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A Thermo-Dynamic Study of Exhaust Turbines and other Means of Improving Reciprocating Engines

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Introduction.

THE success of the Bauer-Wach exhaust-steam turbine system, which, up to the present, has been adopted in 200 vessels with a total output of 855,000 i.h.p., has stimulated further endeavours in the principal maritime countries in the direction of improving new and existing reciprocating propelling plant, but on different lines.

These various schemes partly use exhaust-steam turbine systems which more or less resemble the Bauer-Wach system, and partly combinations of well-known fuel-saving means, which, for purposes of propaganda, have been given various attractive names.

The exhaust-steam turbine systems which most closely resemble the Bauer-Wach, but which up till now have only been applied to a limited number of ships, viz., those of the Parsons Marine Steam Turbine Co., Ltd.,[1] and Messrs. Brown, Boveri & Co., Ltd.,[2] are well known, as they have been extensively handled in the technical Press and in propagandist pamphlets. The same applies to the electric transmission of the energy of the exhaust-steam turbine to the propeller shaft.[3]

All these systems are based on the same thermo-dynamic process as that of the Bauer-Wach. The two newest exhaust turbine systems, however, i.e., those of Johansson-Götaverken[4] and Lindholmen-Motala,[5] use entirely different thermo-dynamic processes. These two combination processes have been put on the market under the designation of "Lentzification" anl other names and submitted to shipowners in various forms.

The object of the following study is an impartial comparison of the exhaust-steam turbine systems and the combination processes mentioned.

Before entering into concrete figures, let the author briefly outline the *general principles* of the processes to be compared.

The working principle of the exhaust-steam turbine can be assumed to be universally known. It works with the waste steam no longer utilisable by the reciprocating engine, e.g., with steam between a pressure limit of about 0·2 atmosphere absolute and the attainable vacuum. For practical reasons, however, a pressure up to a maximum of about 0·7 atmos. abs. before the turbine, is taken.

The maximum increase in output attainable by means of an exhaust-steam turbine, according to the type of reciprocating engine and the steam conditions, is from 25 to 35 per cent., and the problem

[1] "The Shipbuilder and Marine Engine-builder", Nos. 248 and 256, Vol. XXXVIII, pp. 153 and 687.

[2] "The Shipbuilder and Marine Engine-builder", No. 219, Vol. XXXV, p. 644; No. 244, Vol. XXXVII, p. 808; and No. 262, Vol. XXXIX, p. 151.

[3] "The Shipbuilder and Marine Engine-builder", No. 233, Vol. XXXVI, p. 838; and Nos. 238 and 239, Vol. XXXVII, pp. 456 and 506.

[4] "Svenska Sjöfarts Tidningen", 2nd December, 1931.

[5] "The Shipbuilder and Marine Engine-builder", No. 250, Vol. XXXVIII, p. 235.

naturally consists of utilising this gain in output in the most efficient manner for the propulsion of the vessel.

In the *Bauer-Wach system* this is achieved by the exhaust-steam turbine driving the propeller shaft through double-reduction mechanical gearing, in which is incorporated a Vulcan hydraulic coupling. The Vulcan coupling has a transmission efficiency of about 97 per cent., and, besides protecting the gearing from the heavy torque fluctuations of the reciprocator, allows the exhaust-steam turbine to be disconnected from it during manœuvring operations. This is impossible with the Brown-Boveri and Parsons systems, which work with a fixed mechanical coupling.

The electric transmission of the energy of the exhaust-steam turbine to the propeller shaft as advocated by the Metropolitan-Vickers Electrical Co., Ltd., although working on the same thermo-dynamic principle, has a smaller efficiency owing to the double conversion and conduction of energy, and a greater initial cost.

In the *Johansson-Götaverken* and *Lindholmen-Motala* systems, a fundamentally different method is employed for utilising the exhaust-steam turbine energy.

In the Götaverken process, the exhaust-steam turbine drives a turbo-compressor, which raises the steam flowing from the high-pressure to the intermediate-pressure cylinder of the reciprocator to a higher pressure and, consequently, a higher temperature level. In the Lindholmen process, the steam between high pressure and intermediate pressure is brought to a higher temperature level without increase of pressure by superheating it electrically.

At first glance one is readily inclined to assume that these two systems are in principle equivalent to, and therefore as efficient as, the Bauer-Wach system, because seemingly the whole energy produced by the exhaust-steam turbine is again introduced into the thermo-dynamic cycle with only very small loss by radiation or leakage. If, however, we examine the thermo-dynamic process of these two systems more closely, we soon realise that they compare very unfavourably with the Bauer-Wach system. We even find that they represent an erroneous avenue of approach towards economical steam technique.

Perhaps the reason for their inefficiency can best be expressed in the following. In the steam-engine cycle the greater portion of the heat energy of the steam is known to be absorbed by the condenser cooling water and therefore lost, so that even in the best steam plants a utilisation of the heat energy of only about 15 to 20 per cent. is achieved. Consequently, the energy produced by the exhaust-steam turbine is also subject to the same losses if it is re-introduced into the steam-engine cycle in the form of heat. The highly valuable *mechanical* energy produced by the exhaust-steam turbine is converted, partially in the Götaverken, and totally in the Lindholmen-Motala processes, into low value *heat* energy.

Comparative Survey of the Processes of Various Exhaust-steam Turbine Systems.

In order to illustrate and appraise the thermo-dynamic relations of the processes under review, a heat-content entropy (*J-S*) diagram is shown in Fig. 1, while Figs. 2 to 5 show four temperature-entropy (*T-S*) diagrams which are based upon the conditions obtaining in a 2,000 to 3,000-i.h.p. reciprocating engine alone for a cargo vessel. In the *J-S* diagram the following processes are illustrated:—Of the reciprocating engine alone by the index 1, of the reciprocating engine together with an exhaust-steam turbine of the Götaverken system by the index 2, of the reciprocating engine together with an exhaust-steam turbine of Lindholmen-Motala system by the index 3, and of the reciprocating engine together with an exhaust-steam turbine of the Bauer-Wach system by the index 4. The four *T-S* diagrams repeat these four processes separately, and employ the same indices.

Table I., which gives the conditions numerically, shows the efficiencies of each cylinder of the reciprocating engine, as well as the estimated indicated efficiencies of the turbines. The latter are obtained by dividing the effective efficiency of the turbines by their mechanical efficiencies. In the Bauer-Wach exhaust-steam turbine system, for example, the efficiency losses in the Vulcan coupling and mechanical gearing have been taken into account in calculating its indicated efficiency.

With regard to the four diagrams, we observe the following:—

Steam Process of the Reciprocating Engine Alone with Saturated Steam.

The course of the process is illustrated in the *J-S* diagram (Fig. 1) by the continuous line and index 1, and in the *T-S* diagram by Fig. 2. The assumed steam consumption of 6 k.g. (13·2lb.) per i.h.p. per hour for the reciprocating engine alone is attainable with a very good engine with minimum clearance and best valve gear and with saturated steam. The pressure in front of the reciprocator is 13 atmos. abs., and the steam moisture estimated at 3 per cent. The back-pressure of the high-pressure cylinder is 5 atmos. abs., of the intermediate-pressure cylinder 1·3 atmos. abs., and of the low-pressure cylinder 0·22 atmos. abs. The indicated efficiencies of each cylinder are averages from many experimental figures. The total heat content of the steam in front of the engine amounts to 652 heat units, of which, since the heat content of water at the back-pressure of the low-pressure cylinder corresponds to a temperature of 62 deg. C., 590 utilisable heat units remain.

The thermal efficiency of the reciprocating engine is as follows:—If we base it on the given temperature limits, as the ratio of 105·3 (see Table I) to 590 heat units = 17·83 per cent., or, if we base it on a feed-water temperature of 0 deg. C., as the ratio of 105·3 to 652 heat units = 16·15 per cent.

We shall now consider the process in the *T-S* diagram (Fig. 2), the course of which has already been clearly shown in the *J-S* diagram. The *T-S* diagram has the advantage of giving the heat quantities as areas. Further, it does not show the losses like the *J-S* diagram, merely as lump sums but in detail, since the indicator diagrams can also be so transformed as to fit into the *T-S* diagram.

The area *m-a-b-c-n* presents the amount of heat contained in the steam process after deduction of the heat content of the water corresponding to the back-pressure of the low-pressure cylinder at a temperature of 62 deg. C. The measurement of this area gives a heat quantity of 590 heat units, the same value as has already been obtained from the *J-S* diagram.

The amount of heat working in the high-pressure cylinder is shown by the

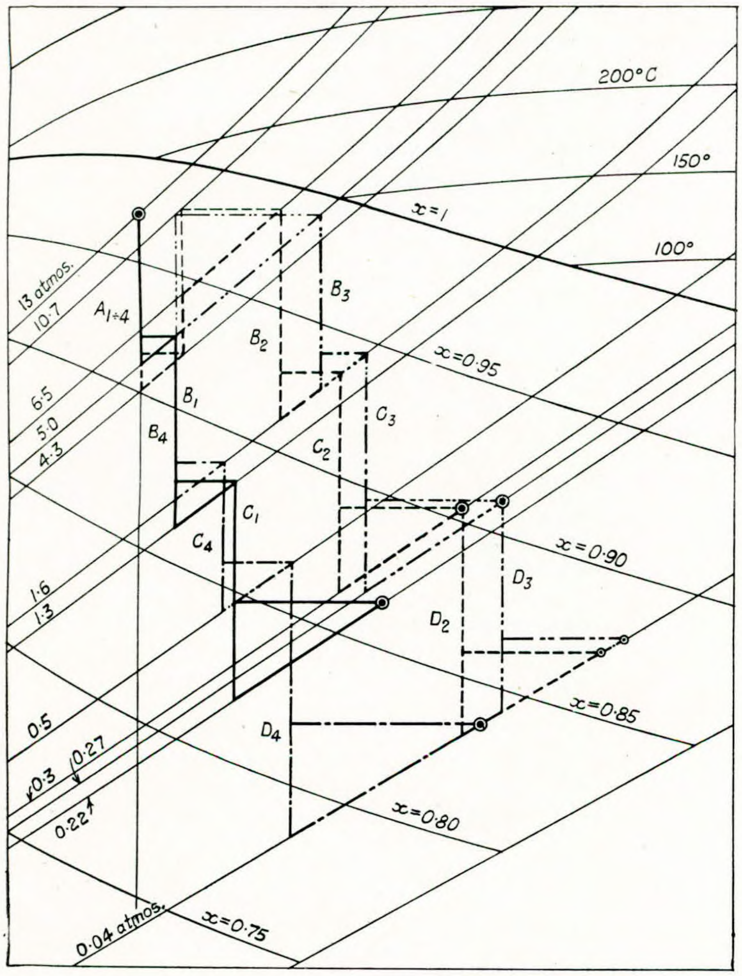


Fig. 1.

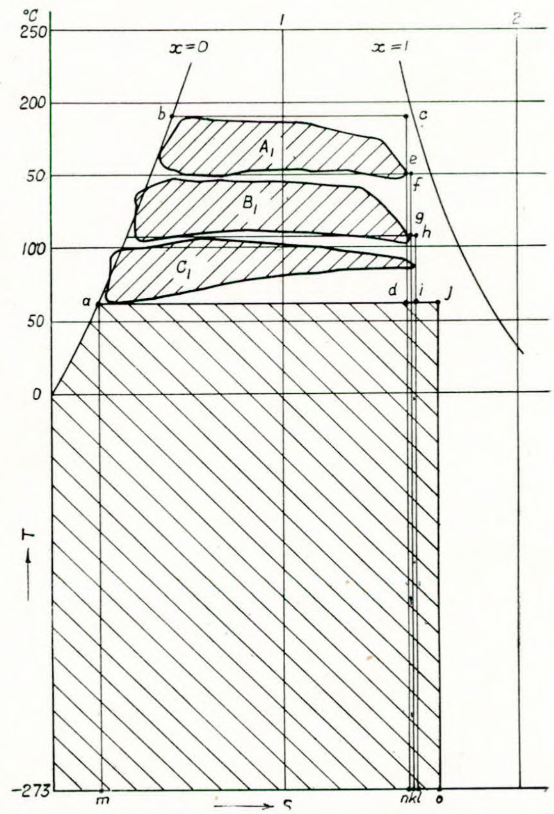


Fig. 2.

Table I.

Triple-expansion Reciprocating Engine for Saturated Steam.

	(1) Alone.			With Exhaust-Steam Turbine System— (2) Götaverken.			(3) Lindholmen.			(4) Bauer-Wach.		
	Adiab. Heat Drop. H.U.	Ind. Eff. %	Ind. Heat Drop. H.U.	Adiab. Heat Drop. H.U.	Ind. Eff. %	Ind. Heat Drop. H.U.	Adiab. Heat Drop. H.U.	Ind. Eff. %	Ind. Heat Drop. H.U.	Adiab. Heat Drop. H.U.	Ind. Eff. %	Ind. Heat Drop. H.U.
H.-P. Cylinder ...	41	80	32·8	47	79	37·1	41	80	32·8	41	80	32·8
I.-P. Cylinder ...	51·5	75·8	39	57·5	78	44·8	47·2	80	37·6	44	77	33·9
L.-P. Cylinder ...	59·8	56	33·5	59·6	61	36·3	64·5	61	39·3	40·6	65	26·5
Exhaust-steam Turbine	—	—	—	(61·5)	(65)	(40)	(57·6)	(65)	(37·4)	74·5	62	46·2
Whole Plant ...	149	70·7	105·3	193·7	72	118·2	193·7	56·6	109·7	193·7	72	139·4
Specific Steam Consumption ...			*6·0*			*5·35*			*5·77*			*4·55*

shaded area A_1. The incomplete utilisation of the available temperature range, as expressed by the indicated efficiency, results in an increase of the entropy to the extent of the area *e-f-k-n*.

The study of the processes for the intermediate-pressure and low-pressure cylinders is carried through in a similar manner to that adopted for the high-pressure cylinder. The areas symbolised by B_1 and C_1 give the outputs of their corresponding cylinders. The corresponding heat losses result in an increase of the entropy to the extent of the areas *g-h-l-k* for the intermediate-pressure cylinder and *i-j-o-l* for the low-pressure cylinder. The amount of heat under the back-pressure line of 0·22 atmos., shown shaded in the graph, gives the amount of heat carried away by the cooling water. A comparison of these areas gives the efficiency of the reciprocating-engine processes as 17·83 per cent. at a feed-water temperature of 62 deg., a figure already obtained in the *J-S* diagram.

Steam Process of the Johansson-Götaverken Exhaust-steam Turbine System with Saturated Steam.

The exhaust-steam turbine of the Götaverken process works, as already stated, by arranging an exhaust-steam turbine driving a steam compressor behind the low-pressure cylinder of the reciprocating engine. This compressor takes steam from the high-pressure cylinder, and, after compressing and partially drying it, delivers it into the intermediate-pressure cylinder. As the direct connection from high-pressure to intermediate-pressure cylinder is cut out during normal working, all the steam from the high pressure passes through the compressor.

Now the volume of this steam, even in comparatively large reciprocating engines, is quite small, so that considerable leakage losses in the compressor have to be reckoned with. As, further, on account of the small steam quantities, the areas of the steam-compressor impeller are very restricted, a good manometric efficiency of the steam compressor cannot be obtained.

In addition, a serious discrepancy between the exhaust-steam turbine and steam compressor exists, as the necessarily large exhaust areas of the exhaust-steam turbine prevent it being driven at the very high speed demanded by the restricted areas of the steam compressor.

It is at once evident, therefore, that in the Götaverken process only a part of the exhaust-steam turbine output is converted directly into mechanical work, while the rest is transformed into heat. Of this heat amount, about four-fifths are lost in the cooling water, as it passes through a steam-engine process.

It would only be possible to obtain a larger percentage of the exhaust-steam turbine output in the form of mechanical energy if the compression of the steam before the intermediate-pressure cylinder were carried very high. Insurmountable difficulties, however, prevent this, as will be shown later—at least in conversions.

In the *J-S* diagram, Fig. 1, the Götaverken process is represented by dotted lines and index 2. It is probable that the back pressure of the high-pressure cylinder must be kept lower than in a reciprocating engine alone, as otherwise the intermediate-pressure cylinder, because of its receiving highly compressed steam, would develop too large an output. The back pressure of the high-pressure cylinder (A_2) is therefore assumed to be 4·3 atmos. abs., that behind the intermediate-pressure cylinder (B_2) to again be 1·6 atmos. abs., and that behind the low-pressure cylinder (C_2) 0·3 atmos. abs.

By an estimate we ascertain what adiabatic heat drop is available for the exhaust-steam turbine (D_2) at a vacuum of 96 per cent., and find it to be 61·5 heat units. At an assumed efficiency of the exhaust-steam turbine of 65 per cent., 40 heat units are converted into mechanical work.

If we take the radiation loss in pipe-line and compressor at 3 per cent., then 38.8 heat units can be re-introduced into the reciprocating-engine process.

Were it possible to produce pure adiabatic compression with the efficiency 1, then the steam pressure of 4·3 atmos. abs. could be raised to 10·7 atmos. abs. through this heat amount. As already mentioned, however, the compressor can only work under the prevailing conditions with a comparatively small efficiency, and therefore without great error we may reckon with a 45 per cent. utilisation of the available 38·8 heat units for raising the steam pressure, so that it rises from 4·3 to 6·5 atmos. abs. Even if the compressor had a quite substantially higher efficiency, the improvement would only be slight, since, as we shall see later, the initial pressure in the intermediate-pressure cylinder must not be raised too high. The initial point of the process in the intermediate-pressure cylinder (B_2), therefore, is the point of intersection of the line of the same total heat (throttle line) with the pressure line of 6·5 atmos. abs. Since the steam is substantially drier than in the reciprocating engine alone, an intermediate-pressure efficiency of 78 per cent. is assumed, instead of 75·8 per cent.

For the low-pressure cylinder also an increase of the indicated efficiency must be reckoned with, the more so as the back-pressure is increased from 0·22 to 0·3 atmos. abs. We therefore assume a low-pressure efficiency of 61 instead of 56 per cent.

Consequently, the indicated heat drop for the low-pressure cylinder (C_2) amounts to 36·3 heat units. From the point on the back-pressure line corresponding to this heat drop down to the condenser pressure of 0·04 atmos. abs., a heat drop of 61·5 heat units (D_2) is available for the exhaust-steam turbine, as estimated.

If we add together all indicated heat drops, we get 118·2 heat units, and consequently a steam consumption of 5·35 kg. (11·8lb.) per i.h.p. per hour. The thermal efficiency of the process based upon the given temperature limits is therefore 19 per cent.

The result of our calculation leads to the conclusion that, compared with the reciprocating engine alone, under favourable conditions, a saving in steam consumption of 10·8 per cent. can be attained with the Götaverken exhaust-steam turbine system.

In the *T-S* diagram the Götaverken process is shown by Fig. 3.

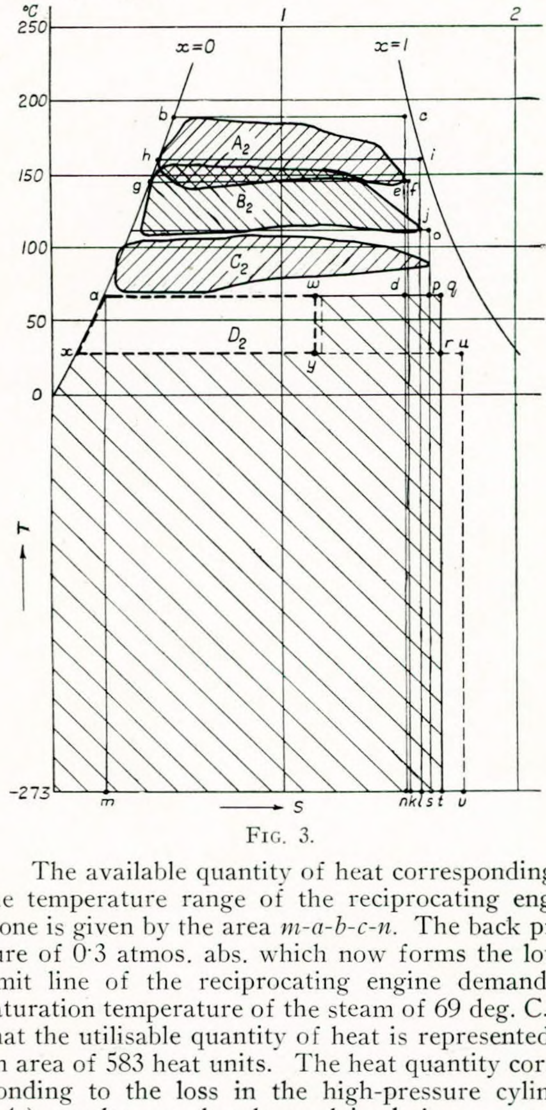


FIG. 3.

The available quantity of heat corresponding to the temperature range of the reciprocating engine alone is given by the area *m-a-b-c-n*. The back pressure of 0·3 atmos. abs. which now forms the lower limit line of the reciprocating engine demands a saturation temperature of the steam of 69 deg. C., so that the utilisable quantity of heat is represented by an area of 583 heat units. The heat quantity corresponding to the loss in the high-pressure cylinder (A_2) results, as already explained, in an entropy increase. This is represented by the area *e-f-k-n*.

The quantity of heat available behind the high-pressure cylinder will thus be increased by the effective output of the compressor, viz., by 38·8 heat units. The simultaneous increase in pressure and steam dryness gives the point *i* as the initial point for the further process. The area *g-h-i-l-k-f-g* must therefore be equivalent to the above-mentioned turbine output, i.e., equal to the area *a-w-y-x* (D_2).

Based on the foregoing, the further course in the *T-S* diagram needs no further explanation. The comparison of the utilised, as against the utilisable, areas gives, as in the *J-S* diagram, a thermal efficiency of 19 per cent., taking the back-pressure in the low-pressure cylinder, and of 18·1 per cent., taking a feed-water temperature of 0 deg. C.

Steam Process of the Lindholmen-Motala Exhaust-Steam Turbine System with Saturated Steam.

The dash and double-dot line and index 3 in Fig. 1 illustrate the steam process of this system in the *T-S* diagram, and Fig 4 shows its *T-S* diagram.

The *J-S* diagram clearly reveals that in the Lindholmen process the heat drop available for the intermediate-pressure and low-pressure cylinders and the exhaust-steam turbine has been moved into the region of higher total heat and less steam moisture. The process, however, still remains wholly within the range of saturated steam, so that the attainable reheating effect is only very small.

For this reason the back pressure of the high-pressure cylinder is assumed to be the same as in the reciprocating engine alone.

An estimate of the conditions in the exhaust-steam turbine shows that an indicated heat drop of 37·4 heat units may be reckoned with. If we assume the generator efficiency at 92 per cent. and the radiation losses at 3 per cent., 33·4 heat units remain available for intermediate superheating of the steam.

Through the introduction of this heat quantity, the exhaust steam of the high-pressure cylinder (A_3) is dried and the steam moisture thus lowered from 7·5 to 0·8 per cent. Consequently, the point showing the steam condition before the intermediate pressure cylinder (B_3) in the *J-S* diagram is not far removed from the corresponding point of the Götaverken process, so that the general course of both processes is very similar. Table I. brings this out very clearly.

In the Lindholmen process only the intermediate-pressure cylinder has a better efficiency, as its steam is somewhat drier and its adiabatic drop smaller. For the low-pressure cylinder (C_3) and the exhaust-steam turbine (D_3) the efficiencies are assumed to be the same as in the Götaverken process.

The adding together of the indicated heat drops in the three cylinders—the exhaust-steam turbine does not supply its power to an outside source—gives a total of 109·7 heat units and a steam consumption of 5·77 kg. (12·7lb.) per i.h.p. per hour. Consequently, an improvement over the reciprocating engine alone of 3·84 per cent. results, so that the Lindholmen-Motala system ranks below the

Götaverken system in respect to the improvement of the reciprocator.

