.

1. For the text of letter to Mr. (afterwards Lord) Cullen of Edinburgh with reference to this, see: "The Steam Engine and its Inventors"(1881) by Robert L. Galloway.

2. As early as 1794 this pioneer had been making inquiries at Soho for an engine for this purpose.

3. One of the "pirates" against whom, in 1795, Watt took out an injunction.

Some of them were genuinely gifted men and the terms in which Watt's original patent was couched were such that they were prevented from carrying out their ideas. This was a distinct handicap to the progress of steam engineering, as some of them anticipated Watt's later work. The extension of time granted him caused further dissatisfaction and not a few proceeded to put into operation the inventions they had made. On numerous occasions Watt successfully invoked the law to put an end to the projects of his rivals, some of whom it must be admitted were mere pirates. Smeaton's first engine was set to work at a pit in Northumberland in 1772. Humphrey Gainsborough in 1775 applied for a patent for an engine but the application, opposed by Watt, was finally refused. Another rival was Jonathan Hornblower, senior engineer at the Tingtang mine in Cornwall where James Watt's first engine in that area was installed. Hornblower's son, in 1777, independently conceived the idea of compound expansion using two cylinders. Watt's idea for single expansion was, of course, included in the 1769 patent, but not till 1777 was an engine (the second of the Soho series) designed to operate on this principle; and four more years elapsed before Watt made a complete ≠ drawing of his compound expansion engine. In the same year (1781) Hornblower obtained a patent for his idea but could not put it into practice as it infringed Watt's first patent. Edward Bull, who had been on the staff of Boulton and Watt's firm was associated with Hornblower in his fight against Watt's monopoly. In company with Richard Trevithick he erected engines in Cornwall till stopped in 1795 by an injunction granted on the application of his late employers. John Rennie, a civil engineer, gave up his business in

Scotland in 1794 to erect engines for Boulton and Watt. Woolf, who for a time was in the employ of the Birmingham firm, erected his first compound engine at a Cornwall mine in 1815. With the higher steam pressure then available, he made a success of the idea Hornblower was not permitted to try.

Many portraits and statues of James Watt were executed by leading artists and sculptors of the time. In Westminster Abbey there is a monument to the memory of the great engineer, and his association with the West of Scotland is commemorated in many ways. One of these is the statue which today stands in the entrance hall of the Royal Technical College, Glasgow. It deserves special mention having been subscribed in sums not exceeding one shilling by the mechanics of this area at the time of his death. Originally it graced the Mechanics Institute in North Hanover Street, from which evolved the modern College. Watt's second son Gregory studied at the Glasgow College in 1794. His oldest son James carried on in a less illustrious way the business and tradition of his father in the engineering world.[1]

1. Many books dealing with the life and inventions of James Watt are available. Chief among them may be mentioned;
"James Watt and the Steam Engine" (1927). A memorial volume prepared for the Committee of the Watt Centenary Commemoration at Birmingham in 1919; by H.W. Dickinson and Rhys Jenkins.
"Life of James Watt" (1839); by D.F.J. Arago.
"The Origin and Progress of the Mechanical Inventions of James Watt." (1854); by James P. Muirhead, M.A.
"Life of James Watt" (1859); by J.P. Muirhead, M.A.
"Lives of Boulton and Watt" (1865); by Samuel Smiles, LL.D.

Much more of interest and importance might be written concerning the life and inventions of James Watt, but attention must now be directed to the early applications of the steam engine in the West of Scotland. Mention has already been made of the engine put down at an Ayrshire pit in 1719.[1] The first in the vicinity of Glasgow, of the Newcomen type, was erected at a pit in Shettleston in 1784. Watt's engine gradually displaced the earlier and less efficient type, but even during the first twenty years of the nineteenth century atmospheric engines were still being laid down in various parts of the country. Three such engines were installed at the Farme Colliery, Rutherglen, in 1810, 1820, and 1821 respectively. The first of these performed the combined duties of winding and pumping and worked continuously for 110 years.[2] It now stands in the court surrounding the Kelvingrove Museum, Glasgow. In a letter dated 3rd February, 1905, the following notes concerning the engine are given by a colliery official:

> "The castings were made at Camlachie Foundry from patterns made by a millwright named John McIntyre, who was employed here and McIntyre superintended the erection of the engine. The boiler was an old haystack one blowing off at some 2½ or 3 lbs. At present it is supplied from a range of boilers through a valve reducing the pressure to 5 lbs. The engine itself makes 15 revolutions in winding a cage from bottom to top, a depth of 44 fathoms and it does this in about 30 to 35 seconds. The winding drum is geared down to 10½ revolutions. The stroke is 5'6" and the diameter of the cylinder 32".
>
> Signed; James Anderson.
>
> P.S. The engine has been working continuously since erection."[3]

1. See p. 75 above.

2. From personal inquiry at the Colliery regarding these engines.

3. From MSS. presently in the possession of Mr. Fleming, the assistant curator of the Kelvingrove Museum.

This surely is a tribute to the material and workmanship of these early times. Incidentally it is an example of a fact frequently overlooked; that old and inefficient machines are not always displaced within a reasonable time by the newer and more economical. The length of time that the engine was kept working might be explained as an extreme example of the widespread though false idea that real loss is involved if a machine is scrapped before it actually falls to pieces, or excused on the ground of hesitation to part with an old and faithful servant. The inexplicable circumstance is the fact that such an engine was laid down at a time when Watt's improved type had been on the market for many years. The superiority of Watt's engine was demonstrated most obviously where a steady output at a relatively high speed of rotation was required and so it was widely adopted for driving the machinery in mills and factories, a task for which the slow moving, irregular stroke of the atmospheric type was quite unsuited. By 1825 there were 310 engines aggregating 6,406 horse-power working in the city and suburbs of Glasgow.[1] A census taken in April of that year[2] shows that these were distributed as follows;

Type of work	No. of Premises	No. of Engines	Maximum H.P. of any engine	Minimum H.P. of any engine	Average H.P. per engine	Total H.P. of all engines
Textile and other manufactures	149	176	70	3	16·9	3,000
Winding and pumping at pits	18	58	64	4	24·3	1,411
Stone quarries	7	7	11	4	5·6	39
Iron works	1	1	-	-	60.0	60
Steam boats	not given	68	not given	not given	28·3	1,926
Totals	-	310	-	-	20·7	6,436

For foot-notes see next page.

1. London in 1827 had about 290 steam engines, totalling 5,460 H.P. See: "A treatise on the Steam Engine" (1827) by John Farey.

2. In his "Historical Account of the Steam Engine" (1825) James Cleland gives a list of all steam engines operating in Glasgow at this time, the names of the owners, and the work performed by the engines. The list below is an abstract showing the type of work upon which the engines were engaged in the "Textile and other manufactures group":

	H.P.
Spinning Cotton	893
Weaving	681
Raising water	262
Bleaching, dyeing, etc.	206
Calendering	160
Grain grinding	153
Founding	124
Distilling	119
Engine making	68
Chemical manufacture	39
Machine manufacture	37
Snuff making	22
Fire brick manufacture	19
Sugar refining	18
Lamp black manufacture	18
Twisting yarn	18
Smith work	18
Grinding drugs	14
Coachmaking	12
Glass grinding	12
Grinding malt and pumping worts	20
Colours grinding	14
Veneer sawing	10
Tambouring	10
Wood cutting	18
Wool carding	8
Pottery manufacture	7
Singeing muslin	6
Tanning	6
Gas manufacture	4
Coppersmith work	4
Total - - -	3,000

Six years later the total had increased by about 15%, making in all 7,366 H.P. Contributing to this figure were 78 cotton mills deriving power from 91 engines. These statistics give an indication of the extent to which steam power was being used at this time and imply considerable engineering activity, even allowing that all the engines were not manufactured in the city.

The cotton industry required the services of engineers locally for the manufacture, erection, and repair of mill machinery and engines. Hence the advent of the steamboat was not delayed nor was its development handicapped by lack of skilled men in the district. But the application of steam power to marine propulsion was not accomplished in any brief period; experimental attempts towards that end have a history exceeded in length only by that of the development of the steam engine itself. Seafarers doubtless from very earliest times had felt keenly their subjection to the whims of Nature. If they carried sails only their ships might lie becalmed for many days. At other times they would be tossed helplessly in the teeth of the tempest unable to progress on their course till the storm died away. These uncertainties were mitigated somewhat by the use of oars as accessories to sails, but only at the expense of heavy and at times incessant physical labour. Not till the power of steam had been harnessed did the possibility dawn of achieving almost complete independence from the vagaries of the weather. Even then a century and a half intervened between the first experiment and the realisation of the aim. Dr. Papin claimed to have ascended the River Weser in a self invented steamboat in 1707, but the authenticity of this claim is doubted; in any case nothing further came of the venture. One of the earliest attempts at steam navigation is indicated by a patent for a horizontal engine taken out by Jonathan Hulls, of Exeter, in 1736. The success of any practical application of this patent is problematical and certainly no permanent result was recorded. Fortyfive years later the Marquis de Jouffroy made unsuccessful experiments at Lyons, France, and in 1785 the attempts of two Americans, James Rumsey and John Fitch, likewise came to nothing. In August, 1787, however Fitch did succeed in a trial of a small steamboat at Philadelphia. Later he had several such boats made and ran them with passengers. The enterprise failed for some unexplained reason. The record of its existence, though authentic, does not seem to have been sufficiently explicit to be of much guidance to others who came after him, for the way had again to be pioneered in America by Evans, Stevens, and Fulton 17 to 20 years later.

The first successful experimenters in the British Isles were Patrick Miller and William Symington who tried a steamboat on Dalswinton Loch, Dumfriesshire in 1788. Miller, who was a wealthy landowner and banker, promoted and financed the experiment. Symington, a merchant of Falkirk, was responsible for making the engine and having it fitted into the boat. The trial took place in the presence of a number of local residents and rumour has it that Robert Burns was on board.[1.] The boat measured 25 ft. by 7 ft. It had a double keel and the paddle was at the stern. Engine and wheel were of the same type as that used by Jonathan Hulls[2.] and, while it is certain that the boat did sail for some time under steam, the experiment cannot

1. Miller was the owner of Ellisland Farm which Robert Burns occupied at that time.

2. The paddle was driven from a capstan or windlass which could be rotated by steam, wind, or hand power.

be said to have been successful, as manual labour at the windlass was required at intervals. Subsequently, under Symington's supervision a larger engine was made at the Carron Works (of which Miller was a director). This was put into another boat and trials made on a stretch of the Forth and Clyde Canal, with but a limited measure of success. A speed of 7 m.p.h. was at times attained. Meanwhile, Gustavus III, King of Sweden,[1.] had heard of the experiments and wrote to Patrick Miller. Patrick Miller, Junr. thereupon took over in parts to Sweden[2.] a double keeled, centre wheeled steamboat as a gift from his father. The following covering letter (a photograph[3.] of which appears on pp. 94b and 94c) was received by Patrick Miller from Baron Gustaf Adolf von Nolcken, Swedish Minister at the Court of St. James,[4.] from 1763-92.

"London, June 7º 18th., 1791.

Sir,

It is with particular pleasure that I convey to you by the hands of your son Mr. Patrick Miller, a letter from the King of Sweden, my Royal Master, accompanied with His picture in a gold box set with Diamonds.

To that esteem for your talents, which His Majesty so fully expresses in His Royal Letter, it would be presumption in me to add more, than the sincere satisfaction, which I have in obeying His Majesty's commands by transmitting to you this distinguished proof of His Royal regard.

I have the honour to remain,
Sir,
Your most obedient humble servant,
Nolcken."

Besides the miniature it is alleged that the gold box contained the first seeds of the Swedish Turnip to arrive in this country.[5.] Another claim to the origin of the first successful steamboat in Europe emanates from Hull.

For foot-notes see next page.

1. Reigned 1771-92; assassinated by Ankarstron.

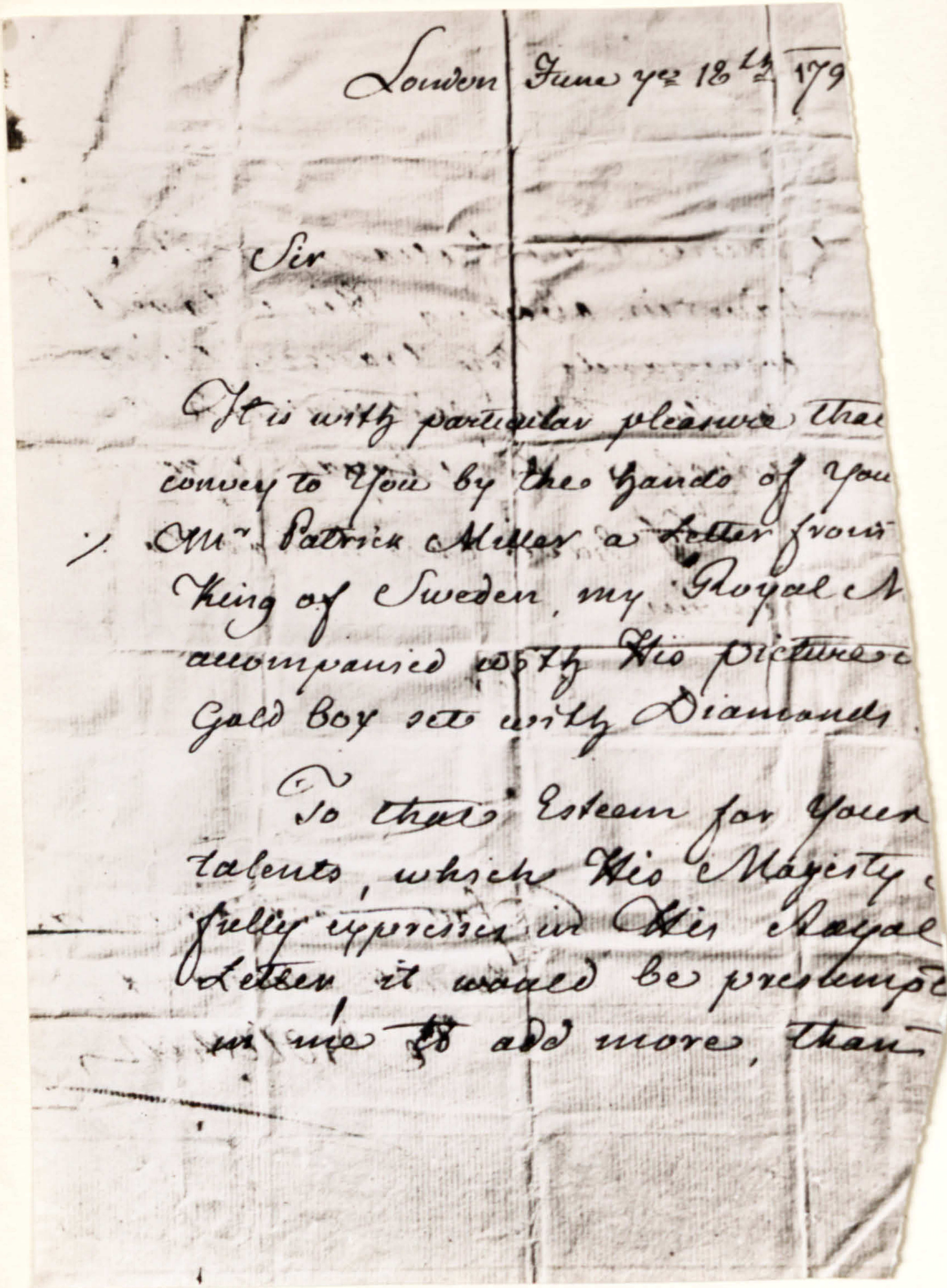
2. In his "Enumeration of the Inhabitants of Glasgow" (1832), Dr. Cleland wrote: "Mr. Miller had another boat of the twin tribe, which lay for some time in the Harbour of Burntisland, Fifeshire. In the end of March, 1789, I had the satisfaction of viewing this vessel - - - -. The stern of this vessel was fancifully ornamented, and I was then informed by the person who had charge of it, that Mr. Miller intended her as a present to His Majesty the King of Denmark." Doubtless this was the boat sent to the King of Sweden, as Miller, though a wealthy man, would scarcely be presenting steamboats at the same time to two crowned heads of European states.

3. The accompanying photographs are given here by the courtesy of John S. Clarke, F.S.A. See also his article: "The First British Steamboat", in "Daily Record", 10th January, 1930.

4. Information received from Baron Palmstierna, present Swedish Minister at the Court of St. James, London.

5. In an article in the "Standard Cyclopaedia of Modern Agriculture" (1908) it is stated by Sir Robert P. Wright that the seed was introduced into Scotland in 1777, having been sent over from Gothenburg by a Mr. Airth to his father, a Forfarshire farmer.
The secretary of the Royal Caledonian Horticultural Society informs me that he can trace no foundation for the allegation that Patrick Miller had any concern with the introduction of the ubiquitous Swede.
The "Encyclopaedia Britannica" account is vague placing the date any time between 1784 and 1795, an interval which certainly covers the time of Miller's correspondence with the King of Sweden.

Patrick Miller, Junr.



London June ye 18th 179

Sir

It is with particular pleasure that
convey to You by the hands of You
Mr. Patrick Miller a Letter from
King of Sweden, my Royal M
accompanied with His picture a
Gold Box sett with Diamonds.

To that Esteem for Your
talents, which His Majesty
fully expresses in His Royal
Letter, it would be presumpt
in me to add more, than

Letter to Patrick Miller, Esq.

Sincere Satisfaction, which I
have in obeying His Majesty's
commands by transmitting
to You this distinguish'd
proof of His Royal regard.
I have the honor to
remain

Sir

Your most obedient
humble Servant
Nolcken

from Baron von Nolcken, Swedish Ambassador.

The following statement[1] appears in the "Port of Hull Annual" for 1927:

> "Steam first became a practical proposition as a propelling agent for shipping in 1815-20 when wooden paddle steamers were being employed in the trades; but we must go back to the year 1796 to find the first example of the steamship in Europe. This vessel was designed and built on the River Hull by Mr. Furness of Beverley, and Mr. Ashton, a physician. It carried goods and passengers on the river between Hull and Beverley.
>
> These two gentlemen were afterwards granted a patent for their invention; also a pension of £70 a year each for life was settled on them by the Prince Regent (afterwards George IV) for whom they had also constructed a steam yacht."

No precise reason is given for the discontinuance of the river steamboat service, but it is evident that the success attained was only temporary.

About the same time the Earl of Stanhope conducted a number of experiments but these also fell short of the measure of success necessary to justify their continuance and extension. The "Monthly Magazine" for July, 1797, records that a small steamboat made journeys on the Sankey Canal, Newton Common, Lancashire, with cargoes of copper slag. During 1801-2 Lord Dundas, Governor of the Forth and Clyde Navigation Co., had an engine made under Symington's supervision and to his design. The boat was a stern-wheeled tug, named the "Charlotte Dundas" in honour of the Governor's daughter. For two years it plied the Canal but was finally discarded as the Governors were of the opinion that the wash would cause undue erosion of the banks. A similar objection was raised when, in 1827, it was proposed to apply steam power to the "Vulcan". Three years later, however, William Fairbairn conducted experiments at the request of the Governors and Council and found that at higher speeds the objectionable surge disappeared; thereafter steamboats were

1. Based on an account given in an early issue of the "Hull Courier".

again put on the canal. The "Charlotte Dundas" had a double-acting engine with crank and connecting rod, the crank being formed on the axel of the paddle-wheel, which was of Miller's improved type. Similar steamboat trials were meanwhile taking place on the other side of the Atlantic. Oliver Evans in 1804 put a flat bottomed, stern-wheel dredger on the Delaware River. Colonel John Stevens built a screw steamer in the same year and greatly improved the existing boiler, converting it to the high-pressure, tubular type. He is said to have crossed the River Hudson in this vessel. He and his son are credited with having done more for the advancement of steam navigation in America in early times than any other inventors of the Western Continent. But the man who achieved for America what Henry Bell performed for Europe, was Robert Fulton of Pennsylvania. He visited Scotland and studied Symington's boat. Having ordered one of Watt's engines in 1803 and another a year later, he returned to America and built the "Clermont", 133' x 18' x 9'. The engine had a cylinder 24" diameter, and 48" stroke, developing 18 H.P. The boat was launched at New York and plied with passengers between that city and the town of Albany, 160 miles distant. Its speed was 5 m.p.h. Commercial steam navigation therefore dates from 1807. Two years later the "Accomodation" took up a route on the St. Lawrence River.

Up to this time the West of Scotland had been identified prominently with the development of the steam engine and with experiments in steam navigation; the advent of Bell's "Comet" linked the name of Glasgow with the steamship for all time. Born near Linlithgow in 1767, Henry Bell early in life became apprenticed to a mason. Giving up this trade he became a millwright and in 1790 settled in Glasgow where he served under Rennie and other prominent local engineers. The "Charlotte Dundas" lay idle for many years on the Forth and Clyde Canal. Having examined it closely, Bell and his friend John Thomson made a number of model steamboats and conducted many experiments with them. In 1808 his wife took over the Baths Hotel, the largest inn at Helensburgh, a small town on the Firth of Clyde opposite Greenock, some 25 miles distant from Glasgow. He had thus excellent facilities for devising projects and testing them experimentally. He became friends with Charles Wood and his brother John, sons of John Wood, a boatbuilder of Port Glasgow, an association which was of very great service to him later. Only dogged determination made it possible for Bell to realise his great idea of raising steam navigation from the experimental stage to the realm of practical achievement. As already noted,[1.] Watt gave him no encouragement; the British Admiralty rejected his proposals, Lord Nelson alone urging that other Governments would take up steam navigation if we did not; other European Governments to whom he appealed later, turned a deaf ear. He even wrote to officials of the United States of America, but failure attended all his efforts to obtain assistance to carry out his experiments and facilities to test his ideas. Denied financial aid by all, he got into debt, part of which it would seem was never liquidated; nor did he get any monetary reward when at last success did crown his labours.

1. See p. 85 above. Even a President of the Royal Society - Sir Joseph Banks - prior to Symington's experiments had doubted the practicability of steam navigation: "It is a pretty plan," he said, "but there is just one point overlooked: the steam engine requires a firm basis on which to work." Quoted by Samuel Smiles in "Men of Invention and Industry - Phineas Pett" (1884).

In 1812 the "Comet"[1] was launched from John Wood's yard[2] at Port Glasgow. The boiler was made by David Napier at his Camlachie Foundry in Glasgow, the engine by John Robertson at his engineering shop in Dempster Street, Glasgow. The vessel was 43'6" x 11' x 6' and at a mean draught of 4' she had a displacement of 24 tons. Over the paddle boxes on either side, she measured 15'. The engine, of the side lever type, had a 16" stroke and the cylinder was 12½" diameter, developing 4 N.H.P. and giving the vessel a speed of 5 to 6 m.p.h. The original cylinder did not give satisfaction so a larger one was fitted and alterations to the paddles were made. The boiler cost £67; the engine as it was at first cost £165, an amount which by reason of the alterations grew to £365. On 12th August, 1812, the "Comet" began to ply with passengers and cargo between Glasgow, Greenock, and Helensburgh, and thus the first commercially successful steamboat service was instituted. The innovation met with opposition from those financially interested in other modes of transport. Like Demetrius, the silversmith of Ephesus, many feared that their business was "in danger to be set at nought." Of such persons Bell wrote;[3] "For so great was the prejudice against steamboat navigation by the hue and cry raised by the flyboat and coach proprietors, that for the first six months very few would venture in her. But in the course of the winter of 1812, as she had plied all the year, she began to gain credit; as passengers were

1. So named because of a brilliant meteor which had recently appeared in the sky.

2. Now part of the shipbuilding yard of Robert Duncan & Co.

3. Quoted in the "Origin and Progress of Steam Navigation" (1848) by Bennett Woodcroft, Professor of Machinery in University College, London.

carried 24 miles as quickly as by the coaches, and at a third of the expense, besides being warm and comfortable. But even after all I was a great loser that year. In the second year I made her a jaunting boat all over the coasts of England, Ireland, and Scotland to show the public the advantages of steamboat navigation over the other mode of sailing." The extinction of the coaches and fly-boats was completed twenty years later by the advent of railways. In 1818 a joint stock company was formed to run the "Comet" to the Scottish Highlands via the Crinan Canal. While it existed the company seems to have prospered, as it paid 37½% dividend for the year 1820.[1] Unfortunately, whilst plying this route to and from Fort William, the "Comet" was wrecked at the Doris Mhor, off Craignish Point, Argyllshire on 15th December, 1820. Its machinery is now preserved in the Victoria and Albert Museum, London.

Bell supervised the building of several other vessels, but despite the signal service he rendered to the country in establishing the first steamboat service in Europe, he received scant financial reward for his enterprise. As old age began to approach, he found himself in straitened circumstances, and it was very difficult to obtain official recognition of his work. A public subscription realised £500; the British Government finally contributed a lump sum of £200; and ultimately the fear of poverty was removed by the pension of £50 a year - raised in 1820 to £100 - awarded by the Clyde Navigation Trustees. Bell died in 1830 and the pension was continued to his widow. A monument to his memory stands at Dunglass Point, near Bowling. Another bearing a bust of the inventor may be seen in the churchyard at Rhu on the Gareloch, near

1. "The Story of the Clyde" (1911) by William Martin.

Helensburgh. Though not possessing genius to the same degree, his name may quite fairly be coupled with that of James Watt - two Scotsmen who stand out as pioneers of the twin industries of engineering and steamship-building which have made the River Clyde famous.

CHAPTER V.

THE DEVELOPMENT OF THE STEAMSHIP.

Following upon the success of the "Comet" a number of similar steamboats were soon plying on the Clyde. Bell had no patent so others were free to apply his ideas and, in course of time, to improve upon them; in fact for a number of years nearly every steamboat launched was larger, more powerful, faster, or in some distinct way superior to those that had preceded it. John Thomson, of Tradeston, Bell's co-experimenter, had been commissioned at the beginning to engine the "Comet". Disappointed when that work was given to Robertson, he ordered from Wood the boatbuilder, a vessel similar to the "Comet", engined it himself, and in April, 1813, put in on the river. The "Elizabeth" was slightly larger than her predecessor measuring 58' x 12'. Her displacement was 33 tons, the engine developed 8-10 N.H.P., and she had a speed of 9 m.p.h. Two other vessels, the "Clyde" and the "Glasgow" were built by Wood of Port Glasgow in the same year. In 1814 nine new vessels were launched from Clyde yards and the circle of steamboat builders was enlarged by the entry of McLauchlan of Dumbarton with whom Denny later entered into partnership, Fyfe of Fairlie, Munn of Greenock, Martin of Port Glasgow, and Smart of Dundee. One or two of the vessels launched that year deserve special mention. The "Marjory", by Denny, had the distinction of being the first steamboat to ply on the Thames. From January 1815 to June of the same year she ran from London to Gravesend. Thereafter, having been purchased by the French Government she was put on the River Seine. The "Marjory" and the "Princess Charlotte" were the first vessels to have condensing engines. Two others, the "Caledonia" (95'6" x 15'; 102 tons; two 16 H.P. engines) and the "Humber", built to the order of John Robertson of Dundee and engined by him, were sent to the River Humber under their own steam. The "Caledonia" was purchased by James Watt, Junr. in 1817 for experimental purposes. He re-engined her with two 14 H.P. engines and sailed to the Rhine and back. She remained in service carrying cargo till 1872. Unique among the launches of 1814 was the "Industry", built by Fyfe of Fairlie and engined by George Dobbie of Tradeston, Glasgow; it justified its name by continuing in active service for 62 years. In 1890 she was still in existence. The engine which gave such prolonged service is now housed in the Kelvingrove Museum, Glasgow. The "Britannia", launched in 1815, was one of the largest and most powerfully engined vessels yet built, and was the first river steamer to run to Campbeltown, beyond the usual ports of call on the Clyde. Later she was transferred to the Glasgow and London service. The "Majestic" of 1816 superseded all previous vessels for size and power, being 350 tons burthen and 100 H.P. She sailed from London to Margate.

With the year 1818 a new phase of steam navigation opened. Hitherto, apart from a few experimental trips, steamboats had plied regularly only on rivers or along sheltered coasts; but in 1818 Denny launched the "Rob Roy", a 90 ton vessel, David Napier installed a 30 H.P. engine in it, and a regular service between Greenock and Belfast was begun. Later she plied between Dover and Calais under the name "Henry IV". Soon after, the "Talbot" (150 tons; two 30 H.P. engines) was put on the Holyhead to Dublin route and the "Robert Bruce" (150 tons; 60 H.P.) took up the Glasgow, Greenock, and Liverpool trip. Larger still was the "Waterloo" (200 tons; two 30 N.H.P. engines) launched in 1819 by Scott & Sons, Greenock. David Napier, the Glasgow engineer, was the pioneer of hull design for deep sea steam navigation. Originally the lines of steamboats followed the prevailing sailing ship practice. Bluff-bowed they smashed rather than cut a passage through the waves. Napier took a trip on the Dublin packet ship for the express purpose of studying the form of bow in relation to sailing qualities. A heavy sea running in the Irish Channel on the night of his voyage suited his purpose admirably and he spent most of his time on board perched on the bow, cold and wet but studying intently the manner in which the waves broke and parted. Later he experimented with models in the ~~in~~ Molendinar Burn,[1] beside which at that time his workshop stood, and found that a wedge-shaped bow

1. A stream which has its source in Hogganfield Loch, to the north-east of the city. It is now covered in for the greater part of its course and serves as a common sewer. At that time it was a very pretty burn, flowing behind the old College garden and uniting with the Camlachie Burn near Jail Square just before it entered the Clyde at the west end of Glasgow Green.

gave very much better results than any of broader type. Subsequent to 1820 he adopted this form for all vessels with the construction of which he was concerned. Other steamboat builders copied the idea but for many years sailing vessels remained of the West Indiaman type.[1]

During the fifteen years following the launch of the "Comet" no improvements of any account had been made in marine machinery. Many experiments were tried but ended in failure. Robertson Buchanan in 1815 endeavoured to make the paddles dip into the water by causing them to move in eccentric circles. An attempt in 1819 to propel a boat on the Clyde by means of a jet of water ejected from the stern,met with no success. On one occasion when the "Dumbarton Castle" had grounded on a sandbank owing to the low tide - a not infrequent occurrence - the engineer noticed that the current caused the paddle wheels to reverse their usual motion. He spoke to James Watt, Junr. about the matter and he, some years later, designed reversing gear. In all, the son of the great inventor performed some 200 experiments without achieving any success comparable to that which crowned the labours of his illustrious father. Bell had taken out no patent for his "Comet" and this not only left the field open for anyone who wished - a distinct encouragement to progress in steam navigation - but it also raised doubts within a few years as to the debt which successors owed to him. However, the danger of being denied the credit for his invention was obviated by the

1. See p.31 above.

following testimonial[1] which confirmed the fact that up to 1825 at any rate no significant departure had been made in the design of marine machinery. Dated 2nd April, 1825, it runs:

> "We, the undersigned, engineers in Glasgow, having been employed for some time past in making machinery for steam vessels on the Clyde, do certify, that the principle of the machinery and paddles, used by Mr. Henry Bell in his steamboat the "Comet", in 1812, has undergone little or no alteration, notwithstanding several attempts, by ingenious persons, to improve it.
>
> Signed: Hugh and Robert Baird, John Neilson, David Napier, Duncan McArthur, Claud Girdwood & Co., Murdoch and Cross, Wm. McAndrew, William Watson, Robert Napier".[2]

James Cook sent a separate testimonial letter dated 4th April, 1825, to the same effect. He remarks, however, that the greatest improvement has been in ships' boilers these "being now (and for many years past) what may be called self-contained, that is, the fire as well as the water is all contained within the boilers, which I believe was not the case at first with the "Comet"." The value of this tribute will be obvious when we scan the names of the signatories and find among them engineers who later became almost as famous as Bell himself. The machinery of all the early steamboats was of the bell-crank lever type. The lever was actuated directly by the piston, the motion being communicated by rod and crank to the main shaft which carried

1. "Historical Account of the Steam Engine" (1825) by James Cleland, LL.D.

2. The order of the signatures is the order in which these, the earliest steam engine makers of Glasgow, commenced business. James Cook comes second, between Baird and Neilson.

the paddles. The steam pressure was low, rarely exceeding 5 lbs. per sq. in. above atmospheric.

During the seven years following the launch of the "Comet", some 42 steamboats aggregating 3,200 tons were built on the Clyde. If the Scottish shipping register examined above[1] is to be relied upon, it would seem that by 1820 at least 35 of the steamboats originating on the Clyde had been sold to owners outside the country. Most probably the register took no account of small steam tugs and luggage boats whilst the figure for total production includes these. Nevertheless, in the early years, the Clyde was the chief steamboat building river of the United Kingdom and many vessels were built for owners in other parts of the country and even for the Continent. The register indicates that at least one other river in Scotland, the Forth, was contributing in a smaller measure to the extension of steam navigation. An output of 3,200 tons in seven years may today seem a paltry figure, scarcely equal to the tonnage of a single modern cargo vessel of very moderate dimensions. At the time it was a great achievement and marked the birth of the industry destined to supersede all others in the West of Scotland. An idea of the cost of these early vessels may be obtained from the following statement:[2]

1. See pp 37-41.
2. "Annals of Glasgow" (1816) by James Cleland, LL.D.

"Albion" - 20 H.P.
launched in 1816 by John Wood, Port Glasgow; engined by James Cook, Glasgow.

Costs:

	£
hull	1,000
upholstery and equipment	850
engine, boiler, and paddle mechanism......	1,600
	3,450

If this be taken as an average figure - a fair assumption for the period, since the larger vessels of 1817-19 will be offset by the small tugs and luggage boats - it will be seen that the total value created by the building of steamboats on the Clyde approximated to £145,000, an average of over £20,000 per annum. The cessation of hostilities with the close of the Napoleonic Wars brought a depression of trade which was felt by the new industry as by others. The revival after 1819 may be observed in the increased output of steamboats; in less than five years the number launched exceeded considerably the total for the previous seven years. Writing in the "Manchester Guardian" in 1824[1], Henry Bell indicated the position reached in Scotland at that time: "At the end of 1823 there had been built in Scotland about 95 steamboats the cost of which will average about £4,000 each. Sunk capital is £380,000. Of that number there have been 40 sold from the ports of the River Clyde that were built and finished there. Last year no less than 55 steam vessels were plying in Scotland, 32 of them belonging to the Clyde." Thus, if all steamboats plying on the Clyde were built locally - an assumption which

1. Quoted in "Glasgow Mechanics' Magazine"; Vol.IV. (1825-26).

is almost certainly correct - 23 out of the Scottish total of 95, had been built in other parts of Scotland; and further, since this is the number plying on other Scottish rivers or routes, it may be argued that the West of Scotland was the only area which had a net export of steamboats. William Bain[1], commander of the steam packet "City of Edinburgh", gave the following statistics,[2] covering the whole country, for 1825:

number of steam vessels in U.K.	-	150
total tonnage of same	-	16,000 tons
individual tonnage varied from	-	30 to 500 tons
total power of marine engines	-	5,000 N.H.P.

Regarding costs he stated that a steam packet of 350 tons and 100 H.P. engine averaged £20,000 (or £61 per ton) of which the boilers alone accounted for £1,200. Prime costs increased at a greater rate than in simple proportion to tonnage; running costs per ton for the larger vessels decreased with increasing tonnage, which accounts for the marked tendency to rapid increase in the size of vessels.

The delay in attempting to navigate open sea by steamboat must not be attributed to lack of engine power or the inability of the hull to withstand the force of the waves; nor were navigators afraid to venture to sea in steam driven craft. If the engine broke down the vessels were provided with sails by which the voyage could be completed. The real difficulty was that the coal consumption of the early vessels was inordinately high,and to carry

1. Captain Bain had previously been skipper of Bell's "Comet" at a wage of 30/- per week. See "The Story of the Clyde" (1911); by William Martin.

2. "Glasgow Mechanics' Magazine"; Vol.IV. (1825-26).

sufficient fuel for a long trip would have occupied all the available cargo space. An example will serve to illustrate the point: the "Toward Castle", built on the Clyde in 1822, had a single 45 H.P. engine; the boiler consumed nearly half-a-ton of hard coal per hour or 25 lbs. per H.P. per hour.[1] At this time, it may be remarked in passing, coal cost 12/6 per ton in Glasgow. The vessel in question was 97 tons burthen, so that to carry sufficient coal for a four days' journey[2] would have reduced her carrying capacity 50%. Thus the impracticability of extended voyages was at bottom economic rather than physical in its nature. The excessive coal consumption was due partly to the inefficiency of the boilers, which were able to sustain only a low pressure of steam, and partly to the engines which consumed an inordinate quantity of steam. Gradually both defects were eliminated, the boiler being the first to receive the attention of engineers. By 1825, as already indicated,[3] the marine boiler had been made a self-contained unit. In 1830 James Napier, a cousin of David, invented and patented the haystack tubular boiler, which achieved a saving of 25% to 30% of the coal hitherto consumed. In company with his cousin William Napier, James was at this time carrying on business at the Swallow Foundry, Washington Street, Glasgow. In the same

1. Compare this with the performance of a modern vessel, e.g. the Baltic, launched in 1908 (24,000 gr. tons; 16,000 I.H.P.) Equipped with reciprocating engines working under a boiler pressure of 210 lbs. per sq. in., she developed a speed of 16.5 knots and consumed only 1.5 lbs. per I.H.P. per hr.

2. Allowing for reduced speed in the open sea this would probably not exceed 500 miles.

3. See p. 105 above.

year they furnished several steamboats incorporating the new type of boiler, and these gave every satisfaction. It is noteworthy also that this firm were responsible for the construction of several of the earliest steamboats which plied on the Clyde.

A departure from the side lever type of engine hitherto prevalent in steamboats was made when, in 1827, Joseph Maudslay of London invented the oscillating cylinder engine.[1] The cylinder was supported on trunnions and its motion through an arc of a circle with these as pivots, obviated the necessity for a connecting rod and gave a more direct pressure to the crank throughout its revolution. The first Clyde vessel engined with this type was the "Fairie Queen".[2] David Napier, in 1835, invented the steeple engine. The first steamboat equipped with this type was the "Clyde" (342 tons; 160 H.P.) launched in 1836. Later he developed the double steeple. All four types of engine mentioned enjoyed popularity as marine units. A further type, which was widely adopted for screw but not for paddle steamers, was the "trunk" engine. In this the piston rod was dispensed with. A trunk cylinder with the piston fixed to it traversed the whole length of the steam cylinder; when the piston was at the middle of its stroke, the trunk cylinder protruded at both ends of the steam cylinder an amount equal to half the length of the latter. The connecting rod was

1. William Murdoch had used the same idea experimentally more than 40 years before. See p. 83 above.

2. Already noted (p. 64 above) because of the additional distinction it bore of being the first iron steamboat to ply on the Clyde.

attached to the centre of the trunk cylinder. Watt had invented both the jet and the surface condenser but had not made any use of the latter. In 1820-1 David Napier revived the neglected idea and patented an improved surface condenser, the first being employed in the "Post Boy", a luggage and passenger boat built in 1822 to run between Glasgow and Greenock in connection with the service from the latter town to Liverpool. Samuel Hall working independently took out a patent two years later for a somewhat similar steam engine auxiliary. The jet condenser operated by reason of a jet of sea water injected into a closed vessel receiving the exhaust steam. Some 20 lbs. of sea water were required per lb. of steam. In the surface type the steam and the condensing water did not come into contact at all. Thus the fresh water formed by the condensation of the steam could be fed back to the boiler again, avoiding the necessity of blowing off periodically from the boiler quantities of hot brine, a procedure hitherto required because the brine in the boiler became progressively more concentrated. Had this brine been left in the boiler, a solid deposit of salt would have formed and this hastened the destruction of the plates composing the boiler shell by burning. Not until about 1865, however, did the surface type of condenser come to be adopted generally. Its defects up to that time seem in practice to have outweighed its advantages and the older jet type, though ruinous to the boilers and wasteful of heat, retained the patronage of engineers.

Many other inventions stand to the credit of David

Napier; some achieved practical success whilst others remained merely as designs. Among the successful, mention may be made of the "feathering" paddle. The blade, which was of sheet iron, instead of being fixed rigidly was permitted to rock and so entered and emerged from the water almost tangentially, resistance being thereby reduced to a minimum. Napier's patent was taken out in 1841, but it must be added that others from 1812 onwards had devised and patented somewhat similar mechanisms; nor was Napier's attempt the last. In 1851 he patented an arrangement for forced draught to marine boilers. Of his unsuccessful designs we may note his water-tube fire bars and a rotary engine, both of which were tried in a remarkable experimental vessel, the "Rotary", built to his order in 1852 by Henderson of Renfrew and engined by Wingate and Co. of Glasgow. After a few trial trips, regarding which great secrecy was maintained, the vessel was converted into an ordinary paddle steamer. Under a different name it sailed the Clyde for some years. Designs for a floating battery, a breech loading gun, and a steam carriage were likewise relegated to the limbo of disappointed hopes. As a solution to the problem of how to remove Clyde sewage, he suggested that barges should carry the waste material to the Firth and there dispose of it. Rejected at the time, his idea was adopted later by the Clyde Navigation Trustees. Though he possessed a fertile inventive brain from which issued many brilliant ideas and designs, the machines produced in his workshop were rather poor in quality and in workmanship. In consequence he was involved in much trouble and litigation, of which one instance may here be cited. In 1835 the boilers of one of his vessels the "Earl Grey", burst as she lay at Greenock. Many persons were killed and injured. After this Napier removed to London where he built steamers for the Margate trip. Subsequently his London shipyard was taken over by Scott Russell in connection with the construction of the "Great Eastern."

By 1835 pressures of 3½ to 5 lbs. per sq. in. above atmospheric were available in marine boilers. Much higher pressures were commonly in use with land installations, including locomotives, but when introduced into marine plants on several occasions disastrous results ensued. In 1817 a Government Commission examined into the circumstances under which the explosion of a high pressure steamboat boiler at Yarmouth occurred. Another Commission was appointed in 1839 to report upon the prevention of such accidents in steamboats. In submitting evidence on the matter a leading firm of engineers wrote:[1] "Our experience has satisfied us that there is no economy in working a marine engine with high pressure steam, and condensing water being always abundant there is no necessity; the only temptation is to obtain rather more effect from an engine of the same weight and cost, though at a great sacrifice of fuel; but competition in speed is often so great as to supersede every consideration of safety, economy, or prudence." Statements

1. Quoted by Fred. J. Bramwell in a paper on "Economy of Fuel in Steam Navigation", read before the Institute of Mechanical Engineers in 1872.

such as this were not calculated to further the progress of marine engineering, nor did they serve to inspire confidence in steam navigation amongst the public. They represent an attempt, not unknown today, to discredit experiments along new lines, in order that some persons with special interests in maintaining things as they are, may not require to bestir themselves to meet the competition of fresh ideas. Temporarily secure and comfortable in the little rut they have dug for themselves, they regard as anathema anything which might compel them to leave it for a less sheltered situation. The remarks quoted do indicate that the economy and importance of speed in maritime transport was receiving recognition.

The possibility of using high pressure steam with economy and safety depends on the use of materials and the application of thermodynamic principles, coupled with careful design, not at that time available to engineers. To use steam at pressures exceeding 50 lbs. per sq. in. (absolute) was impossible so long as:

1. boilers were fed with salt water, because at higher pressures sulphate of lime is deposited in insoluble layers and thus the boiler is burned out;
2. the box type boiler with stayed sides was in use, because it could not withstand higher pressures;
3. a single cylinder only was available, because higher pressures necessitate too great a ratio of expansion producing an irregular turning movement on the crank and excessive temperature variations in the cylinder walls.

The prevailing practice of using high pressure steam in locomotive and stationary engines led marine engineers to investigate what alterations would be necessary to render it safe for them to do likewise. Of the economy achieved by increasing steam pressures there could be no doubt. Smeaton in 1769 computed the average duty[1.] of 15 engines operating at Newcastle-on-Tyne and found it to be 5,590,000 ft. lb. per bushel.[2.] In 1793 a test of 17 of James Watt's engines gave an average of 19,569,000 ft. lb. per bushel. Subsequent progress is recorded in the following table:[3.]

Year	No. of engines tested.	Average duty ft. lb. per bushel	Duty of best engine ft. lb. per bushel.
1813	24	19,500,000	26,400,000
1823	45	28,900,000	43,500,000
1833	56	46,600,000	73,300,000
1837	58	47,000,000	87,200,000

The increased output was due to the increase of steam pressure in the interval. This had gradually risen in land installations to about 45 lbs. per sq. in. (abs.). Reciprocating engines of the twentieth century, consuming 1¼ lbs. coal per l.H.P. per hour and working at steam pressures upwards of 200 lbs. per sq. in., on the same basis of calculation would have a duty of 135,000,000 ft. lb. per bushel of coal.[4.]

The only steamship exceeding 1,000 tons burthen at this time was the "British Queen", launched on the Thames[5.] in 1838. She was supplied with engines of 420 H.P. by Robert Napier of Glasgow and carried also surface condensers

1. For explanation of the term "duty" see Appendix 5.
2. "Proceedings of the Institute of Mechanical Engineers." (October, 1903.).
3. "Journal of the Royal Statistical Society"; Vol.I. (1838).
4. Allowing a mechanical efficiency of 90%.
5. "Ancient and Modern Ships" (1906) by Sir G.C.V. Holmes.

of Hall's type constructed by the same engineer.[1] During the forties the types of marine engine most commonly in use were the steeple and the diagonal. Steam was generated by flue and haystack boilers, and the working pressure of marine engines gradually rose to 40 lbs. per sq. in. (abs.). The prevailing conservatism in respect to steam navigation was fostered rather than dispelled by the attitude of the British Government towards it. The Post Office, equally with the Admiralty, is generally included in the sweeping charge of timidity to venture upon the new means of transport. But when this charge is made the circumstances relating to the Post Office authorities' refusal to embark upon a project for carrying mails to India by steamship are usually obscured.[2] As early as 1820 a steam packet mail service between Howth (Ireland) and Holyhead (Anglesey) was introduced by the Post Office. From 1824 onwards for some years numerous approaches were made by Wilson & Co., Thomas Waghorn, J.W. Taylor, and others to obtain from the Postmaster General contracts to convey mails to and from India by steamboat. That these proposals were rejected is not surprising when one is acquainted with the terms demanded by those who tendered for the work. One proposed to charge 2/6 per letter, the Post Office to receive 9d of this and the contract to be made for the duration of the

1. Article on "Engineering and Shipbuilding" by John Mayer in British Association handbook for Glasgow meeting (September, 1876).

2. For a full account see MSS. at Public Record Office under title: "Steam Navigation to India" (Ref.No.132/1829 under T64/329.) This gives verbatim the correspondence which passed between applicants and Government officials.

Company's charter. At that time the Post Office was getting 10d per letter outward and 1/- inward! A steamboat was to leave London and another to leave India on the first day of each month. During 1824 there were actually 146 departures to India and 220 arrivals at British ports from India with mails by sailing vessels! The P.M.G. finally disposed of this application by pointing out that he only entered into contracts after performance had been demonstrated; this proposal involved the passage of an Act of Parliament before any such demonstration had been given and therefore he could not countenance it[1.] - the only position possible for a public official seeking to maintain the integrity of his trust for the nation. He added that the Government had the sole rights over the conveyance of mails; to sign this contract would give a monopoly to a private company. Mr. Waghorn's proposition was even less acceptable. His vessel was to have an engine of only 50 H.P., quite inadequate to weather the storms met whilst rounding the Cape and crossing the Indian Ocean. Vessels of this power were already operating on the Dover to Calais route. Mr. Taylor proposed that he should get one half of the rate charged for the carriage of letters and should be appointed "Receiver of Indian Letters" overseas! In actual fact the Post Office adopted the steamship to transport mails as soon as its efficacy for ocean crossings had been satisfactorily demonstrated.

It is doubtful if the same extenuating circumstances can be summoned in defence of the hesitancy displayed by the Admiralty towards steam navigation. This department of

1. The first steamboat to arrive at an Indian port from Britain was the "Enterprise" in 1825; see p. 131 below.

State occupies a position somewhat different from the Post Office as regards its powers to experiment with new ideas; and, whilst several good reasons can and will shortly be given as to why early steam vessels were unsuitable for war purposes, greater enterprise might have been displayed in this matter by those charged with maintaining Britannia's supremacy on the waves. It may be recalled that, when Henry Bell was appealing to the Admiralty for assistance,[1] Lord Nelson alone supported his plan and warned his brother Lords of the probable consequences to Britain if they neglected this new mode of navigation. In 1819 they ventured sufficiently far to order a small steam vessel, 210 tons burthen driven by two 40 H.P. engines supplied by Boulton & Watt. Ironically enough it was named the "Comet"! Built in London and commissioned in 1822, she was a non-combatant ship belonging to the "Cutters, schooners, and tenders" class. In the same year Lloyd's registered their first steamboat. Within the next few years several small non-combatant steam vessels were added to our naval forces. In 1828 the first combatant vessels appear: two steam driven gunboats were put into commission. A year later a sloop of 1,111 tons and 320 H.P. was added and in 1837, two steam frigates.[2] One reason for the tardiness displayed by the Admiralty in the adoption of steam power was the inconvenience of the paddles for fighting ships. The paddle boxes occupied valuable gun space on the sides of the ship and, rising as they did above deck level, they limited

1. See p. 97 above.
2. Parliamentary Papers for 1860; session vol. 42.

the area from which guns might be trained upon the enemy. They also made excellent targets for enemy shot and were a most vulnerable part of the ship. The high coal consumption too was a serious matter alike for naval and merchant vessels. The absence of coaling stations would itself have proved a handicap almost insuperable to naval steamships engaged in warfare. Reference has been made above[1.] to the high coal consumption of early marine engines. Although some reduction had been achieved in the ensuing fifteen years, this was still a serious economic problem especially on long voyages. For example: when the "Great Western", a vessel of 1340 tons, crossed the Atlantic in 1838 she required 600 tons of bunker coal. In addition to passengers she was capable of carrying only 250 tons of cargo. Even as late as 1848, Mr. Joshua Field in his presidential address to the Institute of Civil Engineers said: "Vessels intended for speed should not be deeper than is necessary for the accommodation of passengers and to render them seaworthy. Conveying cargo in such a vessel is out of the question and in fact all they can be expected to carry in addition to their passengers is their engine and coal for the voyage." The Admiralty was much more open to criticism on its attitude to iron ships[2.] than on its reluctance, more apparent than real, to replace sail by steam.

In 1836 the most important step forward since the inception of steam navigation was taken. John Ericsson, a Swede engaged in civil engineering practice in London, and Francis Smith, working independently, invented and patented

1. See p. 109 .
2. See p. 55 above.

different types of screw propellers. Many unsuccessful experiments in this mode of propulsion had been made in the past, ranging from those by Baron Seguier in 1792, Fulton in 1796, Trevithick in 1815, to those by Ericsson and Smith in 1836. Earlier patents had been taken out by Joseph Bramah in 1785, William Littleton in 1794, Edward Shorter in 1800, and Samuel Brown in 1825, but from none of these did there emerge any practical machinery. Dr. Birkbeck in a letter to the "Mechanic's Register" in 1824 supported the claim of John Swan of London, as the originator of the screw propeller. In the few years following 1836, four experimental screw driven vessels were constructed. These were the "Francis B. Ogden" and the "Robert F. Stockton" fitted with Ericsson's screw, and the "Francis Smith" and the "Archimedes" equipped with Smith's patent. The Lords of the Admiralty, though treated to a trial trip (which proved quite satisfactory) on a screw driven boat on the Thames, refused to take up the new invention. Sir William Symonds, surveyor and principal designer of H.M. ships, who was on board was emphatically opposed to any new projects. Steam power and iron vessels he detested - a fact which may account for the superficiality of the tests made and the perfunctory manner in which the results were dismissed. This seems all the more strange when we consider that all the disadvantages of the paddle in warfare were thereby eliminated. One important objection to the screw was the high speed at which it had to be driven. Notwithstanding this, Captain Robert F. Stockton of the U.S. navy had the iron vessel bearing his name constructed by

Laird at Birkenhead in 1839. A year later the British Admiralty did venture to have built a small screw driven vessel, the "Dwarf" (210 tons, 120 H.P.). By 1848 a propeller driven second rate ship of the line was in commission, but not till 1852 did a first rate ship thus equipped make its appearance. Three years later seven first rate ships, propeller driven, were on the navy list. By 1856 no less than 327 ships of the Royal Navy had been fitted with the screw propeller,[1] and in 1860 the paddle was definitely abandoned. At the same time gearing was dispensed with. Bennett Woodcroft, Professor of Machinery in University College, London, patented another type of screw which on trial in 1844 proved to be superior to the others. In 1845 the iron hulled screw driven steamer "Great Britain" crossed the Atlantic in fifteen days. It may be noticed in passing that the engines of this ship worked under a steam pressure of only 2 to 5 lbs. per sq. in. above atmospheric. Although in the early days difficulty was experienced with "slip" of the screw, the propeller gave greater satisfaction than paddles, because the efficiency of paddles alters as the vessel, consuming its coal, becomes lighter and floats higher in the water. On a 3,000 mile voyage the efficiency of the paddles, from a somewhat low figure, increases steadily during the first two thirds of the trip but decreases again during the remainder. Thus the screw propeller gained favour because:

1. it is equally effective at varying draughts, provided it is submerged;

1. The number seems large but it is vouched for by Smiles, op. cit. chapter on "Francis Pettit Smith."

2. it is indifferent to rolling, though adversely affected by heaving in a heavy sea;

3. it can be used for large or small powers.

The next step was to drive the propeller by gearing designed to give it a higher rate of revolution than the engine had; i.e. the engine was geared "up". Built by Scott & Sons in 1849, H.M.S. "Greenock" was the first steam frigate constructed on the Clyde and was the largest iron warship of that period. She was one of the earliest vessels to be equipped with a geared screw. With the development of higher engine speeds in later years, gearing was discarded.

From the workshops of Randolph, Elder & Co. (a firm founded in 1852 to take over the business of Randolph, Elliot & Co.) emanated a number of important improvements to marine machinery. Between 1853 and 1867 this firm registered no fewer than fourteen patents, directed towards four main ends:

1. economy of fuel in boilers;

2. economy of steam in the engine itself, thus increasing the power output for a given steam consumpt;

3. the diminution of friction and the reduction of unbalanced forces in the moving parts of the engine to a minimum;

4. efficiency (or avoidance of "slip") of the propeller.

The first pair therefore relate to thermal, the latter pair to mechanical efficiency. Of all the improvements accomplished the most important was that patented jointly by Charles Randolph and John Elder on 24th January, 1853. It defined the principles of construction of the marine compound engine and marked the most striking advance in marine engine practice since steam was first applied to navigation. The steam entered one cylinder where partial expansion was allowed to take place, the exhaust from this passing into a second (and larger) cylinder where expansion to condenser pressure was completed. Previous to this time compound engines of the Woolf type, itself derived from Hornblower's earlier engine,[1.] had been used only in land installations. One or two had been tried with no great measure of success in river steamboats. With the advent of the Randolph-Elder engine, success was assured and it was adapted to drive the screw propeller. The first vessel to be so equipped was the s.s. "Brandon" in 1854. Coal consumption, which by this time had been reduced by boiler and engine improvements to 4 to 4½ lbs. per I.H.P. per hour, fell to 3¼ lbs. Another patent by the same inventors revived the discarded steam jacketing for cylinders, designed to prevent heat losses to the air and to reduced initial condensation - the source of the mysterious "missing quantity" - in the cylinder. The second and third ships to be fitted with the new compound engine were the "Inca" and the "Valparaiso". Steam pressure in these was 30 lbs. per sq. in.[2.] and the cylinders were partly jacketed; fuel consumption of 2½ lbs. and 3 lbs. per I.H.P. per hour respectively was recorded. Such a degree of economy in coal, never before realised, rendered practicable what had hitherto been impossible: trade by steamship across the Pacific Ocean.

1. Hornblower in 1781 had patented a single acting compound engine and in 1804 Woolf patented a double acting compound engine. Neither proved suitable for marine work.
2. 45 lbs. per sq. in. (abs.).

Further improvements in a short time reduced the figure to 2¼ lbs. per l.H.P. per hour. An essential factor in the success of the compound engine was the higher steam pressure now available. About 1860 the average practice ranged around 20 lbs. per sq. in. but in many vessels a figure considerably higher was in use. The majority of engines of the mercantile marine were of the horizontal type; but subsequently the inverted "steam hammer" type displaced the other. For many years horizontal engines were retained in the Navy, because of the greater safety realised by having the engine below the water level. The further development by John Elder of a three cylinder compound engine solved the problem of unbalanced forces almost completely. Rowan and Horton in 1860-1 also took out patents for boiler improvements and for a type of three crank compound engine. The first ship to be fitted with a surface condenser, auxiliary to its compound engine, was the "Thetis", built in 1858 by Scott of Greenock and engined by Rowan of Glasgow. It had water tube boilers working at a pressure of 115 lbs. per sq. in. On trial (certified by Prof. Rankine, F.R.S.) the coal consumption was only 1.018 lbs. per l.H.P. per hour. During the decade 1863-73 the efficiency of the marine engine was doubled by the practice of compound expansion and surface condensation.

