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Super-Pressure Steam Generation.

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CHAIRMAN: MR. F. M. TIMPSON.

IN the present paper an attempt will be made to give a concise outline of the fascinating subject of super-pressure steam generation. By this is meant roughly the use of pressures far beyond the present average practice, and generally above say 1,200 lbs. per square inch gauge, intended mainly for power generation by means of engines or turbines, and with the employment of apparatus different in principle to any ordinary type of boiler at present in common use.

It is obvious that to-day we are in the throes of a complete revolution in our methods of producing power from coal, oil, or other fuels. For over 125 years engineers have in the main been content to burn the fuel in steam boilers and utilise the resulting steam in a condensing engine or turbine, although certainly, remarkable improvements have been made in this general method, culminating say about 10 years ago in 200-275 lbs. gauge pressure, 600-650° F. superheated steam temperature and

$17\frac{1}{2}$% thermal efficiency from the raw coal to the switchboard under the very best conditions, with a condensing turbine. It may be mentioned also that the present average thermal efficiency figures are about 14-17% for ordinary good class electricity stations, 10-13% for the best type of large reciprocating, compound, or triple expansion steam engine, 7-8% for the ordinary smaller industrial condensing steam engine and 4-5% for the steam locomotive.

But the advances made in fuel technology during the past 10 years combined with a renewed study, appreciation, and development of the work of many early pioneers have rendered very obvious that the above general method is doomed, quite apart even from the present rapid increase in the use of the internal combustion heavy oil engine for marine conditions, and of water power on land.

The three main defects of the use of coal, which is, after all, by far the most important fuel, for power generation through the intermediary of steam and the condensing engine or turbine according to present methods are the burning of the coal in the raw state, the waste of over 55% of the total heat in the condenser cooling water, and too low a steam pressure and temperature of superheat. The present paper is concerned only with a particular section of the last item, but it may be mentioned we are rapidly coming to the stage when to burn most qualities of raw coal at all, and to consume as mere fuel all the valuable by-products that can be extracted from it will be regarded as a crime.

The proper scientific practice is to submit bituminous and semi-bituminous coal to low temperature carbonisation, using this term in the very broadest sense of scientific methods involving some form of heat treatment so as to obtain a much improved yield and quality of tar, a large proportion of which for example can be used as Diesel oil. Also in numerous cases sulphate of ammonia is recoverable as a commercial proposition, and in a large proportion of the very many different low temperature processes available, well over 100, there is obtained a residual low volatile but free burning and chemically reactive solid product, which is much superior to raw coal as a fuel for steam boilers, either with hand or most types of mechanical stoker firing. The subject is of course an enormous one, and includes the hydrogenation of coal and the production of synthetic fuels, but we are very near success with more than one process, and as far as steam generation is concerned an important section of the work is combined low temperature carbonisation of the raw coal in front of large water tube boilers, recovery of the valuable liquid products, and the combustion of the resulting fuel under the boilers along with the residual gas. Many large power stations at the present time are burning 1,000 of raw coal a day or over and it is obviously impossible to carry on with such methods. Perhaps the day may come therefore when steamships will burn a large proportion of smokeless low temperature fuel under their boilers instead of raw coal, which incidentally would give a higher efficiency.

Secondly, as regards the latent heat of steam loss in the condenser, this also is a vital matter and the ideal would be for power station work, the sale of low pressure steam and hot water to adjacent houses and factories, thus avoiding the loss in the cooling water. At the same time every effort will have to be made in the way of developing the general principle of the pass-out steam engine or turbine in industrial practice when low pressure process steam is required, just as in marine work all the exhaust of the non-condensing auxiliaries should be utilised for the feed water and other purposes where the heat can be absorbed to advantage.

Turning now to the question that more directly concerns us, the increase in steam pressure, it is common knowledge that the history of steam is largely one long record of attempts to raise the working pressure, for the obvious reason that more energy per unit of steam in the form of heat is thereby rendered available for performing useful work in connection with the use of the condensing steam engine or turbine.

As will be remembered, one of the chief pioneers of the practical use of steam was Thomas Savery, a retired sea captain of the British Navy, with his highly scientific pulsometer type of pump, produced in 1698, described in a particularly clear and lucid manner, with illustrations, in his famous pamphlet "The Miner's Friend," published by S. Crouch at the corner of Pope's Head Alley, Cornhill, London, in 1702. Savery also showed a working model of his pump to a meeting of the Royal Society on the 14th June, 1699, and he was able to pump water continuously to a height of 80ft. The trouble was, however, that for an adequate duty a relatively high steam pressure was required, probably 40-60 lbs. per square inch, and it was at that time impossible to make a steam boiler—beaten copper being employed—larger than a few gallons capacity, and right from the earliest times it has always been the boiler and not the engine or turbine that has been the obstacle to the use of higher pressures. Consequently Newcomen's atmospheric engine, introduced in 1705, came into extensive use because only about 1-2 lbs. per square inch steam pressure was necessary, the principle, as is well-known, being that of driving the air out of the cylinder with steam and then condensing the latter by squirting in cold water, thereby causing a partial vacuum, so that the piston was caused to travel downwards by the pressure of the air. For this, almost any closed vessel would do as a boiler, even brickwork and a partial construction of wood or lead having been employed.

During the following half century many attempts were made to improve the steam pressure, and apparently for example about 1750, the "egg-ended" boiler was produced, made of riveted wrought iron plates in the form of a simple cylinder externally heated like a kettle, while other well-known types up to say 1825 were the "haystack" and the "wagon" boilers. Most of Watt's condensing steam engines only worked at 5-6 lbs. pressure and the firm of Boulton and Watt used the most unscrupulous means to try and prevent anyone else from exceeding these low figures, even to the extent of endeavouring to "wangle" a Bill through the House of Commons to make the use of any higher pressure illegal, although they were eventually compelled themselves to go to 10 lbs. per square inch.

The pioneer of modern high pressure steam, as distinct from super-pressures, is Richard Trevithick, probably the greatest engineer that ever lived, who soon realised that the whole future of the steam engine depended upon increasing the steam pressure and so reducing the weight and bulk of the engine for a given power output, an obvious fact that James Watt apparently could never understand. In 1797 Trevithick produced his epoch-making invention of the internally fired cylindrical "Cornish" boiler, named after his native county, and was soon able to work at 25 lbs. per square inch gauge pressure, constituting a revolution in steam practice and inaugurating the era of what may be termed the modern type of steam engine.

Trevithick is stated to have worked eventually at 100 lbs. pressure and to have reached on one occasion 140 lbs., regardless of personal risk, while he prophesied that 200 lbs. would be obtained.

It is in fact almost entirely due to the genius, imagination, and indomitable courage of Richard Trevithick that the high pressure steam boiler became a practical proposition, and his work made possible immediately both the steam locomotive and the steam ship, which were quite impossible with the Watt type of engine. Curiously enough Trevithick did not occupy himself very much with marine work, but he was the real pioneer of the locomotive, soon applying his new "Cornish" boiler to the production of a steam propelled vehicle. His first model steam locomotive was made in 1797, this being in the South Kensington Museum, and in 1801 Trevithick constructed at Camborne, in Cornwall, a large locomotive which ran on the roads and is the first authenticated practical mechanically driven vehicle in the history of the world. He then built in 1803 at Camborne, a much larger steam locomotive, having two rear wheels 9ft. 10in. in diameter, and this he took up to London and drove about the streets, attaining a speed of 9—10 miles per hour, while the same year he constructed the first steam railway in the world, at Merthyr Tydfil in South Wales, running from Penydaran to Quaker's Yard, a distance of 10 miles, the locomotive travelling at four miles per hour and dragging a load of 25 tons of material, as well as a number of temporary passengers.

This installation included the first locomotive rails, which were thin narrow flat plates with flanges, the locomotive wheels having smooth tyres, and it may be pointed out that Trevithick is not only the real pioneer of the steam locomotive, because of his work in high pressure steam, but he was also the originator of the use of the exhaust in the funnel, the boiler gauge glass, the feed-water heater, and the fusible plug.

Then in 1804 Trevithick sent one of his locomotives to Newcastle-on-Tyne to the order of a collery proprietor, Mr. Blackett, and this was used to haul wagons of coal at the Wylam Colliery, Northumberland, while there was included the original invention of the modern locomotive rail, that is to say with flanged wheels on the locomotive.

It was from this locomotive of Trevithick's in 1804 that came all the railway developments on the North-East Coast, while in 1808 he constructed a much improved type of locomotive called "Catch-me-who-can," which weighed about 10 tons and ran at about 12 miles per hour. Trevithick brought this locomotive to London and ran it on a circular track on the very site where Euston station now stands, many thousands of people paying for a ride.

Following upon Trevithick's locomotive sent to Newcastle in 1804, many other men then set to work and improved the design, including William Chapman, John Blenkinsop, Timothy Hackworth, William Hedley, and Jonathan Foster. It was on the work of these men that George Stephenson, originally a boy at the Wylam Colliery, based his design, and in connection with the recent Railway Centenary the widely spread statements that have appeared, not only in the general Press, but in technical publications as well, that George Stephenson was the originator of the locomotive are simply bosh, and a very grave injustice in particular to the memory of the pioneer of high pressure steam, Richard Trevithick. For example, Stephenson's "Locomotion in 1825 was largely copied from Blenkinsop's and Hedley's designs, themselves improvements on Trevithick's work, and even then Stephenson was helped very materially by Ralph Dodds and William Losh, to whom probably as much of the technical credit is due.

It is perhaps hardly necessary also to point out that the Stockton and Darlington railway was not the first in the world at all, but the original passenger line.

From this high pressure work sprang both the internally-fired cylindrical " Scotch " marine boiler and the "Lancashire " boiler, that is a " Cornish " boiler with two furnace flues instead of one, and during the following 125 years or so generally available steam pressures were gradually pushed up first from 60-80 lbs. per square inch to 100-120 lbs. then to 160 lbs. and finally to 200 lbs. and over, because of improvements in mechanical design and construction.

At the same time we have seen the evolution of the water-tube boiler, introduced many years ago, the first successful type being the French " Belleville," which enabled still higher pressures to be used because of the reduction in size of the drums and the use of a comparatively large number of small bore tubes. Until quite recently, however, as already indicated, the best power station practice was not more than 200-275 lbs. per square inch and 600-650° F. superheated steam temperature, and in fact most electricity stations in the world to-day do not yet exceed these conditions, although for marine practice higher figures have been in use for some considerable time, especially in naval craft. It will be noticed therefore that from the days of Savery in 1698 it has taken over two centuries to attain a steam pressure of more than 200 lbs. per square inch. Since about 1910, however, there has been a very rapid development, and it will be no exaggeration to say that during the last ten years more advance has been made in the general technique of steam generation than in all the previous period put together.

With water-tube boilers we have now arrived at what is regarded as quite common super-power station practice on land, 350 lbs. per square inch and 700° F. superheated steam temperature, corresponding to say about 20% thermal efficiency, with 55% of the heat lost in the cooling water, 20% in the generation of the steam, and 5% in various ways, such as leakage. A considerable number of stations also are at present working with much higher pressures, including for example 475 lbs. per square inch adopted so far back as 1917, at the North Tees Station of the Newcastle Electric Supply Company, and 600 lbs. at the Crawford Avenue Station in Chicago, with a guarantee of 27·4% thermal efficiency, while the latest extensions at Gennevilliers (Paris) are 440 lbs. and the new Rummelsburg Station in Berlin will be 500 lbs. There are also many other high pressure plants, over 400 lbs. per square inch, in the United States, of which a notable example is the Philo Station at 550 lbs., while 650 lbs. is to be adopted at Amsterdam, and 725 lbs. at the Langebrugge Station in Holland.

Along with this we have had a still further development which consists essentially in the construction of very special modifications of the ordinary water-tube boiler, having thick forged steel drums of enormous weight, operating up to 1,200 lbs. per square inch. Work of this character has been in hand for a number of years past, both in the United States and Germany, and for example at the Weymouth Station in Boston, U.S.A. there is a special " Babcock and Wilcox " boiler of the inclined cross drum type. The drum is stated to weigh about 72 tons, being 34ft. 4in. in length, 4ft. inside diameter and 4ft. outside diameter, that is nearly 4in. thick, constituting a huge steel forging, made from an original billet which weighed 117 tons, and the boiler itself is 15,732 square feet heating surface, corresponding to an evaporation of about 120,000 lbs. per hour, with superheater of 2,923 square feet and secondary superheater of 5,938 square feet to reheat the steam between stages of the turbine.

A similar type of installation is at the Calumet Station, Chicago, of the Commonwealth Edison Co., also for 1,200 lb. pressure, with special high speed, high pressure turbine, exhausting at 300 lbs. per square inch to the ordinary mains, for subsequent use with large condensing turbines. In this case the boiler is 15,750 square feet heating surface, the primary superheater 2,120 square feet, the secondary superheater for heating the steam between stages 3,300 square feet and the feed water economiser 9,230 square feet.

The cross drum as before, is of forged steel 48in. diameter with walls 4in. thick while the approximate dimensions of the whole installation are 28ft. wide, 36ft. 6in. deep, and 45ft. high and the temperature of the superheated steam is 750° F. The continuous working results of these two plants are naturally being awaited with great interest. In Germany similar work has been in hand for many years past, largely based on the investigations of Wilhelm Schmidt, who is undoubtedly the modern pioneer of very high steam pressure generation.

Schmidt commenced his work in 1885 and tried to use almost from the beginning 60-100 atmospheres pressure (900-1,500 lbs.) with a special type of reciprocating engine exhausting at about 105 lbs. to ordinary condensing engines. Great difficulties were, however, encountered, but it is interesting to note that about 1895 the well-known German shipbuilding firm of Blohm and Voss of Hamburg constructed a 1,000 h.p. super-pressure marine engine and generator to the designs of Schmidt for the steamship *Allida*, but this particular work was eventually abandoned. Schmidt, however, persevered, and the modern German designs of very high pressure boilers are largely the result of his labours. A good example is the plant now in operation at the works of Messrs. A. Borsig of Berlin, operating at 880 lbs. per square inch (60 atm.), having a drum constructed by Krupps, as usual in the shape of a seamless steel forging. This consists of a horizontal tandem compound engine and a vertical tubular boiler with upper and lower drum of seamless steel 1·89in. thick (48 mm.). At 880 lbs. pressure the degree of superheat corresponds to a temperature of 797° F. (425° C.), and the steam is exhausted from the engine at 160 lbs. per square inch to the ordinary works mains.

Also the Walther Boiler Works, near Cologne, are now building for special conditions water-tube boilers with drums of seamless forged Krupp nickel steel 31·5 inches internal diameter and 2·8 inches thick for pressures up to 1,600 lbs. per square inch. This corresponds to a feed water temperature of about 600° F. (315° C.) and the design is such that the flames and hot gases from the combustion chamber only come into contact with the tubes. Other German very high pressure boilers are those of Hanomag and of Steinmuller.

Enormous steel forgings and steam pressures such as 1,200 lbs. per square inch, with say 750-850° F. superheated steam temperature, would seem, however, on present knowledge, to be the limit for the ordinary general design of water-tube boiler with drums, and whether such types will prove to be a commercial proposition on land remains to be seen, while of course they are quite out of question for marine conditions because of the weight. In fact it will be no exaggeration to state that many serious difficulties commence with the ordinary design of water-tube boiler when about 500 lbs. per square inch is passed, although of course these may be surmounted. Thus the circulation is never positive, simply depending, as well-known, on the difference in specific gravity of water at varying temperatures in the rising tubes aided by the passage of steam bubbles. But in the downcomer tube the action of the bubbles is against the falling water which slows up the current, or may even reverse it, and these factors become more and more troublesome at higher temperatures, while the same applies to dissolved gases and other impurities in the feed water. In fact some power engineers are of the opinion that the thermal efficiency difference of a super station at say 450-600 lbs. steam pressure as compared with 350-400 lbs. is not worth the risk involved and the many new conditions that arise. Altogether those responsible for the design of large stations to-day are in a most unenviable position since an expenditure of say £2,000,000-3,000,000 may result in a plant out-of-date before it can be started up, and it may easily be a better commercial policy to wait for definite super-pressure conditions. This, however, hardly applies to marine conditions, and the results of the new Denny boat for the Clyde service with water-tube boilers at 575 lbs. pressure and 700-725° F. superheat temperature are therefore of more than usual interest.

It ought to be mentioned also that one of the latest developments for ordinary very high pressure conditions, up to say 1,200 lbs. pressure, is the "box" type of water-tube boiler intended primarily for pulverised fuel firing. In this the combustion chamber is composed entirely of a box of tubes through all of which the boiler feed water circulates, as in the new "Wood" and the "Broido" boilers, so as to increase enormously the nett radiant heat absorption surface and overcome another inherent objection to most designs of water-tube boiler, the fact that two or three rows of tubes heated by radiant heat do nearly all the work.

The next stage in evolution of the steam boiler and the attainment of definitely super-pressure conditions would obviously seem to be the elimination of the drums altogether, and the use of small bore steel tubes only, which could be made to stand almost any pressure, even up to 10,000 lbs. per square inch. The position, however, as regards the use of drums or cylindrical containers of considerable size for super-pressures has been entirely altered by the remarkable new work of Professor A. G. Löffler, of Vienna, commenced in 1924, by means of which a comparatively simple and ordinary type of drum can be used at pressures as high as 1,700 lbs. per square inch.