In the *T-S* diagram, Fig. 4, the drying of the

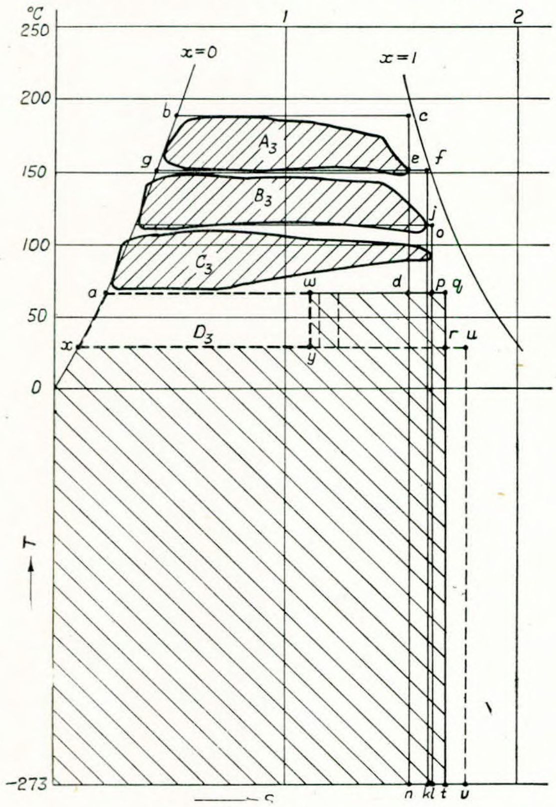


Fig. 4.

steam behind the high-pressure cylinder A_3 obtained in the Lindholmen system reveals itself as an increase in entropy. The condition of the steam before the intermediate-pressure cylinder is represented by the point *f*, and the area *e-f-k-n* equals the area *a-w-y-x* (D_3) if increased by the area which corresponds to the heat losses in the high-pressure cylinder.

The remaining details of Fig. 3 will be clear from the explanations given in the foregoing. The thermal efficiencies of the Lindholmen process are 17·6 per cent. based on the back-pressure in the low-pressure cylinder, and 16·8 per cent. based on a feed-water temperature of 0 deg. C.

Steam Process of the Bauer-Wach Exhaust-steam System with Saturated Steam.

In the case under consideration, which is symbolised in the *I-S* diagram by the dot-dash line and index 4, the pressure behind the high-pressure cylinder (A_4) amounts to 5 atmos. abs., behind the intermediate-pressure cylinder (B_4) to 1·6 atmos. abs., and behind the low-pressure cylinder (C_4) to 0·5 atmos. abs., while for the turbine (D_4) a condenser pressure of 0·04 atmos. abs. has been assumed, as in the previous examples.

As the heat drop is the same, the indicated efficiency of the high-pressure cylinder is also the same as that of the high-pressure of the reciprocator alone, viz., 80 per cent. For the intermediate-pressure cylinder, an efficiency improvement of from 75·6 to 77 per cent. may be assumed on account of the decrease in heat drop. Much greater, however, with regard to efficiency is the effect of the reduced heat drop (40·6 instead of

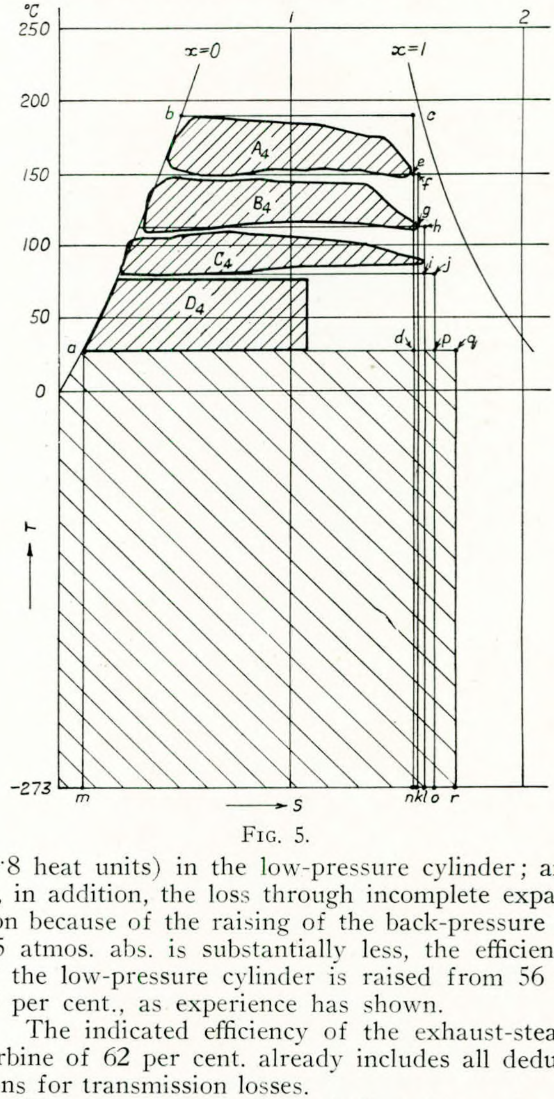


Fig. 5.

59·8 heat units) in the low-pressure cylinder; and as, in addition, the loss through incomplete expansion because of the raising of the back-pressure to 0·5 atmos. abs. is substantially less, the efficiency of the low-pressure cylinder is raised from 56 to 65 per cent., as experience has shown.

The indicated efficiency of the exhaust-steam turbine of 62 per cent. already includes all deductions for transmission losses.

The sum total of all the indicated heat drops, including that of the exhaust turbine of the Bauer-Wach system, amounts to 139·4 heat units, and the corresponding steam consumption to 4·55kg. (10lb.) per i.h.p. per hour.

Consequently, the Bauer-Wach system actually effects a saving in steam consumption of 24·2 per cent. over and above that of the reciprocating engine alone, which is more than double the saving obtained by the Götaverken system, and more than six times that obtained by the Lindholmen system.

The illustration of the Bauer-Wach process in the *T-S* diagram (Fig. 5) is quite clear from the foregoing examples without further comment. The lower temperature limit is 29 deg. C., according to the back-pressure of the exhaust-steam turbine of 0·04 atmos. abs. The total quantity of heat working in the reciprocating engine and exhaust-steam turbine is therefore 623 heat units. Based on this figure, the total heat drop given in the foregoing of 139·4 heat units results in a thermal efficiency of 22·4 per cent., and based upon 0 deg. C. of 21·4 per cent.

Comparison of Exhaust-steam Turbine Systems with Superheated Steam.

We choose a temperature of 315 deg. C. and a pressure of 14 atmos. as a starting point for the steam process, and base our comparison upon the same reciprocating engine as before. For illustrating the steam process of the systems under consideration, however, we limit ourselves to the *J-S* diagram as given in Fig. 6. Here the same symbols are used, viz., continuous, dash-double-dot, dash, and dot-dash lines, and the same indices 1—4 for the four processes, viz., that of the reciprocating engine alone, of the Götaverken exhaust-steam turbine system, of the Lindholmen process, and of the Bauer-Wach system.

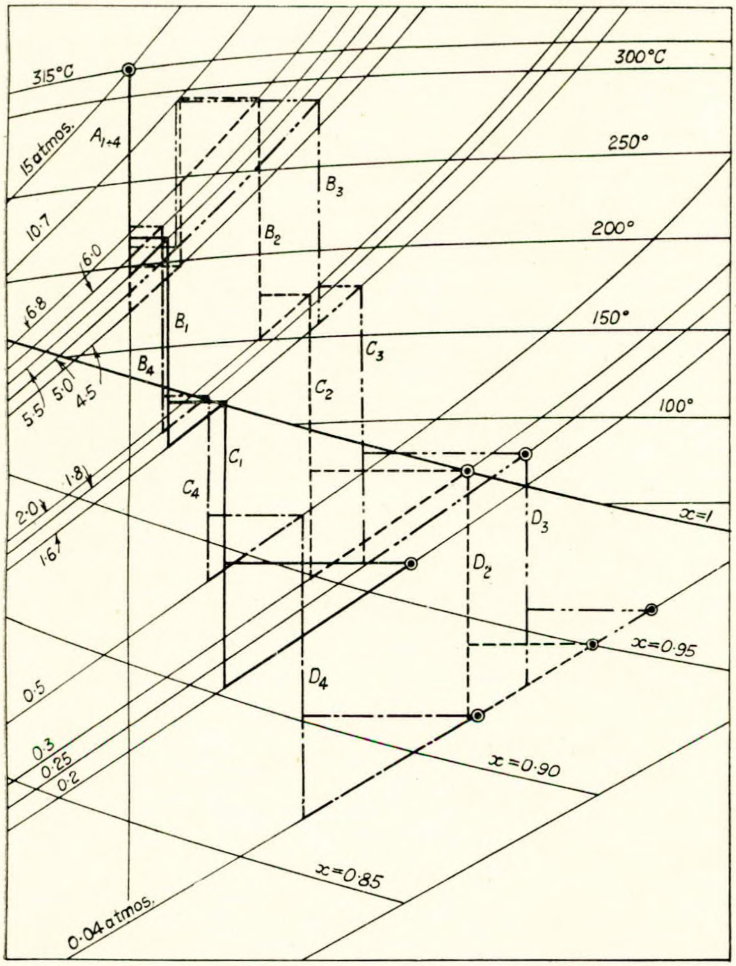


Fig. 6.

The various figures used for compiling the *J-S* diagram are set down in Table II. This needs no elucidation in view of preceding explanations.

What has already been said concerning the back-pressure of the high-pressure cylinders of the four cases under consideration also applies, in principle, to superheated steam. Accordingly, the indicated efficiencies of the high-pressure cylinders are also different. For the exhaust-steam turbines of the Götaverken and Lindholmen systems, indicated efficiencies of 70 per cent., and for that of the Bauer-Wach system of 66 per cent., for the reasons given in the foregoing, have been assumed. It may here be pointed out that, if the Götaverken or Lindholmen system is employed for superheated steam, the high temperatures attained through intermediate compression or superheating between the high-pressure and intermediate-pressure cylinders are not suitable for satisfactory working of the intermediate-pressure cylinder.

Table II.
Triple-expansion Reciprocating Engine for Superheated Steam.

	(1) Alone.			With Exhaust-steam Turbine System— (2) Götaverken.			(3) Lindholmen.			(4) Bauer-Wach.		
	Adiab. Heat Drop. H.U.	Ind. Eff. %	Ind. Heat Drop. H.U.	Adiab. Heat Drop. H.U.	Ind. Eff. %	Ind. Heat Drop. H.U.	Adiab. Heat Drop. H.U.	Ind. Eff. %	Ind. Heat Drop. H.U.	Adiab. Heat Drop. H.U.	Ind. Eff. %	Ind. Heat Drop. H.U.
H.-P. Cylinder ...	56	82	45·9	65·5	81	53·1	60·5	81·7	49·4	51·7	83	42·8
I.-P. Cylinder ...	55·8	80	44·7	65	82	53	60·5	82·5	49·9	55·4	82	45·4
L.-P. Cylinder ...	77	57	43·8	77	62	47·7	75·5	62	46·7	50	64	32·0
Exhaust-steam Turbine	—	—	—	(67·5)	(70·0)	(47·2)	(62·2)	(70)	(43·5)	82·5	66	54·4
Whole Plant ...	184·5	72·8	134·4	231·6	74·2	154·1	231·6	75·5	146·0	231·6	75·6	174·6
Specific Steam Consumption ...			*4·7*			*4·10*			*4·33*			*3·62*

The following steam consumptions are attained:—4·7 kg. (10·4lb.) per i.h.p. per hour by the reciprocating engine alone; 4·1 kg. (9lb.) per i.h.p. per hour by the Götaverken system, an improvement, therefore, over the reciprocator alone of 12·8 per cent.; and 4·33 kg. (9·5lb.) per i.h.p. by the Lindholmen system, i.e., 7·9 per cent. improvement over the reciprocator alone. With the Bauer-Wach system, however, as its steam consumption is 3·62 kg. (7·98lb.), an improvement of 23 per cent. over the reciprocating engine alone is obtained.

Consequently, with superheated steam also the Bauer-Wach exhaust-steam turbine system far surpasses the other two systems.

Instead of only compressing the steam between the high pressure and intermediate pressure as in the Götaverken system, we could, of course, repeat this process between the intermediate pressure and low pressure. In this case the first compression would have to be lower.

Apart, however, from scarcely surmountable practical difficulties, such a proceeding would only have economic disadvantages, as the improvement in steam consumption, which with single compression amounts to 12·7 per cent., would only be 11·4 per cent.

Naturally, a corresponding alteration of the Lindholmen process is possible in so far as only part of the total energy of the exhaust-steam turbine, transformed into heat, is introduced into the steam behind the high pressure and the other part behind the intermediate pressure. Repeating this calculation here would lead too far, so that the author confines himself to stating that through this alternative the improvement over the reciprocating engine alone would only be about 6 per cent.

As in the Lindholmen system electric energy is available in intermediate form, a part of it can be used for driving auxiliary machinery electrically instead of by steam, thus attaining a certain economy. This, however, is not considerable.

The consumption of the usual steam auxiliaries on board is indeed very unsatisfactory. If their exhaust, however, is not led into the condenser, but used for feed-water heating, the overall economy is considerably improved. Consequently, by driving the auxiliaries electrically little is gained, as the raising of the feed-water temperature must then be attained by other means, viz., by bleeding the main engine, which means that it uses more steam.

It is not surprising, therefore, that a calculation—which, however, the author refrains from giving here—would only show an improvement in the total steam consumption of 9—10 per cent. over the reciprocating engine with its steam auxiliaries.

Some Practical Remarks in connection with the Comparison of Exhaust-steam Turbine Systems.

In actual practice, comparatively narrow limits are drawn around the otherwise ingenious Götaverken process by the following conditions:—

As is well known, the classification societies determine the diameter of the crankshaft by the maximum piston pressure which can be exerted in any one cylinder. Consequently, the calculation formula for the crankshaft is based on the product of boiler pressure and the area of the high-pressure piston. The like product for the intermediate-pressure cylinder must not be higher.

Assuming the boiler pressure to be 14 atmos., as in the previous examples, and the ratio of the piston areas of the high-pressure and intermediate-pressure cylinders to be 1 : 2·5, then according to the classification societies the pressure of the compressed steam coming from the compressor must not exceed 5·6 atmos. if the existing crankshaft is not replaced by one of greater diameter. This means that in existing ships the full advantages of the Götaverken system cannot be utilised without entailing the very heavy expenditure of renewing the crankshaft.

A further practical and rather serious disadvantage of the Götaverken system, which also applies to the Lindholmen, is that, unlike systems which transmit the output of the exhaust-steam turbine to the propeller shaft through mechanical gearing, the additional power is not delivered to the propeller shaft with a fully uniform torque, but with the fluctuating torque of the reciprocating engine. For example, in the Bauer-Wach system the exhaust-steam turbine puts practically no additional stress on the shafting, for which reason Lloyd's Register allow the shafting of Bauer-Wach installations to be made according to the formula for pure steam-turbine plants. This is not possible with the Götaverken or Lindholmen system. Consequently with these two systems, a shipowner cannot reap the full benefit attainable by an exhaust-steam turbine, viz., the possibility of increased output and thus increased speed of the vessel, as that would necessitate the renewal of the whole of the tunnel and tail shafting.

Finally, the author would like to point out that neither the Götaverken nor the Lindholmen system produces a flywheel effect on the propeller shafting, as does the Bauer-Wach system. This flywheel effect, which prevents racing of the engine during the pitching of a vessel, and enables her speed to be maintained in bad weather, is highly appreciated by all ships' officers.

In comparing the improvement in steam consumption of the systems under discussion, it must be borne in mind that it refers to the main engines alone. For the shipowner, however, the consumption of the whole engine plant, inclusive of auxiliaries, is decisive.

Now, an exhaust-steam turbine installation of any system requires a better vacuum than a reciprocating engine alone, and thus a vacuum augmenter and a greater quantity of cooling water.

Both measures raise the steam consumption, and this increase must be deducted from the calculated improvements.

As this additional steam consumption is nearly the same for all the three exhaust-steam turbine systems under comparison, the advantage of the more economical system is apparent. Thus the superiority of the Bauer-Wach system over the Götaverken, and especially over the Lindholmen system, is still more striking.

May the author, in spite of its self-evident nature, here make a further important observation concerning the comparison of the various exhaust-steam turbine systems and other means of improving the economy of reciprocating steam engines.

If we compare these, we must naturally take into account the cost of purchase and installation. The system effecting the smaller improvement should, of course, cost less than that giving the greater improvement.

Now, let us suppose that one system effects 20 per cent. economy and costs, say, £10,000, while another for the same vessel gives only 10 per cent. economy and costs £5,000. During the redemption period of the capital outlay both systems will be equal; but after its expiry (the one saving 20 per cent. and the other only 10 per cent.), the advantage of the more economical system will be double that of the other.

It is thus evident that it is a short-sighted business policy to base the choice of a system alone on its purchase and installation price, because in the end it is always the more economical system which brings the greater profit to the shipowner.

For instance, the capital cost of the Bauer-Wach system, under normal conditions and with coal as fuel, is redeemed in 2½ to 4 years; so that, as its life is far longer, the redemption period only detracts by a comparatively small degree from the great saving which the Bauer-Wach system effects.

Other Processes recently developed for Increase in Economy.

Much propaganda has recently been launched in favour of processes which claim to present new methods for increasing the economy of reciprocating steam propelling plants. These are, however, nothing more than a combination of individual improvements, whose principles and construction have been universally known for a long time.

They crop up in many guises, and present a varied selection of the following measures, which are grouped to suit the case in point or the ideas of their promoters :—

(1) Improving the boiler-water circulation by baffle plates, circulating pumps, etc.;

(2) Altering the lead of the boiler-flue gases;

(3) High superheating;

(4) Bleeding steam from the receivers of the reciprocating engine for increasing the feed-water temperature;

(5) Raising the vacuum; and, above all,

(6) Equipping the high-pressure cylinder with poppet-valve gear.

The last-named measure, which is founded on an old Lentz patent long since expired, has led to extended use of the term "Lentzification", but has, of course, nothing to do with the other measures mentioned.

Together with these, a whole series of other measures might be associated, as for example :—

(7) Enlarging the air preheater;

(8) Arranging feed-water preheaters in the smoke tubes;

(9) The Wyndham system for drying the auxiliary exhaust;

(10) The uni-flow principle for the low-pressure cylinder; and several others, quite apart from special designs which require alteration of the whole plant, such as :—

(11) The introduction of super-pressure steam in combination with water-tube boilers;

(12) Pulverised-coal firing; and

(13) Mechanical stokers.

It is obvious that all these measures can be combined at will with an exhaust-steam turbine, especially one of the Bauer-Wach type, since it entails no additional temperature rise in the steam process, as is the case in the Götaverken and Lindholmen systems.

Perhaps it is here opportune to make some remarks concerning the *equipment of the high-pressure cylinder with poppet valves,* as this is one of the chief features of "Lentzification".

For poppet-valve gear the following advantages have been repeatedly claimed with a certain amount of justification :—Quicker opening and quicker closing, as well as larger passages at smaller cut-offs, and therefore less wire-drawing. At normal cut-offs these advantages hardly exist, as is apparent from a comparison of the indicator cards of a normal well-designed slide-valve gear with those of poppet-valve gear.

As a further advantage of poppet-valve gear, it has often been justly claimed that the beginning of the exhaust and compression can be set independently of the beginning of the admission and cut-off, which is not the case with slide-valve gear, where these four phases are interdependent. If, therefore, for any reason whatsoever, a change-over from normal to a small cut-off is necessary, this can be effected in the most favourable way by adjusting the exhaust cams. The correct application of this procedure, however, requires the attention of a reliable and skilled engine-room staff.

Only the Caprotti gear, which has been launched with success in Great Britain by Messrs. William Beardmore & Co., Ltd., permits easy adjustment; as when altering the cut-off the admission remains approximately, and the exhaust and compression completely, unchanged.

Altering the cut-off is effected through a single operation which requires no special skill, so that this easy adaptability of the Caprotti gear to varying circumstances may have a very profitable effect on the yearly average fuel consumption.

With regard to clearance spaces, these are not less with poppet-valve gear in the high pressure than with slide-valve gear. In fact, the case is frequently the contrary. In this connection it may be mentioned that, with superheated steam, the size of the clearance space is of little influence, as the heat transmission between *superheated* steam and the cylinder wall is known to be very small.

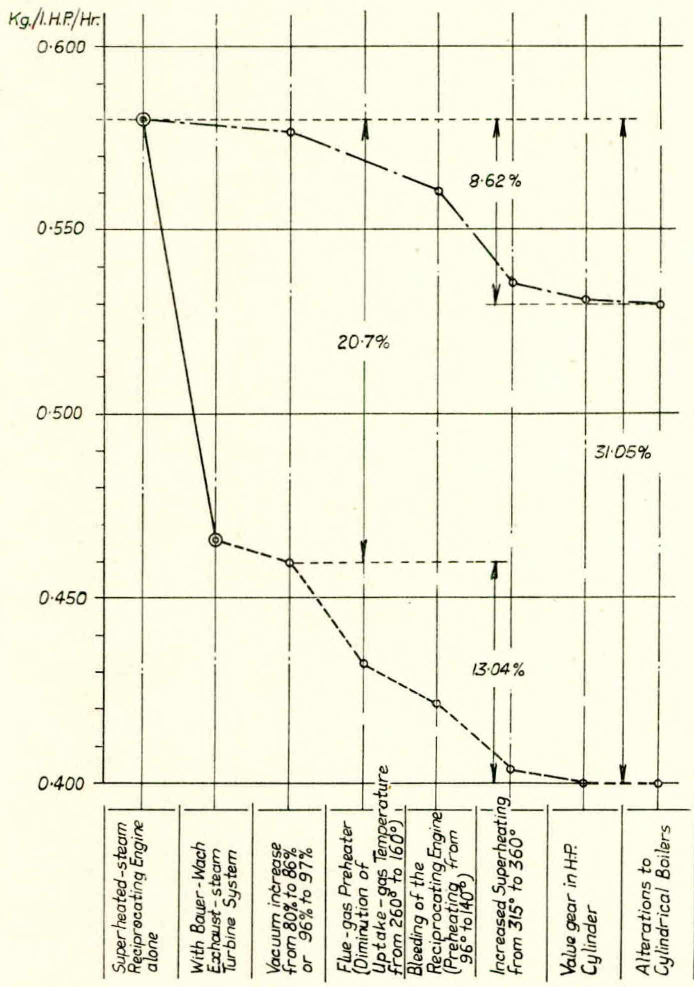


FIG. 7.

With the exception of the Caprotti gear, the improvement in steam consumption of a superheated plant attainable by equipping the high-pressure cylinder with poppet-valve gear does not exceed 1 to 1½ per cent.

It may be remarked in favour of poppet-valve gear for the high-pressure cylinder that, for very high superheat temperature—say, over 350 deg. C. in the engine—poppet-valve gear for the high-pressure cylinder is desirable, as it requires less lubrication.

In the first part of this study it has been shown to what extent the steam consumption of a reciprocator is improved if it is combined with one of the three exhaust-steam turbine systems under discussion.

In the same manner the author will, in the following, illustrate how far the fuel consumption of a reciprocator, or a combination of reciprocator and exhaust-steam turbine of the Bauer-Wach system, is improved if any one of the measures enumerated under (1) to (10) is applied :—

(1) If only the measures (1) to (6), i.e., the so-called "Lentzification", are used, then the coal consumption of a reciprocator alone, working, with superheated steam of the same pressure and temperature as in example (1) of Fig. 6 and Table II., is improved by 8·6 per cent.