The twin screw, an advance towards which David Napier contributed, came into use in a few vessels[1] about 1863, but was not generally adopted until twenty years

1. The first was the "Flora" built at Millwall.

later. Not till 1862 did the Government sanction the use of the screw propeller in the Cunard line vessels which carried the American mails. But the Admiralty and a few of the more enterprising merchant shipowners led the way in trying out the twin screw. The outline given above comprises the more important improvements made on the engineering side prior to 1870. Mention must be made of the commencement of the use of steel for boilers. In 1857 the Admiralty authorised steel boilers in one vessel, but the practical development of this important departure in engineering was delayed until the modern period (i.e. till after 1870).

The size of vessels and the power of their engines increased steadily. The form of the hull was altered as research work determined with greater accuracy the proper streamline shape and the best proportions of vessels. In the early days of the steamboat, a length equal to four times the breadth was considered suitable. The multiplying factor gradually increased to 6, and by 1865 lengths equal to 7, 8, and even 9 times the breadth were not uncommon. In this matter steamships owe not a little to the competition to which they were subjected by sailing ships. To meet the increased speed of steamships, the builders of sailing vessels had to devote more attention to hull design. The fast clipper ship was evolved and although steamship builders were inclined to devote more attention to boiler, engine, and propeller efficiency than to the hull, the remarkable passages effected by clippers convinced them that the form of bow and hull played no small part in determining the speed of a vessel. One interruption in the step by step increase in size of ships must be noted. Begun in 1854, the "Great Eastern" (680' x 82'6" x 31'6"; 18,914 gr. tons; 11,600 I.H.P.) was launched at Millwall, London, in 1858. She was designed to carry 10,000 tons of bunker coal, 6,000 tons of cargo, and 4,000 passengers. For propulsion both screw and paddles were employed. Innumerable difficulties delayed the construction, disaster attended its launch, and commercial failure sealed the fate of this leviathan. These discouraging results did not dismay shipbuilders, who recognised the exceptional features presented by such a decided departure from the prevailing practice; but it did induce many rashly to aver that ships of this size could never possibly be built satisfactorily and that, even if constructional difficulties were overcome, they could not be worked profitably, but would remain, like the "Great Eastern", floating monuments to the misplaced ingenuity of engineers and the false optimism of credulous shipowners. At the launch in Greenock of the P. & O. steamer "Atrato" in 1853, at that time the largest vessel in the world (354' in length; 3,466 tons), Mr. J.T. Caird, the builder, predicted[1.] that in the course of the next fifty years, steamers of 700' to 800' in length would be built and worked profitably. His contention was supported by one other builder only - Robert Duncan; the other builders and naval architects ridiculed it. Doubtless they rubbed their hands with a satisfied "I told you so!" when, a few years after the prophecy was made, the "Great Eastern" enterprise

1. "History of Greenock" (1921) by Robert M. Smith.

proved a fiasco. But in 1903, exactly half-a-century after Caird's statement had been delivered, the "Cedric" (740' in length; 23,984 tons; 13,350 I.H.P.) launched at Belfast the year before, was operating successfully alike from the engineering and commercial points of view.

The advent of larger vessels brought the need for some form of steering gear which did not rely on human energy to actuate it. It is therefore interesting to note that in 1867, seven years after her first Atlantic crossing, the "Great Eastern" was fitted with steam steering gear designed by Mr. McFarlane Gray. During the fifties the haystack tubular boiler predominated, and before 1870 such advances were made that pressures of 60 to 70 lbs. per sq. in. above atmospheric were in common use in marine engines. Giffard's injector for feeding boilers had been introduced and economy of steam had been pursued so successfully that the low figure of 1.62 lbs. per I.H.P. per hour had been achieved on trial trips, whilst the average of a number of ocean voyages was 2.11 lbs. About this time vessels required one H.P. to every 3 to 4½ B.M. (or to 8 d.w.) tons. Boilers were evaporating 10 to 12 lbs. of water per lb. of Welsh coal consumed. At this point it will be convenient to suspend the sketch of technical developments and consider other aspects of the industry during the period so far surveyed. It may be well to emphasise the fact that few inventions or improvements were made which did not either originate or receive their earliest practical application in the Clyde area. Alike in design and execution the vast majority of ships and engines produced in the West of Scotland were unsurpassed by those from any other area of the United Kingdom. The hereditary transmission of acquired characteristics and skill is still in doubt; but the capacity for engineering seems almost to have been native to our district. It may have been that the individual was strongly influenced by his environment, social and economic; but, however it be explained, assuredly engineering ability did run in families, generation after generation of which took up the work where their fathers left off and brought it nearer perfection. In citing Scott and Denny, Watt and Thomson, Elder and Napier, we name only a few of the more notable West of Scotland shipbuilding and engineering families. Here lived and worked many of the early pioneers of iron as against wooden ships; from here came the first steamboats in Europe. But even the most visionary of these men could scarcely have conceived the extent and importance of the industry of which they laid the foundations.

CHAPTER VI.

THE RIVALRY OF STEAM AND SAIL.

The sailing ship did not relinquish her position as mistress of the seas without a prolonged and gallant struggle against the usurping steamship. As with any innovation, particularly when financial interests are involved, strenuous opposition was offered to steam navigation, at first only by those immediately affected - the coach and fly-boat proprietors - but later by business interests much more extensive. So long as steamboats were small in size and of modest power, plying only on rivers and round the coasts, their rapidity of transporting goods was appreciated even by the builders and owners of sailing vessels. But as they grew larger and more powerful, competing for cross-Channel and Continental traffic, the outlook for sail became more ominous. Even then, for many years, the sailing ship with her tall masts and majestic spread of canvas, crossed the ocean unmolested by the ugly, squat, smoky paddle steamers of later days. As the marine engine developed, it became evident that rodomontade about the tried and safe mode of navigation could not effectively resist the encroachment of steam upon the hitherto unquestioned domain of sail, though it might retard it. Innuendo and prejudice - forms of opposition of which the utmost use was made - were alike futile. The owner of the sailing vessel had to compete with the steamship on the economic grounds of cost, speed, and safety. Improved design and numerous economies in working enabled the sailing ship to maintain its existence for upwards of half a century from the time when the first steam driven vessel navigated British waters. The struggle was long drawn out. Like Charles II, the sailing ship was "a most unconscionable time dying"; but its protagonists did not imitate that cynical monarch by apologising for the prolongation of its existence.

Steam navigation naturally began on rivers and sheltered lochs but only a short time elapsed ere steamboats were voyaging along the unprotected coasts and crossing the channels of open sea which separate Ireland from Britain and Britain from the Continent of Europe. In 1816 the "Hibernia" took up the Holyhead to Howth passage. Two years later the "Rob Roy" (90 tons; 30 H.P.) the second steamboat built by William Denny, Senr. at Dumbarton, was plying on the Greenock to Belfast route and after a short period was transferred under the name "Henry IV" to the English Channel crossing.[1] Steam communication between Holyhead and Dublin was initiated by the "Talbot" in 1819. In 1824 Messrs G. & J. Burns commenced their Greenock to Belfast service. Their first vessel the "Fingal" (296 tons; 100 H.P.) was engined by David Napier; their second, the "Eclipse", by

1. See p. 103 above.

Robert Napier. During 1819 the voyage eastwards across the Atlantic was accomplished by the "Savannah" (350 tons; 90 H.P.) built by Francis Fickett of New York. The claim that this constituted the first trans-Atlantic voyage under steam cannot be sustained as the engine was only auxiliary to the sails and, according to the ship's log, was in operation for 80 hours only out of the 29½ days which the trip occupied. The voyage was purely experimental, no attempt being made to establish a regular steamship service till many years later. The "Conde de Pamella", a sailing vessel having auxiliary steam, made the first westward crossing from Liverpool to Brazil, via Lisbon in 1820. Five years later the "Falcon" (176 tons) rounded the Cape of Good Hope and reached India. In this case too the engine was only used as an auxiliary. In the same year, however, the "Enterprise" (470 tons; 120 H.P.) following the same route from London reached India in 113 days, having been under steam during the whole voyage, except for the 10 days occupied in re-coaling on the way. In 1827 the "Curoca" (400 tons; 100 H.P.) made the first direct voyage to South America with auxiliary steam. While in operation her engines consumed 7.14 lbs. of coal per H.P. per hour. The "Royal William", Canadian built but driven by Boulton and Watt engines, crossed from Nova Scotia to Portsmouth in 17 days, but again a considerable part of the voyage was performed under sail alone.

Dr. Lardner, author of a standard treatise on steam, is rpported to have said about this time:[1] "As to the project

1. In a lecture to the Royal Institution in 1838; see "The Ship Under Steam" (1927) by G. Gibbard Jackson.

of making a voyage directly from New York to Liverpool (under steam alone), it is, I have no hesitation in saying, perfectly chimerical and they might as well talk of making a voyage from New York to the moon." Later he denied that his words implied that trans-Atlantic steam navigation would for ever remain an impracticable dream, but merely that, so long as the marine engine remained at the stage of development reached, such a voyage was beyond the bounds of possibility. Nevertheless a literal interpretation of the words quoted would give a fair representation of the attitude of many laymen at this time towards the possibility of ocean steam navigation. However, the advance made in boiler and engine efficiency was so rapid that as early as 1838 the Atlantic was conquered by the steamship. In quick succession four vessels crossed from Britain to America. The first to accomplish the trip was the "Sirius" (178'4" x 25'8" x 18'3"; 703 gross tons, 412 net tons; 250 H.P. and fitted with Hall's surface condensers) built by Menzies of Leith and engined by Wingate & Co., Glasgow. She started from Cork on 4th April, 1838. The trip occupied 18½ days, and passed without any untoward incident, a distinct triumph for Clyde built engines. Larger, and perhaps better known was the second of these vessels, the "Great Western" which, in addition to being an engineering triumph, was a commercial success. In 1839 the Cunard Co. was formed for the purpose of giving a regular steamship service to America.[1] Samuel Cunard, Burns & McIver (who from 1830 to 1840 had organised the Liverpool to Ireland service), and Robert Napier were the chief parties concerned in its foundation. Four steamships - the "Britannia", "Acadia", "Caledonia", and "Columbia" - were built. They were of approximately the same dimensions and power (206' x 44'; 1,150 tons; 440 N.H.P.). The four were built by Robert Duncan, John Wood (of Greenock and Port Glasgow), Charles Wood, and Robert Steel respectively, and all were engined by Robert Napier of Glasgow. The "Britannia" was the first to make the crossing and accomplished it in the record time of 14 1/3 days, arriving at Boston on 4th July, 1840. The aim of the Company was to give a regular and reliable service; hence all their vessels prior to 1855 were wooden paddle steamers. In that year their first iron hulled ship, the "Persia" (350' x 45'; 3,300tons; 3,600 I.H.P.) was launched on the Clyde. The advance in size and power will be noted, but the old form of propulsion by paddles was still retained. She made the New York to Liverpool passage in 9½ days, a very creditable performance for her time. Even after this the Company continued to have wooden paddle steamers built, the last of these being the "Arabia" in 1864. Iron paddle steamers were also built until 1862, the last of this type ordered by the Company being the "Scotia" launched that year. Thereafter the Cunard Co.

1. The Allan Line had been providing a sailing-ship service since 1823, but did not adopt steam until 1854. Other shipping lines founded about the same time included:

P. & O. Coy. 1837-41
Pacific Mail Co. 1843
Collins Line (American) 1850
African Mail Co. 1851.

built up a fleet of iron screw steamships.

Meanwhile an American company - the Liverpool, New York, and Philadelphia Co. - had entered into competition with the Cunard Co. Under the guidance of Mr. Inman they purchased the "City of Glasgow" (1,600 tons; 300 N.H.P.) an iron screw vessel built by Tod and Macgregor of Glasgow. The experiment of sending such a vessel across the Atlantic was regarded as hazardous, but the success of her maiden voyage was such that the same Company followed up with many other vessels similar in type but continuously increasing in size. In 1852 two iron screw steamers were designed by I.K. Brunel and Scott Russel and built by the latter for the Australian Mail Steam Navigation Co. They made the fastest voyages to Australia hitherto accomplished. Cargo vessel owners were also making steady advances in the application of iron hulls and screw propulsion to their type of business. The Cunarder "Scotia" (367' x 47'6" x 32'; 3,871 tons; 4,950 I.H.P.) Clyde built like all the vessels of that Line, was the most famous paddle steamship of her day. On her trial trip she developed a speed of 19 m.p.h. and made the regular Atlantic crossing eastward in 8 days 22 hours. She was remarkable for strength of construction, having six water-tight bulkheads and four cassion compartments. Her complement was 300 passengers and 1,800 tons of bunker coal. Shortly after the "Scotia" came the first screw Cunarder, the "Russia" (358' x 42'6"; 2,959 tons; 3,100 I.H.P.) built by J. & G. Thomson of Clydebank. Smaller than the "Scotia" and with proportionately smaller engine power, she nevertheless made the Atlantic trip in even less time than her distinguished predecessor.

The foregoing account of the progress made in steam navigation will help us to realise the competition which the sailing vessel had to meet. One by one the domains in which sail had been regarded as secure were invaded by steam. The cross-Channel services, the regular Atlantic service, mail transport, and finally, with the economy rendered possible by the advent of the compound engine, the Australian and Pacific trades, successively came within the ambit of the steamship. Up to 1850, however, there was no year in which the steam tonnage launched in the United Kingdom exceeded 13% of the total tonnage launched during the year. Thus, throughout the first half of the nineteenth century the menace of steam to the established mode of navigation was not too serious; but thereafter it became more threatening. Within five years, 30% of the tonnage launched annually was steam. In 1865 the 50% figure was touched. From this time onwards to the end of the century a remarkable periodic fluctuation in the percentage of steam to total tonnage launched took place. The percentage of sailing vessels on the register of the United Kingdom fell continuously except for three brief halts in 1859, 1863, and 1875. These were years when particularly large tonnages of sail were launched. But not till 1882 did steam and sail divide equally the tonnage on the register. In comparing figures for tonnages of steamships and sailing ships three facts must be kept in view:

1. A "steam" ton signifies a carrying capacity twice to three times that of a "sail" ton, owing to the difference in the average speeds of the two types of vessel;

2. The "wastage" of sail is much greater than of steam; for example, in 1858 when 154,930 tons of sail were added to the register, 131,446 tons were lost by wrecking, whereas the figures for steam in the same year were 53,150 tons and 5,720 tons respectively.[1]

3. In addition to accidental loss, many sailing ships were sold to foreigners or broken up every year.

Thus the launch of a large tonnage of sail in any year does not necessarily signify a net addition to the total on the register.

Anticipating for a moment the discussion of a future chapter on the periodic fluctuations in the shipbuilding industry, it may here be noticed that these correspond closely to the general trade cycle. Now it was invariably in the years of depression between 1865 (when the tonnage of steam vessels built first constituted 50% of the total) and 1905 (when sail became quite negligible) that a revival of sail took place. The fluctuations were considerable and persistent. It seems strange that whilst steam was steadily increasing on the register and sailing vessels were being disposed of in large numbers by wrecking, scrapping, and selling, ~~that~~ there should be a periodic revival in the building of new sailing ships. The phenomenon deserves some attention.

Prior to the introduction of the compound engine which resulted in a very large reduction in fuel consumpt, steamships were unable to engage in the trade of the Pacific and other distant parts. Superiority in speed as between

1. Trade report of the U.K. for 1858; quoted in the Journal of the Royal Statistical Society, Vol.23. (1860).

steam and sail was still an open question, though it may be noted in passing that a steamship, carrying troops from Britain in 1857 to quell the Indian Mutiny, arrived before a sailing vessel that had set out a month earlier. The year 1854 will form a convenient starting point; prior to this steam tonnage had never amounted to as much as 25% of any year's output and constituted only 10% of that on the fegister. Sail tonnage had therefore dominated and the total fluctuated accordingly. In the 1855 boom sail and steam moved upwards together,[1.] and fell during the ensuing depression. Again in the 1864-5 expansion they moved pari passu, but thereafter diverged. Sail experienced a boom in 1868-9 when steam was depressed, but in 1872 fell to 12% of the total United Kingdom output whilst steam soared up to 88%. The next depression saw sail again forming the major part of the output and steam down to 36%. At each succeeding boom and depression a similar phenomenon was observed, until 1892 when sail rose for the last time. Clyde figures generally moved parallel with those of the United Kingdom, the only significant divergence being in 1890 when the depression did not begin in the North till the following year. If allowance is made for the fact that one "steam ton" had a carrying capacity equivalent to three or four "sail tons", the inverse variation described held good even for the period 1855-68 when sail seemed to predominate.

Before 1860 ocean transport by the agency of steamships was confined almost solely to mails and passengers.

1. For full data see Table C.3. and Graphs C.1. and C.2.

Steam was utilised by cargo vessels only on coastwise and river routes. Bulky materials such as grain, iron, and coal were taken from one country to another by sailing ships. Up to the middle of the eighties, when twin screws came into general use, steam vessels of all kinds - even the big Atlantic liners - carried sails. Two reasons for this practice may be cited:

1. for cases of emergency, such as a breakdown in the engine room;
2. to assist in the management of the ship when sailing "light" or in heavy seas.

Now engines and boilers constituted a large fraction of the initial cost of a vessel. What more natural then, in periods when shipping was less remunerative than usual, than that owners should omit the costly items and for motive power rely solely on the "unbought winds"? The saving achieved was threefold:

1. in initial cost;
2. in space, for with engines, boilers, and bunkers eliminated anything up to twice the carrying capacity for the same deadweight tonnage could be obtained;
3. in fuel costs.

The auxiliary steam vessel, a ship designed primarily as a sailing vessel but fitted with a small engine to carry it across the "doldrums", was popular during these periods of depression. The engine was of sufficient power to drive the ship in calm water at a speed of 7 or 8 m.p.h. - say one H.P. for every 10 tons burthen. Such vessels were classed as sailing ships; for although all steam vessels at this time carried sails, the line of demarcation was drawn between those in which the engine was in operation during the whole voyage (steamships) and those in which it worked only for a short time (sailing ships). The auxiliary steam vessel realised a very considerable saving in prime costs and yet was not so far behind in speed, the greater part of the time lost by sailing vessels being occasioned by belts of calm encountered during the voyage. There were certain trades also, such as the South American guano and nitrate trade or the North American cotton or tobacco trades, in which speed was of little account, the articles being of the non-perishable class of which large stocks were maintained in the importing country. Another factor in favour of the sailing ship was the smaller crew required, particularly with the fore and aft rig which came into favour as it necessitated only one third of the number of men demanded by the older square rigged type. Sails, for which the flax came from Russia and Poland, and ropes were costly items; but these were required for steam and sailing ships alike. About 1860 wire ropes of iron or steel came into use for the fixed rigging of first class vessels, replacing the cordage which had to be imported from Malabar and the Philippines. Masts and bowsprits of iron or steel were also introduced.

But the economic factors favouring sail outlined above were present during trade booms as well as during depressions, and therefore do not explain satisfactorily the popularity of the sailing ship during the latter periods. The ultimate explanation must be attributed to the fact that, in times of bad trade, merchants having cargoes to ship were looking for the cheapest rather than the speediest mode of transport;

whereas during a boom in trade, time became an important factor. It would scarcely be fair to allege that shipowners as a body were conservative, but they do seem to have been influenced easily by what a few initiated, whether that were an advance or a regression. The spirit in which later they plunged for turbines and diesel engines was the same as that which induced them to return to sail in times of depression and to discard it again, when better times returned, in favour of the latest improvements in marine propulsion. As steam power progressed towards its ultimate conquest of the seas, the designers and builders of sailing ships strove manfully to meet the increasing competition. Just at the time when David Elder was perfecting his compound engine, the clipper ship was being revived for the China tea trade. This was a very fast type of sailing ship designed with graceful stream lines[1]. Efficiently manned and with some luck when crossing the "doldrums", they achieved phenomenally fast passages, rivalling at times the most up-to-date steamships of their day. As an example the Clyde built iron clipper, the "Lord of the Isles", launched in 1856 may be cited. This vessel on one occasion made the passage from Shanghai to London with 1,030 tons of tea in 87 days. On another trip she averaged 320 miles per day (i.e. 13.3 m.p.h.) for five consecutive days. This

1. "Java Head", a novel by Joseph Hergesheimer deals with this period and gives a realistic picture of the opposition which this new type of sailing ship had to meet from those who, being accustomed to the older type, were not sufficiently far-sighted to observe that the rivalry of steam must be met.

performance may be compared with that of the mail steamer "Nemesis" which, sailing from New York in January, 1870, covered 319.4 miles per day on the average.

The "China clippers" began about 1850. They were built on lines similar to two previous types which had flourished for a period, the "opium clippers" from 1830 to 1850 and the American tea clippers which from 1846 to 1860 made the U.S.A. a serious rival to Britain for the mastery of the seas. Ranging from 180 ft. to 210 ft. in length and from 600 to 1,100 tons burthen (averaging about 800 tons), the china clippers were mostly composite ships. One or two[1.] only were of iron. Clyde shipyards had full share in the building of these vessels, being responsible for 37 (totalling 28,637 tons) out of the 85 (totalling 64,658 tons) which were constructed in Britain between the years 1853 and 1869. One of the last and most famous of them, the "Cutty Sark", was built by Scott & Linton - a firm now long defunct - at Dumbarton.[2.] The great years of the clipper were from 1863 to 1869; and this interval, it will be noted, was one of the periods when sail tonnage was rising. The opening of the Suez Canal in 1869 killed the clipper ship, since it shortened the route from Britain to the East by 3,000 to 5,000 miles for steamships.[3.] But the extent to which the sailing ship held its own for many years on the long ocean voyages is illustrated by the following table

1. For example, the "Lord of the Isles" mentioned abovĕ.

2. "The China Clippers" (1926) by Basil Lubbock.

3. Sailing ships cannot negotiate the canal.

which analyses the tonnage cleared from British ports in 1868:

Trade	Sail (net tons)	Steam (net tons)
with U.S.A.	1,744,658	1,429,333
with Egypt	327,945	577,188
with India & China	2,124,787	36,043
with Australia & New Zealand	510,167	7,756

The same conclusion is indicated when we consider the changes in composition of the U.K. register of shipping. Statistics for four decennial periods are given in the tables[1] below the first of which refers to coastal vessels and the second to vessels engaged in foreign trade.

Coastal

Year	Sail			Steam			Total		
	Vessels	Net tons	Aver.	Vessels	Net tons	Aver.	Vessels	Net tons	Aver.
1850	8,830	666,957	75	320	54,196	169	9,150	721,153	79
1860	10,848	821,079	75	402	92,254	229	11,250	913,333	81
1870	11,598	766,742	66	1,070	170,746	159	12,668	937,388	74
1880	10,317	669,301	64	1,295	233,271	180	11,612	893,572	77

Foreign

Year	Sail			Steam			Total		
	Vessels	Net tons	Aver.	Vessels	Net tons	Aver.	Vessels	Net tons	Aver.
1850	7,149	2,143,324	299	86	45,186	525	7,235	2,188,420	303
1860	6,876	2,804,610	407	447	277,437	620	7,323	3,082,047	422
1870	6,757	3,468,717	513	935	760,410	813	7,692	4,229,127	550
1880	4,179	2,749,385	655	2,193	2,216,057	1,010	6,380	4,965,442	778

It will be noticed that, on the average, steamships in both

1. These and several subsequent tables have been compiled from the series of papers on the progress of British shipping read before the Royal Statistical Society by John Glover and printed in the Journals of the Society for the years 1863, 1872, 1882, 1892, and 1902.

kinds of trade were much larger than sailing ships of the same class. We may also draw attention to the fact that the gross tonnage of a sailing ship is normally very little more than the net tonnage, whereas with a steamship the gross tonnage is usually about one and a half times the net tonnage. Sail tonnage in the coastal trade began to decline in the period 1850-60; simultaneously steamships were multiplying rapidly. In the category of foreign trade the decline of sail was delayed till the next decade and even as late as 1880 steam was still some half million net tons[1] behind its competitor. Sail tonnage on the register touched its maximum in 1865. The small rate of increase in the total tonnage of coastal vessels between 1850 and 1870 and the actual decline of this class in the decade following is to be accounted for by the competition offered by the railways.

But mere statistics of tonnage on the register are misleading because steamships in general had a much higher speed than sailing ships and could therefore make many voyages in any given period of time. This is most suitably assessed by what is called the "degree of activity" of the vessel; that is the figure arrived at by dividing the tonnage of British ships entered at and cleared from ports of the United Kingdom during twelve months by the tonnage on the register for the same year. The increasing efficiency of both steam and sailing ships may be gauged from the figures given in the table below. Throughout the whole period under review one "steam" ton equalled in activity

1. See remark above regarding "sail" and "steam" tons; also Appendix 4, "On the Measurement of Capacity of Ships."

kinds of trade were much larger than sailing ships of the same class. We may also draw attention to the fact that the gross tonnage of a sailing ship is normally very little more than the net tonnage, whereas with a steamship the gross tonnage is usually about one and a half times the net tonnage. Sail tonnage in the coastal trade began to decline in the period 1850-60; simultaneously steamships were multiplying rapidly. In the category of foreign trade the decline of sail was delayed till the next decade and even as late as 1880 steam was still some half million net tons[1] behind its competitor. Sail tonnage on the register touched its maximum in 1865. The small rate of increase in the total tonnage of coastal vessels between 1850 and 1870 and the actual decline of this class in the decade following is to be accounted for by the competition offered by the railways.

But mere statistics of tonnage on the register are misleading because steamships in general had a much higher speed than sailing ships and could therefore make many voyages in any given period of time. This is most suitably assessed by what is called the "degree of activity" of the vessel; that is the figure arrived at by dividing the tonnage of British ships entered at and cleared from ports of the United Kingdom during twelve months by the tonnage on the register for the same year. The increasing efficiency of both steam and sailing ships may be gauged from the figures given in the table below. Throughout the whole period under review one "steam" ton equalled in activity

1. See remark above regarding "sail" and "steam" tons; also Appendix 4, "On the Measurement of Capacity of Ships."

between four and five "sail" tons, though this high ratio may be somewhat offset by the fact that a greater number of steam vessels entered or cleared in ballast than was the case with sailing vessels.

Degree of activity of vessels belonging to the U.K.:

	Sail	Steam
1850	2.24	10.71
60	2.31	9.22
70	2.56	11.98
80	2.69	11.37

Another standard by which we may judge the improvements made in the operation of both types of vessel is the diminishing number of seamen required per hundred tons. The following table gives this for British vessels employed in the foreign trade:

	Sail	Steam
1850	4.3	8.4
60	3.4	6.4
70	2.7	4.3
80	2.3	3.3

About 1880 the merchant navies of the leading countries of the world stood in the following order of importance:

Country	Year	Tonnage engaged in foreign trade.		
		Sail	Steam	Total
U.K.	1880	3,799,221	2,720,551	6,519,772
Colonies	1880	1,698,868	228,531	1,927,399
Norway	1878	1,474,925	51,764	1,526,689
U.S.A.	1880	1,196,487	156,323	1,352,810
Germany	1879	944,943	196,343	1,141,286
Italy	1879	933,306	72,666	1,005,972
France	1879	676,894	255,959	932,853
World		11,697,250	3,932,638	15,629,888

The British fleet of merchantmen constituted nearly half the world's total at this time and the steamship tonnage of the U.K. was nearly three times that of all other countries combined. The advent of the triple expansion engine and of twin and multiple screws in the eighties sealed the fate of the sailing ship. Subsequently although two distinct revivals in the construction of sailing ships occurred - during the trade depressions of 1885-6 and 1892 - sail tonnage never again amounted to 50% of the total launched in any year. From 1900 onwards it settled down to a negligible fraction (varying from 8.5% to 2.4%) of the total annual production. Only in three years - 1885, 1891, and 1892 - was there a net addition of sailing ships to the register and this was due partly to a diminution in sales to foreign owners. Even in these years the additions made were not sufficient to reverse the steady fall in the percentage of sail to total tonnage on the register, a fall which had begun with the introduction of steam and which had, with a few temporary interruptions, (the last being in 1875) continued since. After 1888 removals of steam tonnage from the register increased and greatly exceeded removals of sail which took a downward trend. This merely indicates that, as losses and sales continued year by year, fewer sailing vessels remained to be eliminated. At the outbreak of the Great War there was considerably less than a million gross tons of sail on the United Kingdom register compared with nearly twenty million gross tons of steamships.

A large proportion of the sailing ships removed were sold abroad and thus became part of the mercantile navies of foreign countries, competing with British vessels. Norway, Germany, and Italy were the chief purchasers. Onwards from 1890 steamships aggregating hundreds of thousands of tons annually passed under foreign flags, prominent among which were the Italian, Japanese, Norwegian, Greek, German and French colours.[1] Naturally the ships sold were mainly old or even obsolete vessels and therefore lacked the efficiency necessary for effective competition. But advancing industrial countries such as Germany were building modern steam vessels for themselves. The effect may be seen in the following table which shows the tonnage (in millions) of vessels of all countries engaged in foreign trade which entered or cleared from ports of the United Kingdom in cargo or in ballast:

Year	British owned			Foreign owned			Total		
	Sail	Steam	Total	Sail	Steam	Total	Sail	Steam	Total
1840		0.7			0.1			0.8	
1850	7.6	1.8	9.4	4.7	0.4	5.1	12.3	2.2	14.5
1860	9.7	4.2	13.9	10.0	0.8	10.8	19.7	5.0	24.7
1870	11.8	13.3	25.1	9.8	1.8	11.6	21.6	15.1	36.7
1880	10.3	31.0	41.3	11.2	6.2	17.4	21.5	37.2	58.7
1890	5.0	49.0	54.0	7.4	12.9	20.3	12.4	61.9	74.3
1900	2.4	60.3	62.7	5.8	30.0	35.8	8.2	90.3	98.5

So long as the sailing ship was the principal means of transport, foreign shipping carried a very substantial fraction of our imports and exports. When, however, steam superseded sail (approximately from 1865 onwards) British shipping forged ahead and foreign countries lagged

1. For details of this see Appendix 6.

till they too, with the approach of the twentieth century, modernised their fleets.[1]

Unfortunately as one set of statistics shows gross tons and the other net tons,[2] a comparison of the Clyde with the United Kingdom as regards the percentage which sail constituted of the total output year by year cannot be made.[3] Many Clyde builders had begun quite early in the nineteenth century to specialise in the construction of steamships, and thereafter they maintained their technique well abreast of that prevailing generally. One or two, most notably Russell & Co. of Port Glasgow[4] and Connell & Co., devoted themselves almost exclusively to sailing ships, but about 1894 they too turned over to the construction of steamships. In 1877 there were on the Clyde 104 individuals or firms owning iron sailing ships. By 1907, 74 had disappeared, 17 had gone into other business while 13 of the original number remained, and 28 new owners had come in. Thus in all, in 1907, there were still 41 sailing ship owners, but the total value of their vessels was only £950,000.

1. The fact that in 1849 the Navigation Laws (Repeal) Act was passed is not being overlooked. The effect of this measure is considered in Chap.IX. But the argument in the text above holds good irrespective of that Act.

2. See Tables C.1. and D.1.

3. Figures showing gross tonnage for United Kingdom do not begin till 1886. For the separate percentages see Tables C.3. and D.1.

4. In 1846 this firm employed only 60 to 70 men, but by 1893 their employees numbered 1500. See "Royal Commission on Labour"; Vol.III; Group A. (House of Commons Reports and Papers for 1893-4; session vol.32.).

So rarely does a "wind-jammer" of any considerable size today grace a British harbour that, when such an event does occur (the ship usually being a foreign one) photographs of the vessel appear in the daily newspapers and crowds of people gather on the quay to view it; much as, a century ago, a ship driven by steam or constructed of iron was an object of curiosity. To some the passing of the sailing ship signifies the termination of maritime romance; to many it has occasioned genuine and deep regrets. Rudyard Kipling expressed their sentiments when he wrote:[1.]

> "Farewell, Romance!" the traders cried;
> "Our keels have lain with every sea.
> "The dull-returning wind and tide
> "Heave up the wharf where we would be;
> "The known and noted breezes swell
> "Our trudging sails. Romance, farewell!"
>
> "Good-bye, Romance!" the Skipper said;
> "He vanished with the coal we burn.
> "Our dial makes full-steam ahead,
> "Our speed is timed to half a turn.
> "Sure as the ferried barge we ply
> "'Twixt port and port. Romance, good-bye!"

Talk to the "old salts" still to be found "taking the air" daily by the quayside of all but the largest harbours. Real seamanship, they will tell you, is no longer an essential qualification of the "A.B." A ship isn't what it used to be - decks to be chipped instead of holystoned; wire ropes in place of manilla cordage; funnels belching forth black smoke instead of white sails "bellying" to the

1. That he himself did not wholly share this view is brought out in a later verse of the poem ("The King", in the collection entitled "The Seven Seas.").

breeze; everything done by machinery, nothing but noise and dirt! But if there has been a sacrifice of skill in certain categories of labour connected with navigation, in others the application of steam and oil has created the need for a degree of accuracy and co-ordination exceeding anything required in the olden days. If the sailing ship with a full spread of canvas created the sense of beauty combined with peace, no less does the ocean greyhound and battle crüiser present a picture of beauty, enhanced rather than diminished by the accompanying sense of power. Ocean transport today represents a greater control over the forces of Nature than that possessed by the most capable mariner of the age of sail; for the use of the winds which so long served man upon the sea has been discarded only because of the greater service which can now be obtained by tapping the congealed sunlight of bygone ages.

CHAPTER VII.

THE ERA OF STEEL.

The modern era in shipbuilding may be taken as covering the period subsequent to 1875, and it was ushered in by two important changes: one, the invention of the triple expansion engine for marine purposes, and the other the replacement of iron by steel as a constructional material for ships. Though the latter did not take place until some years after the former, we will deal with it first as it concerns the hull of the vessel as well as the engines. Iron had scarcely established supremacy over timber, when mild steel arrived to replace it. The layman who finds difficulty in distinguishing between wrought iron and mild steel may fail to appreciate the full significance of the change, but he will be correct in assessing its importance lower than that from wood to iron. Nevertheless, from the shipbuilders' and engineers' point of view, the substitution of steel for iron did herald the commencement of a new era in their respective industries. The manufacture and working of the new material required a technique different from that for iron, knowledge of which the manufacturers and constructional engineers of the West of

Scotland were not slow to obtain. The advantages of mild steel over iron may be summarised as follow:

1. It is more ductile both across and with the grain.
2. It has 30% greater tensile strength with the grain and 50% greater across it.
3. Its elasticity (i.e. power to resume original form after being subjected to stress) is greater.

For marine boilers steel was first tried by the Admiralty in 1857, but the results were far from satisfactory. After this the hulls of a number of small vessels were constructed of mild steel, one of the first - if not the very first - being the "Ma Robert" in which David Livingston ascended the Zambesi River in 1858. A year later Messrs Samuda Bros. of London built the "Jason", a 452 B.M. ton steel ship for the Black sea, and in 1860-1 five Dover Mail Packet boats (ranging from 566 to 757 tons) all of which had steel hulls, were launched. Iron hulled ships averaged £10 per ton at this time whilst steel ships were £26 per ton.[1.] In 1862 Lloyd's received an application to class a "puddled" steel vessel. Two years later a steel steam yacht for the Viceroy of India was actually classed, a reduction of 25% in the scantlings being permitted. Rules for steel vessels were issued in 1877. These allowed the scantlings to be 20% lighter than for iron but prescribed limits of 27 to 31 tons per sq. in. (raised a few years later to 28 and 32 tons per sq. in. respectively) for the tensile strength of the material used. The first naval vessel of

1. "On the Construction of Iron Ships"; a paper by John Vernon, recorded in the Proceedings of the Institute of Mechanical Engineers. (1863).

mild steel was the "Iris" (3,730 tons; 7,556 l.H.P.) built in 1876-7 at Pembroke Dockyard. In 1877 John Elder constructed at Govan two mild steel paddle steamers for the English Channel service. The table below shows the number and tonnage of steel vessels registered with Lloyd's about this time, and also for comparison the total of all vessels registered with them:[1]

Year	British owned				Foreign owned				Total			
	Steel		All types		Steel		All types		Steel		All types	
	No.	Gr. tons	No.	Gr. tons	No.	Gr. tons	No.	Gr. tons	No.	Gr. tons	No.	Gr. tons
1878	5	2,929	565	533,047	2	1,541	84	41,772	7	4,470	649	574,819
1879	7	14,173	447	486,854	2	1,827	54	34,484	9	16,000	501	521,338
1880	21	33,247	442	493,542	2	2,126	38	24,122	23	35,373	480	517,664

A momentous advance in steel manufacture had been made in 1856 when Henry Bessemer invented the process that bears his name. It was applicable only to those ores which contained a small percentage of phosphorus, the cupola lining being of an acid nature. In 1878, however, S.G. Thomas and P.C. Gilchrist published their discovery of a basic lining for the Bessemer converter. This made possible the use of phosphoric ores which hitherto had been useless owing to the brittleness of the steel produced from them and of which vast quantities existed in Alsace, Lorraine, and Luxembourg. Basic Bessemer steel was thus of untold value to the German industry but of little account in Britain where phosphoric ores were practically non-existent. Its tensile strength was 24 to 28 tons per sq. in. and so did not come up to Lloyd's specification; in fact, about 1887,

1. Figures obtained by courtesy of Lloyd's Registry at their head office, Fenchurch Street, London.

its use for hulls of vessels to be registered with that institution was prohibited. Meanwhile William Siemens had in 1867 succeeded in producing good quality steel in an open hearth regenerative furnace. Messrs Martin made some improvements to the furnace. Consequently this method of manufacturing steel is known as the Siemens-Martin process.

In 1881 iron ships' plates cost £6 per ton whilst steel plates were £9. 12. 6. per ton,[1.] but with the smaller scantlings permitted, the price of a steel ship per d.w. ton exceeded that of an iron ship only by about 10/-. Thereafter steel fell in price, but for a number of years iron was substantially the cheaper material. Mild steel boiler plates were still more expensive, their price in 1881 ranging from £25 to £27 per ton.[2.] However, many vessels were now being furnished with steel boilers having plates ½" to 15/16" in thickness according to the pressure they were required to withstand. In the year 1877-78 only two ships were supplied with steel boilers, but in the following year 120 ships were thus equipped. During 1879-80 no fewer than 280 vessels - representing 600 boilers - were furnished with steel boilers. In the next year over 1,000 steel boilers were installed. But for some years only first class passenger ships were built wholly of mild steel. The first steel liner was launched

1. See paper on: "Iron and Steel for Ships", by John Price; Proceedings of the Institute of Mechanical Engineers (1881).

2. See paper on: "The Increasing Use of Steel for Shipbuilding and Marine Engineering", by John R. Ravenhill; Transactions of the Institute of Naval Architects (1881).

in 1879 by Denny Bros. of Dumbarton, to the order of the Union S.S. Coy. of New Zealand. The second was the "Buenos Ayrean" for the Allan Line, followed by the "Servia" (515'; 7,392 tons; 10,000 I.H.P.) in 1881 for the Cunard Line, both being Clyde built ships. In 1883, out of the 1,100,202 tons of shipping surveyed by Lloyd's that year, 933,774 tons were of iron or wood and only 166,428 tons were of steel.[1] But very soon mild steel became cheaper than wrought iron[2] for ships, considering the lighter scantlings permitted, and by the end of the decade well over 90% of vessels being built were of steel. It is noteworthy that the greatest increase in the percentage of steel to total launched took place in 1886, during the depth of a trade depression. The following table, calculated from annual reports given by the "Glasgow Herald" and relating to Clyde output, illustrates the triumph of steel:

Year	Total launched (gross tons)	Steel (gross tons)	% Steel/Total
1879	174,750	18,000	10.3
80	236,579	42,000	18.1
81	341,022	66,609	19.5
82	391,934	108,254	27.7
83	419,664	129,651	31.0
84	296,854	133,670	45.0
85	193,458	92,677	48.0
86	172,440	116,932	68.5
87	185,362	148,596	80.0
88	280,037	269,480	96.0
89	335,021	326,136	97.2

1. See Presidential Address by Jeremiah Head to the Institute of Mechanical Engineers (1885).

2. Steel plates in 1886 cost £6. 2. 6. per ton.

From the above it will be seen that the Clyde was well ahead of the general position which may be judged by Lloyd's figures for 1884. These show only 15.1% of steel as compared with 45.0% for the Clyde. From 1890 onwards the percentage of steel to total tonnage launched each year in the West of Scotland fluctuated between a minimum of 96.2 in 1896 - a year of sailing ship revival - to a maximum of 99.8% Previous revolutions in shipbuilding and marine engineering practice had taken much longer in accomplishment. Iron did not definitely supersede wood, it will be remembered, till 1855, more than 60 years after the first iron vessel had been launched, and the supremacy of steam was in doubt half a century after the "Comet" had successfully navigated the Clyde.

Other important structural changes in ships took place during the modern era and these merit brief notice. The cellular double bottom, introduced by the English firm Austin & Hunter and incorporated by them in the S.S. "Fenton" launched in 1876, was in general use by 1887; though two of the largest and fastest Atlantic liners built in 1889 still retained the single plated hull. Subsequently all large vessels incorporated the double bottom as it ensured greater protection against damage. Special designs to give cargo vessels a clear hold - that is, one without pillars or supports to interfere with the stowing and handling of cargo - were produced by several shipbuilding firms. Messrs Doxford of Sunderland introduced the "turret" type in 1892, the first vessel exemplifying it being the "Turret", a ship of 1970 gross tons. "Trunk deck" and "trunk self-trimming" ships designed with a similar aim must be credited to Messrs. Ropner of Stockton-on-Tees, who in 1896 constructed the first of this type, the "Trunkby". Another class was termed the "whaleback" type, the "Sagamore" being its first representative. In 1904 Sir Raylton Dixon & Co. followed up with the "cantilever" type exemplified in the first instance by the "Hedwig Heidman." The holds of this type had no obstacles to the stowing of cargo and the engine room was placed aft on the vessel. Finally, and perhaps most important of all, came the Isherwood system of longitudinal framing which promised a complete solution to the problem of obtaining a clear hold. It became fairly popular, but owing to constructional difficulties only a few firms specialised in the production of such ships. Those which did so reaped substantial orders.

Another matter deserving notice is the development of special types of steamships for particular cargoes such as frozen meat and petroleum in bulk. The first cargo of frozen meat was brought in 1880 from Australia to Britain in an ordinary steamer, temporarily adapted for the purpose, whilst the first oil "tanker" was built in 1885. For the former trade, special vessels equipped with refrigerating apparatus and chambers lined with non-conducting materials were soon under construction. For the bulk-oil trade, ships were designed with tanks occupying the space normally devoted to the holds and provided with means of rapid filling and emptying. Elaborate precautions against leakage and rolling effects in a heavy sea are incorporated in the design and, if the ship be driven by steam,[1] the engine and boilers are placed at the stern to minimise the risk of fire. Since the Great War, oil tankers have increased enormously in number, but even in 1914 this class comprised vessels aggregating one and a half million gross tons of the world's merchant fleet. Larger and ever larger ships were built as the following table[2] with reference to the United Kingdom shows:

Year	Average gr.tons per vessel on register.	Average gr.tons per vessel built during year.
1870	870	1,050
1880	1,330	1,580
1890	1,500	2,150
1900	1,900	3,000
1910	2,300	over 3,000

Between 1860 and 1910 the average length of vessels had increased from about 200' to between 350' and 400'; the speed of the fastest passenger vessels from 12.5 to 26 knots; and the number of passengers carried from 250 to 2,600. The twin screw of the eighties gave place (in first class ships) to triple, quadruple, and even more numerous screws. Devices introduced for safety and comfort are too numerous to mention; but it may be remarked that the high water mark of pre-war merchant shipbuilding and marine engineering was

1. Many of this type now being built are motorships.

2. See paper on: "Changes in ships during the past 40 years", by B. Martell; Transactions of the Institute of Naval Architects, Vol.42. (1900). Year 1910 added as calculated from Tables C1 and C2.

reached with the launch by John Brown & Co., Clydebank, in 1914, of the Cunard liner "Aquitania" (901' x 97' x 92½'; 46,000 tons; 60,000 I.H.P.).

Meanwhile striking advances in marine engineering practice had been made. The application of steel to the construction of boilers rendered possible the use of higher steam pressures, thus giving greater thermal efficiency. By this means a 13% increase in efficiency was realised during the decade 1872-81. The following statement[1] gives data obtained by averaging the performances of a number of marine engines at the beginning and at the end of this decade:

	1872	1881
Boiler pressure in Lb. per sq. in.	52.4	77.4
Heating surface in sq.ft. per I.H.P.	4.41	3.92
Piston speed in ft. per min.	376	467
Fuel used in lb. per hr. per I.H.P.	2.11	1.83

This compares with a 30% gain of efficiency during the previous decade. A steam blast to increase boiler draught had been applied in a naval vessel in 1869. Though this involved a waste of steam (and therefore of fresh water) the practice remained common till the forced draught system was developed in the eighties. The forced draught was evolved from the use of fans to supply fresh air to the stokehold, a practice begun about 1870. It necessitated a closed stokehold and involved high furnace temperatures, which soon revealed any weakness in the boiler plates. Marine engines in use in 1881 may be placed in the following order of popularity:

1. From a paper: "The Progress and Development of Marine Engineering", by F.C. Marshall; Proceedings of the Institute of Mechanical Engineers (1881).

1. Two cylinder compound, with intermediate receiver, cranks at 90°.

2. Woolf tandem (i.e. H.P. cylinder above the L.P.).

3. Three cylinder compound, cranks at 120°.

By 1885 pressures of 130 to 160 lbs. per sq. in. were common.

Now such high pressures necessitated rather large ratios of expansion in compound engines. This fact stimulated shipowners to adopt the triple expansion engine, the invention of A.C. Kirk, manager to John Elder & Co. The first engine of this type had been designed by him in 1874 for the S.S. "Propontis", a vessel built on the Clyde by Messrs Smith & Rodger, and owned by Mr. Dixon of Liverpool. The boilers of this ship worked at the extraordinarily high pressure (at that time) of 160 lbs. per sq. in. They were not a success, a fact which is not surprising when we recollect that 90 lbs. per sq. in. was exceptional in 1874. Thus the triple expansion engine had an unfortunate start. The second of its kind was supplied for the yacht "Isa" in 1877, and the third - frequently but mistakenly said to be the first[1] - in the S.S. "Aberdeen". The engines of this latter vessel were manufactured by Messrs R. Napier & Sons and worked under a pressure of 125 lbs. per sq. in. The triple expansion engine achieved an economy of 15% to 20% over its predecessor, the compound engine. A few specific

1. Probably owing to the fact that the S.S. "Aberdeen" was the first large and successful vessel to be equipped with triple expansion engines. Reference to the earlier ventures are given in a paper: "The Progress and Development of Marine Engineering", by William Parker, Chief Engineering Surveyor to Lloyds Registry; Transactions of the Institute of Naval Architects, Vol. 28. (1887).

examples derived from actual practice prevailing about 1885 and illustrating this fact may be given:

1. Of two large passenger steamers (each 4,500 tons; 6,000 I.H.P.) one was equipped with triple expansion engines working under 145 lbs. per sq. in. pressure, whilst the other possessed compound engines with a steam pressure of 90 lbs. per sq. in. Both had a speed of 12 knots. During a round voyage of 84 days the latter burned 1,200 tons more coal than the former.

2. Two cargo vessels steamed to India. They had the same coal consumption and running costs, but the one having triple expansion engines carried 1,200 tons more cargo than the other which was equipped with compound engines.

3. A mail steamer, originally fitted with compound engines working under a pressure of 60 lbs. per sq. in., was brought up to date by replacing these by triple expansion engines having a working pressure of 150 lbs. per sq. in. A saving of 25% in coal consumption resulted.

The year 1885 marked a further step in the progress of marine engineering, when two sets of quadruple expansion engines were constructed. These were to the design of another Clyde engineer, Mr. Walter Brock, partner to William Denny of Dumbarton. Quadruple expansion gave an economy of 5% to 10% over triple expansion; the higher the initial pressure, the greater the economy achieved. Engines of this type were quite common in large merchant ships by 1890. Rankine & Blackmore, a Clyde firm, shortly afterwards produced a three crank quadruple expansion engine, which consumed only 1¼ lbs. of best Welsh coal or 1.43 lbs. of mixed coal per I.H.P. per hour. Brock later introduced a two crank quadruple engine, thus saving considerable engine room space. But when first costs were taken into account, the margin of saving between triple and quadruple engines was so small that many very large liners continued to be equipped with the former type till the era of the turbine dawned with the twentieth century. In 1892 the Cunard liner "Campania" and, a year later, her sister ship (the largest launched in the world in 1893) the "Lucania" (13,000 gross tons), were equipped with triple expansion engines. The boiler pressure was 165 lbs. per sq. in., the coal consumpt 1.5 lbs. per I.H.P. per hour, and the speed of the vessels 22 knots. The German liner "Deutschland", launched in 1900, represented the highest pitch reached in marine reciprocating engine practice. The period 1885-7 was one of trade depression; but in the engineering world it was one of great inventive activity and shipbuilders were ready - "ready, that is to say, with all the improvements which now tend so much to safety and economy"[1.] - for the revival when it came. Messrs G. & J. Weir of Cathcart[2.] were devoting their attention to perfecting marine auxiliaries and about this time evolved the distiller. Mr. Kenys of Stephen & Co., Linthouse, in 1886 patented a "high and low temperature" boiler. The idea was one which had been tried frequently but hitherto unsuccessfully; it consisted of an arrangement for pre-heating the boiler feed water by using the waste flue gases. It was doubtful if the economy thereby secured was sufficient to compensate for the primary cost of the additional forced draught auxiliaries required. In the same year both British and Russian naval

1. "Glasgow Herald Shipbuilding and Engineering Supplement", for 20th December, 1886.
2. A firm founded in 1886.

authorities adopted the triple expansion engine in vessels designed for speeds of 18 to 23 knots. In this connection it may be mentioned that just about this time a fierce controversy was raging as to the relative merits of heavy armour belting and of lightness, with the accompanying possibility of higher speed, for ships of war. The position was that chemical science, for the time being, had outstripped metallurgical science; shells could be made against which the armour belting was not proof. The point at issue therefore was whether warships should be increased in weight sufficiently to resist the shells or made as light as possible to attain a speed sufficient to avoid them. Twenty years later the creation of special alloy steels and the advent of the marine turbine enabled both aims to be achieved simultaneously.

The period of invention to which we have just referred was the prelude to an intensive competition for the "blue riband"[1] of the Atlantic, held at the time by Great Britain. By the end of 1887 only cargo boats were being supplied with compound engines; liners were all equipped with triple or quadruple types for economy and with various other contrivances such as water tight compartments, patent life boats (in numbers sufficient for all passengers) and davits to lower them, and the like, for safety. The "Etruria" and the "Umbria" held the Atlantic speed record,

1. A mythical decoration awarded to the ship which holds the record for the fastest Atlantic crossing. Naturally the firm responsible for building the vessel and engines receives part of the credit for the performance and in shipping circles even the country in which the ship is registered derives a reflected glory.

but two "City" liners were on the stocks at Clydebank for the Inman International Co., two others by Harland & Wolff for the White Star Line, and one for the Cunard Line to challenge all the others. Competition on the Dover to Calais route and on the Liverpool to Isle of Man crossing was keen. The Atlantic speed competition continued up to the beginning of the twentieth century when the German liner "Deutschland" gained the coveted distinction and thereafter our Continental rival held it for eight years. It was regained for Britain by the Tyneside built Cunard liner "Mauretania." For twentyone years this ship retained the blue riband, but recently[1] lost it to the German vessel "Bremen" which achieved the phenomenally short time of 4 days 17 hours 42 min.[2] But even in the early years of the century speeds up to 23½ knots were attained and it was questioned by many engineers if the saving of time achieved compensated for the high coal consumpt per I.H.P. per hour necessitated by this very fast steaming. The blue riband was held by Clyde built vessels for the periods shown:

from	1840	to	1851
"	1864	"	1872
"	1872	"	1891
"	1892	"	1899

On eastward routes too the speed had been forced up to about 18 knots and in the 1890's Australia was but a three weeks' journey from England.

1. August, 1929.

2. Early in 1930 this time was reduced still further by the German built and owned liner "Europa" (46,000 gross tons; 86,000 I.H.P.) launched in 1928, and turbine driven.

The use of crude oil as fuel for marine boilers marks another advance towards current engineering practice. As long ago as 1861 a Russian named Werner had used refuse oil as fuel and a year later some attention was given to its possibilities by American engineers, the first oil well in the Western Continent having been struck in 1859. The British Admiralty experimented with it on shipboard in 1863, and the French Government two years later. In 1867 Russian steamers on the Volga and Caspian Sea adopted oil fuel with success and for many years it was used on the Russian railways. A British merchant vessel and a French yacht gave it a trial in 1868 but thereafter for some years the matter lay in abeyance, coal being cheap and engineers too busy with boiler and engine improvements to concern themselves with experiments on new kinds of fuel. In 1887 oil fuel was tried on a Clyde yacht and on a "Clutha",[1.] but did not give satisfaction. The first vessel of considerable size to be equipped for oil burning was the "Murex", belonging to the Anglo-Saxon Petroleum Co. This was in 1892 and a year later a sister vessel, the "Trocas", was similarly fitted. Ten years elapsed ere a ship crossed the Atlantic burning oil fuel, and this only under one boiler. But the advantages of oil were now being realised and in 1903 the Admiralty, after forty years' neglect, resumed experiments with oil fuel in naval vessels. The advantages of oil over coal may be summarised briefly:

1. The generic name for a number of small vessels belonging to the Clyde Trust which in 1884 began to ply between the wharf at Victoria Bridge, Glasgow, and Whiteinch, calling at Govan and Partick. With the electrification of the tramway system of the city, they were withdrawn in 1903.

1. The stokehold staff can be reduced to about one quarter of the number required for coal and, as combustion is complete,[1] the dirt, waste, and cost of disposal of refuse is eliminated.

2. The radius of action of the ship for the same weight of fuel is increased by 50%; for the same cubic capacity of fuel it is increased 90%.

3. A great saving of time in fuelling is effected. The saving may amount to 50% or more, depending on the ship's equipment for handling the oil. To "coal" a battleship took at least 12 hours; with oil fuel the job can be done in ¾ of an hour, and that irrespective of the weather.

4. Fuelling with oil can be carried out with perfect cleanliness. Further, the oil can be carried in ballast tanks, thus effecting a saving of space.

5. Oil fuel is uniform in calorific value and the flame can be spread evenly over the whole heating surface of the boiler, reducing the cost of upkeep and repairs which is rather heavy with coal fuel, owing to non-uniformity of temperature.

In view of the above outline no further emphasis need be laid on the special suitability of oil fuel for naval vessels of all classes. An oil furnace can be kindled in a few minutes; steam can be raised within half-an-hour;[2] there is no smoke from the funnels, the products of combustion being scarcely noticeable. Small wonder, therefore, that oil fuel became popular alike in the navy and the large merchant vessels. Since the war the advent of the Diesel engine, eliminating boilers altogether, has checked the spread of oil fuel; to this point we return later.[3]

These changes were connected with the development of the marine water tube boiler. In reviewing the early

1. The ashes from coal constitute from 20% to 25% of the original bulk.

2. Steam can be raised on T.B.Ds. in twenty minutes. Ten minutes suffice if the oil has undergone the preliminary heating. This remarkably brief time is due, of course, to modern boiler design as well as to the nature of the fuel.

3. See p. 314 below.

development of the marine engine[1] the difficulties which beset early attempts to obtain high steam pressures were noted. The chief of these were: first, the lack of a strong yet elastic material; and second, the impurity of the feed water. The production of mild steel solved the former difficulty; the development of the surface condenser, and later of the distiller, greatly minimised the second trouble. Now higher pressures mean higher temperatures and, despite the assertions of some engineers in the early days,[2] very considerable economy can be effected by the use of superheated steam - 1%, as a matter of fact, for every 13°F superheat. Triple and quadruple expansion engines were capable of dealing with steam at a very high pressure, so engineers turned their attention to boiler as well as to engine improvements. As early as 1850 patents for the Belville type of water-tube boiler had been taken out. It is unnecessary to dwell upon the repeatedly unsuccessful experiments, not a few of which ended in serious accidents; for, in addition to the two difficulties outlined above, it had been found impossible to get good circulation of water in the boilers. Gradually each handicap was overcome and onward from 1880 the water-tube boiler gained favour with marine engineers by reason of its economy and performance. The advantages it offers are:

1. rapidity of raising steam;
2. reduced weight of plant.

On the other hand such boilers still have two disadvantages

1. See pp. 114-5 above.
2. See p. 113 above.

inherent in their construction and practically impossible to remedy:

1. they lose "steam"[1.] quickly;
2. they require a large quantity of brickwork.