Early History of Super-Pressure Working.

Before describing this, however, it will be as well to give a brief reference to the early history of super-pressure steam generation. Much further investigation on this interesting section of the subject is badly needed, but the real pioneer is Jacob Perkins, who was born in the United States, at Newburyport, Mass, in 1766, although of English descent, his ancestors having emigrated from Gloucestershire in 1631. Perkins was a man of most remarkable achievements, although his name to-day is almost entirely forgotten. Thus, when only 21 years of age he built minting machines in Massachusetts, and later invented a nail cutting and heading machine and a sterotype check plate for printing bank notes sc as to check counterfeiting. He came to England in 1818, and approached the Bank of England on the latter subject, and they seem to have treated him very badly, turning down the invention and then using it afterwards with only minor modifications. Perkins, however, settled in England, and amongst his other inventions were improvements in water wheels, better methods of making leather fire-hose, and improved principles in the heating and warming of buildings.

It was in 1824 that he first turned his attention to super-pressure steam generation and invented a steam gun to propel bullets, using instead of gunpowder, steam at 1,500 lbs. per square inch pressure. The Duke of Wellington was interested in this project, but eventually nothing came of it. Perkins then advocated the use of steam at 1,000-3,000 lbs. pressure in engines and superheated steam at 400-500° F., which was of course at that time regarded by Watt and the foremost engineers of the time as the ideas of a madman and much worse even than those of Trevithick. In 1837 Perkins read a paper before the Institution of Civil Engineers on super-heated steam, and was far in advance of Hirn in 1850, who is generally regarded as the inventor of the idea of raising the temperature of steam so that it can cool again over a considerable range without condensation. He also invented a single-acting uniflow steam engine in 1820, and a compound type in 1827, to work at 1,400 lbs. per square inch and 1,000° F. steam temperature, this idea of the uniflow engine being subsequently developed by L. J. Todd in 1885.

Altogether Perkins was far ahead of his time, and it may be stated also that his descendants have all been clever engineers, his son, A. M. Perkins, being the inventor of a steel engraving process and the first adhesive stamps used in the United States, while he also investigated the use of very high pressure steam for iron smelting. His grandson, Loftus Perkins, born in London in 1834, carried on in a remarkable manner the family tradition of high pressure steam practice. In 1859 he designed a steam engine to work at 600 lbs. pressure and built a yacht called the *Anthracite*, fitted with a triple expansion engine, not only on this principle, but also having the ultra modern method of re-heating the steam between the cylinders, while the boiler was of a special water-tube type. He is stated to have obtained results of $1\frac{1}{4}$ lbs. of coal per shaft horse power, and it is almost incredible this remarkable work was allowed to lapse, in spite of the fact of the results of detailed tests by the United States Navy, which substantiated the inventor's claims. Loftus Perkins also developed many other inventions, including a steam driven motor car and a water meter, while the present and fourth generation of the Perkins' family is engaged in the manufacture of steam baking ovens.

It may be stated also that in Germany nearly a century ago Dr. Alban tried to build steam engines to work at 50 atmospheres (750 lbs.) but met with little practical success, while other much later workers in this field of super-pressure steam are Dr. Jaroslav Havlicek in Czecho-Slovakia and Jacques F. Overwyn in the United States.

The " Löffler " Generator.

The principle of the " Löffler " super-pressure steam generator consists essentially in avoiding the difficulties of the ordinary externally heated water-tube boiler by conveying heat to the water, not through the metal walls of cylinders, drums, or tubes in the usual way, but on the internal principle, with the aid of very highly superheated steam bubbled into the water, the point of heat admission to the circuit from the combustion chamber being the superheater coils only and not the boiler at all in the ordinary sense of the word.

In this way it is claimed a steel cylinder of simple construction can be used for the conversion of the water into steam under super-pressure conditions without being subjected to any stresses and strains from external heating, due to defective circulation and local interruption of the rate of heat transmission to the water, such as normally caused by bubbles of steam or gas and any trace of impurities present, as already indicated, while complications due to constructional difficulties in the way

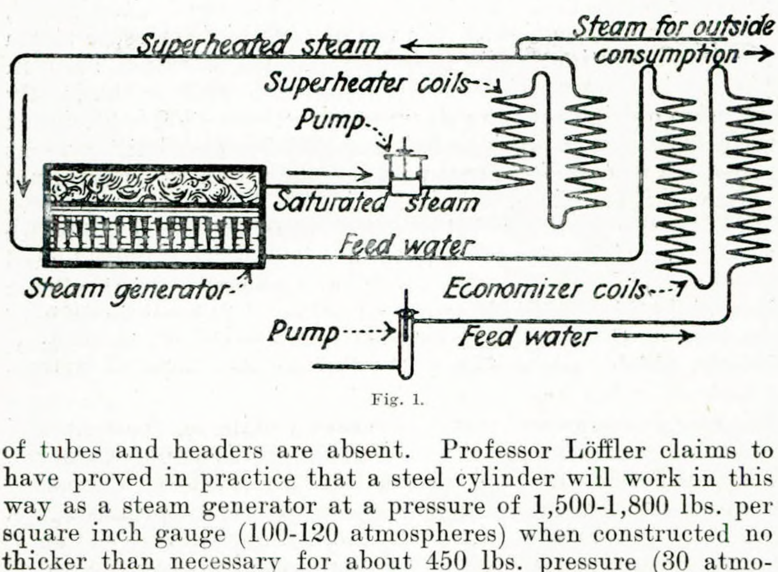


Fig. 1.

of tubes and headers are absent. Professor Löffler claims to have proved in practice that a steel cylinder will work in this way as a steam generator at a pressure of 1,500-1,800 lbs. per square inch gauge (100-120 atmospheres) when constructed no thicker than necessary for about 450 lbs. pressure (30 atmospheres) with the present ordinary water-tube boiler methods of steam generation by direct external heating. That is to say by adding the heat through a simple and comparatively small bore steel coil and using part of the steam itself as the heat conveying medium, pressures of 1,500 lbs. per square inch and over, are rendered available with quite ordinary methods of boiler construction, so that huge and costly forgings several inches thick and weighing up to 100 tons, are quite unnecessary.

The simple principles of the "Löffler" steam generator are shown diagrammatically in Figure 1. On the left is the cylindrical steam generator with a water temperature of about 600° F. (320° C.), that is 1,540 lbs. per square inch pressure, heated only by the direct passage into the water of superheated steam at a temperature of about 930° F. (500° C.), the feed-water being passed in at one end through economiser coils by means of a feed pump as usual, while the superheated steam is admitted at the other. The superheater coils are fired externally in the ordinary way by an oil blast flame or any other convenient method and the hot gases of combustion after passing over the coils, travel round those of the feed-water economiser and return therefore a further considerable part of the heat to the circuit before final discharge to the chimney, giving in this way a high over-all thermal efficiency.

In the circuit between the saturated steam discharge from the cylindrical generator and the superheater is a motor-driven pump or "booster," generally of the piston type, operating under the full pressure, which discharges the steam through the superheater as it is raised to the very high temperature of 930° F. (500° C.). This superheated steam is then returned continuously to the generator, being forced under the surface of the water, thereby producing more steam. The pressure and the amount of steam in the circuit rises rapidly and the surplus is drawn off continuously from a point between the superheater and the generator, as indicated in the illustration. Generally the re-circulation of the steam is such that about 3½ times the volume passes through the water as compared with the amount delivered.

The first experimental steam generation plant on these lines was set at work in December, 1924, at the works of the Wiener Lokomotiv-Fabriks-Aktiengesellschaft at Floridsdorf, Vienna, and the results are stated to have been extremely promising, steam being generated continuously and without difficulty at an average pressure of 1,470 lbs. per square inch (100 atmospheres) and a steady superheated steam temperature of 930° F. (500° C.) without leakage, the outside of the tubes next to the flames not being over 930° F. (500° C.). The simple cylindrical steam generator or "evaporator" as Professor Löffler terms it, was constructed of ordinary Siemens-Martin steel, essentially a drawn tube with covers shrunk into the ends, while the hourly nett evaporation at 1,470 lbs. and 570° F. (300° C.) was 6,600 lbs. (300 kilos).

The steam circulating or boosting pump, of the piston type as already indicated, was driven by an electric motor, and in spite of the fact that the stuffing box of the piston rod has to be tight under conditions of 1,500 lbs. per square inch pressure or over and an average temperature of 590°-605° F. (310°-320° C.), here also the results are stated to be satisfactory.

In testing, the custom was to run for 6-9 hours per day, and a very large number of runs was made under different conditions, which incidentally was an extremely severe strain on the plant because of the continual shutting down and starting up again.

Further, it may be stated that to set the plant at work from cold, steam from an outside source has to be supplied, and a very small auxiliary low-pressure boiler, if necessary down to 28 lbs. per square inch, can be used for this purpose. In the above experimental plant at Vienna a pressure of 170 lbs. was available, and under these conditions 1,470 lbs. per square inch (100 atmospheres) was obtained in about one hour, very much less than required for ordinary boiler plants.

The most important part of the circuit is of course the high temperature superheater, which is also constructed of comparatively small bore tubes of Siemens-Martin steel such as used for ordinary superheaters, and contrary to what might be expected there is stated to be no undue wear and tear or other trouble because of the temperature and the pressure, the installation being also claimed to be small, light in weight, and reliable. The reasons given are that only really dry steam passes through at a steady and very high speed with an absolutely even rate of heat transmission in a manner that does not obtain under ordinary steam boiler conditions.

The general intention is to use the very high pressure steam, at say 1,500 lbs. per square inch, and 595° F. (315° C.) temperature, in an ordinary type of piston steam engine but of stronger design when smaller installations have to be supplied, and to adopt high speed turbines for marine work and large land plants. Also as usual a small very high speed steam turbine can be employed exhausting at any required pressure, say 200-600 lbs. per square inch gauge into the steam mains of any existing power plant.

The Wiener-Lokomotio-Fabriks Aktiengesellschaft are erecting a plant of 1,000 K.W. on this system to drive their factories, with 1,470-1,765 lbs. pressure (100-120 atmospheres) and a superheated steam temperature of 750-930° F. (400-500° C.), using as before, a vertical piston steam engine.

Also a very large commercial installation of 18,000 K.W. is now being constructed for Messrs. The Witkowitzer Steinkohlengurben in Mahrisch-Ostrau, Czecho-Slovakia, in connection with the collieries belonging to this Company. The plant will consist of three very large cylindrical internally-heated steam generators, having a combined output on normal working of 130,000 lbs. of steam per hour, constructed by the Associated Witkowitzer Eisenwerk Company, the working pressure being 1,700 lbs. per square inch, and the superheated steam temperature 840-930° F. (450-500° C.), all on the usual principle of heating the superheater coils and passing the resulting very high temperature steam into the water.

The steam turbine to be used with this installation is of the new "Lossl" design, built by the well-known German firm of turbine builders, Messrs. Erste Bruner Machinenfabrik, being one unit of 18,000 K.W. capacity and having re-heating between the stages on the latest principles, as well as bleeder steam heating for the feed-water passing to the generators.

The "Löffler" system of high pressure steam generation is also claimed to be particularly valuable for locomotive work and there is now being built by the Wiener-Lokomotio-Fabriks Aktiengesellschaft, a large main line express locomotive on this principle, of 2,000 h.p. for a speed of about 62 miles (100 kilometres) per hour, operating at 1,470-1,760 lbs. pressure (100-120 atmospheres) and 840-930° F. (450-500° C.) steam temperature, using triple expansion piston steam engines, while it is the intention also to apply the principle to marine conditions.

SOME PROPERTIES OF STEAM.

With regard to the use of super-pressure steam generators of the simple tube type, that is without drums, before considering the practical difficulties of generating steam in a small bore tube and the methods that have been adopted to cope with the problem, it will be as well, from the point of view of facilitating explanation, to refresh our memories with some of the more elementary facts of steam generation.

When water at 32° F. (0° C.) (freezing point) is heated, it first of all contracts until it reaches approximately 39·1° F. (4° C.), a very striking and contradictory property, common, however, to many liquids. In the case of water 39·1° F. (4° C.) is, therefore, the point of least volume, approximately as 0·9999 is to 1·0000 in comparison with 32° F. As soon as the temperature passes this point the normal expansion begins and continues in the form of a more or less regular and steady curve to 212° F. (100° C.) when a volume of water 1·0000 has expanded to 1·0441, that is only a slight increase.

Then suddenly at 212° F. and the normal atmospheric pressure of 14·7 lbs. the water is converted into steam with violent ebullition or boiling, the 1 lb. of water occupying a huge volume as steam, still at 212° F. (100° C.). That is to say, between 39·1° F. (4° C.) and 212° F. (100° C.) there has been a certain forcing apart of the molecules of the water equivalent to a small increase in volume, but at 212° F. (100° C.) there is sudden very great expansion to form steam in which the water molecules are widely separated, the result being a gas (steam). To do this a large amount of energy is required, what is known as the latent (lost) heat of steam. Thus when 1 lb. of water at 212° F. and 14·7 lbs. pressure is suddenly converted into a gas (steam) at the same temperature of 212° F. the heat absorbed, "lost," or rendered latent is 970·7 units, a huge figure and very different in amount from the approximately 180 units absorbed in heating 1 lb. of water from 32° F. to 212° F.

It will be remembered also that in a given bulk of water under ordinary normal conditions, as in a glass flask, steam boiler, or other vessel, the heat is only absorbed at a given restricted rate. That is small portions of the water nearest the source of heat, at the bottom for example of a glass flask heated by a Bunsen burner, are suddenly converted into steam, which form large bubbles and are given off explosively, constituting what is known as "boiling." Water, as with all other liquids, is converted into a gas (steam) at a temperature depending on the pressure above it, that is the force pressing down on the surface of the liquid water, tending to prevent the evolution of the water in the form of steam.

Thus in the air at sea level the atmosphere is normally pressing down on the level of water with a pressure of 14·7 lbs. per square inch, when the energy in the water in the form of heat is not sufficient to allow it to boil, that is to force continuously particles of steam into the air against this pressure, until the temperature has reached 212° F. As the atmospheric pressure varies (recorded by the barometer) the boiling point of water, therefore, varies also. Thus as mountains are climbed the air pressure diminishes and the boiling point is, therefore, lowered in proportion, and conversely, if the pressure rises, by going down a mine for example or enclosing the water in a pressure tight vessel such as a boiler, the boiling point also rises. That is to say, the latent heat varies with the boiling point, and if the latter is high and the water has in consequence been expanded more, then the latent heat is less because the sudden expansion in the volume to steam is not so great in proportion and less energy is required. These facts are indicated by the following typical figures from the Steam Tables :—

LATENT HEAT OF STEAM AT DIFFERENT PRESSURES.

Approx. Gauge Press. Lbs.	Absolute Pressure actual above zero.	Boiling Point Temperature °F.	Sensible heat to raise 1lb. water from 32°F. to 212°F.	Latent heat to convert 1lb. water at boiling point into steam at the same temperature.	Total Heat.	Weight of cubic ft. of water which at 39·1°F. is 62·425 lbs.	Relative Volume compared with 32°F.
—	1	101·8	69·5	1035·1	1104·6	62·025	1·006
—	5	162·3	129·8	1000·8	1130·6	60·850	1·026
—	10	193·0	160·3	982·6	1142·9	60·250	1·036
0	14·7	212·0	179·3	970·7	1150·0	59·640	1·044
5	10	227·3	195·7	960·1	1155·8	59·375	1·053
20	35	259·0	228·1	938·6	1166·7	58·600	1·060
100	115	338·4	309·2	879·8	1189·0	55·700	1·120
150	165	365·9	338·2	856·6	1194·8	54·860	1·140
200	215	387·9	361·3	837·7	1199·0	53·770	1·160

As the pressure increases, therefore, in a boiler the absorption of latent heat is correspondingly less, although the total heat is greater. Thus at 150 lbs. pressure the latent heat is about 856·5 as compared with 970·7 at the atmosphere, while if water be placed under a reduced pressure by means of a vacuum pump for example the boiling point is lowered and the latent heat increases. Thus under a vacuum of 28 ins. of mercury, equivalent to 1·0 lbs. pressure absolute, water will boil vigorously at only 101·8° F. (38° C.), that is when lukewarm, and the latent heat is 1035·1 instead of 970·7 at the atmospheric pressure of 14·7 lbs.

The great value of the increase in the total heat of steam, as pointed out by Carnot, Rankine, and other investigators, and the cause of the struggle to increase the working pressure, are, therefore, rendered obvious on studying the Steam Tables, since the bulk of the heat energy put into the water is taken up by raising the temperature of the water (sensible heat) and by the latent heat of steam, leaving only the sensible heat in the steam available for useful work in pushing the piston of the engine or the blade wheels of the turbine. Thus from the Steam Table figures at about 16 lbs. gauge pressure the total heat is 1166·3 B.Th.U. per lb. and at the temperature of the steam, 252·0° F., the total heat energy available for work is only 61·2 B.Th.U. But at about 200 lbs. gauge pressure the total heat is 1199·0 B.Th.U. and 94·2 units are available for work. Or in other words, because of the increase in pressure, for 2·8% more heat added to the steam 54% more heat is available for useful work, a very great increase in efficiency from the practical point of view.