(2) If the same reciprocator is combined with an exhaust-steam turbine of the Bauer-Wach system, without the other measures and working under the conditions given in example (4) of Fig. 4 and Table II., the coal consumption is improved by 20·7 per cent.

(3) If to the example under (2) all measures under (1) to (10) are added, then the coal consumption under (2) is further improved by 13·04 per cent., so that, compared with a reciprocator alone without any of the further measures, a total improvement of fuel consumption of 31·05 per cent. is attained.

The foregoing results are shown graphically in Fig. 7.

The coal-consumption figures per i.h.p. per hour given in the ordinates are those which correspond to the measures enumerated in the abscissa if these are added to a reciprocator. The coal consumption attainable by "Lentzification" as under (1) is shown by the dash and dotted line. As will be seen, it is reduced from 0·58 to 0·53 kg. per i.h.p. per hour. The coal consumption attainable by the Bauer-Wach system as under (2) is shown by the continuous line. As is evident, it is reduced from 0·58 to 0·46 kg. per i.h.p. per hour. The measures under (3) are illustrated by the continuous and the dash lines. They reduce the fuel consumption from 0·58 to 0·4 kg. per i.h.p. per hour.

It will here be explained by what method the basic figure of 0·58 kg. per i.h.p. per hour is arrived at as the coal consumption for the reciprocator alone, together with its normal auxiliaries.

This figure is calculated from the steam consumption of 4·7 per i.h.p. per hour given for the reciprocator alone, without auxiliaries, in example (1) of Fig. 6 and Table II. by making the following assumptions:—

(*a*) A steam consumption of auxiliaries of 8 per cent. of that of the reciprocator alone. To this figure corresponds a feed-water temperature of 96 deg. C., attained by heating it through the auxiliary exhaust.

(*b*) A boiler efficiency of 75 per cent.

(*c*) A calorific value of the coal of 7,500 heat units.

(*d*) A boiler steam pressure of 16 atmos. abs. and a superheated steam temperature of 330 deg. C.

The foregoing figures correspond to an 8·74-fold evaporation, and thus to a coal consumption of 0·58 kg. per i.h.p. per hour.

With regard to the coal-consumption improvement figures attainable by the measures enumerated under (1) to (10), as illustrated in Fig. 7, we note the following:—

The improvement contributed by each single measure is, of course, less when using it together with other measures than when applying it alone, as one measure reacts thermo-dynamically upon the other.

Of course it must be taken into account that each measure requires a certain amount of steam, which must be deducted from the steam quantity saved by it.

In a reciprocating engine working alone, the gain by *increased vacuum* is practically all sacrificed because of the extra steam required to increase the cooling-water amount and heating the correspondingly cold condensate.

An increase in air preheating requires an additional induced-draught fan and increased feed-water preheating involves bleeding, and therefore an increase of the main steam consumption; so that, in calculating the gain resulting from all such measures, the extra steam required by them must be taken into account.

In the graph, the improvements enumerated under (8), (9) and (10) are omitted for the following reasons:—

Fitting *feed-water preheaters in the smoke tubes* has the same effect as enlarging the air preheater, viz., of decreasing the flue-gas temperature, in the example selected, from 260 deg. to 160 deg. Consequently, the simultaneous use of both measures cannot bring an additional gain.

The well-known *Wyndham process* of drying the auxiliary exhaust would bring no gain in the case under discussion, as, on account of the high main and auxiliary steam temperature, the auxiliary exhaust hardly shows any moisture.

The uni-flow principle for the low-pressure cylinder has not been taken into consideration, since it does not belong to the first "Lentzification" group, and, besides, would not bring about any gain if used in combination with an exhaust-steam turbine. The advantages of uni-flow lie in the improvement of the indicated efficiency of the low-pressure cylinder, which is occasioned, on the one hand, by a reduction of the condensation losses because of the smaller temperature fluctuations, and, on the other hand, by the increase of the utilisable heat drop through the larger exhaust ports giving a lower back-pressure.

The improvements in fuel and steam consumption attainable by this measure, which, after some decades of oblivion, is now again the subject of propaganda by several firms—such as Christiansen and Meyer, Borsig, Storck, and Fredriksstad M.V.—are disputable, and at best cannot be great.

The result finally obtained from the graph (Fig. 7) is as follows:—By "Lentzification" a decrease in the fuel consumption of 8·62 per cent. in a superheated reciprocating steam engine working alone can be attained. By the addition of an exhaust-steam turbine to a reciprocator, a decrease in fuel consumption of 20·7 per cent. can be effected at easily obtainable vacuum. If the improvements discussed in the foregoing are added to such an installation, its fuel consumption can be still further reduced by 13·04 per cent., ***so that the total fuel saving by an exhaust-steam turbine together with other improvements amounts to*** 31·05 *per cent.*

The foregoing comparison has been based, as stated, on a modern standard superheated-steam reciprocator of first-class manufacture. This is the only fair basis of comparison, ***and sufficient warning cannot be given against excessive claims frequently made in favour of new systems, as the results given are often not based on the most efficient, but on very inefficient reciprocating steam engines.***

The graph (Fig. 7) therefore shows that, for a propelling plant consisting of a reciprocating engine of good standard design and a Bauer-Wach exhaust-steam turbine, a fuel consumption of 0·4 kg. per i.h.p. with coal of a minimum of 7,500 calories can be guaranteed and proved without water-tube boilers, without exceeding the steam-pressure limits of Scotch boilers, and without pulverised-fuel firing or mechanical stoking, and consequently at normal capital outlay.

In larger plants—for example, for 5,000/6,000 combined i.h.p.—the coal consumption is even less, as their steam consumption is at least 2 per cent. better. As, further, their larger boiler units have about 2 per cent. greater efficiency, a coal consumption of 0·39 kg. (·8598lb.) per i.h.p. per hour can be guaranteed.

It is evident that the Diesel engine can only compete under very special conditions with coal-fired propelling plant of so high a standard of economy, especially if the higher initial and maintenance costs of the Diesel plant are taken into account.

The use of suitable combined reciprocating and exhaust-steam turbine propelling machinery is therefore of paramount importance to countries where the utilisation of national coal resources is a main consideration.

The Götaverken System of Marine Steam-engine Economy.

A REPLY TO DR. G. BAUER'S CRITICISM.

By E. JOHANSSON, of Gothenburg.

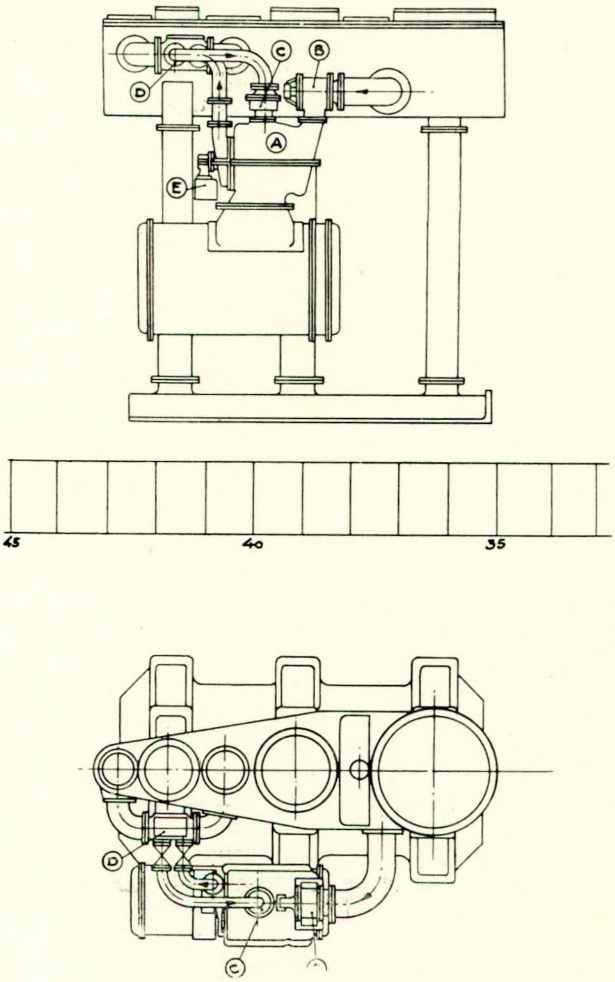
Reprinted by permission from "The Shipbuilder and Marine Engine-Builder", July, 1932.

At Götaverken, Gothenburg, work has for some time been in progress on an improved arrangement of exhaust turbines for marine propelling plant. Pending the results from the first installation, no description of the system has so far been published in the technical Press. Nevertheless, in an article on "A Thermo-dynamic Study of Exhaust Turbines and other Means of Improving Reciprocating Steam Engines", by Dr. G. Bauer, published in *The Shipbuilder and Marine Engine-builder* of May, 1932, the system has been given considerable prominence and subjected to criticism. Unfortunately, Dr. Bauer's information concerning the system seems to have been derived from a popular description of the first installation, published in a Swedish daily paper, and later reproduced in *Svensk Sjöfartstidning (Swedish Shipping Gazette).* On account of the non-technical character of this description, some features of the system were not mentioned, and others were only lightly touched upon, and this has caused Dr. Bauer to overlook certain points. As he, naturally, could not be aware of the results reached at Götaverken with regard to, for instance, the turbo-compressor, his calculations are in certain parts misleading or can be proved erroneous by the results already obtained in actual service. It is to be regretted that Dr. Bauer did not apply to Götaverken for information, in which case he would have obtained correct and complete data.

Among other things, Dr. Bauer states that the Götaverken system has been put on the market under the name "Lentzification". This is not the case, and it ought to be stated here that Götaverken have never had any connection with the Lentz system. In order to avoid further misunderstanding, a description of the Götaverken system will be given below, together with a thermo-dynamic comparison between the Götaverken system and other exhaust-turbine systems, including the Bauer-Wach system. Some practical points of view will be brought out, and in conclusion certain remarks made by Dr. Bauer will be discussed.

General Description of the Götaverken System.

The Götaverken system is an application of the well-known exhaust-turbine principle. When working on the problem, the important question of reliability has been a predominating consideration. Every item added to a machinery installation is bound to cause increased cost and an increased call on the skill and energy of the engine-room staff.



A = Steam Turbo-compressor.
B = Change-over Valve.
C = Tangential Dryer.
D = Valve Chest.
E = Oil Pump.

FIG. 1.

It is important not to be misled into trying to effect a saving in fuel consumption the major part of which will be consumed by increased cost for maintenance and staff. Simplicity, therefore, has been a ruling principle.

The exhaust turbine utilises the heat content of the steam in a pressure range below the range which can be covered by the reciprocating engine alone. In the Götaverken system (Fig. 1), the exhaust turbine drives a compressor placed on the same shaft as the turbine. The exhaust steam from the high-pressure cylinder is passed to the compressor, where it is raised to a higher pressure and temperature. From there the steam returns to the intermediate-pressure receiver and expands in the intermediate-pressure and low-pressure cylinders, and finally through the exhaust turbine. Thus the output of the exhaust turbine is conveyed to the main engine by the steam flow making the exhaust turbine mechanically independent of the main engine. Gears, couplings or electrical transmission are entirely absent.

From the h.-p. cylinder the steam is passed to the compressor and returned from there with increased pressure to the i.-p. valve. Consequently a dividing wall must be provided in the receiver. This can be done without difficulty in practically all engines; and, of course, if the connection between the h.-p. and i.-p. cylinders is an outside one, the arrangement will be very simple. This dividing wall is provided with spring-loaded non-return valves. When the compressor is in action, the pressure in the i.-p. receiver is always higher than the pressure of the h.-p. exhaust. If the compressor is cut out, the steam can freely pass through the non-return valves from the h.-p. direct to the i.-p. cylinder. From the l.-p. cylinder the steam is led to the turbine through a short pipe. By working a change-over valve in this pipe, the turbo-compressor unit can instantly be cut out and the steam passed directly to the condenser. This, however, is not necessary when manœuvring or going astern. The turbo-compressor automatically regulates itself to these varying conditions without danger of overspeed or pressure rise, and the complication of interlocking controls and cut-out gear is avoided.

If the main engine works with saturated steam, a steam dryer is placed in the pipe leading to the compressor. The drain from this dryer is led to the hotwell or preferably to a feed-water heater.

The turbo-compressor can be conveniently located on top of the condenser. The advantages of this position are, firstly, that no space will be occupied which could be utilised in any other way, and, secondly, that the pipe connections between the turbo-compressor and the main engine will be the shortest possible, giving minimum losses. As the turbo-compressor is connected with the main engine through pipes and nothing else, the installation work is exceedingly simple, and no fear need be felt on account of the movement which always occurs between the different units in an engine installation. No structural alterations are required.

The turbine and the compressor are built together in one housing, thus forming a self-contained unit. The speed of the turbine shaft can be selected with no other consideration than the design of the turbine and the compressor. This is important when high efficiency is aimed at. For the turbo-compressor the design of the well-known A.B. Ljüngstroms Angturbin, of Stockholm, especially their patented blade-shape, has been applied; and, in addition, considerable experimental work has been carried out on this special type in order to arrive at the highest possible efficiency.

The efficiency of the turbine is more important than that of the compressor, because it determines the amount of which work can be got out of the steam. With the present design, it has been possible to achieve a turbine efficiency ratio of over *80 per cent.* The following calculations, however, are based on an efficiency ratio of only 75 per cent. The turbine has a spiral inlet, which makes it possible to extract the water from the steam without extra losses. The steam connections on either side of the turbine being short, the external resistance is small, but has been taken into account and included in the turbine efficiency given. Regarding the compressor, it has been found *in actual tests* that, with suitable design and dimensions, it is possible to achieve an adiabatic efficiency of 63 per cent. In the following calculations, however, the efficiency has been assumed to be only 60 per cent.

On account of the higher vacuum which is required for all exhaust turbines, the condenser is provided with a vacuum augmenter, and the cooling-water pump is arranged to supply an increased amount of cooling water. The top of the condenser has to be rebuilt to serve as a support for the turbo-compressor unit.

Thermo-Dynamic Considerations.

By raising the steam to a higher pressure, and consequently a higher temperature level, the energy (heat content) of the steam is increased. In addition, the increase in steam temperature (reheating) has the effect of increasing the indicated efficiencies of the i.-p. and l.-p. cylinders. In order, first of all, to demonstrate the gain in efficiency due to this reheating, the author has selected as an example an engine from which test figures are available for saturated as well as superheated steam.

Comparison between a Reciprocating Engine driven with Saturated Steam and the same Engine driven with Superheated Steam.

The example is selected from tests made by Professor A. Watzinger, of the Royal Norwegian Institution of Technology, on the steamship "Kong Gudrod" and published in "Schiffbau" in 1919. The results as given by Professor Watzinger are given in Table I and plotted in the Mollier diagram (Fig. 2).

TABLE I.

	Saturated Steam.	Super-heated Steam.	Difference per cent.
Boiler pressure, kg./cm². ...	12·6	12·6	—
Total steam temperature, deg. C.	Sat.	287	—
Adiabatic heat drop, cal. ...	154·5	180	—
Heat consumed/kg. steam ...	604*	677†	—
Thermal efficiency (adiabatic expansion), per cent. ...	25·6	26·6	3·9
Indicated heat drop, cal. ...	106·4	136	27·8
Indicated efficiency, per cent.	68·8	75·5	9·7
Indicated thermal efficiency, per cent.	17·6	20·1	14·2
Steam per I.H.P./hour, kg....	5·94	4·65	—
Heat consumed, cal./hour ...	3,588	3,148	—

* Condensate 43° C.
† Condensate 45° C.

From Table I and Fig. 2 it will be seen that when changing from saturated to superheated steam the thermal efficiency on the Rankine cycle is increased from 25·6 to 26·6 per cent. if the increase is calculated in percentage:—

$$\frac{26{\cdot}6-25{\cdot}6}{25{\cdot}6}\times 100=3{\cdot}9 \text{ per cent.};$$

while at the same time the indicated efficiency is increased from 68·8 to 75·5 per cent., or, if calculated in percentage as before:—

$$\frac{75{\cdot}5-68{\cdot}8}{68{\cdot}8}\times 100=9{\cdot}7 \text{ per cent.}$$

This is a clear illustration of how the increased economy, when changing from saturated to superheated steam, is due more to the engine utilising the heat drop more efficiently than to the increase in thermal efficiency.

With superheated steam, the losses are reduced due to reduced cylinder condensation and throttling losses.

The above example has been used as it represents a careful investigation of a very economical marine engine of standard design. The results are in agreement with Götaverken experience.

In the system developed by E. Johansson-Götaverken the reheating is achieved as an additional asset, when the steam pressure is increased by the compressor. This tends to increase the economy gained through the Götaverken system over and above the gain theoretically due to the compression and heating of the steam performed by the turbo-compressor.

Comparison between a Reciprocating Engine with and without the Götaverken Turbo-compressor.

I.—Saturated steam. Output of the engine unchanged. (Table II.)

The steam process in the engine without compressor is illustrated in Fig. 2 on the left-hand side. The steam process in the same engine with turbo-compressor is shown in Fig. 3. Without compressor the steam in the h.-p. cylinder is expanded to 5·2 kg./cm.² and the cylinder efficiency is 81·2 per cent. When the compressor is used, the saving effected will result in a less amount of steam in the h.-p. cylinder, but this is compensated for by the steam expanding to a lower pressure, 3·75 kg./cm.² abs. The losses due to incomplete expansion will be somewhat less, but the losses due to cylinder condensation will be slightly increased. The efficiency of the h.p. cylinder can therefore be assumed to be approximately 81 per cent. when the turbo-compressor is working. The adiabatic heat drop is 51·5 cal. and the indicated heat drop:—

$$0{\cdot}81\times 51{\cdot}5=41{\cdot}7 \text{ cal.}$$

After the expansion in the h.-p. cylinder, the moisture of the steam has increased from 4 per cent. to 9·4 per cent. To introduce this moist steam in the compressor and to use the output of the exhaust turbine to evaporate the water in the steam would be a mistake and entirely destroy the economy attainable by this process. (Dr. Bauer in

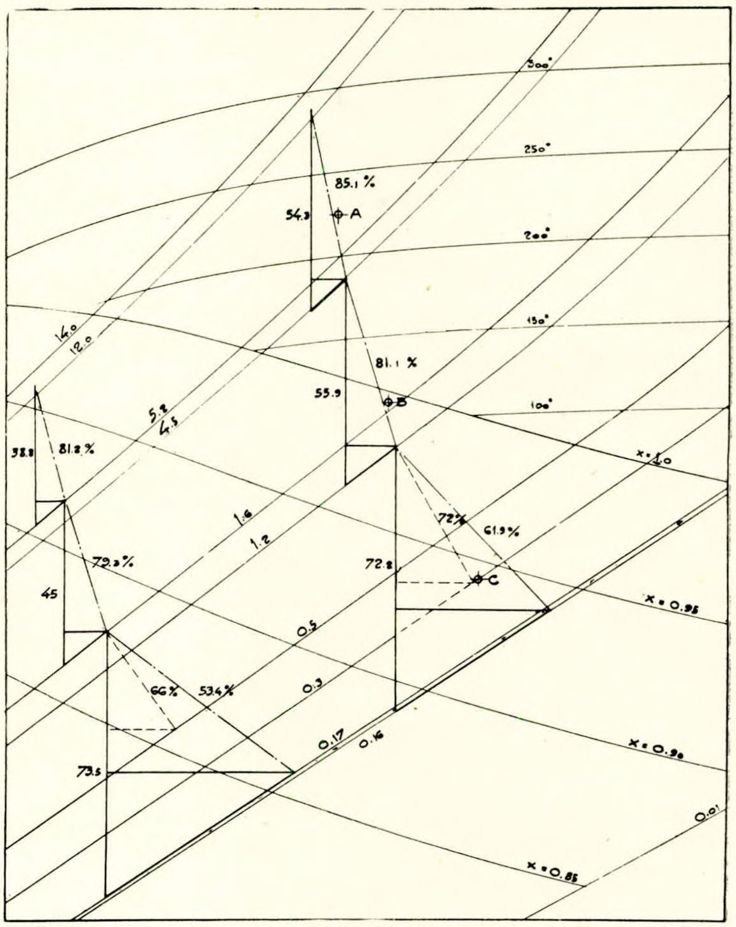


FIG. 2.

TABLE II.—TRIPLE-EXPANSION RECIPROCATING ENGINE FOR SATURATED STEAM.

	(1) Alone.			With Exhaust-steam Turbine System. (2) Bauer-Wach.					(3) Götaverken.				
	Ad. Heat Drop. Cal.	Ind. Eff. %	Ind. Heat Drop. Cal.	Ad. Heat Drop. Cal.	Ind. Eff. %	Ind. Heat Drop. Cal.	Amount of Steam. %	Ind. Heat Drop corrected for Steam Quantity. Cal.	Ad. Heat Drop. Cal.	Ind. Eff. %	Ind. Heat Drop. Cal.	Amount of Steam. %	Ind. Heat Drop corrected for Steam Quantity. Cal.
H.-P. Cylinder ...	38·5	81·2	31·5	28·5	81·8	31·5	100	31·5	51·5	81	41·7	100	41·7
I.-P. Cylinder ...	45	79·3	35·7	45	79·3	35·7	100	35·7	62·5	82	51·2	91·6	46·9
L.-P. Cylinder ...	73·5	53·4	39·2	40·2	66	26·5	100	26·5	65·5	74	48·5	91·6	44·4
Exhaust Turbine	—	—	—	74·5	(62)	(46·2)	(96·1)	44·4	(67·5)	(75)	(50·6)	(83·6)	(42·3)
Total ...	154·5	68·8	106·4	192·5	71·8	139·9		138·1	192·5	69·4	142·1		133·1
Specific Steam Consumption ...	5·95 kg.			4·58 kg.					4·75 kg.				
Steam Saving rel. 1.	——			22·9%					20·0%				
Specific Heat Consumption ...	3,588 cal.			2,766 cal.					2,830 cal.				
Heat (Fuel) Saving rel. 1. ...	——			22·9%					21·1%				

his article assumes this mistake to be made, and by basing his calculation on this he arrives at a very poor figure for the Götaverken system). A great part of the moisture in the steam, about 90 per cent., is separated from the steam before it is allowed to enter the compressor (Fig. 3). The water separated from the steam is utilised for heating the feed water. If this is done, the drying of the steam will not cause any theoretical or practical loss to the thermal process. The pressure drop caused by the separator has been taken into account in the following calculations.

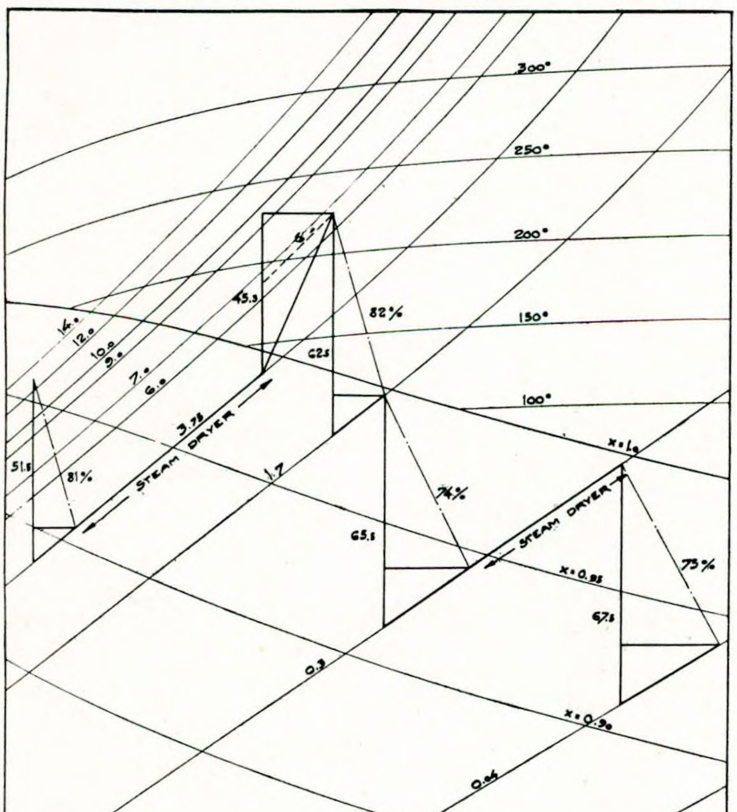


FIG. 3.