As the advantages outweigh the disadvantages, this type of boiler has been widely adopted - universally, it might almost be said - for warships of all classes, liners, and large merchantmen. Several types are in common use: Belville, Babcox, and Thornycroft, to mention the best known. The revival was initiated by John I. Thornycroft who, in 1882, was responsible for equipping a small missionary vessel "Peace" with a water-tube boiler. Some ten years later three T.B.Ds. - "Speedy", "Daring", and "Hornet" - were supplied with water-tube boilers, those for the two former being of the Thornycroft type and for the latter of the Yarrow type. In 1894 boilers of the Belville type were tried on H.M.S. "Terrible", a vessel of 25,000 l.H.P. Not till 1911 were cross Channel steamers so fitted; in that year the "Riviera", "Engadine", and "Newhaven", and in 1912 the "Princes Royal", were furnished with water-tube boilers. Only during the war did the owners of ocean liners venture to specify this type of boiler and the first so equipped was a Clyde built vessel. Since the war, however, they have become very popular with shipowners and builders.

Compound engines are now supplied only for tugs, tenders, fishing boats, and small coasting vessels. For

1. An engineering brevity for "steam pressure".

tramp steamers the triple expansion engine still holds its own by reason of its relatively low first cost, its easy supervision, and the fact that turbines are most efficient only when the speed of the vessel exceeds 16 knots. The idea of applying the steam turbine to marine propulsion had been entertained as early as 1884, but not till eight years later was any serious attention given to the matter. By that time it had shown its superiority to the reciprocating engine for driving dynamos. In 1894 the Marine Steam Turbine Co. Ltd. was formed and three years later a trial vessel, the "Turbinia" (100' x 9' x 6'; 42 tons displacement) driven by turbines developing 2,400 S.H.P.[1] at a speed of 34½ knots. The Parsons Marine Steam Turbine Co. was then formed for the commercial exploitation of the invention. In adopting this new form of prime mover for the T.B.Ds. "Viper" and "Cobra" in 1898 the British Admiralty gave a lead to merchant shipowners and to the naval authorities of foreign countries. The speed of 36½ knots obtained on trial satisfied expectations and established the fact that, for high speeds at least, the turbine was more economical in fuel and in steam than the reciprocating engine. Respective coal consumptions showed 1.2 to 1.7 lbs. per S.H.P. per hour and 1.8 to 2.1 lbs. per B.H.P. per hour. Steam consumpts were 13 lbs. and 16 lbs. respectively. The Clyde pleasure steamer "King Edward", built in 1901, marked the first application of the turbine to merchant vessels. The cross Channel

1. Shaft horse power; for further explanation see Appendix 5.

passenger vessels "Queen" and "Brighton" followed in 1902 and 1903 respectively. Launched by Denny of Dumbarton, these vessels serve as reminders that Clyde engineers and shipbuilders were bent on maintaining the reputation of the River for progress and first class workmanship. In 1904 the third class cruiser "Amethyst" was turbine driven and two years later the battleship "Dreadnought" was similarly equipped. Trans-Atlantic turbine service began in 1905 with the Allan liners "Victorian" and "Virginian", followed shortly after by the Cunarder "Carmania" and her sister ship the "Caronia". The idea of equipping the two large Cunard liners "Lusitania" and "Mauretania" (each 32,000 gross tons) at this time under construction at Clydebank and on the Tyne respectively, had originally been rejected by the owners as being too revolutionary a step to take with such huge vessels. So successful was the turbine proving that this decision was revised and both liners, launched in 1906, were equipped with turbines developing 70,000 I.H.P. and calculated to give a speed of 24½ knots. The enterprise shown has been amply justified by results. Both ships have given admirable service on the Atlantic route,[1] more than fulfilling the hopes of the Cunard Company and the expectations of their respective builders and engineers.

Two limitations of the turbine served to bring about the development of a new type, the geared turbine. Quite early it was realised that the turbine rotor must run at a high speed. With a direct drive to the screw propeller, this necessitated that the latter should also rotate quickly

1. The "Lusitania" was torpedoed in 1915; the "Mauretania" is still running.

and that therefore the ship itself must be designed for a speed too high for the medium sized liner or cargo vessel. Further, the turbine cannot reverse so that two sets, one for ahead and one astern, had to be carried. The introduction of gearing between the turbine rotor shaft and the propeller shaft solved, to a large extent, both difficulties. As early as 1897 the geared turbine had been tried experimentally in a 22 feet launch. On a large scale the new arrangement was first adopted by the Admiralty. By 1910 its success was sufficiently assured to encourage one or two enterprising shipowners to try it in a few passenger ships; thus, in that year the single screw steamer "Vespasian" was fitted with mechanical gearing. In 1911 the cross-Channel steamers "Normannia" and "Hantonia" were fitted with geared turbines. The first ocean going vessel to be equipped with them was the Cunard liner "Transylvania", built at Greenock in 1913. Single and double reduction gearing have been developed to suit different requirements, the former type being capable of giving ratios between 5 and 9 to 1, and the latter of ratios exceeding 9 to 1. But even a reduction of 9 to 1 still gives a sailing speed exceeding the requirements of the average merchantman, if the turbine revolutions are kept up to the figure giving maximum efficiency. The only alternative to lowering the rotor speed of the turbine is to apply double reduction gearing. The largest gear wheel which it is practicable to cut is about 13 feet in diameter; large wheels are excessively heavy and involve a higher shaft centre in the ship than is permissible. Hence a larger ratio than 9 to 1 cannot be obtained with single gearing. Double gearing introduces considerable mechanical difficulties and reduces the efficiency of the drive; nevertheless it is preferable to the alternative of reducing rotor speed and has been adopted in quite a few large cargo vessels. By 1913 no fewer than 90 sets of marine geared turbines were at work or on order and since the War substantial additions to this number have been made. Another arrangement which has achieved considerable popularity and has been applied in a number of the largest passenger liners is that of combined reciprocating engines and low pressure turbines. The exhaust from the final cylinder is led into an L.P. Parsons turbine. This system was first employed on the T.B.D. "Velox" in 1903. Five years later the "Otaki" (464' in length) for the New Zealand Shipping Co. and the White Star liner "Laurentic" (655' long) were similarly equipped. The system is specially suited for very large vessels. It was fitted in the "Olympic", launched in 1910, and in the "Britannic" (a vessel of 47,500 tons) four years later. The following table gives an indication of the extent to which turbine propulsion had been adopted within 15 years of its origin. The table[1] shows the number and S.H.P. of marine turbines completed and under construction in 1911; also the type of vessels into which the machinery had been or was to be fitted:

Ownership	Warships		Merchant Vessels		Yachts		Total	
	No.	S.H.P.	No.	S.H.P.	No.	S.H.P.	No.	S.H.P.
Great Britain & Colonies	156	2,480,300	62	631,000	6	17,000	224	3,128,300
World	281	4,869,800	87	942,000	10	29,200	378	5,841,000

1. See paper on: "The Marine Steam Turbine 1894-1910"; by Sir Charles A. Parsons, F.R.S.; Transactions of the Institute of Naval Architects, Vol.53, pt.ii. (1911).

The fact that war vessels predominate is a tribute to the enterprise of naval authorities and refutes the prevalent idea that government departments are always conservative in their outlook. It will also be noted that one half of the world's turbine driven warships and two thirds of the merchant ships sailed under the British flag. Besides the Parsons type of turbine there is the Brown-Curtis type in which the velocity of the steam, not its pressure, is the source from which power is derived. This type has not gained favour with marine engineers though it was tried on H.M.S. "Bristol".

Consideration of the most recent development in marine engineering - the diesel engine - will be delayed to the chapter[1] dealing with post war conditions, as very few motorships were constructed prior to 1914. Meanwhile one further type of reciprocating engine remains to be mentioned: the central exhaust or uniflow engine. Invented in 1885 by L.J. Todd of Edinburgh, the design was rescued from oblivion in 1909 and developed by Professor J. Strumpf of Charlottenburg. The essential difference from the ordinary type of reciprocating engine resides in position of the exhaust outlet, which is at the centre of a double cylinder. Thus the temperature gradient (or flow of heat along the cylinder walls) is always in the same direction and is not, as in the ordinary double acting engine, reversed at the end of each stroke. By 1911 a few engines of this type had been installed in Britain, but it did not attain here even the limited popularity achieved on the Continent. Its importance in marine engineering is negligible.

1. Chapter XIII.

Throughout the period under review the tendency towards higher and ever higher pressures has been most marked. In 1870 a good average was 30 lbs. per sq. in.; at the beginning of the twentieth century a figure ten times this was not uncommon. Since 1900 there has been a distinct tendency to lower pressures, ranging around 250 lbs. per sq. in., to avoid some of the difficulties which are inseparable from excessively high temperatures. Improved condensation, giving a lower back pressure, has been responsible for a significant part of the rise in the mean effective pressure available in engines. Over the same period the coal consumption has been cut by approximately 50%. All marine units - boiler, engine, auxiliaries, and screw propeller - have received the attention of inventors, and improvers. Higher speeds were developed by the reciprocating engine. The floor area per I.H.P. occupied by engines and boilers was reduced by one half. To matters pertaining to the convenience of passengers, the preservation of cargoes, and the safety of life, a great deal of thought and ingenuity was devoted. Luxurious liners, progressively increasing in size, speed, and comfort were built. Ship designers devoted themselves to increasing the degree of stability of vessels in heavy and stormy seas. It is characteristic of most improvements to machinery that the initial costs are increased but that the running costs are reduced. To this general rule marine engines and ships are no exception. But there is also a marked tendency in marine engineering and shipbuilding, more than in other industries, to revert during trade depressions to earlier and better established types which have lower first costs and are more certain in operation, even although this involves a loss of efficiency in running. In general, improvements and inventions took a long time to "arrive"; thorough and satisfactory tests had to be performed before shipowners could be induced to specify the new type. The adoption of steel to replace iron occupied the shortest period of any of the major changes. The similarity of the two materials probably accounts for this fact; but, to effect even this change, occupied a decade. Shop and yard equipment was also subject to constant improvement the tendency, of course, being to substitute machinery for manual labour. It is difficult to get a basis for comparison of the time taken to build a ship in 1870 and in (say) 1910; for types were constantly changing and the size of vessels in any given class was increasing. From the point of view of the work required, a vessel of 8,000 gross tons is not simply twice one of 4,000 tons. Allied industries such as steelmaking and rolling kept up with the requirements of shipbuilding. Special alloy steels were produced to meet the requirements of the higher stresses to which engine parts (e.g. the rotors of turbines) were subject owing to the increased steam pressures used. Throughout the period under review the Clyde maintained its place in respect to output, although towards the end of the nineteenth century severe competition from Germany was experienced. As at earlier times Clyde shipbuilders maintained and, during this period, enhanced their well earned reputation for turning out sound workmanship and seaworthy vessels at competitive prices.

PAGE NUMBERING AS ORIGINAL

CHAPTER VIII.

THE DEVELOPMENT OF GLASGOW AND THE CLYDE.

Before proceeding to consider the fluctuations in the shipbuilding and engineering industries, it will be convenient to interpose an account of the development of the River Clyde, on the banks of which came to be situated most of the large shipyards of Scotland. The growth of Glasgow and adjacent Burghs must also be considered, as these became centres of the marine engineering industry which contributed much to the prosperity of the area. It would be quite impossible to give an account of the growth of each firm; and, fortunately, it is also unnecessary to do so in order to get an insight into the economic factors which were operating during the nineteenth century. A brief record of a few of the leading firms will suffice. Founded over two centuries ago, the firm which since 1904 has borne the name "Scotts' Shipbuilding and Engineering Co. Ltd.", has the longest history of any on the Clyde. During the whole time since 1711 successive generations of the founder's family have retained an active interest in the business. John Scott was a member of the Incorporation of Hammermen. Living in Greenock, he was a friend of James Watt's father. In 1711 he opened a boatbuilding yard in the town and here many of the local herring "busses" were constructed. Gradually the business extended and his grandson, John Scott, built in Greenock the first dry dock on the Clyde. In 1790 the Greenock foundry was acquired and twelve years later the name of the firm was changed to John Scott & Sons. They began the manufacture of steam engines in 1825 under the title Scott, Sinclair & Co. and, four years later, Daniel Weir in his "History of the Town of Greenock" was able to record: "The building yard of Messrs Scott & Sons is allowed to be the most complete in Britain, excepting those which belong to the Crown." Engines up to 200 N.H.P. were being manufactured in 1828. At this time the firm employed 220 men at a weekly wage bill of £180. They specialised quite early in steamship construction and in 1838 received their first Admiralty order for H.M.S.S. "Hecla" and "Hecate". To them fell the honour of building H.M.S. "Greenock", the first steam frigate to be launched on the Clyde. This vessel, it may be remarked, represented one of the earliest attempts to drive the screw by gearing. Steady progress and enterprise in keeping abreast of the most up to date technique has maintained the firm in the front rank of Clyde shipbuilders. In 1918 their engine works alone employed over 2,000 men with wages aggregating £7,500 per week. Other early shipbuilders of Greenock may be mentioned: R. & A. Carswell, R. Duncan & Co., Joshua Muiross, James McMillan, R. Steel & Co., and William Simons & Co. Many small boatbuilders in addition had slipways along the shore. Steel and Carswell had begun a partnership in 1796 at the Bay of Quick, a spot occupied by shipbuilding yards for over half a century. Twenty years later they set up separate establishments in the town. Caird & Co. opened a foundry in 1809, but fifteen years later the manufacture of engines and machinery was included in their activities. Later still the firm became shipbuilders as well as engineers and it figures as one of the most important on the Clyde throughout the nineteenth century. In 1826 they were employing about 200 men. William Simons & Co., now of Renfrew, commenced business in Greenock in 1817. In the first twelve years of their existence they launched over 5,000 tons of shipping, including three steamboats. Whilst the Scott Co. hold the record with an uninterrupted existence of 218 years, not a few of the other Clyde firms celebrated their centenary several years ago. To those mentioned above we may add the names of Barclay, Curle & Co., and Stephen & Sons of Linthouse. Quite a number of shipyards in active service today have existed in the same spots for well over a hundred years, although during that time their ownership has changed hands. Few of the shipbuilding companies operating today on the Clyde have less than half-a-century of work to their credit. Priority of commencement of business apparently has little to do with the extent of later development. In general the firms which prospered were those that anticipated and prepared for the conquest of steam and of iron whilst these were still unpopular. The oldest yards are, of course, on the lower reaches of the river since the latter was innavigable above Port Glasgow to any but the smallest ships until the nineteenth century was well advanced. As the river was made wider and deeper, shipbuilding yards tended more and more to approach the city, whence supplies of raw materials, engines, fittings, and the like were obtained by road and rail. Later, when the harbour at Glasgow suffered repeated extensions, many yards were ousted from their position. As all favourably situated places near the city were already occupied, the displaced firms and those which came late upon the scene had to move well down the river. In time new suburbs grew up around these shipyards. To this the Burgh of Clydebank[1.] owes its origin and growth. When an extension of the harbour swallowed up the yard belonging to Messrs J. & G. Thomson, that firm took a site some six miles down the river on the north bank. For a time the employees were greatly inconvenienced, as the supply of houses in the locality was inadequate and as yet there was no railway from the city. Gradually, however, a suburb sprang up around the shipyard and later developed into a thriving and populous burgh.

The growth of Glasgow and the improvements made to the river have already been traced to the end of the eighteenth century. The Clyde Lighthouses Trust had been incorporated by Acts of Parliament of 1754-55. Two further Acts in 1758 and 1770 had enabled the Town Council to have the river straightened, widened, and deepened sufficiently to permit vessels up to 60 tons burthen and drawing 6 feet of water to come right up to the Broomielaw. At the beginning of the nineteenth century some fifteen hundred small craft arrived at the Glasgow Bridge every year, but the vessels which might at any time be observed moored to the quay there consisted mainly of coal barges and herring wherries. The series of Acts passed at the instance of the Clyde trustees during the nineteenth century bears eloquent testimony to the determination of the city merchants not to remain handicapped by reason of the natural deficiencies of the river.

1. The district, which a few years before had been entirely rural, was elevated to the status of a police burgh in 1886.

The quayage at Glasgow in 1800 was but 382 yards in extent with a water area of 4 acres. In 1809 the third Act of the series appointed the Lord Provost, Magistrates, and Council of the city to be statutory trustees of Clyde navigation. Hitherto they had acted as a municipal corporation. The Act authorised the trustees to deepen the channel to at least 9 feet at low tide and provided also for the enlargement of the quays and sheds. Golborne's scheme of building jetties was continued, the ends of these at the water being joined up by parallel dykes. This together with the scour occasioned by the steamboats added 3 feet to the depth already attained. By 1820 thirteen passenger and four luggage steamboats were plying regularly from Glasgow to coast towns. In 1824 the first steam dredger began operations. It had a 12 H.P. engine and the buckets reached to a depth of 10'-6". A fourth Act in 1825 prescribed a depth of 13 feet and the dredger was altered accordingly. Further extensions of the quays and of the Broomielaw harbour were also authorised. The board of trustees was augmented by the addition of five business men interested, by reason of their business, in river development. The five were to be nominees of the Town Council. The stretch of river under the control of the trustees was extended to the extreme east end of Glasgow Green in the one direction and to Port Glasgow in the other. Another feature of this Act was the establishment of a Pilot Board for the Clyde.

Mention must be made here of the founding of the Mechanics' Institution in 1823. Small in its beginnings, it later came to play a most important part in the educational system of the city. Some twentyeight years before this time John Anderson, Professor of Natural

Philosophy in the University had founded a College. In 1800 Dr. George Birkbeck, a London Physician, whilst Professor of Natural Philosophy in Anderson's College, invited the Mechanics of Glasgow to attend a course of lectures. The class was continued by his successor, Dr. Ure, and prospered till 1819. Two years later it was revived and the attendance rose to 600. From this enterprise a committee was appointed. They leased the gallery of a city church, fitted it up as a lecture room, purchased apparatus, and got together a library of some 1,300 volumes. On 5th November, 1823, the Mechanics' Institute was formally opened. To begin with lectures on Chemistry and Mechanical Philosophy were delivered. In 1824 Mathematics was introduced. The majority of those who attended were manual workers, mechanics, and apprentices. A small charge was made but poor apprentices, in the proportion 1:20, were admitted free. Premises in Inklefactory Lane were occupied in 1831 and a year later the Institute transferred its activities to a new building in North Hanover Street, which had been gifted. Half a century later it became the Glasgow College of Science and Arts and subsequently the Glasgow and West of Scotland Technical College. Of its later developments more will be said hereafter. Meantime we may note that the educational side of industry was not being neglected and many of the technicians who helped to bring shipbuilding and engineering on the Clyde to its present state of technical perfection acquired much of their knowledge at classes under the auspices of the Mechanics' Institution.

Although owing to the state of the river at the time there could be very little shipbuilding done near Glasgow at the beginning of the nineteenth century, the city was becoming a centre of engineering activity. In 1810 Simons

& Co. removed from Port Glasgow to Renfrew and there established what remained for a number of years the only shipyard on the upper reaches of the river. This firm later became well known as specialists in dredgers and ferries. The foundations of some of the engineering enterprises that later achieved distinction were laid at this time. In 1802 John Napier had a small engineering shop in Howard Street. Later the shop was transferred to the east end and became known as the Camlachie Foundry. By 1810 his son David was taking charge of it and there in 1811 the boiler for the "Comet" was constructed. Robert Napier, David's cousin, after serving an apprenticeship with his own father in Dumbarton, opened a small engineering business in Glasgow in 1815. Six years later he leased the Camlachie Foundry from David who had purchased a piece of ground at Lancefield Street, and had built a new workshop there. Equipment in an engineering shop at that time was not what it is today. Camlachie Foundry was furnished only with a few 10" and 12" lathes, a rude horizontal boring mill, a vertical drilling machine, machine and hand tools, and casting appliances. Nevertheless Robert Napier turned out first class work. His first engine, one of 12 H.P. for a Dundee mill, worked for over fifty years. His first marine job was for the "Leven", built by Lang of Dumbarton in 1823. It outlasted three hulls and was finally placed on a pedestal at Dumbarton Castle. When business extended he was fortunate in choosing David Elder, father of the patentee of the compound marine engine, as manager. By 1827 Robert Napier had the enviable reputation of producing the best engineering workmanship in the vicinity of Glasgow. As a natural result, business extended. In 1828 he took over the Vulcan Foundry and in 1835 his cousin's Lancefield Street works also came under his control. Three years later his first successful tender for a government contract, comprising two sets of 280 N.H.P. side lever engines, was made, the price being £13,480 per set.

The oldest established building yard on the upper reaches of the river was that founded by Robert Barclay at Finnieston in 1818. Later the firm became Barclay, Curle & Co. Till 1857 this enterprise confined itself to shipbuilding; after that the activities of engineering and boilermaking were added. Wingate & Co. began shipbuilding in 1823, followed a year later by James Stephen. Two of David Napier's shop foremen, David Tod and John Macgregor, entered into partnership as marine engineers and iron shipbuilders in 1834. A year later they had the distinction of building the first iron vessel constructed on the banks of the Clyde and launched into it.[1] In 1846, owing to harbour extensions the yard was removed to Meadowside. All the Inman Line vessels were built at this yard with the exception of two - the "City of Berlin" and "City of Chester"- which Caird of Greenock built. The "City of Glasgow"[2] was the first twin screw vessel to ply regularly between Glasgow and New York. About 1874 David Tod, junr. sold out to David and William Henderson and under the latter title the shipyard still operates at Meadowside, Partick. Another partnership which later developed into a first class firm was formed in 1834 by Charles Randolph and R.S. Cunliffe. A beginning was made in a small millwright's shop in Tradeston. Three years later John Elliot joined the

1. Prior to this an iron boat had been built some two miles from the river and taken there on lorries to be launched; see p. 64 above.

2. Built in 1859 for other owners but purchased later by the Inman Line.

partnership and the title was changed to Randolph, Elliot & Co. This firm later came to be the Fairfield Shipbuilding and Engineering Co. Meantime other shipbuilding yards were being opened up. Under the name of Napier & Sons, Robert Napier and his family began shipbuilding at Govan in 1841. His brother James also joined the firm. The firm acquired the services of William Denny[1] as designer. Like many other shipbuilders of the Clyde, Napier concentrated on the construction of iron ships. From 1840 to 1865 the engines for the entire Cunard fleet were constructed in Napier's workshops. In 1856 Napier launched the "Erebus", the first British armoured vessel. Five years later the "Black Prince", second in point of time of all British ironclads and the first of its kind to be built on the Clyde, was launched from the Govan yard. When such warships were contemplated Napier took over Parkhead Forge, the management of it being entrusted to his son-in-law Mr. Rigby, and the firm operated under the title Rigby and Beardmore. Rigby died in 1872 and the forge was thereafter carried on by Beardmore alone. Between 1823 and 1876 Napier's shops constructed engines aggregating over 60,000 N.H.P., whilst his yard up to the latter date launched approximately 250,000 tons of shipping. On the death of Robert in 1876 the shipyard and engine works were sold to John and James Hamilton and A.C. Kirk for a sum of £270,000, but the old title of the firm was retained for many years.

In 1847 two brothers, James and George Thomson, who had been foremen in Robert Napier's shop, opened engineering premises in Finnieston Street, Glasgow. Four years later

1. This was the William Denny who later resuscitated and made famous the Dumbarton firm.

they added shipbuilding to their work, beginning in a yard at Govan. They too confined their attention to iron vessels. In the same year Anthony and John Inglis commenced business as engineers and millwrights with premises in Warroch Street. Twenty years later they too took up shipbuilding. Meantime notice must be taken of the founding of the firm Denny Bros., at Dumbarton. At the beginning of the century William Denny's father, in partnership with James Maclachlan, had begun boatbuilding in a small way. When steam navigation made its appearance they immediately took up the building of steamboats and were responsible for the launch of a number of the early river steamers, including the "Rob Roy". Thereafter the firm disappeared to be revived in 1844 by the three brothers William, Peter, and Alexander Denny, sons of the founder of the firm. This partnership was an outcome of their recently established partnership as marine architects in Glasgow. Within ten years some 45 vessels, some of which were 1,500 tons and 300 N.H.P., had been launched. Under the title of Tulloch and Denny marine engineering was begun in 1850. The firm progressed rapidly, being ready always to adopt the latest inventions, and must be included in the list of those that brought renown to the Clyde. By 1853 there were 8 or 9 shipbuilding concerns in the immediate vicinity of the city, a number which was doubled within the next ten years. Of the other yards mention may be made of Smith and Rodger,[1.] Charles Connell & Co., and Hedderwick & Co. Many new engineering firms sprang up

1. Afterwards became the London & Glasgow Engineering and Iron Shipbuilding Co.

and these industries began to supersede the cotton industry in point of importance in the West of Scotland.

In 1852, John Elder, junr., who was Robert Napier's chief draughtsman, joined the firm of Randolph, Elliot & Co. The name of the firm was changed to Randolph, Elder & Co., and marine engineering was added to the millwright work which they undertook. Two years later boilermaking also came within their ambit. From their premises in Centre Street, Tradeston, in 1854 came the first successful compound marine engine. In 1860 shipbuilding was begun in a small yard in the city but four years later they removed to Fairfield, just beyond Govan. The first four vessels built by this firm were blockade runners for the American Civil War. Ample room existed here for expansion and large vessels could be launched without difficulty. In 1868 both Randolph and Cunliffe retired and the year after Elder died. The firm was reconstituted and during the sixty years to date has continued to occupy an important niche in the shipbuilding and engineering industry of the Clyde. For the year 1869 their output comprised 14 steamships and 3 sailing ships aggregating 25,235 tons, nearly twice the figure of the next biggest yard on the river. Harbour extensions had meantime forced many of the older firms to move to new premises down the river. Wingate & Co. went to Whiteinch; Barclay, Curle & Co. to Clydeholm Yard, Whiteinch; Stephen to Linthouse, Connell to Scotstoun, and (as already noted) J. & G. Thomson to Clydebank. Napier, Hedderwick, and the London & Glasgow Co. only remained in their original positions on the south bank and Stephen & Sons[1.] on the north bank of the river.

1. Afterwards became Aitken & Mansel and not to be confused with Stephen of Linthouse.

Of all the early shipbuilders Robert Napier was the most outstanding figure, "the father of Clyde shipbuilding" as he has been called; for most of the other firms were founded or managed by men who had served their apprenticeship or had worked with him. Among these may be mentioned William Denny, James and George Thomson, John Elder, William Beardmore, Smith and Rodger, David Tod and John Macgregor, Aitken and Mansel, Shanks and Bell, Miller, Scott, Dunsmuir and Jackson.

Meantime the city was increasing in size and beginning to acquire the elements of modern municipal organisation. The Scottish Municipal Reform Act of 1833 gave the ratepayers of Glasgow the right to elect their own Town Council. A regular police force had been authorised by an Act of Parliament in 1800 and other Acts respecting this matter followed in 1821, 1837, 1843, 1846, and 1866. Gas lighting was inaugurated by a private company in 1818 and a second gas company began in 1843. The adjacent district of Blythswood was annexed in 1830. But our chief concern is with the river and its development, the above facts receiving mention only to indicate that progress and expansion was taking place in all directions. Until 1834 river and harbour dues were disposed by public sale; after that date they were collected by the Trustees. In 1840 the fifth Act relating to Clyde navigation was passed. The river was now 15 feet deep; the quayage extended to over a mile and the harbour had an area of 23 acres; the annual revenue from dues was approaching £50,000. The new Act fixed a depth of 17 feet for the river and altered the constitution of the Trust to include nominees from the Chamber of Commerce, the Merchants House, and the Trades' House. Of the total membership of 33, the Town Council was represented by 23 members. As yet the city had no dock and the Act of 1840 authorised the provision of this convenience, but no attempt was made to fulfil that part of the Act. A further Act of 1846 again authorised the Trustees to proceed with the building of a wet dock or tidal basin but the project was not undertaken. In the same year a basin 3½ acres in extent was opened at Bowling (some ten miles down the river from Glasgow) by the Forth and Clyde Canal Co. The Burghs of Calton and Anderston and the Barony of Gorbals, each of which up to this time had its own magistracy and police force, were annexed by Glasgow in 1846. The population of the city was thereby increased to over a quarter of a million.

The seventh Clyde navigation Act was put on the statute book in 1854. Its provisions were purely financial, extending the borrowing powers of the Trustees, making regulations for the establishment of a sinking fund, etc. Two miles of quayage and 51 acres of harbour space were now available but still there was no dock. In 1856 the Clyde Trust opened a basin 8½ acres in extent at Bowling. The eighth Act in 1857 continued, renewed, and extended the powers already granted and a year later another legislative measure consolidated and, in minor points, amended those previously passed. The constitution of the board was again altered, the number of members being fixed at 25, to be elected as specified in the Act. A new title was conferred on the body; henceforth it was to be styled: "The Trustees of the Clyde Navigation" - hence the abbreviated name which it still bears: Clyde Navigation Trust. Some twenty years earlier Mr. Walker a consulting engineer, had reported the depth at the Broomielaw to be 7 to 8 feet at low water and 12 to 15 feet at high water during neap and spring tides respectively. The new Act provided for the deepening of river and harbour to a minimum of 17 feet at neap tide, for the maintenance of wharves, cranes, etc., and for the accomplishment of the wet dock previously authorised. Large vessels were now able to come right up to the city, but the journey from Port Glasgow frequently extended over two tides, vessels being temporarily stuck in the shallow water at low tide. Four single bucket and two double bucket steam dredgers were at work keeping the channel clear. Records show that vessels of the size indicated below actually arrived at the Glasgow harbour:[1]

in	1828	vessels	up	to 280	tons
"	1835	"	"	" 320	"
"	1840	"	"	" 600	"
"	1850	"	"	"1000	"
"	1857	"	"	"3600	" [2]

At the harbour some 19 cranes, of which 4 were operated by steam, dealt with the loading and discharging of cargo, the largest being capable of lifting 60 tons. As yet there was no public graving or dry dock though a private one (450 feet x 55 feet) belonging to Tod & Macgregor was completed in 1858.

Between 1770 and 1857 no less than £2,676,505 was expended in river and harbour improvements. Of this sum £574,708 was spent on the purchase of land, £658,473 on the construction of works, £253,963 on dredging and deepening, and the remainder - £1,189,361 - on management, maintenance, interest on money borrowed, etc. The irony of the situation was that much of the land which had to be

1. Paper to the Statistical Section of the British Association; Dublin meeting; 29th August, 1857, by John Strang, LL.D.

2. This was the Cunard liner "Persia".

bought at a high price was land created during the early operations (when the channel was being narrowed) by the material from the river bed which had been thrown on the banks behind the jetties and dykes. The expense incurred in the improvement of the river was borne by local effort and finance, no Government assistance having been received at any time. Shipping dues were by this date bringing in an income of over £80,000 per annum. Improvements in the facilities offered by the river were constantly under review and the dredging of the channel went on continually, so that larger and larger ships could come right up to the city. In 1852 and again in 1861 diving bells were called into service to remove large boulders from the river bed. The effect of thus making Glasgow accessible by water is seen in the extensive trade now handled in the city and surrounding area. Prior to river improvements the revenue collected by the Crown from Glasgow's trade was negligible; by 1856 it approximated to £2,800,000. Population too was increasing; and, whereas in the middle of the eighteenth century the total rental of the city amounted to but a few thousand pounds sterling, a hundred years later it was over £1,300,000.[1.]

The primary reason for deepening the river was to permit of large ships loading and discharging in the harbour; but the improvements also made possible the construction and launch of large vessels in and in the vicinity of Glasgow. Thus shipbuilding benefited indirectly by the expansion of commerce. Harbour facilities were further extended by the tenth Act, passed in 1864, authorising the Trust to lay rails to the quay. Three years later the lack of dock accommodation which had

1. Figures are authoritative after the 1854 Valuation Act but not before.

hitherto been responsible for congestion of the harbour was remedied to some extent by the opening of the Kingston Dock, a small basin half a mile down the river on the south bank. It added 830 yards of quayage and had an area of $5^{1}/_{3}$ acres, 10 to 14 feet deep at low water. The eleventh Act in 1868 provided for the construction of a graving or dry dock at Yorkhill and extended the borrowing powers of the Trustees. Two years later another Act authorised a wet basin on the north bank larger than that recently opened on the south bank. The new dock was to be served by railway lines connected up to the main system. Congestion still handicapped the harbour, ships frequently having to discharge when they lay "two or three off".[1] During the shipbuilding boom of 1872, vessels fitting out had to wait for weeks to get a crane berth, so the extension of quayage to Govan on the south bank of the river was begun. A further Act in 1873 authorised the construction of a graving dock near Govan. The state of development at the beginning of the modern era may conveniently be summarised at this point. Glasgow was now a flourishing city with a population of half a million. The annual rental exceeded £2,000,000. Street trams had been begun in 1870. In and around the city there were no fewer than 23 shipbuilding yards and many more engineering workshops. Nearly four miles of quayage and over 75 acres of water were available for vessels at the harbour. The pressure of commerce seeking economical facilities for the import and export of goods had rendered necessary the improvements to the river which made Glasgow, in every sense of the term, a port. From an insignificant 2,000 tons at the beginning of the century, the tonnage of ships on the register at Glasgow had grown to half

1. That is, there were two or three vessels between them and the quay side.

a million,[1] and the annual revenue of the Clyde Navigation Trust was now in the region of £170,000. Many growing industries brought wealth to the city, whilst those dying out were being replaced by new enterprises more suited to the geographical situation and resources of the area. But of them all the shipbuilding and engineering industries were undoubtedly the most important. Having struck its forte Glasgow proceeded in a businesslike way to create the facilities, where those were lacking, and to strengthen the opportunities presented to make itself worthy of the status since attained of second city in the United Kingdom.

The first public graving dock in the city - that authorised by the Act of 1873 - was opened in 1875 at Plantation, on the south bank of the river. This provision of facilities for scraping, painting, and repairing the hulls of vessels marked an important advance in Glasgow's position as a port and the expenditure involved in the undertaking was amply justified by the additional inducement it offered to vessels to dock here. In 1878 the fourteenth Act relating to Clyde navigation was passed. In accordance with its provisions a steam ferry service across the river was established at Finnieston, a mile below the lowest bridge then existing. Further borrowing powers were also conferred on the Trust. Two years later the Queen's Dock, authorised and begun eight years before, was opened. Situated on the north bank of the river, at the foot of Finnieston Street, it had a water area of 33¾ acres divided into three basins which were lined with quays nearly 2 miles in length. Even at low water a depth of 20 feet was available.

By 1883 there were 43 ship and boat-building yards in the Clyde area. This figure, it should be mentioned,

1. See Table H.5.

included some small premises which confined their attention to yachts. The following list shows the distribution of these yards on the river and firth, beginning at the extreme upper reaches and proceeding down the river.[1]

No. of yards.	Situation of Yards.
1	Rutherglen
1	Blackhill (on Monkland Canal)
1	Maryhill (on Forth & Clyde Canal)
5	Glasgow (within precincts of harbour)
1	Partick
2	Govan
4	Whiteinch
1	Scotstoun
2	Renfrew
1	Yoker
4	Paisley
2	Clydebank
1	Bowling
5	Dumbarton
4	Port Glasgow & Greenock

The table below gives the names, site of premises, date of commencement of the leading firms at this time, and number of workmen normally employed by each. Subsequent changes in name are noted.[2]

Name of firm	Site of yard	Date of commencing shipbuilding	No. of workmen employed.
D. & W. Henderson	Partick	1835	3,600
Robert Napier & Sons	Govan	1842	3,500
Dobie & Co.	Govan		1,500
John Elder	Govan	1860	1,000
A. & J. Inglis	Pointhouse	1867	1,700
Stephen & Sons	Linthouse	1842	1,000
Barclay, Curle & Co.	Whiteinch	1823	1,900
Wingate & Sons	Whiteinch	1822	2,400
J. & G. Thomson	Clydebank	1851	1,800
Wm. Simons & Co.	Renfrew	1817	800
McMillan & Son	Dumbarton	1835	2,300
Denny Bros.	Dumbarton	1844	900
Blackwood & Gordon	Port Glasgow	1850	800
John Scott & Co.	Greenock	1711	1,800
Robert Steel & Co.	Greenock	1816	1,300
Caird & Co.	Greenock	1842	3,500

1. "The River Clyde" (1884) by James Deas.
2. See Appendix 8.

Quite a number of the above had been in business as engineers prior to taking up shipbuilding and most of these continued their engineering activities. Some firms confined themselves solely to marine engineering and amongst these we may mention Dunsmuir & Jackson, Hutson & Corbett, Wm. King & Co., Lees, Anderson & Co., Muir & Caldwell, Muir & Houston, Ross & Duncan, Rowan & Son, J. & J. Thomson, and Walker, Henderson & Co.

Dock accommodation, both wet and dry, was still less than the tonnage entering and clearing from Glasgow required. In 1883 the fifteenth Act was passed authorising the construction of two additional tidal basins and two graving docks on the south bank of the river. Sheds were to be built, rails laid, and other conveniences to the discharge, loading, and repair of ships were to be provided. Wharves at Shieldhall and at Dalmuir were authorised by the following Act in 1884 and two years later the second public graving dock in the city - that begun three years before - was opened. A further Act of 1887 extended the time permitted by the 1883 Act for the compulsory purchase of land by the Trust. In 1888 the constitution of the Clyde Navigation Trust, as laid down in 1858, was altered and two years later the nineteenth Act of the series projected the construction of a third graving basin with roads, etc. whilst acquiescing in the abandonment of the two authorised earlier but never actually begun. This third graving basin was situated beside the two already in existence at Plantation and was opened in 1898. Wharves, roads, etc. to be constructed at Clydebank were provided for by the twentieth Act passed during the year 1891. Three years later the Trust's powers were again extended and in 1897 a further amending

Act was passed.[1] The latter year also witnessed the opening of the Prince's Dock - authorised fourteen years before - on which work had been proceeding for upwards of five years. In 1899 an Act to replace that of 1891, the provisions of which had not been carried out, was passed. Wet basins with wharves, roads, rails, cranes, etc. at Clydebank were provided for on a larger scale than had been contemplated previously. They covered 35 acres and had a quayage over two miles in length. At low water its depth varied from 20 to 28 feet according to the tide. The river channel all the way to Port Glasgow had now a depth of 20 feet at low water and the bottom was practically level. It had really evolved into a ship canal, artificially constructed and only by incessant dredging kept free from mud and silt brought down by the current. The total cost of dredging up to 1928 has been £2,000,000 and the maintenance work absorbs £58,000 annually.

Meantime the city was extending its boundaries. In 1891 the Burghs of Crosshill, Govanhill, Hillhead, and Pollokshields East and West were annexed by Glasgow. Five years later the lands of Bellahouston were also embraced. Thus the city valuation was increasing steadily. In the twenty years 1871-91 it had risen from £2,126,324 to £3,455,540 and the extension of the boundaries in the latter year brought it up to £4,033,554.[2] Revenue from river and harbour dues showed an even more striking advance due largely to the increased facilities provided for shipping.[3] In 1871 it had been £164,189; in 1881 it was

1. Amending the Clyde Lighthouses Trust Act of 1871 as well as extending the Clyde Navigation Act of 1894.
2. "The River Clyde and Harbour of Glasgow" (1898) by Sir James D. Marwick.
3. Accounts of the Clyde Navigation Trust.

£248,062; ten years later this had increased to £354,581 and the first year of the twentieth century showed the unprecedented figure of £444,077. The advance was practically uninterrupted, relapses even in years of bad trade being insignificant. During the last quarter of the nineteenth century the harbour area was more than doubled and at the end of the century had a water area of 240 acres. Eleven miles of quayage, 78 acres in extent excluding sheds, rather more than half of which was on the south bank of the river, was now available to vessels. The sheds alone covered 35 acres and were capable of storing many thousands of tons of goods awaiting shipment or removal for distribution, whilst cranes of varying capacity up to 130 tons facilitated outfitting, coaling, loading, and discharging of vessels. Six steam ferries were operating within the harbour bounds in addition to others further down the river. From 1810 to 1897 the total cost of river improvements amounted to £7,209,393.

The first Act of the twentieth century relating to Clyde navigation - the twentyfourth of the series - was passed in 1904. It concerned the purchase of Erskine ferry 11 miles down the river from Glasgow and the building of a wharf at Merklands. A year later another Act confirmed an arrangement between the C.N.T. and Renfrew Town Council by which the former body undertook certain responsibilities in connection with Renfrew Harbour development. By the provisions of another Act of the same year the constitution of the Clyde Trust was again changed. The municipality ceased to hold a majority of seats on that body and therefore no longer controlled the river. Fortytwo trustees were to be elected by the various interested parties, Glasgow Corporation being allotted twelve seats. Nominees of other adjacent local authorities also joined the board.[1] From Albert Bridge, the point where the river leaves the Glasgow Green, to Port Glasgow, a distance of twenty miles, the management of the river is vested in the Clyde Navigation Trust; from Port Glasgow to the Tail o' the Bank the Clyde Lighthouses Trust exercises authority. An Act passed in 1907 authorised the construction of a wharf at Meadowside, Partick, to extend some 540 yards. Cranes, sheds, etc. were also to be provided and the Trust was empowered to borrow for the purposes outlined £650,000 in addition to the £7,850,000 already permitted. A granary was opened there in 1914. During 1907 Rothesay Dock - the project at Clydebank authorised many years before - was opened. It was equipped with the most up-to-date electrically operated coaling cranes, hoists, and other accessories.[2] A superannuation scheme for employees of the Trust was confirmed[3] by an Act of 1908. Two other important pre-war Acts must be mentioned. The earlier in 1911 authorised the construction of a tidal dock at Renfrew. Two basins, an outer one 590 yards long by 270 yards wide and 32 acres in extent, and an inner 442 yards by 90 yards were projected; also a graving dock and a quay fronting the river. This new dock together with Rothesay Dock on the opposite bank and all the works connected therewith were to form part of the harbour of Glasgow. The steam ferry across the river at Renfrew was to be purchased and operated by the Trust, as the ferry at Erskine a few miles further down the river had been some years before. The borrowing powers of the Trust were increased by £1,200,000. The 1914 Act gave permission for the construction of two tidal basins at Shieldhall together with dock tramway lines, etc. The

For foot-notes see next page.

1. This constitution is operative at present. The full list of members is as follows:

Corporation of Glasgow	12 members
County Council of Lanark	2 "
County Council of Dumbarton	1 member
Town Council of Dumbarton	1 "
Town Council of Renfrew	1 "
Town Council of Clydebank	1 "
Glasgow Chamber of Commerce	2 members
Glasgow Merchants' House	2 "
Glasgow Trades' House	2 "
Payers of dues on ships and goods	18 "

All give their services gratuitously.

2. It was the first dock in the world to possess a complete electrical equipment.

3. It may be mentioned that the procedure in obtaining authority to proceed with improvement schemes is to get a Provisional Order which is later confirmed by Act of Parliament.

road from Glasgow to Renfrew was to be diverted to permit of these operations. The new docks when completed will form[1] part of the harbour of Glasgow as defined in the Acts of 1904 and 1911. To carry out this scheme the Trust was authorised to borrow a sum not exceeding £1,700,000 - this in addition to the £9,700,000 already allowed by the various antecedent Acts. Altogether up to the war some £10,000,000 had been spent on river facilities and improvements. Of this £7,000,000 was borrowed. The revenue for the year prior to the outbreak of the war was £624,826.

The above account has shown the constantly increasing provision made for handling shipping on the Clyde. It remains to give a brief sketch of how shipbuilding firms took advantage of these improvements for the expansion of their industry during the forty years prior to 1914. Table H.1. shows the Clyde output year by year from 1875 to 1929 whilst Tables D.2, D.3, H.2, & H.3. give statistics of the production of individual shipbuilding and marine engineering firms.[2] During the thirtynine years, 1876-1914, some eleven yards have, at one time or another, taken first or second place for output on the river. Of these only seven have taken first place. The Port Glasgow firm Russell& Co. has occupied first place no fewer than 27 times and has taken second place 3 times. The table below gives a summary of the "placings":

Name of firm	First place	Second place
Russell & Co.	27	3
Elder & Co. Fairfield S.& E.Co.	5	4
Denny Bros.	2	7
J.& G. Thomson John Brown & Co.	2	6
Connell & Co.	1	6

Name of firm	First place	Second place
Stephen & Sons	1	5
McMillan & Co.	1	–
Barclay, Curle & Co.		5
London & Glasgow Co.		1
Scott & Sons		1
Caird & Co.		1

1. The work upon this scheme began only a few years ago and is at present proceeding.
2. Many of these have changed their titles; some have become defunct. In Appendix 8 a note of these changes is given.

A scrutiny of the output of all the Clyde shipyards over a period of some ten years before the war shows that about 75% of the total output was produced by a dozen firms; nor did all the firms benefit proportionally to their productive capacity by increased orders during a boom or suffer from lack of work during a depression. The period 1908-13 inclusive, covering a boom and a depression, was investigated in detail. The total annual output on the Clyde varied by 75% of the average annual output.[1] Only seven firms - Russell, Connell, Denny, Stephen, Napier & Miller, Hamilton, and the Ailsa Shipbuilding Co. - had no greater variation in their annual outputs compared with their average outputs, than had the total with its average. This shows that depressions hit some firms more severely than others whose output maintains a more constant figure. One significant reason seems to be that certain firms specialise in particular types of ships and when these are not in demand business is slack. It may be noted that Russell & Co. who head the list do not build any special vessels but confine their production to the largest class of all, the general tramp steamer. They did a considerable amount of speculative building in anticipation of demand. Up to 1894 this firm was world famous as builders of sailing vessels. As we have already noticed, subsequent to this date, the sailing ship entered upon a period of decline from which it has not recovered. In 1895 and 1896 Russell & Co. were down the list for output but in 1897 again took first place, but now for steamship output. They continued to hold that distinction until 1914, with the exception only of the year 1903. Brown, Fairfield, Denny, Beardmore, and Scotts' make a speciality of war vessels. Brown, Fairfield, Connell,

1. Total output (1908-13): 3,179,253 gr.tons ; average per annum: 529,875 gr.tons ; minimum year (1908): 355,586 gr.tons ; maximum year (1913): 756,976 gr.tons a difference of 401,390 gr.tons or 75.7 % of the annual average.

and Henderson are well equipped to build large passenger vessels. Denny Bros. have been responsible for many fast river and cross channel ships and still make a feature of these.

Marine engineering work is even more concentrated than shipbuilding. Table D.3. gives year by year for the period 1887-1914 the six firms whose output was highest. Table D.4. summarises the output of these six and compares it with the total Clyde production. It will be noticed that the output of the six leading firms seldom fell below 50% of the total and on one occasion it rose as high as 65.7%. In all only seven firms have at any time occupied first or second place and only four first place. The table below shows the number of occasions upon which the firm was "placed".

Name of firm	First place	Second place	Third place	Fourth place	Fifth place	Sixth place
J. & G. Thomson Clydebank Co. John Brown	13	7	2	1	1	–
Fairfield S. & E. Co.	10	10	4	1	–	1
Denny Bros.	4	5	13	4	–	–
Scott's Sons	1	2	–	3	1	4
Rowan & Co.	–	2	1	8	2	3
London & Glasgow Co.	–	1	–	3	1	4
Wm. Beardmore & Co. Robert Napier & Sons	–	1	–	1	3	3
Caird & Co.	–	–	2	1	1	6
Yarrow & Co.	–	–	1	2	–	–
Dunsmuir & Jackson	–	–	1	1	4	5
D. & W. Henderson	–	–	1	1	1	–
Muir & Houston	–	–	1	–	6	1
Barclay, Curle & Co.	–	–	1	–	2	–
James Howden & Co.	–	–	1	–	–	–
Stephen & Sons	–	–	–	2	5	2
J. & J. Thomson	–	–	–	–	1	2
A. & J. Inglis	–	–	–	–	1	–
Rankin & Blackmore	–	–	–	–	–	1

Some of these firms, it will be noted, were engaged both in shipbuilding and in marine engineering. In 1913 on the Clyde there were twenty firms, each having an annual output of over 1,000 gross tons, engaged both in shipbuilding and in marine engineering, whilst sixteen firms with outputs of the same magnitude undertook shipbuilding only. Fourteen firms were marine (and general) engineers only. In addition to the above there were eighteen small yards, with an output of less than 1,000 gross tons per annum, doing boat and yacht building only and one of similar size engaged both in boatbuilding and in the manufacture of small marine engines. With very few exceptions, vessels built on the Clyde were engined locally and in addition many engines were constructed by West of Scotland firms for ships built in England and elsewhere. A great deal of repair and renewal work, of which no satisfactory measurement can be given, was also performed.

Earlier in this chapter a brief account was given of the beginnings of organised technical education in Glasgow. This work progressed steadily under the auspices of several institutions until in 1886 these were united to form the Glasgow and West of Scotland Technical College. New buildings in George Street were opened in 1905 and further additions at the same site in 1908, 1909, and 1910. Since 1912 (when King George V authorised the change) it has been known as the Royal Technical College. Courses are provided in all branches of engineering, naval architecture, applied chemistry, building, and textile manufacture in day and evening classes. The one hundred and thirty third session (dating from the foundation of Anderson's College in 1796) was completed in 1929. Day class students during this session numbered 967 and evening class students

2,939. There is now also a widespread network of educational institutions throughout the West of Scotland providing tuition in engineering and allied sciences at day and evening classes. The University of Glasgow was the first in the United Kingdom to establish a Chair of Engineering. This was instituted by Queen Victoria in 1840[1.] and is designated the Chair of Civil Engineering and Mechanics. Some years later a supplementary endowment to it was made by Mrs. John Elder, widow of the Clyde shipbuilder. A degree in Science was instituted in 1872 and a similar degree in Engineering in 1893. The "John Elder" Chair of Naval Architecture (including Marine Engineering) was founded by the munificence of Mrs. Elder in 1883. The "James Watt" Engineering Laboratories were opened in 1902 and extended in 1920. In 1902 also a lectureship in Mining was instituted; it was raised to the status of a Chair five years later. Two additional Chairs were founded in 1921; the "James Watt" Chair of Electrical Engineering[2.] and the "James Watt" Chair of the Theory and Practice of Heat Engines, both being endowed by a fund raised by the Institution of Shipbuilders and Engineers in Scotland. During the session 1928-29 there were 380 students in Engineering at Glasgow University. The city and surrounding area may well be proud of the educational facilities it affords for the study of the applied sciences that provide occupations for such a large fraction of the populace.

The shipbuilding industry on the Clyde was rendered possible only by the huge expenditure which had made and

1. Marking the first meeting of the British Association held in Glasgow (the tenth of the series).

2. A lectureship in this subject had been in existence since 1898.

which kept the river navigable up to Glasgow. Had the river remained in anything like its natural state, shipbuilding above Port Glasgow would have been confined to the construction of small vessels. As it is, however, the yards in which the largest vessels are built are situated only a few miles from the centre of the city. Messrs John Brown & Co.'s establishment is conveniently placed on the north bank of the Clyde, just opposite to the point where the tributary River Cart joins it. Here the Clyde is 800 feet wide. From this yard in 1914 was launched the "Aquitania", (901' x 97' - 45,647 gross tons; 60,000 I.H.P.) at that time the world's largest liner, and here also during the war, huge armoured vessels such as H.M.S. "Hood" and "Tiger" were constructed. For the past fifteen years vessels drawing 30 feet of water have been able, at high tide, to dock in the Glasgow harbour. If we compare the river of today with the river as it was a century and a half ago, when the first organised attempt at improvement was made, we may acquiesce in the terse description with which another writer[1] concludes his survey of the changes: "Glasgow", he says, "has created a river out of a ditch." It can scarcely be doubted that man's efforts and ingenuity have here operated beneficially upon Nature's creation and, if present indications be allowed as criteria, his efforts in this direction are not yet exhausted.

1. Adam Kirkaldy in "British Shipping" (1914).

CHAPTER IX.

FLUCTUATIONS IN OUTPUT UP TO 1874.

Prior to the nineteenth century fluctuations in trade were directly related to abnormal occurrences such as wars, famines, and the discovery of new lands, especially if these latter provided an increased supply of the precious metals. Subsequently such events still exercised a powerful influence upon the course of trade but not in the same direct fashion as formerly. The development of transport and communications tended to lessen the force of such shocks within the area directly involved, but caused the effects to be spread over a much wider field than hitherto. Trade crises, (conjunctures, as Professor Cassel calls them) which cannot be ascribed solely to any of the factors mentioned above, occurred at intervals sufficiently regular to warrant the nomenclature "trade cycle". This phenomenon has been a feature of the commerce and industry of all developed countries during the last century and has every appearance of originating in the internal organisation (or lack of organisation) of commerce and industry itself. Monetary changes serve to complicate matters and make any attempt to isolate causes extremely difficult if not quite impossible. A.C. Pigou[1.] gives the following list of

1. "Industrial Fluctuations", (1927) by A.C. Pigou, M.A.

"impulses" tending to produce industrial fluctuations; good and bad harvests, industrial disputes, wars, inventions, discoveries of new mines, errors of optimism and pessimism in business forecasts, autonomous monetary changes, changes in taste and in foreign demand. He comes to the conclusion that "... the varying expectations of business men... and not anything else constitute the immediate and direct causes or antecedents of industrial fluctuations."

A discussion of the general trade cycle is outside the scope of this special study and attention will be confined to a consideration of the fluctuations in the shipbuilding and marine engineering industries as they relate to the general fluctuations of trade without seeking ultimate or final explanations. Depressions, though probably felt first in the luxury trades where the elasticity of demand is greater than unity, exert their maximum force upon the heavy manufacturing industries. The longer the period of gestation of the goods manufactured, the more susceptible is the industry to the evil effects of errors in judgment as to future requirements. "The industries with the largest amplitude," Pigou states, "are shipbuilding and engineering." The figures submitted in this chapter and detailed in Table C.1. certainly show very violent fluctuations in these joint industries. Variations in output amounting to 25% of the average, on either side of it, over the period of a cycle were not uncommon. A striking feature is the increase in amplitude subsequent to 1850, and after 1874, in the modern period, this becomes positively alarming. Thus, in 1881 United Kingdom production had reached 900,000 net tons; five years later it had dropped to 330,000 net tons. Again in 1906 it had risen to 1,150,000 net tons only to fall to 600,000 net tons in 1908.

Fluctuations in trade are a fruitful source of labour unrest. As a boom develops prices rise and a demand for higher wages is put forward. This the employers may be willing to concede in principle but the fixing of a figure frequently occasions strife. Similarly at the onset of a depression, when falling prices necessitate lower costs of production, resistance by the workers to what they conceive to be an attempt to lower their standard of living is experienced and serves to accentuate the travail of the period. Thus a feature which originates as a result in the end becomes a cause, if not of the depression itself, at least of its prolongation. Wages and conditions in shipbuilding and allied industries are dealt with in Chapter XI below. Improvements in ships and engines were slow of general adoption. In the phraseology of Sir Josiah Stamp,[1.] the inventions took a long time to "arrive", that is to be adopted for all replacements and new work. Improvements and inventions are factors in trade fluctuations; but, as Pigou remarks: "It is not the making of an invention or a discovery that sets up either the reactions of which we have just been speaking in the industries primarily concerned or the reactions in other industries; it is the adoption and actual working of the invention or discovery that does this. But there is no close connection in time between the discovery of these things and their exploitation." The example of railway development which Pigou cites can be paralleled in shipbuilding and marine engineering. If Chapters III to VII be examined with an eye to the dates at which the various inventions, discoveries, and improvements were first made, no connection between these and any

1. "Invention as an Economic Factor;" Watt Memorial Lecture at Greenock, 1929.

period of outstanding prosperity can be discerned. The interval which elapses between the making of a discovery and its general adoption is usually so protracted that to ascribe to this adoption any particular period of prosperity is unjustifiable and certainly not susceptible to convincing proof. The date of the "adoption and actual working of the invention or discovery" is very indefinite. When exactly was mild steel adopted for shipbuilding? Even the table on p. 154 above leaves as groping for an answer, and the replacement of iron by steel was possibly the most rapidly adopted of all the important advances. Periods of depression and keen competition (for example, by sailing ships) possibly stimulated efforts towards economy which resulted in inventions being made, but another period of prosperity was usually well on the way ere the improvement had been incorporated in a sufficient number of vessels to have any real effect.

In 1855 a new principle of business organisation was legalised - the principle of limited liability, and the Act of 1862 resulted in the formation of larger productive units than had hitherto been feasible, especially in the heavy industries. The advent of the limited liability company was a great boon to industry in general; but it must be conceded that the formation of larger units intensified the tendency to errors of optimism and hence to over-production in times of boom, and made competition keener in the lean times which followed. Regarding the cyclical nature of the fluctuations Professor Pigou concludes: "... that some part in determining the recorded rhythm of industry may well be played by each of the several factors which have been considered - -. Sometimes supporting, sometimes cancelling one another, they, in association, no doubt, with a number of sporadic accidents of greater or less importance, jointly determine the duration of successive industrial cycles." It is with the "sporadic accidents" of greater importance as they related to shipping and consequently to shipbuilding that this chapter and the next will be chiefly concerned, rather than in trying to give a complete account of the causes of the general trade cycle.