The essential difficulty of the abolition of cylinders and drums in boiler construction, and the use of tubes only, is ebullition, due to the absorption of latent heat, that is the sudden and violent conversion of a small volume of liquid (water) into a very large volume of gas (steam). For this reason, if water is heated in a narrow tube the formation of bubbles of steam means that the generation of steam is erratic, spasmodic, and almost explosive, the contents being lifted up bodily and blown out so that it is impossible for the water to remain permanently in contact with the heated tube wall. It is true that the latent heat of steam and therefore the intensity of ebullition diminishes with the increase in pressure, and the following few figures, mainly below super-pressure conditions, from the Steam Tables illustrate the point:—

REDUCTION IN LATENT HEAT OF STEAM (AND THEREFORE INTENSITY OF EBULLITION) AT HIGH PRESSURES.

Approx. Gauge Press. Lbs.	Absolute Pressure actual above zero lbs.	Boiling Point Temperature °F.	Sensible heat to raise 1 lb. water from 32°F. to 212°F.	Latent heat to convert 1 lb. of water at boiling point into steam at the same temperature.	Total Heat.	Volume cubic feet per lb.
350	365	435·9	412·3	790·2	1202·5	1·273
450	465	460	438	763	1201	1·003
500	515	471	450	752	1202	0·903
750	765	513	500	695	1195	0·59
1000	1015	547	538	649	1187	0·43
1250	1265	575	571	604	1175	0·35
1500	1515	600	604	558	1162	0·274

But even at 1,500 lbs. per square inch the latent heat of steam is still 558 B.Th.U. per lb. as compared with 960·7 at atmospheric pressure, and the consequent degree of ebullition renders the use of narrow bore tubes an impracticable proposition under ordinary conditions.

THE "ATMOS" BOILER OF J. VICTOR BLOMQUIST.

A very ingenious method of surmounting this inherent disadvantage of the generation of steam in a comparatively small bore tube is that of J. Victor Blomquist of Stockholm, known as the "Atmos" boiler, intended for normal operation at about 1,500 lbs. per square inch pressure.

The principle consists in the use of a long horizontal steel tube, about 12 ins. in diameter, which in the stationary position is about half filled with water, and is made to rotate at a comparatively high speed, approximately 300 revs. per minute. This rotary tube is then heated on the outside for its full length from underneath and the action of centrifugal force causes the water to be maintained firmly in contact with the tube all round the inner surface, against the action of the steam bubbles forming a layer $\frac{1}{4}$ in. to 2 ins. thick so that continuous and

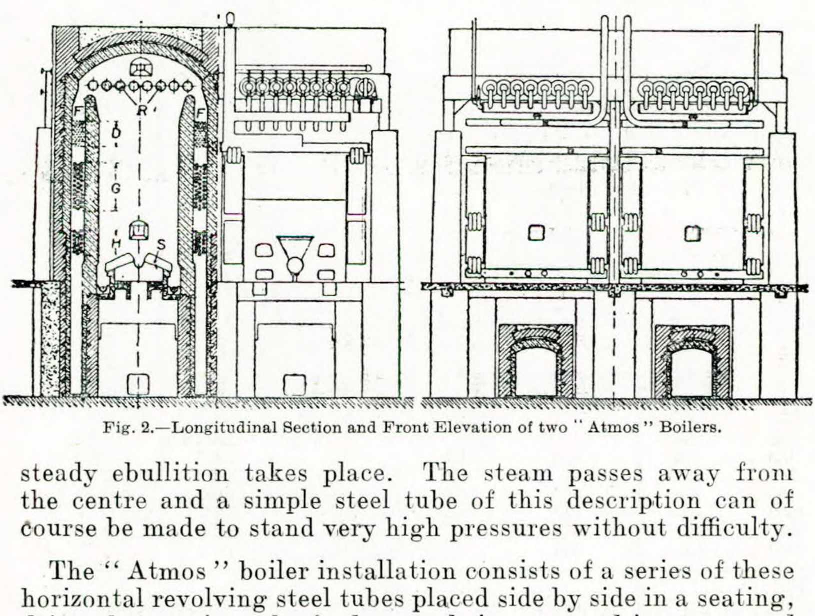


Fig. 2.—Longitudinal Section and Front Elevation of two "Atmos" Boilers.

steady ebullition takes place. The steam passes away from the centre and a simple steel tube of this description can of course be made to stand very high pressures without difficulty.

The "Atmos" boiler installation consists of a series of these horizontal revolving steel tubes placed side by side in a seating, driven by gearing, the feed-water being pumped in at one end continuously and the steam withdrawn at the other, there being included a special form of packing joint between the rotary tube and the stationary casing at each end, which is claimed to withstand without leakage a pressure of 1,500 lbs. per square inch or over. The firing is carried out by means of coal, with mechanical stokers of pulverised fuel burners, oil, gas, or any other desired manner.

This boiler was first set at work in 1923 at the Carnegie Sugar Refinery, Gothenburg, Sweden, operating at 900 lbs. per square inch and a second boiler was subsequently installed for 1,500 lbs. The illustrations (Figures 2 and 3) represent

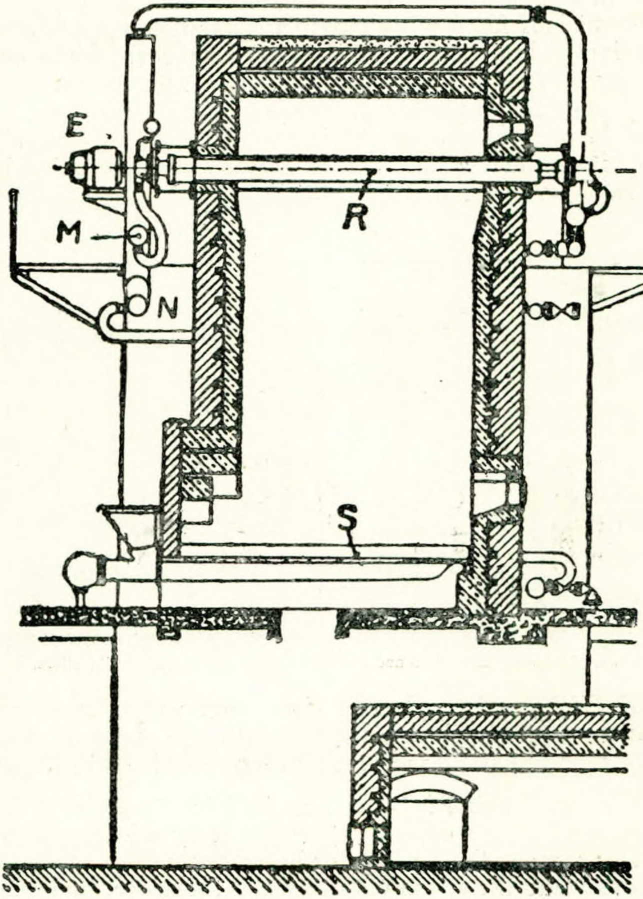


Fig. 3.—Cross Section of "Atmos" Boiler.

the longitudinal and the cross sections of an installation of two "Atmos" super-pressure steam generators, each of which consists of eight horizontal steel tubes or rotors, which have an effective length of 11 ft. 2 ins., and are 12 ins. external diameter, the thickness of the tube being $\frac{3}{4}$ in. This gives a rated capacity of 16,500 lbs. of water per hour, that is 2,060 lbs. for each tube, and, as seen in the illustrations, the tubes project out at each end of the setting back and front.

As regards the construction of the joints between the rotating tubes and the inlet and outlet portions for the water and steam respectively, this is indicated in Figure (4), the rotating

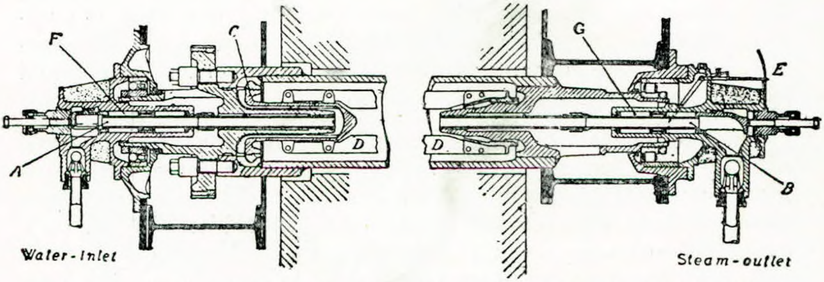


Fig. 4.—Section through joints of the "Atmos" boiler showing the ends of a Rotary Tube and the Patent Stuffing Boxes.

tubes in the two illustrations being (F and G). The stuffing boxes are packed in the ordinary way and divided into two portions by a gland through which lubricating oil is passed under high pressure to give about 8 ins. of an oil column above the steam pressure in the rotating tubes, and it is stated that the arrangement is highly satisfactory, there being little or no leakage, while the amount of oil required is extremely small. Thus it is claimed that in the original installation at Gothenburg the oil consumption for the six rotary tubes, that is 12 stuffing boxes, is only one-tenth of a gallon for the day's run of 10 hours.

The speed of each of the rotary tubes is 330 revs. per minute, the drive being by means of gearing through a small electric motor or steam turbine (E) and the whole arrangement runs on ball bearings, being so fixed that no longitudinal movement can take place at the driving end. To allow for expansion and contraction, however, the tubes can move freely at the opposite end on roller bearings, the supporting ring being made specially wide enough to allow of this motion without difficulty.

The whole setting is heated in this case by any convenient type of mechanical stoker (S), the flames and hot gases after passing round the rotating tubes (R) being conducted down through the vertical flues (F) at each side, in which are placed at the top superheater tubes (D) and two groups of feed-water or economiser tubes (G and H) at the bottom, giving in this way a very high over-all thermal efficiency. These feed heaters (G and H) are constructed of steel pipes which have welded to them a series of projecting spirals or fins so as to increase the rate of heat transmission, and the velocity of the flue gases at this point is very high, about 2,000 feet per minute, obtained by mechanical draught, with the object of preventing deposition of any soot or other solid material by the mechanical scouring action of the gases. Alternatively the tubes can be cleaned by the usual type of steam jet blower.

The feed-water is supplied to the installation at a pressure of about 140 lbs. per square inch by a centrifugal pump, passing first into the lower tubes (H) and generally the water is discharged from this section of the tubes at about 320° F. to a closed vessel where the separated scale and any other solid material that may be present is allowed to deposit. From here the water is taken by a very high pressure pump, also of the centrifugal type, driven at a constant speed by a steam turbine or electric motor, and passed into the second or high-pressure section of the economiser (G) at a figure of 1,500 lbs. pressure per square inch, going from here direct into the front end of the rotating tubes. The arrangement is such that, as already indicated, the pumping continues at one steady speed, and any excess water is automatically passed back again to the suction side by means of an automatic valve without altering the running of the pump, while the temperature of the water entering the rotating tubes is about 600° F., that is to say approximately boiling point at 1,500 lbs. pressure. The steam is then delivered from the back end of the rotating tubes and at the speed mentioned, namely, 330 revolutions per minute, the thickness of the water skin or layer all round the inside of the tubes being, as stated, approximately $\frac{1}{4}$ in. to 2 ins. according to the rate of the evaporation required. If, however, pure distilled water is used for the evaporation, which would seem to be the best practice, then the two portions of the feed-water economiser (G and H) are combined together as one high-pressure set in series, raising the water direct to 600° F.

The installation further includes inside the tubes a spiral arrangement of thin steel plate which compels the water in a positive fashion to follow the rotation of the tube and give an even layer inside, while drain cocks are also embodied in the feed-water chests (M and N). Also, there is a special safety device in order to ensure a continuous supply of feed-water to the tubes in case by any chance steam should be raised in the high-pressure feed-water section (G), this being carried out by the use of steam chests (M and N) which are essentially steam separators or water locks, any steam being automatically conducted past the rotating tubes without interfering with the water supply, while there is in addition an automatic feed-water regulator, which is an essential part of the design in view of the small water content. This consists of a cast steel vessel containing inside an inverted bell suspended from the top by means of a long spiral spring and having the open end submerged in mercury. The interior of this floating bell is connected to the water end of the revolving boiler tubes while the space in the casing outside the bell is joined to the steam end, the remainder of the space available, both inside and outside the bell, being entirely filled up with condensed water. The pressure difference between the steam and the water ends of the rotating tubes therefore causes a vertical movement of the inverted bell, and by means of a lever and spindle mechanism this movement operates a needle valve which acts as a bye-pass between the delivery and the suction side of the high pressure pump and alters automatically the amount of the water passing to the rotating tubes. Further, it may be stated that the installation includes a special water gauge arrangement which indicates at a glance the thickness of the water layer in the rotating tubes.

The "Benson" Generator.

The principle adopted by Mark Benson to overcome the troubles of ebullition in a narrow bore tube is the even more remarkable one of doing away with it altogether, generating the steam under the actual "critical" conditions of about 3,200 lbs. per square inch absolute pressure and 706° F. (375° C.) temperature when water is converted into steam at the same volume and therefore without the absorption of any latent heat.

For many years Benson, who is a native of Czecho-Slovakia, but long resident in the United States, was a chemist in the petroleum industry and carried out a large amount of work on the "cracking" of the heavier fractions to lower boiler point products, that is petrols, suitable for high speed internal combustion engines. In this work, highly superheated steam was used, which lead to a detailed study of the Steam Tables for all pressure conditions and the idea of converting water into steam without ebullition under the critical conditions.

The Benson super-pressure steam generator was patented throughout the world in 1922, the first installation being erected and operated at Rugby (England) early in 1924. In general the principle, subject to numerous minor modifications, consists of a very long vertical coil of small bore ($\frac{3}{4}$ in. diameter) steel tubing with walls $\frac{1}{4}$ in. thick fixed between an inner and outer circular casing of refractory material, the whole arrangement being about 8 ft. high and 7 ft. diameter. Distilled water was passed continuously through this coil, entering at the bottom with the aid of a gear-driven force pump operating always at 3,200 lbs. pressure per square inch, while the coil was heated externally by means of an oil blast flame, entering at the top and passing downwards. As the water travelled upwards through the coil it was gradually heated up until finally, within about 10% from the end of the travel, it reached 706° F. (3750° C.) the critical conditions, the volume being at this point about three times that of water at 60° F. The pressure was of course maintained all the time at 3,200 lbs. because of the pump, the water being quietly converting into steam at the same volume and, therefore, without ebullition and the absorption of latent heat, the rated evaporation being 10,000 lbs. of water per hour.

The steam at 3,200 lbs. was then discharged at a temperature of about 720° F. to a special reducing valve and the pressure lowered, corresponding to a temperature of about 620° F., followed by a passage through a superheater consisting of a similar but somewhat shorter coil of $\frac{3}{4}$ in. steel tubing above the generator, the whole setting being 17 ft. high, so that the final pressure of the steam delivered was 1,500 lbs. per square inch and the temperature approximately 865° F. (465° C.), that is about 270° F. (135° C.) of superheat at 1,500 lbs. pressure, although in some cases the figure rose to 910° F. (490° C.).

The design of the complete experimental plant at Rugby also included the use of a high pressure steam turbine running at 25,000 revolutions per minute, exhausting at 200 lbs. per square inch, with the development of 350 K.W. by the drop in the pressure, to an ordinary pressure condensing turbine, giving another 900 K.W., that is a total of 1,250 K.W.

The principle of Benson's work will be clear on studying the higher figures of the Steam Tables, the following typical figures being taken from Goodenough's well-known book "Properties of Steam and Ammonia."

LATENT HEAT OF STEAM AT HIGH PRESSURES.

Approx. Gauge Press. Lbs.	Absolute Pressure actual above zero lbs.	Saturation °F.	Sensible heat to raise 1 lb. water from 32 to 212°F.	Latent heat to convert 1 lb. of water at boiling point into steam at the same temperature.	Total Heat.	Volume cubic feet per lb.
1770	1785	620	633	518	1151	0·226
1900	1915	630	648	495	1143	0·205
2040	2055	640	664	470	1134	0·186
2350	2365	660	700	412	1112	0·151
2510	2525	670	721	377	1098	0·134
2865	2880	690	776	280	1056	0·101
3060	3075	700	820	198	1018	0·080
3185	3200	706	921	Nil.	921	0·0

It will be seen, therefore, that as the pressure rises the amount of the latent heat continues to diminish and after 2,000 lbs. pressure the figures become abnormal and drop very rapidly, being for example 470 B.Th.U. at 2,040 lbs. gauge pressure, but only 280 B.Th.U. at 2,865 lbs. gauge as compared with 960·5 B.Th.U. at the atmosphere. But even at 3,060 lbs. gauge there is still a perceptible amount of ebullition, and the obvious method is to go right up to the critical conditions of 3,185 lbs. gauge or 3,200 lbs. absolute when there is no latent heat at all and entire absence of steam bubbles, so that a narrow bore coil can be used without difficulty. It may be mentioned that this phenomena of "critical conditions," that is the conversion of a liquid into a gas at the same volume, was discovered in 1822-1823 by Cagnaird de la Tour and was investigated by Faraday. It is well illustrated by a familiar laboratory experiment in which liquid CO_2 is heated in a sealed tube of thick glass. The liquid expands for a time in the ordinary way and then suddenly at the critical temperature (88·7° F. in the case of CO_2) the definite line or meniscus at the top of the liquid, which has already begun to flatten out, becomes hazy and then suddenly vanishes so that the whole tube contains gas only at the same total volume as before. When once steam is produced then it can be lowered again in pressure to any desired amount according to the turbine conditions, down as low as 1,500 lbs. or even under, but the main point is that steam has been generated in a cheap and simple coil under super-pressure conditions.