In order that the comparison between an engine with and without turbine installation should be correct, it is necessary that the condensate should be returned with the same temperature in both cases. In the example selected, the temperature of the condensate without the exhaust turbine is 43 deg. C. With the exhaust turbine it can be assumed that for a vacuum of 0·04 kg./cm.^{2} abs. the temperature of the condensate will be, say, 23 deg. C. The difference amounting to 20 deg. must be compensated by an increased feed-water heating. If this heating of the feed water is assumed to be performed in the most economical manner, i.e., through steam bled after the l.-p. cylinder, the amount of steam through the turbine is reduced by:—

$$\frac{20}{596-43}\times 100 = 3{\cdot}6 \text{ per cent.}$$

In addition, the steam before the turbine is dried and 5·3 per cent. of water is extracted. Therefore the amount through the turbine as compared with the amount through the compressor is:—

$$0{\cdot}964 \times 0{\cdot}947 = 0{\cdot}913.$$

The steam before the turbine has a pressure of 0·3 kg./cm.^{2} abs. and contains 0·5 per cent. of moisture. The pressure after the turbine is assumed to be 0·04 kg./cm.^{2} abs. The adiabatic heat drop available is then 67·5 cal. The amount of heat transmitted to the steam in the compressor will be if calculated per kg. of steam passing the compressor :—

$$67{\cdot}5\times0{\cdot}75\times0{\cdot}913=46{\cdot}2\text{ cal.}$$

The efficiency of the compressor is assumed to be 60 per cent. Losses in the separator, pipes, etc., have to be allowed for, and on this account the overall efficiency is reduced to 56 per cent. According to Götaverken experience, this is well on the safe side. Consequently, of the heat units available, 56 per cent. is returned in the form of increased pressure, and 44 per cent. in the form of increased temperature. It can be assumed that the radiation losses of the compressor and connecting pipes amount to about 2 per cent. The increase after the compressor is then :—

Adiabatic compression	$46{\cdot}2\times0{\cdot}56=25{\cdot}9$	cal.
Heat	$46{\cdot}2\times0{\cdot}42=19{\cdot}4$	„
Total	45·3	cal.

The compressor thus increases the pressure before the i.-p. cylinder from 3·75 to 6·6 kg./cm.^{2}. The steam which after the h.-p. cylinder had a moisture of 9·4 per cent. has been raised to a superheat of 63 deg. C. The temperature of the steam entering the i.-p. cylinder in Fig. 3 corresponds to point *A* in Fig. 2. The indicated efficiency of the i.-p. and l.-p. cylinders will accordingly be increased in the same way as occurred in the tests cited, when the same engine was changed from saturated to superheated steam. In the i.-p. cylinder the steam is expanded from 6·6 to 1·7 kg./cm.^{2}. The steam is superheated during the major part of the expansion, and the efficiency can be assumed to be 82 per cent. (compare Fig. 2, points *A* and *B*). The adiabatic heat drop is 62·5 cal. and the indicated heat drop :—

$$0{\cdot}82\times62{\cdot}5=51{\cdot}2\text{ cal.}$$

The steam having been dried before entering the compressor, the amount of steam in the i.-p. cylinder is 8·4 per cent. less than in the h.-p. cylinder.

To make the calculations as clear as possible, the indicated heat drop can be referred to the amount of steam working in the h.p. cylinder, i.e., to one kg. of steam in the h.-p. cylinder as a unit.

The indicated heat drop in the i.-p. cylinder referred to one kg. of steam in the h.-p. cylinder is :—

$$0{\cdot}82\times0{\cdot}916\times62{\cdot}5=46{\cdot}9\text{ cal.}$$

In the l.-p. cylinder the steam, when entering, is almost dry. The efficiency can be assumed to be 74 per cent. (compare Fig. 2, points *B* and *C*). The steam quantity is the same as in the i.-p. cylinder. The adiabatic heat drop is 65·5 cal. The indicated heat drop is $0{\cdot}74\times65{\cdot}5=48{\cdot}5$ cal., and the indicated heat drop referred to the h.-p. cylinder :—

$$0{\cdot}74\times0{\cdot}916\times65{\cdot}5=44{\cdot}4\text{ cal.}$$

The total indicated heat drop for the whole engine is

$$41{\cdot}7+46{\cdot}9+44{\cdot}4=133{\cdot}0\text{ cal.}$$

The steam consumption is now 4·75 kg./i.h.p./hour.

Compared with the engine without turbo-compressor, the steam consumption has been reduced by :—

$$\frac{133{\cdot}0-106{\cdot}4}{133{\cdot}0}\times100=20{\cdot}0\text{ per cent.}$$

It has not been taken into account that 8·4 per cent. has been separated from the steam as water at a temperature of 141 deg. C., and utilised for feed-water heating. If this is done, the heat consumption per i.h.p./hour will be :—

$$Q=4{\cdot}75\ 0{\cdot}916\ (647-43)\ 0{\cdot}084\ (647-141)$$
$=$*2,830 cal. per i.h.p./hour.*

With the engine without turbo-compressor, the amount of heat consumed is 3,588 cal. per i.h.p./hour.

The saving in heat (fuel) consumption through the turbo-compressor installation is then :—

$$\frac{3{,}588-2{,}830}{3{,}588}\times100=\mathit{21{\cdot}1\ per\ cent.}$$

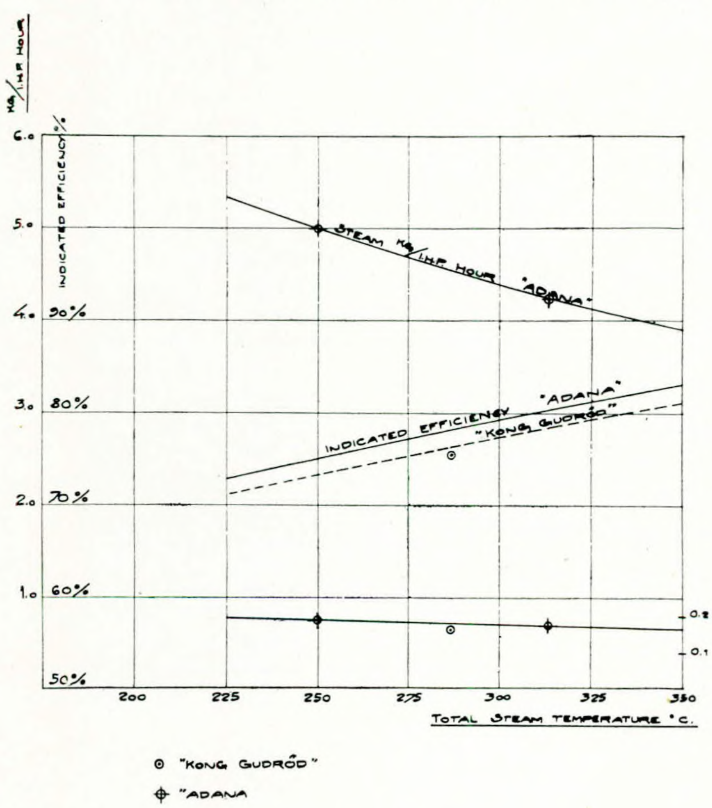


FIG. 4.

Comparison with a Bauer-Wach Installation.

If the engine is converted according to the Bauer-Wach system, the saving according to Dr. Bauer's calculations would be 24·2 per cent., giving a steam consumption in this case of 4·50 kg./i.h.p.

In the foregoing calculations the temperature of the condensate has been taken into consideration in order to get a correct comparison with the original installations. In this case also the heat required to bring the temperature of the condensate back to 43 deg. C. should be calculated. Assuming that feed-heating is done in the most economical manner possible, i.e., by bleeding steam before entering the turbine, the following corrections should be applied.

(The same data as in the previous calculations. Back pressure after the l.-p. cylinder is assumed to be 0·5 kg./cm.^{2} as in Dr. Bauer's example).

The amount of steam bled at 0·5 kg./cm.^{2} required to heat the feed-water from 23 deg. C. to 43 deg. C. is :—

$$\frac{20}{553-43}\times 100 = 3{\cdot}9 \text{ per cent.}$$

Assume: Adiabatic heat drop in the turbine 74·5 cal.;

Indicated heat drop in the turbine 0·62×74·5=46·2 cal.;

Total indicated heat drop 140·6 cal.

The comparable steam consumption would then be :—

$$4{\cdot}50\times\frac{140{\cdot}6}{140{\cdot}6-0{\cdot}039\times 46{\cdot}2}=4{\cdot}56 \text{ kg./i.h.p./hour,}$$

and the saving obtained *23·2 per cent.*

Comparison of an Engine with and without Turbo-compressor.

II.—Superheated steam. Output of the engine unchanged.

The calculations refer to the same engine as before (Watzinger: *Kong Gudrod*). The first task is to examine how the efficiency of the i.-p. and l.-p. cylinders will be affected by the changed conditions created by the compressor. This can be done by a reasoning similar to that applied for saturated steam. The first step is to determine the influence on the indicated efficiency of increasing the superheat, and the author selects as a basis Dr. Bauer's conclusions from tests on the steamship "Adana", published in *Werft und Reederei* in 1921. The results of these tests are shown on the graph, Fig. 4. If the figures for the "Adana" are compared with the figures for the "Kong Gudrod" previously cited, and the difference in the conditions are allowed for, it will be found that the indicated efficiency of the "Kong Gudrod" is about 2·0 points below that for the "Adana". (The author refrains from giving the complete calculation here). In the following it will be assumed that the efficiency of the "Kong Gudrod" can be taken as 0·975 times the indicated efficiency found in the case of the "Adana".

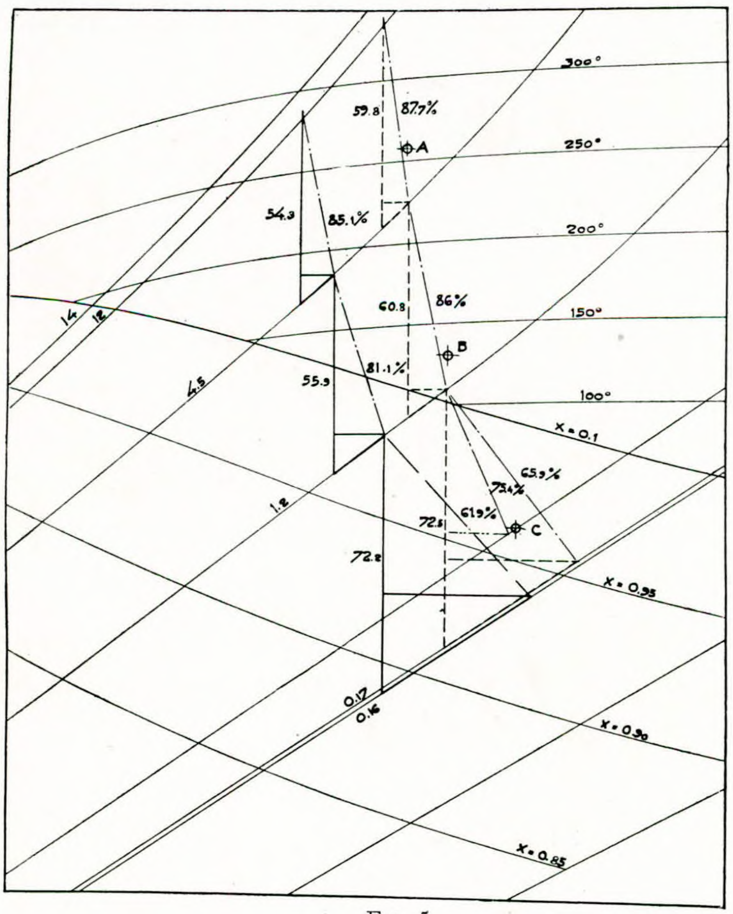


FIG. 5.

Fig. 5 shows the diagram for the engine of the "Kong Gudrod" with 287 deg. superheat according to the test (full drawn) and the same engine with 340 deg. superheat (dotted) calculated by comparison with the tests of the "Adana".

In Fig. 6 is shown plotted the diagram for the same engine with turbo-compressor fitted and working with a steam temperature of 287 deg. C. at the stop valve. By comparing Figs. 5 and 6 it will be seen that with the turbo-compressor working the i.-p. and l.-p. cylinders cover the range worked by the points *A, B* and *C* in Fig. 5, i.e., close to the range corresponding to 340 deg. C. steam temperature at the throttle. Consequently, the indicated efficiencies can be accurately calculated by comparison. The details of the calculations need not be given here. Table III gives the principal

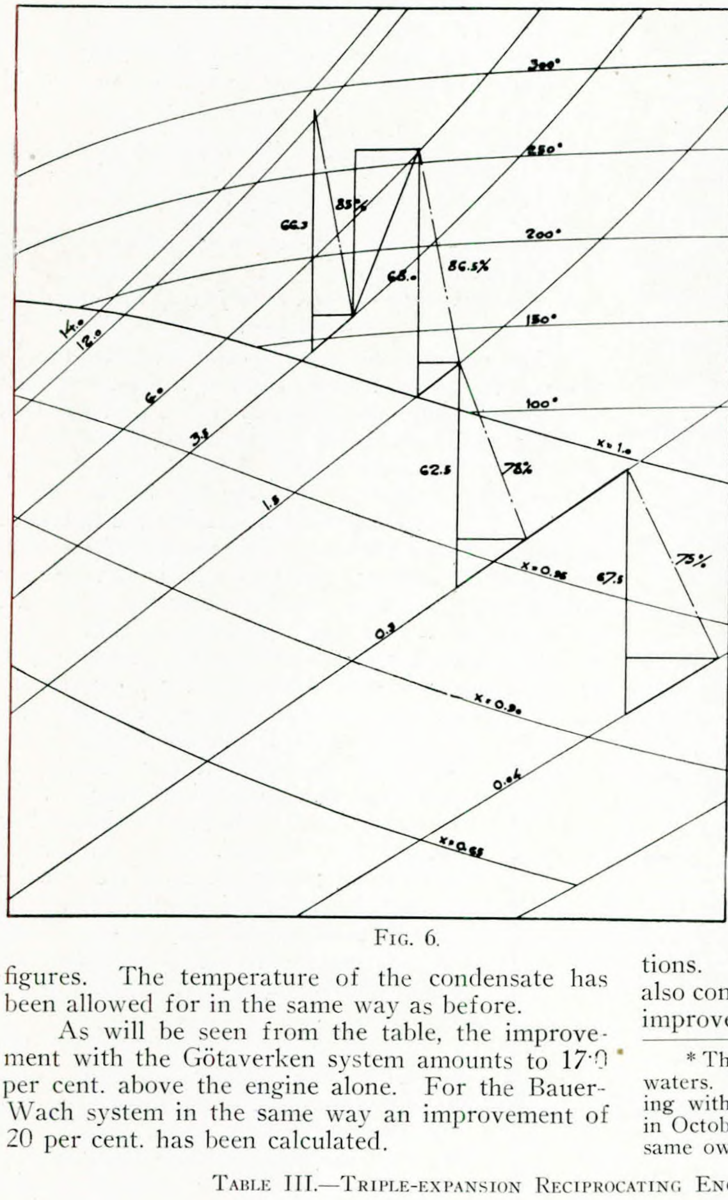


FIG. 6.

figures. The temperature of the condensate has been allowed for in the same way as before.

As will be seen from the table, the improvement with the Götaverken system amounts to 17·0 per cent. above the engine alone. For the Bauer-Wach system in the same way an improvement of 20 per cent. has been calculated.

Some Notes on the Foregoing Comparison.

1.—*The Saving Obtainable.*

In the foregoing calculation it has been shown that the saving effected by the Götaverken system can be given in round figures as 21 per cent. for a plant with saturated steam, and 17 per cent. for a plant with superheated steam. For the same conditions, the Bauer-Wach system has been calculated to save with saturated steam 23 per cent. and with superheated steam 20 per cent.

These figures refer to the water rate for a modern first-class engine. Other improvements can be added to any of the two systems in equal degree. By combining such other improvements with the Götaverken system, a total saving of some 30 per cent. may be obtained with a normal first-class plant—sometimes even higher, depending on the particulars of the installation in question.

Dr. Bauer's calculations on the saving effected by the Götaverken system are, as has been shown, based on insufficient knowledge of the system. In actual practice a saving of 17·5 per cent. has been obtained on the first installation. This figure is inclusive of auxiliaries, and consequently for the main engine alone corresponding to some 19 per cent., against 10·8 per cent. calculated by Dr. Bauer for approximately the same conditions. The experience from this first installation* also conclusively shows that the result can be further improved. It should be specially mentioned that

* The ship is at present time-chartered in foreign waters. The owners state that the system has been working without any trouble whatsoever since its installation in October, 1931. Götaverken have also received from the same owners a repeat order for a similar installation.

TABLE III.—TRIPLE-EXPANSION RECIPROCATING ENGINE FOR SUPERHEATED STEAM.

	Alone.				Exhaust-turbine Installation. Götaverken.				Bauer-Wach.				
	Ad. Heat Drop. Cal.	Ind. Eff. %	Ind. Heat Drop. Cal.	Per cent. of Steam in H.P. %	Ad. Heat Drop. Cal.	Ind. Eff. %	Ind. Heat Drop. Cal.	Per cent. of Steam in H.P. %	Ad. Heat Drop. Cal.	Ind. Eff. %	Ind. Heat Drop. Cal.	Per cent. of Steam in H.P. %	Ind. Heat Drop ref. to 1 kg. Steam in H.P.
H.-P. Cylinder ...	54·3	85·1	46·2	100	66·3	85	56·4	100	49·4	85	42	100	42
I.-P. Cylinder ...	55·9	81·1	45·3		68	86·5	58·8	100	51	82	41·8	100	41·8
L.-P. Cylinder ...	72·2	61·9	44·7		62·5	78	48·8	100	45	76·5	34·4	100	34·4
Turbine	—	—	—		(67·5)	(75)	(50·6)	(92·6)	82	66	54·1	96·1	51·9
Total ...		136·2				164							170·1
Steam kg./I.H.P.		4·65				3·86							3·72
Improvement per cent.		—				17·0							20·0

no improvement of any kind outside the exhaust-turbine installation has been made in this case.

2.—*The Plant used as the Basis for Calculating the Saving.*

Much stress has been laid by Dr. Bauer on the comparison being based on the most efficient and not on an inefficient reciprocating engine. This is a most proper consideration, and from Table IV it will be seen that the foregoing calculations are based on an engine which is slightly more economical before conversion than that indicated in Dr. Bauer's calculation.

TABLE IV.—COMPARISON BETWEEN THE PLANT USED AS THE BASIS FOR COMPARISON IN THE FOREGOING CALCULATIONS AND BY DR. BAUER.

	Saturated Steam.		Superheated Steam.	
	Dr. Bauer.	Göta-verken.	Dr. Bauer.	Göta-verken.
Initial steam pressure, kg./cm.^{2}...	13·0	12·6	15	12·6
Initial total steam temperature, °C.	—	—	315	287
Moisture in steam at throttle valve, %	3	4	—	—
Ind. efficiency, %	70·7	68·8	72·8	75·5
Steam consumption, kg./I.H.P.	6·0	5·94	4·7	4.65

3.—*Steam Consumption of Auxiliaries.*

A further point raised by Dr. Bauer is that any exhaust-turbine installation raises the steam consumption of the condenser auxiliaries, and that this rise is an argument in favour of the system giving the highest saving. Firstly, the foregoing calculations have shown the difference between the systems with regard to the saving effected to be small. Secondly, it is true that, if the amount of cooling water is increased in an old condenser installation, the steam consumption of the cooling-water pump is raised considerably. This rise, however, can be effectively counteracted in such a number of different ways without excessive expenditure as to render a discussion on general lines unfruitful, which may be the reason why Dr. Bauer refrains from giving any indication of the additional amount he has in mind. All that can be said is that the amount ought to be small. Thirdly, as it is common practice to utilise the exhaust from auxiliaries for feed-water heating, the loss or gain will be narrowed down to the difference between this additional amount of steam for feed-heating being taken through the cooling-water pump or bled from the main engine.

4.—*Efficiencies of the Turbo-compressor Unit.*

Dr. Bauer in this connection appears to have discovered a number of difficulties.

He concludes that the turbo-compressor unit cannot attain very high efficiencies, and assumes 65 per cent. for the turbine and 45 per cent. for the compressor. The simple answer is that in actual practice it has been found possible to attain considerably higher efficiencies, the figures 75 per cent. for the turbine and 60 per cent. for the compressor used in the calculations including a fair margin, as previously explained. These results are due to utilising high effiicencies, and to extended research work on this particular combination carried out in co-operation with Messrs. Ljüngstrom. For certain parts of the research work *on the compressor* the Swedish Academy of Engineering Science (I.V.A.), of Stockholm, has given valuable help.

Having no gears or other mechanical connections, the speed of the turbine as compared with that of the Bauer-Wach system can be chosen with more freedom, and the turbine can be located in the most convenient position, viz., on top of the condenser, thus securing the shortest possible steam connections and increasing the efficiency by avoiding losses due to long leads.

The questions of pressures and temperatures have been dealt with elsewhere, and it has been shown that they are kept within safe limits.

The Götaverken System in Combination with other Processes for increasing Economy.

Dr. Bauer in this connection enumerates 13 points, and goes on to say:—

> "It is obvious that all these measures can be combined at will with an exhaust-steam turbine, especially of the Bauer-Wach type, since it entails no additional temperature rise in the steam process, as is the case in the Götaverken and Lindholmen systems".

It may be sufficient to state that there is no reason whatever why the Götaverken system could not be combined with any of these measures, as well as with other measures not specifically mentioned.

Economic Considerations.

Table V. has been worked out to show the percentage return on capital obtained by fitting (*A*) an installation costing £10,000 and giving a saving of 23 per cent., and (*B*) one costing £5,000 and giving a saving of 20 per cent. The vessel chosen for comparing the installations is a 9,000-ton deadweight tramp steamship fitted with ordinary triple-expansion machinery of about 2,200 I.H.P. and burning 40 tons of coal per day before conversion. She is assumed to make three complete voyages per year, with an average freight of £1 per ton per voyage.

From Table V. it will be seen that the cheaper installation gives approximately two-and-a-half times the return on the capital expenditure.

The Effect of Increased Pressure in the Intermediate pressure Cylinder.

As the Götaverken system will increase the pressure in the i.-p. cylinder, the stresses caused by this must naturally be taken into account, especially with regard to installation in existing plants, the most important question being that of the crank-shaft and bearings.

If the purpose of the installation is the saving of fuel, the output of the engine remaining the

Table V.	A.	B.
First cost	£10,000	£5,000
Percentage saving	23%	20%
Coal per year before conversion, tons	8,000	8,000
Coal per year after conversion, tons...	6,150	6,400
Saving in coal per year, with coal at 18s. per ton	£1,665	£1,440
Saving due to additional cargo carried owing to reduced coal required ...	£1,150	£1,000
Total saving	£2,815	£2,440
Additional expenditure on interest, depreciation and insurance at 15 per cent. of capital value	£1,500	£750
Net saving due to conversion ...	£1,315	£1,690
Percentage return on capital ...	13%	34%

same as before, it will be clear that the forces on the shaft will remain at the same value as before. The distribution of the output on the individual cylinders is effected by varying the cut-off in the same manner as usual.