As the earliest consecutive figures begin about the year 1760 this date will be a convenient starting point. The cessation of the Seven Years' War with France is reflected in the 10% rise of tonnage on the Scottish register in 1763. Thereafter there was an almost uninterrupted increase till the outbreak of the American War of Independence. The depressions associated with the latter period and with the first part of the Napoleonic war have already been dealt with. The financial panic of 1772 - the effects of which may be seen in the diminished Scottish and English imports and exports for that year and in the slight reduction of tonnage on the United Kingdom register during the succeeding year - was allayed by a large issue of Exchequer bills. During similar panics between 1793 and 1797, and gain in 1810, the Bank of England suspended gold payments. The increase in tonnage during and following upon wars was at that time due in a large measure to the capture of prizes - for merchant ships were also fighting ships - which served to replace vessels wrecked, scrapped, or lost to the enemy and at times even resulted in a net increase to the total on the register. Table B.1. shows the tonnage of prize vessels on the British register between 1801 and 1812 and also the totals as they would have been had the losses but not the gains taken place. During this period between one fifth and one quarter of the tonnage on the register is accounted for by captured vessels. After the Napoleonic wars this factor becomes progressively of less account until we come to the close of the Great War when, by the peace terms, Germany's merchant fleet was surrendered for sale among the Allies.[1]

Following the cessation of hostilities in 1815, prices, which had been on the downward grade since 1809, fell precipitously in 1816. Trade, as judged by net tonnage entered at and cleared from British ports, likewise declined from 5,548,000 tons in 1810 to 4,269,000 tons in 1815 and a further drop of over 700,000 tons was experienced in 1817. Thus at its very outset steam navigation, ushered into an unhappy and unsettled world, began under a handicap. In 1812 two steamboats aggregating 55 tons were launched on the Clyde; four years later the output had risen to 529 tons, but in 1817 only one fifth of this amount was launched. Tonnage launched in the United Kingdom - steam and sail together - fell steadily from 102,943 net tons in 1815 to a minimum of 50,928 net tons in 1822. Thereafter a trade revival set in. Many companies were formed to undertake work of an ostensibly useful character at home and abroad. Britain, it seemed, was destined to provide the world with its needs; large quantities of goods were manufactured and exported on borrowed money, but unfortunately the schemes set on foot were not all equally sound and remunerative. Over investment in Mexican and South American mines was also a feature of the boom. Between 1821 and 1825 tonnage entered and cleared rose by nearly 2,000,000 tons, an increase of 50% in four years and tonnage launched rose more than proportionately. Previous

1. See Chapter XIII below.

fluctuations had not been without their lesson to experienced observers and so by 1823 the inevitable crash had been foreshadowed. In response to a request of H.M. Government for a summary of trade prospects in the West of Scotland, the Lord Provost of Glasgow in February, 1823, rendered a statement in the course of which the following passage occurred:

> "Periods of great prosperity are naturally followed by others of an opposite description. And as the extent of business has, during the last year, been unusually great in this department, it is not difficult to foresee a change, the more especially as the increased production of the present time will require more extensive markets; that a pressure causing great stagnation, and consequently lower wages, and distress among the operatives must take place at some time, probably not very far distant, seems to be beyond all question. And much will depend on the political circumstances of the country, as to the period when such a pressure may be expected to occur. It may be added, that the recent practice of our manufacturers exporting their goods to foreign markets on their own account, and of obtaining advances on their goods from commission merchants, to whom they consign them, seems likely to lead to over production, to occasion more frequent gluts in distant markets, and consequently to give rise to greater vicissitudes in trade, than the system which formerly prevailed."

Even at this comparatively early date the outstanding features of the trade cycle had been recognised - this at a time when the imminent depression could not be ascribed to any war, famine, or other exceptional occurrence.

The break came in 1825, a year which marked the highest point yet reached in shipping and in shipbuilding. For steamship building the maximum did not occur till the following year, probably because of the longer period of gestation of such vessels. It may be noted that during two years of this decade - 1823 and 1827 - no steamboats at all were launched on the Clyde. The drop of ships on the register from 2,387,275 net tons in 1826 to 2,153,820 net tons in 1827 must not be ascribed solely to the depression. An indefinite but undoubtedly considerable part of it is to be attributed to the passing of an Act[1] which remedied a defect hitherto prevalent in shipping statistics. It had been the custom to maintain on the register all vessels originally placed there unless proof of their destruction or sale (not always available) had been furnished. Many ships which had suffered such a fate were, by the provisions of the Act, erased from the register in 1827. The bottom of the depression was touched in 1831 when, in the United Kingdom, only 56,852 net tons were launched as compared with 122,479 net tons at the height of the boom. Steamboat building on the Clyde suffered even more severe extremes falling from 1,332 tons in 1826 to only 194 tons in 1831. Thus from the very beginning of steamships right up to the end of the nineteenth century, the readiness of shipowners to revert during depressions to the cheaper though less efficient mode of transport by sail - a proclivity discussed at greater length in Chapter VI - has been a striking feature of the development of navigation and trade.

A period of expansion, associated with the first railway boom in England and U.S.A., now supervened but experienced a sudden check in 1835. Excessive loans to foreign countries, "particularly those that by Revolutions or Declarations of Independence promised a new career of social development and honourable enterprise", served to produce a financial panic which reacted on home industries. Recovery was rapid and an upward trend again set in till 1840 when a new maximum of 211,289 net tons launched in the United Kingdom was recorded. This was succeeded by a fall

1. Geo.IV. c.110.

to 83,097 net tons in 1843. The unsettling circumstance of the country being plunged into war with China in 1840 no doubt accentuated the general feeling of insecurity which prevailed. But the period is one of especial interest to the present study as it marks the beginning of independent variations in steamship building, which in 1842 for the first time, reached 10% of the total annual output of tonnage in the United Kingdom. The following table illustrates the situation:[1]

Year	England		Scotland		Ireland		U.K.	
	No.	Net tons	No.	Net tons	No.	Net tons	No.	Net tons
1840	59	6,186	16	4,110	-	-	75	10,296
41	38	3,158	9	7,863	1	342	48	11,323
42	47	9605	10	2,999	1	1,112	58	13,716
43	39	3,858	7	2,271	-	-	46	6,129

The peculiar movements shown were due to the commencement of Atlantic steam navigation. The year 1838 witnessed the first Atlantic crossing under continuous steaming. The Scottish figures for 1841 therefore include three of the four vessels with which the Cunard Line commenced its transoceanic steam service. All three were built at Greenock and aggregated 5,000 tons. The English total for 1842 is swollen by the inclusion of the Bristol built "Great Britain", 3,270 tons burthen. "Great progress" in shipbuilding during the previous decade is reported by a historian of Glasgow, who adds that at this time "Clyde shipbuilding began a vigorous infancy." The shipbuilding activity of the whole country during this period of

1. Only steam vessels are included in the table.

expansion is reflected in the rapid rise of tonnage on the register from 2,264,476 net tons in 1837 to 2,933,493 net tons in 1842.

A period of unparalleled distress, known historically as the "hungry forties", now set in. Failure of the harvest - especially of potatoes - in 1846 aggravated the distress. Steamship building suffered very severely. In 1845 the Clyde output of this class of vessel was lower than it had been for twelve years; the paltry 576 tons launched during that year is reminiscent of 1814 and was but one thirteenth part of the output of 1841. The Bank Charter Act was passed in 1844 and it had a powerful influence on subsequent financial crises. Although it suffered several suspensions before the end of the century, and to its restrictive provisions some attributed the blame for financial panics, it came to be recognised by the majority of business men as a steadying force in commerce. A second boom in railway construction set in; from about £7,000,000 in 1844 railway investments jumped to over £40,000,000 in 1847. Shipbuilding too experienced a boom, followed in 1848-9 by a temporary relapse. Revolutionary events in France, culminating in the Paris Commune of 1848, doubtless played a part in creating a feeling of insecurity. Thereafter, the busy time which was experienced by shipping, by reason of the gold discoveries in California and Australia, encouraged owners to extend their fleets and the shipbuilding industry expanded to meet the demand. Zenith was reached in 1855 with an output of 323,200 net tons in the United Kingdom for the year. A rapid rise in tonnage on the register marks the period 1852-55. The commencement of the Crimean war in 1854 made a heavy but temporary demand on shipping for the transport of troops and supplies; freight rates rose very considerably. Small wonder that a 60% increase in tonnage output took place in the year 1854-55.

An index of the increasing capacity of shipyards is given by reference to the previous maximum output. This had occurred in 1840 when 211,289 net tons were launched. Thus in fifteen years capacity had grown by 50%, assuming that at both dates - 1840 and 1855 - the industry was fully employed. Judged by net tonnage sail still predominated, the output of this class being in 1854 twice and in 1855 three times that of steam. From about this time may be dated the specialisation in steamship building by Clyde firms, a departure which proved to be such an important factor in the later development of this area. Table B.4. shows in detail how the various Clyde burghs contributed to the output of steam vessels from 1846-52. Only for the latter year are the figures incomplete. Glasgow and Dumbarton were specialising in iron, whilst Greenock and Port Glasgow were more devoted to timber. Denny's of Dumbarton were producing little else but screw driven vessels; paddle steamers predominate in the output of the towns on the south bank of the river. Glasgow executed 50% of the total steamship construction for the area and 75% of the marine engine work. Of the engines for ships not constructed locally, Glasgow manufacturers accounted for one half. The average tonnage of iron vessels is lower than that of timber ships because of the large number of small iron vessels built. Dredgers and the like, however, are not included in the figures given and repairs, for which no figure can be computed, also added considerably to the industrial activity of the West of Scotland. In submitting the table to the British Association meeting in 1852, Dr. Strang explained: "Previous to the last ten years steamboat building and marine engine making on the Clyde and elsewhere may be said to have been in their infancy, but no sooner was the problem of ocean steam navigation solved than a stimulus was given to the construction of steam vessels altogether extraordinary. Previous to 1850 no marine engines were made in Dumbarton, such machinery being furnished by the manufacturers of Glasgow and Greenock." The high water mark of 84,750 tons launched on the Clyde was touched in 1855.

The Crimean war dragged on till 1856, but already in the previous year a decline which culminated in a serious industrial depression had set in. Large investments in American railways had been made, but the chief cause of the crisis seems to have been over trading. Encouraged by the apparently insatiable demand for British goods abroad, merchants optimistically continued to export ever increasing quantities of articles of all kinds, financing their trade by money raised on loan. A financial panic of the first degree accompanied the crisis and, for the second time since 1844, the Bank Act was suspended. A number of joint stock banks in Scotland and in England failed, including the Western Bank of Scotland. The City of Glasgow Bank closed its doors for a month. For six weeks in November and December, 1857, the Bank Rate stood at the unprecedented figure of 10%. During the three years 1855-7 nearly 400,000 emigrants left these shores for America. The depression was prolonged. In his report for 1858, Dr. Strang, City Chamberlain of Glasgow wrote: "While iron shipbuilding has not as yet experienced its former, perhaps too rapid, development it too is beginning to feel the effects of an extending commerce." This seems to have been the expression of a hope rather than a statement of fact. Only in the far East was there any considerable activity. The Indian Mutiny of 1857-8 and the second Chinese war of 1857-60 gave employment to ships as troop carriers. Shipowners therefore were prepared to accept very low freights from the East to Britain in order to get their vessels home to share in the Government contracts. But only in this sphere was shipping in any way brisk. During 1859 the launches in the United Kingdom reached the meagre total of 185,970 net tons of which 35,707 tons were iron ships launched on the Clyde. This represented a drop of 40% on 1855 totals. Recovery was slow; in 1860 distress was still so rampant that tickets for soup, coal, etc. were being distributed to the poor of Glasgow.

The last of the Navigation Laws had been repealed in 1849, thus giving effect to the principle of complete freedom of trade as urged, inside and out of the House of Commons, by Ricardo. This step really meant the repeal of sundry customs duties on certain goods when these were imported in ships other than those registered in Britain or flying the flag of the country in which the goods had been produced. The gradual decay of the mercantile system had left "protected tonnage" an anomaly.[1.] Doubt had been expressed at the time as to the wisdom of the step about to be taken. Gladstone had argued for conditional relaxation instead of repeal, but a clean sweep was made.[2.] As it happened a period of prosperity followed and the prophetic

1. Between 1796 and 1822 minor relaxations particularly in respect to trade with U.S.A. and our Colonies had been made. From 1822 to 1849 reciprocity treaties were made with many other States, each treaty involving the modification of some part of the Navigation Laws.

2. Regulations had been in operation since 1381. After 1853 the employment of foreign sailors on British ships was permitted and in 1854 our coastal trade was thrown open to the world.

Jonahs were silenced. The depression which characterised the second half of the next decade - the period we have just been describing - gave the opportunity for the opponents of repeal to raise their voices in lamentation regarding the tempestuous sea of foreign competition into which British shipping had been driven. A public meeting of "Shipowners of the United Kingdom and others interested in British navigation" was held at the London Tavern on 15th December, 1858, the stated object being: "To take into consideration the present ruinous condition of the British Shipping interest."[1] Deputations came from the leading ports of the British Isles, Scotland being represented by no fewer than 17 delegates from 8 seaports. Of these Glasgow sent 2 and Greenock 3, the others, significantly enough, being from east coast towns which, quite independently of the legislative enactment under discussion, were all more or less in a state of decline. A resolution asserting: "That British Shipping is at present, in all its important branches in a state of deplorable and ruinous depression, partly caused and greatly aggravated, by the excessive competition to which, by the repeal of the Navigation Laws, British Navigation is now exposed with the shipping of foreign nations," was moved and seconded. They were not advocating protection but demanding justice, said the mover of the resolution. To "Mr. Ricardo, a name dear to every political economist, but a man totally ignorant of and unconnected with navigation", was attributed the role of principal villain, whilst G.R. Porter and his "Progress of the Nation", the "Times", and the "Economist" were apportioned their share of the blame. As

1. The facts here submitted were extracted from a pamphlet published at the time giving a verbatim report of the meeting.

a matter of fact not a few British merchants were quite anxious to charter American ships which they could get more cheaply. Certainly Canadians, whose preference in grain had been abolished by the repeal of the Corn Laws in 1846, were anxious to have American vessels for their West Indies trade. At the meeting statistics were adduced to prove the case. It could not be denied that over the past eight years trade had increased, but it was emphasized that entrances and clearances of foreign owned ships were increasing at an alarming rate, much faster indeed than were British vessels. One of the Glasgow delegates, Mr. Gilmour, seconded a further resolution demanding that retaliatory measures be taken against countries which had not given reciprocity to the United Kingdom. These countries were Spain, France, and America in respect to her coasting trade.[1] In doing so, he added: "I would however say, on behalf of the shipowners of the Clyde, that in joining this movement they have no intention whatever to interfere with the progress of free trade. All they want is fair play."

The total capital invested in shipping and allied trades was placed at £70,000,000. American competition was particularly vigorous and just before the Civil War broke out the American merchant fleet was practically level in tonnage with that of the United Kingdom. In 1815 the ratio of British to American tonnage had been two to one. During the next fifteen years this ratio fluctuated and then fell steadily, until by 1850 only 750,000 tons separated the rivals. By 1861 the margin - still in Britain's favour - was a paltry quarter million tons.[2] This was

1. From New York to California was considered a coasting voyage.

2. Not differentiating between steam and sail.

their closest approach; thereafter there was a steady divergence until in 1900 the figures were: Britain, 12,897,592 net tons; U.S.A., 1,954,568 tons.[1] Regarding the statistics submitted to the protest meeting a few comments seem necessary. The intervals taken for comparison were the eight years prior to the repeal of the Navigation Laws and the eight subsequent years. The intervals were quite arbitrary; had five years or ten been taken different results would have emerged. In 1854 the Merchant Shipping Act, which altered the basis for tonnage calculation of vessels built subsequently, was passed. This should have been taken into account as its effect was to reduce the net tonnage figure by 10% of what it would have been had the old system of measurement prevailed. But the most important omission of all was the failure to distinguish between steam and sail. Every "steam" ton was equal to at least three sail tons as a carrying agent, and of the steam tonnage entered at and cleared from British ports in foreign trade during 1857, 90% was registered in Britain. The following table exhibits the relevant figures:

Year	Net tons on register			Increase			% Increase		
	Steam	Sail	Total	Steam	Sail	Total	Steam	Sail	Total
1842	107,927	2,933,493	3,041,420	51,757	392,781	444,538	48	13	15
1849	159,684	3,326,274	3,485,958						
1850	168,474	3,396,652	3,565,133	248,992	744,622	993,614	148	22	28
1857	417,466	4,141,274	4,558,740						

Practically all the steam vessels in use by foreign competitors were either entirely British built or at least had engines supplied by British manufacturers. Statistics

1. Including American river and lake craft.

distinguishing between vessels built for home and colonial owners and those for foreign owners are available from 1855 onwards. It is noticeable that few sailing ships were being built for abroad; each country built its own. The steamships constructed to the order of foreigners during the decade 1855-64 constituted a quarter of the total output in the United Kingdom. Thus, while it was true that some of these went into direct competition with British ships, the gain to this country in building them exceeded, at that period, any loss which the shipping industry thereby incurred. Had the sailing ship been destined to retain the leading place in ocean navigation which for centuries it had occupied, doubtless the increase of foreign shipping would have been a real menace to Britannia as mistress of the seas, in peace and in war. As it happened, the development of the iron steamship - a development towards which Clyde builders and engineers made invaluable contributions - served but to emphasize the feebleness of foreign competition during the ensuing thirty years. Until other countries too acquired a mercantile fleet of steamships they participated only in the less remunerative branches of sea transport. If the agitation of 1858-9 produced no legislative results it did make British shipowners realise that, if they were to retain their place on the high seas, they must surrender the prejudices which had hitherto caused them to neglect - or even to reject - the new designs and inventions that builders and engineers had to offer. By 1860 few wooden ships were being built on the Clyde and it is from this date onwards that the river became the most famous in the United Kingdom. The industry, as Dr. Strang remarked, dealt "chiefly with articles of home produce and the raw materials were products of our own soil." For the decade 1853-62, Clyde output of iron vessels consisted of 952 ships aggregating 586,914 tons. To convey some idea of what this represented in money values we may take the output of 1861 as follows:

	£
81 iron steamships (60,185 tons) hulls and fittings	1,252,300
engines for same (12,493 N.H.P.)	456,800
5 iron sailing ships (3,060 tons) hulls and fittings	50,560
	1,759,660

This averages out at £21 per ton for steam vessels without engines or £28 per ton with engine, £16. 10/- per ton for sailing vessels, and £36 per N.H.P. Including wooden vessels, repairs, and engines for ships built elsewhere, of which there are no records, the sum accruing annually to the West of Scotland by reason of its shipbuilding and marine engineering activities, cannot have fallen much short of £2,000,000 for an average year. Of the period 1849-60 the historian McGregor says: "Shipbuilding was becoming a most important industry of Glasgow and its neighbourhood." After this it became the most important industry of the district.

Early in the sixties the country experienced another boom in trade. It involved more or less all industries, but especially railways and shipping. The expansion was aided, if not in some measure caused, by the formation of many new companies and the extension of existing enterprises in consequence of the Joint Stock Companies Acts of 1855 and 1862. The principle of limited liability widened the circle of investors and seemed to offer greater security to shareholders than had hitherto existed. Unfortunately speculators too found encouragement in the provisions of these Acts, the spirit and intent of which were flagrantly broken. In many instances only a small fraction of the nominal capital was called for at the beginning and thus limited liability differed only in name from that of the unlimited variety. Especially was this the case with finance or "money lending" companies. Shipbuilding received an incentive from the demand for ships to run the blockade imposed by the Northern States during the Civil War. Of the total Clyde output of 184,000 gross tons in 1864, no less than 30,000 tons were definitely built for this purpose. This internal struggle in the U.S.A., begun in 1861, came to an end in the Spring of 1865. For the latter year Clyde production amounted to 161,180 gross tons of which only 2,715 tons were specifically for blockade running. But the American convulsion had a still more important effect on British shipping. It brought about an extensive sale of ships by Southern owners and their transfer mainly to the British flag. The unusually large additions of tonnage to the register at this time - 400,000 gross tons in 1863 and 300,000 gross tons in 1864 as compared with an annual average of 117,000 gross tons for the previous decade - is thus explained, the United Kingdom outputs for these years being 378,307 net tons and 460,833 net tons respectively. Whilst North and South were busy settling their internal differences by force of arms, British merchants took the opportunity of seizing the trade with India and China, trade in which previously America had been our keenest rivals and had actually been gaining on our merchants. A large part of the direct trade with America also fell into our hands as is witnessed by the fact that the tonnage of vessels registered in Britain and engaged in this trade rose from 945,668 net tons in 1860 to 1,853,145 net tons in 1866. In 1860 some 2,750,000 tons of merchandise had been carried to and from British ports in American hulls; ten years later this figure had fallen to 1,150,000 tons.

The twenty years following the repeal of the Navigation Laws (or of such relics of them as still remained in 1849) is generally considered to have been a crucial period for British shipping. It is sometimes even contended that, had the American Civil War not taken place so opportunely, the attack upon Britain's supremacy in sea transport would have been successful. Before proceeding to the discussion of fluctuations in modern times an evaluation of this contention will be attempted. That the legislation of 1849 encouraged and stimulated foreign competition for sea borne traffic no one can reasonably doubt. Nor is it necessary to question the sincerity of those who interpreted the depression of 1856-60 as heralding the permanent decline of British shipping. The plight of builders and owners was serious; many ceased to build except to order. By the end of 1858 steamers of which the original cost was £36 per B.M. ton (engines included) were selling at one third of this figure. Superior "twelve year class" sailing ships, which with the low prices ruling during 1858 cost £17. 10/- to £20 per ton to build, were selling at £13 per ton, less than a year later. But the alarm of these years was false in asserting that a fundamental change in Britain's position was taking place. The depression was felt in all industrialised countries, most severely in the United Kingdom because it was the most developed. As to the importance of the Civil War, it is almost sufficient to point out that the bottom of the depression had been touched before the war broke out. Doubtless the struggle as to mercantile supremacy would have been more prolonged had the North and South chosen to compose their differences without recourse to arms, but surveying the whole series of facts that the passage of time has revealed, it is difficult to believe that the Civil War had any effect other than to hasten by a few years the development which was bound to have taken place in any case. Consider the actual figures. The following table gives the percentage tonnage of foreign owned vessels of the total tonnage entered at and cleared from ports of the United Kingdom in foreign trade.

Year	Steam & Sail: Cargo & ballast	Steam & Sail: Cargo only	Steam only: Cargo & ballast
1820	15 %		
1830	26		
1840	31		
1850	35	33 %	18 %
1860	44	42	16
1870	32	30	12
1880	30	28	17
1890	27	26	21
1900	36	35	30

There is no evidence to support the contention that the repeal of the Navigation Laws had more than a transitory effect on British shipping. The main factor in Britain's superior position and the only one without which her trade would most surely have declined, was the development and wide adoption of the iron steamship. Whilst the rate at which steam and iron replaced sail and wood may have been accelerated by stress of competition during the decade succeeding 1849, the factor itself was surely independent of Navigation Laws and internal American strife. It was much more dependent on the opening of the Suez Canal in 1869, because sailing ships could not negotiate that narrow and often becalmed waterway. What is really doubtful is whether, had these Laws remained on the Statute Book, the enormous expansion of British trade would have taken place!

After the crisis of 1866, when for the third time in twenty years the Bank Act suffered suspension, a depression lasting three years set in. Bankruptcy court records for this time show numerous failures in businesses of all kinds. In 1868 the Abyssinian Expedition, entered upon during the previous year, gave employment to some 300,000 tons of shipping at a cost of £4,000,000 to the country. Freights to the East were high and this gave some stimulus to shipbuilding, of which the output from 1868 onwards was rather more than might have been expected in the circumstances. Apprehensions were entertained in certain quarters that the phenomenal continuation of additions to the register, especially of steam vessels, would end in disaster. For each of the three years 1869-71 Clyde output hovered just below 200,000 tons but did not actually reach this figure till 1872. Similarly for the whole United Kingdom, output had fallen off in 1866; in 1867 was 33% below 1865; and thereafter, increased year by year. The eight months' war of 1870-71 between Prussia and France temporarily disabled two of our keenest competitors, and the subsequent expansion of Germany created an unusually keen demand for British-built steamships. For abroad there were built in 1871 only 36,703 net tons; in each of the next three years over 80,000 net tons were launched to foreign orders. Increasing trade and the scrapping of sailing ships maintained the shipbuilding and marine engineering industries on a wave of prosperity until 1874 when the highest output figures hitherto attained - 603,867 net tons for the United Kingdom and 266,838 gross tons for the Clyde - were recorded.

CHAPTER X.

FLUCTUATIONS IN OUTPUT (contd): 1874-1914.

Indications were not lacking during the second half of 1874 that the high level of production could not continue much longer and that lean times ahead were to be expected. Orders for new vessels were greatly reduced and, as a result, output in the following year was down, in the United Kingdom by 130,000 tons and on the Clyde by 50,000 tons. Reaction followed the over production which had undoubtedly taken place after the close of the Franco-German war. More striking even than the fall in output of ships to be registered in Britain, was the complete collapse of orders from abroad. No less than 82,664 net tons had been launched for foreign sale in 1874; two years later the figure was 17,655 net tons and the next year was even lower. Of the 1877 output, it may be remarked, one half was sail. A feature of this as of previous depressions was a financial crisis during which, in October 1878, the City of Glasgow Bank closed its doors permanently. Many thousands of working class people thereby lost their life's savings and much distress resulted. Relative to the East coast production, the Clyde experienced at this time a temporary decline. Renewed activity began in 186 continued till 1883 when the record output of 419,664 was attained. Many who knew nothing of shipping - "inland shipowners" as they have suggestively been called - invested capital in shipping. The boom was encouraged - it cannot be said caused - by the introduction of the triple expansion engine which brought the Pacific Ocean trade, the last stronghold of the sailing ship, within the ambit of the steamship. For the five years 1879-84 the tonnage of sailing ships launched constituted only 12% of the total for the Clyde and in 1880 fell as low as 6.4%. Shipbuilding costs rose 20% to 40% and by the end of 1883 empty slipways in the yards foretold the approach of the inevitable depression. "If the cause can only be ascertained, no great difficulty need be found in applying the remedy", said one writer[1.] - facetiously, one is almost tempted to think; for despite the increased working week and substantial wage cuts, establishments found drastic curtailments necessary and hundreds of cargo steamers were laid up during 1884. In retrospection at the end of this year the same journal - probably the same writer - discovered that overproduction had been the cause of this and of the two previous depressions: "The freight markets of the world became unable to find employment for a fleet that was increasing by leaps and bounds, and in the end the inevitable stagnation set in."[2.]

Throughout 1885 and 1886, the depression continued. The Government's decision to extend their naval programme held out slender hopes of greater activities, but only for certain areas. On the Clyde, for example, Messrs J. & G.

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 20th December, 1883.

2. "Glasgow Herald Shipbuilding and Engineering Supplement" for 20th December, 1884.

Thomson's whole output of 8,810 displacement ton year 1885 consisted of war vessels. Of this class 15,334 displacement tons were launched on the Clyde that year. The close of 1886 left industry in much the same position as it had been at the beginning of the year. An idea is prevalent in some quarters that periods of depression stimulate a wider adoption of new inventions with a view to greater economy rendered necessary by low prices. But immediate cheapness and efficiency are not synonymous, and in shipbuilding and marine engineering bad times have the contrary effect. Thus in 1885 sail tonnage, which had been on the increase again since 1883, constituted 55% of the total launched and the number of novelties or departures from the normal in ship design were fewer than usual. It has been suggested that the failure of de Lessep's scheme for the Panama Canal gave renewed hope to owners of sailing ships that they might still be able to resist the encroachment of the steamship in the Pacific, especially in the grain trade. In view of the fact that the scheme was begun in 1881, suspended in 1887, and the company finally dissolved in 1888 it is difficult to see how this could be a source of encouragement in the years 1883-5. The use of mild steel in place of iron was becoming more general. The fall in the price of steel of course accelerated the change - a fall due partly to the fall in the genrral price level and in wages, and partly to improvements in the technique of manufacture. Most of the larger vessels being built were fitted with triple or quadruple expansion engines.

The depression scourged the whole country and a Royal Commission was appointed to consider causes and remedies, but little of note emerged from their deliberations and their conclusions were vague. Indications of a revival were manifest towards the end of 1886. Orders booked on the Clyde during the closing four months of the year were as follow:

September	- 10,000 gross tons	-	very low.
October	- 37,000 gross tons	-	good.
November	- 27,000 gross tons	-	fair or average
December (first fortnight only)	- 65,000 gross tons	-	exceptional.

Thus came to an end a depression which, if output as compared with the previous maximum be taken as the criterion, must be described as the most serious ever experienced in shipbuilding prior to 1914; for in 1883 there had been launched in the United Kingdom no less than 892,216 net tons, whereas in 1886 only 331,528 net tons (37% of the former figure) were launched. At the beginning of 1887 labour and materials were cheap, but by the end of the year prices were rising rapidly. Shipbuilders refused to tender at the lower prices and so in a few months these rose 15% to 25%. To those engaged in the industry, employers and workers alike, this leap to prosperity gave great satisfaction; but those who were considering the wider aspects of the situation had grave misgivings. "Has the decrease in the shipping register been so great or has the trade of the world developed so suddenly as to warrant such a number of new ships being ordered in such a short time?" asked a contemporary writer.[1] The answer is that after a fall in 1886, tonnage entered and cleared in cargo increased by 2,400,000 net tons in 1887, by 2,600,000 net tons in 1888, and by 2,800,000 net tons in 1889, a rate of increase not at all exceptional in times of expansion. Tonnage on the register had declined by

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 21st December, 1887.

100,000 net tons between 1885 and 1887, a fall more than amply accounted for by removals of sail from the register. For the five years' period 1881-5, the tonnage removed annually averaged 370,000 gross tons. The year 1886 was 55,000 tons above this average, whilst 1887 was 115,000 tons above it. Thus, despite increased output the net additions to the register during 1886 and 1887 were practically nil. During 1888, however, there was a substantial net addition and in 1889 this reached the huge amount of 555,000 gross tons wholly steam. If now we make the reasonable assumption that ships launched in any year were ordered the previous year we obtain the following net "potential additions" for the period 1886-9; 67,000; 64,000; 265,000; and 518,000 tons respectively. The removal of ships from the register is seen to be in preparation for new tonnage about to be added; the removals though antecedent to are not a cause of the additions.[1] For the year in question (1887-8) the large orders given were not necessary to replace the ships removed from the register in 1886-7. In the early autumn of 1888 the price of iron and steel advanced by over 20% in a few weeks. A well equipped cargo steamer with triple expansion engines, over the same short period, rose in price from £27,000 to £33,000. Speaking at a meeting of the Chamber of Shipping, Mr. John Williamson said;[2] "I regard this burst of building with dismay and feel absolutely hopeless as to the immediate future of shipowning in this country, the more so that we seem to forget the continually large increase and competition of foreign tonnage and that our new cargo steamers make much more frequent voyages, now steaming,

1. For a more detailed account of removals and additions to the register see Appendix 6.
2. Quoted in "Glasgow Herald Shipbuilding and Engineering Supplement" for 21st December 1888.

instead of the old 8 knots, 10 and 11 knots, thus increasing our carrying power by 25%."

Judged by tonnage entered and cleared, trade continued to expand till 1890. Simultaneously with this expansion of trade it is significant that tonnage entered and cleared in ballast also increased considerably. This indicates that all the new vessels were not obtaining constant employment[1]. Tonnage entered and cleared remained fairly constant throughout 1891-2 but fell in 1893 only to rise again in 1894-5 to a higher level than before. Meantime tonnage in ballast continued to increase till 1894. Summing up it may be said that some part of the expansion which took place in shipbuilding from 1888 to 1890 was justifiable, but as on former occasions the boom overshot the mark. To return, however, to 1887; prosperity reigned where a short time before distress had stalked and neither workers nor shipbuilders gave much consideration to a problematical overstocking of the market for ships. Great activity characterised the Spring of the year, followed in the Summer and Autumn by numerous launches of vessels begun towards the close of 1886. For a time during the latter half of 1887 new orders fell off, but a rise in freight rates stimulated a renewal of the spate of contracts. Rising costs of labour and materials, coupled with indications of an imminent fall in freight rates, again induced a temporary diminution in orders. The boom continued throughout 1889. Production for sale abroad exceeded anything previously recorded and accounted for over one fifth of the total consisting, as always, mainly of steamships. A considerable fraction of the total output was naval vessels and not a few of these were for foreign governments. Prices were anything up to 45%

1. Or that older vessels previously employed were now thrown idle.

higher than during the previous year, steel having advanced £2. 10/- per ton. But freights were falling and vessels were laid up in the East for want of cargoes. The rise of 40% to 50% in freights which had taken place earlier in the year was quite wiped out by the fall which commenced towards the end of the year. Experts were gloomy in their predictions. Could there possibly be work for all the new ships?

The length of time during which the boom persisted was quite unprecedented. In each of the years 1890-91-92, output exceeded 800,000 tons. The Clyde and the Tees in 1890 actually showed an increase on their respective outputs for 1889; this despite the fact that, according to shipowners, freights were so wretched that it involved less loss to lay up some of their vessels than to run them. Tonnage entering and clearing in ballast was increasing. By the end of 1891 a depression seemed inevitable. Owners claimed that only their acceptance of "beggarly freights"[1] had staved it off so long. Ships differ from many other commodities in that they cannot be produced and kept in stock till better times. They must get employment at once if they are to pay, for types alter quickly and a lapse of 4 or 5 years generally sees economies which handicap older vessels in competition for cargoes. With a meagre 268,000 gross tons on hand on the Clyde the outlook for the shipyards during 1892 appeared to be anything but cheerful and builders were reduced to the expression of hopes that the imminent collapse would not touch the depths experienced six years earlier. Yet the year witnessed but a negligible fall in output for the United Kingdom and, owing to warship

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 19th December, 1891.

launches, the Clyde total for 1892 actually exceeded that of the previous year. According to builders, however, business was much less profitable than it had been a few years before and low freights, necessitating economical running, certainly induced many owners whose ships were still equipped with compound engines to have these replaced by the later triple or quadruple expansion types. A further point worthy of note is that no less than 48% of the tonnage launched on the Clyde in 1892 was sail. The demand of the time was undoubtedly for cheap vessels though this marked the final revival of that type of vessel. Before the end of the year evidence that the long anticipated depression had really arrived was unmistakable, nor was Britain alone affected. Bad harvests and a drought in the Antipodes aggravated the situation.

The ensuing five years can be suitably described only by the term "stagnation". Countries which had indulged in a policy of bounties to encourage shipbuilding were actually, in that industry, the greatest sufferers. [1]"Attempts to bolster up the shipbuilding industry by means of subsidies seems to be proving a complete failure", was the considered judgment of a writer at the time. In Britain shipyards were operating at little more than half their capacity. Despairing appeals to the Government to give more substantial subventions to first class mail-carrying passenger ships were made by shipowners, whilst builders urged the advisability of an extended naval programme. "The necessity for an increase of our Navy seems undoubted", pleaded a writer in a shipbuilding annual. "It is to be hoped that the Government will place a large number of orders for new ships of war with

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 19th December, 1892.

private builders and thus confer much needed benefits on the industry".[1] The Navy, it would seem, had its advantages in time of peace as well as in time of war. Sweet are the uses of a government! From a paltry 8,000 tons displacement in 1893 and 5,300 tons in 1894 launches of naval vessels from private yards rose to 69,000 tons displacement in 1895, followed by a further 51,000 tons in 1896. From Government yards the output was 70,000 tons and 66,000 tons respectively in these two years. The term stagnation has already been applied to the period 1893-97. As a matter of fact average output was quite fair and on the whole, the Clyde area suffered less than others. Its output during 1896 exceeded the previous maximum of 1883. But a feeling of uncertainty and "deadness" vitiated the industrial atmosphere. Unemployment in 1893 and the year following exceeded 11%. A bank rate of 2%, maintained for two and a half years, failed to give the necessary stimulus after the collapse of 1893. At a rate of less than 1% at times money was idle on the market. Pessimism prevailed universally and a temporary revival in 1894 served only to darken the shadows ahead. Although the freights were fairly well maintained, the succeeding year was anticipated with feelings akin to dread. The fear that too many ships were still being added annually to the register was uppermost in many minds.

It must be kept in mind that each succeeding boom involved a further extension of plant and almost every year witnessed improvements in technique and economies in production. On account of this, orders which would have strained to the utmost the capacity of shipyards and shops a decade before, now gave but moderate employment to machines

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 18th December, 1893.

and men. One feature which did something to relieve the situation was the annual removal from the register from 1894 to 1898 of large quantities of tonnage so that the total on the register, though representing every year a greater carrying capacity, remained at a figure which was practically constant. Owing to the prolonged dispute of 1897, production was down badly that year, but with 386,000 gross tons on hand the succeeding year inspired hope. "Our shipbuilding trade is as sound as ever and may soon be as prosperous as ever", was the comment of a correspondent and his optimism was justified by the 35% increase in output which took place in a single year. Good fortune again favoured the Clyde for here the increase was greatest of all. Fresh output records were established in all areas. Shipyards were taxed to capacity and a continuation of the spate of orders during 1899 necessitated extensions of plant. According to Sir Thomas Sutherland, ships were now 50% dearer than four years before. Certainly costs of labour and materials were exceptionally high. Sailing ships were almost extinct so far as new production was concerned, not a single one of the old square rigged type being constructed on the Clyde during the year. Two foreign countries only continued to add to their numbers of this class; the United States, because the routes on which her ships traded and the kind of cargoes carried were eminently suited to sailing ships; France, because of the Government bounty paid on all vessels constructed irrespective of type.

For some years previously foreign competition, not only in trading but also in building, had been growing more keen. Britain's chief rivals were U.S.A. and

Germany. A few years earlier the latter country had begun to build for other countries in addition to supplying her own needs. But the total of foreign and colonial output barely exceeded that of the Clyde area alone, so that the menace was not serious. Labour costs were lower in Germany because hours were longer, and shipyards of the U.S.A. were better equipped with machinery than ours, but could not produce so cheaply as the United Kingdom. For example, in 1902 the Clyde price for a 5,100 ton steamer was $225,000, whilst for one of only 3,000 tons the price at Philadelphia was $350,000. Clyde built ships had held the blue riband of the Atlantic for the past twenty years with but one short break. This was now won by a German built vessel. According to Professor Biles, Germany could beat Britain in economy of running but not in economy of construction of ships. The French Government in 1903 gave a bounty of 65 francs (equivalent to £2. 10/-) per registered ton and 15 francs (11/6d) per 100 kilograms engine weight, for all vessels built and engined in France. The sum voted to this purpose for the ensuing three years was used up in nine months and the bounty proved to be quite futile because of the heavy duties levied on imported materials. Nevertheless the system was maintained and in 1906 the bounty was nearly twice the initial figure per ton. Thus the menace to our position in the shipping world was much more serious than in shipbuilding. The point now arrived at - the end of the nineteenth century - is an eminently suitable one from which to take a survey of the situation from the American Civil War onwards.

The repeal of the Navigation Laws had but a transient adverse effect upon British trade, which gained considerably by the check suffered by the U.S.A. in 1861. As the pioneer of machinery and of railways, Britain had become the workshop of the world, and the rise of iron shipbuilding between 1850 and 1873 confirmed her position as the greatest carrier of the world. The advent of mild steel consolidated this position for over a decade and the development of the triple expansion marine engine more than offset the elaborate system of bounties instituted by Continental countries to foster their shipping. The only state assistance which British shipping received was the postal subvention granted originally to the Cunard, Peninsular and Oriental, Royal Mail Steam Packet, and the Pacific Steam Navigation companies. This applied only to fast passenger vessels and in 1894 affected only 3% of British tonnage. In 1881 an elaborate system of reduced railway rates, payment of Suez Canal dues, bounties on tonnage built, and so forth was begun by France. Four years later the example was followed by Germany, Italy, Austria-Hungary, Japan, Russia, Denmark, Spain, Belgium, and U.S.A. Not till the late nineties did the stress of foreign competition show any effects upon Britain's virtual monopoly of sea borne traffic. This is demonstrated in the following tables the first of which shows our rivals in order of importance and the percentage of foreign to total tonnage (sail and steam) entered at and cleared from ports of the United Kingdom:

Year	Foreign Competitors					Foreign Total %
	First	Second	Third	Fourth	Fifth	
1850	U.S.A.	France	Norway	Denmark	Holland	33.2
1860	U.S.A.	Germany	Norway	Denmark	France	41.9
1870	Norway	Germany	U.S.A.	Italy	France	29.7
1880	Norway	Germany	Sweden	Denmark	France	27.8
1890	Norway	Germany	Holland	Denmark	Sweden	26.2
1900	Norway	Germany	Sweden	Holland	Denmark	34.5

The next table shows the same data if steam tonnage only be considered. It will be noted that although the percentages increase after 1870 those are all lower than in the former table. The alterations in the relative positions of our competitors will also be noted.

Year	Foreign Competitors					Foreign / Total %
	First	Second	Third	Fourth	Fifth	
1860	Germany	Holland	Belgium	France	Spain	15.5
1870	Germany	Belgium	France	Spain	Holland	11.6
1880	Germany	Holland	Sweden	Denmark	Spain	15.9
1890	Germany	Holland	Spain	Denmark	France	19.7
1900	Germany	Norway	Holland	Sweden	Spain	31.5

Of the countries mentioned above Norway, Italy, Germany and France were extensive purchasers of second-hand vessels from British owners.[1] Lastly a table showing the percentage of British to total tonnage entered at and cleared from ports in foreign countries is given.

Country	British / Total %		
	1880	1890	1900
Russia	86.5	55.1	44.7
U.S.A.	78.7	52.8	52.8
Italy	61.0	48.4	23.8
Holland	69.3	52.0	44.6
Sweden	64.6	22.1	12.0
France	72.0	40.6	43.0
Germany	62.4	36.6	29.9
Norway	30.0	16.3	12.0

The above figures give eloquent testimony of the growing independence of foreign countries in the carriage of their own sea-borne traffic. As a competitor with Britain for

1. See Appendix 6.

the remainder of the carrying trade, including that to and from the United Kingdom, the only country of any account was Germany. Although German shipowners were assisted by state bounties, it must in fairness be admitted that they scored their greatest success on the Atlantic routes on which they had no governmental assistance. This was due in no small measure to the very efficient, if somewhat objectionable, organisation of their emigrant traffic and to the fact that their shipping was concentrated upon two large and well equipped ports, Hamburg and Bremen. As an offset to her loss of foreign traffic, Britain developed a very large trade with her overseas Empire, which resulted in a steady increase in her shipping up to 1914.

The South African war, while it lasted, (1899-1902) accounted for entrances and clearances of 1,500,000 tons per annum. Its effect on the shipbuilding industry was small. Owing to increased foreign demand the peak year for United Kingdom output occurred in 1901, whilst for vessels for British and Colonial owners the peak was not reached till the following year. In 1900 a third of the tonnage launched on the Clyde was for abroad. Freight rates, which had risen rapidly both on homeward and outward routes at the commencement of the Boer war, fell precipitously during 1901 and 1902. In both of these years Clyde output for the first time exceeded the half million gross tons. It would seem that the substantial fall in the price of cargo vessels half way through the year 1901 was responsible for a renewal of the spate of orders for new vessels which made 1902 a peak year, especially on the Clyde. The introduction of pneumatic tools in place of those operated by hydraulic power, which were costly and cumbersome, is worthy of notice. They were also capable of use for work previously performed by hand. So great was the economy of working time achieved by the new machines that in 1905 an agreement was arrived at between employers and men to reduce the "shell" hand work rates of pay by 40% and the "inside" hand work rates by 35%. Just at the beginning of the century also, tool steel which had been in the process of development since Mushet's experiments with tungsten, manganese, silicon, and carbon in the sixties, reached a very high stage of perfection by the introduction of the Taylor-White heat treatment process.[1]

Indications pointed to an approaching depression and the demobilisation, following upon the cessation of hostilities, served to augment the ranks of the unemployed. Of the 470,000 tons on hand in Clyde shipyards at the end of 1902, almost one quarter consisted of war vessels. Demarcation disputes did not help matters during 1903, but they gave an indication of the scramble amongst the trade unions to ensure as much work as possible for their respective members. Freights, though fairly well maintained for inward cargoes, were wretched for outward voyages, dropping during 1904 to less than half of what they had been at the beginning of the century. Competitive pricing, particularly amongst firms of the north east coast, resulted in a very low figure for new ships thoughout 1904 and during that year the depression continued unrelieved. "The market is overstocked with tonnage in search of employment", was the verdict of a shipping correspondent. When the revival did come in 1905 the Clyde area was the last to feel it as it had been last to experience the commencement of the depression.

1. Since then vanadium and chrome-vanadium high speed steel has superseded the earlier types.

A period of expansion lasting for three years now supervened. Each succeeding year touched a higher maximum despite poor freights, higher prices of materials, German and Dutch competition, and not infrequent labour disputes in all three years. Even with lower wages the German cost was from 10/- to £1. per ton more for cargo vessels than was the British cost and despite the exemption of shipbuilding materials from tariffs and cheap railway transport, German builders found it difficult to keep their home orders. Costs in the U.S.A., a country similarly hampered by tariffs, were fully 30% in excess of costs in the United Kingdom. Between 1905 and 1907 tonnage entered at and cleared from British ports increased by 11%, in actual figures by 10,000,000 net tons. But tonnage in ballast increased by over 50% (i.e. 12,000,000 tons). A net addition of 750,000 net tons was made to the United Kingdom register during the same period. It is therefore evident that all the new tonnage was not obtaining full employment. For the United Kingdom the peak year was 1906 with the unprecedented output of 2,000,000 gross tons; for the Clyde it was 1907 with a record of 620,000 tons. With improved tools and more extensive yards than her competitors, Britain maintained her leading position in the world. Orders could be executed with despatch and during 1907 many palatial passenger vessels, including the "Lusitania" at Clydebank, were launched. But the overstocking of the market could not continue indefinitely and the falling off of orders coupled with keen price cutting to get those available, heralded the approach of a depression.

The collapse of 1908 was almost without a parallel in the history of the industry. The drop in Clyde output was precipitous, from 619,919 gross tons in 1907 to 355,586 gross tons the following year. Not since 1897 had production fallen to such a low figure and, relative to the capacity of the yards, the only comparable depression was that of 1886. In 1908 trade fell off more rapidly than in any previous year, and tonnage in ballast exceeded in 1908 and in 1909 the already high total of 1907. From 1907-10 tonnage on the United Kingdom register remained practically constant. Two causes of the depression are alleged by contemporary writers viz. the financial upheaval in U.S.A. which began in 1907 and the old enemy over-production, the latter being reinforced and magnified by the practice, prevalent at that time, of speculative construction in anticipation of demand. We quote a few phrases current at the time:[1.] "... world overstocked with ships; ... more ships on the seas than employment can be found for... Speculation has, by providing unnecessary ships, staved off the revival in trade which is now overdue." It would therefore seem that the prosperity of the three preceding years had been artificially induced. Some slight recovery was made in 1909 but revival was slow to manifest itself as the market was still overstocked. However matters were moving to remedy this, at least so far as the United Kingdom was concerned. In 1909 some 350,000 gross tons of old vessels were sold to foreigners. In the next year 600,000 gross tons, and so on progressively to 1913 when 800,000 gross tons were disposed of in this matner. It must be remembered however, that although this relieved the British register and induced new shipbuilding, most of these vessels sold remained on the seas under foreign

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 30th December 1908.

flags, to compete with British shipping. Throughout 1909 relations between capital and labour were amicable enough. Fruits of the 1908 "we want eight and we won't wait" agitation by the advocates of a "two power" naval standard began to appear in 1910, when over 100,000 tons of war vessels were on the stocks throughout the year. The total launches of 1910 were below those of the previous year but did not touch the minimum of 1908. Two Parliamentary elections and several industrial disputes, including the three months lock-out of the boilermakers towards the end of the year, did not help matters. Indications pointed to a recovery during the ensuing twelve months and the year closed with almost half-a-million gross tons on the stocks in Clyde shipyards.

Phenomenal activity marked the year 1911, nor was this in any sense localised; all the industrial countries of the world shared it. The fears of over-production had, like the Arabs, stolen silently away and even rising costs of labour and materials caused no apprehension. Once again the industry was on a rising wave. No serious disputes in engineering or shipbuilding marred the year's work; masters and men kept the industrial weapon sheathed nor did either side so much as threaten to withdraw it. There was employment everywhere for more men than could be obtained. Over 630,000 gross tons of shipping left Clyde yards during the year. The boom continued throughout 1912 the output being 10,000 tons in excess of that of the previous year. Disinclination to appeal to force in the settlement of disputes was increasing and during 1913 production was limited only by the capacity of the plant available. The total for the Clyde reached the unparalleled figure of 756,976 gross tons, constituting one third of the

United Kingdom total. Wages increased and complaints by employers of the men's broken time, "in many ways more injurious to the employer's work than organised hostility on the part of the men",[1] were plentiful. But as the year drew to a close it was evident that the crest of the wave had been passed in the last two months and that leaner times loomed ahead.

The whole situation was radically altered by the outbreak of war and little purpose would be served by quoting the partial figures available. The trend during the first six months of the year was downwards and it would seem probable that, had international peace prevailed, industry would once more have suffered a depression, the severity of which would doubtless have been directly proportional to the degree of prosperity which preceded it. Surveying the shipbuilding statistics of the century 1814-1913[2] one cannot fail to be impressed by the magnitude of the fluctuations which occurred, a feature prominent long before steam power was of any importance in navigation. The table below gives the years of real maxima and minima in United Kingdom production,[3] together with the percentage which each minimum and maximum constituted of the immediately preceding maximum. The purpose of calculating it in this manner is to convey an idea of the severity of the depressions and the need for extensions created by each ensuing expansion, assuming only that at the height of each boom the shipyards were working to capacity.

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 30th December, 1913.

2. See Table C.1. and graph C.1.

3. The measure being net tonnage and the figures including both steam and sail but excluding war vessels for the British Admiralty.

	Year	%		Year	%		Year	%
Max.	1815		Min.	1861	59.8	Max.	1889	96.0
Min.	1822	49.5	Max.	1864	132.0	Min.	1893	68.5
Max.	1825	119.1	Min.	1867	66.5	Max.	1901	114.9
Min.	1831	46.4	Max.	1874	131.0	Min.	1903	77.1
Max.	1840	172.1	Min.	1876	62.7	Max.	1906	117.6
Min.	1843	39.4	Max.	1883	147.8	Min.	1908	52.1
Max.	1855	165.3	Min.	1886	37.2	Max.	1913	106.7

The fluctuations follow the course of the general "trade cycle" and exhibit no greater degree of regularity. They are, however, much more extreme than those that occur in the supply of consumable goods. Even amongst the constructional industries no other shows expansions and contractions so violent or having so great an amplitude. The proportions which minima bear to preceding maxima show no definite trend, but a justifiable deduction seems to be that maxima are tending to increase at a smaller rate as time goes on. Observers at different times - some of whom we have quoted verbatim above - have ascribed the depressions to "over production" but clearly that cannot be accepted as an ultimate explanation. What induces or encourages over production?

Orders for ships are given by three groups: (1) British shipowners; (2) foreign shipowners; and (3) British and foreign governments. Each will be considered in turn. (1) Ships are instrumental commodities and the number which are required or to which profitable employment can be given depends upon the volume of cargo to be transported. Since Britain throughout the nineteenth century conducted between 90% and 60% of the world's transport by sea, the tonnage capable of employment depended upon the state of world trade and not upon

British trade only. The best measure of world trade - possibly the only one available over the century - is one involving shipping, namely tonnage entered at and cleared from ports of the United Kingdom. To obtain data for all the ports of the world for the nineteenth century (if such data exist) would involve an amount of work which would not be justified by results. From the studies of fluctuations already made by economists it is clear that these fluctuations affect all industrial countries at approximately the same time. Taking into account, therefore, the large part played by the United Kingdom as an importing and exporting country, figures for United Kingdom entrances and clearances in cargo may be taken as a reliable representation of what is happening in the general trade of the world. The figures mentioned, extending from 1771 to 1928, are given in Table C.4. and are also graphed from 1827-1914 against tonnage on the register. Between these two curves there is fairly close correlation, brisker shipping resulting in an increase in tonnage on the register. In addition to those entering and clearing in cargo, there are always a substantial number of vessels which, unable to get a cargo, enter or clear in ballast. Statistics concerning the latter commence in 1827. In that year no less than 20% of the total tonnage entering and clearing was in ballast. By 1847 this figure had reached 24%. Thereafter it fell to 14% in 1867 and remained around that level for upwards of 20 years. Then an upward movement supervened and by 1905 tonnage in ballast constituted 20% of the total. A steeper rise began in 1907 and in the following year 25% was recorded. In 1914 the exceptional figure of 29% was reached, but post war years have shown even higher values (35% in 1920 and 33% in 1923) and since then only a small reduction has taken place.

Tonnage entered, as might be expected, is approximately equal in any year to tonnage cleared. Such margin as exists between the two quantities may be explained by reference to first voyages, selling, scrapping, wrecking, and voyages extending to a longer time than the period to which the statistics apply. Investigation shows that, with the exception of the period 1873-78 and the years 1920, 1921, and 1926, from 1855 onwards the tonnage entered in ballast each year exceeded that cleared in ballast. The margin between these two figures was sometimes very large indeed, especially subsequent to 1900, and whenever there was a striking increase in the total tonnage sailing in ballast, this was due to tonnage entered.

(2) The influences inducing foreign shipowners to give orders for new vessels or deterring them from so doing will be similar to those actuating British owners, but so far as orders to British shipbuilders are concerned two additional considerations enter. Firstly, foreign owners may purchase more or fewer second hand vessels. If they increase such purchases the British owners who sell will presumably order replacements. On the other hand if purchases are less it may be presumed that orders for new vessels will be increased. In either case the result seems to be orders for new vessels and the source from which these come merely indicates whether foreign shipowners or British (or both) are bent upon keeping their fleets up to date.[1] Secondly, foreign countries were (and still are) endeavouring to develop the shipbuilding industry within their own borders and thus to render themselves independent of Britain. The

1. The matter of the purchase of second hand vessels is discussed in Appendix 6.

steps taken by the French and German governments towards that end have already been dealt with. Not till the beginning of the twentieth century did this factor have any appreciable effect upon British output and this was more than counterbalanced by the increasing demand from other parts of the world. Since the United Kingdom output in 1913 was higher than at any previous time it can only be said that, had Britain retained the entire foreign market which previously she possessed, the output would have been still higher. There is no reason to think that the advent of foreign competition in shipbuilding altered the length of the intervals at which depressions arrived or affected the relative magnitudes of the fluctuations, though it may have affected the actual output figures.

(3) Orders by the British Government for war vessels accounted, on the average, for a fifth to a quarter of the tonnage under construction in the United Kingdom and a sixth of that on the Clyde during any quarter from 1893 to 1914. Because of the longer time required in construction, war vessels launched accounted for only one ninth to one tenth of the tonnage launched in the United Kingdom during that period. For the Clyde the figure is one sixteenth.[1] According to shipbuilders' statements the money value of war vessels constituted one fifth to one quarter of the total. The smaller fraction in respect to the Clyde is due to the fact that the Royal Dockyards, which between 1899 and 1913 accounted for two fifths of the total output of war vessels, are all situated across the Border. If allowance be made

1. For decennial totals of warships (not including smaller naval vessels) built on the Clyde and in the United Kingdom from 1858-1908, together with the output accounted for by the leading Clyde firms, see paper: "Fifty Years of Warship Building", by Professor (Sir) J.H. Biles in the Proceedings of the Institute of Engineers and Shipbuilders in Scotland; Vol.53. (1908-9.).

for this, it will be seen that the Clyde got rather more than its proportionate share of the war vessels allotted to private yards. It has frequently been urged - on one occasion by a Royal Commission[1] - that the Government ought to time its orders for war vessels and other supplies so that these fall to be executed during periods of general trade depression. As a matter of fact, judging by the year of launching, war vessels were more evenly distributed than were merchant vessels. This appearance is deceptive; for if we study the statistics for tonnage on hand at the end of each quarter - a better index for our purpose - it is obvious that war vessels correlated closely with merchant tonnage. Without venturing to discuss the contention that the Government ought to regulate its orders with some regard to the general state of trade, it may be pointed out that were it decided to do so, the orders for ships would require to be given immediately the first signs of a depression appeared. As matters stood in the past, Government orders were generally given too late to be of much service in alleviating the distress and unemployment during depressions. From the graphs of merchant and war tonnage "on hand," it is evident that if the "mountains" of the latter had been fitted into the "valleys" of the former, a substantial reduction in the erratic movements of the total tonnage curve would have resulted. Whilst badly timed Government orders may have magnified the range of the fluctuations they cannot be said to have initiated them. Foreign war vessels built in the United Kingdom are included with merchant ships in Table C.1. This class varied greatly in tonnage from year to year being as low as 152 tons displacement in 1901 and as high as 55,024 tons in 1913.

1. Report of the Commission on the Trade Depression, 1886.

They constitute a negligible fraction of the whole and can safely be neglected as a special class. Clyde builders, it may be added, got a fair share of such work.