The original design of the proposed experimental lay-out for Rugby is shown in Figure (5), reproduced from "Power" (U.S.A.), 22nd and 29th May, 1924, in which was given by P. W. Swain the first description of the "Benson" generator. The details will be clear from the attached description, but the complete installation as shown was not erected, the main point of course being to find out if steam could be generated in this way, the turbine being a relatively minor matter. Thus a number of turbine builders are prepared to-day to build units to operate at 20,000-25,000 revs. per minute with steam at 1,500 lbs. per square inch and 850° F. temperature. In fact there is no reason why 2,000 lbs. pressure or over should not be used, whilst it is almost certain ordinary speeds of 3,000 revs. per minute will be found to be satisfactory, although naturally a number of problems have to be solved, such as disc friction, and tight yet sensitive gland spindles and governor valves.

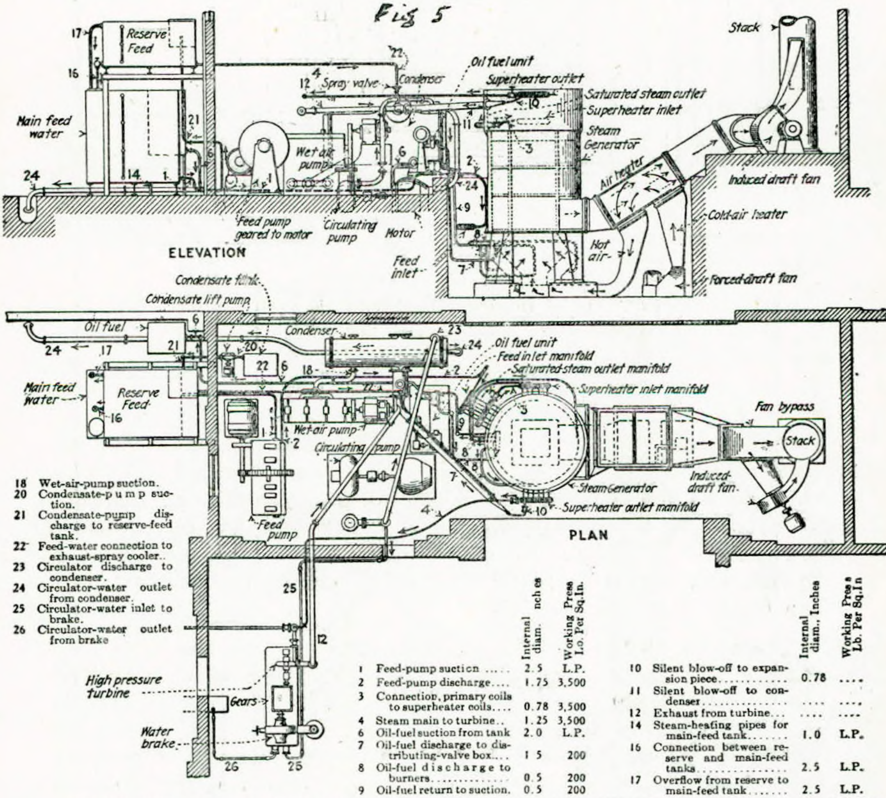
The steam generator is seen in the centre of the illustrations showing the cylindrical container, the bottom part of which contains the generator coil and the upper portion the superheater. As regards the thermal efficiency this is probably over 95% the oil blast flame as already indicated being directed downwards between the two walls, first over the superheater coils and then the generator, the hot gases being finally discharged at the bottom of the setting and passing up through an air heater to the chimney as controlled by an induced draught fan. The air for combustion at the burners is heated in this way and it is stated the final gases in the chimney base can be cut down below 250° F.

The tests, the first of which was carried out on the 17th February, 1924, were a great success, and proved conclusively that steam can be generated in this way continuously and quietly under critical conditions in a small bore steel tube, the output being about 8,000 lbs. of steam per hour because a temporary condenser used was not large enough to take the full load of 10,000 lbs.

The enormous possibilities in the way of using steam under the very high super-pressure conditions possible with the Benson generator are illustrated in a simple manner by taking any given total heat of steam, say 1,350 B.Th.U. per lb. calculated from water at 32° F. If this was used in a condensing steam engine at 100 lbs. gauge pressure, for example, the steam temperature necessary to attain a total heat of 1,350

B.Th.U. would be 648° F. and the total heat units available for actual work down to 29 ins. vacuum would only be 400, that is 29·6% of the total in the steam, calculated of course on adiabatic or theoretically perfect expansion principles. With a super-power station figure, however, of 350 lbs. gauge pressure the total temperature would have to be 677° F. and the

Fig 5



18 Wet-air-pump suction.
20 Condensate-pump suction.
21 Condensate-pump discharge to reserve-feed tank.
22 Feed-water connection to exhaust-spray cooler.
23 Circulator discharge to condenser.
24 Circulator-water outlet from condenser.
25 Circulator-water inlet to brake.
26 Circulator-water outlet from brake

		Internal diam. Inches	Working Press. Lb. Per Sq.In.
1	Feed-pump suction	2.5	L.P.
2	Feed-pump discharge....	1.75	3,500
3	Connection, primary coils to superheater coils....	0.78	3,500
4	Steam main to turbine..	1.25	3,500
6	Oil-fuel suction from tank	2.0	L.P.
7	Oil-fuel discharge to distributing-valve box....	1 5	200
8	Oil-fuel discharge to burners..............	0.5	200
9	Oil-fuel return to suction.	0.5	200
10	Silent blow-off to expansion piece............	0.78	....
11	Silent blow-off to condenser...............	....	....
12	Exhaust from turbine...	....	....
14	Steam-heating pipes for main-feed tank.......	1.0	L.P.
16	Connection between reserve and main-feed tanks...............	2.5	L.P.
17	Overflow from reserve to main-feed tank.......	2.5	L.P.

–EXPERIMENTAL 1,000-KW. PLANT AT RUGBY (PATH OF FEED WATER AND STEAM SHOWN IN SOLID BLACK)

Reproduced from "Power" (New York), 22nd May, 1923.

heat theoretically available for work 468 B.Th.U. or 34·7% of the total. Since the efficiency of generation, expansion efficiency, and the other factors are approximately the same at different pressures, the increase in efficiency by raising the steam pressure from 100 lbs. to 350 lbs. and using a condensing engine or turbine, is about 17% calculated from the raw coal.

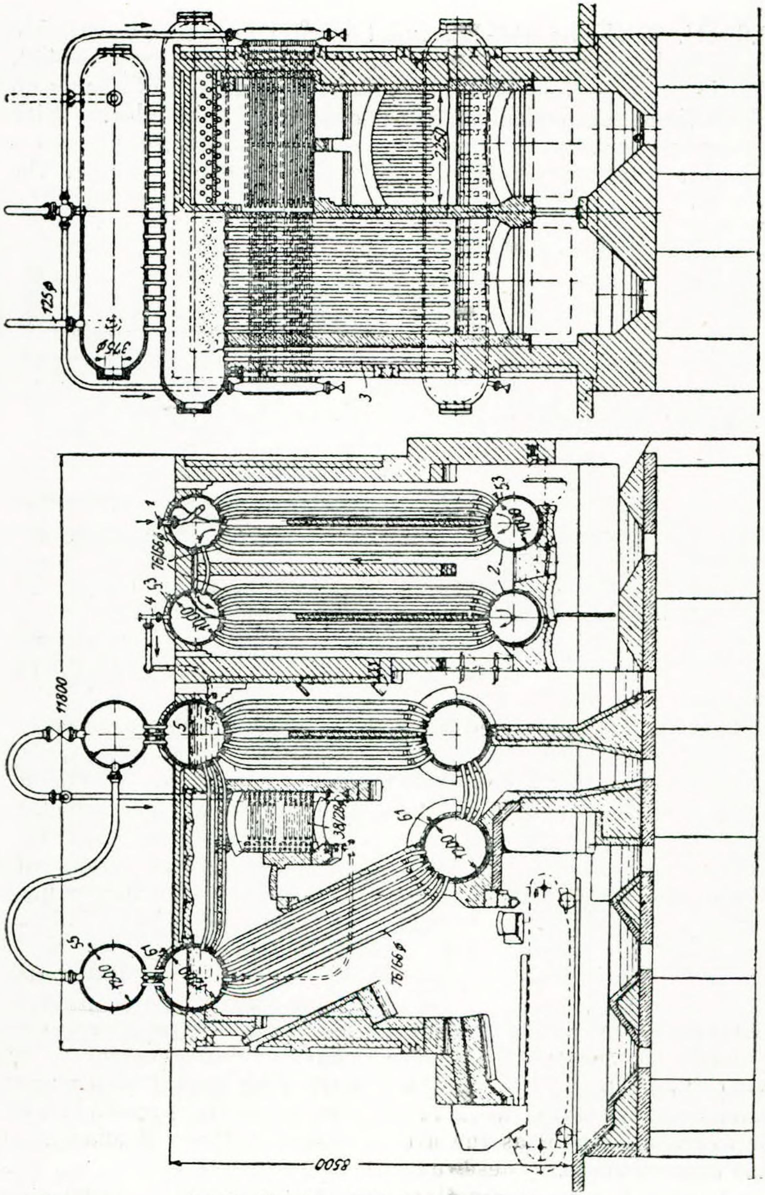


Fig. 6.—"Walthers" High Pressure Boilers.

At 3,200 lbs. the total heat would have to be 987° F. for the total heat content of 1,350 B.Th.U. and the heat units available for work would be 595, that is 44% of the total or about 26% saving in the coal bill over and above that of present super-power station conditions at 350 lbs. pressure.

In practice a "Benson" generator delivering steam at 1,500 lbs.and 850° F. superheat would give about 30-32½% thermal efficiency and there would seem to be every possibility of operating at 2,000 lbs. or over, with several stages of reheating, so as to give 35-40% thermal efficiency, practically equal to the internal combustion heavy oil engine. It should be emphasised that this high thermal efficiency has nothing to do with the absence of latent heat and even if steam were used at 3,000 lbs. pressure in a condensing turbine set at say 40% thermal efficiency, there will always be a very serious loss of heat in the condenser. The advantage is merely that the method enables steam to be produced in a simple and practical fashion at these enormous pressures, and the thermal efficiency is due entirely to the use of this high pressure because of the increase in the proportion of total heat in the steam available for work as compared with say 300 lbs. pressure. That is to say if someone invented an ordinary water-tube boiler with large water content, to work at 2,000 lbs. pressure, the thermal efficiency would be just the same as a tube generator at 3,200 lbs. pressure subsequently reduced to 2,000 lbs.

The advantages claimed for the "Benson" steam generator are simplicity, convenience, efficiency, small capital cost, light weight, and reduced floor space for the production of steam at the highest pressures to give a much better thermal efficiency than is possible with huge boilers made of steel forgings. Obviously the question of weight per unit of power generated with a condensing steam turbine is a matter of primary importance to marine engineering and it is stated for example that under the best conditions with high pressure "Scotch" boilers 750 lbs. of water is carried in the boiler per 100 shaft horse-power, whereas with the "Benson" generator the figure would be 70 lbs. and at the same time the saving in floor space is 30-60%. The subject is also of equal importance for locomotive and motor vehicle work, while being a vital matter for modern super-station work in the way of saving ground space for example as well as the attainment of a thermal efficiency that approaches the Diesel engine.

A large "Benson" installation of steam generator and high-speed high-pressure turbine with a capacity of 2,000 K.W. has been erected in Berlin, but no detailed information is yet available, except that experience has shown the steel tubes of the generator are better arranged as a matter of convenience in the form of short horizontal lengths connected at each end by bends than in the coil form.

CONCLUSION.

It should be mentioned also that other special types of steam generator may be rendered available for super-pressure conditions. Thus, for example, there is the "Brunler" boiler, a Belgian invention, in which steam is generated by means of an oil blast flame actually under the surface of the water itself and many types of "flash" boiler belong to this category. As an example we have the "Becker" boiler in Germany, according to which water in the form of a high pressure very finely atomised spray is blown over the surface of a highly heated steel coil contained in a closed box or generator, the flame of an oil or other burner passing up through the coil, the invention being intended primarily for small units such as motor vehicles or launches.

Also many attempts have been made in the past to develop a steam driven motor car on these lines of a flash boiler, such as in the "White" and the "Stanley" steam cars, in some cases the boiler approaching 1,000 lbs. per square inch.

The general importance of the whole matter of super-pressure steam generation to marine engineering are obvious, and because of the primary conditions of weight and space it is by no means settled that the Diesel engine unit will prove to be superior under all sea-going conditions to the super-pressure steam unit. For land practice, however, it would seem that in general the proper method for Great Britain, with no home supply of petroleum and relatively little inland water power, is to submit the coal to low temperature carbonisation and extract the oils. For direct power generation only, that is when no process steam is required, the internal combustion heavy oil engine would then be employed, or alternatively the low temperature fuel would be prepared in a chemically reactive condition, gasified, and used in gas engines or perhaps gas turbines. In this event all the heavy oils would be cracked to motor spirit. When, however, process and general low pressure steam is necessary then super-pressure steam would be employed, using the solid low temperature fuel to heat the generator, and the steam bled out from high-speed high-pressure turbines, over 20,000 revs. per minute, perhaps combined with ordinary turbines at, say, 3,000 revs. per minute. This would do away with all the latent heat of steam loss and give a nett thermal efficiency of well over 75%.

Finally, it should be stated there is now very extensive literature on super-pressure steam generation, and an important Convention on the subject was held by the Vereine Deutscher Ingenieure (Institute of German Engineers) in January, 1924. A few of the more important recent contributions are:—

(1) Eskil Berg: "Advantages of High Pressure and Superheat as Affecting Steam Plant Efficiency." American Society of Mechanical Engineers (New York), 17th June, 1918.

(2) Friedrich Munzinger: "Steam Generation at Very High Pressures." Published by Julius Springer, Berlin.

(3) O. C. Hartmann: "The Present Day Position of High Pressure Steam Operation for Stationary Power Plants in Various Industrial Countries." Vereine Deutscher Ingenieure, Berlin, 29th December, 1923.

(4) O. C. Hartmann: "High Pressure Steam up to 60 atmospheres based on the Work of Dr. Wilhelm Schmidt." Vereine Deutscher Ingenieure, Berlin, June, 1921.

(5) H. Gleichmann: "Super-pressure Steam and Economy of Energy." Vereine Deutscher Ingenieure, Berlin, 29th December, 1923.

DISCUSSION.

The Chairman: We are indebted to Mr. Brownlie for an interesting and historical paper on a most important subject. I can corroborate what he says about the installation at Rugby, which came to my notice some time ago. It seems evident that pressures of 400/500 lbs. may become common shortly, whilst still higher pressures have been adopted in the United States and Germany. About 1880 a steam yacht built by R. Steel and Co. of Greenock, was fitted with boiler at 500 lbs. steam. One of the greatest difficulties experienced with that installation was due to the breaking of gauge glasses.

There is no doubt a great deal to be said on this subject, which of course, is associated with a more economical use of coal, an important factor to this country.

Mr. W. Brooks Sayers: I would like to support the Chairman's remark, that we are greatly indebted to Mr. Brownlie for this paper.

There is one very important point which has not been touched upon by the Author. What occurs if you take the water which has been transformed into steam at 3,200 lbs. pressure and allow it to expand? If you have saturated steam at any other pressure, as soon as you allow it to expand it becomes wet, and the water requires to be re-evaporated. If you take the steam at this critical point and allow it to expand to steam at 100 lbs. pressure, I suppose you will have to continue to add heat, unless you put in sufficient superheat at the beginning? The question is, what is the amount of heat you have to put in as the steam expands; in other words, what is the difference between that amount and the heat required to raise it in the first instance to steam at 100 lbs. or any other pressure. Have we any information as to what additional heat is required to keep it in the form of effective steam?

Mr. Richard Beynon ("Syren and Shipping"), Visitor: I am only speaking as a layman, but I would like to endorse what I am sure will be your general opinion, that we have listened to a very excellent paper this evening. The only point I regret is that the author has not devoted his attention more intensively, as I think he might have done, to the benefits which the Mercantile Marine might possibly obtain from the economics in steam generation which he has indicated. So far as I can gather from the paper, the author has devoted himself to what has been done in connection with generating plants ashore. I do not think that I need assure him that there is vast scope for improvement and economy in steam generation as regards plants afloat. At the present time it does not need any words of mine to assure members present that steamship owners and engineers are out to secure every improvement and economy which can be indicated to them, provided that it can be demonstrated satisfactorily in a sea-going installation, and can show a distinct economical advantage. I wish, therefore, that Mr. Brownlie had gone a little more deeply into the economical side of the question from that aspect. I hope that the paper may be extended in this direction at no distant date.