If, however, it is desired to increase the output of the engine, the shaft will naturally have to perform a heavier duty. The effect of the Götaverken system would then be the same as increasing the cut-off. In most engines the cut-off used for economical speed is less than the designed maximum cut-off. Thus there will normally be a fair margin for increasing the power.

The predominating problem for the shipowner to-day, except in special cases, is not increased speed, but a decreased fuel bill. As a rule, a ship is designed and engined for her economical speed, and experience shows that the possibilities of increased speed are hardly ever utilised in actual practice. As already stated, however, increasing the speed is by no means impossible with the Götaverken system.

With regard to the rules for the diameter of the crankshaft, the classification societies are guided by the maximum piston pressure which can be exerted in any one cylinder. The calculation formula is based on the boiler pressure and the area of the h.-p. piston. For the i.-p. cylinder the piston pressure exerted must not be higher.

Assume the boiler pressure to be 14 atmos. and the ratio of the piston areas of the h.-p. and the i.-p. cylinders to be 1 :2·5. In that case the maximum difference in pressure between the two sides of the i.-p. piston must not exceed $\frac{14\times1}{2{\cdot}5}=5{\cdot}6$ atmos. The pressure on one side of the piston is the pressure in the l.-p. receiver, say, 1·7kg./cm^2. The maximum pressure permissible in the i.-p. receiver is then 5·6+1·7=7·3kg., a pressure higher than that which can be reached with the efficiencies, etc., used in the foregoing calculations†.

It has been claimed that the flywheel effect of the gears and turbine of the Bauer-Wach system will increase the speed of the vessel in bad weather. There may be some justification for this, but it seems that the gain at best cannot be great, as, if it had been, a similar device would probably have been introduced on marine engines long ago. In any case the gain is obtained at a heavy expenditure in weight and space.

† In exceptional cases, an excessive pressure on the i.-p. piston can always be reduced to normal by fitting a liner in the i.-p. cylinder.

Temperatures.

If the temperatures which occur with the Götaverken system are more closely examined, it will be clear that they are all within normal present-day practice. Superheated steam has been used in marine installations for a considerable time, and the practical difficulties connected with this are well known and have been thoroughly discussed. With the Götaverken system, there will normally be no other problems in this respect, except such as have been encountered many times before with quite normal superheat.

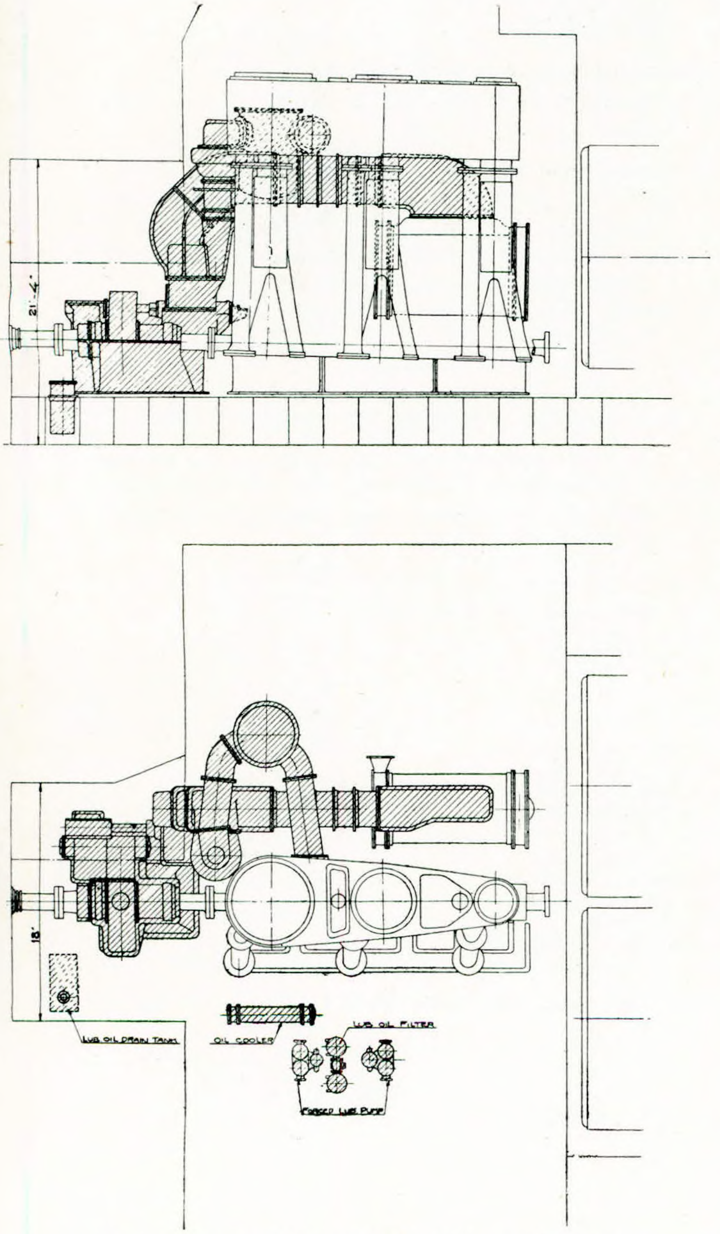
A Comparison of Installation and Maintenance Costs.

The Bauer-Wach installation requires considerable structural alteration to the ship. The recess in the after bulkhead has to be enlarged, thus encroaching on cargo space. The tank top has to be strengthened for the turbine bed, and considerable care has to be exercised to secure alignment for the gears, etc. Some auxiliaries may also have to be moved to provide space for the installation.

For the Götaverken system no structural alterations whatever are required. No space is occupied which can be utilised in any other way, nor does the installation cramp the engine-room space. The upper part of the condenser has to be rebuilt to serve as a support for the turbo-compressor; but this being comparatively light and not producing any vibration, no heavy bed is required. The compressor is connected to the main engine with pipes only; thus the movements between the various parts of the installation can be allowed for and the question of alignment is eliminated.

The simplicity of the Götaverken system in comparison with the Bauer-Wach installation is evident from Fig. 7, in which is reproduced the arrangement of the machinery in the liner "Boniface" with a Bauer-Wach installation as published in a paper‡ read at the 1929 Spring Meetings of the Institution of Naval Architects by Mr. C. F. A. Fyfe. There is also shown the Götaverken system applied to the same engine, the new parts of both systems being cross-sectioned. From this it will be observed that the Bauer-Wach installation encroaches upon the cargo hold in the vicinity of the turbine recess to a considerable extent, besides crowding the engine-room floor; whereas the Götaverken system can be installed without taking away any space whatsoever from the engine-room floor.

‡ "Shipbuilder", No. 225, Vol. XXXVI., p. 374.



Arrangement of Bauer-Wach Exhaust Turbine, S.S. "Boniface".

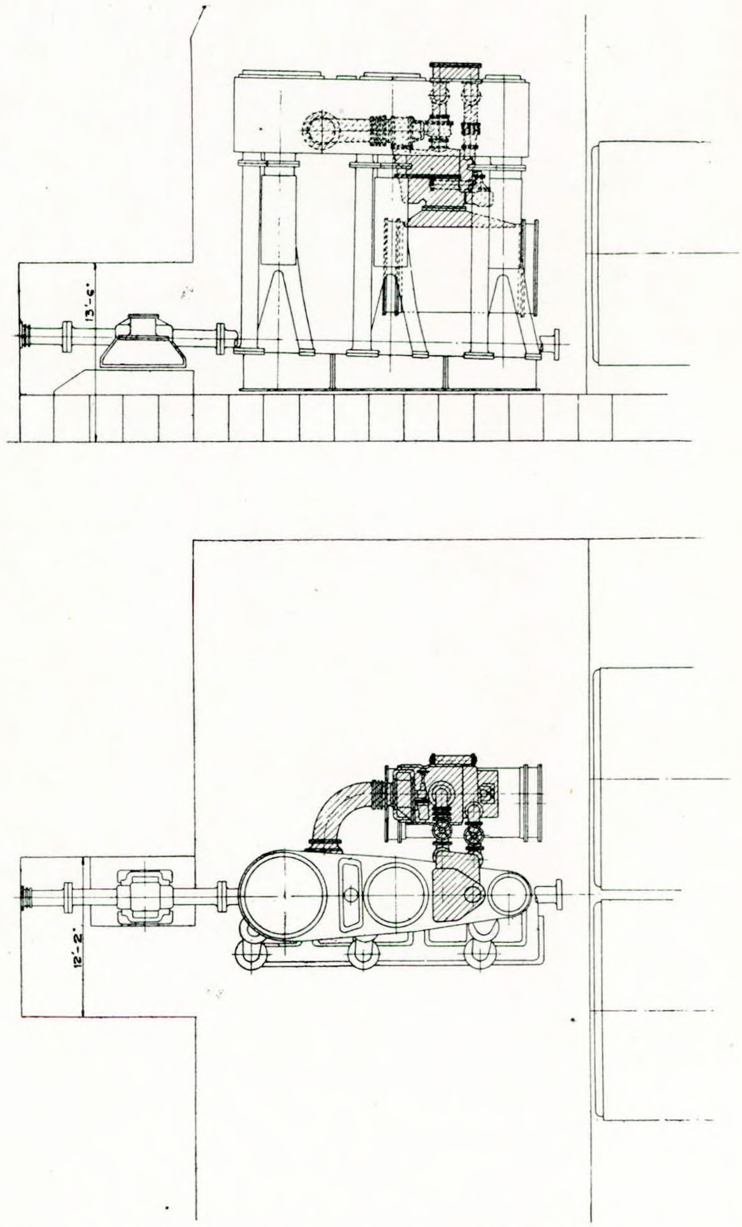


FIG. 7. Arrangement of Götaverken Steam Turbo-compressor, S.S. "Boniface".

The simplicity of the work of installation reduces the risks of bad workmanship, and also reduces the time required for installation. The Götaverken system can be installed in 25 to 30 per cent. of the time required to install the Bauer-Wach system—an important consideration for the shipowner. The Bauer-Wach installation not only encroaches on the cargo space, but the weight of the installation is considerable and reduces the deadweight. The weight of the Götaverken system is only about 25 per cent. of that of the Bauer-Wach installation.

The moving parts of the Götaverken system consist of the turbine and the impeller mounted on the same shaft, totally enclosed, and not mechanically connected to any outside arrangement. No gears, automatic couplings or similar devices are used. The result is low maintenance cost and very little extra work for the engine-room staff.

During manœuvring operations the Götaverken turbo-compressor takes care of itself, no attention being required from the engine-room staff and no automatic couplings having to be watched.

All the foregoing points are important, and they all go to show that the Götaverken system is technically and economically a sound proposition, and that it can claim to be one of the most efficient exhaust-turbine systems evolved.

INSTITUTE NOTES.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, July 4th, 1932.

Members.

Duncan Black Abercromby, 8, Soroba Park Terrace, Oban.

Duncan Black, 20, Broadstone Avenue, Port-Glasgow.

D. Christie, 29, Rookwood Street, Grangetown, Cardiff.

David Noel Findlay, 54, Young Street, Sydney, N.S.W.

William Augustine Fox, 14, Saltwell Place, Gateshead.

William Jacobsen, Musselburgh, Dunedin, N Z.

William Owen, Anvers, Valley, Anglesey.

Andrew Baxter Rae, c/o Turner Morrison & Co., Managing Agents, Asiatic Steam Navigation Co., Calcutta.

William Trevor Williams, Aldworth, Hakin, Milford Haven.

Associate Members.

Eric Ronald Bathurst, Lynwood, Ashchurch Road, Tewkesbury, Glos.

William Henry Smith, c/o B.I.S.N. Co.'s Agents, Beira, P.E. Africa. .

Associates.

Robert Chalmers, 2, Dolphin Avenue, South Circular Road, Dublin.

George Reginald Webster, Rutland House, Romilly Road, Finsbury Park, N.4.

Students.

Leslie Charles Bingham, 47, Maison Dieu Road, Dover.

John Coates, 31, Laburnum Avenue, Wallsend-on-Tyne.

Henry Freeman, 128, Stanhope Road, South Shields.

Wilfrid Hunter, 31, Gladstone Terrace, Usworth Station Road, New Washington.

Herbert George Kimber, 4, Redvers Road, Chatham.

Robert McDonald, 43, Quarry Road, Felling-on-Tyne.

George John Slaughter, 19, South Esk Road, Forest Gate, E.7.

Robert Hood Watson, 52, Rothbury Terrace, Heaton, Newcastle-on-Tyne.

Transferred from Associate Member to Member.

George Gee, 29, Sun Street, Birkenhead.

Transferred from Associates to Associate Members.

Norman Alexander McLeod, Aldersyde, Cyprus Avenue, Bloomfield, Belfast.

William Stuart Rae, Fairholm, Eden Avenue, Swansea.

Transferred from Student to Associate Member.

Charles Herbert Haines, 32, St. John's Road, East Ham.

Transferred from Students to Associates.

Francis George Bennett, 97, Bedford Hill, Balham, S.W.12.

Arthur Hayward Fisher, The Grange, Blackhorse Lane, Walthamstow, E.17.

Leonard John Thomas, 59, Thorold Road, Ilford, Essex.

BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examinations for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

Name	Grade	Port of Examination
For week ended 9th June, 1932:—		
Lyon, Alexander	1.C.	Glasgow
Birnie, John S.	2.C.M.	„
Dalton, James G.	2.C M.	„
Martin, Thomas	2.C.M.	„
Milne, Archibald M. ...	2.C.M.	„
Crawford, George ...	1 C M E.	„
Grace, Eric F.	1.C.	Liverpool
Graham, Donald -... ...	1.C.	„
Tannahill, John	1.C.	„
Evans, Jack	2.C.	„
Fogg, Oliver O.	2.C.	„
Maddocks, William ...	2.C.	„
Stephenson, Thomas A. ...	2 C.	„
Gee, George	1.C.M.	„
Williams, William T. ...	2.C.M E.	London
Eyres, Geoffrey M. ...	2.C.	Newcastle
For week ended 16th June, 1932:—		
McNeilly, Peter	2.C.	Glasgow
Taylor, William A.... ...	2.C.	„
Wyllie, Stewart A.... ...	2.C.	„
Peacock, Colin F.	1 C.M.	„
Firman, Alfred C.... ...	2.C.	Sunderland
Young, John R.	2.C.	„
Maxfield. Frederick ...	2.C.M.	„
Cartwright, Alfred ...	1.C.M.E.	Newcastle
Olsen, Albert O.	1.C.M E.	Liverpool
Scott, Thomas	1.C.E.	Sunderland
Ward, William H. S. ...	1.C M.E.	Liverpool
Wilkie, Thomas G.... ...	1.C.M.E.	Sunderland
Wilkins, Frederick E. ...	1 C.M E.	Liverpool
Witty, John C.	1.C.M.E.	Hull
Wrangham, William S. ...	1.C.M E.	Newcastle
Chenery, Frederick J. ...	1.C.	London
Hawkins, John R.	1.C.	„
Webster, James	1.C.	„
Simmons, Ernest A. ...	2.C.	„
Swanbrow, Charles J. ...	2 C M.	„
Stapylton, Thomas H. ...	2.C.	Newcastle
Grandison, James	1.C.M.	„
Crossley, Edward	1.C.	Liverpool
Harrison, William N. ...	1.C.	„
Nicolle, Philip K.	1.C.	„
Gibbs, Thomas H.	2.C.	„
Nutter, Robert	2.C.	„
Sherwood, John H... ...	2 C.	„
Rourke, Wilfred	1.C.M.	„
Nimmo, William C... ...	1.C.	Glasgow

Name	Grade	Port of Examination
For week ended 23rd June, 1932:—		
Harrison, Walter V. ...	1.C.	Newcastle
Stephens, John C.	1.C.	"
Ferrier, James P. M. ...	2.C.	Glasgow
McLachlan, Robert ...	2.C.	"
MacLean, Alexander ...	2.C.	"
King, William B.	1.C.M.	"
Hobby, Frederick J. ...	1.C.	Cardiff
Irving, Albert F.	1.C.	"
James, Thomas G	1.C.	"
Maplestone, Clifford R. ...	1.C.	"
Paterson, Peter M. ...	1.C.	Leith
Stewart, Alexander B. ...	1.C.	"
Stewart, John F.	1.C.	"
Wilson, James	1.C.	"
Lancaster, Ellis	2.C.	"
Jolly, James S.	2.C.M.	"
Scott, James Mc.D. ...	2.C.	Liverpool
Jones, James M.	1.C.	London
Cole, Alfred	1.C.M.	"
Hawkins, Charles F. ...	2.C.	Cardiff
Harvey, James R.	1.C.M.E.	London
For week ended 30th June, 1932:—		
Jessop, Claude S.	1.C.	Southampton
Polden, Louis A.	1.C.	"
Shepherd, Arthur P. ...	1.C.	"
Kittow, Geoffrey C. ...	2 C.	"
Lynas, Samuel	1.C.	Glasgow
Mowatt, John W.	1.C.	"
Cromwell, Oliver	2.C.	"
Gauld, Archibald L. ...	2.C.	"
Howie, William T.... ...	2.C.	"
Price, David	2.C.	Liverpool
Seymour, Thomas	2.C.	"
Bode, Stanley	1.C M.	"
Higgins, Bernard	1.C.	London
Spiers, John R.	1.C.	"
Taphouse, Herbert W. A...	1.C.	"
Blake, Lawrence B. ...	2.C.	"
Walsh, Frederick C. ...	2.C.	"
Scott, Andrew H	2.C.M.	"
Hunter, John L.	1.C.	Newcastle
Barker Robert A.	1 C.	Sunderland
Binks, Arthur	1.C.	"
Longmore, Samuel J. ...	1.C.	"
Munchin, Gordon W. J. ...	1.C.	"
Parkinson, George E. ...	1.C.	"
Strong, George W. ...	1.C.	"
Pickering, Norman ...	1.C.M.	"
Russell, Frank	1.C.M.	"
Broughton, Ernest ...	1.C.M.E.	"
Ripley, William H. ...	1.C.M E.	"
Fernie, David B.	1.C.M.E	Glasgow
Hunter, William W ...	1.C.M E.	Newcastle
Blackmore, Walter H. ...	1.C.M.E.	London
Molloy, William J. ...	2.C.M E.	Newcastle
McDonald, Ian F.	1.C.M.E	Southampton
For week ended 7th July, 1932:—		
Smith, Charles W. ...	1.C.	Belfast
McNabb, John G.	1.C.M.	"
MacPherson, Angus A. S.	1.C.	Cardiff
Hadley, Leonard A. ...	2.C.	"
Price, Rees W.	2.C.	"
Taylor, Harold	2.C.	"
Burns, John C.	1.C.	Leith
Beveridge, Andrew P. ...	2 C.	"
Hutton, James C.	2.C.	"
Russell, Charles S. ...	2.C.	"
Scott, Alexander H. G. ...	2.C.	"
Scott, David	2.C.	"
Allison, Norman J. ...	1.C.	Glasgow
Brewer, Robert B.	1.C.	"

Name	Grade	Port of Examination
Brown, Frederic C. B ...	1.C.	"
McGilp, Frank B.	2.C.	"
Miller, Andrew B. W. ...	2.C.	"
Nimmo, Robert	2.C.	"
Thomson, Thomas C. ...	2.C.	"
Hamilton, John N. ...	2.C.M.	"
Cureden, Joseph E. L. ...	1.C.	Liverpool
Mould, Richard A. ...	1.C.	"
Bennett, Allan M.	2.C.M.	"
Golder, John S.	1.C.	London
Hilson, James R. L ...	2.C.	"
Purse, Robert B. W. ...	2.C	"
Vann, Charles E. A. ...	2.C.	"
Lester, Albert F.	1.C.M	"
Hobson, Samuel	1.C.	Newcastle
Hobson, Robert A. ...	2.C.	"
Munton, Rupert	2.C.M	"
Clouder, Reginald C. ...	1.C	Southampton
Benke, Arthur L.	1.C.M.	"
Pringle, Harry	1.C.M.E.	Liverpool
Tavener, Ernest G. ...	1.C.M.E.	"
Williams, Alfred L. F. L.	1.C.M.E	Cardiff
Graham, John B.	1.C M.E.	Glasgow
Golden, Edward C. ...	1.C.M.E.	London
Evans, John C.	1.C.M.E.	Cardiff

ADDITIONS TO THE LIBRARY.

Purchased.

Scottish Education Department—Memorandum relating to Educational Appointments Overseas. Published 1932 by H.M. Stationery Office, 2d. net.

Board of Trade—Load Line Loading of Steam and Sailing Ships. Explanatory Notes on the Chart of Zones and Seasonal Areas. Published 1932 by H.M. Stationery Office, 4d. net.

King's Rules and A.I. Amendments. K.R.5/32. Published 1932 by H.M. Stationery Office, 1d. net.

Report on the Examinations of Candidates for Certificates of Competency in the Mercantile Marine and the Sea-Fishing Service. Published 1932 by H.M. Stationery Office, 2d. net.

Presented by the Publishers.

Nickel Bulletins published by the Mond Nickel Co., on: "Nickel Alloy Steel Castings" and "Nickel-Iron Alloys in Temperature Control".

"Electric Resistance Welding and High-Speed Production". Paper read by C. A. Hadley before the Institution of Welding Engineers.

"The Care, Handling and Storage of Lubricants". No. 8 of the Gargoyle Technical Series published by the Vacuum Oil Co., Ltd.

"Corrosion in Hulls of Merchant Vessels". Paper read by J. Montgomerie, D.Sc., and W. E. Lewis, B.Sc., before the Institution of Engineers and Shipbuilders in Scotland.

Selected Engineering Papers published by the Institution of Civil Engineers as follows :—

No. 107. The Strength of Concrete used in Road-Construction.
No. 108. The Deformation of Concrete Road-Slabs.
No. 109. The Effect of Adding Flange-Plates to Plate-Web Girders.
No. 110. Bwetgyi Bridge, Burma.
No. 111. Pile-Driving and the Supporting-Capacity of Piles.
Methods of Haulage Underground.
No. 104. Construction of a Regulator and Lock at Kafr Bulin.
No. 105. The Flow of Water through Groups of Sluices.
No. 106. Rainfall, Off-Flow and Storage in the Central Provinces, India.
No. 117. Winter Construction of an Automatic Low-Head Hydro-Electric Plant in Canada.
No. 118. The Effect of Reservoir-Area on the Discharge of the Overflow Weir.
No. 119. A Direct Method for the Construction of Influence Lines for Continuous Girders.
No. 120. The Aerial Cableways at Nag Hammadi Barrage, Upper Egypt.
No. 112. Poole Harbour Bridge.
No. 113. Whirling Speeds of Shafts supported in Multiple Bearings.
No. 114. Mitering Lock-Gates.
No. 116. The Proportioning of Railway Track Fish-plates from an Economic Standpoint.

Vol. 121 of Transactions of The Institution of Mechanical Engineers containing the following papers :—

Inglis on "Cambridge as a Place of Education".
Gresley on "Locomotive Experimental Stations".
Atkinson on "Mechanical Aspects of Electricity".
Carpmael on "The Manufacture and Use of Steel Railway Sleepers".
Underwood on "The Combustion of an Oil Jet in an Engine Cylinder".
Dymond on "Some Factors Affecting the Riding of Coaching Stock".
Main on "Resistance to Abrasion in Relation to Hardness".
Hider on "Waste-Heat Boiler Design".
Griffiths on "Factors Influencing the Design of Normalizing Furnaces".
Beeby on "The Handling of Materials in a Mass-Production Factory".
Russell on "Modern Machine Tools".
Hamblin on "The Mass-Production of Tin Containers".

"Wiring Systems", by Laurence M. Waterhouse. Published by Gee & Company, Ltd., 6 & 8, Kirby Street, London, E.C., 5s. net. (pocket edition 3s. 6d.).

Dealing with the book from a general point of view, it was hoped that as at last wiring in casing and capping had been omitted, a really up-to-date work had been produced. A closer examination showed that our hopes are not yet realised.