The matter may be summed up by saying that fluctuations in the shipbuilding industry of the United Kingdom coincided in point of time with the fluctuations in the other heavy constructional industries and were closely related to the requirements of sea transport as indicated by tonnage entered and cleared. The menace of over production followed by depression is a feature of industries the demand for whose products is relatively inelastic, and whose costs of production are subject to friction rendering these incapable of rapid reduction. It is increased in this case by reason of the ease with which persons lacking a thorough knowledge of shipping and its probable course could, in times of expansion, invest their capital in the enterprise in the hope of obtaining the profits attaching to the high freight rates temporarily prevailing. A further factor is the period of gestation of ships which is long relative to the period of fluctuation of freight rates, if these can be said to show any periodicity at all. A ship took twelve to thirteen months to build and equip, according to its size and design, and during that time freights may have risen and fallen several times.

Conditions in the shipping industry are subject to all the forces operating to increase or to diminish world trade: wars, famines, new discoveries of gold (and later of oil), the growth and movements of population, the development of new countries and the expansion of old, changes in the character of the goods consumed in any country, and monetary disturbances. Occurrences which exert only local effects upon other industries, affect the shipping of all countries and hence indirectly affect the shipbuilding industry. The irregular manner in which Governments have replaced or expanded their naval forces has tended to increase the amplitude of the swing from maximum to minimum. New inventions and improvements in ships and engines seem to have had little to do with inducing expansion in shipbuilding. These new departures have usually been taken on a small scale many years before they received general sanction and wide-spread application, being left in abeyance until what seemed a suitable opportunity presented itself for their introduction on a large scale, usually a period of prosperity. Perhaps it may with truth be said that then an excessive optimism as to the results in speed, safety, or economy of fuel - the three major aims of all such improvements - resulted in an overstocking of the market. Progress in most spheres halts for a time "on palsied feet" and then suddenly awakes to a period of concentrated activity only to halt again, temporarily exhausted, and this erratic movement has been reflected in no productive enterprise more faithfully or has reacted with more disturbing effects in no economic activity than in the shipbuilding industry.

CHAPTER XI.

WAGES AND CONDITIONS OF LABOUR.

The alternate rise and fall in the general price level is a well known feature of the trade cycle and is in fact commonly used as an index to identify the commencement, progress, and termination of the rhythmical periods of production. Another index is the percentage unemployment in the various trades, but reliable figures for this are lacking prior to 1850. Closely associated with both phenomena are variations in wage rates. These however, especially in later times, are modified by trade union action and by the feature which distinguishes labour power from commodities; its lack of mobility. Thus wage variations do not invariably show a perfect correlation either in time or in degree with the unemployment percentages. Wages are said to be "sticky"; they are inclined to lag behind movements of the price level. But they do correlate to some extent. It is undoubtedly easier for a body of workmen to obtain an advance in wages when industry is booming and prices are rising. Their claims at such a time draw support from the logic of the situation and from the fact that, as labour is in greater demand, the workers have a powerful weapon in the threat to strike. To the employer, the realisation of the extra profits which accompany rising prices depends largely upon business being kept going without interruption. Nevertheless, until the trade revival is well under way, industrialists cannot be certain that the upward trend will continue for any length of time and therefore hesitate to anticipate, even by a few weeks, the advance in wages which they know they must grant if the boom continues.

On the other hand, when the crisis takes place, followed by a drop in the price level, employers can make out a good case for reductions and are in a position to enforce these if necessary. Against this must be set the natural reluctance of the workers, thinking as they do mainly in terms of money wages, to accept what they conceive to be a lowering of their standard of living. In the absence of any agreement for a fixed period, industrial strife is to be expected in the early stages of a boom and at a similar point in a depression. Towards the end of the nineteenth century this fluctuation of wages with the course of trade came to be accepted as inevitable alike by trade unions and employers' associations. Hours and conditions of labour then loomed larger in disputes than did questions of remuneration.

Complete records of wages in shipbuilding and engineering, such as have been submitted in connection with output, are not available. Tables covering the greater part of the nineteenth century and referring to the Clyde area are given[1] for the leading trades in these industries. One deals with time rates, another with the

1. Tables G.1, 2, & 3.

wage for an ordinary week's work, and a third gives index numbers of average rates in various districts. All refer to money earnings, but Sauerbeck's index number for each year from 1782 to 1914 is given in Table G.4. and thus an idea as to real wages may be obtained; while Table G.5. indicates in a general fashion the relationship between money wages, prices, and real wages in the United Kingdom from 1790-1910. Except where stated otherwise, references in this chapter to specific wage rates or earnings apply to Glasgow and the Clyde area.

During the first half of the nineteenth century trade unions had not yet become established and so the separate occupations were not differentiated as later they became. Prices rose so rapidly during the Napoleonic wars that even the 60% advance which took place in money wages left real wages in 1810 lower than they had been in 1793. From 1810 to 1819, for a 60 hour week, mechanics were paid 19/- whilst blacksmiths' wages rose from 14/- to 17/-. In the boom which followed, the mechanics' wages rose as high as 25/-. Patternmakers came between smiths and mechanics at 21/6 per week. Dr. Cleland gives the rate for 1831 the same as that for 1819, and adds that it was considered that the labourer could support his family with a fair degree of comfort when his daily wage equalled the price of a peck of oatmeal. This price varied very considerably as the following list shows:

1810	1811	1812	1813	1814	1815	1816	1817	1818	1819	1831
1/8	1/8	1/9	2/2	1/9	1/6	1/6	1/10	1/10½	1/3	1/2

The wages of a certain class of weavers came well below these figures at times and those of building trade labourers barely maintained equality with it. Wages in other occupations were generally well above the minimum requirement. Engineers had not at this time achieved the position which later they attained of being amongst the highest paid craftsmen.

From 1830 to 1850 wages remained fairly constant. At times certain fortunate groups in the engineering industry rose to 30/- per week. The trend of prices was downwards so that real wages were rising slowly. Normal hours of work remained around 60 per week. The average engineering wage in Glasgow in 1851 was 20/7, practically the same as it had been twenty years before. The expansion in trade which took place during the next five years encouraged an upward movement to 24/- in 1856; but prices were rising even faster and the succeeding slump brought wages down slightly in 1857-58, leaving the situation for the men worse than it had been eight years before. During these crucial two years unemployment rose to 12% of those engaged in all industries. The shipbuilding and engineering figure was slightly higher and the wage of shipwrights fell from 30/- to 24/-. About this time iron rollers, who were the best paid of all manual workers, had over £4 per week; the building trades were commonly a shilling or two above engineering; and coal mining rates fluctuated considerably, being at times above and at other times below engineering rates. Dr. Strang's figures correppond closely with those given by Professor Bowley. The boom of the middle sixties brought wages up beyond the level of the previous decade. Shipjoiners reached 28/- per week and shipwrights had their 30/- restored; nor did prices rise so high even during the crisis of 1866, which was less serious both as regards unemployment and wage reductions than its predecessor. Nevertheless

10% unemployment was touched in the metal industries and 8% all over. Wages fell but not to their previous low level. In 1868 engineers averaged 26/- per week.

Dr. Glover, in a paper to the Royal Statistical Society in 1869, submitted an interesting comparison of wages and costs prevailing in the several shipbuilding centres of Britain. If the number 100 be taken to represent the rates of wages prevalent on the Thames, the figure for the Mersey was 92, for the Tyne 82, and for the Clyde 76. After a strike in 1825, the London engineers had obtained a "price book", the terms of which still held good, although the nature of their work had changed completely. When this district had to meet the competition of northern districts, it found itself severely handicapped. A table showing daily wages for various trades in the three leading centres for the year 1869 is given below:

Trade	Thames	Wear	Clyde
Carpenters	7/-	5/-	4/6
Joiners	6/-	4/6	4/6
Platers	7/-	4/6	4/8
Caulkers	6/-	5/-	3/8
Riveters	6/-	4/2	3/8
Painters	5/6	4/6	5/-
Riggers	5/6	6/-	4/4
Sailmakers	5/-	5/-	4/2
Boilermakers	6/-	4/3	5/8
Engineers	6/-	4/3	4/4
Turners	6/-	4/3	5/4
Patternmakers	6/-	4/3	4/10

The above table may be summarised by saying that wages on the Thames were higher for every trade except that of rigging than either the Wear or the Clyde, whilst the Wear rates were higher than those of the Clyde for everything but engineering and boilermaking. The decline of the Thames and the simultaneous advance of the Clyde forms an interesting example of the operation of underlying economic causes. It was no temporary or chance occurrence, the decade 1860-70 merely witnessing the culmination of a process which had been in progress for many years previously. London had always specialised in the highest class of wooden ships. When iron was replacing timber, the Metropolis still confined its shipbuilding activities to the highest class of work in the new material and for such work claimed to be as cheap as northern districts. The burden of blame for the decline was attributed to the workers demanding wages in accordance with the 1825 book for the inferior class of work which was now in demand. Glover gave the following comparison of the three rivers, the figures representing the cost of 1 day's labour of each trade contributing to the building of a ship: Thames, 72/-; Clyde, 58/8; Wear, 55/8. These totals are unweighted so do not give an accurate valuation of relative costs. Accepting them, however, as a suitable basis for comparison, they show that Thames costs were 23% in excess of Clyde costs and 30% above those of the Wear. Materials were almost as cheap in the south as in the north, with the exception of coal, of which the price was 15/- to 20/-, 5/- to 12/6, and 2/6 to 4/- per ton on the Thames, Clyde, and Wear respectively. Establishment charges on the Thames were double those on the northern rivers. Steam driven cargo boats with as powerful but less well finished engines could be supplied by engineers of the Tyne, Wear, Mersey, or Clyde at 15% to 30% less than the London price, and such vessels were in great demand. So the Thames was crushed out and now does not appear even amongst the first fourteen shipbuilding centres of the kingdom.

The year 1873 witnessed rates of wages higher than any hitherto. Engineers' wages ran up to over 28/- per week and shipwrights' to 34/-. Prices too reached a peak higher than any since 1839 or any subsequently touched until the Great War. Real wages also were at a high level; in fact this year was the culmination of the long steady rise in real wages which had begun at the close of the Napoleonic wars. All the figures given above represent time rates of wages. Actual earnings were sometimes less and sometimes more; in general less in the higher paid groups where frequently a full week's work was either not available or not performed. Piece workers expected to earn 50% more than the standard rate. In busy times overtime earnings increased the workman's income, but against this must be set the loss sustained during holidays or spells of unemployment. Meanwhile an important change in hours had taken place. London engineers were among the earliest to become organised in a trade union. In 1836 their hours were reduced from 10½ to 10 per day and in 1844 to 57 per week. Other areas followed suit and from that time to 1871, hours of labour varied from 57 to 60 per week according to the district. In 1871 a movement in favour of a 9 hours' day was organised all over the country; this meant 54 hours per week, with no reduction in wages. In some districts in England the demand was conceded without any difficulty; in others it was gained after a brief strike. A year later - in November, 1872, to be precise - when unemployment reached the remarkably low figure of less than 1%, a further reduction of three hours per week was granted by Clyde shipbuilders without involving a stoppage.

It is pretty safe to say that the shorter week and the increased wages detailed above would not have been obtained had the workers remained unorganised. In the shipbuilding and engineering industries local societies had existed at various times (subsequent to the repeal of the anti-combination laws in 1824-25) at such centres as London, Manchester, Newcastle, Bradford, Derby, etc. A few had attempted organisation on a national scale; the Steam-Engine Makers, the Journeymen Steam-Engine and Machine Makers and Millwrights, the Associated Fraternity of Iron Forgers (or the "Old Smiths", as they were usually called), and the Boilermakers - established in 1824, 1826, 1830, and 1832 respectively. But in trade union organisation, as in trade, at this time anarchic competition was a noticeable feature and hence the unions exerted little force in the industrial world. Finally in 1850, after several abortive attempts to achieve real unity, the Amalgamated Society of Engineers was formed as a result of painstaking and tactful work by William Newton and William Allan. One fairly large body - the Friendly Boilermakers' Society - stood out of the amalgamation. Founded at Manchester in 1834, this Society opened its first Scottish branch at Greenock in January, 1849, although a similar Scottish union was already operating there. Two years after its formation the A.S.E. had to face a very stiff test of unity. Members struck against piece work and overtime. The question as to what class of men should be engaged on self-acting or automatic machines was also disputed. Some members remained at work and the dispute, which was a prolonged one, finally ended in a deadlock. The men resumed work on the old terms and the employers failed in their aim, which was to break up the Amalgamation. The A.S.E. however had exhausted the whole of its accumulated funds and its membership had dropped by over 2,000. All trade unions experienced a very trying time in the depression of 1857-8. In particular the Boilermakers' Society barely survived the strain. As a result of a strike for the 57 hour week, the Associated Blacksmiths' Society was founded at Greenock in August, 1857. Whilst giving concessions to other bodies of organised workmen, the employers had refused to treat with the blacksmiths who were unorganised. The men found a remedy in forming the Associated Blacksmiths' Society, the title being changed later to the "Scottish United Operative Blacksmiths' Protective and Friendly Society". A successful strike was conducted by Greenock shipwrights against a proposed reduction of wages in 1859. In 1866 the Clyde Shipbuilders' and Engineers' Association was formed by local employers and thereafter, in the same year, a bitter struggle between masters and men took place. The men demanded payment by hourly rates and also a reduction in the working week. The employers retaliated by issuing an ultimatum demanding that the men leave their unions. Failure to accept this demand was to be followed by a three months' lock-out. One of the clauses of the ultimatum read as follows; "That all workmen in our employ sign a declaration binding themselves to renounce all Unions of Workmen and that they will neither assist morally nor pecuniarily, directly or indirectly, any workman who may be locked-out or who may be on strike in opposition to the interests of the employers." The lock-out began on 28th May and 20,000 men of the Clyde area were affected.

After thirteen weeks the stoppage ended in a complete victory for the men. Not only was the attack on their organisation repulsed, but their claims for a 57 hour week and payment by the hour were conceded.

Just about this time several legal decisions were given which caused a general furore and nearly wrecked many Unions. Several cases of embezzlement of union funds had occurred. To the amazement of everyone concerned, the decision was that trade unions, being illegal bodies, had no remedy at law against officials who abused their trust. In the judgment given in the Hornby v. Close case by the Court of the Queen's Bench the following statement was included; "Whether the rules of a Trade Union were illegal so as to bring those who acted on them within the operation of the Criminal Law or not, they were, in the sense of not being enforceable in a Court of Law, illegal, as being in restraint of trade." In 1868 the United Operative Blacksmiths' Society had applied to be registered under the Friendly Societies' Act of 1855. The Registrar General for Scotland (Mr. Carnegie Ritchie) refused the application in the following terms; "The rules are to unite against all encroachments of their interests, and again, to afford a weekly payment to the members thereof during the time of sickness or being out of employment - thus it might be encouraging a strike."[1.] In 1866 the Government instituted an "Inquiry upon the Organisation and Rules of Trade Unions and Other Associations," the report of which was published in March 1869. Many of the handicaps suffered hitherto by trade unions were removed by the Act of 1871 which gave these organisations a legal standing. Further amendments were

1. Annual Report of the Scottish U. Op. Blacksmiths' P. & F. Society for 1867-68.

made in 1874 and a workmen's compensation Act was also passed. The fact that the Act of 1871 was based upon the recommendations of the minority report may be ascribed mainly to the increased political power wielded by the workers, consequent upon their enfranchisement in 1867.

Reference to the further reduction of hours obtained in 1871-2 has already been made. From the "9 hour day" strike on the Tyne and Wear in 1871 emerged the United Kingdom Patternmakers' Association. Another body, the Associated Patternmakers, was already in 1872 operating in the Glasgow district. It declined to amalgamate with the new Union and finally became defunct. The U.K.P.A. opened their first Scottish branch at Dundee in 1874. Three years later their Glasgow branch was formed. The year 1874 marked the peak of production but also heralded another depression. Ominous signs of a coming struggle were manifest and masters and men alike made preparations for it. The Clyde Employers' Association issued a questionnaire to firms outside the Association to find what support would be forthcoming if they endeavoured to retrieve the position relinquished in 1871. As a counter move the A.S.E., the Iron Founders' and Steam-Engine Makers' Association, and the Boilermakers Society convened a joint conference at which it was agreed to raise a reserve fund to resist any attempts to encroach upon the gains achieved three years before. The clash did not actually materialise till several years later, when trade was once more in a thoroughly depressed condition. The period up to 1874 therefore witnessed the birth and early struggles of trade unionism in the shipbuilding and engineering industries. Not till 1876 were the unions established on firm legal foundations which enabled them to command the support of an increasing percentage of industrial workers. Though dimly perceived at the time, the fact was that industries and the workers in them were entering upon a new era, the modern era.xxxxxxxxxxxxxxxxxxxx xxxxxx

The approach and recession of periods of contracted trade are the usual background of industrial unrest. In the depths of a depression, trade union funds are depleted by unemployment and the workers are of necessity tractable, if not powerless, as regards wage variations. With the slump prices fall and employers must reduce their working costs if business is to be maintained at all. The workers realise that if, in such circumstances, resistance to alterations in their conditions be maintained too long, workshops may be closed down indefinitely. Trade union membership - especially paying membership - goes down and the organisations find themselves in a weak and at times precarious position. In 1875 the shipwrights lost 3/- and the ship-joiners 2/- per week in wages. Short time also helped to reduce the actual amounts of wages earned. For another year engineers, whose rates at all times had been lower than those of shipyard workers, preserved their wage rates unbroken. Slackness of employment begins first on the shipbuilding side because the engineering industry caters for a wider market. This to some extent accounts for the lag in wage reductions. The policy of asking more than is expected dates far back beyond the beginnings of trade unionism. It was, however, adopted and consistently used by trade unions when making application for advances; a fact which, being known to both sides, gave an air of unreality to certain demands. It may be added that employers likewise exaggerated their demands and frequently countered an application for an advance in wages by an intimation of a proposed reduction. Both sides were then satisfied to compromise by agreeing to maintain the status quo.

It was in this spirit that, without any justification in the state of industry at the time, the shipwrights early in 1877 intimated a request for a 10% rise, whilst the carpenters exhibited even greater temerity, blended no doubt with hope, by demanding a 15% increase. To both demands the employers returned an emphatic negative. A request by the Unions concerned for a joint meeting with the employers also met with a refusal. On 24th March a strike began. The employers replied with a general lock-out on the Clyde which took effect on 19th May and continued till 10th August, when all but the Boilermakers accepted the old terms again.[1] The employers insisted on a revision of the rules of the latter Union[2] and a fresh lock-out of its members, who had meantime resumed work, was enforced over the whole Clyde area on 17th October. For a time the employers would not enter into negotiations with the general secretary or with the executive council of the Society, but advised a large body of men whom they did meet to form a separate Scottish society. The advice tendered was rejected, but the deadlock was finally brought to an end on terms which may be summarised as follow:

1. The wages question to be left in abeyance for six months.
2. No victimisation of strikers.
3. All piece work to be contracted for and prices negotiated by the individual men or groups actually performing the work, not by trade union officials.

1. The shipwrights' dispute was settled by arbitration, Lord Moncrieff the umpire deciding in favour of the employers.
2. Known at that time as the United Boilermakers' and Iron & Steel Shipbuilders' Society.

When reminded in June, 1878, of the promised revision of wages, the employers seized the opportunity of entering a demand for a decrease of wages or an increase of hours. The demand was speedily followed up by 14 days' notice to extend the working time from 51 to 54 hours per week. The case against increased hours was presented to a deputation of employers, who promised to place it before the Association. No reply was forthcoming, but a private circular was issued to employers outside the Association urging common action in the matter. Unanimity however could not be obtained, but a further notice announcing a wage cut of 7½% to take effect 7 days hence was posted. All trades except the boilermakers accepted this without demur. About 9% of those engaged in shipbuilding and engineering were unemployed all over the country and in certain crafts and districts the figure was even higher; nor was there any sign that the turning point had been reached. The boilermakers alone decided to fight and they were left to fight their losing battle alone. After a strike lasting several months work was resumed in February, 1879, at the lower figure. Before the end of the year the 54 hour week was again in vogue.

The events of 1878 left much bitterness between the A.S.E. and the Boilermakers' Society. The former accused the latter of acting foolishly and selfishly playing a lone hand in a game of which one of the elementary precepts was solidarity. The Boilermakers retorted that the A.S.E. lacked the courage to fight and had deserted them in time of need. Whatever may have been the rights and wrongs of the case at the time it is easy now to see that the precipitate and undiplomatic action of the Boilermakers aided the employers in their successful attack upon the shorter working week, gained by the men seven years before. Wiser generalship might at least have avoided this set back. All ship-owners and others concerned in the industry had not taken the superficial view that lower wages and longer hours were necessary for profitable and efficient production. Lord Brassey,[1] a pioneer of the idea that has come to be termed "the economy of high wages", in his "Lectures on the Labour Question" quoted the following; being part of a letter received by him from an eminent shipbuilder;[2] "The intro-duction of the piece work system in connection with Iron Shipbuilding reduced the wage cost in the Iron Department by about 20% and this was accomplished over and above providing for the reduction which took place immediately preceding that period in working hours per week from 60 to 54. In 1868 we launched 9 steamships, in round numbers aggregating 13,000 tons. I take gross new measurement in each case for the purpose of comparison. The wages bill was £78,963; average number of men and boys employed, 1,776. In 1873 we launched 7 steamships in round numbers aggregating 18,500 tons; wages bill £91,838; average number of men and boys employed 1,550. In 1868 the average wage earned per week of 60 hours was about 17/1. In 1873, per week of 54 hours it was about 22/9. In 1873 the cost per ton gross new measurement, in wages only, was fully 20/- per ton cheaper than in 1868." The Boilermakers' Society paid dearly for their pyrotechnic display. When it was over they had to sweep up the ashes and endeavour as best they could to recreate their organisation. Member-ship contributions were increased and benefits in all departments reduced. Rigid economy had to be exercised even to the extent of abolishing the office of vice-president.

1. At that time, Thomas Brassey, M.P.
2. Assumed to be of the firm of Robert Napier and Sons.

Their reserve fund was down to £3,500, a paltry 11/- per member as compared with £3. 11/- a few years before. Bankruptcy was only narrowly avoided and membership dwindled.[1] A writer in the "Glasgow Herald" throws a significant light on the helpless condition of the unions at this time when he remarks: "... the return to the 54 hours week, which has been acquiesced in by the workmen with a willingness which does credit to their common sense, will largely aid Clyde employers in the competition." The depths of the depression were plumbed during 1879, when unemployment reached the figure, unprecedented and till 1920 never again touched, of 15%. Trade disputes in that year were few; men cannot fight on empty stomachs nor can trade unions on empty chests.

During every trade depression a diminution in union membership is a noticeable feature. Various reasons for this may be adduced. Among them the following may be selected for special emphasis: emigration abroad, inability to maintain contributions even when employed, disappointment that the union has not been able to maintain wages, and the greater ease with which non-unionists (in certain occupations at any rate) could obtain work. Yet it is just at such times that trade unions are in greatest need of moral and financial support if they are to be effective when a revival in trade takes place. The fluctuations of membership of the Scottish Operative Blacksmiths' Society may be cited in illustration of our contention.[2] In the year 1865-6 this Society claimed a membership of 1,602; two years later, in the depths of the depression, the number dropped to 1,084. By 1876-77 it was up again to 1,554;

1. "Glasgow Herald Shipbuilding and Engineering Supplement" dated 22nd December, 1879.
2. Table G.7. shows membership each year from 1857 to 1914.

in 1879-80 it had fallen to 1,380. Prosperity restored the membership to 1,682; the succeeding depression reduced it to 1,027. Similar fluctuations may be observed in each further cycle. The manner in which employers had used their opportunity to defeat the men was not readily forgotten. For years after it remained a bitter memory and undoubtedly influenced the course of industrial relations during the succeeding 20 years. In his report for the year 1878-9 the secretary of the Blacksmiths' Society wrote regarding the employers; "...every agreement...they have either violated or set aside;...have left in the minds of their workmen a rankling sore, which it will be difficult to eradicate or efface." Commenting upon the situation a writer in the "Glasgow Herald" remarked that shipbuilding prospects would be better "could an end only be put to the ridiculous antagonism which is the normal attitude of masters and men in this neighbourhood."

With the trade revival which set in towards the end of the year matters improved. During 1880 most of the Clyde firms restored the 7½% cut. The replies received to a request for a rise in wages are interesting as they give an indication of the growth of concerted action on the employers' side. We quote a selection;[1.]

"If any other concedes the advance I will grant it."

"I will procure the average wages paid in three shops and will pay equal to them."

"I will not be the first to move but if others give the advance so will I."

"Will concede along with other employers, but will give a definite answer after consulting with local employers."

1. Annual report of Scottish U. Op. Blacksmiths' P. & F. Society for 1879-80.

Clearly combined action on the part of the workers was justified. The return of better times tended to make the men forget the dire straits into which the depression had brought their union funds and a clamour arose for a reduction of contributions. The Boilermakers' Society, as noted, had been particularly badly hit yet before long members refused to continue to pay their Society contribution of 1/3 per week. The sum of 1/1 per week for twelve months was agreed to only on the executive's threat to reduce benefits if this figure were rejected. At the end of the specified period the extra 1d. was withdrawn although their reserve fund stood at only 35/- per member. Typical wage rates at this time were; fitters, 27/- to 28/-; patternmakers, 29/-; shipwrights, 30/-. By 1883, as a result of increases gained in the interval, these rates had become 32/6 to 33/-, 34/- to 35/-, and 36/- respectively. In 1881 the Employers' Liability Act was passed and, as an insurance against claims, a fund termed the "Employers' Liability Expenses Fund" was created by the Employers' Association. The fund continued as such for twenty years when the various levies were merged into one.

Employment began to slacken off towards the end of 1883 and early in the new year a 10% reduction was demanded by the masters and grudgingly ceded by the men. This was but a beginning to what (from the workers' point of view) proved to be the most disastrous twelve months ever experienced in the annals of the industry. Within the year all the advances of the previous four years were surrendered. In out of work benefit one society paid £57,025 in 1884, equivalent to £2 per member, as compared with £3,171 the previous year; its accumulated funds were thereby reduced by 50%. In reply to the questionnaire issued by the Royal

Commission, which had been set up to consider the depression of trade and industry, the Glasgow Chamber of Commerce, in October, 1885, said that "with the exception of those employed in shipbuilding, workmen generally, both skilled and unskilled, are in full employment with good wages, which wages have at present a purchasing power that has never been exceeded or even equalled at any previous time." It is true that real wages were rising, but if the former part of the statement was correct Glasgow must have been an exceptionally fortunate area, for the general unemployment percentage for the whole country exceeded 10%. In shipbuilding and engineering conditions were particularly bad. Giving evidence before the same Commission, Mr. John Scott (of the Greenock shipbuilding firm) said that rates of wages prevailing in his industry and district were 40% less than in 1882-3, and 10% less than they had been in 1879, the previous depression. Time and piece rates stood at a figure lower than any recorded during the preceding twenty years. Riveters who on piece work earned wages even higher than did platers, had been making £2 and £3 a week in 1882-3, whereas in 1886 they could rarely exceed 28/-. That there had been a smaller fluctuation in the wages of shipwrights, joiners, and engineers Scott agreed, but even these had dropped by from 3/- to 6/- per week. Professor Bowley's figures do not confirm entirely those given by Mr. Scott, but they do show substantial reductions. In general reductions up to 1½d. an hour, with an average of 1d., had been made on time rates and 25% on piece rates.

The upward trend began again in 1888, a year of special importance in the industry locally because of the formation of the Clyde District Employers' Association. Two years later the patternmakers obtained a differential rate of 1/- or thereabouts per week above the engineers. A report by Mr. John Anderson, Assistant Secretary of the Amalgamated Society of Engineers, indicated the enormous progress made by that body. Founded in January, 1851, the Society started off with a membership of 7,417. By the end of the year this had risen to 11,829. In 1864 it was 28,815 and ten years later was 42,382. By 1885 there were 50,681 members and now in 1890 a membership of no less than 66,846 could be claimed. Of these nearly 80% were in England and less than 10% in Scotland. In the reserve fund the Society had £230,000. The Boilermakers' Society, which had again suffered severely by the depression, wisely took the opportunity of imposing a 10/- levy per member whilst trade was good and by the end of 1890 their funds stood at approximately £150,000. They also raised with the employers the question of the ratio in numbers of apprentices to journeymen. One firm, for example, employed 33 boys and only 5 men. At that rate, it was argued, the supply of journeymen would in future exceed the demand and hence wages automatically would fall. The Society therefore laid down rules on the matter. Five years' apprenticeship was to be served and only one apprentice to be employed to every five journeymen. Cards were issued to members and after 1893 no one lacking a card would be countenanced by the Society. This interference aroused the indignation of employers and after a meeting with union representatives the latter agreed to suspend the card system till a final agreement had been reached. This was achieved and signed on 11th October, 1893. The following points were incorporated:

For shipyards:

Five years' apprenticeship, to be served with one firm, prior to 23 years of age.
Apprentices to be indentured.

> Apprentices to be employed on repairs or new work, at time or piece rates, according to the employer's discretion.
> Apprentices not to be members of the Society except for benefit purposes.
> Not more than two apprentices to be employed for every seven journeymen.
> This agreement to hold for six years.

For boilershops:

> The agreement for boilershops was signed in December of the same year. It was similar to that for shipyards except that no restriction was put on the number of apprentices relative to the number of journeymen and that the agreement was to be permanent, six months notice of proposed alteration to be given by either side.

The shipyard agreement lapsed unnoticed by the men in 1899. Later a new agreement making no restrictions on the number of apprentices was signed.

Another period of depression was encountered in 1892 and a fall in wages began. A 10% reduction in piece work rates and ½d. per hour on time was demanded but labour was not "accommodating and absolutely refused to bear its just proportion of the fall."[1] 5% and ¼d. per hour respectively were finally agreed to. Unemployment increased at an alarming rate and an endeavour to put a stop to systematic overtime was made by the Unions.[2] Disputes were rife in 1893; nor were these confined to matters of wages. A demarcation dispute between the joiners and the shipwrights, involving some 2,300 men in an eight days' strike, occurred in September. A month later seventeen firms locked out over 2,000 ship-joiners for a period of nearly four months - a drastic measure by which to bring to an end an overtime dispute which had arisen with one Clydebank firm. The dispute originated in a demand for overtime payment when men, officially on short time, were called upon to work the full week. Only 320 men were involved at the

1. "Glasgow Herald Shipbuilding and Engineering Supplement", for 19th December, 1892.
2. For unemployment figures see Table G.6.

beginning but soon 3,000 were directly affected and many more indirectly. The settlement reached early in 1894 embodied a conciliation agreement in which power was given to delegates of the masters and men to settle any future disputes of a similar nature; failing agreement the matter was to be submitted to arbitration, Sheriff Berry to be the arbiter. Wage rates in 1894 averaged as follows: fitters, 30/-; turners, 31/6; patternmakers, 34/-; shipwrights and joiners, 34/-; platers, riveters, and caulkers, 31/- per week. The period of stagnation continued till 1896 when improving trade and a full naval programme by the Government heralded better times. Advances ranging from 1/6 to 3/6 per week for time workers and up to 15% for piece workers were general. In that year also the House of Commons Fair Wages Committee was appointed. The Engineering Employers' Federation, a combination of local Associations, came into existence in 1896. At its inception it embraced only 180 firms, but the dispute of 1897-98 brought accessions to its ranks and at the end of the dispute there were no less than 702 federated firms.

The year following is generally regarded as having been one of the blackest and yet one of the most satisfactory in the history of shipbuilding and engineering in the West of Scotland. This paradox can be resolved only by a detailed consideration of the events which took place. Far some years experiments with an 8 hour day had been conducted in Government yards and workshops. These had proved so successful as regards output and economical working that it was felt by many that private employers might, without loss to themselves and with obvious benefit to their workmen, follow the example set. The determined efforts which were at this time being pressed for better conditions culminated in a definite demand for the 8 hour day. To enforce the demand a national strike was called on 3rd July, 1897. As happens so often in such cases, the original causes were soon forgotten. Internal dissension amongst the Unions was not lacking. Concerning this matter the secretary of the Blacksmiths' Society wrote in his annual report; "The question of demarcation has become a serious and continuous source of trouble in the shipbuilding industry and frequently great loss is being inflicted on employers on account of these troubles." The newly formed Employers' Federation seized the opportunity to make a counter demand for the institution of a scheme whereby in future disputes (or at least stoppages) might be avoided. The boilermakers and patternmakers stood aside from active participation in the strife. In one case where the patternmakers, in an attempt to aid the engineers, refused to work overtime, a threat to lock them out achieved the desired end. While the dispute lasted other crafts were refused all concessions and demands, and so badly were these workers hit indirectly by the stoppage that they could not afford to press their claims. The engineers and shipwrights at first rejected the employers' "Provisions for Avoiding Disputes", but the prolonged period of idleness latterly had a salutory effect. The men capitulated; the demand for the 8 hour day was relinquished and the employers' memorandum signed. The agreement is much too long to quote here in full,[1.] but it had such an important bearing upon future relationships between employer and employee that it will be advisable to summarise its main provisions. It was divided into two parts;

1. See; "Thirty Years of Industrial Conciliation" (1927); Engineering and Allied Employers' Federation.

1. Terms of settlement of the dispute actually in progress.

II. Provisions for avoiding future disputes.

I. A declaration of the general principle of freedom of employers in the management of their works formed a preface to six clauses which asserted;

1. Freedom of employer and employee alike in respect to trade union membership.
2. The right of employers to institute piece-work and to arrange prices therefor with the workmen concerned.
3. Overtime for normal shop work not to exceed 40 hours per man per lunar month but no restrictions for breakdowns, repair work, or trial trips.
4. Regulations regarding collective wage negotiations and agreements.
5. No limitation of the number of apprentices.
6. Freedom to employers to choose machinemen from any class of workmen and to train them.

II. To avoid stoppages in future it was agreed that the employers would at any time receive deputations of their workmen. Failing agreement on any point the local Employers' Association would negotiate with local T.U. officials. Matters of major importance would be negotiated between officials of the Employers' Federation and the Central Authority of the trade union concerned. Meantime work would proceed under the prevailing conditions and, until the matter in dispute had been fully considered by and between both sides, no stoppage would take place.

The men returned to work on 24th January, 1898. The agreement began to operate under favourable conditions. Vessels on which work had been suspended were awaiting completion and new orders were pouring in. Wage increases were general and the only matter which gave rise to any difficulty was the question of weekly instead of fortnightly pays. At a conference in Glasgow in the month of November it was agreed to give the new system a trial for twelve months, beginning in April, 1899, though grave fears were expressed by the employers that bad timekeeping would result. On the expiration of the trial period the employers insisted on a return to the system of fortnightly payments. They claimed that their fears had been realised all too completely, especially as regards piece workers. The men in vain repudiated the charges; the older system was resumed. About this time the Blacksmiths' Society became affiliated to the Engineering and Shipbuilding Trades' Federation but the Patternmakers' Association stood aloof, alleging that they found association with the A.S.E. detrimental to their interests since the Engineers were bound by agreement whilst they were not. Also the patternmakers had successfully resisted the attempted imposition of any "payment by results" system on their craft. The first years of the new century were merely average as regards output and in 1902 signs of a contraction appeared. The cycle of wages began again, reductions being general in 1902-3. As an interesting example of the manner in which trade unions had come to accept the idea that wage fluctuations in accordance with the state of employment were inevitable, we may cite the instance of the patternmakers at this time. Whilst other trades in the industry were languishing and depressed, their trade as it happened was brisk. So when a demand for 1/- per week reduction in their wages was made, this was indignantly repelled on the grounds that there was no justification for it so far as their trade was concerned since employment was good. Demarcation disputes between the "white" and "black" squads were a feature of 1902-3, but to describe the shipyard worker as one who "works when it suits, idles when he likes, and provokes a perfect logomachy when he is remonstrated with "- to quote one writer[1] - was to slander the vast majority of men in the yards and shops.

Piece work rates were now, in many instances, lower than they had been in 1873; but too much stress must not be placed on this fact as methods of production had changed very considerably as had also the material. Further reductions were made in 1904, a year which, as the secretary of the Blacksmiths' Society wrote, "was unrelieved by a single attempt to improve wage conditions." With the promise of a trade revival, the first move towards an increase of wages seems to have been made by the pattern-makers in 1905 with a demand for an additional ½d. per hour. In the West of Scotland there were 60 firms outside the Employers' Association and of these 10 were already paying the rate demanded, 26 agreed to do so, and 24 declined. A strike was called in the workshops of the recalcitrant employers and an embargo placed upon Clyde work wherever possible, an illustration of the use of another powerful weapon - the boycott - occasionally called into service by trade unions. When in September ¼d. per hour was conceded to the engineers a like offer to take effect on 15th November was made to the patternmakers if they would resume work on 9th October. The offer was rejected but work was finally resumed on 16th October on the understanding that the advance commenced forthwith. The strike had lasted six months, had cost the Society some £16,000 in benefits and involved the 650 odd participants in a loss of wages approximating to £20,000. One is tempted to sigh with the poet, "Alas, that justice should be so dear"!. An unexpected depression set in during the latter half of 1907.

1. "Glasgow Herald Shipbuilding and Engineering Supplement", for 30th December, 1902.

Commencing in America in October and accompanied by a monetary crisis, the decline swept eastwards round the industrial countries of the world. The advances granted two years before were cancelled and the two succeeding years are described by many unions as the worst in the history of their trades. In January, 1908, the shipyard workers and engineers were assured that if they accepted the small wage reductions asked orders would follow, but although reductions were conceded no such desirable occurrence took place. The A.S.E. and the Boilermakers applied for separate conferences with the employers in a scramble to effect the first and more favourable wages agreement. In the end all fared alike. Unemployment reached 13% on the Clyde, short time and enforced idleness being common amongst skilled as well as unskilled men. A renewed demand for the limitation of overtime to six hours per man per week was pressed. The employers responded with an offer of a weekly maximum of ten hours modified by a limit of 32 hours per month, and this was accepted. The Blacksmiths' Society entered into an agreement for the avoidance of disputes to operate for three years. The depression lasted till the end of 1909. As a result of it, Labour Exchanges under Government auspices were commenced the following year. Towards the end of 1910 the reductions of January, 1908, were restored. Once more industry entered upon a period of expansion.

Henceforth a new feature made its appearance in wage agreements; most of them had an "embargo" placed upon them - that is to say the unions had to agree not to demand any further advances within a specified time, commonly six months. The employers urged that this was necessary as they had entered into contracts at fixed prices.

Throughout 1911 and 1912 advances were general; but prices too were rising fast and, as a matter of fact, real wages in most instances were falling. The advent of the Health and Unemployment Insurance Acts gave a stimulus to unions to increase their membership and, where two societies catered for the same class of worker, competition to enrol men was keen. A further rise of ½d. per hour was obtained early in 1913 and about the same time the boom reached its height. The shipbuilding and engineering industries were not involved in any of the big disputes of 1910-13 in which mining and transport workers took such prominent parts, but a restlessness was evident subsequent to April, 1913, though few of the disputes led to actual stoppages. To all appearances another decline was imminent when in July, 1914, the world was staggered by the outbreak of war.

CHAPTER XII.

THE WAR AND POST-WAR PERIOD.

Britain's entry into the European war on 4th August, 1914, produced immediate and drastic effects on the shipbuilding and engineering industries, the first of which took the form of wholesale dismissals of workmen. Important markets were closed; contracts in various stages of completion were perforce cancelled and the situation can fairly be described as one of mild panic. True, the unemployment was transient but the activity which followed it was directed to ends completely different from those aimed at prior to the outbreak of war. A couple of months of under employment were followed by years - seemingly interminable - of excessive overtime. Government requirements more than replaced all that had been lost in the closing of foreign markets. The table below shows the percentage unemployment figures for the United Kingdom and for Scotland for the three months before and after the declaration of war.

1914	Shipbuilding		Engineering		General
	U.K.	Scotland	U.K.	Scotland	U.K.
May	4.0	2.2	3.1	2.4	3.2
June	4.1	2.0	3.3	2.8	3.5
July	4.7	2.6	3.2	2.7	3.6
August	4.9	2.8	6.6	6.1	6.2
September	4.4	2.5	4.9	4.7	5.4
October	3.9	2.3	3.2	2.5	4.2

Engineering, it will be noted, was much more sensitive to the shock than was shipbuilding. The general percentage (that is, in all insured occupations) was almost equally sensitive. After this unemployment diminished steadily in all industries and in engineering and shipbuilding it reached almost zero. If Scotland alone be considered we had the unprecedented figure 0.0% in May, 1916, an absolute minimum never before touched.

Statistics issued during the war gave scanty information concerning ships and engines produced. All war work was excluded and even the merchant totals were incomplete. At the close of the war, however, the public were permitted to know what had been happening during the previous four and a half years. The table[1.] below gives Clyde output, including warships, during the war. It is complete except for the production of two firms, Harland & Wolff and Connell & Co.

Year	No. of vessels	Gross Tons	I.H.P.
1914	346	583,246	1,149,407
15	296	325,197	1,204,130
16	393	506,922	1,862,410
17	432	461,589	1,588,370
18	432	573,294	2,033,869
Total	1,899	2,450,248	7,838,186

1. Compiled from "Glasgow Herald Shipbuilding and Engineering Supplements" for 28th December, 1918 and 30th December, 1919. H.M.S. "Hood" has been allotted to its proper year, namely 1918.

The annual average for the period is 380 vessels of 490,050 gross tons and 1,567,637 I.H.P. By way of comparison a table is given below showing the same data for the five years immediately preceding the war.

Year	No. of vessels	Gross tons	I.H.P.
1909	354	403,187	610,985
10	358	392,392	593,840
11	413	630,583	786,889
12	389	640,529	878,325
13	370	756,976	1,111,440
Total	1,884	2,823,667	3,981,479

The annual average for this period is 377 vessels of 564,733 gross tons and 796,296 I.H.P. The first peculiarity which would strike an observer is that whilst war time tonnage is substantially down the engine power is twice what it was in the pre-war period. This is entirely due to high-powered naval vessels which, like torpedo-boat destroyers for example,[1.] have a relatively small displacement tonnage but a very high I.H.P., amounting in many cases to more than twenty times the tonnage figure. Over the five years 1914-1918 war vessels of all kinds averaged 8 I.H.P. per ton, whilst merchant vessels showed only 1 I.H.P. per ton. The table below shows the Clyde naval output for the period 1914-18.

1. Large battle cruisers had engines developing an I.H.P. three and a half times their displacement tonnage, e.g.

H.M.S. "Tiger"	- 28,550 d.tons	- 105,000 I.H.P.
"Hood"	- 41,200 " "	- 144,000 "
"Barham"	- 27,580 " "	- 75,000 "
"Repulse"	- 26,500 " "	- 115,000 "

to mention a few of the ships produced on the Clyde between 1914 and 1918.

Firms	No. of vessels	Displacement tonnage	I. H.P.
Brown	47	196,353	1,707,500
Fairfield	43	136,270	1,157,570
Beardmore	69	118,080	634,290
Denny	46	56,456	666,900
Scott	33	52,099	651,350
Barclay, Curle	39	47,246	114,850
Yarrow	48	32,554	613,900
Other firms	156	172,489	691,470
Total	482	811,547	6,237,830

The firms named in the table were those responsible for building the vessels and the I.H.P. credited to them in consequence was not necessarily executed by them. The first three firms in the list were employed almost exclusively on naval work. The lower tonnage output during the war was offset by the enormously higher I.H.P. and the reader may be reminded that a battleship of given displacement tonnage represents much more work - and money - than does a merchant vessel or liner of equal gross tonnage.

During the five years 1909-13 there were launched on the Clyde 1,803 merchant vessels and liners aggregating 2,572,998 gross tons and 81 war vessels totalling 250,669 displacement tons. During the five war years the respective totals were 1,417 vessels of 1,638,701 gross tons and 482 naval ships of 811,547 displacement tons. In addition 996 naval vessels were refitted and the machinery of 1,659 vessels repaired or reconditioned. As an illustration of how during the war the needs of the merchant service were sacrificed to those of the Navy the following facts may be given. At the end of June, 1914, there were under construction in the United Kingdom 1,722,124 gross tons and on the Clyde 663,285 gross tons of merchant shipping. At the end of each successive quarter these figures became less until at the end of March, 1915, they were 1,587,467 gross tons and 589,488 gross tons respectively. The tonnage of war vessels under construction which in June, 1914, had been 592,545 and 163, 373 displacement tons for United Kingdom and Clyde respectively, of course rose rapidly. To the normal losses at sea were now added the destruction by cruiser, submarine, and mine. Even before the war had been in progress for six months, some hundred British vessels aggregating approximately 200,000 tons had been destroyed in this way. Matters became more serious during the ensuing year when no fewer than 451 vessels representing 814,233 gross tons were destroyed by enemy action whilst 181 vessels totalling 207,795 gross tons were lost at sea due to other causes. In addition, sale abroad, chiefly to America and other neutral countries, reduced the British register during 1915 by 213 vessels aggregating 429,304 gross tons.[1.] Finally 230 vessels ~~aggregating~~ totalling 83,569 tons were scrapped and broken up. Thus in 1915 we had, from all causes, the formidable total of 1,075 vessels aggregating 1,534,901 gross tons removed from the register; and of this only 334 vessels of 82,222 gross tons were sailing ships.[2.] Already in the first year of the war a greater tonnage was being destroyed by enemy activities than was being built; 451 vessels of 814,233 gross tons as against 432 vessels of

1. The fact that the Declaration of Paris (1856) gave immunity to goods for belligerents carried in neutral bottoms, probably accounted for this surprisingly large figure.

2. Statistics are from the statistical section of Lloyds Annual Register and from official Statistical Abstracts, 1912-26 (1929); they exclude war vessels of all kinds.

767,649 gross tons launched in 1915. Purchases abroad however amounted to 375 vessels of 756,101 gross tons, bringing the total added to the register during the year up to 807 vessels of 1,532,750 gross tons, including 152 sailing ships which aggregated 61,934 gross tons. Our net loss for the year was therefore 2,151 gross tons; a loss which, though not in itself large, was significant when it is remembered that during the previous year, including as it did five months of war, the net addition to the register was 404,630 gross tons.[1]

Matters showed no signs of improvement. During the quarter ending 31st December, 1915, and the following quarter less than 100,000 tons of merchant vessels were launched in each, an amount equal only to one third of current losses by hostilities. The need for fighting ships remained imperative and, at the same time, the necessity for merchantmen became more acute as the submarine menace developed. During 1916 war losses accounted for 1,200,000 tons of shipping, whilst losses due to other causes were rather above normal. Many ships in the yards were held up for lack of engines because engineering shops were compelled to manufacture munitions as well as marine engines. But as the war progressed it became apparent that victory or defeat depended as much upon our ability to maintain our supplies of food and other necessaries from abroad as on the success of our military and naval forces. The destructive submarine warfare of the Central Powers continued to gain in intensity, and the menace of mine and torpedo rendered the calling of merchant sailors as

1. The average annual net addition to the register for the five years preceding the war was 263,795 gross tons.

dangerous as that of the naval forces engaged in active combat. From the very commencement of the war freight rates had been rising rapidly owing to the shortage of shipping, a shortage which was aggravated (from the private trader's point of view) by governmental action in commandeering vessels as troopships and transports. Insurance premiums rose to heights hitherto unrecorded and thus added substantially to freight costs. The Government finally established a complete control over shipping and initiated a number of schemes to expedite the production of merchant ships and to minimise the labour thereon. In December, 1916, a scheme of "standardised" cargo-steamers was begun. Standardisation implies that the article is designed to be produced at the lowest prime cost consistent with efficient performance, and to perform its function with maximum economy. Now it cannot be said that the standard ships built during the war complied with these conditions; they were really repetition ships. Several sizes of them were built the largest being 450 ft. long x 58 ft. broad x 40 ft. depth of hold and 8,000 gross tons capacity. The engines were triple expansion with Scotch boilers working at 180 per sq. in. pressure. A few of the larger vessels had geared turbines and water-tube boilers. Steam to the H.P. end had 200° F superheat giving 12% fuel economy over saturated steam. Sea speeds varied from 10½ to 13 knots. In all fifteen types were designed. The vessels took from 6 to 15 months to build according to size and type. Altogether 148 were built before the armistice and a further 414 were completed later. In 1918, 198 of these vessels aggregating 886,000 gross tons were launched. After the war they were regarded as "super tramps" and were in demand because of the excellent quality of hull, engines and general equipment.[1]

Under Government aegis ferro-concrete and fabricated vessels were built. As a shipbuilding material, ferro-concrete was first made the subject of experiment in France as far back as 1849, but no further progress was made till 1887 when a small vessel was built in Holland. It was next tried in America in 1892 and in Italy in 1896. In 1905 a cargo vessel of 150 tons was built in Italy and operated successfully. Other countries followed; Germany, Canada, and Great Britain in 1910 and Denmark the following year. All the vessels were small in size, the first British one being a barge built on the Thames by the Cubitt Construction Co. Many pontoons of ferro-concrete had been giving satisfactory service prior to the war in many parts of the world, but when in 1917 tramp steamers of this material were put in hand in British yards, no experience of the sea-going qualities and little of the constructional difficulties of this type of vessel existed. Thus it turned out that a ferro-concrete ship of given tonnage cost 50% more than a steel ship of similar size and involved a greater amount of skilled labour than had been anticipated. Consequently this material was not exploited to any great extent and the building of such ships came to an end with the war. In all 209 vessels of this type were ordered but only a single barge of 1,000 tons had been completed when the war ended. In 1919 however 53 reinforced concrete vessels totalling 32,467 tons were launched in the United Kingdom. By the term "fabricated ship" is meant one which has been made in pieces, erected - most probably in an inland yard - and then dismantled for transport to a place where water for launching

1. For a fuller account of the standard ships and other related matters see "The War and the Shipping Industry" (1927) by C.E. Fayle.

is available. This practice was quite common in pre-war days in the production of small river craft, especially flat-bottomed boats for foreign countries. Messrs Alloy and Maclellan, with a yard at Polmadie, Glasgow, specialised in this type of work. Its application to sea-going vessels was introduced by America on her entry into the war in 1917.

In the main, however, we had to rely upon the building, in an orthodox way, of ordinary tramp steamers. Many yards, therefore, continued during the war their production as in peace time; nevertheless they were performing national service equally important as the construction of battle cruisers. Russell & Co. of Port Glasgow topped the list for tonnage output on the Clyde in each of the five war years and in 1915 were first in the United Kingdom; yet throughout the whole period they built only one vessel of 615 tons for direct war purposes. By 1917 extensions were being made in many shipyards and engineering shops, but the difficulty of shortage of materials - direct war work being classed "A", with a prior claim to supplies - and labour for the building of merchant ships remained to the end. Maritime losses reached their maximum in 1917 when over three and a half million tons of British shipping were destroyed by enemy action, less than one third of this being replaced by new construction. From 1916-18 sales abroad were negligible, but it need scarcely be pointed out that this exercised but a small effect towards nullifying the seriousness of the losses. It cannot be doubted that Britain was in greater peril of defeat by reason of supplies by sea being cut off than by the possibility of disastrous naval engagements. The submarine campaign reached its height in April, 1917, when in a single month 545 ships were lost by enemy action. Thereafter, owing to the more successful precautionary measures adopted, losses diminished but nevertheless during 1918 they reached the substantial total of 1,700,000 tons. Sufficient has been said at this juncture to emphasize the precarious position into which the shipping industry was forced during the war. The most striking contribution by Clyde shipyards to the national needs was, of course, the series of huge battle cruisers built there.

Few actual stoppages of work took place in the engineering and shipbuilding industries during the war, but this does not imply that the workers were satisfied with wages and conditions nor that they refrained from exercising pressure to gain improvements. After the commencement of the war wage rates moved upwards but slowly; by the end of 1915 they had risen by only 10%. Earnings, however, were much larger than in pre-war days, being augmented by almost unlimited overtime and Sunday work at higher rates. Against this must be set the rising cost of living with which wages did not keep pace and much broken time, avoidable and otherwise. During 1916 wage rates lagged far behind prices. At the beginning of the year earnings, it was estimated, had risen by 30%. The Government's introduction of unskilled labour on the wholesale scale on which it was carried out was quite naturally resented by the men, just as was the institution of state control of shipping and shipbuilding (and latterly the opening of state owned yards) by the employers. Each feared that by such action its accepted privileges and standards would be permanently impaired and only the national exigencies prevented on the one hand serious stoppages of work and on the other a boycott of the Government's proposals. A brief strike which resulted in the deportation of 10 shop stewards took place at

Parkhead Forge, Glasgow, from 17th March to 4th April, 1916. The restrictions imposed by the Munitions and Defence of the Realm Acts were found irksome by employers and employees alike and Ministers of the Crown found it necessary to employ to their fullest extent the allied arts of diplomacy, conciliation, and compromise. Despite all the efforts in this direction it cannot be doubted that the simmering discontent, aggravated by the knowledge that enormous profits were being made by not a few industrial and commercial capitalists, was responsible for retardation of production which the nation was ill situated to sustain. Materials, too, rose in price; by the end of 1915 steel plates were up by 40% on their 1914 level and by 1917 a single deck cargo vessel which pre-war cost £9 per gross ton could not be built for less than £16 per ton. The war period exhibited three phases; at the beginning the army and navy were recruited from all classes of society and without regard to the occupation of the individual. A shortage of skilled men was soon felt and many of these were returned to the workshop. With the passage of the Military Service Acts distinctions were introduced which caused widespread discontent and sense of injustice, at times illconcealed, between those engaged upon "work of national importance" and others whose places could be filled by unskilled or unfit. Influence and favouritism, it was felt, were exploited by many to obviate the necessity of taking up active combatant service. The need for maintaining and even increasing the strength of our armies came into conflict with the need for the provision of huge quantities of war supplies. Finally the former need triumphed and only the signing of the Armistice in November, 1918, prevented an extensive clearance of workshops, shipyards, and offices. The war ended with production screwed up to a higher pitch than ever before. In particular, shipyards and engineering shops were in full swing, working to capacity upon ships, engines, and machinery of all kinds in various stages of completion. This then was the situation when hostilities were suspended and peace declared.[1.]

In 1919 control of shipping was relinquished by the Government. Vessels which had been commandeered were handed back to their owners and the state owned ships were sold off. Many of the standard ships came into commission that year as super-tramps. Shipbuilding and engineering ceased to be subject to restriction; private enterprise once again held sway. The disorganisation which characterised the first few months of peace resembled that which had occurred on the outbreak of war. Work upon Government orders was suspended and thousands of men were dismissed. Many of these contracts were resumed later and carried to completion. The first effect, however, was a temporary increase in unemployment, as illustrated by the following table:[2.]

1918	Shipbuilding %		Engineering %	
	U.K.	Scotland	U.K.	Scotland
October	0·26	0·14	0·68	0·66
November	0·31	0·14	0·85	0·91
December	2·43	2·15	8·62	6·71
1919				
January	4·65	4·21	13·06	8·12
February	6·07	4·92	14·18	11·07
March	6·27	5·55	12·77	9·17
April	5·98	5·04	10·51	7·28
May	5·57	5·11	8·48	5·75

1. Publications dealing with the war period are now so numerous that it would be superfluous to expand further the brief sketch given. Reference is made in the Bibliography to a few of the authoritative works dealing with the war-time history of the shipbuilding and engineering industries.
2. Compiled from statistics given in the "Board of Trade Labour Gazette" each month.

But the rise in the general price level did not come to an end with the war and, following the period of disorganisation, there ensued a period of expansion exhibiting all the features of a pre-war boom. Shipbuilding yards and engineering shops continued to be busy for nearly two years after the signing of the Armistice. Unemployment never again reached the minimum of war time but the figures did fall substantially lower during 1920 than they had been in the few months following the war, and doubtless would have fallen even lower had industry been spared the disputes which soon broke out between employers and employees. That industrial troubles would be plentiful immediately the war ended might have been anticipated, both from the history of previous wars and from the ominous restlessness which had been evident during 1917-18 in nearly all industries, not least in shipbuilding and engineering. The following table[1] shows the course of the unemployment percentages during nine months of 1920;

1920	Shipbuilding %		Engineering %	
	U.K.	Scotland	U.K.	Scotland
January	5.35	5.31	9.81	6.21
February	4.15	3.88	6.52	5.54
March	3.49	2.83	5.16	4.39
April	2.87	2.10	4.01	3.46
May	3.04	2.10	3.52	2.98
June	3.27	2.01	3.38	2.76
July	3.74	2.38	3.27	2.46
August	3.85	2.37	3.50	2.69
September	5.37	3.04	4.58	3.34

Many of the Trade Unions had relaxed their rules in response to patriotic appeals during the war that nothing

1. Compiled from the "Board of Trade Labour Gazette."

should be enforced or maintained which was likely to restrict the output of munitions.[1] Official promises had been given that these war-time concessions would be restored when the national peril had passed; but, with the advent of demobilisation, the workers feared that their hard won privileges would be permanently lost. The Restoration of Pre-War Practices Act of 1919 compelled the owners of establishments to restore, or permit to be restored, pre-war practices which had been suspended. But the operation of the Act was limited to the period of one year. The cost of living, too, was still advancing. By national negotiation between employers and employees an agreement was reached that the hours of labour, which at that time were 54 per week as a rule, would be reduced to 47 per week without any wage reduction, the change to take effect as from 1st January, 1919. The shorter working week has been maintained since that date.