Mr. T. A. Bennett: I have not had time to study this paper closely, but I should like to point out one or two slight errors which are evidently due to first proof setting. From a statement made in the paper—and I think the lantern slide showed the same—one might infer that the specific volume of steam in the critical condition is 0; it is given in Goodenough's tables as ·048.

Also in the sketch of the Benson Generator given in a later page, it appears as though the steam supplied to the turbines is at 3,500 lbs. per sq. inch, working pressure, whereas it becomes 1,500 lbs., having been reduced when leaving the Benson generator from 3,200 lbs. to this pressure.

I notice that the author's steam tables differ considerably from Callendar's.

The Author: I used Goodenough's tables.

Mr. Bennett: I notice that they differ as much as 20%.

It is interesting to notice that in a boiler referred to of the Babcock and Wilcox type, working at 1,200 lbs. pressure, the shell, 34 ft. long, 4 ft. diameter and 4 inches thick, has a working stress of only 3½ tons per square inch, so that in a forging of this type a very high factor of safety is used.

The author seems surprised that a pump was necessary with the Löffler boiler. You have to consider that the booster has to take all the steam coming from the boiler, not only for the engine, but 3½ times as much steam as goes to the engine goes back to the boiler to generate steam; that booster would have to be very large. I think that a better plan would be to use a system of injectors. Of course, you would have to have a pressure drop in the returning steam, but I think that could be raised again by injecting the feed water with it. The Benson generator seems to be very good in many points.

Saturated steam at 3,200 lbs. is reduced by means of a reducing valve through the superheater to 1,500 lbs. With throttling we are going to have condensation taking place. When we throttle steam at moderate pressures we dry it, but in this case, although the steam is superheated to 720°, that does not bring the total heat as high as saturated steam at 1,500 lbs. Therefore, some condensation must take place as the steam enters the superheater coils. I have heard two lectures at this Institute recently on boilers, the last one being on the Brunler boiler. The question appears to be steam versus internal combustion engines, and I do not see how we can expect to get any higher efficiency from the plant described by the author than we obtain with the internal combustion engine. It is not with steam, but with coal, that the trouble lies.

The Author: Pulverised coal is used, you will remember.

Mr. Bennett: The plant described uses an oil burner as the flame must be spread downwards, and it would be of no advantage if we have to burn oil. In the Benson boiler it seems only possible to have an oil spray. There is another point; the total heat of saturated steam is a maximum at about 500 lbs. Therefore it seems that there would be no advantage in working with saturated steam at any higher pressure. To obtain any advantage we must go into superheat. As we go into higher pressures the specific heat of superheated steam becomes higher. I take the figures at saturated temperatures, that is, the first degrees of superheat, and I find that they obey the linear law, the specific heat being a function of the density of the steam :—

$$\text{Specific heat} = 0{\cdot}454 + \frac{0{\cdot}464}{\text{Specific volume}}$$

If this law remained true at the high pressures, the specific heat at 3,200 lbs. per square inch would be about 10, but this falls quickly as we increase the degree of superheat, the average for the first 100° being about 3. At the ordinary pressures which we are using to-day, the average specific heat is about 0·55.

Referring to comparisons, the author has given a number of figures in connection with the efficiencies of these engines. And a little later on he quotes some efficiencies which are well worth investigation; for example, at 100 lbs. gauge, efficiency 29·6%; at 350 lbs. gauge, efficiency 34·7%; at 3,200 lbs. gauge, efficiency 44%. You notice also that at 350 lbs. the total temperature is 677° F., from which it jumps up to 987° F. at 3,200 lbs. Unfortunately, the temperature and efficiency at 1,500 lbs. are not given, and a rough calculation points to the efficiency at this pressure comparing favourably, with a minimum degree of superheat, and I cannot see any advantage in going up to 3,200 lbs. It seems more advantageous to drop to about 1,500 lbs. as is done in the Benson boiler. One of the disadvantages of superheated steam at ordinary boiler pressures, is that as we heat the steam, the heat per cubic foot becomes less. If you are working with saturated steam and change over to superheated steam, you must open out the engine to obtain the same power, but at higher pressures, if we superheat the steam it expands according to absolute temperature, but with the high specific heat the total heat per lb. increases quicker than the volume. Therefore the total heat per cubic foot is increased by superheating and we could use smaller engines to develop the same power.

Mr. W. Brooks Sayers: While the author suggests that owing to the small quantity of water in the boiler it would not explode, and that even if it did, it would not do any harm, the last speaker suggests that it would actually contract. If so, how can it drive the turbine? How is it possible to get any power from it?

The AUTHOR: This question of what would happen under such conditions is very complicated. Mr. Bennett asks what happens when the steam expands, that is, will it condense? Of course it will not, because it is superheated. In the Benson generator, the inventor reduces down to 1,500 lbs. pressure merely as a matter of convenience, and the figure can be altered as required. I think he did not wish to frighten the turbine builders, but they have found since that they can make turbines to work at higher pressures without difficulty.

There are two problems: the first is, how are we going to produce steam under high pressure conditions? Even if we assume at the moment that 500 lbs. pressure is the best (I do not agree that it is, but that is immaterial) how are we going to generate steam at that pressure? One answer is, by building an enormously costly and weighty boiler of steel forgings. Benson claims to get over the difficulty by using a simple coil. Having achieved this object successfully he has accomplished the main object, that is the elimination of the trouble of ebullition. Of course, the next step is to superheat it. What Benson did at Rugby was to raise the water to 706° F. in 90% of the length of the coil, and then to superheat it slightly, followed by a passage through a reducing valve so that it was finally delivered at 1,500 lbs. Speaking from memory, saturation point is about 600° F., but the degree of superheat was about 300° F., that is to say a temperature of approximately 900° F. I do not see where the anticipated trouble comes in, and there is no condensation because of the superheating carried out for this purpose.

Mr. BROOKS SAYERS: Does it require less heat to produce the steam at the pressure after it has expanded slightly?

The AUTHOR: Yes, certainly.

Mr. BROOKS SAYERS: Have you not really done the same thing as if you supplied the latent heat?

The AUTHOR: Latent heat has nothing to do with it. What Benson has done is that he has generated steam without latent heat absorption, that is, he has used a narrow coil in a manner otherwise impossible.

Mr. BROOKS SAYERS: But he has to put the heat in, after all.

The Author: Naturally, but he has generated steam without costly boilers made of forgings 3 or 4 inches thick, the nett thermal efficiency being about 35%. It is simply a matter of arithmetic. In the American power station I mentioned (Crawford Avenue, Chicago) the ordinary type of water tube boiler is to work at 27·4% thermal efficiency. If it were operated at 2,000 lbs. pressure instead of 650 lbs., that efficiency would be raised; but when you get into the high regions of the steam tables it becomes a very complicated matter. Obviously, many of the figures given in the higher tables may not be correct at all, since they are largely based on calculation and possibly Benson's practical work may cause much alteration. The reason I have used Goodenough's Tables is that at the time they were the only ones available giving the higher figures.

Mr. Brooks Sayers: I think that in your first explanation, where you give tables showing the latent heat as nil at 3,200 lbs., you are supposed to be getting round the problem of the lost latent heat.

The Author: Not at all. With the Benson generator you still will have 55% of the heat lost in the condenser, and if it were possible to build any present standard type of boiler that would work at 3,200 lbs. you would get the same results as Benson, exactly.

Mr. Brooks Sayers: If you allowed your steam to expand down to ordinary pressures, you would get water. You do not really get round the latent heat loss.

The Author: The problem of the latent heat on our present knowledge is insoluble, and as already stated Benson still loses the 55% in the condenser.

I said that the amount of water in the generator coils was so small that if it exploded it would not do any serious harm, because there would not be enough water present to do any damage; that is, the total contained energy is small.

With regard to Mr. Beynon's point, I am sorry I have not enlarged upon this question sufficiently for marine engineers. I thought that the paper was too long already. I have simply tried to show you what is the latest practice in land stations, and the possibilities for sea-going conditions.

With regard to the booster pump of Löffler's, Mr. Bennett mentioned that that was the greatest objection to the system. I agree. I do not make any claims for the system, and I say also that if Benson's claims are justified it is one of the greatest advances yet made in steam practice. Whether it will be successful on a commercial scale remains to be seen.

With regard to the use of oil fuel, Benson merely used oil because it was the most convenient at the moment. He intends to use pulverised coal, and to arrange the flame at the top, while in this connection, the latest development is atomised coal, ground to pass through a 200 mesh. Coal burnt on these lines is practically the same as gas or oil.

As regards the question, what is the pressure at which the best use is obtained from the total heat of the steam, one speaker suggests 500 lbs. I am not sure that I agree; in any case it is a very complicated and difficult problem to solve, but it is of relatively little importance compared with the problem of the most efficient steam generation. For the Benson boiler, it is claimed that it generates steam at these high pressures without difficulty, which has never been done before. The "Atmos" boiler is a much more complicated proposition, and obviously running tubes at fairly high speeds and keeping the joints tight is not an easy matter.

I understand that the Benson boiler people think that they can work up to 2,000 lbs. per sq. in., or even higher in the turbine.

Mr. F. O. Beckett: Mr. Brownlie's paper includes a short history of Trevithick. I would like to add a note which the author has omitted, namely, that Trevithick invented the plunger pump, a most valuable invention.

The author has referred to pulverised coal and he has discounted the risk of these boilers exploding. Can he say why the boiler at the Birmingham Generating Station exploded? I understand that the pressure there was 350 lbs., and that one of the tubes exploded, then the combustion chamber was ruptured, but the actual cause of the explosion is not known. It was assumed to be due to overheating, caused by shortage of water, but the boiler was fitted with an automatic feed regulator. In fact, it had every safety device that is possible for men to devise. Nevertheless, it was destroyed after only four months use. What would occur, then, with a pressure of 3,200 lbs.? The effective force of the explosion of steam is enormous. I consider that many factors of this problem of high pressures are not yet understood, also the feed water is a limiting factor, as it should be distilled for a coil boiler. I have been very much interested and impressed by the particulars of the design of the Benson boiler shown by the author to-night, and I think they deserve appreciation as the work of an important pioneer.

Mr. J. Clark: I think I am speaking for most of those present when I say that Mr. Brownlie's name is very well known to us. His paper appeals to us because he does not claim phenomenally high boiler efficiencies, such as 85% and thereabouts, which we sometimes hear claimed. There is no doubt that we do lack a great deal of information regarding the nature of steam, especially at the higher pressures. There are even phenomena associated with low pressures which have not yet been explained. A pressure of the order of 1,040 lbs. apparently gives the maximum efficiency with adiabatic expansion. It is an extraordinary thing, when you can obtain, on paper, a better efficiency at a more moderate pressure than at the extreme high pressures. Mr. Brownlie mentions the interesting system of Löffler. I am not sure that Löffler is the first in the field. Certainly in this country similar results have been accidentally due to working at high temperatures. The author, in his paper, has given us a great amount of information, and it would be very difficult to find a paper published to-day containing so much on the subject. When all is said, however, they are more or less laboratory results. We want figures to prove whether these high pressures are practicable. I am speaking in the broad sense of electrical power stations as manufactures, and we want to know whether these high pressures are reliable and economical. There are very few results published, so far as these high pressure stations are concerned. Perhaps it is because we have gone ahead a bit too rapidly, and if the wise old adage "Festina lente," applies to anything, it surely applies to the adoption of high pressure steam.

Mr. W. Hamilton Martin: As regards the danger of explosion of these boilers, the Benson boiler is constructed on the same lines as the White steam boiler. There was no special risk attached to that boiler.

The Author: Yes, the White and the Stanley steam cars used the coil boiler, but the pressures were much lower.

Mr. Martin: We once took one of the White steam boilers to a country where we were not allowed to run it because it had not a fusible plug or a gauge glass. We satisfied the authorities that no danger existed. For our own satisfaction we made the following test; we fired her up and when we judged that the pressure was about 3,500 lbs., three times higher than its gauge showed as a maximum, one of the coils burst. Nothing happened, except that about a pint of water squirted out, which shows that an explosion in a boiler like that cannot do much harm. We often noticed that the steam pipe to the engine was cherry-red hot in service, but the existing superheat had no detrimental effect on cylinder liners and piston springs, only making them all a beautiful blue.

The CHAIRMAN: Confirming Mr. Martin's statement, I had personal experience some years ago with a high pressure boiler in which the circulating tubes collapsed, but no harm was done.

The AUTHOR: Referring to Mr. Beckett's remarks, it is interesting to learn that Trevithick invented the plunger pump, and he invented so many things that it is almost bewildering to attempt their enumeration in any detail.

I do not see that the explosion of the boiler at Birmingham has any bearing on the question under review, and in any case I am not aware of the details. I do not quite understand Mr. Beckett's apprehension regarding the high pressure boiler, as the matter is not a question of the pressure, but of the bulk, that is, the amount of heat in the water. It would, for example, be much more serious if a steam wagon boiler burst than if a Benson generator collapsed, and incidentally, it may be found eventually that this high pressure generator is of the utmost importance for use in motor vehicles. There was apparently no mechanical reason why the "White" or the "Stanley" cars should not have eventually established themselves successfully, and obviously one of the advantages of steam is the elimination of change gears.

Mr. BROOKS SAYERS: If this small quantity of steam will not do any harm if the boiler burst, do you suggest that it would drive a 10,000 k.w. generator?

The AUTHOR: Yes, because of the velocity at which the steam comes through. The rate of evaporation was 10,000 lbs. of water per hour; the coil was 11 ft. high and 8 ft. diameter. At that rate it will be seen how extremely small is the amount of water in the coil at any particular moment.

Mr. BROOKS SAYERS: But if you are going to drive a turbine you want a large amount. It seems to me that the effect of bursting must have some relation to the quantity required to drive the turbine. I am referring to the large quantity of water consumed.

The Author: There are, I think, about 30-40 gallons of water actually in the coil; in a Lancashire boiler there are probably 3,000-4,000 gallons. This question of circulation is very complicated, and in many water tube boilers a surging action occurs, more often than is generally imagined. As regards Mr. Clark's desire for more practical test data, I agree that we want to see the Benson or the Atmos boiler working day in and day out for several months. Meanwhile, we are waiting for such data, but the work is being carried on.

One of the chief difficulties experienced in the "White" or the "Stanley" cars, working at 900 lbs. pressure, was ebullition in the coil, which it is the essential principle of the "Benson" generator to eliminate.

The Chairman: As commented by several speakers, the Institute is very much indebted to Mr. Brownlie for his paper. The more economic use of this country's natural fuel, coal, is very important, but I think that the marine engineer would be much easier in his mind if he were assured of a perfect condenser, along with the use of super-pressure steam.

I have much pleasure in proposing a hearty vote of thanks to Mr. Brownlie.

Carried unanimously.

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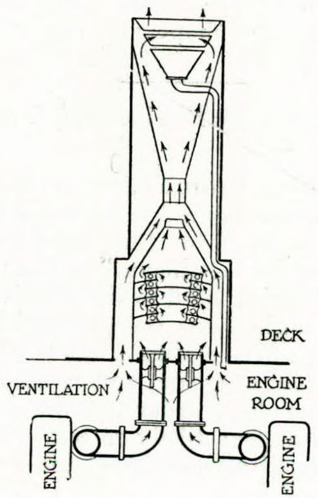
Notes.

Ventilation.—In the discussion on this subject, Mr. W. H. Martin showed a sketch, referred to on page 75 (July issue), which was not available for reproduction at the time. The accompanying illustration is from "The Motor Cycle," with description by Mr. Martin.

Silence.—There is a simple type of silencer which has proved highly efficient on large marine and stationary Diesel engines, and is now being considered for smaller work—such as on aero-engines. It is a patented method, and use is made of one or more light valves which may be either gravity or spring-controlled, according to the type of engine on which the silencer is fitted. The exhaust gases are led into these valves, through which they pass to the silencer.

The silencer is fitted directly over these valves and consists of a baffle-chamber, with a jet-shaped orifice which expels the gases up the restricted part of a combining tube, thereby inducing a large amount of outer air with them, with which they mix and gradually expand up the diverging cone, and escape, practically noiselessly, to the atmosphere.



The idea is that ordinarily the noise is created by the impulse action of the issuing gases suddenly meeting the stationary outer air, like the explosive gases issuing from the muzzle of a gun or rifle. If then it were possible to transform this impulse-action into one of a substantially uniform flow, the cause of the noise would be eliminated and thus a silent exhaust would be obtained.

The special type of valve employed in conjunction with this silencer actually does this, and silence is obtained on large Diesel installations. It does, in fact, more than this, as the powerful induced draught set up by it is used to advantage for ventilating the engine room of the vessel, while the intensive mixing and cooling of the gases when expanding in the diverging cone arrests and extinguishes all troublesome sparks. Back pressure will, moreover, be found to be a minimum.

Although this idea has as yet not been applied to motor cycle engines, it would seem quite likely that the principle might prove of great advantage. The sketch shows one of these silencers for a 1,500 b.h.p. marine Diesel installation, on which it has been working now with success for some years. Two main engines exhaust into the instrument, which is built integral with the ship's funnel.

For aero or motor cycle engines this silencer would be of a horizontal stream-line shape, having a spring-controlled valve.