The author makes no mention in his preface of the class or classes to whom this book is intended to appeal. In one place he deals with faults in gas systems having an electrical origin, a matter which cannot be classified as elementary, whereas at the end of the book he finds it necessary to define roughly the Watt and the Board of Trade unit, terms which one would have expected anyone in the industry to have understood.

Further, a very large percentage of the book consists of descriptions, illustrations, etc., which are at least equally well presented in makers' catalogues, whilst there is no complete account of the way these various systems should be installed, and, in fact, very little information to enable a decision to be taken as to which system of installation should be adopted in any given set of conditions. Roughly speaking, the first hundred pages deal with conduit installations and the remaining sixty pages with wiring systems using metal covered or tough rubber-covered cables.

The reviewer was particularly interested in the illustrations on pages 16-17, which purport to show the manner in which light gauge (close joint) tubing can be sett. It would require a first-class man to sett heavy gauge tubing in the manner shown in the illustration, and the writer has yet to meet an electrician who can bend close joint tube in the manner shown. The author appears to be somewhat out-of-date, in that he seems to suggest that conduit should be bent only where a standard fitting is not available, whereas modern practice is to eliminate fittings as far as possible by setting the tube. In passing, one may say that all reputable makers of tubing thread the conduit after enamelling and not before.

The question of main distribution receives very scanty treatment, being dismissed in about two and a half pages, part of which is historical. It contains a reference to three-wire D.C. supply, and no reference at all to three-phase four-wire distribution, which is becoming daily more important. No reference at all is made to the use of paper or fibre insulated cables for main distribution.

Finally, we notice in one or two places a reference to a reduction in cost of house wiring installation, whch appears to be linked up with an advocacy of close joint conduit. We venture to suggest that a truer picture is given in one of the advertisements in the book, drawing attention to the fact that the cost of electrical installation in many small labour-saving houses is only one per cent. of the total cost. We would suggest that if the cost of the electrical installation were doubled so that it formed two per cent. of the total cost, by the use of good class materials and by the provision of a larger number of socket outlets, it would be a good thing for the industry and the country in general.

"High-Speed Diesel Engines", by P. M. Heldt. Published by Iliffe & Sons. Ltd., Dorset House, Tudor Street, London, E.C.4, 22s. 6d. net, post free 23s.

Much has been written in recent times on the subject of Diesel and other types of oil engines. It is, therefore, a commendable aim on the part of the author "to present a condensed, orderly review of some of the research work that has been done both here" (presumably the United States) and abroad on problems connected with various phases of design of the high-speed type. This object, acknowledged as of great value to students, designers, experimenters and pioneer operators, has been carried out only partially, mainly owing to the fact that this important subject cannot be treated as a specific aspect of the general subject of Diesel engines, but must be reviewed as a main subject all on its own. In fact, for that very reason, "High-Speed Oil Engines" should prove a more appropriate description. The author does not define "high-speed", and it is certainly a point for debate whether certain of the described designs and constructions really fall in the category under review.

The first chapter deals with the all-important subject of application, and it is questionable whether the author has marshalled the main available facts and figures in the best fashion. The way he jumps from railcar to 'bus and back again to locomotive suggests that he is travelling with one of our very useful and economical T-O-T tickets.

Chapter II on "Thermo-Dynamics" might have been omitted; it is very incomplete. In fact, the oil engine cycle has been analysed so fully in many of the publications referred to by the author, that it can be considered redundant in any book treating only the general aspect.

Chapter III on "Combustion Phenomenon", Chapter VII on "Atomisers and Sprays", and Chapter VIII on "Injection Pumps" are in keeping with the admirable aim of the author. These vital subject matters might have been elaborated with considerable advantage. Much additional work by Schweitzer, as well as other eminent American research workers, could have been included, because of its high educational value.

The author would have served a more useful purpose with his book if he had given us an authentic review of American progress. Much interesting detail could have been given about recent research and experiments; also those designs which have been particularly successful, and others which never emerged from the experimental stage. Again we know too little about the running experience of the leading types and the results that may be expected in practical conditions. Altogether the information is lacking very much in this respect. For instance, one particular American type, of which much has been said in the technical press and other text books, is not even mentioned; this despite the fact that one hears very favourable reports about the behaviour of this engine in practice.

The author has not done justice to the British and Continental position. But then the advance has been so rapid that only the very closest contact with the important industry on this side would make it possible to review authentically the work in progress and the trend of development.

"The History of the Oil Engine", by A. F. Evans, M.I.A.E., M.I.Mar.E. (with a foreword by Sir Dugald Clerk). Sampson Low, Marston & Co., Ltd., price 25s. net, 318 pp.

In a historical work on the oil engine a title to embrace every form of prime mover of this type is a good selection, but the steps by which inventors of different decades advanced and improved the mechanism of the various types should have been treated in a more methodical manner. Carburation, external and internal vaporisation, Akroyd type, Diesel type, all of which are principal chapters in the oil engine history, are mixed up with subsidiary subject matter. As a result there is a fair amount of overlapping and redundant matter, and the story loses conciseness and clearness. The object of reserving one chapter to deal with the history of the history does not appear clear.

The author, being an Akroyd Stuart medallist, was to be expected to deal at some length with the Akroyd type. It is satisfactory to note that he does not wish either to rob Stuart of the merited credit or to disparage the work of Diesel. One has heard a great deal of this controversy as to what Akroyd Stuart did and what Diesel did, and Sir Dugald Clerk, who was a contemporary of both and who had honoured the author with a foreword, might have re-quoted his own views:—

> "Akroyd applied successfully, and for the first time, the idea of igniting and vaporising the oil charge by means of the hot surface of certain portions of the combustion chambers".

> "Diesel compressed the air to such a high pressure and corresponding temperature that the oil charge ignited as injected".

Both men have an important place in the history of the oil engine and both are entitled to their due, but Sir Dugald mentions neither in his foreword, the major portion of which is a quotation from Ricardo.

As regards the Diesel section the author has divided the subject into the history of the Diesel engine in America and in the remainder of the World. The author's reason for such treatment is not at all clear. Perhaps he had in mind that on German history Riedler in his book said that "the Diesel engine was not invented, but found, developed and tried".

The author's reference to certain engines, which may be considered as still in the experimental stage, is irrelevant, and it would have been better if, for purposes of record, he had fixed a date, say 1910, beyond which he could consider that history merged into contemporary development. Such a treatment would have been appropriate, particularly as it appears that the author is going to appoint himself as the reporter of oil engine developments and intends in future volumes to deal with developments from the date of the close of this book.

The patent index on early gas and oil engines is very valuable and is to be continued (and, it is hoped, extended) in future editions.

It is also to be hoped that in future editions the author and publishers will find it possible to place the illustrations opposite the relevant text.

Broadly considered, the book is one which meets a real need, for it is the only really complete historical work on the oil engine that is published in this country. It contains a great deal of information which should be of the utmost value to designers, students, and others.

"Steam Boiler Construction". Rules of the National Boiler & General Insurance Co. Ltd., by E. G. Hiller. Published by The National Boiler & General Insurance Co. Ltd., at 3s. 6d. net.

This book is a revised and enlarged third edition of the Rules of The National Boiler and General Insurance Co., and is a remarkably full and efficient guide to the construction and maintenance of land boilers and their connections. As far as can be judged now, but very little alteration or addition would be necessary to bring the contents into conformity with what appears likely to be the results of the deliberations of the various Committees now working under the direction of the British Standards Institution on the design of land boilers.

Builders of marine boilers have, for many years, had the guidance of and safeguards embodied in the Rules of the Marine Department of the Board of Trade, which are, of course, now also those of the Registration Societies, but those Rules cannot claim to include the completeness of detail which is given in the Rules of the National Boiler and General Insurance Company. It seems that having such a text book on design before him, no land boiler builder could be excused if he should have a serious failure due to faulty design. The instructions given in this section of the book are in fact what might be expected from one having such a long and varied experience as its author.

This thoroughness and reliability are also as noticeable in those sections dealing with the fittings, steam pipe lines, setting, etc., and it is gratifying to see how those lessons which have been impressed upon those who have watched the working of the Boiler Explosions Acts, are embodied and stressed in the requirements or recommendations now offered to those who are responsible for the installation and maintenance of steam plants, large or small. As an instance of this, the remarks on waterhammer may be taken, and it would perhaps have been justifiable to have stressed even more highly the objection to cast iron for stop valves and other fittings, which is referred to in this section. A second instance is the advice given in regard to such cast iron structures as hot plates, etc., many of which have failed with serious results to those using them.

The section dealing with steam pipes is excellent and very complete. No part of a steam plant has been the subject of more casual consideration in years past than the steam range, and many disastrous explosions have resulted from ranges when in use. The rules and advice given in this section of the Rules should enable even those inexperienced in such work to instal a steam pipe line free from those faults, such as inadequate provision for expansion, support or drainage, which have been the most serious causes of failure in years past.

From these remarks it will be gathered that in the new edition of this valuable reference book, the high standard of the work has been maintained. Those boiler owners who possess the advantage of having such expert supervision and advice as is likely to be given them by an organisation governed in its inspections by such rules and recommendations, can be considered fortunate.

"Dynamics of Engine and Shaft", by Ralph E. Root. Published 1932 by Chapman & Hall, London, at 18s. 6d. net.

This book is one which should be studied thoroughly or not at all. It is essentially a text book treating engine balance and the other problems that arise from inertia forces and uneven turning moment in a reciprocating engine, but it is written in a manner that makes it of little value as a work of reference. It would, for example, be of no value to a designer who expected to refer to the index and be able to find a formula for solving some problem relating to a particular engine. That it should not be possible to use it in this way is rather an advantage than otherwise, as the subject dealt with is one that has suffered considerably in the past from literature and works of reference containing empirical methods that can be used and frequently misused by people with an incomplete knowledge of the subject.

The first seven chapters deal with engine balance, turning moments and bearing pressures in a manner which, in many respects, is more complete than in any previously published work. Important points which are completely ignored in most books and papers relating to the subject, are clearly brought out in this work. A few examples of these will indicate the thorough method of treatment, viz.: in dealing with unbalanced forces, the author not only treats the 1st and 2nd order, as is usual, but also the higher orders and shows that there are quite appreciable forces of the 4th and 6th order; the very considerable rolling couple set up by variations in the transverse velocity of the connecting rod is dealt with, an important force rarely considered when engine balance is discussed; included also is a fact not generally mentioned in connection with balancing, i.e., that the balance of a multi-cylinder engine is based on the assumption of an infinitely rigid engine frame (this fact is brought out clearly by Mr. Root and it is shown that unless the engine framing is rigid, severe external forces may give rise to vibration even in an engine that would normally be considered as perfectly balanced).

The modifications to the balancing calculations necessary for special arrangements of drive, such as offset cylinders, or two or more cylinders acting on the one crank through articulated rods, are clearly explained. The subject matter of these chapters deals essentially with principles and will enable the student who masters these principles to solve the various problems discussed for any type of engine.

The only fault that can be found is that the author has tried to condense the subject matter into too small a space and clarity has to some extent been sacrificed. It would have greatly improved the book if the last three chapters had been omitted and the space devoted to an extension of the first seven.

Chapters VIII to X deal with torsional and transverse vibrations and critical speeds, but they do so in a manner, except for transverse vibration (the chapter on which, though far from complete, would probably enable the student to deal with most problems arising in practice), so incomplete as to be worse than useless. The chapters on torsional vibration and critical speeds are definitely dangerous, as they may lead the student who reads them into the belief that he understands these subjects, whereas to treat the principles of either would fill a volume larger than the one under review.

A casual glance through this work might leave the impression that it is highly mathematical; actually, however, any engineer with a sound knowledge of algebra and an elementary idea of calculus can follow without difficulty all the subject matter of the first seven chapters.

The book is well provided with examples and data is given relating to a number of actual engines which will enable those students to whom such information is not otherwise available, to carry out detailed calculations and so make themselves thoroughly conversant with the practical application of the principles located generally in the subject matter. To those who wish to study the subject privately, it would be an advantage if a supplementary chapter were included giving the answers to the questions, so that they could determine whether the results they obtain are correct.

The term "student" has been frequently used in the foregoing review, but it has been meant in its broader sense, the book being of value not only to the pupil at college or technical school but to every designer or engineer who has to deal with the construction or installation of reciprocating machinery. It is of particular value in that it deals comprehensively with a subject of which so many engineers have only the most sketchy knowledge, and even those who have previously made a study of engine balance and allied problems will learn much from this work.

"Theory of Machines", by L. Toft and A. T. J. Kersey. Second edition published 1932 by Sir Isaac Pitman & Sons, Ltd., at 12s. 6d. net.

This book, the first edition of which appeared in 1927, is the excellent result of a collaboration between a mathematician, used to teaching engineering students, and an engineer who is exceptionally sound on the fundamental principles of mechanics. The book, although written for the special needs of a student reading for an engineering degree, deals with various mechanisms, friction, cams, balancing, gearing, and critical speeds, all of which are of interest to the marine engineer. From the point of view of the latter more should have been written on the Michell bearing particularly, introducing some of the theoretical work of R. O. Boswell. Turbine reduction gears might also have been given fuller treatment.

The authors could well have left out the section dealing with the effect of friction on the line of thrust in a connecting rod. Their treatment is the usual academic one based on the friction of dry surfaces, and to give a reasonable deviation of the line of thrust, an absurd value of μ, the coefficient of friction, has to be taken to draw the friction circles. In practice crank pins, gudgeon pins, and crosshead pins have lubricated surfaces for which μ is small and the line of thrust comes on the opposite side of the connecting centre line to that for dry surfaces.

The book is well illustrated with clear and simple drawings and plenty of examples with answers have been included. In the second edition examples have been added and misprints and errors corrected.

The proof of a pudding is in the eating and the reviewer has found the first edition so digestible that he can safely recommend this edition to those engineers who are more interested in a subject developed *ab initio* than in a mere collection of formulæ.

The book will undoubtedly long continue as a standard work on the subject.

Benevolent Fund.

The Committee gratefully acknowledge receipt of the following donations :—

W. J. Bloomfield, Member, Curacao, 6s. 3d.; A. Girdwood, Member, Edinburgh, £1 1s.

Visit to the Witton Engineering Works of The General Electric Co., Ltd.

On Wednesday, 15th June, approximately 60 members of the Institute visited the Engineering Works of The General Electric Co., Ltd., at Witton, Birmingham, by the kind invitation of the Company. The party included members from London and various parts of the country.

The main party travelled from London by the 9.10 a.m. train from Euston, arriving at Birmingham at 11.10, where they were met by charabancs and conveyed to the works, which lies several miles to the north of Birmingham. On arrival the party was split up into groups and started on a tour of the various shops accompanied by guides.

Lunch was served in the Company's "Magnet Club", which adjoins the works, under the Chairmanship of Dr. Railing (Director) supported by Dr. Garrard (Manager Switchgear Dept.), Mr. W. H. Heaton (Works Manager), Mr. C. W. Saunders (Manager Marine Dept.), and other representatives of the G.E.C. In welcoming the visitors Dr. Railing expressed his pleasure at their presence, particularly as he believed that a stage in marine engineering had been reached where wholehearted co-operation between marine engineers and electrical manufacturers was most desirable in view of the large amount of electrical equipment now installed on ships. He felt that the more electrical manufacturers could draw on the experience of marine engineers and the more marine engineers became familiar with modern electrical engineering practice, the better it would be for both great industries.

In replying on behalf of the visitors, Mr. S. N. Kent, Vice-Chairman of Council, expressed keen appreciation of the arrangements which the Company had so kindly made for their edification as to the important developments which were being effected in electrical machinery for marine purposes. The case for electric propulsion was being constantly and very ably presented by the pioneers of the system on the manufacturing side, but they had to judge the matter from the operating engineer's standpoint. That day they were being afforded an excellent opportunity to gain real insight into the proposition by being privileged to see under construction some of the very latest electrical machinery for main propulsion and auxiliary service.

It was well known that marine engineers held widely different views amongst themselves on the rival systems of propulsion. He personally was not yet converted to the belief that the electrical system was *the* coming system, but he would concede that, rather than being a convinced opponent of the system, he was at least beginning to question how far Dr. Railing and his colleagues were wrong in their convictions.

In conclusion he hoped that all the members present would avail themselves fully of the unique opportunity afforded them by the Company to examine these things for themselves and thereby help to form a sound opinion on the matter.

After lunch the tour of the works was continued, the itinerary including the Main Engineering Shop where turbo-alternators, large A.C. and D.C. motors, and converting plant are manufactured, the Standard and Small Motor Shops, Power House, Test Dept., and Foundry, Switchgear Works, High Tension Works and the High Tension Laboratory.

The Witton Engineering Works of the G.E.C. does not deal with the manufacture of all the Company's products. Heavy mechanical engineering plant, such as steam turbines, Diesel engines, mining plant, etc., is made at their Fraser & Chalmers' works at Erith, Kent, while they also possess a huge Telephone Works at Coventry, Heating and Cooking Works at Landor Street, Birmingham; Cable Works at Southampton; Meter and Instrument Works both at Birmingham and Salford; and the famous Osram Lamp Works at London and Wembley. In addition there are several other works situated in various parts of the country, the total number of employees being approximately 25,000, of which 6,500 are employed at Witton.

The Witton Engineering Works, which is the largest unit in the Company's chain of factories, is a town in itself. It has its own housing estate; its own private roads patrolled by traffic controllers; its own power house which is actually larger than those of many provincial towns; while it also possesses acres of playing fields for its employees, a large social club provided with rest rooms, billiard rooms, a ball-room fitted with a fully-equipped stage for amateur theatricals and a restaurant capable of seating over 1,500.

The site occupied by the works extends over an area of about 150 acres, on which are built separate shops for the production of heavy electrical plant, switchgear, transformers, standard motors, small motors, fans, vacuum cleaners, carbons, batteries, lamp black, moulded products, hoists and cranes, mica insulation, in addition to the Development Department, Foundry and Pattern Shops, Power House, Testing Department, High Tension Laboratory, Plating and Enamelling Shops and Central Stores.

Taken in conjunction with the huge block of administration offices, this list affords convincing proof of the statement that Witton is the site of one of the largest groups of electrical engineering factories in the world.

In marine electrification the success of the Quadruple Screw Turbo-Electric Liner "Monarch of Bermuda", recently placed in commission on the New York-Bermuda service, has helped to bring the electric propulsion of ships into the foreground of marine engineering development. In a recent report it was stated that probably no other ship in the world has put up such a remarkable performance as the "Monarch of Bermuda" in the reliable, punctual, express-train like service which she had given since her inauguration on the New York-Bermuda run. The whole of the electrical equipment in this vessel was manufactured and supplied by the G.E.C., the two 7,500 kw. turbo-alternators supplying power to the four 5,000 h.p. motors driving the four propellers, and the control switchgear, together with four auxiliary generators and the hundreds of small motors and auxiliary drives being made in the Engineering Works at Witton, while the lavish scheme of lighting provided throughout the vessel and the equipment installed in the large electric kitchens were supplied by the Magnet Works of the G.E.C. at Landor Street.

During the course of the visit the party was able to inspect the main and auxiliary generating plant and the four 5,000 h.p. propulsion motors for a sister ship, the "Queen of Bermuda", which were being manufactured.

Another important marine electrification scheme recently completed was that of the "Cementkarrier", a cement carrying vessel for service on the Canadian Great Lakes. Some idea of the close manœuvring demanded from a vessel plying on these lakes may be gained from the fact that between Montreal and Lake Ontario there are some six canals and twenty-one locks, while between Lake Ontario and Lake Erie, the connecting link of which is the Welland Canal, there are no less than twenty-five locks. Conditions of operation are such that a ship must check way immediately on entering these locks. This can only be accomplished by means of the most reliable manœuvring arrangements, and the inability of the early electrically propelled ships to withstand these admittedly gruelling conditions was responsible for the unpopularity of Diesel-electric drives, a stigma which has only been removed within the last year or so. The "Cementkarrier's" normal run is on Lake Ontario between the ports of Toronto and Belville, which is on the north shore of Quinte Bay, at the mouth of the Moira River.

The electrical propelling machinery includes two 360 kw. D.C. main generators driven by 500 h.p. Atlas Diesel engines, two 50 kw. auxiliary generators coupled in tandem to the main generators and the main propulsion motor rated at 775 h.p. at 100 r.p.m. There are also two 30 kw. emergency generators and the main switchboard.

These are but two instances of the class of undertaking in which the Engineering Works are constantly engaged. Limitations of space prohibit a full description of the numerous other industrial electrification schemes that are carried out, as for example the complete equipment of a super-power station such as that at Hams Hall, Birmingham, or the electrification of railways, textile mills, steel rolling mills, collieries and the like both in this country and abroad.

Another important activity of the Witton Works is the manufacture of equipment for large or small overhead electrical transmission systems, of which the British "Grid" is perhaps the best known, although it is by no means the only example. Quite recently two very important schemes of this type were supplied to Palestine and Egypt respectively. In the latter case, the overhead line conveys electrical power along the Nile for the operation of pumping stations and is thereby instrumental in converting thousands of acres of hitherto barren land into fertile soil through the scientific application of irrigation. The outdoor switchgear involved in the construction of these overhead lines, and also, incidentally, in a large portion of the British "Grid", has all been produced in Birmingham at the Witton Engineering Works where a special factory has been built and equipped solely for the manufacture of this class of gear.

It is in this factory that the famous High Tension Laboratory is situated. Visitors from all parts of the country and from abroad have made the journey to Birmingham in order to inspect what is undoubtedly one of the most lavishly equipped High Tension Laboratories in the world. Every class of high tension testing appliance is represented, many of which are unique in their design. No less than three high voltage generators are installed, each capable of giving a million volts for testing purposes.

Situated close to the Witton Engineering Works is the Carbon Works, which is the only factory in the British Empire producing the searchlight carbons so vital to the fighting services and to the Empire at large. Before the War the combined Admiralty and War Office demand for searchlights amounted to 150,000 per annum. During the period of hostilities the Witton Carbon Works of the G.E.C. provided over 5,000,000 searchlight carbons for Government use, and approximately 7,000,000 arc-lamp carbons for dockyard lighting and similar purposes, in addition to the large consignment supplied to Allied Governments. The Battery Works adjoin the Carbon Works and are responsible for the "Gecophone" Wireless batteries, in addition to a large number of types of dry battery used in industry.

An important member of the Witton group of factories is the Moulded Insulation Works which is devoted to the manufacture of a wide range of moulded products made of bakelite, or "Wittonite" such as insulators, wireless valve caps, terminal blocks, lamp-holders, switch covers, wiring and cable cleats, etc. The range of moulded products has increased during the last two or three years to an enormous extent and the list is added to practically every day.

Mention must also be made of the Foundry, which is one of the largest in the Midlands and is capable of producing castings weighing well over 50 tons. Neither should the Standard Motor, Small Motor, and Fan Shops be omitted as theirs are the "bread and butter" products, and although motors and fans are common objects in modern industry, their familiarity must not be allowed to breed contempt. All types of motors are produced in these works, from the very small motors used to drive sewing machines and the like up to the gigantic motors of 20,000 h.p. installed in rolling mills.

In conclusion a few of the more impressive equipments seen by members of the party during their tour of the works are given below :—

20,000 h.p. Turbo-electric plant for the "Queen of Bermuda" on test.

13 - 1,200/1,500 kva. mercury arc rectifiers for British Railways being assembled.

9 - 1,500 kw. rotary converters for British Railways being assembled.

37,500 kva. turbo-alternator rotors being wound.

1,000 h.p. electric winders for collieries.

1,500,000 kva. metalclad switchgear in course of erection.

132,000 volt "Grid" oil circuit breakers in course of erection.

30,000 kva. 132,000 volt transformers on test.