Many small and local disputes took place,[2] but the first extensive stoppage did not occur till September, 1919. In that month, after unsuccessful negotiations with the employers, ironfounders, moulders, and allied trades struck work to enforce a demand for an increase in wages. The claim was for an additional 15/- per week for journeymen and 7/6d for apprentices. With the situation as it is today, such a claim may seem to have been extravagant; but it must be kept in mind that the cost of living index then was nearly double what it is today and also that it was an

1. As a result of a conference between the Chancellor of the Exchequer, the President of the Board of Trade, and Trade Union representatives.

2. For example the "40 hours" strike in Glasgow lasting from 25th January to 11th February, 1919, a fruitless endeavour to obtain a working week of 40 (later reduced to 30.) hours.

accepted practice on the part of both sides to ask for twice or even three times the minimum which they were prepared to take or even expected to get. When the slump came a year later the reductions enforced by the employers were considerably greater than the increases previously asked for by the men at any one time. After five months of idleness, involving the loss of 5,000,000 working days, 5/- per week, which was being granted to the engineering trades generally in January, 1920, was conceded and accepted. Shipbuilders claimed, with considerable justification, that the cost of raw materials was excessive. At the beginning of 1920 steel plates stood at £19. 15/- per ton. A few months later the price had risen to £27 per ton. Comparative costs of two similar 10,600 ton ships, one pre and the other post-war were given by J.W. Noble, President of the Chamber of Shipping,[1] allowance being made for the higher power and finer lines of the later vessel:

	Labour	Materials	Total
1913-14 ship	£ 24,300	£ 49,585	£ 73,885
1920 ship	£ 67,866	£141,318	£ 209,184
Increase %	179	185	183
1920 ship at 1913-14 quality	£ 67,006	£ 137,115	£ 203,121
Increase %	172	177	175

An examination of the running costs of ships revealed an even greater increase. Exclusive of management and depreciation, ten voyages in the coasting and home trade showed an increase of 149%, and eighteen in foreign trade an increase of 285%

Early in 1920 indications of an impending break were not lacking. Launches continued to be heavy throughout

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 30th December, 1920.

the year and in fact were within 100,000 gross tons of the 1913 figures which were, of course, the largest ever recorded. Strangely enough, it may be remarked, the whole margin between 1913 and 1920 was accounted for by the drop in Clyde output. Employment, as shown above, remained good during the first three quarters of the year. But prices were falling rapidly. By December of 1920 steel plates had dropped to £25. 10/- per ton and continued to fall throughout the ensuing year. The second extensive stoppage in the industry since the close of the war began in December, 1920, when the ship joiners struck against a proposed cut of 12/- per week in their wages. This was the special advance which had been granted only eight months earlier. The strike came to an end in August, 1921, by which time it had become apparent that, in view of the prevailing depression, reductions could not be resisted. About 2,000,000 working days were lost by this dispute. The terms agreed upon were: 6/- per week reduction forthwith; a further 3/- per week cut to take effect on 1st October, 1921; and the remaining 3/- to be the subject of negotiations in December. The third national dispute emerged at the beginning of 1921. In December, 1920, an agreement had been reached between the Engineering and Allied Employers' Federation and the A.E.U. on the matter of overtime. Shortly After this it transpired that the two bodies put a different construction upon the terms of the agreement which permitted overtime to the extent of 30 hours per man per month in special circumstances. The Union claimed the right to be consulted as to whether or not these special circumstances necessitating overtime had arisen, and placed an embargo upon overtime concerning which they had not been consulted, on the grounds that excessive and unnecessary overtime, undesirable considering the large number of engineers who were unemployed, was being worked. The employers challenged this view and argued that such interference on the part of the Union constituted a breach of the Provisions for Avoiding Disputes[1.] as amplified and amended in 1914 and 1920. Joint conferences were held throughout 1921 but in January, 1922, by a substantial majority, members of the A.E.U. rejected the recommendations made by their leaders regarding settlement of the difficulty. It may be remarked in passing that only 21% of the Union's members took part in the ballot. Towards the end of February, 1922, another fruitless conference took place and on 11th March members of the A.E.U. were locked out. Meantime the Employers' Federation had requested the other organisations which were affiliated to the Federation of Engineering and Shipbuilding Trades to indicate their attitude towards what had come to be called "managerial functions." The reply of these organisations being deemed unsatisfactory, their members too were locked out on 2nd May. Meantime also a Court of Inquiry, in accordance with the provision of the Industrial Courts Act of 1919, under the chairmanship of Sir William W. Mackenzie, K.C., was being held. The Court reported in favour of the employers' contention and the stoppage which had involved 250,000 men in the loss of over eighteen and a half million working days came to an end early in June.

The post-war slump began to intrude its effects into the unemployment figures early in 1921. The prolonged stoppages in the coal industry during this and the previous year did not improve matters; allowance must also be made from the figures given below for those thrown idle by

1. See p.277 above.

reason of the ship-joiners' strike. But even when all allowances have been made for labour disputes, a substantial increase in unemployment remains due directly to the industrial depression which succeeded the boom of 1919-20. The following table continues the tables previously given, showing percentage unemployment in the shipbuilding and engineering industries of the United Kingdom.

1921	Shipbuilding %		Engineering %	
	U.K.	Scotland	U.K.	Scotland
February	14.13	11.39	11.86	8.00
March	19.34	15.51	14.35	10.63
April	28.46	22.30	20.21	10.63
May	34.43	28.47	24.13	21.60

The last dispute of any consequence in the shipbuilding industry materialised early in 1923 with the boilermakers. In February an agreement concerning night shift work and overtime had been negotiated between the Shipbuilding Employers' Federation and the Federation of Engineering and Shipbuilding Trades. The Boilermakers' Society was affiliated to the latter body and nominally would automatically have been a party to the agreement; but a ballot on the terms had been taken and the boilermakers had declined to take part in this. On 5th April the boilermakers of North Shields struck work and shortly afterwards the dispute extended to South Shields. A general conference was held with the employers but without result and on the 18th of the same month the latter posted lock-out notices to take effect twelve days later. The Amalgamated Society of Woodworkers and the United Operative Plumbers were also involved. These bodies however accepted the termsoffered; the boilermakers refused and were locked out. Many fruitless efforts were made to negotiate a settlement between the disputants[redacted]. After two months of idleness a ballot of the members showed a huge majority in favour of continuing the struggle. A committee of the Trade Union Congress finally succeeded in mediating in the dispute and satisfactory terms were arrived at on 16th November, work being resumed a week later. Nearly 6,000,000 working days were directly lost owing to the stoppage and the completion of many vessels delayed till the following year. A proposal to cut off shipyard workers' war bonus of 26/6 per week resulted in a short strike lasting from 29th March to 6th May, 1923. Some reduction seemed inevitable and the final terms were a reduction of 10/6 per week forthwith; 3/- a week to come off a month later and a further 3/- at the end of the next month. The 10/- remaining was the source later of prolonged negotiations. Typical wage rates at the end of 1923 were:[1.] fitters, 55/-; patternmakers, 59/6; shipwrights, 48/6 per week. By 1929 these rates had risen somewhat, an average being 58/-, 62/6, 55/6 respectively, for a 47 hour week. The 1923 output both from the Clyde and from the United Kingdom was lower than for any year since 1887.

At the end of 1923 steel was still 39% above pre-war prices. New vessels were 2% dearer than they had been twelve months before. Orders for vessels are extremely sensitive to price variations. According to Mr. W. Ayre of the Burntisland Shipbuilding Co. an alteration of 10/- per ton at that time, when steel plates were £10 per ton, made all the difference between a scarcity and a plentiful supply of orders. The table below gives the output including warships from Clyde yards for the five years immediately following the war.

1. Statistical Abstracts, 1912-26. (1929. Cmd. 3253).

Year	No. of vessels	Gross tons	I.H.P.
1919	421	605,757	1,364,771
20	330	672,438	620,615
21	249	511,185	478,460
22	143	388,481	345,429
23	128	175,586	166,936
Total	1,271	2,353,447	2,976,811

The annual average for this period is 254 vessels of 470,689 gross tons and 595,362 I.H.P. We may now make a comparison between the five pre-war years, the five war years, and the equal post-war period.

Period	Merchant vessels		War vessels		Total	
	No.	Gross tons	No.	Displacement tons	No.	Tons
1909 - 13	1,803	2,572,998	81	250,669	1,884	2,823,667
1914 - 18	1,417	1,638,701	482	811,547	1,899	2,450,248 [1]
1919 -23	1,246	2,302,971	25	50,476 [2]	1,271	2,353,447

The lower tonnage of the war period does not imply that the Clyde shipyards were not fully occupied during that period. The smaller output of merchant tonnage was more than compensated for by the higher displacement tonnage of warships and the enormously greater I.H.P. of these. All shipbuilding yards and engineering shops of the United Kingdom were working to capacity during the war.

The course of the post-war boom and slump as it related to wages and employment has been traced and the same period will now be reviewed as to output. A large tonnage left the yards in 1920 but even in that year, in many instances, when a ship left the stocks its place was not

1. Output of Harland & Wolff and of Connell & Co. is unavoidably omitted.
2. Wholly accounted for by launches in 1919, no war vessels being launched from 1920 to 1923 inclusive.

taken by another keel. Throughout 1921 this feature became more widespread and during the year following many Clyde yards did not launch a single vessel. Freights fell and the tonnage entering or clearing in ballast increased substantially. In 1922 no less than 51,000,000 gross tons of shipping entered or cleared from British ports in ballast compared with 103,000,000 gross tons in cargo. For the five years prior to the war the proportion of ballast to total was just over one quarter. Since 1922 the idle tonnage has constituted almost one third of the total. The pitiful showing of 1923 was in no small measure due to labour disputes but even apart from this new contracts were scarce. Surveying the year a writer said:[1.] "Orders could not be obtained for new ships,when existing ships could only be operated at a loss, laid up at a cost higher than that loss, or sold at a very heavy capital loss." The cessation of warship building hit the Clyde shipyards particularly heavily: the merchant tonnage launched in the period 1919-23 was 270,000 tons less than that for the period 1909-13; the warship tonnage was down by 200,000 tons. This lack of naval work, of course, affected chiefly the few extensive shipyards which specialise in that type of work.

Quarterly figures for ships commenced touched the maximum during the third quarter of 1919 when 713,927 gross tons were begun in the United Kingdom. The first quarter of 1920 was not much lower with 708,031 gross tons but thereafter decline was rapid. Fifteen months later only 23 vessels of 69,028 gross tons were commenced and by the second quarter of 1922 even this small figure had dropped to 21 vessels of 38,877 tons. A revival began in the fourth

1. "Glasgow Herald Shipbuilding and Engineering Supplement" for 29th December, 1923.

quarter of 1922 and throughout 1923 an average of 240,000 gross tons was commenced each quarter. The poorest quarter for launches was the third of 1923 when only 43 vessels aggregating 66,474 gross tons left the stocks in the United Kingdom. Elsewhere it has been remarked that tonnage on hand is a better index of prosperity at the time than tonnage launched during the preceding twelve (or even three) months. But in the post war years an old feature which must be taken into account when making a judgment reappeared in a more acute form. Work was suspended or delayed indefinitely on many vessels, though quarter after quarter and year after year these appear included as tonnage on hand or under construction at the end of the periods in question; the real test therefore was work in progress. The following table[1] referring to the United Kingdom will illustrate this:

Year	Quarter	On hand at end '000 gr. tons	Suspended or delayed at end '000 gr. tons	In progress at end '000 gr. tons
1921	1	3,799	847	2,952
	2	3,530	1,179	2,351
	3	3,283	1,188	2,095
	4	2,994	720	2,274
1922	1	2,236	617	1,619
	2	1,920	481	1,439
	3	1,617	419	1,198
	4	1,469	348	1,119
1923	1	1,492	181	1,311
	2	1,338	130	1,204
	3	1,271	242	1,029
	4	1,395	164	1,231

It will be observed that the third quarter of 1923 was the worst, but it must also be remembered that the depression in the shipbuilding industry was aggravated during 1922-23 by stoppages of work. It may also be remarked that other

1. Compiled from Lloyd's Register Shipbuilding Returns, Quarterly.

countries were suffering to a proportionate degree. Millions of tons of ocean going shipping were laid up at ports all over the world. In this respect U.S.A. suffered most severely on account of the huge additions to her fleet in 1919-20.

The following period of five years, 1924-28, showed a slight improvement upon the period just considered. Output never again fell to such a low point[1] as in 1923 although the year 1926 was extremely poor, and we have still to go back as far as 1887 to find a comparable year. From the point of view of work in progress 1926 was decidedly worse than three years before. The following table illustrates the period 1925-27:

Year	Quarter	On hand at end '000 gr. tons	Suspended or delayed at end '000 gr. tons	In progress at end '000 gr. tons
1925	1	1,165	74	1,091
	2	1,094	76	1,018
	3	1,009	81	928
	4	885	97	788
1926	1	843	80	763
	2	841	78	763
	3	775	107	768
	4	760	99	661
1927	1	1,217	20	1,197
	2	1,390	9	1,381
	3	1,536	8	1,528
	4	1,580	6	1,574

The rapid reduction during 1927 of tonnage delayed prevented the small amount in progress during 1926 showing up in tonnage launched during 1927, and the amount on hand at the end of the latter year was a good augury for the ensuing

1. The figures for net tonnage for the United Kingdom in 1926 were less than for 1923 but gross tonnage was somewhat greater.

twelve months. On the other hand the absence of labour disputes of any magnitude during the period under consideration might have led to the expectation of an output in excess of that actually achieved. Further, naval tonnage again began to occupy the stocks. The fact is that, taken all over, the second half of the decade following the war was little better than the first half. It can be said that the output was more evenly distributed over the period, and that it gave earnest of the industry settling down to more normal conditions than those prevailing immediately after the close of the war.

Millions of tons of shipping were still laid up in port. At the middle of 1924 the figure for the world was 6,000,000 net tons of which U.S.A. accounted for two-thirds and the United Kingdom for 700,000 tons. Two years later the situation was still much the same; "too many ships in the world", was the universal complaint heard amongst builders. Matters improved somewhat in 1927 at least so far as the United Kingdom was concerned. On 1st October the figure for shipping laid up at the principal ports of the United Kingdom had fallen to 280,000 tons. Unfortunately the ensuing twelve months witnessed an increase of 140,000 tons on this figure.[1] Clyde production reflected that of the whole country. The table below corresponds in the data it gives to the others, already presented above for previous quinquennial periods.

Year	No. of vessels	Gross tons	I.H.P.
1924	251	538,021	450,258
25	280	523,322	433,243
26	173	286,350	433,465
27	274	462,565	647,874
28	241	604,611	673,907
Total	1,219	2,414,869	2,638,747

1. July, 1930, shows 927,000 net tons laid up compared with 266,000 tons nine months before.

The annual average was 244 vessels, 482,974 gross tons, and 527,749 I.H.P. The comparatively high I.H.P. for 1926 was due to the inclusion in that year's figures of marine engines totalling 210,000 I.H.P. for warships previously launched. War vessels for the period numbered 11 aggregating 53,932 tons displacement. With somewhat less than 600,000 gross tons on hand at the end of 1928 - a figure smaller by 100,000 tons than that for the previous year - prospects for Clyde shipyards during 1929 were not too bright. As it happened orders increased towards the end of the year and employment accordingly was better than had been hoped.

Nothing has been said in this chapter regarding technical changes which took place after the war. Some of these had actually been in progress a year or two before the war but had perforce been neglected for five years - neglected by British engineers and shipbuilders, it should be said, for neutral countries on the Continent were not slow to see the possibilities and to endeavour to forestall the United Kingdom in the matter of developing new inventions. This subject is dealt with in the next chapter, as are also the outputs of individual Clyde yards, river improvements, and other matters relating to the present circumstances and future prospects of the shipbuilding and marine engineering industries.

CHAPTER XIII.

THE OUTLOOK FOR THE FUTURE.

A question of national interest today is whether Britain is losing her place as the leading shipbuilding country of the world, and of local importance is the question of whether the Clyde is maintaining its position within the United Kingdom. From the commencement of the twentieth century up to the outbreak of war Britain supplied 18% of the tonnage launched in the world. For five years she was incapable of replacing her own losses much less of building to the demand of foreign countries. Combatants and neutrals alike were therefore thrown back upon their own shipbuilding resources and many of them discovered latent powers in themselves. Japan and U.S.A. made determined efforts to supplant the United Kingdom as producers for those countries lacking sufficient resources to supply their own needs. In 1918 the output of the U.S.A. exceeded their total production for the decade 1907-16 and was more than three times that for 1917. It amounted to 57% of the total world output or to 74% if the United Kingdom be excluded. A considerable fraction of the U.S. output consisted of lake and river steamships, and 31% was of timber. But the rise of both countries as shipbuilders was rapid. In 1913 Japan had only 6 shipbuilding yards comprising 17 berths and these, employing 34,000 workmen, had a total output for the year of 4 vessels - all merchantmen - aggregating 34,500 gross tons. Five years later 57 yards with 157 berths were employing 95,000 men and producing, in 1918 alone, 189 merchant ships totalling 618,800 gross tons. When the war ended industry in the United Kingdom experienced a short lived boom and was thereafter plunged into a depression which has continued, in varying degree, ever since. Let us see how our competitors fared. The war time output of the various foreign countries cannot be given, but the table below gives the names and respective outputs of the three leading nations each year from 1919-29.[1]

1. Compiled from "Glasgow Herald Shipbuilding and Engineering Supplements."

Year	Order	Country	No. of vessels	Gross tonnage	I.H.P.
1919	1	U.S.A.	1,337	4,736,103	4,550,300
	2	U.K.	1268	729,490	1,590,894
	3	Japan	345	697,650	405,241
1920	1	U.S.A.	698	2,743,067	3,397,325
	2	U.K.	1,169	2,140,928	1,700,106
	3	Japan	242	597,048	730,475
1921	1	U.K.	804	1,596,272	1,318,788
	2	U.S.A.	292	1,303,735	1,510,894
	3	Germany	246	623,722	369,811
1922	1	U.K.	542	1,043,590	812,466
	2	Germany	240	631,485	356,080
	3	U.S.A.	179	260,347	313,335
1923	1	U.K.	591	685,147	538,751
	2	Germany	184	415,547	271,083
	3	U.S.A.	240	276,978	354,700
1924	1	U.K.	900	1,487,848	1,104,254
	2	Germany	169	230,335	171,381
	3	Holland	566	225,145	133,254
1925	1	U.K.	887	1,195,487	1,039,919
	2	Germany	233	439,706	320,063
	3	Holland	627	315,682	90,012
1926	1	U.K.	634	724,693	1,034,028
	2	Holland	637	278,513	154,347
	3	Italy	33	259,032	502,140
1927	1	U.K.	932	1,314,380	1,342,540
	2	Germany	195	359,869	469,282
	3	Holland	631	329,088	287,422
1928	1	U.K.	939	1,576,478	1,907,821
	2	Germany	147	405,338	469,282
	3	Holland	675	346,623	287,422
1929	1	U.K.	1,107	1,623,430	1,872,667
	2	Holland	644	405,390	228,824
	3	U.S.A.	368	313,879	818,780

It will be noticed that U.S.A. soon lost its leading place and progressively fell off till in 1928 it occupied only sixth place in the world with an output of 178 vessels aggregating 124,379 gross tons. A substantial recovery to 313,879 gross tons is shown in the 1929 figures. Supply means supply at a price; and whilst U.S.A. with the high prices ruling during and immediately after the war, might be able to supply the demand at the high price, it was unable to supply it when prices fell. In recent years Germany and Holland have been our nearest rivals, but the total German output has not since 1923 equalled, much less exceeded, the output from the Clyde alone and Holland's tonnage is swollen by numerous barges, as is indicated by the relatively small I.H.P. Japan's enjoyment of a leading place also depended upon high prices; in 1929 it ranked fifth in the world for output.

Thus by 1921 Britain had regained its pre-war pinnacle. But it was a lower pinnacle than in pre-war days. Table H.1. shows Clyde, United Kingdom and world output figures since 1891. In that year the United Kingdom was producing 85% of the world's tonnage, a figure which two years later, when output was exceptionally low all over, rose to 93%. Thereafter there was a steady fall until in 1913 the figure stood at 53%. Figures for world output from 1914-18 are not available and even if they were would have no significance to this enquiry. In 1919 the United Kingdom output, large as it was, constituted only 22% of world output which reached the huge total - never approached before or since - of 4,160 vessels of 8,588,215 gross tons and representing propelling power of 8,992,421 I.H.P. This was followed the next year by 3,274 vessels of 6,947,184 tons and 6,737,880 I.H.P. The following year witnessed a reduction of a million and a half tons and two and a half million I.H.P., 20% greater than the output of 1913. In 1922, owing to the slump, output was only 70% of that of 1913, but the British share of this had risen to 35%. During the year following, a set back occurred and the United Kingdom percentage dropped to 32; the slump was experienced more severely in Britain than elsewhere. Since the war the highest percentage, though not the highest total output, occurred in 1924 when it reached 57%. The year just closed (1929) showed the maximum production since the slump of 1921 and it is a hopeful sign to note that this follows upon a year almost equally high.[1] In both 1928 and 1929 Britain contributed 46% of the tonnage launched in the world.. This is a fairly close approach to the 1913 figure and, with the reorganisation presently proceeding in the industry, it is not too sanguine to expect that the United Kingdom may regain the position it held in the world immediately before the war.

Much is heard these days of industry moving southward in Britain. Are there signs of this shift in the shipbuilding and engineering industries? Is the Clyde and West of Scotland generally losing its pre-eminent position in the United Kingdom? The table referred to above will aid in answering these questions. Data for the Clyde and United Kingdom begin in 1878; in that year the Clyde was responsible for 35% of the total United Kingdom output. This fraction rose to almost 40% in 1884 and thereafter fell to 25% in 1891. Two years

1. 1930 shows no sign of justifying this hope. On the contrary, tonnage commenced is badly down.

later it was again over 30% and from then to 1914 fluctuated around this figure. During the war the range was from 38% in 1915 to 30% in 1918. Abnormally large fluctuations have characterised the post war years as shown in the table below:

Year	Clyde output / U.K. output %
1919	32.2
20	31.4
21	32.0
22	37.2
23	25.7
24	36.2
25	43.8
26	39.4
27	33.8
28	38.4
29	34.8

Regarding the position taken by the Clyde in total Scottish output, little need be said. For over 40 years shipyards of the west have been responsible on the average for 90% of the tonnage launched annually in Scotland. As it happens the Clyde seems to suffer more during trade depressions than does the shipbuilding industry of the east coast, the percentage on these occasions falling below the average. On the other hand it is during depressions that the proportion of Clyde to United Kingdom output rises. From 1918 to 1923 Clyde output was considerably below its average 90%, falling in the last named year to 81.2%. Since then, however, its old position has been regained and there certainly is no evidence of any tendency for the east coast to gain at the expense of the west so far as shipbuilding and marine engineering is concerned.

In the West of Scotland itself, so far as output is concerned, the shipbuilding yards may be grouped into two districts: Glasgow (including Clydebank, Dalmuir, and Renfrew) and Greenock (including Port Glasgow, Dumbarton, and the smaller towns of the Firth). Glasgow district since the war has accounted for about two-thirds of the tonnage launched on the river and firth. But the fluctuations in the Greenock district have been smaller than in the Glasgow area. A survey of tonnage on hand at the end of each quarter since 1917 shows the maximum for Greenock was 386,430 gross tons at the end of June 1920, and the minimum 120,460 tons at the end of September 1922. The Glasgow maximum was 1,009,277 gross tons at the end of March 1921, and the minimum 160,880 tons at the end of December 1926.[1] The ratio minimum to maximum was therefore 31% for the Greenock district and 16% for the Glasgow district. The city and its environs account for 75% of the marine engine I.H.P. produced in the West of Scotland. The shipyards and workshops of Glasgow district have a much larger capacity than those situated on the lower reaches of the river and hence reap the benefit of periods of boom but suffer correspondingly during depressions.

In a further answer to the question as to whether or not Britain is maintaining its position in the world of shipbuilding and engineering, a brief account of the technical advances which have taken place during and since

1. The Greenock figure for this date was also very low, namely 122,400 gross tons.

the war must be given. A time of war is scarcely the time for experimenting with new types of marine machinery; reliability is even more important in such circumstances than speed or efficiency. Thus the only innovations in the British mercantile marine from 1914-18 were the standard ships and the concrete ships already mentioned above,[1.] and no departures in methods of propulsion were made. Not so, however, amongst neutrals on the Continent and elsewhere - their engineers and shipbuilders were taking advantage of the latest inventions and, at the end of the war, Britain had a considerable leeway to make up. By 1914 the geared turbine had been brought to quite a high degree of efficiency, the loss of power in the gearing being less than 2% and the wear of the teeth negligible after 100,000 miles of voyages. The maximum power developed by any marine turbine set was, however, less than 15,000 S.H.P. Even before the war double reduction gears were in use; the practice of superheating steam had been revived and a turbo-electric drive, the prime mover using superheated steam, was on trial. Oil fuel and Howden's forced draught for boilers had become well established. A new prime mover, the internal combustion engine, was being experimented with for marine work. This type of engine had of course been in use for many years in road vehicles, small fishing craft, and electric generating stations. A point of supreme importance in its favour is that it renders boilers, condensers, piping, etc. unnecessary and thus lowers very much the weight of plant required per

1. See p. 290.

H.P. developed. It is also of inestimable value for submarine propulsion. The particular form which finally succeeded in meeting the exacting requirements of sea going vessels was the Diesel type, invented by the German engineer Rudolf Diesel and patented by him in 1893. It is capable of operating with many kinds of oil but of course the lighter varieties such as petrol and kerosene can be used with greater effect in other types of engines. Thus the Diesel engine is generally supplied with crude oil, and differs from other internal combustion engines in that no external means of ignition need be supplied. Air is compressed to 500 lbs. per sq. inch and over and the resulting temperature (1000°F and upwards) is sufficient to ignite the charge of oil which is sprayed into the cylinder during a short fraction (about one tenth) of the stroke. As the engine is not self-starting compressed air from cylinders has to be supplied initially. The first constructed in Britain was by the Mirrlees, Watson Co. of Glasgow in 1897, and by 1900 engines were on the market. In 1906 two Diesel driven dynamos were fitted in a battleship, since when every subsequent battleship has been equipped with one or more such. Relative to the H.P. delivered, they are lighter than steam engines, a four cylinder Diesel delivering 160 B.H.P. at 400 r.p.m. weighing 14 tons. Ships driven by Diesel engines have come to be termed motorships and hereafter this term will be used. The first sea-going motorship was the Italian built "Ranagua" in 1910. The first large motorship in the world was the "Jutlandia", of 5,000 tons and 3,000 I.H.P., launched on the Clyde in 1911. During the war, as explained above, this new unit could not be developed in Britain, but it gained in popularity and in efficiency at the hands of engineers in other countries. By 1919 the Diesel engine had become established as a rival to all types of steam engines. Four stroke Diesels, developing 3,000 to 4,000 H.P. per shaft, were being applied to twin screw vessels and giving satisfactory performances.

In the advances made after the war the Clyde did not lag behind other areas or other countries; many new departures in type were made and the whole character of marine engineering underwent a change. Space permits mention of only a few leading examples of these new types. In 1921 the first passenger motorship, the "Domala" (460' x 58' x 35'; 2,330 I.H.P.) built by Barclay, Curle & Co. and engined by the N.B. Diesel Co. for the British India Steam Navigation Co., was put into service. The second was built by Harland & Wolff for the Elder, Dempster Co. It had the most powerful marine Diesels (6,400 I.H.P.) yet installed in any vessel. During 1921 Scott & Co. of Greenock were experimenting with the "Still" engine, a double acting Diesel, generating steam in the cylinder jackets and conveying it to the under side of the pistons, there to add its quota to the output of the engine. In January 1924, the "Dolius", a vessel of 6,000 gross tons and 2,500 H.P. driven by a "Scott-Still" engine, was launched by Scotts S. & E. Co., of Greenock for Messrs Alfred Holt the Liverpool shipowners. So successful did her maiden voyage prove that in June of the same year the owners ordered a similar but larger vessel. In 1923 the 20,000 ton motorship "Aorangi" (600' x 72' x 37'6") was on the stocks at the Fairfield yard. Within two years, equipped with four 2 cycle single acting six cylinder engines developing 14,000 S.H.P., this first motor liner was giving efficient service at 17 knots on the high seas. For size and power it had to give place in 1925 to the Italian built and engined motorship "Augustus" (710' in length; 30,000 gross tons; 28,000 I.H.P.). As an illustration of the competition which British engineering firms have now to contend with from countries which before the war were our customers, it may be mentioned that the firm which constructed the engines for the "Augustus" had the highest output of engines - 272,250 I.H.P. - of any firm in the world during that year. Geared Diesels made their appearance in 1924, and double acting engines were also developed. Of the vessels equipped with the latter type the first trans-Atlantic crossing was made by the "Tampa" in 1926. Reference has already been made to the fact that the honour of inventing the Diesel engine must be ascribed to a German engineer. An "all British" marine internal combustion engine is now on the market. Known as the Richardson-Westgarth type it is a two stroke double acting engine. The hull of the first vessel, the oil tanker "Irania" (2,250 gross tons; 1,400 I.H.P.), to be equipped with this type was constructed in 1928 by the Blythswood Shipbuilding Co. Two other vessels launched the same year and representing notable departures from normal practice may be mentioned: the "Brunswick" (8,947 gross tons; 3,900 I.H.P.) by Scotts S. & E. Co., the first Diesel-electric driven ship to be built on the Clyde, and the "Viceroy of India" (19,300 gross tons; 20,800 S.H.P.) by Stephen & Co., the first turbo-electric passenger carrying vessel to be constructed in Europe. Unfortunately we cannot attribute the construction of the engines for these three vessels - and the engines of course constituted their chief claim to special notice - to any Clyde firm. The secondary electric drive is more popular with U.S. naval authorities than with the British Admiralty. Finally, as an example of the constant search for economy in running costs rather than as an example of a type of vessel likely to displace other types, we may mention the German designed and built Flettner "rotor ship" of 1924. This vessel relied upon wind power applied to vanes on turret-like masts and, under suitable conditions, gave satisfactory performances. Such a vessel is of course subject to the disadvantages attaching to sailing ships and it seems unlikely that the type will achieve any wide measure of popularity.

The economy of oil fuel compared with coal has already been remarked. Despite the higher price per ton of oil, the fact that one ton of it possesses steam raising ability equivalent to one and a half tons of coal whilst occupying only one half of the space and necessitating only one third of the stokehold staff implies considerable economies in running costs. Small wonder, therefore, that, after the war, shipowners being hard pressed by competition from rivals should, in ever increasing numbers, adopt oil fuel for their new vessels. Many had their old vessels adapted to the newer system, the replacement costs being moderate. Comparing the Diesel engine with oil burning boilers we may point out that the prime cost of the former is a quarter to a third greater than that of a steam engine to develop say 3,000 S.H.P.; but the consumpt of oil is only ½ lb. per S.H.P. per hour in an internal combustion engine compared with 1 lb. per S.H.P. per hour for oil fired boilers supplying superheated steam to an efficient geared turbine. On the other hand a Diesel plant for an 8,000 d.w. ton vessel costs about £25,000 more than steam plant, an addition of £3. 3/- per ton to the prime cost of the vessel, despite the saving of boilers and auxiliary plant achieved by its use. Fuel oil is cheaper than that required for Diesel engines and the latter also use larger quantities and better qualities of lubricating oil than steam engines do. The very best practice as exemplified by an American turbo-electric passenger liner (50,000 S.H.P., taking steam at 550 lbs. per sq. in. at 725°F and with a condenser vacuum of 29") showed a close approach to the motorship in fuel oil consumption, viz. 0.55 lbs. per S.H.P. per hour. To meet the competition of the motorship, which is becoming more popular every year, high pressure turbines are being tried. In 1926 Denny, of Dumbarton, engined the cross-channel steamer "King George V" with turbines of a type similar to those in common use in up-to-date land installations delivering 3,500 H.P. The steam pressure (575 lbs. per sq. inch) is greatly in excess of any previously used in marine practice. Another new departure is represented by the "Berwindlea" (5,726 gross tons; 2,300 I.H.P.) commenced in 1928 and launched the following year by the Blythswood Shipbuilding Co. of Scotstoun. This coal carrying steamer is the first with boilers specially designed to burn pulverised coal. It is too early yet to make any judgment upon the degree of economy or success possible by the use of this new fuel. The initial cost of the plant as matters presently stand is greatly in excess of that for oil fuel, though the fuel itself is less expensive and has much in common with oil so far as cleanliness, ease of handling, even distribution of temperature, and economy of space in "bunkers" is concerned. If in future prime costs can be reduced substantially and if no unforeseen difficulties emerge in the operation of the plant, a keen rivalry between the Diesel engine and the high pressure geared turbine, fed with steam from water tube boilers fired with pulverised coal, will probably be witnessed.

But initial costs weigh heavily with shipowners; with British shipowners, it would seem, even more than with foreign owners. Hence one reason for the somewhat tardy adoption of the motorship in the British mercantile marine, another being that many owners and builders in the United Kingdom are of the opinion that, for the type of work which the tramp ship is called upon to perform, the modern triple expansion reciprocating engine will hold the field, as it has done up to the present time, against all innovations. Efficiency of running, they believe, is to be sought more in methods of steam raising than in the utilisation of the power produced. The table below[1] summarises Clyde output of merchant ships from 1920 to 1929 according to type of engines in use. Small vessels such as tugs, launches, barges, etc. and sailing ships are omitted and hence the totals do not correspond to totals previously given in other tables relating to the Clyde.

Year	Steam (gr. tons)		Total steam (gr.tons)	Motorships (gr.tons)	Total (gr.tons)	% recip. / total	% turb. / total	% total steam / total	% motor / total
	Reciprocating	Turbines							
1920	321,063	254,708	575,771	59,854	635,625	50.5	40.1	90.6	9.4
21	176,499	205,466	381,965	51,846	433,811	40.7	47.4	88.1	11.9
22	77,092	198,347	275,439	58,112	333,551	23.1	59.4	82.5	17.5
23	82,324	36,957	119,281	32,097	151,378	54.4	24.4	78.8	21.2
24	302,813	82,278	385,091	109,623	494,714	61.3	16.6	77.9	22.2
25	240,668	116,520	357,188	139,899	497,087	48.5	23.4	71.9	28.1
26	150,749	56,419	207,168	49,319	256,487	58.8	22.0	80.8	19.2
27	223,783	57,320	281,103	135,111	416,214	53.8	13.7	67.5	32.5
28	283,560	72,779	356,339	172,256	528,595	53.7	13.8	67.5	32.5
29	271,526	48,279	319,823	223,654	543,477	50.0	8.9	58.9	41.1

It is evident that the motorship is gaining at the expense of the turbine but it should be noted that the geared turbine is used for nearly all the large passenger liners. With only a

1. Compiled from statistics given annually in "Glasgow Herald Shipbuilding and Engineering Supplements."

temporary reversal, since 1921 the turbine has lost ground steadily whereas the motorship has increased to an equal extent. With considerable fluctuations from one year to another - rising, it may be noted, in years of depression - the reciprocating engine has held its own at an average of 53% of the total for the decade. In the United Kingdom output as a whole, the advance of the motorship was less rapid, though somewhat less erratic also, than in Clyde production. But foreign countries have far outstripped us in this department. The following table[1] gives for the United Kingdom the same data as the preceding table gave for the Clyde.

Year	Steam (gr.tons) Reciprocating	Steam (gr.tons) Turbines	Total steam gr.tons	Motorships gr.tons	Total gr.tons	% recip. total	% turb. total	% total steam total	% motor total
1922	506,637	443,879	950,516	78,341	1,031,081	49.0	43.0	92.0	8.0
23	432,148	121,075	553,223	87,244	645,651	67.0	18.8	85.8	14.2
24	992,236	202,982	1,195,216	237,458	1,439,885	68.9	14.2	83.1	16.9
25	646,669	164,889	811,558	267,217	1,084,633	59.6	15.3	74.9	25.1
26	312,525	119,308	431,833	201,913	639,568	49.0	18.5	67.5	32.5
27	427,845	137,628	865,473	355,779	1225873	59.4	11.1	70.5	29.5
28	874,680	138,094	1,012,774	427,916	1,445,920	60.5	9.7	70.2	29.8
29	848,412	107,477	1,05,5889	464,188	1,522,623	55.7	13.6	69.3	30.7

The table below[2] gives comparable figures for world (including United Kingdom) output.

1. Compiled from Lloyd's "Annual Summaries of the World's Shipbuilding" and excludes ships of less than 100 gross tons. Sailing ships however are included.

2. Also compiled from Lloyd's "Annual Summaries", and figures are given to the nearest thousand tons.

Year	Steam (gross tons)		Total steam (gr.tons)	Motorships (gr. tons)	Total (gr. tons)	% recip. / total	% turb. / total	% total steam / total	% motor / total
	Reciprocating	Turbines							
1922	1,479,000	776,000	2,255,000	212,000	2,467,084	60.0	31.5	91.5	8.5
23	1,107,000	304,000	1,411,000	232,000	1,643,181	67.2	18.7	85.9	14.1
24	1,452,000	285,000	1,737,000	511,000	2,247,751	64.7	12.6	77.3	22.7
25	1,066,000	262,000	1,328,000	865,000	2,193,404	48.6	12.0	60.6	39.4
26	651,000	301,000	952,000	723,000	1,674,977	38.8	18.0	56.8	43.2
27	1,070,000	336,000	1,406,000	880,000	2,285,679	46.8	14.8	61.6	38.4
28	1,121,000	361,000	1,482,000	1,217,000	2,699,239	41.6	13.4	55.0	45.0
29	1,338,000	174,000	1,512,000	1,281,000	2,793,210	47.9	6.3	54.2	45.8

In respect to the progress of the motorship in foreign countries these world figures are of even greater significance if we recollect that they include the relatively small United Kingdom output of this type of vessel, although the total United Kingdom output constitutes over 50% of the total world output.

These changes in types of vessels and methods of propulsion of ships being built at the present time will, of course, take a long time to alter substantially the character of the existing world fleet of merchant ships which at the end of June, 1929, stood at the enormous figure of 62,896,000 gross tons, excluding sailing ships and wooden-hulled steamships. Nevertheless the motorship which in 1914 constituted only half of one percent. and ten years later 3.5% of the world's fleet now constitutes over 10% of the same. Vessels using oil fuel instead of coal have increased in number much more rapidly owing, as already explained, to the comparative ease with which the alteration can be made. In 1914 the percentage of mechanically propelled vessels burning coal and oil respectively were 96.4 and 3.1; ten years later the figures were 66.7 and 29.8; and in 1929 they were 58.5 and 30.9 respectively.[1] Not only is coal fuel decreasing as a percentage of the world total (which, of course, is constantly increasing) but it is also decreasing in the actual tonnage figure. The gross tonnage figures for the world (with the exceptions noted above) are displayed in the table[2] below (in thousands):

Year	Steam driven		Motorships	Total
	Coal	Oil fuel		
1914	40,970	1,310	234	42,514
1924	38,376	17,154	2,000	57,530
1929	36,847	19,421	6,628	62,896

During 1929 in the world 410,000 gross tons of ships launched were oil burning vessels, that is 36.7% of the total 1,504,000 gross tons of steamships for the year. For the United Kingdom the figures were 306,000 gross tons oil burning, being 29.9% of the total 1,056,000 gross tons of steamships launched. In this respect too the United Kingdom lags behind the rest of the world. The two largest vessels of the year were both launched in the United Kingdom; the "Britannic"[3] (26,840 gross tons) a motorship launched from the Belfast yard of Harland & Wolff and the "Empress of Japan"(25,000 gross tons) a turbine driven liner launched by the Fairfield Co. of Govan. The enormously increased demand for oil has brought about another striking change in the composition of merchant

1. Motorships raise the total to 100%

2. Compiled from Lloyd's "Annual Summaries".

3. This ship has the distinction of being the first motor liner on the North Atlantic service.

shipping. Mention has already been made of the special type of oil carrier, the "tanker" vessel. In 1914 the total tonnage of such vessels in the world was 1,479,000 gross tons; ten years later this had increased to 5,243,000 gross tons; and in 1929 the figure stood at 7,071,000 gross tons. The Isherwood system of longitudinal framing is much in favour for this type of ship. Lastly it may be noted that the war, which had restricted the construction of ships in Britain, had the contrary effect in neutral countries. The following list shows the quinquennial gross additions to the merchant fleet of the world for the period 1910-30 inclusive.

Years	Gross tons launched.
1910-14	13,695,397
1915-19	18,419,497
1920-24	16,561,361
1925-29	11,646,509

The abnormal figure for the period 1920-24 was, of course, due to the boom years 1920-21. The net increase in the last five years has been 5,366,000 gross tons; thus 6,281,000 gross tons of shipping have been lost or scrapped in the world during that period.

Further striking figures, indicating how far Britain is falling behind other countries of the world in the production of the newer types of marine engines, and especially oil engines, are published in Lloyd's Quarterly Shipbuilding Returns. It is unfortunate that the figures, which show the I.H.P. (or for turbines, the S.H.P.) under construction in all the leading countries at the end of each quarter, date back only to June, 1925. Reciprocating engines, turbines, and oil engines are distinguished, and, if any judgment may be made upon so short a period it would be this; that whilst British engineers are maintaining their share of the reciprocating engines constructed in the world the same assurance cannot be given in regard to turbines or to Diesel engines. It may of course be a temporary phase, but certainly Britain's proportion of the world output of oil engines was less in 1928-29 than it was during 1926-27. This would seem to be the most disturbing feature of British shipbuilding and marine engineering at the moment; that Britain is not moving as fast as other countries - once her customers, now her competitors-in the modern forms of marine propulsion; and that her own mercantile marine is not keeping pace with the fleets of shipping rivals. It is clear that those countries which are acquiring a fleet of merchant ships are in a better position to equip themselves with the latest and best types than one which is merely augmenting and replacing its fleet as occasion offers or need demands. To maintain the British fleet at a par with others would necessitate a greater volume of scrapping and sales, at relatively low prices, than would seem to be economical in the circumstances. Nevertheless the shipowner cannot be exonerated on these grounds; past experiences shows that, especially in times of depression, he is rather conservative in his outlook. Whether an augmented supply of capital at a rate of interest lower than that which has prevailed in recent years will be a sufficient inducement to him to alter his outlook, is difficult to say; but it is safe to assert that, if Britain is to retain even the limited amount of sea borne traffic which she has regained since the war her fleet must be made what it was during the nineteenth century, the best and most up-to-date in the world.

A return may now be made to the consideration of the part being played by Clyde firms in the post-war shipbuilding and engineering world. A considerable reduction in costs has at length placed the Clyde and other shipbuilding areas of the United Kingdom in the position of being able successfully to compete with Continental countries both for the construction of new vessels and for repairs even though, as Sir William Seager states, the cost of building a steamer is still about 50% above pre-war costs. The fact that industrial peace has reigned since the General Strike of 1926 has greatly helped builders in this respect. The greater concentration of industrial units on the river is dealt with at length in Appendix 8, and this is borne out by a consideration of the firms that have taken a leading place in the area since 1914. The tables below are a continuation of those given on pp.200-2 above. It may be noted that the year 1914 is duplicated, as the former account for that year neglected the output of warships and their machinery. The first table shows the shipbuilding firms which occupied first or second place on the river. Russell & Co. under their new title of Lithgows, Ltd. continue to lead, though Harland & Wolff take first place no fewer than five times.

Name of firm	First place	Second place
Lithgow's Ltd.	8	3
Harland & Wolff	5	1
Barclay, Curle & Co.	1	4
Wm. Beardmore & Co.	1	1
A. Stephen & Sons.	1	1
John Brown & Co.	-	3
Scotts' S. & E. Co.	-	2
D. & W. Henderson	-	1

The next table shows the placing of engineering firms. Fewer names appear than in the pre-war table - thirteen only[1] as against nineteen - but the output of the first six frequently exceeds 70% of the total Clyde production and in 1916 touched a maximum of 78.2%. J.G. Kincaid & Co., though not a new firm, appear for the first time, and that prominently. Brown and Fairfield, as in pre-war times, head the list.

Name of firm	First place	Second place	Third place	Fourth place	Fifth place	Sixth place
John Brown & Co.	6	3	-	-	2	2
Fairfield S. & E. Co.	4	5	-	-	1	2
J.G. Kincaid & Co.	3	1	3	1	2	-
Rowan & Co.	2	1	1	5	-	1
Wm. Beardmore & Co.	1	2	2	2	2	3
A. Stephen & Sons	-	2	-	1	-	1
Scotts' S. & E. Co.	-	1	1	2	-	2
Barclay, Curle & Co.	-	1	-	-	1	-
Denny Bros.	-	-	5	3	1	1
Harland & Wolff Ltd.	-	-	2	-	4	1
Yarrow & Co.	-	-	2	1	3	1
Dunsmuir & Jackson	-	-	-	1	-	1
D. & W. Henderson	-	-	-	-	-	1

As with shipbuilding the Clyde is maintaining its position in marine engineering in the United Kingdom, and whatever may be true of other industries or of new ventures moving southward, it can be stated that assuredly the twin industries of this area exhibit no signs of relative decline.

1. One of these Dunsmuir & Jackson have since closed down.

Messrs Harland & Wolff by devoting their Govan yard almost exclusively to the construction of large motorships are doing much to maintain the reputation of the Clyde as a river capable of supplying any size and any type of vessel. This firm and its subsidiaries also supply locally most of the engines for the vessels they build here. The Fairfield Co. make a speciality of turbine driven vessels, including war vessels. Nor has the Clyde reached its limit as a shipping centre - or at least the Clyde Navigation Trustees do not believe it has.[1] At the present time this body is engaged upon the construction of a huge dock at Renfrew. Originally authorised in 1914, the undertaking was held up by the war but was resumed in 1924 when a contract for the construction of the quay walls of the first basin was placed. This is now nearing completion and will be capable of accommodating 9 large liners, the depth being 32 feet at low and 44 feet at high water. In 1929 the Trust was, by Act of Parliament, authorised to borrow a further £2,000,000 to defray the cost of operations at Shieldhall. The total borrowing powers of the Trust now amount to the enormous sum of £13,400,000. Although at the present time only one dock is under construction, ample room for expansion exists on this site, where more than forty years ago the Trust first acquired a piece of land and have since added to it as opportunity offered until now about 700 acres are available with a river frontage extending two miles. The whole scheme provides for six tidal basins and several graving docks which when completed will add six miles to the quayage of the Glasgow Harbour. The growth of Glasgow as a port is being anticipated and provision made that the city

1. In 1927 the revenue of the Trust exceeded £1,000,000

will not lack equipment for the realisation of this hope. Nor is an increase in the city's trade being left to chance. The secretary of the Clyde Trust recently made a tour in Australia to induce shippers there to send a larger proportion of their exports direct to Glasgow instead of to English ports, whence they have to be brought north by road, rail, or water. In May, 1930, the Trust set up a Trade Development Department with the express purpose of furthering Glasgow's trade, especially with the Dominions.

The war was scarcely over when the complaint, admitted on all hands today, that the world was overstocked with ships was heard. "The deficiency of British tonnage has been made good in a remarkably short period of time", wrote one correspondent,[1] "and there is not now employment for all the ships which are in existence." This may seem strange when we consider that Britain lost over seven and a half million gross tons of steam shipping and 121,000 gross tons of sailing ships as a direct consequence of hostilities and some 3,000,000 gross tons of steamships and nearly 200,000 gross tons of sailing vessels from other causes during the war period. Against this must be set off the prizes taken and the tonnage acquired by Britain in terms of Art.19. of the Treaty of Versailles (June 1919), whereby Germany had to surrender all her ships over 1,600 tons, half of those between 1,000 and 1,600 tons and a quarter of her steam trawlers and fishing boats. Under these two heads Britain acquired 411,475 gross tons in prizes and 426 vessels aggregating 1,878,165 gross tons as reparations. Our Allies received amongst them 1,326,111 gross tons of which 150 vessels of 584,741 tons constituted the Austro-Hungarian fleet surrendered. Britain did not enforce her claim for new vessels, allowed under par.5., Annex III

1. "Glasgow Herald Shipbuilding & Engineering Supplement" for 30th December 1920.

of the Treaty, but some of the Allies did. It will be noted that prizes and reparations ships by no means compensated for our war-time losses. The surrender of the German Navy, which was also enforced, has served mainly to provide work for salvage men and ship-breakers.[1] Nevertheless the fact was that at the end of 1920 the owners of many of the vessels under construction were putting off delivery and cancelling orders. Five years later it was estimated that there was an excess of 10,000,000 tons of shipping in the world considering cargo and passenger requirements at that time. "There is a limit", says a leader writer at the close of 1926,[2] "to the amount of new tonnage which the shipping world can absorb year after year, and when the producing capacity of the yards exceeds that limit there cannot be profitable employment for them all. At present the limit is exceeded by a very pronounced margin. There are more shipbuilding facilities than are ever likely to be required, and until they are reduced there can never be really good trade. Three large British concerns have already had to readjust their finances to the new conditions, and quite a number of smaller companies have gone out of business. The process will have to continue until a proper balance is obtained in supply and demand. When that stage is reached British shipbuilding will be once more economically sound, even if it never produces the high tonnage of recent years."

Between 1922 and 1927, the Shipbuilding Employers' Federation states, only one half of the available berths in the shipyards have been occupied. Matters have been somewhat better in 1928-29 but at no time have more than 55% of

1. For further facts refer to; "Report on Work of Reparation Commission, 1920-22". (1923); also; "History of the Peace Conference of Paris" (1920-24) ed. by H.W.V. Temperley.
2. "Glasgow Herald Shipbuilding & Engineering Supplement" for 30th December 1926.

the berths been in use. The estimate that to keep Clyde shipyards and marine engineering establishments fully employed would require an annual production of one and a quarter million gross tons and one and a half million I.H.P. has already been recorded.[1] This increase of 50% on the 1913 capacity of yards and shops is due to the extensions of plant made towards the end of the war and to the increased efficiency of the machinery now in use. The two years of highest output on the Clyde since 1919 have been the year following and 1928 with 672,438 gross tons and 604,611 gross tons respectively, barely 50% of actual capacity. To occupy fully the establishments of the United Kingdom would necessitate orders at the rate of 3,500,000 gross tons per annum with corresponding I.H.P. In 1920 launches amounted to 2,140,928 gross tons or 61% of the possible; but since then 1929 with 1,623,430 or 47% has been the year of highest output. Can the increase in orders for ships that would be necessary to occupy the yards reasonably be expected to mature in the not too distant future?

The additional efficiency of ships equipped with Diesel engines or high pressure turbines adds considerably to the increase in world trade which would be required to justify such an increase in output. Extended facilities at ports for loading and discharging cargo and the raising of the Plimsoll load line also added to the carrying capacity of vessels. Further it may be pointed out that the world's merchant fleet totals 68,000,000 gross tons as against a pre-war total of 49,000,000 gross tons and owing to the competition of this excessive tonnage, freights in October, 1929, averaged only 12% above pre-war whereas running costs were still 70% to 80% higher than in 1913. The enormous production of ships by neutral countries during the war can

1. See Appendix 8.

easily be understood when the extremely high values ruling between 1914 and 1918 are considered. The following table[1] shows the values in £ per gross ton used in the official calculation of British losses during the war. The figures were based upon the actual selling prices of Norwegian vessels in the same categories.

Year	Vessels under 12 knots	Vessels over 12 knots, and tankers	Sailing vessels
1914	£ 10.5	£ 12.1	£ 4.5
15	16.8	19.3	6.8
16	42.5	48.9	14.0
17	77.8	89.5	26.0
18	84.6	97.2	28.0
19	86.0	98.9	29.0

Rates for hire of vessels based upon the actual rates prevailing for neutral vessels were taken as follows:

1914	- 5/-	per	gross	ton	per	month.
15	- 12/6	"	"	"	"	"
16	- 31/6	"	"	"	"	"
17	- 58/-	"	"	"	"	"
18	- 63/-	"	"	"	"	"
1919	- 64/-	"	"	"	"	"

Lastly we must take account of the changed situation with respect to naval armaments. Statistics of the output of ships of war on the Clyde and in the United Kingdom have already been given.[2] Certain firms specialise in naval work; their yards are well equipped for it, their staffs are familiar with its special requirements, their craftsmen are capable of the accuracy essential to its execution and last, but not least, their boards of directors have mastered the art of obtaining Admiralty orders. It is true that only a few shipyards are capable of constructing large battleships and that they are not wholly dependent

1. Taken from "Shipping Problems, 1916-21" (1928), by W. Palin Elderton, C.B.E.
2. See pp. 251, 302.

on such work for employment. Nevertheless the limitations already imposed by the Washington Agreement have hit severely a number of well known Clyde firms, and the success of present and future efforts towards the reduction of armaments would reduce still further the amount of work available for them. It would be foolish to advocate extended naval programmes in order to provide work for shipyards;[1.] but the point must be considered in answering the question propounded above.

Having surveyed the situation, the somewhat depressing conclusion emerges that there is no hope of all British shipbuilding yards ever again being occupied to their full capacity. The same must of course be said of marine engineering establishments. A writer in the "Glasgow Herald Shipbuilding and Engineering Supplement" for 1928[2.] avers that British shipbuilders now realise this to be a fact. For the reasons given above the world's tonnage will increase more slowly than before; the average tonnage per ship is increasing annually and there is less work per ton in one large vessel than in several small vessels of the same total tonnage. A million and a half tons pre-war meant 500 vessels; today the same figure means only 350 vessels. Fewer warships (and it may be less expensive ones) will be required and it is probable that a greater proportion of those actually built in future will be constructed at the Royal Dockyards. Britain cannot hope to regain the percentage of the world's shipbuilding which she was fortunate to have throughout the second half of the nineteenth century; although if the conciliatory spirit betwixt employers and employees which has characterised

1. Sir J.C. Stamp in his "Current Problems of Finance and Government", has shown the economic folly of such a proceeding.
2. 29th December 1928.

the past few years continues[1] and if shipbuilders get up to date and keep so in their equipment and in the types of vessels they produce, she may hope to increase substantially her present percentage. Despite an increase both in wages and in the costs of raw materials during the past year foreign competition which a few years ago seemed extremely menacing is not being met successfully. Re-organisation or rationalisation, to use the more modern term, has been proceeding somewhat slowly in the industry but promises to be speeded up in the near future. The question of whether surplus productive capacity should be left to straighten itself out by the slow and painful but nevertheless certain process of the survival of the fittest, or whether an organised effort should be made to reduce this capacity,has been answered by the formation of a new company under the title of National Shipbuilders' Security Ltd.

This company was registered on 27th February, 1930, with the rather unique object of the "elimination of redundant capacity and the securing of more economical costs by the resultant concentration of production." Its nominal capital is registered at the modest sum of £10,000, but it has borrowing powers up to £3,000,000 for the "purchase and

1. A writer in the "Glasgow Herald Shipbuilding and Engineering Supplement" for 31st December, 1929, remarks upon the "... good timekeeping, the almost complete absence of local disputes, the apparently final departure from the pernicious ca' canny system, the improved plant and organisation of the shipyards and engineshop," as notable characteristics of the industry of the Clyde during the year.

selling of shipyards", etc.[1] Perhaps it is better that the extinction of certain yards and workshops, if this be deemed necessary, should be accomplished deliberately rather than haphazard as would be the case were the industry to be left to the operation of untrammelled economic forces. In the latter case the small and financially weaker undertakings would go to the wall. Now it happens that many of these small yards are eminently suitable for the type of work they do and it is to be hoped that a scientific process of rationalisation will recognise this fact and that they will be allowed to survive. Capability in production is not always allied to financial ability to withstand the ruinous effects of a prolonged trade depression. It would be too pessimistic to think that the present situation, unique in the annals of shipbuilding, will baffle the ingenuity or daunt the courage of Clyde shipbuilders and engineers. Crises have appeared in the past only to be met by adaptation and new devices which lifted the industry on a higher wave of production than had previously been its fortune to experience. Though many of the forces operating in these post-war days seem to be outwith the control of industrialists themselves and though it would be too optimistic to anticipate a similar consummation to

1. On 10th April (see daily press of following day) the Board of Directors of the Company was announced:

Sir James Lithgow, Bt.
Chairman.
Mr. A.L. Ayre.
Mr. John Barr, C.B.E.
Cmdr. Craven, R.N.
Mr. J.W. Kempster, D.L.
Sir Alex. M. Kennedy.
Mr. F.C. Pyman.
Mr. A. Murray Stephen.
Mr. T.E. Thirlaway.
Mr. R. Norman Thompson.

All are men well known as directors of shipbuilding and engineering firms in Britain.

the troublous times now being experienced, it may quite reasonably be expected that the Clyde, which was the cradle of the modern shipbuilding industry, will maintain a high and honourable place in the world of marine engineering and shipbuilding.

CHAPTER XIV.

SUMMARY AND CONCLUSION.