The following is from the Engineering Supplement of "The Times" of July 3rd:—

Marine Propulsion. High Temperatures and Pressures. —The adoption of steam geared turbines in the new passenger vessels that are to be built for the Canadian Pacific Railway Company is of particular significance at the present time when so much attention is being paid to the relative economies of oil engines and steam engines for the propulsion of ships. After careful consideration of the claims of the two types, the decision has been made in favour of steam, and on account of the innovations that are to be made in order to reduce the fuel consumption, these steamers appear likely to mark the beginning of a new era in steam propelling machinery for ocean-going ships.

In the *King George V.*, now being completed on the Clyde, steam at the high temperature of 750° F. is to be employed, and it was generally anticipated that little advance in steam temperature and pressure would be recorded until the results of that vessel's performance were available. The adoption of a pressure of 350lb. per square inch with a temperature of 685° F. for the new C.P.R. passenger boats, and of 250lb. pressure with a temperature of 655° F. for the new cargo vessels, is, however, suggestive of a much more general use of higher temperatures with steam machinery in order to enable it to compete with the oil engine in respect of fuel consumption.

With the materials at present available, the limiting steam temperature for marine turbine machine is about 750° F. This temperature could be obtained by superheating steam of 250lb. pressure by 350°, but higher efficiency can be realised by securing this temperature through the adoption of higher pressure with reduced degree of superheat. The fuel consumption for this temperature of steam at 250lb. pressure has been quoted by Sir Charles Parsons as 0·501lb. of oil per s.h.p. hour, while an increase of pressure to 1,000lb. with superheat of 200°, giving the same steam temperature, would reduce the consumption to

0·455lb. of oil per s.h.p. hour. The pressure of the boilers in the *King George V.* is 500lb. per sq. in., but it appears improbable that such high pressures will be adopted for ocean-going steamers until actual experience has been obtained of their use in marine service, and the tendency for the immediate future will be the adoption of pressures such as are being employed in the new C.P.R. vessels.

The boilers for these vessels will be of the Yarrow type developed for the use of high pressure in the mercantile service. The passenger steamers will be arranged for oil burning, but a distinct innovation is being introduced in the cargo steamers by the employment of boilers of this type fitted with mechanical stokers of the underfeed type arranged for burning coal. The uniformity of firing provided by their adoption ensures a high furnace efficiency comparable with that of oil firing, while in both cases the use of superheaters and air preheaters eliminates losses up the chimney through heat carried away by the products of combustion and excess air, so that a high over-all boiler efficiency is obtained.

Auxiliary Machinery.—One of the most serious losses in economy with turbine machinery has in the past resulted from the excessive consumption of steam auxiliary machinery, and there has been a more general adoption of electric auxiliaries for all purposes. The high efficiency of more recent marine turbine installations, as in the new Orient liners and in the Conte boats built on the Clyde for the Lloyd Sabaudo, is largely a consequence of the adoption of this policy. The recently completed Hapag liner *Hamburg* is so fitted, and it is claimed that the operating costs have been brought down to such an extent that there is little margin between them and that of the most efficient machinery of the Diesel type. In this case the current is generated by auxiliary oil engine generators, which in conjunction with high-efficiency steam propelling machinery results in a very low specific fuel consumption at sea, while the fuel consumption for all port services is reduced to that of an oil-engined vessel. Hence most of the advantages of Diesel machinery are combined with the advantage which steam propelling machinery possesses in so far as first cost and maintenance are influencing factors. The new passenger liners of the C.P.R. will also embody this feature, and their operation with the maximum degree of over-all efficiency is thus assured.

Analyses made on paper certainly indicate that there is still a wide field where marine steam machinery can be usefully employed, and it appears probable that in the very near future fuel consumptions of 0·6lb. of oil and 1lb. of coal per s.h.p. hour will be obtainable with steam machinery in which the latest improvements are embodied.

The following are reprints from the Engineering Supplement of "The Journal of Commerce" of July 8th and July 15th:—

Powerful Diesel Electric Dredger. Designed and Built in U.S.A. Four Diesel Engines of 3,400 h.p. total.—The City of Portland, Oregon, U.S.A., situated on the Williamette river, 110 miles from the mouth of the Columbia river, having grown so rapidly the last decade, has found it necessary to increase its dockage facilities for shipping and to straighten the channel of the Williamette river.

It has been found more difficult year by year to dispose of the material dredged from the river in deepening the channel with its present fleet of dredgers, on account of the long pipe lines now required to handle the material which necessitates the aid of a booster. When the port of Portland decided to deepen the harbour, straighten the channel of the river and reclaim many acres of land, it was also decided to increase the dredging equipment by the addition of a high-powered dredger, which culminated in the design and construction of the new Diesel electric dredger *Clackamas*, which is not only one of the most powerful pipe line dredgers but the most economical of its kind in existence for the work for which it was designed, and the history of this dredger will give an idea as to the construction and some of the machinery installed.

On the 27th of March, 1924, the Port of Portland Commission signed a contract with the Wallace Equipment Co., of Seattle, Wash., to build the steel hull of the dredger. On the 26th of February, 1925, the dredger was launched at the ways of the Peninsula Shipbuilding Co., Portland, ready for the installation of the machinery.

The machinery having been assembled at the plant of the Port of Portland Drydock in St. John's, the hull was towed to this plant and the machinery installed by its own crew, the dredger running trials on August 1st, 1925.

Description of the Vessel.—The hull is of steel and is 236ft. long, 50ft. beam, 12ft. 9in. deep, and has a displacement of 2,480 tons at a draft of 7ft. 8ins. This displacement includes a week's supply of fuel oil, fresh water, and perishable commissaries, a month's supply of stable commissaries, a three months' supply of lubricating oil, engine stores, and spare parts.

The port having had three dredgers sunk; two from being rammed by steamers and one by the bursting of the discharge pipe, particular attention was given to the construction of the hull to make it strong enough to hold the heavy Diesel engine equipment and minimise the damage as much as possible in case of collision, therefore, on each side of the hull, located 7ft. inboard from the shell plating, is a longitudinal watertight bulkhead about 188ft. long extending from the forward athwartship bulkhead of the athwartship bulkhead, this also strengthens the hull, particularly the bottom, to offset stresses in case of grounding. The space between this bulkhead and the side of the hull is divided by athwartship partitions or bulkheads making six watertight compartments on each side of the hull.

These watertight compartments are used for storage of fuel oil, Diesel oil, lubricating oil, and drinking water, thereby saving space which otherwise would be taken up by separate tanks, as well as conserving weight and cost.

Four transverse watertight bulkheads divide the hull into six compartments between the longitudinal bulkheads. The forward bulkhead is located at the after end of the ladder well (32ft. back of the bow), and is the aft bulkhead of a compartment on each side of the well. The second bulkhead is 48ft. aft of this bulkhead and is placed between the dredging pump and the pump motor. The third bulkhead is 72ft. back of the second bulkhead and is placed between the forward set of two 900 h.p. engines, and the aft set of two 800 h.p. engines. The fourth bulkhead is 60ft. aft of the third bulkhead, leaving a stern compartment 24ft. long.

These bulkheads also strengthen the dredger through being placed between the different main machinery units and thoroughly tying the machinery keelsons to the longitudinal bulkheads and the sides of the hull. In addition there is a heavy frame 4ft. 2in. deep tied to each panel point of the trusses, extending to the longitudinal bulkheads and the side of the hull, with additional deep frames 6ft. apart tied to the longitudinal bulkheads.

The aft engines and their generators are in one compartment. The forward engine and their generators and the main pump motor are in another compartment and the main dredging pump is in a separate compartment. Should the bottom of the dredger be injured, causing the filling of any one of the compartments, the damage would be local and affect the electrical equipment in the compartment only. Similarly, should a hull pipe or the dredging pump be ruptured from any cause, the damage would be limited to the compartment where the injury occurred.

There is a heavy bridge type steel truss extending the full length of the hull, the forward end being extended to form the "A" frame for the ladder hoist, and the spud masts aft being tied into and forming a part of the truss. This truss also carried the crane runway girders.

This truss is calculated to support the weight of the dredger in case of grounding on the two ends. Each of the two side trusses is located one-half the distance from the centre line of the dredger to the side plating of the hull. There is ample space between the truss and the longitudinal bulkhead for a passageway and auxiliary pumps on the port side, and for the hull pipe and passageway on the starboard side.

The panel points are spaced 35ft. apart, and the angle of the diagonal members is approximately 45°. Forward of the deck house to the digging ladder near the outer end top members of the trusses converge, meeting forward member of the "A" frame 32ft. forward of the bow. At this location a structural steel frame is formed, carrying five sheaves for the ladder hoist tackle, the lower one of which consists of a quadruple sheave block chained to the digging ladder near the outer end. The after end of the truss is built into the spud-well frames and spud-mast frames. The spud masts are sufficient in height to accommodate the 80ft. steel spuds, and so designed that they may be used to unship or ship a spud in case of breakage.

The spuds are 35 inches in diameter and 80ft. long, constructed of $\frac{3}{4}$in. steel plates rolled into a cylindrical tube. There is a hollow cast-steel conical point at the bottom for setting into the bed of the river. There are 14 flanged diaphragm plates riveted to the shell, spaced about five feet apart throughout the length of the spud, which keep the spud from buckling under a beam strain. Constructed in this manner, these steel spuds have double the strength of a timber one and are easily repaired or rebuilt in case of injury.

The spud wells are placed at the stern and constructed of heavy cast-steel hinged keepers which enable the removal of spuds should they become bent. The dredger's crew with the equipment aboard can readily replace a damaged spud.

Machinery Installation.—The main engine installation consists of two 800 h.p. McIntosh and Seymour Diesel engines, stationary type, each direct connected to a 540 k.w. d.c. generator, and two marine type Diesel engines of the same make, each connected to a 610 k.w. d.c. generator.

The 800 h.p. engines are 8-cylinder units of the 4-cycle trunk type, and each at full power turning 200 r.p.m. will consume one barrel of fuel oil per hour. The 900 h.p. engines are 4-cylinder units of the 4-cycle trunk type, and each at full power turning 150 r.p.m. will consume $1\frac{1}{8}$ barrels of fuel oil per hour.

The combined power is 3,400 b.h.p., and the total consumption of fuel oil is $4\frac{1}{4}$ barrels per hour (full power), or 102 barrels per day of 24 hours. However, the average pumping time will probably not exceed 20 hours per day, and with varying loads will require the consumption of about 70 or 75 barrels per day.

Having four units, it is possible to stop one and obtain approximately 80 per cent. efficiency with the remaining three; thus a breakdown of one unit would not seriously hinder the operation of the dredger. On short pipe lines it might, at times, be advisable to shut down one or more of the engines.

Electrical Equipment.—In the electric main drive the generators are of the Westinghouse Electric and Manufacturing Company's design, and include two 610 k.w. 150 r.p.m. 500 volt d.c. generators and two 540 k.w. 200 r.p.m. 500 volt d.c. as the main generators and one 50 k.w. 325 r.p.m. 125-250 volt d.c. auxiliary generator. There is one five unit 1,200 r.p.m. motor generator balancer set consisting of two 200 k.w. 250 volt d.c. units for 500-250 volt 3-wire system, and to drive set, one 200 k.w. 250 volt d.c. generator for cutter drive by variable voltage system, one 60 k.w. 250 volt generator for forward swing hoist drive, variable voltage system, and one 60 k.w. 125-250 volt d.c. generator for lighting and auxiliary power.

The dredging pump is a high-speed, square volute, lined centrifugal type pump developed by the Port of Portland, having 30in. suction and discharge openings. The casing is rectangular in section and $8.10\frac{1}{2}$ft. in diameter inside of the liners, which are of mild steel $\frac{3}{4}$in. thick. The casing is made of cast steel to provide extra strength and reduce weight. This reduces the possibility of breakage from boulders or water ram, and also facilitates patching by electric welding. Being of rectangular section concentric with the impeller, simplified the machining of the head liners and the periphery liners. The liners are made in sections to minimise the expense of replacing any section worn out.

The main pump motor is a 2,700 h.p. 250 to 360 r.p.m., 500 volt, adjustable speed compound wound d.c. machine, direct connected through a flexible coupling and marine horseshoe-type thrust bearing to the dredging pump. It is the largest of its kind ever built for dredging purposes. The compounding is adjustable to give a no-load speed of 450 r.p.m. and a full-load speed of 360 characteristic, giving additional velocity and maintaining torque to clear the discharge pipe-line in case of chokings. The pump motor is controlled by motor driven rheostatic controllers operated by push buttons.

The cutter-motor is a 250 h.p., 600 r.p.m., 250 volt d.c. shunt wound motor for operation from special variable voltage generator, and to include flexible coupling. The forward swing hoist motor is of 75 h.p., 600 r.p.m., 250 volt shunt wound motor, for operation from special variable voltage generator. The forward ladder hoist motor and the stern hoist motor are of 45 h.p., 515 r.p.m., 230 volt d.c. series wound motor, with magnet brake.

For fire and service are 2 of 50 h.p., 230 volt, 1,200 to 1,700 r.p.m. adjustable speed d.c. motors, and the two engines circulating pump motors are of 15 h.p., 230 volt, 1,150 to 1,700 r.p.m. adjustable speed d.c., while there are five fresh water, bilge and oil-heating pump motors of 5 h.p., 230 volt, 1,150 to 1,700 r.p.m. adjustable speed of d.c., and the three oil transfer pump motors are of 10 h.p., 230 volts, 850 to 1,200 r.p.m. adjustable speed d.c.

A two-ton refrigerating machine, a complete machine shop with power tools, travelling cranes and such equipment is located on the main deck. The dredging ladder is the standard Port of Portland type, 75ft. long, 10ft. wide, and 8ft. 6in. deep, of open rectangular frame construction.

Careful attention has been given to the living quarters of the crew, which consists of 50 social halls, which are equipped with radios; galley, equipped with electric ranges and bake ovens; washroom, shower baths, etc.

The dredger in three days' time, working on a 7,590ft. line, with a net terminal lift of 29·3ft., delivered about 800 cubic yards of heavy sand and gravel per pumping hour, which is practically double the output of the 2,000 h.p. steam dredger

Tualatin working in the same class of material with the aid of an electric booster. This makes a saving to the port of some 1,500·00 dollars per day for this particular class of dredging.

Steam Raising.—Power Station Developments.—The principle of the super-power station continues to forge ahead, and it is stated that the Barking super-station, the first section of which (100,000 k.w.), was opened by the King last year, is now to be greatly extended. Full details are not yet available but a contract has been placed with the International Combustion Ltd., of London, amounting to over £750,000 for the entire steam generation plant, which presumably refers to a second section of 100,000 k.w.

This will include 10 "Babcock and Wilcox" boilers, 16,500 square feet heating surface each, fitted with superheater of 6,500 square feet, feed water economiser of 6,100 square feet, "Usco" multiple plate air-heaters of very large size, 18,600 square feet"Lopulco" pulverised fuel equipment, including large 15-ton super-"Raymond" pulverising mill with exhauster and cyclone separator and "Murray" water-cooled fin tube walls of 6,500 square feet, the whole forming 10 separate self-contained steam generating units. Further, each of the combustion chambers will have a volume of 10,800 cubic feet, which will correspond to 16,800 B.Th.U. per cubic foot on normal rating, with 24,000 B.Th.U. per cubic foot maximum, and in addition to the "Murray" tubes and usual "Lopulco" water screens, will also be fitted with the modern "Detrick-Usco" suspended firebrick arch and 11 seperate pulverised fuel burners on the latest fish-tail principle. Further, the installation will include five steel chimneys, one for each two boilers provided with grit catchers, an array of "Bailey" boiler-house control instruments, boiler feed pumps, and 30 forced or induced draught fans electrically driven.

It is particularly interesting that pulverised fuel firing is to be employed in spite of the fact that the first section is operated entirely with mechanical stokers of the travelling grate type, along with both air-heating and economisers, while also both feed water economisers and air-heaters are included, in spite of the large size of the latter. The "Detrick-Usco" suspended firebrick arch is now making considerable progress, not only for mechanical stoking, many installations now being at work in Great Britain, but also for pulverised fuel, while it is applicable to every type of furnace and particularly in the metallurgical industries. The suspended arch has enabled single travelling grate stokers to be constructed of almost any width—over 20 feet if necessary—which removes one of the main disadvantages of this type, since hitherto the maximum width was about eight feet because of the sprung arch.

BIG TURBINE REPAIR.

100,000 Blades Replaced.

There have been few examples of such an important turbine repair as was carried out recently on one of the biggest C.G.T. liners, and the job has been described by M. Thooris, a naval architect belonging to the Havre staff of the above company, in a paper read before the Association Technique Maritime.

The damage occurred in the L.P. starboard turbine of the liner, and was due to the breaking of the tail-end shaft, involving the loss of the propeller. The repair was carried out by the Havre staff of the C.G.T., assisted by experts from three well-known French shipyards, viz.: the Chantier et Ateliers de Saint-Nazaire-Penhoet, the Ateliers et Chantiers de la Loire, and the Forges et Chantiers de la Mediterranee. Over 100,000 blades had to be renewed.