The members were further entertained to tea at the close of the tour, when a most hearty vote of thanks was accorded on the proposal of Mr. D. A. Stewart Lee to the Company's officials who had acted as guides and mentors throughout the day. The party for London left by the 6.20 train, reaching Euston two hours later.

JUNIOR SECTION.

Visit To Snowdown Colliery and Dover.

The Mid-summer Visit of the Junior Section, arranged jointly with the Leyton Technical College Engineering Society, took place on Saturday, July 2nd, 1932.

A party of 55 journeyed, one half by road and the remainder by rail, to Snowdown Colliery, Nonington, near Dover. Arriving at 11.10 a.m., the visitors were met by members of the colliery staff, and after being divided into three groups, proceeded under their guidance on a tour of the surface plant of the colliery. The output from the Snowdown pit is 12,000 tons per week; the number of employees is 2,000, including 1,500 miners and other underground employees working in three shifts of 500 each. The coal mined from the Kent seam is of high calorific value, averaging 14,500 B.T.U's. It is exceptionally friable, and is therefore very suitable for use in powdered fuel installations. The main seam lies 3,000ft. below the surface; the internal temperature of the seam is 98° F., and the air temperature in the workings is 80° F.

The electric winding machinery, which is of the very latest type, was a feature of special interest to the visitors. The speed and precision with which an unceasing raising and lowering of loaded and empty trucks was maintained was a marvel of combined mechanical and human efficiency. So also was the elaborate mechanical screening and sifting plant, by means of which the "slack" is separated from the small coal or cobbles. The friable nature of the coal was evident here, and was further confirmed when we were told that the slack amounted to approximately 60 per cent. of the coal raised.

Other departments which afforded considerable interest were the lamp store and re-charging room, where each of the miner's electric lamps is thoroughly inspected, re-charged, tested and sealed between shifts; the check-weighing station adjoining the pit, where two tally-clerks representing the owners and the miners respectively record the weight of coal contained in each truck and credit it to the individual miner, whose identification mark is attached to the truck; the large ventilating fan and system of air-locks round the shaft head by means of which adequate circulation of air through the mine is maintained; and the machine and fitting shop where running repairs to the whole plant are carried out. It was perhaps disappointing to many of the visitors that permission to descend the mine could not be granted, it being explained that to take such a large party below would necessitate somewhat special arrangements, and moreover, which was obviously the chief difficulty, would incur objections by the men working below, who complained of the dislocation and interference with their output which such underground trips by large parties involved. These difficulties would not affect one or a very few visitors to the same extent, and although we had on this occasion to forego any such privilege, it is possible that at some future date a few members who specially desire the experience may be given facilities to make the trip underground.

On leaving the colliery, the visitors proceeded to Dover and dispersed in small parties for lunch, re-assembling at 3 p.m. at the Prince of Wales Pier. Here they were met by Mr. D. McQueen, Marine Superintendent of the Southern Railway, and Mr. H. H. Jacques, B.Sc., A.R.C.S., Principal of Dover Technical College, who had together very kindly planned arrangements on our behalf by which the afternoon programme proved particularly enjoyable and instructive.

By the courtesy of Mr. McQueen the party were first permitted to inspect his Company's T.S.S. "Maid of Orleans", which was lying at the pier with steam up, ready to proceed to sea. Under such ideal conditions for inspection the vessel afforded so much interest that it was 4.30 p.m. before the party proceeded to the Eastern Arm of the Harbour, where Mr. McQueen introduced the visitors to representatives of the Harbour Board and the Tilmanstone Colliery respectively, who, like himself and Mr. Jacques, very kindly gave up the afternoon (and, as it eventuated, the best part of the evening) in our interests.

The Terminal Bunker, at which coal is delivered by overhead conveyor a distance of 4½ miles from Tilmonstone Colliery, was inspected in every one of its many interesting structural, mechanical and electrical features, and as a special favour Mr. Hewitt, the Company's manager, and his assistant were good enough to demonstrate the plant in actual operation, showing how the coal would be transported from the bunker by electrically driven belt conveyor and distributors to the hold of a vessel alongside.

Finally, Mr. McQueen conducted the party to the Coal Staithes at the inner end of the breakwater, where coal is delivered by rail from the Snowdown Colliery and loaded by special machinery into vessels berthed alongside. The process of receiving and emptying each truck in a rotary cage, thence elevating and distributing the coal by belt conveyor to the loading hopper and shutes was actually demonstrated by employees of the Railway Company and the contractors for the plant. For arranging this privilege we were once more indebted to the enthusiasm and thoroughness of Mr. McQueen, to whom and to Sir William Crundall, J.P., our warmest thanks have been accorded, not only for the privilege of inspecting these installations but particularly of seeing them in operation at a time when they would normally have been idle.

Our visit terminated with but little time to spare before the rail party boarded the 7.58 p.m. train for London, reaching Victoria at 10.27 p.m. after a most enjoyable and profitable day.

B. C. C.

ABSTRACTS.

The Council are indebted to the respective journals for permission to reprint the following abstracts and for the loan of the various blocks.

*Problems of Ship Propulsion.

"The Engineer", June 17th, 1932.

SIR,—In the interesting article by Mr. G. S. Baker under the above title, which appeared in your issue of May 27th, the author states that "in our usual haphazard way, Great Britain's representation was left to the chance choice of a number of technical institutions scattered over the country". He then gives a list of those present from Great Britain, but, presumably inadvertently, omits the British member, Mr. W. Lumsdon, who attended the Conference as an official representative of this Institute. Mr. Lumsdon's name appeared in the list of representatives which you published in the preceding week's issue, but it is perhaps desirable that readers of Mr. Baker's article should be acquainted with the omission to which this letter draws attention.

In connection with the question which Mr. Baker raises as to the value of such international conferences, it may be of interest to add the opinion of some of the visitors, as reported by our representatives, that the Conference, although very well prepared, suffered somewhat from the abundance of the papers and contributions, all on a rather high scientific plane. They consider that it exceeds by far the capacity of even a specialist to receive and assimilate during the Conference this great amount of scientific matter, and they consider that the real value of the Conference will be determined later on when all these papers and discussions have been printed and circulated.

B. C. CURLING,
Secretary, The Institute of Marine Engineers.

London, E.C.3., June 14th.

* The above letter should be read in conjunction with Mr. John de Meo's speech at the Conference, which was published in the June Transactions, pp. 269 - 270.

The Survival of the Paddle Steamer.

By G. W. TRIPP, F.C.G.I., M.I.Mech.E., M.Inst.C.E.

"The Engineer", 27th May, 1932.

In these somewhat utilitarian days, when engineering masterpieces are ruthlessly destroyed in the interests of so-called progress, when such a celebrated fabric as Rennie's bridge over the Thames stands tragically condemned to extinction, when soulless commissioners would render the Stephenson locomotive as obsolete to future generations as the stage coach is to the present one, no apology is needed for introducing a subject that must be of interest to all engineers. maintaining, as it does, a link with the earliest days of steam navigation—the paddle steamer.

In 1901, when the first passenger turbine steamer, the graceful little "King Edward", proved eminently successful on the Clyde, over whose waters the fast paddle boat had held undisputed sway since the days of "Comet", it appeared as if the death knell of the older craft had been definitely sounded. Yet when over a quarter of a century had

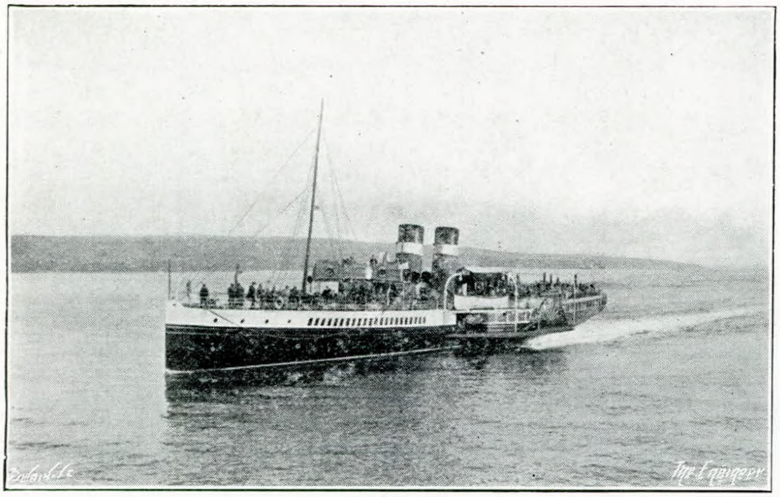


FIG. 1.—L.N.E.R. Paddle Steamer "Jeanie Deans".

lapsed the number of passenger paddle steamers was easily in excess of the turbine, and at the present day there are 14 paddle steamers operated in connection with the railways to five turbines—including the one now building—while of privately owned vessels the ratio is two to one in favour of the older type.

Admittedly this is negative evidence, which might merely suggest a lingering death, but on the positive side there is the fact that new tonnage of paddle steamers has continued to be added. When England declared war on Germany the North British Railway was expecting delivery from Inglis of a new paddle steamer, but "Fair Maid" was destined never to carry holiday makers, for she succumbed to a German mine, and no new steamer took her place.

The London and North-Eastern Railway, as successors to the North British, realised that new tonnage was essential, for several of their Clyde boats were already veterans, propelled by single-cylinder inclined engines of about 52in. cylinders by 72in. stroke, rotating the 17ft. 4in. paddle wheels at 49 revolutions per minute. When it was definitely decided to build a new vessel, speculation was rife as to the type likely to be adopted, until the announcement was made that she was to be a modern paddle steamer. "Jeanie Deans"—Fig. 1—was put on service last year and has already proved popular with a somewhat fastidious public.

As she has not been described in these pages a few particulars may not be out of place. She was built and engined by the Fairfield Shipbuilding and Engineering Company and has the distinction of being the first steamer in the Clyde fleet to be propelled by inclined triple-expansion engines, which have cylinders, in line, of 26in., 41½in., and 60in. diameter respectively, with a stroke of 60in. The paddle wheels are rather smaller than those of the older boats, as they measure 16ft. 8in. over the floats, but the speed of rotation is higher, being 58 revolutions per minute. Steam is supplied by one double-ended boiler working at a pressure of 180lb. per sq. in, under the closed stokehold system of forced draught. Her speed on trials was 18·5 knots, with an indicated horse-power of 2,300 at 58 revolutions per minute. Her leading dimensions are as follows: Length between perpendiculars, 250ft.; beam, 30ft.; and depth, 9ft. Her tonnage is 635 gross and 259 net registered. She can carry 1,715 passengers on a No. 5 and 1,022 on a No. 3 certificate.

"Jeanie Deans" is the first vessel of the fleet to have a promenade deck extending from the bows almost to the stern, although it might be mentioned in strict accuracy that "Waverley" had hers extended after her post war reconditioning. The main deck affords excellent shelter for bad weather, as the fore cabin is fitted with large glass windows, which enable unimpaired views to be obtained. Behind the engine-room is a comfortable first-class lounge, as well as the cosy tea-room, which is apparently regarded as an essential feature of the Clyde passenger steamer. Dining saloons are provided on the lower deck.

With a single pole mast and two short funnels painted in the distinctive colouring adopted by the old North British Railway—red with black band at the top, separated from one another by a narrow white band—this vessel is easily identified, particularly as each of her sisters

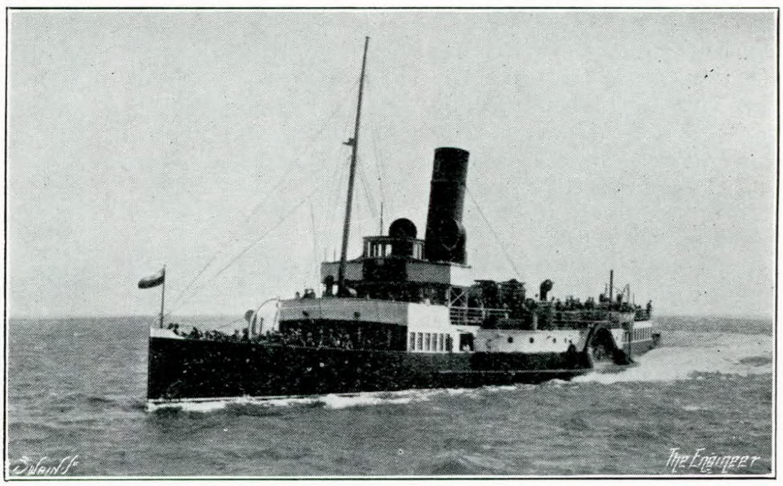


FIG. 2.—S.R. Paddle Steamer "Portsdown".

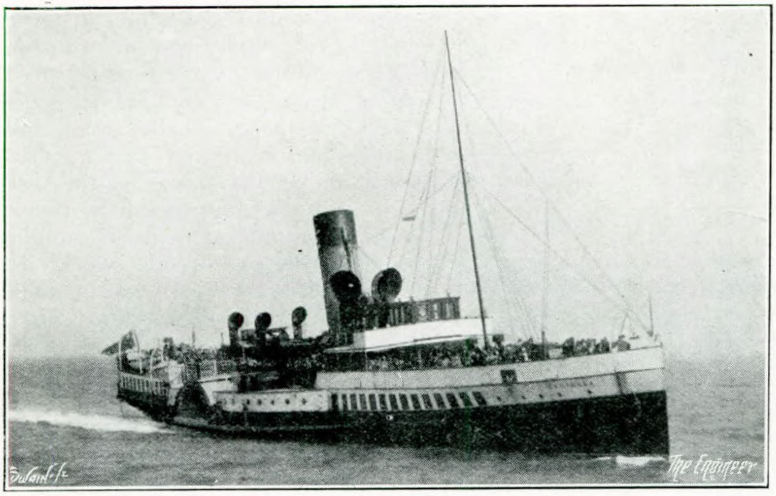


Fig. 3.—S.R. Paddle Steamer "Southsea"

has but one funnel.

Those who recall the very short piers on the Firth of Clyde, which gave an indication of the deep water to be found near the shore, may be surprised at the survival of the paddle boat in this area. Actually, however, Graigendoran, the headquarters of this fleet, is situated on a sandy shore on the north bank of the river, where at low tide there is very little spare water, and occasional visits of turbine steamers have not been made without anxiety.

Other well-known services that have been maintained by paddle steamers are those between the mainland and the Isle of Wight, the bulk of passengers being carried by the railway vessels between Portsmouth and Ryde, supplemented by those sailing between Lymington and Yarmouth, but there are also boats which ply between Southampton and Cowes operated by the company with the high sounding title of the Southampton, Isle of Wight and South of England Royal Mail Steam Packet Company.

It is of particular interest to mention that practically the whole of the Southern Railway fleet has been replaced since the Great War and entirely by paddle boats. "Shanklin", the first post-war addition, which appeared in 1924, was generally similar to the later boats built for the Portsmouth station, and when "Merstone" and "Portsdown"—Fig. 2—joined the fleet in 1928 it appeared as if a standard type had been determined. They are serviceable craft, constructed by the Caledon Shipbuilding and Engineering Company, of 360 tons gross register, and driven by inclined compound engines, with cylinders 27in. and 51in. respectively, and a stroke of 54in. The paddle wheels rotated by these engines have a diameter over floats of 14ft. 3in.—or 11ft. 7in. through float pin centres—and make 47 to 48 revolutions per minute. These steamers are about 190ft. long and have a beam of 25·1ft. and depth of 9·7ft.

The chief drawback from the passengers' point of view lies in the fact that frequently in the summer time the whole of the main deck forward of the high deck is given over to trucks of luggage, milk cans, baggage, and the like.

The two latest additions to the fleet show a marked advance on any of their predecessors. For the first time a long promenade deck extending up to the bows has been provided, and the bugbear of the luggage has been removed, for the trucks are now slung and lowered through two hatches on to the main deck and the passenger has an unimpaired view ahead. But although provision has been made for the efficient handling and stowing of luggage, these boats have also been built with excursion work in view, and "Southsea"—Fig. 3—and "Whippingham" are frequently seen in the Solent with a full complement of passengers bound for Southampton to visit the docks and to be conducted round one of the North Atlantic liners. The Southern Railway claims that these two are the largest and most luxurious excursion steamers on the South Coast, a claim which certainly can be allowed, for their most formidable rival, P. and A. Campbell's "Devonia", though a faster craft, is neither as large nor as well equipped.

Both boats were engined and built by the Fairfield Shipbuilding Company, Glasgow, and embody the unusual feature for paddle boats of a

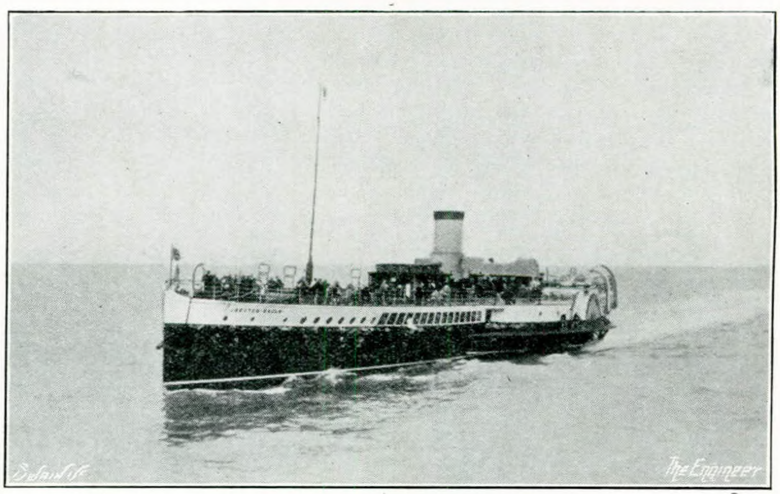


Fig. 4.—Paddle Steamer "Crested Eagle".

cruiser stern. They have a gross tonnage of 825, and their main dimensions are:—Length, 244ft.; beam, 30·1ft.; depth, 10·5ft. Their paddle wheels, which have a diameter over the floats of 16ft. 1in., or 13ft. through float pins, pitch circle diameter, are rotated at 51·5 to 52·5 revolutions per minute by inclined compound engines, having cylinders of 30·5in. and 59in. diameter respectively, and a stroke of 54in., and impart to the vessels a speed of 16 knots. Each boat can carry 1,350 passengers, for whom there is a spacious first-class saloon in polished oak on the main deck, and good second-class accommodation. There is also a large smoke-room and bar in the centre of the promenade deck.

Before leaving the Isle of Wight services, it should be mentioned that the Southampton company has added one paddle steamer, "Princess Elizabeth", to its fleet since the war, but its latest venture, "Medina", is a twin-screw boat, driven by Gardner paraffin engines—an interesting packet—but falling outside the scope of the present article.

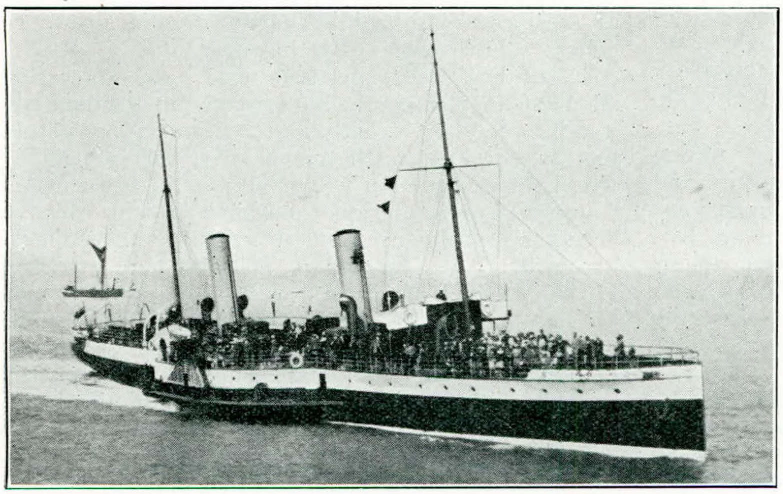


Fig. 5.—Paddle Steamer "Queen of Thanet".

Perhaps the clearest indication of the survival of the paddle steamer is to be found in London itself, and on the broad waters of the Thames estuary, where for pleasure sailings this type of boat has more than maintained its position. In 1906 the General Steam Navigation Company built the first turbine steamer for the Thames, "Kingfisher", a vessel that was fully described in "The Engineer" at the time. Her performance on service did not justify the faith that had been put in her, for her manœuvring qualities were inferior to tho e of her paddle sisters, and after a few seasons she was sold to Greek owners, and as "Venezia" has had quite a long career. She was succeeded by the very well-known "Golden Eagle" in 1909, and the ascendancy of the paddle boat was re-established. Then came the Great War, during which this boat and her older sister "Eagle" did excellent work as troop transports. In 1924 it was decided to build a new boat for the next season's traffic, but the problem was rendered more difficult by the fact that it was intended to use the Old Swan Pier as the London starting point, which necessitated sailing under London Bridge, no easy a matter for a boat of over 1,000 tons. Apart from the difficulties of construction, the æsthetic side suffered, for it resulted in a telescopic funnel which looks out of proportion, as does the light and short pole mast, which is hinged for lowering; altogether a craft not to compare with "Golden Eagle" for good looks.

"Crested Eagle"—Fig. 4—is, however, interesting in many ways. She was the largest excursion steamer that had been constructed for these services, being 1,110 tons gross register. Her main dimensions are: Length, 299·7ft.; beam, 34·6ft.; depth, 11·1ft. She was built by J. Samuel White & Co., Cowes, and is registered for 1,797 passengers. Her inclined triple-expansion engines, with cylinders 30in., 46in., and 69½in. diameter respectively and a stroke of 66in., drive her 19ft. 6in. diameter paddle wheels at 55 revolutions per minute, imparting to the vessel a speed of 18½ knots. She is the first boat of her class to have oil-fired boilers, a fact which stood her in good stead during the coal strike. Another innovation is the position of the main dining saloon, which is on the main deck, and in the bows, with large glass windows, so that passengers can dine in comfort without losing the interest of the surroundings. The saloons generally show a marked advance on those of her predecessors.

Considering the period of depression through which this country has been passing, as well as the increased competition of the motor coach, the fact that the General Steam Navigation Company decided last year to build another boat for the Thames excursion traffic is evidence of faith in the future that is encouraging to notice. Before deciding that the new vessel should be propelled by steam and paddles, every other form of power and drive was explored, but in view of the larger deck space available, the greater ease of navigation and manœuvring in the river, and finally the lighter draught of the paddle steamer—an important point in the shoal water of the Thames estuary—the final decision was made in favour of the older type.

"Royal Eagle" was built by Messrs. Cammell Laird, of Birkenhead, and was launched on February 24th of this year, and it is admitted that she is the most luxurious vessel built for Londoners, of whom she can accommodate some 2,000. She is over 289ft. long and has an extreme breadth of 68ft. 10in., but her draught is only 7ft. Her gross tonnage is approximately 1,560. She is built with a straight stem, cruiser stern, two pole masts, and one funnel, and is equipped with a streamlined rudder, and also a bow rudder, both controlled by steam steering gear, operated from the navigating bridge. A double set of navigating lamps has been provided for steaming astern as well as ahead. There are four decks—lower, main, promenade, and sun—and nine water-tight bulkheads, the main deck being the bulkhead deck. Beneath the sun deck part of the promenade deck is made into a spacious shelter deck with teak-framed windows, which afford an unobstructed view. Steam is raised in two single-ended cylindrical boilers of the return tube type, burning oil fuel, on the closed stokehold system of forced draught. The engines are triple-expansion, arranged diagonally, the cylinders having diameters of 28½in., 44in., and 68in. respectively, with a stroke of 60in. The paddle wheels, which have a diameter of 18ft. 9in., rotate at a speed of 55 revolutions per minute. The smaller dimensions of engines and paddle wheels compared with those of "Crested Eagle" are accounted for by the fact that the working pressure of the boilers is 200lb. per square inch, or 20lb. higher than that used in the older boat.