The beginnings of boat-building in the Clyde area date back to pre-historic times. The existence of deep beds of sand far from the present river channel and other geological considerations, suggest that the site on which Glasgow now stands was formerly part of an inland sea. Whether or not this be so, archaeological discoveries prove beyond the shadow of a doubt that the valley of the Clyde bore a more extensive sheet of water than it does today. Ancient canoes have been found far from the present river.[1.] Thus the very early inhabitants of the area may have had considerable experience in navigation and skill in constructing primitive boats. Such considerations however form too slender a basis to account for the origin and development of the modern industry with which this history is concerned and may safely be dismissed. Nautical activities on the part of the inhabitants of the shores of the Firth of Clyde in more recent times may also be discounted, being in no way exceptional or unusual for people so situated.

1. For further facts see; "The Scenery of Scotland" (1865) by Sir Archd. Geikie, F.R.S.

The circumstances to which the birth of the modern shipbuilding industry in the West of Scotland may be ascribed are rather to be found in the occupation of fishing commonly pursued by the dwellers in coastal towns of the Firth at least from the fifteenth century onwards and in the expansion of commerce which took place as a result of the Act of Union in 1707. The surrender of Scotland's independence met with much opposition at the time and is still a target for the recently formed National Party of Scotland; but it carried with it the right to trade directly with the American Colonies, a fertile field for commerce hitherto monopolised by English merchants. Very sonn an extensive business was being done between Glasgow and the West Indies, Virginia, Carolina, and other parts of the New World. Huge imports of tobacco, sugar, and rum, much of which was re-exported to Continental countries, were paid for by exports of manufactured articles of all kinds - linen fabrics, iron utensils, delftware, etc. Some fifty years before the Union the merchants of the city had deemed it advisable to have a port of their own and for this purpose chose a site twenty miles down the river, where in 1668 Port Glasgow was founded. But with the great expansion of trade during the eighteenth century it became obvious that the only satisfactory port would be the city itself. In a similar way the economy of possessing a fleet instead of hiring it from Whitehaven and other ports became apparent. The further saving and convenience of having the ships built locally whenever possible also made a strong appeal and a number of boatbuilders who were already experienced in the construction of herring "busses" and other small craft at various coast towns, commenced building small square-rigged ships for use in foreign trade. The first of these were launched at Greenock in 1764. When larger vessels came to be in demand, difficulty was experienced for a time in having these built locally. Lack of timber in the vicinity was a serious handicap, as was also inexperience in the design of large vessels. At this time, as a matter of fact, the River Forth was a more important boatbuilding area than the Clyde and in 1820, of the total tonnage on the Scottish register, one third had been constructed beyond the boundaries of Scotland.

But the continuity of the shipbuilding industry on the lower reaches of the river from these early times to the present is evidenced by the flourishing existence today of Scotts' Shipbuilding and Engineering Co. of Greenock, a firm whose origin dates back to 1711. All the deficiencies were remedied in time. The great expansion of foreign trade increased the demand for ships and it was found profitable to import large quantities of timber for shipbuilding purposes. Necessity showed herself to be the parent of enterprise and East and West Indiamen were successfully attempted. Many new firms commenced building at Greenock, Cartsdyke and Port Glasgow about the beginning of the nineteenth century. By the time that iron appeared as a superior alternative to wood for ships, solving simultaneously the problem of local supplies of raw material, Clyde shipyards were equipped and able to produce any required type of vessel. The River Clyde in its natural state did not provide a waterway for ships and the further problem of making Glasgow its own port could be met only by clearing, straightening, widening, and deepening the river. To this task the city authorities applied themselves with a determination which unfortunately was not equalled by the facilities available for the execution of the work. Progress was slow and the creation and development of river conveniences lagged behind the expanding commerce. Shipbuilding followed in the wake of these improvements and was not at any time handicapped owing to lack of width or depth of water for launching. Until about 1845, it should be said, the majority of the vessels built on the Clyde were launched at the ports bordering on the Firth.

Meanwhile, mainly as a result of the application of James Watt's genius to it, the steam engine was well on the way to becoming an efficient prime mover capable of application to almost all situations requiring a supply of power. These changes in design had no particular relationship to the West of Scotland, apart from Watt's personal associations; but they did revolutionise the textile industries and, through the medium of cotton manufacture, had a powerful influence upon the future development of the Clyde valley. The collapse of Glasgow's tobacco trade forced merchants to seek a substitute which they readily found in the production of cotton goods. The advent of cotton altered the whole character of the city's export trade. Most of the tobacco, sugar, and rum had been re-exported in its raw state; cotton had to be worked up and so home produced goods began to predominate in the export trade. The manufacture of cotton goods was largely responsible for the introduction of machinery into Glasgow and machinery created the need for workshops and workmen to make, erect, and repair it. The application of steam to drive textile and other machinery greatly extended the field of engineering. Thus it came about that when Watt's patents had expired and Henry Bell's painstaking experiments reached their consummation, Glasgow was already the centre of an area of considerable industrial activity capable of supplying from local resources the needs of the new type of shipbuilding. The trade in cotton had a further effect on shipbuilding: being bulkier than tobacco, cotton required larger vessels for economical transport and the long voyages involved exerted an influence in the same direction. The mineral resources of the area were exploited more intensively, supplies of iron ore and coal with which to smelt it being plentiful. The nineteenth century was not far advanced ere it became apparent that the iron industry was more indigenous to the West of Scotland than was the manufacture of cotton goods and would in time displace it.

The area was fortunate in having the services of a succession of brilliant inventors who applied their genius to the various branches of the iron industry, metallurgical and constructional. The discovery of blackband ironstone and the application of the hot blast ensured a cheap supply of this indispensable metal. For ship construction Clyde builders adopted iron to a much greater extent than was done in any other part of the United Kingdom, and Clyde engineers were indefatigable in their efforts to increase the efficiency of the marine steam plant. The high coal consumption which originally placed severe limitations on the effective range of the steamship was reduced and the low steam pressure which necessitated large engine cylinders was gradually increased. Boilers, engines, and auxiliaries were constantly undergoing changes each of which brought the plant nearer perfection. Many outstanding inventions (e.g. the haystack tubular boiler, the surface condenser, the compound, the triple, and finally the quadruple expansion marine engine) emanated from local workshops. Within thirty years of its introduction, the steamship was an effective rival to the sailing ship. The conquest of the Atlantic by steam established this mode of navigation, and the advent of the screw propeller a few years later was the determining factor in compelling the adoption of iron for the hulls of ships. Then it was that the faith of the pioneer shipbuilders of the Clyde was vindicated before the eyes of a sceptical world and reaped the reward of early enterprise. The Cunard Co., the first to establish a regular steamship service across the Atlantic, was sponsored by a Glasgow engineer and all their early vessels were constructed and engined on the Clyde. In 1871 there were in iron shipbuilding yards as many employees in Scotland as in the rest of the kingdom.

The sailing ship maintained a long but losing struggle. The first severe blow to its prestige was struck when the screw propeller superseded paddles and the second when the compound engine (a product of the Clyde) made a huge cut in the coal consumpt. Hope for a revival of sail, which had been stimulated by the success of the clipper ship of the sixties, expired when the opening of the Suez Canal eliminated the "Cape" from the route to the East. The triple expansion engine (another Clyde product) and the adoption of multiple screws drove the sailing ship from the seas. To the end certain Clyde firms specialised in sail and in this department maintained the same high standard of craftsmanship as the builders of the rival steamships on the river. When in the eighties mild steel, with its numerous advantages over iron, displaced the older material the West of Scotland was already equipped to provide the new material in large quantities. About the same time legislation caused particular attention to be paid to the safety of ships at sea and the development of world trade necessitated special types of vessels for specific cargoes. Shipbuilders in the Clyde area readily evolved designs to comply with all the conditions laid down. The need for specialisation in production began to manifest itself and from this time onwards the output of the various yards and shops ceased to exhibit the general undifferentiated characteristics hitherto the rule. The situation of the yard of course put a maximum limit on the size of vessels it was capable of building. But the specialisation went further than that; certain firms acquired plant and equipment for the construction of large passenger or naval vessels and gained experience in that type of work so valuable that when such ships were in demand they obtained the orders. Others specialised in tramp steamers or general cargo vessels, in oil tankers, in cold storage vessels, in dredgers, in torpedo boat destroyers, in fast pleasure and channel steamers, and so on. In a similar way marine engineering shops gained a reputation for particular types of engines; for high speed reciprocating engines, for marine auxiliaries, for steering gear, for propellers, for engines to drive electric dynamos, for turbines, and latterly for diesel engines. To all such changes whether in methods of production, of construction, or of propulsion,shipbuilders and engineers of the West of Scotland have shown themselves adaptable, moving with the times and often ahead of them.

Of the periodic fluctuations in output little need be repeated here. They followed the fluctuations of the general trade cycle but were more extreme than those of any other large industry. After 1860 they became more violent than formerly as the industry grew to its full stature, and the Clyde yards, responsible for over a third of the output of the United Kingdom, were seriously involved in the consequences. Being an instrumental industry shipbuilding and its associate industry, marine engineering, is susceptible to all the economic forces, at home and abroad, tending towards variations in the demand for final products, durable or consumable; to wars and famines, to the development of new countries, to the discovery of new supplies of the precious metals, to inventions, to financial crises, to speculation, and to the more frequent errors of optimism or pessimism on the part of entrepreneurs anticipating the future. The clearance of old vessels from the register - a proceeding characterised by a similar liability to fluctuations - provided a means of keeping the British fleet up to date, but much of the tonnage so removed was disposed of to foreign owners and so remained to swell the carrying capacity available in the world.[1.] Hence towards the end of the nineteenth century and subsequently, there was a big increase in the tonnage of vessels travelling in ballast.

Besides producing efficient ships and engines, the Clyde area bred a race of men with a special aptitude for the mechanical arts. The position occupied by the workers of the West of Scotland in the sphere of engineering corresponds to that held by the Lancashire textile operatives in the world of cotton - they can and do produce the best. In general wages rates on the Clyde were lower than in the south and wages costs were also less, but actual earnings frequently were substantially higher. Labour troubles have been plentiful in the Clyde valley, national disputes

1. A similar problem is met today in the motor car industry where the supply of second-hand vehicles is glutting the market.

not infrequently originating there. Apart altogether from wages, three matters have repeatedly been fruitful sources of violent disagreement between employers and employees: "excessive" overtime, the introduction of payment by results, and demarcation troubles between groups of workers. All three may be classed under the single title of "managerial functions". The first and third items mentioned were the cause of the first strike organised by the Amalgamated Society of Engineers soon after its inception. In 1897 and again in 1923 managerial functions was the storm centre. With particular emphasis on the local aspects of this tendency on the part of the workers to assert aggressively what they conceive to be their "rights", it may be remarked that such a state of affairs is rather to be anticipated when dealing with a body of efficient men. Despite the loud and frequent complaints by employers concerning this characteristic when strife is in progress, it is doubtful if at heart even they fail to appreciate that the determination which renders the workers so intractable during disputes, springs from the same source as the energy and pride which, in times of industrial peace, makes them one of the most reliable and hard-working communities to be found in the whole world.

In pre-war years (and of course in war time) naval vessels formed a substantial fraction of Clyde output, several yards being specially equipped for this type of work. Financially associated with one of these and conveniently situated in Glasgow was Parkhead Forge, which specialised in the production of armour plate and guns. The tremendous drop in naval requirements, amounting almost to a cessation of such work, in post-war times is one of the outstanding problems facing the industry locally. The extension of productive capacity during the war has left the more general problem, common to all shipbuilding areas of the United Kingdom, of berths that even the most buoyant optimism regarding trade prospects cannot visualise as required to satisfy the demand for ships. Since 1920 this problem has been clamant. Some old firms have gone out of business; many more have been absorbed by combines. An attempt to resolve the difficulty by the systematic elimination of redundant shops and yards has been set on foot. Only the future can take the measure of the success of the scheme. The few years immediately preceding the war witnessed the birth of many changes in methods of production and in ships and engines themselves. Diverted from its normal work for five years, the United Kingdom has not quite kept pace, quantitatively at any rate, with the technical advances made since 1914. In the matter of fuel there is keen rivalry between coal and oil; in prime movers the high-pressure geared turbine competes with the marine diesel engine.

The evolution of the marine engine presents an interesting study in the application of certain important principles of economics. Apart from those directed solely towards reliability and the satisfaction of technical requirements, (considerations which have economic aspects too) improvements have aimed primarily at obtaining the maximum output of energy per unit of fuel consumed and of supervisory labour applied. But improvements have invariably meant increased first costs, a rather unattractive proposition for shipowners and one which has been responsible for the tardy adoption of many new ideas. It also happened that, in some instances, the economy to be gained manifested itself only at high speeds and with high powers. When an increase in speed is contemplated a balance has to be struck between the cost of the additional power needed and the saving per voyage in victualling, wages, and depreciation. Beyond a certain figure, too low to be entertained for modern passenger ships, any increase in speed involves a disproportionate increase in engine power. As an instance consider the performances of two German built liners; the "Imperator" (now the "Berengaria") and the more recent "Bremen". The latter is slightly smaller but is speedier than the former. Neglecting this difference in size, an increase in speed[1] of 16% has necessitated an increase in power of 70%. Similar considerations, though to a less degree, apply to an increase in size;[2] against the economy of additional carrying capacity must be set the cost of the additional power to propel the larger vessel.

That progress in improvements will continue to be made there can be no doubt and it is satisfactory to note that British shipbuilders and owners are steadily recovering the leeway sacrificed during the war. In these times of trade depression it is particularly gratifying to the inhabitants of the West of Scotland to know that the Clyde is maintaining its pre-war percentage of world output and improving its position as a constituent shipbuilding area of the United Kingdom. The tenacity of a district to an industry once firmly established is a well recognised phenomenon of which many examples might be cited in Britain, but none would form a better illustration than the

1. From about 24 knots to 28½ knots.

2. The capacity of the wet and dry docks available and the depths of the river channels to be navigated, obviously limit the maximum practical size, a maximum closely approached by many of the modern ocean greyhounds.

shipbuilding and marine engineering industries of the Clyde valley. Handicapped in many respects at the beginning, it nevertheless had certain natural advantages which were exploited to the utmost, whilst simultaneously the hindrances were steadily overcome. Today both the advantages and the hindrances are relatively smaller compared with other parts of the country and of the world than they were a century ago. With the increase in population the world market is slowly expanding, but there are more sources of supply than formerly. There is also a growing endeavour on the part of all countries to provide their own needs of manufactured products, to protect their home markets, and to perform their own sea transport. Customers have become competitors and Britain no longer retains unchallenged her proud place as workshop of the world. A momentum not wholly divorced from human volition and its expression in effort and enterprise, still maintains the West of Scotland as the premier shipbuilding and marine area; but the position is precarious. It may be kept, but only by that form of safeguarding which is natural, permanent, and sure; a constant vigilance, a facility for adaptation to new conditions, a readiness to co-operate, and strenuous exertions on the part of all concerned.

APPENDIX 1.

ON THE EARLY TRADE OF GLASGOW.

The list given below is a selection of the chief items of Glasgow's trade for the year 1771.[1] It exhibits both the home manufactured exports and the re-export trade in tobacco and rum. Considerable import and export trade was done via London of which the following list takes no account:

Imports:	tons	cwt.	qr.	lb.
Tobacco	20,560	6	2	11
Sugar	2,367	17	3	26
Iron: bars	835	18	2	13
pigs	896	0	0	0
Cotton wool	26	9	3	11
Planks: oak	3	3	3	14
mahogany	386	10	0	0
Barrel staves	760	5	0	6
Rum	179,544½ gals.			
Linen: Irish	1,100,291 yds.			
Salt	39,922 bush.			
Timber: pine	9,867 cu. ft.			
elm	13,120 " "			
oak	27,539 " "			
birch	3,734 " "			
fir	21,419 " "			
Boards: pine	7,350 " "			
oak	8,372 " "			
Planks: walnut	1,000			
pine	11,260 " "			
mahogany	82,000 " "			
Wood hoops	53,764 pieces			

Exports:	tons	cwt.	qr.	lb.
Tobacco	19,594	2	1	9
Sugar	1,580	11	3	24
Iron: wrought & manufactured	641	7	1	20
ironmongery	7	5	3	8
cutlery	5	9	3	2
Rum	128,887 gals.			
Linen: British	2,175,431 yds.			
Irish	732,012 "			
chequered & striped	362,894 "			
Kenting	46,385 "			
printed	80,280½ "			
German	2,836 "			
Cambrics	7,506½ "			
Salt	2,205 bush.			
	tons	cwt.	qr.	lb.
Ware: cabinet	–	11	0	18
upholstery	4	0	3	29
copper & tin	40	1	0	22
Woollens	256	17	2	25
Haberdashery	265	2	0	7
Cordage	187	18	2	11
Soap	8	13	3	24
Snuff	8	14	1	7
Ware: delft & stone	64,077 pieces			
earthen	49,046 "			
Stones: brick	25,000 "			
slate	40,000 "			

1. The complete list is given in the "History of Glasgow" (1771) by John Gibson.

APPENDIX 2.

ON THE TRADE AND SHIPPING OF SCOTLAND IN THE EIGHTEENTH CENTURY.

Some references to Scottish trade during the second half of the eighteenth century have already been made in the text above. Table A.2. gives the yearly values in £ sterling of imports, exports, and re-exports and Graph A.2. exhibits and compares these. Till 1798 the values are "official values" in all cases and may therefore be compared without fear of significant error. From 1755 to 1775 exports exceeded imports; thereafter for six years they are practically equal; and finally from 1782 to 1798 imports are in excess of exports to almost the same extent, in the aggregate, as the latter exceeded the former during the previous period. There is the suggestion here of a cyclical movement but the period covered is not sufficiently long to justify any definite deductions. Whilst the American War undoubtedly caused a severe depression in trade it must not be forgotten that the falling off of exports began in 1771, three years before the outbreak of war and that during these three years imports were fairly well maintained. Thus the depression was not solely a feature of the compulsory interruption of trade by war. Graph A.2. shows plainly that the decline was due to a reduction of re-exports. Tobacco imports and exports declined to a small extent; the remarkable drop was in the trade in rum. In 1770 Scotland imported 844,428 gallons and exported 780,284 gallons; in 1771 the respective figures were 826,741 gallons and 764,558 gallons. During 1772 however only 193,239 gallons were imported and 98,207 gallons exported.[1] The next year a further reduction was recorded. No doubt part of this drop/

1. Public Record Office MSS. ($T^{36}/13$).

was due to an Act,[1] designed to suppress smuggling which laid it down that no rum, sugar, coffee, etc. should be "entered out" of Ireland for shipment to Great Britain after 5th July, 1772, and none should be imported into Ireland in vessels of less than 70 tons burthen. At any rate the drop of £34,000 in Scottish imports from Ireland[2] in 1772 forms part of the £196,000 representing the total fall in Scottish imports that year.

After the cessation of war in 1783, Scottish exports climbed slowly upward only to relapse again from 1791 to 1796, the first phase of the Napoleonic Wars. Thereafter an unprecedented expansion took place and the century closed with imports and exports vastly in excess of any figures hitherto recorded. It may be noted that, in the fortyfive years' record submitted, a maximum occurs on the average every tenth year, though each succeeding maximum is not always higher than the previous one. Prior to the outbreak of the American War, re-exports constituted by far the larger portion of the total exports. Subsequent to 1776 the position was reversed and home produced goods took the leading place. This represents the rise of the Scottish cotton industry. Tonnage on the Scottish register shows an approximate correspondence with trade fluctuations. A phenomenal increase in tonnage was recorded in the period 1784-7. This was in the main due to an increase in the number of vessels engaged in foreign trade; but, as the tonnage engaged in coastal trade and in fishing also showed a substantial increase, it cannot be ascribed to a mere transference of vessels from one type of service to another. Nor must it be assumed to represent a great expansion in

1. 12. Geo.III. c.55.

2. "Annals of Commerce", Vol.III. (1805) by David Macpherson.

shipbuilding though some extension of this no doubt did take place consequent upon the declaration of peace with America, France, Spain, and Holland. It must be attributed mainly to the acquisition of prize vessels during the war. This feature may be noticed after every war and figures showing tonnage added to the register must be studied with that in view. Similar upward movements may be noted in 1763 and in 1797.[1] Conversely a downward trend in tonnage marks the beginning of wars owing to vessels being commandeered for service,

Table A.4. enables us to compare the growth in importance of Scottish ports over the sixty years 1760-1820. This may be summarised as follows:

Order	1760	1780	1800	1820
First	Greenock	Greenock	Greenock	Aberdeen
Second	Leith Port Glasgow	Bo'ness Leith	Aberdeen	Greenock
Third	Irvine Bo'ness	Port Glasgow	Leith	Leith

The absolute increase in each case is quite remarkable, especially from 1800 to 1820 when tonnage belonging to Aberdeen multiplied two and a half times and that belonging to Leith doubled. The supersession of the West Coast ports by those of the East was only a temporary phenomenon marking the damage to the trade of Glasgow and Greenock resulting from the long series of wars.

Table A.5. classifies the tonnage belonging to Scottish ports in 1800. In foreign trade, as in Total tonnage, Greenock is an easy first. Though Aberdeen takes second place for total tonnage, this is swollen by coastal vessels and thus for foreign trade Port Glasgow is a rather poor second to her sister port. Strangely enough

1. Table B.1. shows the prize ships on the British register for the period 1801-12.

Kirkcaldy is third in foreign trade and Leith a close fourth.

APPENDIX 3.

ON THE INTERPRETATION OF OFFICIAL TRADE STATISTICS.[1]

The first attempt to collect official statistics of the commerce of England and Wales was made in 1697 when the office of Inspector-General of Imports and Exports was established. A similar officer for Scotland was appointed in 1755 and statistics of imports and exports for our country begin that year. A connected account of the shipping of Scotland begins four years later. Up to 1786, when a new Act of Parliament came into force, the records show registered tonnage, actual tonnage being about one third more.

In 1870 the Statistical Department of the Board of Trade, recommended as early as 1857, was established. It collected figures for the United Kingdom and, from then onwards, with few exceptions, the data of any one year are comparable with those for any other year. Prior to 1870 much of the statistical material cannot be regarded as exact.

From 1694 to 1854 import figures are "official" values and were determined in the following manner. The prices of all known articles in 1694 were taken and multiplied by the respective quantities imported each year thereafter. The prices of new articles were taken for the year in which they were introduced and the total estimated in a similar manner. Thus, as the quantity of each article imported varied from year to year, the total values of imports for different years

1. Information on which this Appendix is based was derived from;
"An Estimate of the Comparative Strength of Great Britain; and of the Losses of her Trade from every war since the Revolution." (1804) by George Chalmers, F.R.S. and from;
the paper on "The Official Trade and Navigation Statistics" by Stephen Bourne; Royal Statistical Society's Journal, Vol.35. (1872).

cannot be compared, more especially if a considerable interval has intervened. The figures do however have some significance as quantities of goods and, when trade is being considered in general, not in detail, they furnish quite a useful index to the trend of trade over a given period. Exports were treated similarly till 1798 when "declared" values took the place of "official" values, a method of estimation continued ever since. In 1854 imports were given a "computed" value; that is, a more or less arbitrary value was assigned to each article and the total value calculated. For this in 1871 "declared" values were substituted, thus at long last rendering possible accurate comparisons between different years and between import and export values.

APPENDIX 4.

ON THE MEASUREMENT OF THE CAPACITY OF SHIPS.

The term tonnage seems to have originated in the old wine measure, the tun. This comprised 4 hogsheads or 252 gallons. When wine ceased to be an important item of cargo the term was changed in spelling and became ton. The meaning also underwent a change; from being a measure of capacity it became more commonly a measure of weight. But in respect to shipping it still retained significance as a measure of a ship's capacity to carry cargo whilst also acquiring something of the new meaning relating to weight - hence the confusion which in turn brought the necessity for the complicated but nevertheless definite legal unit which prevails today.

The earliest English law on the subject was that of 1422, which applied only to "keels" carrying coal at Newcastle-on-Tyne. The measure specified was the chaldron, equal to 36 bushels. The bushel was a dry measure equivalent to 8 gallons. Twopence per chaldron of coal transported had to be paid as the king's dues. In 1679 this law was extended for revenue purposes to boats plying from the River Wear. In 1694 the dead weight of the vessel was substituted for the chaldron measure and the formula prescribed for the calculation of this was:

$$\text{dead weight (d.w.)} = \frac{\text{length} \times \text{breadth} \times \text{depth of hold}}{94} \text{ tons}$$

the linear measurements being in feet. The factor "94" was adopted quite arbitrarily to reduce cubic capacity to a measure of weight. The attempt to measure the cubic capacity of a vessel, though crude, is obvious in this formula which constitutes the first English tonnage rule. The Act of Parliament establishing it was repealed only two years later. A further Act 1720 defined the tonnage of a ship to be; length x breadth x $\frac{breadth}{2}$, measurements as before being taken in feet. In 1773 a much more important rule was given legal sanction and two years later its application was extended to embrace all vessels loading coal. It became the accepted standard for all vessels and was known as the "Builders' Old Measurement" (B.O.M.) rule. The formula was:

$$\text{tonnage} = \frac{(\text{length} - {}^{3}/_{5}\ \text{breadth}) \times \text{breadth} \times \frac{\text{breadth}}{2}}{94}$$

The length was measured "between the perpendiculars", (b.p. for short) that is to say between perpendicular lines dropped from the apex of the main stern post and from the bow; the breadth was taken to the extreme outside of the planking. The "$^{3}/_{5}$ b" which is subtracted was the allowance for the rake (that is the departure from the vertical) of stem and stern posts. As this rule was independent of the depth of the vessel, shipowners demanded narrow, deep ships so that the registered tonnage figure would be low whilst the actual carrying capacity would be undiminished. Now, narrow deep ships are unstable[1.] and it was found necessary to design a better formula. This was done in 1835; but many builders retained for popular usage the B.O.M. rule. Even in the British Navy that rule was not finally discarded until 1872. Most of the early records fail to specify the rule used in calculating the tonnage figures given; hence tonnage data are not always comparable nor is there any means of making them so.

The 1835 Act restored the depth factor in the formula and measurements were to be taken at specified intervals along the centre line of the ship; but these positions were

1. Lloyd's at this time was recording an average loss of 6 ships every 4 days.

few in number and this invited the wholesale evasions which, in fact, took place. The divisor was altered to 92.4. Finally in the Act of 1854 a fairly satisfactory system from all points of view - known as the Moorson system of measurement - was evolved. The formula of 1835 was retained but measurements were to be taken at much more frequent intervals along the length and allowances for engine room, seamen's quarters, etc., were made. Complaints and objections from interested parties were not lacking, but it is doubtful if a perfect rule, acceptable to all, could ever be devised. Other Acts of Parliament followed in 1860 and in 1889; a consolidating Act in 1894; and further provisions in 1906. The Act of 1854 is, however, fundamental to all subsequent legislation; further, it was adopted by all the important shipbuilding countries of the world.[1.]

The term "tonnage", as now used, has several different meanings according to the adjective preceding it. This adjective is often omitted and, when this is so, the assumption is that "registered tonnage" is meant; but assurance must always be lacking that the assumption is correct and thus no little confusion is caused when comparisons of figures are attempted. In the text and

1. This international acceptance of the main provisions of the Act of 1854 took place as follows:

U.S.A.	1864	Netherlands	1876
Denmark	1867	Norway	1876
Austria Hungary	1871	Finland	1877
Germany	1873	Greece	1878
France	1873	Russia	1879
Italy	1873	Haiti	1882
Spain	1874	Belgium	1884
Sweden	1875	Japan	1884

tables herewith the adjective is given wherever possible; if omitted this is due to its omission at the source. Of all the terms the most easily understood is "displacement tonnage". This is the actual weight of water displaced by the vessel at its designed draught and can be found by measuring the external volume of the ship and dividing by 35[1] the number so obtained. The weight of water displaced is, of course, the same as the weight of the ship displacing it. This mode of statement has now been adopted universally for naval vessels. Clearly it is the only reasonable standard for this type of vessel which carries neither passengers nor cargo. Where total production is exhibited in the tables relating to modern times the displacement tonnage of naval vessels has been added to the gross tonnage of merchant ships. This is quite justifiable because the work involved in building a battleship and the cost of same is several times greater than is required for a merchant ship of the same linear dimensions. Now displacement tonnage is approximately three times the net register tonnage or twice the gross tonnage; thus no great error is involved in adding displacement and gross tonnages when the aim is to represent the output of shipyards over a period of time.

Another measure, less commonly used today than formerly, is "lightweight tonnage" (l.w.). This is the weight (or displacement) of the ship fully equipped and with steam up but without cargo or consumable stores. Allied to this is the measure referred to as "deadweight tonnage" (d.w.). This is the weight of cargo, stores, and passengers which may be carried without submerging the draught or Plimsoll line. Hence:

displacement tonnage = l.w. + d.w.

[1] 35 cu.ft. of sea water weighs 1 ton.

The modern measure is really one of volumetric capacity, not of weight. The required volumes are obtained by calculating the cross sectional area of the ship at intervals along the centre line; the application of Simpson's Rule gives us the required volume. It is then assumed that this space is filled with cargo having a uniform density of 1 ton per 100 cu.ft. Thus we arrive at the "gross tonnage." The space assumed to be occupied by cargo comprises all enclosed spaces, viz. holds, engine room, seamen's quarters, etc. Spaces "open to the sea" (e.g. 'tween decks) are not included. If from the gross volume the spaces essential to propulsion, navigation, and the like (but not seamen's [1.] or passengers' quarters) are subtracted and the result divided by 100, the result obtained is the "net register tonnage" (or simply the "net tonnage"). This figure is chiselled on the main beam of the vessel, as is also the serial number which the ship bears on the official register of British ships.

It will be seen that no definite relationship exists between measures of tonnage and therefore statistics are frequently incomparable. Gross tonnage - the measure usually quoted now-a-days in connection with shipbuilding - represents most accurately the size of the ship and the work involved in its construction, but it is unsafe on this basis to make comparisons between individual vessels if they are of different types. Here we are dealing in the main with aggregates where such differences will cancel out. Net tonnage, on the other hand, is the best measure of carrying capacity and this therefore is the figure most commonly

1. Hence the tendency to make their quarters as small as possible, and to allot for this purpose those parts of the ship least useful for other purposes. The minimum space allowable per man is now fixed by statute.

given in shipping journals and in Board of Trade returns. Harbour and canal dues are based on the net tonnage figure, but it must be emphasised that comparisons between individual ships as to linear dimensions, carrying capacity, and earning powers on the basis of a net tonnage figure may be quite erroneous if the ships are of different types.[1] Aggregates of gross and of net tonnage may of course be compared when, as is often the case, only maxima and minima are in question.

If the aggregates of a large number of vessels be compared the following approximate relationships emerge;

$$\frac{\text{gross tonnage}}{\text{net tonnage}} = \frac{8}{5} \quad [2]$$

$$\text{d.w.} = 2 \times \text{net tonnage} \quad [3]$$

$$\text{d.w.} = 2 \text{ to } 2.5 \times \text{l.w.} \quad [3]$$

hence;

$$\text{displacement tonnage} = \frac{15}{8} \text{ (say 2) gross tonnage.}$$

Mitchell gives the following relationships for two types of steamer;[4]

typical coaster; d.w. = $2\frac{1}{2}$ to $2\frac{3}{4}$ x net tonnage

shelter-deck tramp; d.w. = $2\frac{1}{2}$ to 3 x net tonnage

These formulae apply only to steel ships. For wooden hulls; d.w. = l.w.

Even vessels of the same type may differ considerably according to the design followed. Holmes compares three shelter-deck steamers;[5]

1. The standard cargo density of 1 ton per 100 cu. ft. is quite an arbitrary figure. A few actual densities may be cited;
   1 ton of cotton (compressed bales) occupies 120-130 cu.ft.
   1 ton of tobacco, 70-230 cu.ft.
   1 ton or iron ore (bulk), 12-17 cu. ft.
2. "British Merchant Shipping" (1922) by Clement Jones, C.B.
3. "Encyclopaedia Britannica" (11th edn.) article on "Shipping."
4. "Shipbuilding and the Shipbuilding Industry" (1926) by J. Mitbhell.
5. "Ancient and Modern Ships" (1906), Vol.II. Appendix II. by Sir G.C.V. Holmes.

Ship	Gross tons	Net tons	Gross tons / Net tons
A	949	493	1.924
B	951	401	2.371
C	952	371	2.566

The vessels cited are too small in size to be called typical and, only in a very few cases, would so great a difference be found in vessels say ten times the gross tonnage of those given. Several special types (e.g. turret and shelter-deck ships) were designed to give a large d.w. tonnage with moderate register tonnage. Controversy still exists as to whether or not fairness among different types of vessels is achieved by the prevailing measurement rules, but doubtless dissatisfaction would be voiced concerning any scheme of measurement that might be framed and devices conceived to circumvent its purpose.

APPENDIX 5.

ON THE MEASUREMENT OF THE POWER OF ENGINES.

Since the earliest use to which the steam engine was put concerned raising water, it was natural that the performance of the engine should have been expressed in terms of the quantity of water raised to a stated height relative to the fuel consumed in the operation. Hence the early formula measuring the "duty" of an engine;

$$\text{duty} = \frac{\text{weight lifted x vertical height of lift}}{\text{bushels of coal consumed}}$$

the weight being in lb., the lift in ft., and the bushel equal to 94 lbs. In Savery's time the bushel had been taken as 84 lbs. but Watt made the change to 94 lbs. and the latter figure continued in use till 1856. The idea of equivalence to work done by a horse had been mooted by Savery and was later resuscitated by Smeaton. In 1782 we find James Watt calculating in terms of work done by horses. There is no evidence that he performed any experiments; but he took 180 lbs. as the pull of a horse[1.] and in August, 1782, was using the figure 32,400 ft. lb. per min. as one H.P. In September of the following year, without explanation, the value 33,000 ft. lb. per minute was adopted and, within a few years thereafter, engine power came to be measured commonly in H.P. In the "Edinburgh Review" for August, 1809, the definition of a "horse power" appeared in print for the first time and it was there alleged[2.] that as a result of experiments on brewery horses, conducted in London, Boulton and Watt had fixed the figure 33,000.

1. Desaguliers in his book "A Course of Experimental Philosophy" (1763) adopted the figure 200 lbs. for this.

2. It may be emphasized that no evidence for this is to be found in Watt's manuscript.

Till 1820 or thereabouts the power of engines was calculated according to the formula;

$$\text{Nominal horse power (N.H.P.)} = \frac{\text{Area of piston} \times \text{effective pressure} \times \text{piston speed}}{33{,}000}$$

where the area of the piston was taken in square inches, the effective pressure assumed to be 7 lbs. per sq. in.,[1] and the piston speed estimated by an arbitrary rule[2] issued by the Admiralty. The formula which holds today subsequently came into use;

$$\text{indicated horse power (I.H.P.)} = \frac{p.\ l.\ a.\ n.}{33{,}000}$$

where "p" is the mean effective pressure in lb. per sq. in. derived from a study of indicator cards taken from the particular engine, "l" the length of the stroke in ft., "a" the piston area in sq. in., and "n" the number of strokes executed per minute by the engine. On the up-stroke the area of the piston exposed to steam is diminished by the area of the piston rod. Thus the work done on the upstroke is slightly less than that performed on the downstroke, but this difference is usually neglected. The idea of "duty" was maintained for pumping engines for many years after the I.H.P. formula had become well established.

For Newcomen and other early engines N.H.P. ≒ I.H.P., but as engines developed the empirical figures taken for effective pressure and for piston speed ceased to represent

1. In Watt's own account of the H.P. unit - penned in 1814 - the figure given is 7 lbs. per sq. in. but sometimes 7½ lbs. was assumed.

2. Part of this may be quoted from "Shipbuilding in Iron and Wood and Steamships" (1863); by Andrew and Robert Murray.

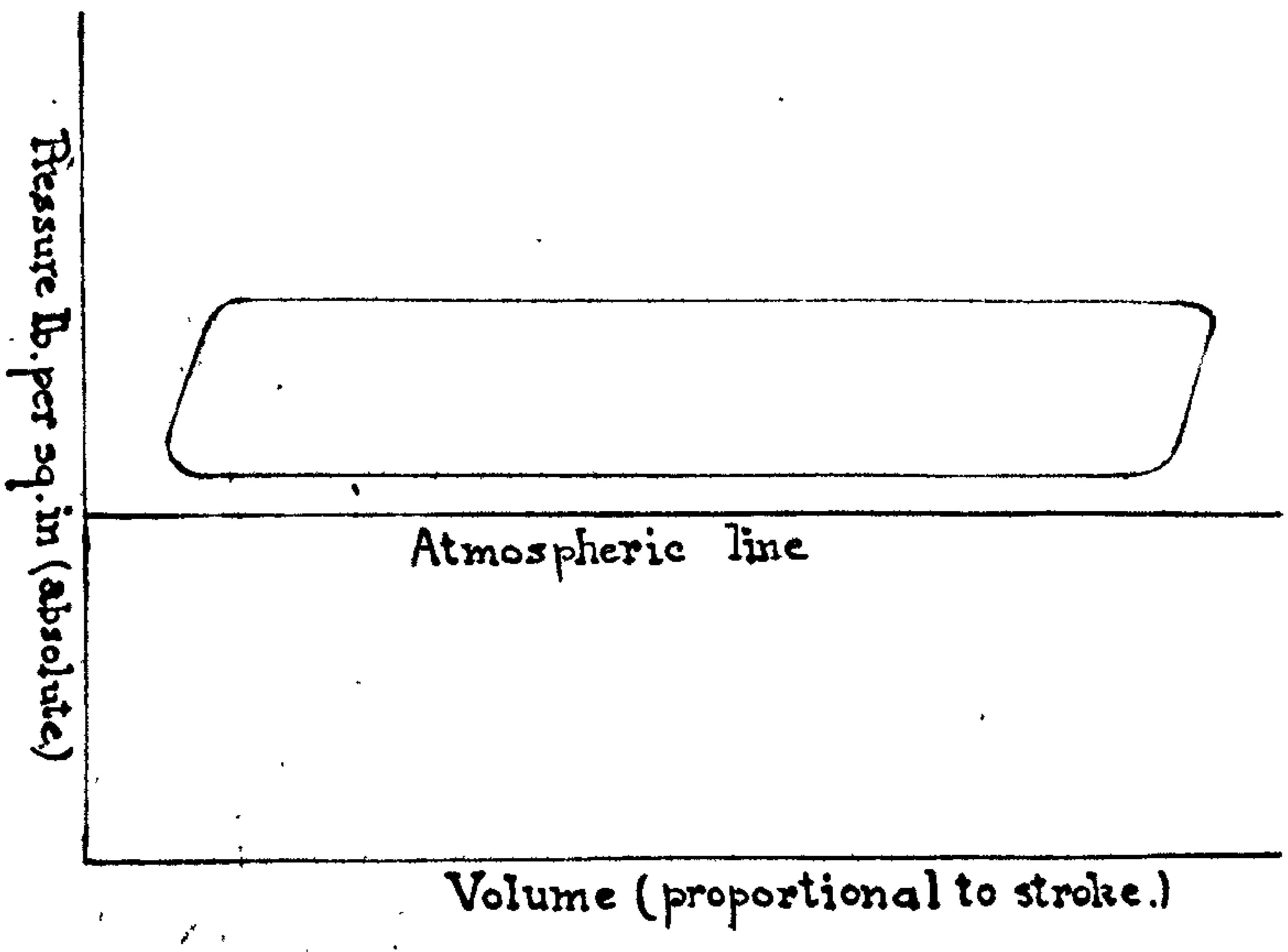
Length of stroke in ft.	Piston spped in ft. per minute.
3	180
4	196
5	210
6	221
7	231
8	240
9	248

even approximately actual pressures and speeds, until by 1850 N.H.P. was anything between two and four times the I.H.P. During the discussion following a paper read by Commander Leopold G. Heath, R.N. before the Institute of Civil Engineers in 1851 it was suggested that the usual I.H.P. formula multiplied by the coefficient $\frac{3}{4}$ to allow for friction, would give a suitable measure of N.H.P.. The "Third Report of the Commission on the Trade Depression (1886) quotes the following as the rule prevailing at that time;

$$N.H.P = \frac{D^2 + \sqrt[5]{S}}{100},$$

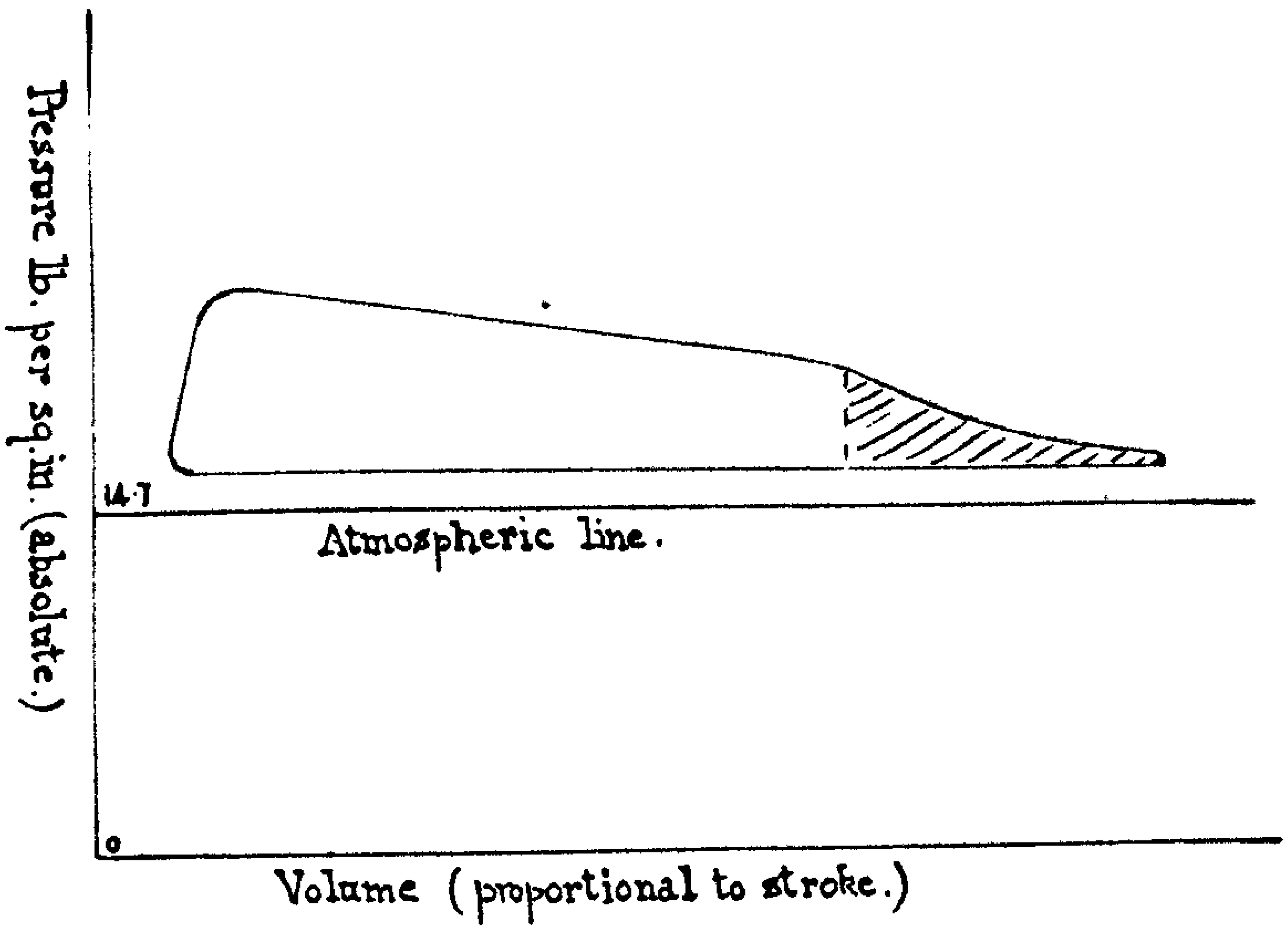
where D is the diameter of the cylinder in inches, and S the length of the stroke in inches. The plain I.H.P. formula, however, progressively gained favour and finally replaced all others as the standard measure of the power of engines.

Sketches of indicator diagrams such as might be obtained from non-expansive and expansive engines[1] are given below, the admission pressure being the same in each case.



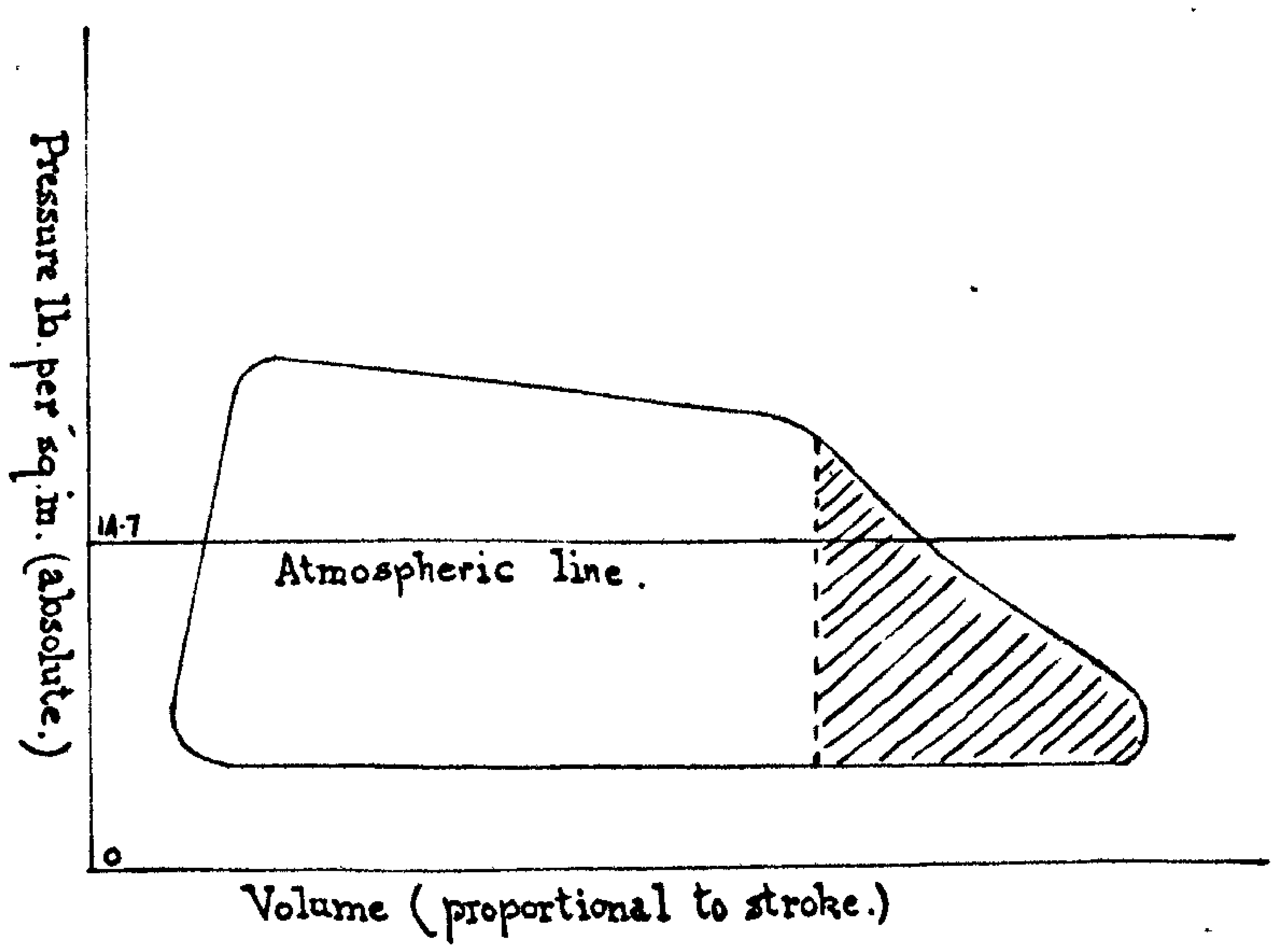
1. Card from a non-condensing, non-expansive engine.

1. See p. 82 above.



2. Card from a non-condensing, expansive engine; cut off at 0.67 of stroke. The shaded portion shows the work obtained "for nothing".

The actual work done per stroke is less in the second case than in the first, but the quantity of steam used is also less and thus the work done per lb. of steam used is greater. The third sketch below is one that might be obtained from a condensing expansive engine having the same admission pressure as before, but exhausting at a pressure 10 lbs. per sq. in. below atmospheric (i.e. a condenser vacuum of about 5 lbs. per sq. in.)



3. Card from a condensing expansive engine; cut off at 0.67 of stroke. Note the large increase in work obtained by condensation.

Brake horse power (B.H.P.) is the power actually delivered by the engine in contrast to I.H.P. which represents the power developed in the cylinder. It is measured by an instrument called a dynamometer. Friction horse power (F.H.P.) is the horse power absorbed by friction of the moving parts of the engine.

$$I.H.P. - F.H.P. = B.H.P.$$

Shaft horse power (S.H.P.) is the term applied to rotary prime movers (e.g. turbines). It is equivalent to B.H.P. in reciprocating engines and is measured by the torsion meter. Steam pressures, it may be added, are invariably quoted in lb. per sq. in. They may be given as "above atmospheric" (i.e. above 15 lbs. per sq. in.) or "absolute" (i.e. above zero). In the latter case the abbreviation "(abs.)" is usually affixed to the statement - e.g. 45 lbs. per sq. in. would be equivalent to 60 lbs. per sq. in. (abs.).

Lloyd's still retain the designation "Nominal Horse Power" in the measurement of engines. Their formulae for various types are as follow:

Reciprocating engines:

(a) where the steam pressure does not exceed 160 lbs. per sq. in. (abs.):

$$N.H.P. = \frac{P+340}{100}\left(\frac{D^2\sqrt{S}}{100} + \frac{H}{15}\right)$$

(b) where the steam pressure exceeds 160 lbs. per sq. in. (abs.):

$$N.H.P. = \frac{P+590}{150}\left(\frac{D^2\sqrt{S}}{100} + \frac{H}{15}\right)$$

where D = L.P. cylinder dia. in ins.
S = Stroke in ins.
H = heating surface of boiler in sq. ft.
P - working pressure in lbs. per sq. in.

For steam turbines:

substitute $\frac{S.H.P.}{6}$ for $\frac{D^2\sqrt{S}}{100}$ in above formulae.

If forced draught is in use or induced draught substitute $\frac{H}{12}$ for $\frac{H}{15}$.

Diesel engines;

$$N.H.P. = \frac{C \times N \times D^2}{\frac{S}{D} + 50}$$

where N = number of cylinders
D = cylr. dia. in ins.
S = stroke in ins.
C is a number having values between 5 and 18 according to type.

APPENDIX 6.

ON ADDITIONS TO AND REMOVALS FROM THE UNITED KINGDOM REGISTER.

In our study of fluctuations we have been concerned with output rather than with the accumulation of tonnage on the register. Yet on this figure - tonnage on the register - as related to the volume of sea transport to be done, will depend to a great extent the number and size of new vessels ordered.[1] That it will show a continual increase is to be expected, since population and the demand for goods from foreign countries were both increasing. Rarely did the tonnage on the register show a definite decrease and upon such occasions as it did, this was entirely due to removals of sailing ships. Trade depressions are represented by a temporary interruption of the increase or by a diminution in its rate. An example of the former is to be seen[2] in the year 1884 when the figure remained stationary for the two following years; an example of the latter in the period 1907-10. Even in times of expansion of trade the register total was not increased by anything like the amount of tonnage launched during the year; firstly, because about 1/5th of the tonnage built in the United Kingdom was for registry under foreign flags,[3] and secondly, because large numbers of vessels were removed each year from the register by wrecking, scrapping, and sale abroad. A series of figures,[4] complete from 1880 to 1913, showing gross tonnage

1. There are other important factors of course; shipbuilding costs, types of vessels in use, etc.

2. Graph C.2.

3. From 1900-09 inclusive tonnage built for foreigners averaged 188,000 net tons per annum out of an average annual output of 900,000 net tons in the United Kingdom.

4. Compiled from the statistical section of Lloyd's Register of Shipping.

added to and removed from the register each year, subdivided under the headings steam and sail and also under steel, iron, and wood and composite, are given in Tables E.1, 2, 3, & 4. The figures for net additions are never negative although the table showing net tonnage on the register[1] on several occasions shows a drop. This arises because the "added and removed" tables show gross tons whilst the "tonnage on the register" table shows net tons.[2] Additions by purchase from abroad were so small as to be of no practical account. Only in 1898, the year of prolonged stoppage in British shipyards, did they constitute 10% of the total additions.

Throughout the whole period surveyed the tonnage of wood and composite vessels added to the register was negligible. After 1883 removals of wooden tonnage diminished, the big bulk of timber hulled vessels having been eliminated previously. Sales of this type abroad were also negligible; for steam power implies an iron or steel hull. Wrecking and scrapping accounted for the disappearance of the majority of these ancient hulks. Thus the figures for net additions of wooden ships are negative throughout. The change over from iron to steel can easily be seen in these tables. After 1883 removals of iron tonnage increased whilst those of steel were too small to be of any account for many years. Only after 1895 did this figure rise even to moderate dimensions, steel vessels being comparatively new. Subsequent to 1885 net additions of iron tonnage may be neglected but every "inch of ground" - if the

1. Table C.2.
2. In Appendix 4. this matter was dealt with in detail and it was there shown that no constant relationship between the two measures of tonnage exists. Net tonnage forms the better index of carrying capacity - tonnage entered and cleared is given in net tons - gross tonnage is a better index of the labour employed and materials used in shipbuilding.

metaphor be allowed in this connection - lost by iron was more than covered by steel, and thereafter steel tonnage dominated the situation. This may be observed in the close correlation existing between the curves showing net additions of steel tonnage and net total tonnage added to the register. During the great depression of 1886-7 net additions of a paltry 3,062 tons and 3,690 tons respectively took place.

Prior to 1894, wrecking and breaking up or scrapping accounted for the majority of vessels removed from the register; subsequently selling abroad and to our Colonies became the more important factor. As Britain was the only nation in the world which, until the last decade of the nineteenth century, did a large carrying trade, the foreign sales market was correspondingly limited. Unfortunately the statistics with which we are dealing do not separate tonnage removed by wrecking from that destroyed by breaking up. Over a long period the former quantity will tend to be a constant percentage of the total tonnage on the register, the actual amount increasing somewhat but the percentage figure remaining the same or diminishing slightly as a result of the greater safety at sea. For the period 1902-13 Lloyd's give a statistical account of the steam and motor ships of over 100 gross tons which came to grief by wrecking. Only two years show departures from the average; 1902 was exceptionally low and 1912 exceptionally high. The average loss[1] per annum from this cause works out at 173,000 gross tons. Accepting this figure the average tonnage scrapped per annum over this period works out at 94,000 gross tons. A rather remarkable feature, but one which is susceptible of easy explanation, is the

1. This is the same whether or not the exceptional years be included as these cancel each other.

fact that the tonnage broken up towards the end of depressions was greater than during the subsequent booms. The reason is that old vessels were cleared off in preparation for the new additions. After 1894 sales abroad accounted for the majority of the "removals". The actual figures for these appear, at first sight, to be staggeringly large; for example in 1898 well over half a million tons were disposed of by this means. In general sales preceded launches. It might therefore be hastily concluded that increased production took place as a direct result of such sales, but it must be kept in mind that orders for vessels are given upwards of twelve months before the vessels actually come on the register. The explanation would seem to be that, having come to the decision to bring their fleets up to date, shipowners proceeded to find a market for the older vessels. The sales were a result rather than a cause of the decision to build.

Turning now to consider the division into steam and sail, it will be observed that the totals of added, removed, and net additions must be identical with those for steel, iron, and wood. On two occasions only during the period under review did sail exert a determining influence on the total tonnage launched during the year; in 1885 and again in 1891-2. Prior to 1886 sail tonnage removed exceeds steam tonnage removed, the former averaging 200,000 and the latter 150,000 gross tons per annum. For six years thereafter the respective figures were equal at an average of 200,000 tons of each type, but from 1890 onwards steam rose rapidly whilst sail diminished spasmodically. Up to 1895 the sail tonnage launched averaged 150,000 gross tons per annum but it was being removed at a greater rate, so that only in the three years mentioned above was there any net addition of sail to the register and this was so small as to be negligible. After 1895 the sail tonnage launched per annum averaged 50,000 gross tons and removals 175,000 gross tons; subsequent to this net additions were therefore negative and steam tonnage completely dominated the "additions" figures, but sail remained an important factor in removals. Removals of sail followed the same course as those of steam and so do not affect the general trend of the "removals" curve.

Examining next the causes of removals we observe that, in respect to steam tonnage, sale abroad accounted for two thirds to three quarters of the amount disposed of after 1894, in which year just under 50% of the removals were so caused. For considerable periods equal importance attaches to sale and to wrecking and breaking up as causes of removals of sail. From 1886-96 breaking up and wrecking exceeds sales abroad, though for the three years 1888-90 the latter almost equals the former. For the four years following 1896, sale abroad is greater; then from 1901-8 both factors exercise equal weight. Finally from 1909-13 sale abroad vastly exceeds the total of wrecked and broken up. In 1910 the tonnage sold abroad amounted to three times the combined total of wrecked and broken up.