Balancing 60 Ton Rotor.—The rotor was slightly deformed as a result of the stresses exerted by the bundles of entangled blades. These deformations disturbed the balance of the rotor, which had to be corrected after the reblading. M. Thooris stated that to his knowledge this was the first time that the static balancing of so big a part was carried out on board a vessel, the rotor in question weighing over 60 tons.

When the damaged blades were removed from the rotor measurements were taken at intervals, and it was found that the maximum depth of the deformation was about 5 mm., the deformation extending over a length of about 930 mm., and an arc of about 60 degrees.

It was thus necessary to shorten the blades over that area, for which purpose the affected part of the rotor was divided into three concentric zones, A, B and C, the A zone being the innermost. The 330 blades of the A zone were trimmed down by 5 mm.: the 270 blades of the B zone by 4 mm.; the 1,262 blades of the C zone by 2 mm.

Shortening Blades.—The deformation of the drum introduced an unbalanced force that could be approximately calculated; this was found to be 1.035 kilogrammetres. The shortening of the blades caused an opposing lack of balance, the value of which was 6.694 kilogrammetres. In order to restore the centre of gravity of the rotating mass to the axis of the shaft it was therefore necessary to trim some blades on the opposite side. Calculation showed that the required result was obtained if an equal number of blades to those comprised in the A, B, and C zones, *i.e.*, 1,862 blades, were reduced by 2 mm. in a position 180 deg. from the C region.

In the regions other than that of the chief deformation the blades were somewhat cut down (without any calculation), whenever it was deemed necessary sufficiently to ensure suitable clearances. The blade sectors fixed on the turbine casing were similarly curtailed to provide for at least the normal clearances. After the reblading it remained to ensure that the balancing of the rotor, as corrected by calculation, was satisfactory.

Testing the Balance.—The apparatus constructed for that purpose, after the study made by the Chantiers et Ateliers de Saint Nazaire Penhoet, consisted of two bearings with rollers and a thrust block. Each bearing comprised a steel cylindrical roller 400mm. diameter and 150mm. long and two side rollers 200mm. diameter and 200mm. long. The rotor, when supported on the bearings, was inclined aft by an angle of about 20/1,000. The thrust block at the fore-end of the shaft prevented any movement of the rotor due to the inclination of the shaft. Thrust blocks and rollers were fitted with ball-bearings. The test was made at night, the work being started at 9 p.m., and completed at 3 a.m.

M. Delaporte's Method.—The method adopted was that described by M. Delaporte in a paper read at the 1924 meeting of the Association Technique Maritime, and consists in measuring the oscillation periods of the rotor by successively fixing an additional weight P at regular intervals on the periphery of the rotor in a plane perpendicular to the axis of rotation. The circumference was divided into equal parts by 8 numbered points. For instance, the additional weight being fitted at the No. 1 point and arranged to pass in front of a reference mark, the rotor is released and the full oscillation time T is measured. The operation is repeated for the other positions of the weight P. The values of the oscillation times are of the form :—

$$T = \frac{K}{\sqrt{P^1}}$$

P^1 being the moment due to P and the unknown unbalanced force "x." It follows that if the values of T are plotted as ordinates and the positions of P as abscissae,

$$T \text{ max.} = \frac{K}{\sqrt{P-x}} \text{ (x and P in opposition)}$$

$$T \text{ min.} = \frac{K}{\sqrt{P+x}} \text{ (x and P in conjunction)}$$

Thus, both the positions and value of x can be determined by drawing the horizontal tangents to the T curve. It comes:—

$$\frac{T^2 \text{ max.}}{T^2 \text{ min.}} = \frac{P+x-X}{P+x} \text{ hence } x = P\frac{X-1}{X-1}$$

The ratio of the maximum to the minimum oscillation period is:—

$$\frac{T \text{ max.}}{T \text{ min.}} = \sqrt{\frac{P+x}{P+x}}$$

For a fixed value of x, the resultant increases as the value of P approaches that of x. It therefore seems advisable in order that the values of T max. and T min. may differ sufficiently for easy reading, to provide for P values approximately to those of x.

But the value of x may be anything, and if too small a value be taken for P, there is to be feared that the results may be affected by frictional resistance. Hence, contrary to the above conclusion, a relatively high value is taken for P, which may differ greatly from that of x, if the latter is small. In the present case the value of P was 168.5 kilogrammes.

The results obtained were as follows:

Positions of P...	1	2	3	4	5	6	7	8
Values of T (secs)	38.5	38	38	38.5	39.5	40.5	40.8	40

Successful Tests.—On plotting the above results it is seen that the joints obtained are distributed along a curve of quite regular form. The maximum ordinate is about that of position 7, and the minimum ordinate very near that of position 3. Hence it appears that the unbalanced weight x is situated at point 3; the correcting weight has to be fitted at point 7. The value of that weight is obtained from the following calculation:—

$$\left.\begin{array}{l}T \text{ max.} = 37.9\\ T \text{ min.} = 40.8\end{array}\right\} \times = 1.159 \quad P = 168.5 \text{ kg. hence}$$

$$x = \frac{X-1}{X+1}P = 168.5 \times 0.0736 = 12.4 \text{ kilog.}$$

The correcting weight was divided into two parts, fitted on either side of the plane of its centre of gravity, so as to balance the resultant centrifugal forces.

After being closed, the turbine was driven at about 200 r.p.m. to ensure that it was well balanced dynamically and that there was no tendency to vibrate. That test being satisfactory, a 7-hour sea trial of the ship was successfully performed at 230 r.p.m.

Contribution from Mr. W. F. Jacobs (Member).

As a result of reading the book on Internal Combustion Engines, and the recent Transactions of the Institute, I wish to make the following remarks, not with the idea of publication, unless thought to be of interest to members in general.

It is the opinion of all that I have met who have read the book on Internal Combustion Engines that the Council of the Institute are to be thanked for getting the book published.

The sea-going engineer, if he wishes, can fairly easily obtain books on the design or thermo-dynamics of these engines, but to obtain helpful advice in running and overhauling them is very hard.

And we think here that the Institute is filling the gap by publishing these papers. I wish to mention the extreme usefulness of "adjustment and maintenance" papers, one of the best to my mind, being the imaginary conversation between a second engineer and a junior engineer in the October, 1925, number. Several of us have picked up some very useful hints from this paper, and in the somewhat remote event of sailing with internal combustion engines, will find them helpful. I also wish to make a mild protest against the attitude of some writers in the technical press and elsewhere, implying that the man who does not go into an internal combustion engined ship is out of date.

I wish to point out that there are a good many engineers who would like to have the chance to make a trial voyage with these engines, but owing to circumstances beyond their control they cannot do so. In regard to suitable types of engines for marine work, I am looking forward to seeing a double acting, two-cycle, airless injection engine filling the bill.

From what we hear, and reading between lines, the blast air compressor seems to cause a good deal of trouble. And as it takes up a fair percentage of power to drive, one does not see why we should use blast air, if it can be done without.

I would like to see a sliding cylinder North British Engine fitted with airless injection as an experiment.

For apparent robustness, and ease of running I think that so far, I would fit the Doxford type of engine to a ship making long voyages to out-of-the-way ports and perhaps a not too experienced staff. (I may as well say that I am not known to the two firms concerned.)

Now with regard to geared turbines I have noticed recently that several single reduction gears have been fitted. From previous results this seems to be a sound move to avoid gear trouble. May I ask if anyone has tried a flexible coupling between the main wheel of a gear and the thrust shaft in order to take care of any mal-alignment of the shafts due to the ship working?

I think it could be fairly easily done by having a spider bolted on to the forward end of the thrust shaft, and the arms of the spider bearing on pads fitted to the turning wheel. These pads might be of rubber in order to damp out any vibrations transmitted along the shaft from the propeller, and so save the teeth. In one case I note that a special semi-flexible seating was fitted for gear box to avoid twisting same.

I imagine that a rigid connection between the line shafting and the gear box would tend to throw the gears out of line when the ship 'worked,' and so cause trouble. In the case of the electric drive, in some of the published plans of this type, there does not seem to be room for an intermediate length of shaft between the tail end and the thrust shafts. I think one should be fitted in all cases in order to allow the tail end shaft to be drawn in without disturbing the thrust shaft. With electric drive the tunnel might just as well be built along the ship's side, thus giving a clear hold space aft. From a certain amount of electrical experience I find that a fairly well built electric motor is one of the most reliable things in an engine-room, and I should not worry at being put in charge of an 'electric drive' ship.

With regard to ordinary coal fired steamers; those in charge might endeavour to arrange that the fires should be cleaned at something like even intervals throughout each watch; instead of, as in most ships that we have run across, cleaning all the fires in the first hour of each watch with the engine shut in and the steam back, and then drive hard for the next three hours in order to maintain a fair average of revolutions.

I have heard it said "the firemen won't do it." Well they do it in the ship that I am chief of (7,000 I.H.P., 24 furnaces, quadruple expansion engines).

The men will do it if the watch keeping engineers are firm on the point. In this ship, links and throttle are hardly moved (throttle never) at sea, and with any fair sort of coal, the steam is kept within 10 or 15 lbs. of blowing (215 lbs.) the whole time.

I admit that with new firemen we have a job at times to break them in, but we do it, and I maintain that if a somewhat similar routine was carried out in most ships, there would be no trouble and a better average speed for the same consumption.

I am quite sure that an even 80 r.p.m. for instance is better for coal consumption and speed, than 74 r.p.m. for one hour and 82 for the next three. Another point, when giving the coal burnt in lbs. per I.H.P. hour, surely some reference should be made to the heat value of the coal in question. I have known one ship to indicate 6,000 I.H.P. on a daily consumption of 78 tons and also on 96 tons.

One cannot take the lbs. of steam per I.H.P. hour as a basis when talking to the shipowner, as that does not take into account the efficiency of the boiler plant.

Many times have I wished that a meter had been fitted in the feed line to the boilers, for when the plant is not doing as it should one has to try and trace all faults from bunkers to propeller. Whereas if a feed meter was fitted one would know at once whether the stokehold or engine-room was at fault. We must never forget that the only thing the owner is concerned with, is carrying so many tons of cargo or passengers the greatest distance per shilling, at the required speed. And the shilling has to cover all expenses from interest on capital charges and office expenses to the Office Staffs' wages.

Finally, where are the men coming from to run the ships in the future?

I ask this, for while it is said that for a man to be a marine engineer requires the training and knowledge of a B.Sc., yet I find it hard to get an assistant engineer who is a good fitter and who even after several voyages experinece can be trusted to overhaul a dynamo or pump properly.

Hardly any of the assistants I have had of late have attended a technical school at day or evening classes, and they do not understand the 'why' of things. If a chief always makes a bad or indifferent report on his assistant engineers, the management will, I imagine, consider that perhaps the chief is at fault, but as a result of the last two or three years experience I do wish that all engineers before sailing as such, had to pass a fitting test and an elementary examination in mathematics and mechanics. And several chief and second engineers that I know are in agreement with me on this point.*

THE NATIONAL PHYSICAL LABORATORY.—The annual inspection by the General Board of The N.P. Laboratory was held on June 22nd, when a number of interested visitors, invited for the occasion, were present. In the Aerodynamics Department main building the visitors assembled and were received by Sir Ernest Rutherford, President of the Royal Society; Chairman of the Board, Sir R. Glasebrook; and the Director, Sir Joseph Petavel.

The tours of inspection were carried out to suit the special desires of the visitors, and guides were in attendance to direct each one to the court of enquiry containing the objects aimed at.

The experiments in the aerodynamics section were of great interest, indicating the tests made to obtain efficiency and safety in air ships of different types. The workshops contained models and apparatus in course of construction up to date.

The Engineering Department embraces a large number of testing machines, for efficiency and endurance tests; mechanical properties of metals under high temperature conditions, rust prevention, etc.

In the Metallurgy Department, the foundry furnaces and arrangements are shown and details to cope with the different types of metals and alloys in order to obtain the best results shown by careful research in the laboratory tests.

* This was advocated by the Institute 20 years ago, or an equivalent 3rd class certificate after a short sea experience as a step-by-step encouragement in place of the coaching tour.

The experimental tests in the Wm. Froud Tank were carried on by means of a model single screw vessel, self-propelled, to show the speed, thrust, revolutions and power developed under speed conditions.

Data were on view in the different sections attached, showing the moulding of models of various types of vessels; diagrams illustrating waves and wave resistance, pitching, etc., steering gear and rudders, single and double screws.

The Metrology Department contains instruments of all kinds and testing apparatus with the methods used in testing them.

The service of the X-Ray apparatus illustrated clearly the sectional views of the alloys.

The Electrical Department is extensive and contains a very interesting collection of models and machines with a large assortment of apparatus for testing magnitudes, light, currents, voltage, etc.

At the Wireless Hut and surroundings are shown the methods used in sending forth sound by transmitters, with the wave length ranges and the instruments, the receiving sets and apparatus explanatory of the system.

The N.P.L. is being added to year by year, and has been greatly extended since our first visit.

The Royal Sanitary Congress was held in London this year, July 5th to 10th, when the jubilee of the Royal Sanitary Institute was also celebrated. A large number of papers were read in the different sections comprised under the following headings:—A. Sanitary Science and Preventive Medicine. B. Engineering and Architecture. C. School Hygiene. D. Personal and Domestic Hygiene. E. Hygiene of Food. F. Hygiene in Industry.

Conferences were also held by: I. Representatives of Sanitary Authorities. II. Representatives of Port Sanitary Authorities. III. Medical Officers of Health. IV. Engineers and Surveyors. V. Veterinary Inspectors. VI. Sanitary Inspectors. VII. Health Visitors. Full reports of these will be published in the journal of the Royal Sanitary Institute.

The subjects which were of special interest to Marine Engineers were the carriage and storage of food products. The papers dealing with these are given by permission of the Royal Sanitary Institute.

The meetings were held each day at Westminster in Caxton Hall, the Central Hall, and at the Institution of Civil Engineers; also in the Mansion House.

The proceedings were opened on July 5th, when the Duke of Northumberland, President of the Institute, greeted the members and delegates at a reception in the Hotel Victoria and subsequently he presided at a meeting in the Guildhall when Mr. Neville Chamberlain (Minister of Health) gave an address.

The following telegram received from the King, was read by the President at the opening of the meeting :—

" I have received with much appreciation the message of loyal greetings on the occasion of the Jubilee of the Royal Sanitary Institute, for which I sincerely thank you, the president, the members of the Institute, and the delegates from the United Kingdom and all parts of the British Empire. As patron, I offer my hearty congratulations on the useful and beneficient results of the work achieved during the past 50 years by the Institute, and I trust that its endeavours thus to promote the well-being of my people in this land and throughout the Empire may be blessed with every success.—GEORGE R.I."

Mr. Chamberlain, in his opening remarks, referred to the improvements made in sanitation and the developments which had taken place in regard to the national welfare since the Institute was founded 50 years ago. He expressed regret that his duties in the House would not admit of delivering his address in person, but Mr. E. G. Gibbon, Ministry of Health, would do so on his behalf. He referred to the expenditure of local authorities on Public Health Services now, as compared with 1875-6, showing an increase of £56,000,000.

The new Smoke Abatement Bill in hand was intended to improve general conditions in the atmosphere, and point out to the authorities concerned where improvements could be affected.

It was desirable to maintain helpful relationship between the voluntary hospitals and the authorities and societies engaged in health work; all working together for the common good. The good accomplished by voluntary effort should be upheld and encouraged. The Institute had done good work in advancing the cause of sanitation and in encouraging all conditions tending to improve the public health.

A reception and tea were held in the evening at the Cannon Street Hotel by invitation of the National Temperance League, and afterwards a visit was paid to the premises of the Institute and the Parkes Museum, Buckingham Palace Road.

On July 6th after the meetings for papers, a garden party was held by invitation of the Duke and Duchess of Northumberland at Zyon House, Brentford, and at 8.30 p.m. visits were paid to the College of Nursing and to the R.A.M. College Hygiene Laboratories, where demonstrations were given.

On July 7th, after the papers and discussions, visits were paid to Messrs. Lyons' Works, Greenford; to the Household and Social Science Dept., King's College for Women; to Messrs. Curtis Bros. and Dumbrill Dairy Co., Streatham; to the Blind, Deaf and Open-air Schools; to Messrs. Macfarlane, Lang and Co.'s Factory, Fulham; to Messrs. Oxo's Factory, Southwark; to the Treloar Cripples' Hospital and College, Alton; to the Fishmongers' Hall, where, with a demonstration on fish, a paper was given by Mr. C. Hattersley; to the Army School of Sanitation, Aldershot; to Littleton Reservoir and Pumping Station; to Welwyn Garden City. An "At Home" party was given at 9 p.m. by the Marquis—President of the Women Sanitary Inspectors and Health Visitors' Association—and Marchioness of Salisbury.

On July 8th the visits arranged were: to the Port of London Authority Docks, Wharves and Shipping; to Messrs. Curtis and Dumbrill Dairy Co.'s Works; to Golders Green Crematorium; to Hampstead Garden Suburb; L.C.C. Becontree Housing Estate; to the New Buildings in Regent Street; to Messrs. Oxo's Factory; to Messrs. Macfarlane, Lang and Co.; to Messrs. Virol, Ealing; to the P. and O. *Chitral*, Tilbury Dock; to Bedford College for Women, Regents Park.

On July 9th the visits were: to the L.C.C. Sewage Pumping Station, Abbey Mills, and the Northern Outfall Sewage Disposal Station, Barking; to the L.C.C. County Hall, Westminster; to the Hammersmith and Acton Borough Council's Housing Estates; to Messrs. Macfarlane, Lang and Co.'s Factory; to Messrs. Oxo's Works; to Colindale Hospital for Tuberculosis, Hendon; to Queen Mary's Hospital for Children, Carshalton; to the new premises of Messrs. Liberty, Regent Street; to the London School of Hygiene and Tropical Medicine, Torrington Square. In the evening at eight a reception was held in the Guildhall by the Lord Mayor and the City Corporation.

On Saturday, July 10th, all day excursions were arranged to Windsor, to Oxford, to Brighton, to King George V. Sanitorium, Godalming; to Cambridge University.

The members and delegates had the choice of what papers to give ear to and attend the meetings preferred, so also with regard to the visits, giving early notice for due arrangement being made.

The following quotations indicate the objects and aims of the Congress:—"In attempting to define the attitude which preventive medicine should adopt towards health of the mind in relation to health of the body, Dr. H. P. Newsholme, M.O. of Health, Croydon, said, in opening the subject of his paper: "I will refer first to one experience common to us all, which suggests a close association between an unfretted mind and a healthy body. Feelings of mental anxiety, apprehension, anger or resentment, if long continued produce a sense of strain, diminish the sense of well being, interfere with interest in and appreciation of the surroundings, give a diminished or unbalanced consciousness of the needs of others as well as of ourselves, make recreation less recreative, and on the physical side may be associated with loss of appetite, digestive disturbances, fatigue and sleeplessness."

Dr. A. F. Tredgold opened by saying "This Congress marks what may be regarded as the jubilee of preventive medicine in this country. It is an occasion upon which the medical profession, and particularly those members of it whose work lies in this special department, may rightly feel some pride concerning the great advances made during the past 50 years. But it should also be an occasion for stocktaking and for considering what has been the effect of these advances upon the health of the nation. And if this stocktaking should prove not entirely satisfactory, I venture to think that it is an occasion upon which we should carefully consider whether we are applying all the knowledge which at present exists to further the end we have in view."

While pondering over this paper, one's thoughts turn to the conditions of life around us, and review peculiar mentality illustrated in various directions and in various ways. We find the grace of courtesy lacking where it ought to prevail; one section of a community arrogating to itself a place on a pinnacle, regardless of the rights of others or without a courteous consideration of what is due unto them.

The most prominent instance in regard to the industrial progress of the country on which each and all depend, is the coal supply and the attitude of those who have eyes to see but see not, having generated a mist to blind themselves and those around them. May wise considerations prevail to bring about peace and harmony, with goodwill to work in the right way and the right spirit.

The papers were so numerous and full of interest that even quotations cannot be made from each one, but they will be published in full by the Royal Sanitary Institute and will be available in our Library. The following are quotations from the paper on "Preservation of Meat during Transport by Chillings," read by one of our Vice-Presidents, Mr. A. R. T. Woods:—

The proper preservation of meat during its transport from the producer to the consumer is a matter of great and increasing importance in world economics.

The capital invested in production, preparation for export, and the specialised ocean carriers designed for its transport is enormous, and whether these undertakings are remunerative or not is largely dependent upon the produce being placed before the consumer in a thoroughly sound, and at the same time, attractive condition.

Some of the many problems which confront the producer, the carrier and the distributor, have been satisfactorily solved by either long and expensive experience or by painstaking and enlightened research. There is, however, much remaining to be done before it can truly be said that wrongful practice and unscientific methods have been mostly eliminated, and that the various phases of production and transport have attained a very high standard of economic efficiency.

To begin with, the beasts destined for export as chilled meat must be well bred, sound, healthy and absolutely free from disease. More attention is now paid to securing good stock than formerly, but though the resultant quality of the beef has improved during recent years, there is still room for betterment in some of the sources of supply. In the case of Argentine cattle the majority of these are raised at less than 150 miles or so from the freezing works, and it is interesting to note the care which is taken respecting their transport. Where the distance is not too great, the beasts make the journey leisurely on foot. If they travel by rail the trucks of the train are well ventilated and open at the ends, where the entering beasts pass into what is practically a corridor-wagon train, the door partitions of which are secured when each compartment has received its proper quota. This arrangement makes for easy travel. On arrival at the camp of the freezing works the animals are rested and fed upon grass, if possible, until they are moved to the corrales, where they are fed, watered and rested for 48 hours, after which they receive water only for a day. They are now, having passed under the supervision of the local inspector, ready for slaughter, immediately prior to which they are put under a spray bath, a process which cools the animals, alleviates their mental distress and incidentally improves the post mortem appearance of their flesh. The actual killing is humanely carried out in a "knocking box," holding one beast, the lethal weapon employed being a special flat hammer which does not prejudice the commercial value of the brain. The procedure followed at the freezing works thus carefully eliminates any suspicion of cruelty and reduces the sufferings of the animals to the minimum, which has been gradually evolved from the teachings of experience, and has certainly aided in enhancing the reputation of chilled meat.

From the "knocking box" the carcase is removed by mechanical means and "conveyed" to the bleeding room, whence it proceeds to the dressing hall, where the hide and internal organs are removed and the body divided into halves or sides. At this stage another inspection is made to make sure there is no suggestion of disease. Then the sides are washed, trimmed, cleaned and dried.

I attach the greatest importance to this washing and drying process, and have always urged that it should be done with fresh water, either distilled or sterilised. Careful cleansing must be followed by *thorough drying*, as any moisture which is allowed to remain on the carcase, especially at the tail point, aitch bone, kidney vein and gullet, may, during the ocean voyage, create a taint or bring about a condition favourable to the evolution of mould.

From the dressing hall the sides are run by rails to the chilling rooms, which are sufficiently spacious and lofty to allow cold air to circulate all round the meat. The preliminary chilling process should be a gradual one, and experience has convinced me that it is advantageous to allow the carcases to remain in the open chill room for some time, so as to allow the natural heat to dissipate gradually where and when possible before the meat is taken to the refrigerating chilling rooms proper, where the cooling is continued by air circulating over a battery of direct expansion coils sprayed with concentrated brine, an arrangement by which the air is both cooled and dried. But it cannot be too strongly emphasised that the gradual and natural method of chilling gives the best results, and should be followed wherever possible.

The next step in the preparation of the meat for its ocean journey is the quartering of the sides into hinds and fores, which is followed by grading, as only the best quality is selected for chilling. The picked quarters are "shirted" and their temperature gradually reduced to 33° Fah., an operation which requires the utmost care to ensure that no freezing takes place, for if it does the market value of the meat may be affected. Then comes the work of transferring the meat to the hold of the waiting ship. If the wharf is adjacent to the Frigorifico the beef is taken either in trolleys on rails, which run from the cold rooms to the quay, or by overhead runner rails. In both cases, however, the run ways should be covered in, so as to afford protection from rise in temperature, rain, dust or dirt, the deposition of which would tend to prejudice the meat. Some freezing works are at a distance from the ship, and hence the meat has to be transported by rail or water. If the former means of conveyance is employed the refrigerated cars must be so designed as to prevent bruising, must be well insulated and provided with ample ice bunkers and, what is of the greatest importance, they should *be pre-cooled before the meat is loaded*. The bunkers to be replenished en route should the conditions call for it. When the transportation is effected by water then the holds of the vessels into which the meat is loaded must be effectively insulated, and the refrigerating machinery must be capable of maintaining an equable temperature coinciding with that of the cold store. The maintenance of a practically invariable temperature from the frigorifico to the ship is a *sine qua non* of success. A temporary failure, such as the exposure of the chilled meat to the warm external atmosphere, causes a precipitation of moisture favourable to the creation of mould spores, which, under congenial conditions, may develop very rapidly and thus effect untold damage. From this brief sketch of the treatment of the meat between the pasture and the ship's side, it will be seen that the various phases of preparation approximate to the conditions of an exact science. Nothing is left to chance, manhandling in the later stages of the work is minimised and the chilled meat presented for shipment should be, if the various precautions suggested have been faithfully carried out, like Cæsar's wife, altogether above suspicion.

The next link in the chain of communication between the producer and the overseas market is the ship, which, besides carrying the precious cargo some 6,400 miles, and incidentally through the tropics, has also to maintain a constant temperature in her cold chambers and deliver her three or four thousand tons of meat in the same condition as received. She undergoes a meticulous preparation before commencing to load her cargo. The chambers in which her meat will be carried are first thoroughly cleaned, after which cooling operations are commenced, the temperature being reduced to about 24° or 25° Fah., which is lower than the temperature of the chilled meat to be shipped. While being cooled down each chamber should be sterilised with some non-odorous and effective disinfectant, which will destroy any mould spores, fungus, bacteria, etc., which may have survived the cleaning process. These precautionary measures are very essential, for if the meat is received into a chamber which is absolutely clean and the atmosphere ot which is pure the conditions are certainly favourable to the shipment reaching its destination in the best possible condition. Of course, the whole of the refrigerating machinery, insulation, etc., has been surveyed, and the whole installation passed as being in a fit and proper condition to receive the hall mark of Lloyd's Register R.M.C. certificate.

When the ship is ready, loading commences. Generally the work of loading and stowing is performed by the shippers, which by long experience and practice have raised the operation to the dignity of a fine art, with the result that complaints are the exception. They recognise that anything approaching tight packing may spell disaster by interfering with the proper circulation of air round the quarters of meat, and stow accordingly. They are equally regardful of the fact that it is imperative when once a chamber is opened to receive cargo it must be loaded as speedily as possible, so as not to interfere with that uniformity of temperature which is essential if the meat is to be delivered in all is pristine freshness.

The loading completed, and the final instructions as to the temperatures at which various consignments are to be carried, which will probably range between 28° and 29½° Fah., the ship commences her voyage and the anxiety of the engineer commences.

I would like to remark as a tribute to the work of these experts that the majority of them take the keenest interest in the carriage of the delicate, perishable and valuable cargoes entrusted to them, and the measure of their success is the excellent condition in which the bulk of chilled meat arrives in this country. Throughout the voyage the temperatures of the various chambers are regularly ascertained from thermometers placed at several points in each. These are carefully recorded along with brine temperatures, circulation and pressures, the data thus collated forming an invaluable record in case anything should go wrong.

With regard to the system of brine circulation, which is now adopted on all chilled meat carriers, I favour the Closed in preference to the Open Circuit System, as the former is more effective in its working, ensures better control of brine temperatures and lends itself to the easy application of a simple type of flow-meter which registers the brine flow through each circuit and indicates any choke or leakage which may arise.

In conclusion I would like to say a few words concerning the methods of handling and distribution of chilled meat as practised in our home ports. In many cases they are in strong contrast to the care and attention bestowed upon it by the producer and the shipowner. Manhandling is still rife both in removing meat from the ship and loading it into railway cars or road vehicles. This is an objectionable feature, which, it is only fair to point out, is being dealt with in some of the London docks, specially equipped for the discharge of chilled meat. Then in the case of river barges, railway wagons and road vehicles used for meat transport, the insulation is often imperfect, and pre-cooling seldom is or can be used, with the result that the work of preparation and the efforts of the shipowner are jeopardised. The latter spares no expense to ensure that his vehicle of transportation is thoroughly equipped for the task entrusted it. Why should not the other carriers concerned be compelled to adopt equally efficient methods? If they were, the shipper and the consumer would both benefit, waste would be prevented and a very serious blot on our distribution system removed.

The following are the opening paragraphs of the paper on "The Trade Pasteurisation of Milk and the Public Health," by Henry Kenwood, C.M.G., M.B., F.R.S.E., Emeritus Professor of Hygiene and Public Health in the University of London, and Medical Officer of Health of the Bedfordshire County Council:—

There has been a great movement of population away from "the fountain-head" of the milk supply, viz., the rural districts, and the average time expended in the passage of the milk from the cow to the consumer has therefore much increased. Whereas in 1851 the census returns classified 50 per cent. of the population of England and Wales as "Urban," in 1901 this figure had reached 77 per cent., and at the present day it is about 80 per cent. It was inevitable that this growing urbanisation of our population would be responsible for great changes in the public milk services of at least our larger towns. It was, first of all, responsible for the very general addition of chemical preservatives to milk in order to keep it sweet. With chemical preservatives prohibited (1912) it was necessary to adopt some other means of preventing milk from souring, and the trade turned to the heating of it. This has become so extensively adopted in recent years that in some of our large towns from 50 to 80 per cent. of the entire public supply is of milk which has been heated. From an economic point of view the whole liquid milk industry of our large towns could hardly be conducted nowadays without the assistance of heat; and it seems impossible to provide any more satisfactory substitute.

The most scientific application of heat for the purposes of the liquid milk market is by raising the temperature of the milk to 145°—147° F., by providing conditions which will ensure that the whole of the milk is maintained at that temperature for 30 minutes, and then quickly reducing the temperature of the milk to 50° F. or lower.

Almost all of the pasteurised milk upon the market is sold without the fact of pasteurisation being declared; and so the question may be asked why a large section of the trade is now facing the trouble and expense involved in trade pasteurisation without making any extra charge? The reasons are as follows:—

(1) It prolongs the keeping powers of the milk.

(2) It is a protection against the losses involved by souring, outbreaks of milk-borne infection, and guards against the danger from tuberculosis.

(3) It helps to establish public confidence in the safety of milk, more especially to infants and so favours an increase in the sale of the article.

Royal Navy Engineer Officers.—The following letter is from the Daily Mail:—

Sir,—Referring to the status of Royal Naval engineers as effected by Admiralty Fleet Order 3241/25, a question recently raised in the House of Lords by the Duke of Northumberland, may I call attention to one point which may be considered by some to be of little or no importance? I refer to the re-introduction of the purple stripe.

The Duke of Montrose was quite right when he said, "There is nothing undignified about the purple stripe." It has been, and is, the honoured badge of the Naval Engineer. I for one would not give it up for one moment, and I do not think any of those officers still serving who are entitled to wear this badge would consent to give it up if they were consulted.

The Duke of Montrose however, misses the point. The future engineer of the Royal Navy joined under totally different conditions from those ruling in the past. He joined under the system of common entry, which came into force in 1902, and by that system all officers wear the same uniform. It is a breach of faith to attempt to differentiate between the various branches by making the lieutenant (E) wear a purple stripe. It might just as well be contended that the lieutenant (G) should wear a yellow stripe, and the lieutenant (T) a green stripe.

It may seem a small matter to the general public, but it is splitting a great service into factions. The order is a stupid one and should be withdrawn at once.

J. H. H. Ireland,
Engineer Captain, R.N. (retired).

3, Sussex-terrace, Southsea.

Boiler Explosions Acts, Report No. 2754.—While the *Helmsdale*, 3,149 gross tonnage, built in 1907, was in Barry Dock after undergoing a survey with steam raised preparatory to the Safety Valve test, a loud roar was heard while the Chief Engineer was on the top of the starboard boiler, near the safety valves, the Second Engineer on the top of the port boiler, and the Donkey-man in the stokehold attending to the fires, with about 170lbs. steam pressure, being 10lbs. short of the maximum. Steam escaped into the stokehold through a burst tube in the starboard wing box of the port boiler, severely scalding the Donkey-man so that he had to be removed to the hospital for attention. The Chief Engineer was slightly scalded and injured by falling into the stokehold, but was able to sail in the ship on the following day. Mr. A. W. Powell, Board of Trade Surveyor, Cardiff, investigated the circumstances and wrote the Report, November, 1925, after the ship had made a voyage. There were two main cylinders of the ordinary cylindrical type, 16 feet diameter by 10ft. 6 inches long, of steel, with iron cap welded tubes, and three furnaces of the Deighton type with Gourlay necks, 4 ft $2\frac{11}{16}$ inches diameter. The wing combustion chambers had 118 tubes, and the centre chamber 110 tubes, 6 ft. 9 inches long, $3\frac{5}{16}$ inches diameter The Safety Valves were adjusted for 180lbs. pressure. In 1921, three combustion chamber backs were renewed, also the supporting screwed stays. Since then 220 tubes had been renewed, about 100 being in the port boiler, due to leakages. The tube which collapsed on this occasion was found on examination to be so wasted by corrosion on the water side, that it gave way for a length of about 18 inches.

After the tube gave way, and the Engineers got to the Engine Room, the Donkey pump was started on the port boiler, the fires being drawn, and the boiler cooled down. A stopper was fitted in the collapsed tube, and the boiler tested by hydrolic pressure, this proved satisfactory, and the ship afterwards sailed, when steam was raised and the valves tested.

The observations of Mr. Carlton on the subject, were that a considerable number of the tubes of this boiler appeared to have been renewed from time to time on account of leakage, and the tubes generally had been very badly corroded, unusually so in fact. The prudent course would have been to renew the whole of the plain tubes when failures were becoming frequent. The injuries to the Chief Engineer and the Donkey-man appear to have been sustained mainly in endeavouring to escape from the stokehold. The plain tubes have now been renewed and additional means of escape from the stokehold provided.

In a letter from a member in S. Africa the following occurs "I am afraid the coal strike is seriously upsetting things in the Old Country. It is a dreadful calamity coming just when trade was looking up. I sincerely hope it will soon be settled and things get back to normal."