The height to which sales figures mount in 1911-13 is amazing. In these three years nearly two and a half million gross tons were sold. That such an extensive market for second hand vessels should have existed may come as a surprise to those unfamiliar with the shipping industry. An examination of the returns for the period 1891-1913 reveals the fact that the largest buyer was Norway, with Italy a close second. Germany, our keenest competitor in shipbuilding at that time, came third on the list of purchasers; then followed Japan, Greece, and France. These six nations accounted for 55% of the total tonnage sold by British owners during the twentythree years under review. Of the steam tonnage sold they purchased just over 50% and of the sail tonnage 72%. The table below exhibits the actual totals purchased:

Country	Total tonnage	Steam tonnage	Sail tonnage
Norway	1,391,747	695,013	696,734
Italy	1,342,836	1,113,698	229,138
Germany	969,519	650,509	319,010
Japan	725,653	725,653	—
Greece	670,644	669,355	1,289
France	667,166	577,055	90,111

All six countries shared largely in the extensive sales of 1911-13. Italy, Japan, Greece, and France, though not themselves shipbuilding nations, aimed at sharing in the shipping business of the world. They therefore purchased a much greater quantity of steam tonnage than of sail.

This annual selling of hundreds of thousands of tons of shipping indicates the determination of British owners to keep their fleets up to date. At the same time, the fact that purchasers were available shows that the older craft could hold its own competing successfully on certain routes and for certain types of cargo. Norwegian and German owners seem to have found work even for sailing ships. The facts displayed above indicate an important consideration, frequently overlooked when freights are rising and the shipping industry seems about to experience a period of prosperity. The net additions to the register, large as these may be at times, do not represent the whole increased carrying capacity competing for cargoes. Vessels sold still remain, though they sail under foreign flags. World tonnage is the significant figure. From the total tonnage built annually, only that wrecked or scrapped must be deducted to arrive at a figure representing the effective addition to carrying capacity, and in deciding whether further shipping facilities are required regard must be had to this figure.

APPENDIX 7.

SHORT PERIOD FLUCTUATIONS IN OUTPUT.

In Chapter X annual fluctuations in output were dealt with for the period 1874-1914. Figures showing tonnage commenced, launched, and on hand are available for the period 1888-1914.[1] A study of the "commenced" and "launched" figures reveals a series of short period fluctuations within the larger fluctuations of the "trade cycle" period. As the quarterly variations (shown on Graph F.1.) tend to obscure the general trend, curves displaying tonnage commenced[2] and tonnage launched annually are shown on the same graph. A curve of tonnage on hand[3] at the end of each quarter is also given since it shows at a glance the state and the trend of the industry at any time, and also the long period fluctuations. The annual figures call for little comment as the main features which they exhibit have already been dealt with in Chapter X. The curve showing tonnage launched naturally follows fairly closely that showing tonnage commenced, but lags behind the latter by a time interval equal to the average period of gestation.[4] That this period was approximately a year can be seen clearly at the maxima (e.g. 1898-9, 1905-6, 1912-3) or minima (e.g. 1892-3, 1899-1900, 1902-3, 1903-4) or at

1. See Tables F.1, 2, & 3 which were compiled from "Lloyd's Quarterly Returns", the "Board of Trade Labour Gazette", and the shipping journal "Fairplay".
2. "Commenced" means that the keel has been laid.
3. The total tonnage of a vessel is reckoned to be "on hand" whether the vessel is almost completed or only just begun.
4. The term is used in this Appendix to signify the time between commencement and launching. It is frequently used in a wider sense to mean the interval elapsing between the order and the final sale (of consumable goods) or between the order and the coming into use (of durable and capital goods). With ships this interpretation would therefore make the term include the time between ordering and commencement, and also the time involved in fitting out after launching - an addition of at least 50% to the period stated in the text.

numerous other intermediate points and halts. In the early years covered by the figures the interval was, in fact slightly in excess of twelve months; towards 1913 it became somewhat less than a year.

The quarterly figures, however, display a rapid rise and fall rather unexpected considering the more gradual and extended rise and fall of the annual figures. Frequently a rise and a fall occurs twice in twelve months. Reference to Table F.1. shows that the quantity of tonnage launched very often coincides with the quantity commenced in the same quarter and Graph F.1. makes the matter even more apparent. It may be noted that, to avoid the confusion which would otherwise occur, the figures for tonnage commenced have been plotted on the ordinates representing the beginning of each quarter, while those for tonnage launched have been plotted mid-way in the quarter to which they refer. Tonnage on hand at the end of each quarter has, of course, been plotted at the end; the annual figures, commenced and launched, have both been plotted at the middle of each year.

Now it may be asserted with obvious truth that tonnage commenced must determine tonnage launched, and that therefore if at any given time a large tonnage is commenced there should be a time later showing a large tonnage launched, the interval being the period of gestation. Ships differing in size and type require different lengths of time for construction, but over the large and varied tonnage built each year in the United Kingdom it might be anticipated that there would be an average time, particularly as the vessels composing the major part of the total tonnage are of medium or average size. Confirmation of this expectation is got by reference to the annual "commenced" and "launched" curves, a fact already remarked above. The regularity of this relationship between tonnages commenced and launched is disturbed and rendered inexact at times by various circumstances. During trade depressions work is suspended or retarded on many vessels, often on the request of the future owner who is not anxious to have delivery of a ship which, with low freights ruling, would be more a liability than an asset to him. Stoppages of work obviously have the same effect of lengthening the gestation period. If extreme accuracy in this matter be desired, it may be mentioned that Lloyd's Quarterly Returns gave a figure for tonnage which had been commenced but upon which no further work had been done during the quarter. To have quoted these figures <u>in extenso</u> would have overloaded the tables submitted in connection with this Appendix, but a few examples from periods of depression may be cited. The tonnage of steamships "suspended" in the yards during 1894 averaged 12,000 gross tons; during 1903-4/-5 the annual averages were 46,500-70,000 - and 48,000 gross tons reppectively; while in the next depression the figures for 1908 and the two following years were 53,000 - 38,000 - and 35,500 gross tons respectively. At times therefore anything up to 7% of the tonnage on hand (the 1904 figure) was "suspended".

In seeking an explanation for the quarterly fluctuations and the repeated coincidence of tonnages commenced, entirely different factors must be considered. The assertion that tonnage launched at any given time must depend upon tonnage commenced at some stated time previously, an assertion which was accepted as a self-evident truth when annual statistics were being considered, no longer retains its validity owing to the brevity of the period under review. The varying periods of gestation will make themselves felt in a manner which is absent when a yearly span is taken. It is not to be expected (nor is it observed in the graph) that one quarter during which tonnage commenced was high (or low) will be followed twelve months after by a quarter showing a similarly high (or low) output. The striking feature is the numerous occasions on which the tonnage commenced during a quarter is approximately equal to the tonnage launched in the same quarter. To explain this the organisation of shipyards must be taken into account. A ship is not "commenced" immediately the order is given. To do this would be physically impossible;for designs have to be made, drawings prepared, estimates obtained, and materials ordered and received - work which under the most favourable conditions (viz. when industry is depressed, when large stocks of materials are on hand, and when berths of all sizes are vacant) will take one or two months at least. During times of boom it is evident that that time may be very much extended. In the early years for which quarterly statistics are available,Lloyd's gave figures for tonnage ordered but not begun and at times,when the industry was booming,these figures ran up to very considerable dimensions.[1] There is thus an interval between the receipt of an order and the commencement of the vessel, an interval which is capable of extension when such a course is deemed desirable, though there may be a lower limit beyond which contraction is impossible.

Shipbuilders endeavour to keep berths in use continuously, to have another keel on order to replace that launched. During trade depressions the more fortunate establishments, aided by the inevitable suspensions and

1. The actual figures are withheld in deference to the request of Lloyd's.

delays, achieve a fair measure of success in their efforts to keep going, even though all their berths are not simultaneously occupied. In periods of prosperity all the berths are full and immediately one ship leaves the ways another is commenced. Hence at such times the "commenced" and "launched" figures coincide. The long-period truism is reversed - launches determine the amount of tonnage which can be commenced! As the graph shows, it is when business is experiencing the initial stages of an upward or a downward swing (e.g. in the third quarter of 1892 or in the first quarters of 1904, 1905, and 1907) that "commenced" and "launched" are far from equal. Yet another point calls for some comment. There is no obvious reason why yards should be launching a large tonnage one quarter and considerably less in the next, a process repeated again in the ensuing six months. Over the large area of the United Kingdom with its numerous building yards at many ports, it might seem that the tonnage launched should be fairly evenly spread over the four quarters of any year.

It will be noted that no regularity can be ascribed to these quarterly fluctuations, either in their temporal or their quantitative aspects. It is unlikely therefore that this quarterly variation will be susceptible to any simple or single explanation. It results from the operation of a number of more or less distinct and fortuitous causes, among which may be suggested; the different sizes of vessels (and consequently the different periods necessary for their construction), the time distribution of orders, the stage of completion of the tonnage on hand when an expansion sets in, and the diverse capacities of shipyards. Doubtless at bottom the fluctuations in tonnage commenced have some relationship to the immediate state and prospects of trade and shipping, but the connection is obscure. It can be asserted quite definitely that the figures for tonnage commenced do not correlate with those for tonnage entered and cleared each quarter.[1] From 1888 to 1914 (the period under review) this latter quantity fluctuated with the regularity of a pendulum, rising during the second and third quarters of each year and falling during the fourth and first quarters, with a steady upward trend over the whole period. The tonnage commenced figures display no such regularity.

The ultimate causes of any short period fluctuations are difficult to discern, being dependent to such a large extent upon the transient impulses of the moment. In the shipbuilding industry they are relatively unimportant and so do not merit an analysis more searching than that already made. Tables and appropriate graphs for the tonnage of war vessels on hand in the United Kingdom and on the Clyde[2] and for unemployment percentages at quarterly intervals are also submitted.[3]

1. Quite a fair index of the state of shipping and trade at the time.

2. Table F.4. Graph F.4.

3. Table G.9. Graph F.4.

APPENDIX 8.

ON CHANGES IN NAME AND OWNERSHIP OF CLYDE FIRMS.

The following lists show the names of the shipbuilding and marine engineering firms in the West of Scotland operating in 1929.

1. Firms which are both shipbuilders and marine engineers number sixteen. Their engineering shops, in certain instances, are at some distance from the shipyard. The location given is that of the shipyard and the order of the list is according to tonnage output during 1929.

Harland & Wolff, Ltd., Govan and Greenock.
John Brown & Co., Clydebank.
Barclay, Curle & Co., Whiteinch and Scotstoun.
Fairfield Shipbuilding & Engineering Co., Govan.
Alexander Stephen & Sons, Linthouse.
Scotts' Shipbuilding & Engineering Co., Greenock.
D. & W. Henderson & Co., Partick.
A. & J. Inglis, Pointhouse.
Ailsa Shipbuilding Co., Troon and Ayr.
Bow, McLachlan & Co., Paisley. — Fleming & Ferguson, Ltd., Paisley
Lobnitz & Co., Renfrew.
Wm. Beardmore & Co., Dalmuir.
Ferguson Bros., Port Glasgow.
Wm. Simons & Co., Renfrew.
Yarrow & Co., Scotstoun.

With the exception of the last named, the output of each firm exceeded 1,000 gross tons, Harland & Wolff heading the list with 49,274 gross tons and 69,330 I.H.P., followed closely by John Brown & Co. with 45,007 gross tons and 113,600 I.H.P.

2. Firms which undertake shipbuilding only number twelve, as follow (in order of output for 1929):-

Lithgows Ltd., Port Glasgow.
Robert Duncan & Co., Port Glasgow.
Wm. Hamilton & Co., Port Glasgow.
Napier & Miller, Old Kilpatrick.
Blythswood Shipbuilding Co., Scotstoun.
Charles Connell & Co., Scotstoun.
Ardrossan Dockyard Ltd., Ardrossan.
Archd. McMillan & Son, Dumbarton.
Greenock Dockyard Co., Greenock.
Ayrshire Dockyard Co., Irvine.
Scott & Sons, Bowling.
George Brown & Co., Greenock.

In addition to the above there are about fifteen firms that confine their activities to the building of small craft - barges, yachts, motor-boats, etc. Two other firms deserve mention by name; James Lamont & Co. Ltd., ship repairers, Port Glasgow, and Alley & Maclellan who, at their inland yard at Polmadie, build shallow draught, flat-bottomed vessels which are taken to their destination in sections and there re-erected. The 1929 output of the above firms varied from 91,327 gross tons launched by Lithgows Ltd. to 923 gross tons by George Brown & Co. The premises of most of the small yacht and motor boat firms are situated at small holiday resorts on the Firth of Clyde such as Fairlie, Roseneath, or Sandbank. One or two have their yards on the banks of the Forth and Clyde Canal.

3. Firms which undertake marine engineering[1] work number twelve as follow (in order of output for 1929):

John G. Kincaid & Co., Greenock.
David Rowan & Co., Glasgow.
Rankine & Blackmore, Greenock.
Bergius Co., Glasgow.
McKie & Baxter, Govan.
Atlantic Engine Co., Wishaw.
Gleniffer Motors, Glasgow.
Aitchison, Blair Ltd., Clydebank.
Campbell & Calderwood, Paisley.
Gauldie, Gillespie & Co., Glasgow.
Fishers Ltd., Paisley.
James Ritchie, Partick.

The annual output of the above ranged from 137,550 I.H.P. by J.G. Kincaid & Co. to 350 I.H.P. by Gauldie, Gillespie & Co.

In 1913 there were twentyone firms doing both shipbuilding and engineering; sixteen shipbuilding only; nineteen barge, yacht, and motor boat building; and fourteen marine engineering. Thus the number of firms operating has decreased but capacity both for tonnage and for engine production has increased. Summing up the

1. Though they do not all confine themselves to marine work.

estimates given by each of the firms of their own productive capacity we arrive at approximately 1,250,000 gross tons and 1,500,000 I.H.P. as the total annual capacity of Clyde shipyards and marine engineering shops. Even the list of names given above does not imply separate ownership. The following statement, without pretending to be exhaustive, indicates the fate of many firms whose names were prominent fifty years ago but do not now appear in above lists of Clyde shipbuilders and engineers. Some have become defunct, some have been absorbed by others, and in a few cases the title only has changed. Changes already detailed in the text (e.g. J. & G. Thomson; Randolph, Elliot & Co., and Tod & Macgregor) have been omitted below;

Shipbuilders;-

Aitken & Mansel, of Govan, now defunct.
A. Rodger & Co., of Port Glasgow, taken over in 1912 by Russell & Co., now Lithgows Ltd.
Blackwood & Gordon, of Port Glasgow, later became the Clyde Shipbuilding Co., now James Lamont & Co.,ship repairers.
Caird & Co., of Greenock, taken over by Harland & Wolff, Ltd. in 1916.
D.J. Dunlop & Co., of Port Glasgow, later became Dunlop, Bremner & Co.,[1] now Lithgows Ltd.
Dobie & Co., of Govan, now defunct; yard is occupied by Harland & Wolff Ltd.
Mackie & Thomson, of Govan, who occupied Robert Napier's yard, are now at Irvine, Ayrshire; yard is occupied by Harland & Wolff, Ltd.
Robert Steel & Co., of Greenock, now defunct; yard occupied by Scotts' Shipbuilding & Engineering Co.
Robert Napier & Sons, of Govan, became Wm. Beardmore & Co. and yard was transferred to Dalmuir.
Russell & Co., of Port Glasgow, became Lithgows Ltd.
Shanks & Bell, of Old Kilpatrick, later became Napier, Shanks, & Bell, and is now Napier & Miller.
Smith & Rodger, of Govan, became the London & Glasgow Iron & Steel Shipbuilding Co., absorbed in 1911 by Harland & Wolff.
Wingate & Co., of Whiteinch, now defunct.

1. These works were closed in 1926 owing to the depression in that year.

Engineers:

Dunsmuir & Jackson, of Yoker, now defunct; premises occupied by Murray, McVinnie & Co's stores.
J. & G. Thomson, of Finnieston, later became the Clydebank Co., now John Brown & Co.
Muir & Houston, of Govan, now McKie & Baxter.
Ross & Duncan, defunct since 1926.

There has been a distinct move in recent years towards a greater unification of control and a number of Clyde firms, while still operating under old familiar names, are owned or controlled by other larger groups. A war-time attempt to gather a number of firms[1.] under one control, known as the Sperling Combine, failed after a brief existence, the firms concerned returning to autonomous management. Before the war less than half of the sixty firms operating were limited companies, but it may be remarked that the capital of these latter amounted to £7,000,000 compared with the £2,000,000 capital of private firms. A post war attempt to consolidate other Glasgow shipbuilding firms also came to grief. Nevertheless a considerable degree of consolidation has taken place and the statement below, whilst again not purporting to be exhaustive, may convey some idea of the extent to which financial and managerial combination has taken place.

Lithgows Ltd., in addition to the absorptions detailed above, own the firms bearing the titles Robert Duncan & Co. and Wm. Hamilton & Co. both of Port Glasgow; and have a controlling interest in David Rowan & Co., engineers of Glasgow (founded in 1865) and in the coal business of James Dunlop & Co.

Swan, Hunter, & Wigham-Richardson, the North-East Coast firm of shipbuilders, have a controlling interest in Barclay, Curle & Co. of Whiteinch and Scotstoun. The latter firm had acquired the business of John Reid & Co. and (in 1925) of the North British Diesel Engine Co. (previously Burmeister & Wain[2.]) both of Whiteinch.

1. Including the Fairfield Co. and the newly founded (1914) Blythswood Shipbuilding Co. of Scotstoun.

2. An important Danish firm, with headquarters in Copenhagen, specialising in the production of Diesel engines, for which they hold the patents.

The Wallsend-on-Tyne firm also owns the Glasgow Iron & Steel Co., at Wishaw.

Harland & Wolff Ltd., who began business at Queen's Island, Belfast in 1858, have a controlling interest in D. & W. Henderson, A. & J. Inglis (both of Glasgow), and Archibald McMillan & Son.(of Dumbarton). Together with John Brown & Co. this Belfast combine acquired a large interest in David Colville & Co., steelmasters of Motherwell and Glengarnock. Through Lord Pirie, who until his death in 1924 was chairman of Messrs Harland & Wolff, this shipbuilding enterprise became associated with many important shipping companies.

Shipping companies seem to find it desirable to have a direct interest in shipbuilding yards and the following are instances of this:

Viscount Inchcape of the P. & O. Line has an interest in Messrs A. Stephen & Co. of Linthouse.

Alfred Holt & Co. has an interest in Scotts' Shipbuilding & Engineering Co. of Greenock.

Clan Line have an interest in the Greenock Dockyard Co.

On the other hand, no doubt to assure preferential supplies of plates and forgings, a syndicate of Clyde shipbuilding firms comprising Messrs Stephen, Yarrow, the Ardrossan Dockyard Co., the Greenock Dockyard Co., and the Ayrshire Dockyard Co., have bought up the business of the Steel Company of Scotland, with works at Newton and Blochairn, Lanarkshire, and an authorised capital of £900,000. The Lanarkshire Steel Co. of Motherwell, it may be mentioned, is allied to Workman, Clark & Co., the large Belfast shipbuilding firm.

In Glasgow and district there are thirteen firms which devote their attention to the manufacture of shipbuilding and marine engineering tools.

APPENDIX 9.

ON THE NUMBER OF PERSONS EMPLOYED IN SHIP-BUILDING AND MARINE ENGINEERING.

The first complete census of the United Kingdom was taken in 1801. Since that time censuses have been taken decennially. In those of 1801, 1811, and 1821 no attempt was made to classify the population according to their occupations. Families were grouped loosely into three classes; those engaged in agriculture, those engaged in trade, and others. It would be futile, therefore, to endeavour to estimate how many persons were employed in shipbuilding and engineering. The population was divided geographically in counties and several large cities were also distinguished.

In the next census (1831) in addition to the geographical and age divisions previously given, the population is sub-divided according to trades or occupations. For the 1841 census the occupations enumerated were increased and did not correspond to those of ten years before. Again and again this difficulty of altered classification crops up, rendering the successive occupation figures not comparable with each other. Each fresh classification is, of course, more detailed than the former. A change was again made in 1851, but in 1861 a classification was begun which remained with little alteration until 1911 when division by industry, irrespective of occupation, and by occupation, superseded it. The figures for the five censuses - 1861, 1871, 1881, 1891, and 1901 - are therefore reasonably comparable. Not until 1921 was marine engineering separated from general engineering. Since quite an erroneous impression would be given by the figures for general engineering, statistics given below have been confined to the class entitled "Ships". Thus only a fraction of the persons who contributed to the supply of materials and specific articles which go to make a ship, are shown, the figures being confined to those actually engaged on the construction and erection of vessels in shipyards. The occupations included in the figures given below are specified in the census records as follows:

1831:

Boatbuilder (shipwright)
Caulker.

1841:

Block, oar, and mast maker.
Boat and barge builder.
Sail and tarpaulin maker.
Shipbuilder, carpenter, wright, caulker.
Shipsmith and rigger.

1851:

Order XI; sub-order 14:

Shipwright and builder.
Boat and barge builder.
Others.

1861:

Class V. Order 10; sub-order 13: Working and dealing in ships:-

Shipbuilder; shipwright.
Block, oar, and mast maker.
Boat and barge builder.
Sailmaker.
Naval architect.
Ship surveyor.
Shipsmith.
Ship rigger.
Ship chandler.

1871:

Class V. Order 10; sub-order 13: Working and dealing in ships:-

Iron-shipbuilder.
Wood-shipbuilder, wright, labourer.
Block, oar, and mast maker.
Boat and barge builder.
Sailmaker.
Ship chandler.

1881:

Class V. Order 15: Working and dealing in ships and boats.
sub-order 1. Hull:-

Shipbuilder.
Shipbuilder's labourer.
Shipwright, ship carpenter (ashore).
Boat and barge builder.

sub-order 2. Masts, rigging, etc.:-
Mast, yard, oar, block maker.
Shiprigger, fitter, chandler.
Sailmaker.

<u>1891</u>:
All as for 1881.

<u>1901</u>:
Order 10; group 8: Ships and boats (excluding dealers):-
Ship platers, rivetters, etc.
Other workers in iron.
Shipwrights.
Other workers in wood.
Others in ship and boat building.

In the censuses of 1911 and 1921 the shipbuilding industry is dealt with in a much more comprehensive fashion, all engaged in it, whatever their occupation, being included. Commercial, clerical, and auxiliary labour of all kinds connected with the industry is covered by the figures. Marine engineering is not given separately in the 1911 census, but is allotted a special sub-group in that of 1921. For the latter year we give in the table below only the inclusive figures so that it may be comparable with the figures for 1911. The 1911 and 1921 figures include retired persons; no mention is made in previous censuses of this class, but their numbers are relatively small and therefore, whether included or excluded, will not materially affect the statistics. A table showing the occupations of the populace, irrespective of the industry within which the occupation is pursued, appears in the 1911 report. The most recent census (1921) incorporates a new table giving the relationship between the industrial and the occupational tables. This latter table does not give a division by counties - indeed it would be difficult to see how this could possibly be done within reasonable compass, so numerous are the occupations distinguished. It has only been possible therefore to give the Scottish totals from it. Retired persons are excluded.

The following table[1] exhibits the figures which have been explained above. Males only are given, the number of females engaged in shipbuilding being negligible. For each year dealt with, another set of figures is given to provide a measure of the growth of the industrial population of each of the counties and of Scotland as a whole. Glasgow is, of course, included in Lanarkshire. Although large cities are separated in the census returns it was not possible (owing to changes in the city boundaries) to give figures for Glasgow which would have been comparable for even three successive decades.

1. From 1861 to 1891 the census classes are as follow;

1. Professional
2. Domestic
3. Commercial
4. Agricultural and Fishing.
5. Industrial
6. Unoccupied or Unspecified

In the 1901 census report there are 23 orders covering all industries; the previous classification into six main groups disappears. In the census report of 1911, fiftythree industries are distinguished, of which No.18. is Shipbuilding. The 1921 report shows twentytwo industrial classes and 475 separate industries.

	Census specification	Counties: Lanark	Renfrew	Dumbarton	Ayr	Bute	West of Scotland	All Scotland
1831	As enumerated above Over 20 years of age	37	264	116	69	9	487	2,055
	Manufacture (including machines) Over 20 years of age.	26,677	9,167	1,998	8,311	215	64,818	83,993
1841	As enumerated above Over 20 years of age.	316	618	179	83	13	1,209	3,043
	All occupied persons Over 20 years of age.	102,185	33,963	11,074	33,173	2,981	183,376	569,784
1851	Order IX, sub order 14 All ages.	746	706	277	216	15	1,960	4,395
	Total population Over 20 years of age.							705,909
1861	Class V, Ord.10, sub.ord.13 All ages	2,884	1,771	816	372	69	5,912	9,148
	Total Class V. All ages	138,607	33,951	10,581	37,278	1,587	222,004	465,049
1871	Class V, Ord.10, sub-ord.13 All ages	6,047	3,297	1,325	363	46	11,078	16,250
	Total Class V All ages	170,720	37,500	11,429	36,914	1,459	258,022	517,746
1881	Class V, Order 13 All ages	7,538	3,980	2,760	316	36	14,630	18,470
	Total Class V All ages	223,440	49,681	17,943	44,774	2,144	337,982	675,964
1891	Class V, Order 13 All ages	9,488	5,465	2,746	520	34	18,253	23,433
	Total Class V, All ages	260,461	50,388	23,258	47,252	1,770	383,129	742,036
1901	Class V, Ord.10, group 8 Over 9 years of age	12,641	10,086	5,811	841	44	29,423	34,527
	All occupied persons Over 9 years of age	442,263	83,292	35,391	78,937	5,259	645,142	1,391,188
1911	No. 18 over 9 years of age	24,268	18,206	11,403	1,370	38	55,603	62,471
	All occupied persons Over 9 years of age	465,680	97,344	43,909	80,894	4,924	692,751	1,473,757
1921	Class VI, group 7 Over 11 years of age	44,767	25,097	18,437	6,404	384	95,089	122,374
	All occupied persons Over 11 years of age	507,491	98,023	49,200	93,968	8,954	757,636	1,569,505

Note: In the above figures males only are included.

The comparable groups (1861-1901) confirm the general deductions made in the text. The following table shows the percentages which the males engaged in shipbuilding constitute of the males engaged in all industrial occupations (Class V.).

Year	Percentage of Class V engaged in Shipbuilding.						
	Lanark	Renfrew	Dumbarton	Ayr	Bute	West of Scotland	All Scotland
1861	2·08	6·23	7·71	1·16	4·35	2·68	1·96
1871	3·54	8·80	11·59	0·98	3·13	4·29	3·20
1881	3·38	8·02	15·39	0·71	1·68	4·33	2·73
1891	3·65	10·86	11·80	1·10	0·84	4·77	3·16

The striking rise in Dumbartonshire between 1871 and 1881 was due to the migration of several shipyards westwards from the city to the neighbourhood of Scotstoun and Clydebank, as noted in the text.[1] Consequently Lanarkshire and Renfrewshire lost what Dumbartonshire gained. Over that decade there was a slight increase in the percentage for the West of Scotland, but a diminution for Scotland as a whole, clearly due not to any reduction in the total number of persons engaged in shipbuilding but to the opening up of new industries.[2] Bute, a shire in which ship and boat building was never of much consequence, shows a steady decline almost to extinction, whilst the industry in Ayrshire has always been dwarfed by the coal mining, steel making, and textile industries of the county.

It only remains to be added that the table in the 1921 census giving a cross classification of industries and occupations (Scotland only) reveals the following composition of the shipbuilding and marine engineering

1. See Chapter VIII

2. Especially the manufacture of mild steel (with the consequent increase in output of coal), railway, and general engineering.

industry:[1]

Group 25:

Occupational group	Males	Females	Total
Metal workers	69,231	100	69,331
Wood workers	15,346	215	15,561
Electrical workers	1,914	3	1,917
Stone workers	438	-	438
Painters	2,112	4	2,116
Shipbuilders	18,012	49	18,061
Water transport workers	1,480	-	1,480
Gas, water, and electrical workers	255	-	255
Motor drivers	169	-	169
Draughtsmen, etc	2,181	466	2,647
Clerks and typists	2,015	1,164	3,179
Other unskilled workers	7,922	648	8,570
Total	121,075	2,649	123,724

A further source of data concerning the numbers employed in various industries is now to be found in the Census of Production reports. Three such censuses have been taken (in 1907, 1912, and 1924) but, owing to the war intervening, the results of two only (those of 1907 and 1924) have been published. Because of alterations made in classification and the separation of the Irish Free State from the United Kingdom, the statistics of 1907 and 1924 are not strictly comparable. Only the preliminary reports of the most recent census have as yet been published.[2]

1. Figures are for 12 years of age and over and exclude retired persons. In the complete table (No.14. of the census report) no less than 92 industrial groups comprising 612 occupations are dealt with. Group No.25. is Shipbuilding and Marine Engineering.

2. In the "Board of Trade Journal", commencing 24th February, 1927. The reports with reference to Shipbuilding and Marine Engineering appeared in the issues dated respectively 31st March and 30th June, 1927. Northern Ireland was dealt with separately on 16th February, 1928, but the preliminary reports include Scotland with England and Wales and give figures only for Great Britain.

For the purposes of the 1907 census, the shipbuilding and marine engineering activities of shipbuilding firms were not separated; marine engineering establishments which were not directly associated with shipbuilding were classed with general engineering. In the 1924 preliminary reports the former were allotted a class as before, but in the latter group marine engineering is shown separately. This applies both to numbers employed and to quantities and values produced.

The table below shows the average numbers of persons of both sexes and of all ages employed in the different sections of the industry in 1907 and in 1924.[1]

Area	Industry	Private firms			Government			Total		
1907		Wage	Salary	Total	Wage	Salary	Total	Wage	Salary	Total
Scotland	S. & M.E.	61,444	3,380	64,824	–	–	–	61,444	3,380	64,824
U.K.	S. & M.E.	175,105	9,452	184,557	24,038	809	24,847	199,143	10,261	209,404
1924		Oper.	Managmt.	Total	Oper.	Managmt.	Total	Oper.	Managmt.	Total
Gt. Britain	S.	125,410	10,190	135,600						
	M.E.	35,814	5,111	40,925						
G.B. Total	S. & M.E.	161,224	15,301	176,525	33,387	2,282	35,669	194,611	17,583	212,194
N. Ireland	S. & M.E.			7,546	–	–	–			7,546
G.B. & N.I. Total	S. & M.E.			184,071	33,387	2,282	35,669			219,740
1907										
Comparable U.K. figs	S. & M.E.			188,312						

Of the above totals about 10% are under 18 years of age.
In 1907, 0.7% were females, whereas in 1924 this figure had risen to 1.9% - a well known post-war phenomenon.
The increase in Government employees, approximating to 50%, will be noted.[2]

For foot-notes see next page.

1. The extent of shipbuilding and marine engineering in the Irish Free State is negligible; so the inclusion of Northern Ireland with Great Britain virtually constitutes the United Kingdom for purposes of comparison. There is no warrant given in the Preliminary Reports for 1924 for assuming that the groups described in 1907 as "wage" and salary respectively correspond to the grouping "operative staff" and "managers, technical assistants, clerks, etc." in 1924. The Irish figures for 1924 are not distinguished in this respect. The group specified as "marine engineering" in 1924 includes only those firms which are directly associated with shipbuilding firms. The figures for other marine engineering establishments are given below.

2. This in spite of the fact that the 1907 figures include persons (totalling at the maximum estimate about 300) engaged in the generation of electric current, who are given a separate category in the 1924 report.

In addition in 1924 there were employed in marine engineering establishments (not directly associated with shipbuilding yards) in Great Britain 18,775 persons (male and female) of whom 16,052 were operative staff and 2,723 managers, technical assistants, clerks, etc. The only figures which are really comparable are those representing the total numbers employed in shipbuilding and marine engineering associated with shipbuilding yards viz.

	M.	F.	T.
1907 -	187,095	1217	188,312
1924 -	180,240	3831	184,071

No satisfactory deduction can be made from these figures; for, although there was a greater tonnage of merchant ships on hand during 1924 than during 1907 (1,438,000 as against 1,146,000 gross tons) scarcely any work at all was done on naval vessels during that year whilst in 1907 there was an average of 260,000 displacement tons[1] on hand. Appendix 10, dealing with values produced, throws further light on this subject.

1. Including work at naval dockyards.

APPENDIX 10.

ON THE VALUE OF SHIPS AND ENGINES PRODUCED.

Scant attention has been paid in the text above to the money value of the large quantities of ships and engines produced year by year. This apparent omission is easily explicable. The products of the twin industries have never been standardised[1.] and it is therefore quite impossible to relate gross tonnage or I.H.P. to £s. sterling. The shipping journal "Fairplay" gave the variations in cost of a "standard" ship over a period of years. But such a ship was an imaginary entity, defined only by the following specification;[2.]

Up to 1906; 360' x 48' x 30'10" - 7,000 to 7,250 tons d.w.
After 1906; 380' x 49' x 29' - 7,060 to 7,330 tons d.w.
Lloyd's new tonnage rule, issued in 1910, added some 150 tons capacity without alteration in dimensions.

The ship was a single deck cargo steamer. It is doubtful if a single ship conforming exactly to this specification was produced every year in the United Kingdom and the figures submitted by "Fairplay" have little more significance than the monthly index number showing the variations in wholesale prices of general commodities. They serve only to emphasize the greater extremes to which the shipbuilding industry is subject in the matter of prices. A common rough way of estimating the cost of a cargo vessel, of normal type and dimensions, was to multiply the price per ton of mild steel ships' plates by the deadweight carrying capacity of the vessel.

1. Except to the small extent during the war, an abnormal occasion from which no significant facts can be deduced.

2. "Fairplay" for 25th December, 1913.

Thus, while the cost of war vessels or of a particular merchant ship, especially one of the luxury liners, might receive publicity from time to time, no comprehensive figure could be put upon the value created annually in the shipbuilding and engineering workshops of the country until the first Census of Production was taken in 1907. The intention was that such a census should be taken quinquennially thereafter. A second was taken in 1912 but, owing to the intervention of the war, the results were never published. When the third was due in 1917 a special Act of Parliament was passed obviating the necessity of taking a census that year and provision was also made that in future there need be no regular interval between one census and the next, but that these be taken at times considered opportune by the government of the day. The third was therefore taken in 1924 and, with the limitations and conditions mentioned in Appendix 9, it is now possible to make considered judgments regarding the total values of the annual output of the shipbuilding and marine engineering industries. The tabular statements below exhibit the more important facts which emerge. When figures for 1907 and 1924 are set side by side, approximate comparability is implied. Duplication has been eliminated and the values given are contract or selling value of the products in their finished form (e.g. ships, with engines installed, fittings supplied, and all ready to be transferred to the owner). It must be understood that the figures represent actual work done during the year, whether or not the vessel was completed and launched.[1] Government establishments are dealt with separately. Their values are "cost of production" (i.e. wages, cost of materials, and a proportion of establishment charges). The tables

1. Any quantities given therefore do not correspond with the output as judged by tonnage launched that year.

given below have been compiled from the more complicated and separate tables of the respective censuses.

Output of Shipyards:

Type of product		U.K. 1907 £'000	G.B. 1924 £'000	N.I. 1924 £'000	G.B.&N.I. 1924 £'000
War vessels		3,512	558		558
Steamships:	Hull	19,157	26,720	1,556	28,276
	Machinery	4,766			
Motorships			5,661	1,078	6,689
Sailing ships		255	508	3	511
Boats and barges		479	355		355
Other products		551	821	31	852
Repair work		8,371	16,652	604	17,256
Total		37,091	51,225	3,272	54,497
Cost of materials used			29,003	1,818	30,821
Net output			22,222	1,454	23,676

Scottish yards in 1907 accounted for a little over one third of the total output (£37,091,000).

Repair work constituted 23% of the total value in 1907 and [redacted] 32% in 1924.

In 1907, 34% (i.e. 576,000 gr. tns.) of the total output (1,690,000 gr. tns.) was exported.

In 1929, 11% (162,000 gr. tns.) of the total output (1,475,000 gr. tns.) was exported, constituting by value 15% (i.e. £5,523,000) of the total output of new vessels (i.e. £37,241,000, the gross total less repairs.).

In 1924 the imports of new vessels, with machinery (excluding re-exports) were negligible, totalling only £102,000.

Net output per employee of shipbuilding yards:	1907 (U.K.)	- £ 98.
	1924 (G.B.&.N.I.)	- £164.
of shipbuilding and marine engineering:	1924 (N.I.)	- £193.

Output of all Marine Engineering establishments for 1924:

Type of product	Great Britain: Shipbuilding firms £'000	Great Britain: Mar. Eng. firms £'000	Great Britain: Total £'000	Great Britain: Other firms £'000	Great Britain: Total £'000	N. Ireland: Shipb. & Mar. eng. firms £'000	GB & N.I.: Total £'000
Steam: Reciprocating	2,303	2,131	4,434	110	4,544	282	4,826
Steam: Turbine	1,270	315	1,585	49	1,634	195	1,829
Internal combustion	1,915	608	2,523	76	2,599	17	2,616
Boilers	1,061	437	1,498	94	1,592	302	1,894
Other marine machinery	545	2,089	2,634	775	3,409	81	3,490
Total	7,094	5,580	12,674	1,104	13,778	877	14,655
Other products	3240	1,135	4,379				
Iron & steel structures	4	–					
Repairs, etc.	1,396	461	1,857				
Total	11,734	7,176	18,910				
Work in progress at end of year	7,225	1,990	9,215				
Total	18,959	9,166	28,125				
Work in progress at beginning of year	5,297	2,236	7,533				
Goods make and work done during year	13,662	6,930	20,592				
Materials used, etc.	7,124	3,648	10,772				
Net output	6,538	3,282	9,820				

Thus, of the total gross output of marine engines and machinery (i.e. £14,665,000), 92% (i.e. £13,551,000) was due to shipbuilding and marine engineering establishments.

Of the total net output for Great Britain (i.e. £9,820,000), two thirds (i.e. £6,538,000) was due to workshops directly associated with shipyards.

In 1907 the total gross output of marine machinery by shipbuilding and marine engineering establishments was £6,544,000; this is comparable with £13,551,000 in 1924.

In 1924 exports of marine machinery from Great Britain were;

				£
Steam; reciprocating	- 65	sets,	valued	500,000
turbine	- 7	"	"	249,000
Internal combustion	- 95	"	"	334,000
Boilers	- 129	"	"	397,000
Other mar. machinery				273,000
				1,753,000

In 1924 imports were negligible, including only 9 sets of internal combustion engines valued £1,500.

Net output per employee in 1924;

of marine engineering shops directly associated with shipyards - £160

of separate marine eng. shops - £175

The low net output per head may be attributed to short time and irregular working in 1924; and the difference in the two classes of establishments is due to the basis of calculation of values, the shipyard figure excluding profit whilst the other is the actual selling value.

Output of Royal Dockyards and Workshops in United Kingdom.

Type of product	1907-08 £	1924-25 £
War vessels	3,440,131	2,601,249
Other steam & motor vessels	35,722	—
Boats and barges	19,022	—
Repairs	2,184,984	5,913,120
Other work	689,189	1,395,525
Total gross output	6,369,048	9,909,894
Materials, etc.		3,357,841
Net output		6,552,053

Total shipbuilding and marine engineering work done was:

£5,679,859 of which 61% was new constr^{n}. and 39% repairs in 1907-8.

£8,575,078 " " 31% " " " " 69% repairs in 1924-5.

Net output per employee:

1907-8 - £98

1924-5 - £184

Allowing for the 33% fall in the value of money between 1907 and 1924 (as judged by Sauerbeck's index number) the following facts emerge:

Net output per employee per annum had risen in the United Kingdom:

in merchant shipbuilding from £98 to £109 i.e. 11%

in Royal Dockyards & Workshops from £98 to £128 i.e. 20%.

Whilst it is true that the comparisons just made cannot be regarded as quantitatively exact, they do possess sufficient accuracy to make it possible to assert that output per head has gone up since 1907 and this despite a reduction of hours in private shipyards from 54 to 48 per week. Much of the increase is undoubtedly due to improvements in machinery and workshop organisation which received an impetus during the war, and from the general urge towards greater efficiency which has been in evidence since 1921. When the final reports of the 1924 census are issued they will doubtless provide statistics upon which to base a more intensive analysis than it has been possible to give at present.

BIBLIOGRAPHY.

The list given does not exhaust all the references in the text and footnotes, but it covers the main sources of information and data upon which the text and statistical tables have been constructed, including a number not previously mentioned. For convenience it is laid out under six subject headings. Books dealing with more than one of these have been given a brief reference under each appropriate heading. The sources of information have been classified as follows:

(a) Published books.
(b) Periodicals, Pamphlets, Reports of Societies, etc.
(c) Official and semi-official Reports and Tables.

The dates given in brackets are dates of publication.

1. GLASGOW AND THE WEST OF SCOTLAND.

(a) Aird, Andrew - Glimpses of old Glasgow (1894).

Anonymous - Industrial Rivers of the United Kingdom (1888).

Bremner, David - The Industries of Scotland (1869).

British Association Handbooks in connection with Glasgow meetings. (1855, 1876, 1901, 1928).

Brown, Andrew - History of Glasgow, 2 Vols. (1795).

Campbell, Dugald - Historic Sketches of the Town and Harbours of Greenock (1879).

Cleland, James (LL.D.) - Statistical Account of Glasgow (1803).
Annals of Glasgow (1816).
Statistics of Glasgow and Lanarkshire (1823).
Rise and Progress of the City of Glasgow (1829).
Statistics of Glasgow and Lanarkshire (1832).
Statistical facts descriptive of the Former and Present State of Glasgow (1837)
Rise and Progress of the City of Glasgow (1840).

Deas, James - The River Clyde (1876; 1884).

Defoe, Daniel - Tour in Scotland (1727).

Denholm, James - History of the City of Glasgow and Suburbs (1804).

Denny, William & Bros. - Souvenir (1909).

Gibson, John - History of Glasgow (1777).

Gillespie, Robert - Glasgow and the Clyde (1876).

McGregor, George - History of Glasgow (1881).

McUre, John - History of Glasgow (1830).

Marwick, Sir James D. - The River Clyde and Harbour of Glasgow (1898).
The River Clyde and the Clyde Burghs (1909).

Millar, William J. - The Clyde from its Source to the Sea (1888).

Napier, James (M.A.) - Life of Robert Napier (1904).

Pagan, James - Sketch of the History of Glasgow (1847)
(ed.) Glasgow, Past and Present, 3 Vols. (1851-6).

Smith, Robert - History of Greenock (1921).

Strang, John (LL.D.) - Reports on Census of Glasgow and Suburbs (1851; 1861).

Weir, Daniel - History of Greenock (1829).

Wallace, Andrew - History of Glasgow (1882).

(b) Scottish Geographical Magazine, January, 1921.[1]

Strang, John (LL.D.) - Paper to Royal Statistical Society; Journal, Vol.20. (1857).

(c) Clyde Navigation Acts and Trust Accounts, 1758-1929.

Post Office Directory for Glasgow. v.d. 1803-1930.

Trading Account of Scotland, 1755-1801; MSS. at Public Record Office.

1. Wholly devoted to various aspects of Glasgow and the Clyde.

Reports on the Improvement and Management of the River Clyde and Harbour of Glasgow, from 1755 to 1853; published by the Trustees. (1854).

2. INVENTIONS, TECHNIQUE, AND MATERIALS OF CONSTRUCTION.

(a) Anderson, Romola and R.C. - The Sailing Ship (1926).

Arago, Dominique F.J. - Life of James Watt (1839).

Bald, Robert - General View of the Coal Trade in Scotland (1812).

Chapman, Frederick - Treatise on Shipbuilding (1775).

Cleland, James (LL.D.) - Historical Account of the Steam Engine and its Application to Propelling Vessels (1825).

Dickinson, Henry W. & Jenkins, Rhys - James Watt and the Steam Engine; a Memorial volume in connection with the Watt Centenary Commemoration at Birmingham, 1919 (1927).[1]

Fairbairn, William (F.R.S.) - A Treatise on Iron Shipbuilding (1865).

Farey, John - Treatise on the Steam Engine (1827)[2]

Fincham, John - A History of Naval Architecture (1851)[3]

Galloway, Robert L. - The Steam Engine and its Inventors (1881) Annals of Coal Mining and the Coal Trade; 1st series (1898).

Grantham, John - Iron Shipbuilding (1858).

Hardy, A.C. - Merchant Ship Types (1924).

Holmes, Sir George C.V. - Marine Engines and Boilers (1889). Ancient and Modern Ships, 2 Vols. (1900-6).

Jackson, G. Gibbard - The Ship Under Steam (1927).

Jones, Clement - British Merchant Shipping (1922).

Knowles, John (F.R.S.) - Elements and Practice of Naval Architecture (1822).

Lindsay, William S. - History of Merchant Shipping, 4 Vols. (1874-6)[4].

Lubbock, Basil - The China Clippers (1926).

1. This book gives an exhaustive account of Watt's life and inventions.
2. A very full historical and practical account.
3. An excellent account of early vessels, sail and steam, paddle and screw.
4. Especially Vols. 2 to 4.

McQueen, Andrew - Clyde River Steamers of the Last Fifty Years (1923).
Echoes of Old Clyde Paddle-wheels (1924).

Mitchell, James - Shipbuilding and the Shipbuilding Industry (1926).

Muirhead, James P. (M.A.) - The Origin and Progress of the Mechanical Inventions of James Watt (1854).
Life of James Watt (1859).

Murray, Andrew and Robert - Shipbuilding in Iron and Wood and Steamships (1863).

Pollok, David - Modern Shipbuilding and the Men Engaged in It (1884).
The Shipbuilding Industry (1905).

Rankine, William J.M. (F.R.S.) - Memoir of John Elder (1871).

Scotts' Shipbuilding and Engineering Co. - Two Centuries of Shipbuilding by the Scotts at Greenock (1920).

Scrivenor, Harry - History of the Iron Trade (1854).

Smiles, Samuel (LL.D.) - Lives of the Engineers, 3 Vols. (1861-2).
Lives of Boulton and Watt (1865).
Men of Industry and Invention (1897).

Stuart, Robert - Descriptive History of the Steam Engine (1824).

Thurston, Robert H. - History of the Growth of the Steam Engine (1883).[1]

Williamson, Capt. James - The Clyde Passenger Steamer (1924).

Woodcroft, Bennett - Origin and Progress of Steam Navigation (1848).

(b)

Channel, The;- a Clyde Shipbuilding, Engineering, and Electrical Gazette, 5 Vols. (1917-22).

Glasgow Mechanics' Magazine, 5 Vols. (1824-26).

Civil Engineers; Proceedings of the Institution of, 1837-1928.

Engineers and Shipbuilders in Scotland; Transactions of the Institution of, 1857-1928.

Marine Engineers; Transactions of the Institute of, 1889-1928.

Mechanical Engineers; Proceedings of the Institution of, 1847-1928.

1. For an account of early American steamboats.

North East Coast Engineers and Shipbuilders; Transactions of, 1884-1925.

Naval Architects; Transactions of the Institution of, 1860-1928.

3. SHIPPING AND TRADE.

(a)

Browne, J. Houston (LL.B.) - The Navigation Laws - their History and Operation (1847).

Chalmers, George (F.R.S.) - An Estimate of the Comparative Strength of Great Britain; and of the Losses of her Trade from every War since the Revolution (1804).
Caledonia, 6 Vols. (1807-24).

Kirkaldy, Adam (B.A.) - British Shipping (1914).

Knowles, Lilian C.A. (Litt.D.) - Industrial and Commercial Revolutions in Great Britain during the nineteenth century (1921).

Levi, Leone - History of British Commerce (1872).

Lindsay, William S. - op. cit. 2.

Macpherson, David - Annals of Commerce, Manufactures, Fisheries, and Navigation, 4 Vols. (1805).[1]

Page, William - Commerce and Industry; Historical Review, 1815-1914 (1919).

Porter, George R. (F.R.S.) - Progress of the Nation (1847;1851).

(b)

"Glasgow Herald Shipbuilding and Engineering Supplement"; annually, 1863-1929.

Glover, Sir John - Papers to Royal Statistical Society; Vols. 26,35,45,55,65. (1863, 1872, 1882, 1892, 1902.).

McCulloch's Commercial Dictionary (1859).

Statement of the Proceedings of a Public Meeting of Shipowners of the United Kingdom, etc. held in London on Wednesday, 15th December, 1858 (pamphlet form, 1859).

1. Especially Vols. 3 & 4.

(c)

List of Shipping registered in the different ports of Scotland, compiled and arranged under the inspection of the Association of Underwriters and Brokers of Glasgow (1821).

Merchant Shipping Acts. v.d. 1694-1907.

Public Record Office MSS.:

Board of Trade: B.T. $\frac{6}{185}$.

Treasury Accounts for Scotland: T. $\frac{36}{13}$; $\frac{64}{251}$; $\frac{64}{329}$ $\left\{\frac{132}{1829}\right\}$

Trade of Scotland, 1779-1808: Customs $^{17}/_{1}$ to $^{17}/_{30}$.

Shipping and Navigation of the United Kingdom; Registrar General's annual Reports of, 1802-1929.

"Shipping World" Year Book; annually, 1886-1929.

Statistical Abstracts of the United Kingdom. v.d. 1862-1929.

4. OUTPUT OF SHIPS AND ENGINES.

(a)

Pigou, Arthur C. (M.A.) - Industrial Fluctuations (1927).

Porter, George R. (F.R.S.) - op. cit. 3.

Strang, John (LL.D.) - Economic and Social Statistics of Glasgow (1855).

(b)

"Fairplay" (a shipping magazine) v.d. 1899-1929.

"Glasgow Herald Supplement"; cit. 3.

Glasgow Mechanics' Magazine; cit. 2.

Strang, John (LL.D.) - Paper to British Association Belfast meeting; 1852.

(c)

Board of Trade Labour Gazette; monthly, 1887-1914.

Census of Production, Report of First: Pt.II. - House of Commons Accounts and Papers; sess. vol. 109 (1910).

Census of Production, Preliminary Report of Third - Board of Trade Journal; 31.III.27, 30.VI.27, 16.II.28, 15.III.28.

House of Commons Accounts and Papers; sess. vol.57 (1852-3)

Lloyd's Register: Annual Summary of the Mercantile Shipbuilding of the World; 1888-1929.
Shipbuilding Returns; quarterly, 1887-1930.
of Shipping; annually, 1879-1929.
Rules and Regulations (1927).

Shipowners, Shipbuilders, and Marine Engineers; Directory of, (1929).

Statistical Abstracts of the United Kingdom. cit. 3.

Strang, John (LL.D.) - Paper to Royal Statistical Society; Journal: vol. 15. (1852).

5. LABOUR AND WAGES.

(a)

Bevan, George P. - Industrial Classes and Industrial Statistics (1877).

Cumming, D.C. - History of the United Boilermakers' and Iron & Steel Shipbuilders' Society (1905).

Mosses, W. - History of the United Patternmakers' Association (1921).

Strang, John (LL.D.) - Economic and Social Statistics of Glasgow, 1851-61 (1862).

Webb, Sidney and Beatrice - History of Trade Unionism, 1666-1920 (1920).

(b)

Amalgamated Society of Engineers, Jubilee Souvenir of, (1901).

Bowley, Arthur L. (Sc.D.) and Wood, George H. - Papers to Royal Statistical Society: Journal, vols.68-9. (1905-6).

"Glasgow Herald Supplement". cit. 3.

Glover, Sir John - Paper to Royal Statistical Society: Journal, vols. 31-2 (1868-9).

Industrial Remuneration Conference; Proceedings of, (1885).

Jevons, W. Stanley and Sauerbeck, Augustus - Papers to Royal Statistical Society; vol.28. (1865) and v.d. 1886-1915.

Scottish United Operative Blacksmiths' Protection and Friendly Society; annual reports, 1858-1914.

Social Science Congress; Report of, (1874).

Strang, John (LL.D.) - Paper to British Association, Leeds meeting (1858).

Thirty Years of Industrial Conciliation; Engineering and Allied Employers' National Federation (1927).

(c)

Census of Population, Scotland (decennially, 1801-1921).

Census of Production, First. cit. 4.

Census of Production, Third. cit. 4.

Depression of Trade and Industry; Report of Royal Commission on, (1885-6).

Labour, Report of Royal Commission on, vol.III, group A. (1893-4).

Labour Statistics; Seventeenth Abstract of, (1915).

6. WAR AND POST-WAR.

(a)

Aberconway, Lord - The Basic Industries of Great Britain (1927).

Elderton, W. Palin - Shipping Problems, 1916-21 (1928).

Temperley, Harold W.V. - History of the Peace Conference of Paris, 6 vols. (1920-4).

Economic and Social History of the World War (British Series); Carnegie Endowment for International Peace:
Bowley, Arthur L. (Sc.D.) - Prices and Wages in the United Kingdom, 1914-20 (1921).
Cole, George D.H. - Trade Unionism and Munitions (1923).
- Workshop Organisation (1923).
Fayle, Charles E. - The War and the Shipping Industry (1927).
Hill, Sir Norman - The War and Insurance (1927).[1]
Salter, James A. - Allied Shipping Control (1921).
Scott, William R. (Litt.D.) and Cunnison, James (M.A.) - The Industries of the Clyde Valley during the War (1924).
Smith, Joseph R. - The Influence of the Great War upon shipping (1919).
Wolfe, Humbert - Labour Supply and Regulation (1923.)

1. Section on: State Insurance against War Risks at Sea.

(b)

"Glasgow Herald Supplement". cit. 3.

(c)

Board of Trade Labour Gazette; monthly, 1914-1930.

Reparations Commission, 1920-22; Report on Work of, (1923).

INDEX TO TABLES.

4. Net tonnage of vessels (including foreign owned) entered at and cleared from ports of the United Kingdom in foreign trade (distinguishing "in cargo" and "in ballast"); annually, 1771-1928.

Group D.

1. Number and gross tonnage of ships built on the Clyde (distinguishing sail and steam); annually, 1863-1914. Also percentage sail to total and steam to total; annually, 1866-1914.

2. Leading shipbuilding firms on the Clyde and their output; annually, 1876-1914.

3. Leading marine engineering firms on the Clyde and their output; annually, 1887-1914.

4. Total output of first six marine engineering firms on the Clyde and total I.H.P. produced on the Clyde; annually, 1887-1914.

Group E.

1. Number and gross tonnage of ships added to and removed from the United Kingdom register (distinguishing steel, iron, and wood & composite); annually, 1879-1913.

2. Number and gross tonnage of ships added to and removed from the United Kingdom register (distinguishing sail and steam); annually, 1879-1913.

3. Summary showing net additions (number and gross tonnage) of ships to the United Kingdom register (distinguishing steel, iron, and wood & composite); annually, 1880-1913.

4. Summary showing net additions (number and gross tonnage) of ships to the United Kingdom register (distinguishing sail and steam); annually, 1880-1913.

Group F.

1. Number and gross tonnage of ships commenced and launched in the United Kingdom (distinguishing sail and steam); quarterly, 1888-1914.

2. Number and gross tonnage of ships commenced and launched in the United Kingdom (distinguishing sail and steam); annually, 1888-1914.

3. Gross tonnage "on hand" in the United Kingdom (distinguishing home and foreign ownership); quarterly, 1887-1914.

4. Gross tonnage of merchant ships and displacement tonnage of warships "on hand" (distinguishing Clyde and United Kingdom); quarterly, 1887-1914 and 1893-1914 respectively.

Group G.

1. Time rates of wages in shipbuilding and engineering on the Clyde; annually, 1793-1914 (incomplete).

2. Wages in shipbuilding and engineering on the Clyde for an ordinary week's work; annually, 1856-1904 (incomplete).

3. Index numbers of average rates of wages in shipbuilding and engineering in various districts of the United Kingdom; annually, 1850-1904.

4. Index numbers of prices; annually, 1782-1914.

5. Fluctuations in nominal wages, prices, and real wages; by periods, 1790-1913.

6. Unemployment percentages in the United Kingdom (distinguishing engineering, shipbuilding, & metal trades and general); annually, 1850-1914.

7. Membership of West of Scotland branches of the Scottish United Operative Blacksmiths' Protection and Friendly Society; annually, 1857-1914.

8. Net annual income and balance of the S.U. Operative Blacksmiths' P. & F. Society; quinquennially, 1858-1913.

9. Unemployment percentages in shipbuilding and in engineering (distinguishing the Clyde, the East coast of Scotland, and the United Kingdom); quarterly, 1902-14.

Group H.

1. Gross tonnage of ships built (distinguishing the Clyde, Scotland, United Kingdom, and World); also percentage which Clyde output constitutes of the others; annually, 1875-1929 (incomplete).

2. Leading shipbuilders on the Clyde and their output; annually, 1914-29.

3. Leading marine engineers on the Clyde and their output; annually, 1914-29.

4. Total output of first six marine engineering firms on the Clyde and total I.H.P. produced on the Clyde; annually, 1914-29.

5. Number and net tonnage of ships on the register at Glasgow; annually, 1810-1929 (incomplete).

INDEX OF GRAPHS.