On the main decks are two large dining saloons, extending the full width of the ship, and fitted with square windows of liberal dimensions. On the lower deck will be found smoke room, bar, and auxiliary dining saloons. Among the novelties incorporated in this vessel may be noted a soda fountain, and oil cooking, thus substantiating the claim that this is the first Thames pleasure steamer on which oil is used throughout.

No review of the development of the paddle steamer in recent years would be complete without an allusion to the part played by the New Medway Steam Packet Company, a company whose activities have increased considerably in recent years. During the war the Admiralty found that the shallow-draught excursion steamer was admirably suited to the strenuous work of mine sweeping, and although many summer favourites were pressed into this service, the number available was insufficient, with the result that in 1916 additional paddle craft was specially constructed for mine sweeping duties. After the Armistice and subsequent clearing of the seas, they were no longer required for naval work, and the Medway Company acquired H.M.S. "Atherstone" and set to work to convert her into a pleasure steamer, undertaking the reconstruction in their own yard. As "Queen of Kent" she instituted a service between Chatham and Calais, with calls at Southend and Margate, a sailing which soon became very popular, so much so that her owners decided to purchase another, and in 1928 "Queen of Thanet"—Fig. 5—(ex H.M.S. "Melton") joined her sister at Chatham.

Both vessels are generally similar in appearance, with two masts, two funnels, set well apart, cruiser stern and two decks, both being equipped with wireless. They were built by the Ailsa Shipbuilding Company, Troon. The leading dimensions of "Queen of Kent" are: Length, 235·2ft.; breadth, 29·1ft.; depth, 9·2ft.; and tonnage, 798 gross. The compound diagonal engines have cylinders 26½in. and 52in. diameter and a stroke of 54in., and drive paddle wheels of 14ft. diameter at 57 revolutions per minute, thereby giving a speed of 16 knots. Recently both steamers have been converted to burn oil fuel.

Altogether there still seems to be a good deal of useful work in store for the paddle steamer.

Paddle Tug with High-pressure Turbines and Water-Tube Boilers.

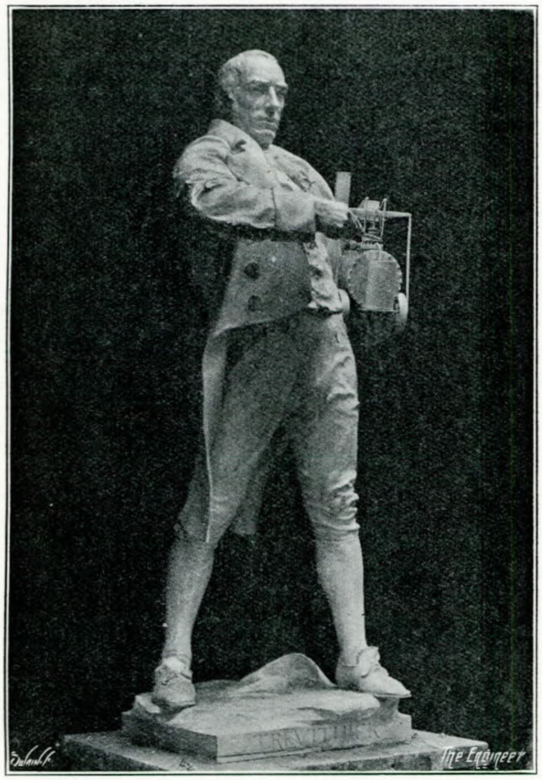
"Marine Engineer", June, 1932.

Due to the conditions of navigation on the Rhine, tugs on that river are almost exclusively of the paddle type, fitted with the usual arrangement of reciprocating paddle engines with fire-tube boilers. For some years, however, the H.P.L.M. company have used Niclausse water-tube boilers to allow of an increase in horse-power in the limited weight. As they recently required a very powerful tug, they decided to use turbine drive for the paddle wheels in conjunction with high-pressure Niclausse boilers of special design. Turbines had previously been successfully tried out in a Rhine tug engined by Escher-Wyss, in 1922. The tug built for the H.P.L.M. is 214ft. long by 22ft. beam and only 4ft. 3in. draught. The Escher-Wyss impulse turbines have high-pressure and low-pres ure cylinders, each with six stages of expansion, and the astern turbine, with two stages, is arranged in the low-pressure casing. The high-pressure turbine turns at 7,500 r.p.m., the low-pressure at 5,800 r.p.m., and the speed is reduced to 45 r.p.m. at the paddle wheels; the normal output of the turbines is from 1,050 to 1,500 s.h.p. The two Niclausse boilers each have a heating surface of 1,600 sq. ft., a superheater of 770 sq. ft., and an economiser of 620 sq. ft., and are designed to generate 6,600 to 11,500lb. of steam per hour at 300lb. per sq. in. and 600° F. The boiler differs from the older Niclausse designs in the great increase of the combustion chamber volume and in the arrangement of tubes along the sides of the combustion chamber, so that the surface exposed to radiant heat is very great. The use of both a superheater and economiser is also a new feature in this type of boiler. A separate turbine drives circulating and air pumps, the exhaust steam being used to heat the feed to about 200° F. before it is taken to the economiser. Extensive trials were carried out between Arles and Lyon, during which it was found that the increased power with this light type of machinery gave the tug a speed 20 per cent. higher than that of the older vessels with reciprocating engines.—*Bulletin Technique du Bureau Veritas,* April, 1932.

The Trevithick Memorial.

"Engineering", 20th May, 1932.

It is appropriate that any memorial to Richard Trevithick, the inventor of the locomotive and one of the first to suggest and use high-pressure steam, should be erected at Camborne, since he was born near by at Illogan, and received his early education and carried out a good deal of his pioneer work in that town. At the same time it must be admitted that this recognition, which takes the form of a statue and of a scholarship fund to provide free instruction at the Camborne Mining School, is a little belated, since Trevithick was born in 1771. We must suppose, however, as is sometimes done, that the idea is to link up this tribute with the centenary of his death, which occurred in 1833. The statue, which was unveiled by H.R.H. Prince George, K.G., on Tuesday, May 17th, represents Trevithick holding the model of the locomotive, which was tried at Camborne in 1801 and after-



Richard Trevithick.

[Block kindly lent by "The Engineer".

wards run in the streets of London in 1803, in his hand, and looking towards Beacon Hill, where his first experiments with this machine were made. The plinth on which the statue is mounted is decorated with bronze panels. These bear representations of allegorical female figures holding models of the Cornish boiler, of the Merthyr Tydfil locomotive being placed on the rails, and of the dredger being placed in the water. In the background of the last two are models of a modern engine and a liner, respectively. The centre panel at the back is occupied by a sailing ship with the sun rising behind it, while on the right is Carn Brea, and on the left the mule track over which Trevithick took his engines from Lima to the Serro de Pasca mine. The posture of the figure itself strikingly conveys the bodily strength for which its subject was famous, while the plinths no less clearly tell the story of a man who, in spite of the disappointments and discouragements which are too often the lot of the English inventor, correctly foresaw that the steam engine "would double the population of the kingdom and make our markets the cheapest in the world". Though he, as is also customary, received little reward for his efforts in his lifetime, and his fame, since his death, has often been overshadowed by that of those who followed him, history will always accord him a leading place among the pioneers of engineering progress.

Sulzer Circulating Pumps for Gas compressed to 1,000 Atmospheres.

"Sulzer Technical Review", No. 1, 1932.

When manufacturing synthetic ammonia according to the Claude process, the gas enters the synthetic apparatus at a pressure of 1,000 atm. This process with one catalyser tube gives a yield of ammonia of about 50 per cent., so that with four tubes arranged in series all but a comparatively insignificant amount of the gas coming from the compressor is converted into ammonia. Consequently the circulating pump, which is generally necessary for maintaining a regular circulation of the gas, has up to the present not been adopted in the Claude process. The gas which was left over, issuing from the fourth catalyser tube still at a pressure of 850 atm., was allowed to expand down to 25 atm. and added to the fresh synthetic mixture in the coke gas treating apparatus. Of course, this method entailed a certain loss of energy, but this was considered to be compensated by the simplicity of the plant.

In order to eliminate this loss and thereby increase the efficiency of the Claude process, which was already high, the process has lately been carried out in a somewhat different manner. The gas left over from all the catalyser tubes is collected by means of a special circulating pump and compressed from 850 up to 1,050 atm. and then converted as far as possible into ammonia in another catalyser tube.

A high-pressure gas circulating pump (Fig. 6) for carrying out this new process was built by Sulzer Brothers. The design of the pump is based on that of the well-known Sulzer hyper-compressor. The pump has two single-acting vertical cylinders, the pistons of which are worked hydraulically. This method of construction gives a very good distribution of pressure; in this respect it may be compared with that of double-acting single cylinder pumps. It is superior to all other methods of construction as regards erection, dismantling, accessibility and ease of attendance. A further advantage of the Sulzer pump is the mushroom shape of the cylinders, adopted from the hyper-compressor (Fig. 7); this compensates for any weakness caused by the holes for the valves and offers greater security against breakage. The cylinders of the double-acting horizontal machines have, in contrast to this method of construction, two stuffing-boxes and to them the motion of the horizontal primary pistons.

A Sulzer circulating pump (Fig. 8) has been in service in the nitrogen works of the Gewerkschaft Victor, Rauxel, since January, 1931. It was built for a suction volume of about 8,000 m^3 per hour at an initial pressure of 800 atm. and an end pressure of 1,000 atm., the power required being 150 b.h.p. As a matter of fact the pump is working to-day between pressures of 880 and 1,100 atm.

There was difficulty in finding a suitable method

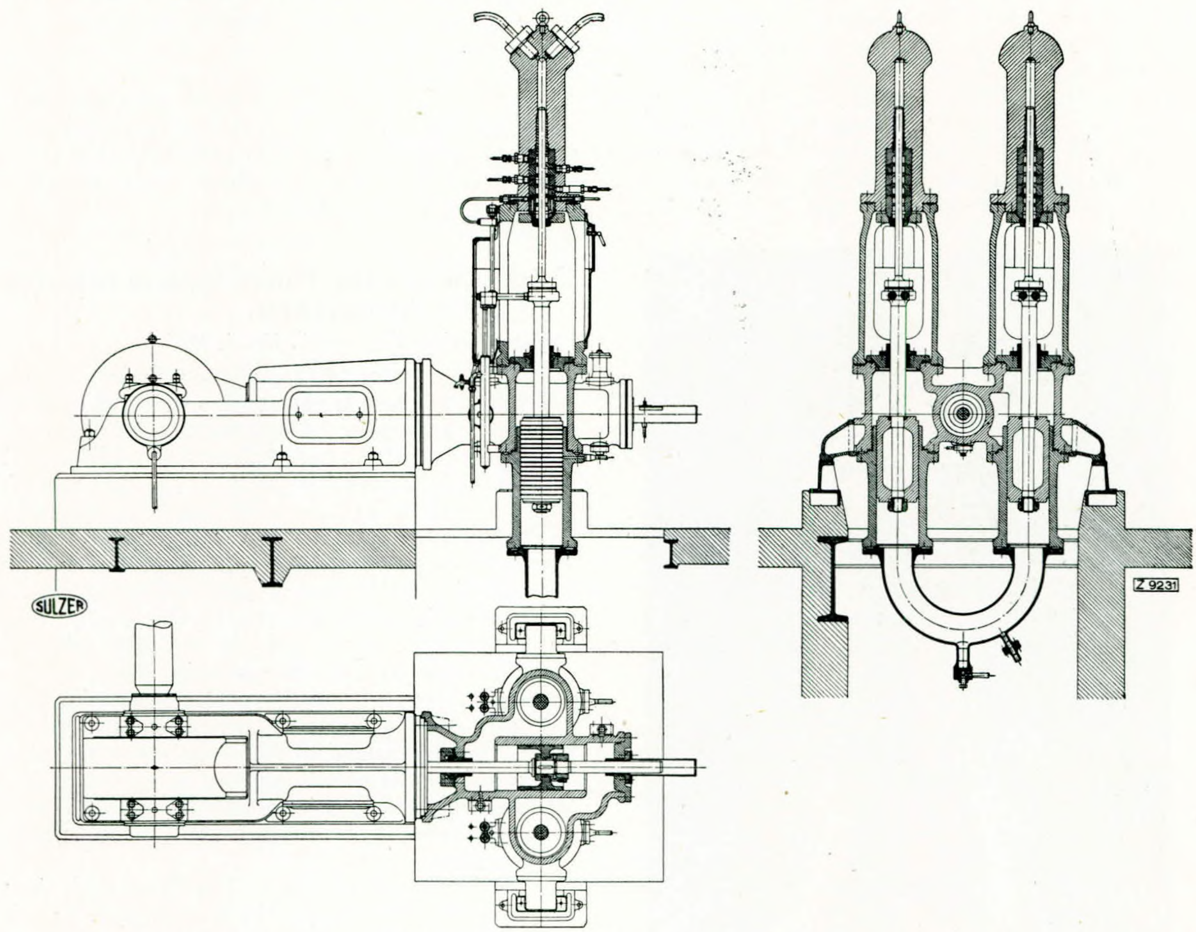


FIG. 6.—Sections through a 1000 atm. (14,200lb. per sq. in.) Sulzer gas circulating pump with hydraulic drive for hyper-compressor plant manufacturing synthetic ammonia.

various passages for valves which greatly reduce the strength of the material.

The oil pistons for driving the two plungers are connected together by a U-shaped tube, through which the pressure on the two sides is equalised. In consequence of this, the only effective power required for operating the plungers is that necessary for overcoming the difference in pressure between 850 and 1,050 atm., so that the frame and the driving gear can be made lighter in correspondence to the lower stresses to which they are subject. The plungers are driven by oil columns, which transmit of regulating the speed with electric drive from A.C. motors, since the motor is installed in a room where explosions might occur.

Finally it was decided to instal a three-phase motor with adjustable pole windings and regulation of the rotor through resistances. The construction of the motor and the necessary switch gear was undertaken by the Bergmann Elektrizitätswerke A.-G. The stipulated output was 145 kw. at 1,465 r.p.m., and 100 kw. at 980 r.p.m. The torque is the same at both speeds. The supply is 380 volts 50 periods. The motor was provided with two stator

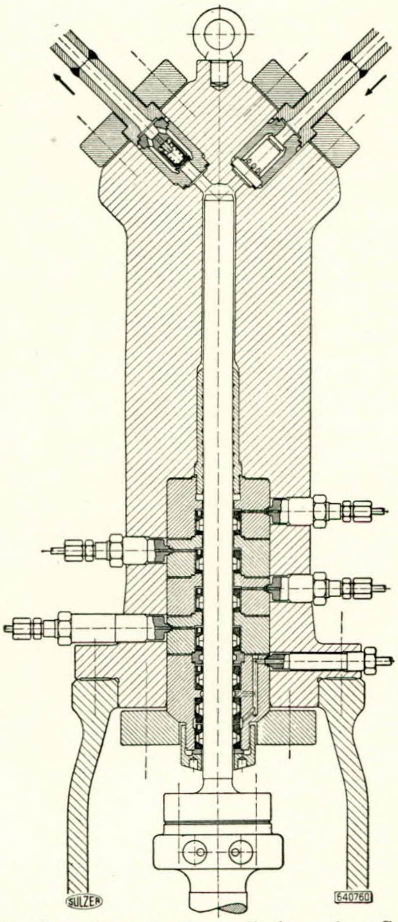


FIG. 7.—Section through the cylinder of a Sulzer high-pressure gas circulating pump for 1000 atm. (14,200lb. per sq. in.), with stuffing-boxes and valves.

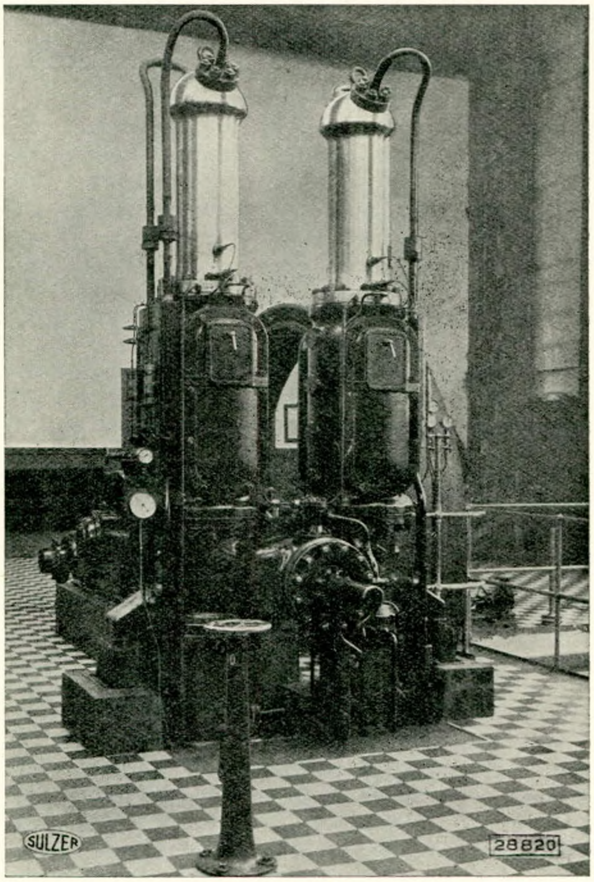


FIG. 8.—1000 atm. Sulzer gas circulating pump, Gewerkschaft Victor, Rauxel, Germany.

windings and two rotor windings (6 pole and 4 pole) in an air-tight casing with the slip rings outside. The starter is of the open type.

Some New Observations on the Measurement of Temperatures in Diesel Engines.

"Sulzer Technical Review", No. 1, 1932.

An article has already been published in the "Sulzer Technical Review" on "Temperature Variations and Heat Stresses in Diesel Engines". Supplementary to this, some observations made on wall temperatures in Diesel engines are given below; these may help to throw some light on the processes taking place in the cylinder.

Distribution of the injection air.

First of all, it is not without interest to follow the directions taken by the injection air, in so far as this can be done with the help of the wall temperatures.

From the temperature diagrams taken at various loads at different spots in the cylinder cover, cylinder liner and piston, the distribution of the average temperatures, the temperature movements in the surfaces of the combustion space in contact with the gas, and also the moment at which the temperatures start rising can be determined. Measurements of the distribution of the average temperature in cylinder head and piston were made on a Sulzer two-cycle engine of 600mm. bore, 1,060mm. stroke, running at 100 r.p.m. It is seen from the low temperature in the middle of the piston, which was water-cooled, that the expanded injection air had also a cooling action on it. Both in the piston and cylinder head, the maximum temperature at a given load lies closer to the point of injection at low loads and moves outwards as the load increases. The injection stream, as it becomes stronger, carries the combustion always further outwards, where only there is still an excess of oxygen to be found. At no load, the outer parts of the piston and cylinder heads are scarcely heated at all, whilst at maximum load their temperature is very much greater than the temperature in the neighbourhood of the point of injection.

This is fully confirmed by the temperature movements measured; they lead to the same conclusions as the average temperatures.

Finally, the sequence in which the individual measuring spots come into contact with the combustion at full load is similarly characteristic. The measuring spots were placed at four successive intervals from each other, corresponding respectively to crank angles of 10°, 15°, 20° and 25° beyond the upper dead centre. The first measuring spots which begin to take up heat suddenly about 10° after the upper dead centre are the spots in the cover lying next to the place of injection. When the crank has turned through a further 5°, the measuring spots at half the radius of the cover and piston are affected, and then another 5° later the outer measuring spots in the piston, cylinder head and liner. Only last of all, after a further 5° crank angle, the temperature of the centre of the piston, which until then has been protected by the cold injection air, begins to increase slightly.

Influence of the speed.

A change of speed, with the torque remaining the same, influences in the first place the individual movements of the temperature in the walls; according to observations and calculations, as the speed increases, the temperature movements then made must become less, and approximate to the fundamental form of their vibration because of the suppression of the "over tones". The measured temperature diagrams show this clearly.

But also the average height of the wall temperatures at a certain point will be influenced, increasing with the speed if the mean indicated pressure remains constant. Practical experience has shown that with increasing speed the engine is subject to higher heat stresses, corresponding to the larger amount of energy being converted in the cylinder. From first considerations, this is certainly not to be expected, since a succession of identical working processes should result in the contents of the cylinder having a mean temperature which is independent of the speed at which the cycle is completed. If, however, there is nevertheless a slight increase in the temperature of the walls, this is because of other factors intervening; the principal ones are:—

- Increase in frictional losses in fresh air and exhaust gases;
- Increase in pressure and quantity of injection air;
- Reduction of the proportion of fresh air introduced when charging or scavenging;
- Lateness of ignition and consequently postponement of combustion to the expansion period;
- Stronger turbulence in the engine, lasting also during expansion, i.e., increase of heat transmission;
- Influence of the time factor on heat transmission.

From the indicator diagrams taken at 70 and 130 r.p.m. curves were obtained with regard to retarded combustion.

Nevertheless with regard to heat stresses the influence of speed was not so great as the influence of mean pressure. The measurements give the rise of piston temperature with the speed when the mean pressure remains constant, or the rise of piston temperature with the mean pressure when the speed remains constant, and show that an increase in output starting from about full load will be more favourably obtained by increasing the speed rather than by increasing the pressure, a fact which is known to the designer from practical experience.

Temperatures in Starting and Exhaust Valves.

Finally the results obtained from temperature measurements in the starting and exhaust valves of a four-cycle engine should be interesting. The tests were made on a four-cycle engine of 420mm. bore and 600mm. stroke working with solid injection and running at the very moderate speed of 143 r.p.m. The thermo measuring spots were located in the middle of the valve plate on the side next to the combustion chamber and ½-mm. beneath the surface of the material, the temperature difference between the inlet and outlet valves being particularly interesting. The temperatures of the exhaust valve rise to 600° C.; these are certainly the highest temperatures found in Diesel engines.

G. Ei.

Initial Costs.

"The Marine Engineer and Motorship Builder", July, 1932.

One of the strongest claims made for steam propulsion in preference to diesel machinery is that it is less costly in the first case. At one time the cost disparity existing between the two basic systems of propulsion was considerable, but the marine diesel engine industry has made determined efforts to reduce the gap, and to-day there is but little to choose between the high-class steamship and motorship in the 10,000/20,000 s.h.p. class. This statement, it might be added, refers to the products of firms who have given the subject of oil engine manufacturing costs as much attention as has been given to steam engine production.

A number of firms in this country and abroad have equipped themselves with very fine machine tools, jigs, etc., for the economical manufacture of marine diesel engines, one or two of them actually specialising on the work to the virtual exclusion of steam engine building. Naturally, such concerns can turn out diesel engines at prices that are very attractive to the owner. Another side of the business where a fair cost disparity exists is in the installation of diesel machinery on board ship. At one time this was universally somewhat higher than was the case for steam machinery, but certain of the leading motorship specialists have been able to effect savings in this direction. Costs have also been reduced with the passing of the built-up engine seating constructed to almost boiler-shop standards of workmanship. In this way the cost per gross ton of the motorship has been brought more nearly into line with that of the equivalent steamship, and this factor should make the competition of the types even keener than hitherto when times improve.

Engine design has, of course, played its part in reducing motorship machinery costs, the adoption of double-acting types, airless fuel injection, supercharging and trunk-piston machinery all making for a reduction in the first cost and/or weight and space occupied. Many firms have also standardised two or three cylinder sizes and piston strokes in an endeavour to keep production costs down. Further progress seems possible, we think, by the adoption of quicker-running engines.

On the steam machinery side, the adoption of higher steam pressures and temperatures has had a beneficial effect upon the first cost, weight and space occupied, so far as turbine machinery of moderate and high powers is concerned. Further progress might be possible, for moderate powers, by quicker-running turbines and double-reduction gearing. In our opinion the cloud under which double-reduction gearing has languished for almost a decade will be lifted by economic necessity and technical good sense, and the system will become adopted in numerous future installations of moderate power. If the cost per s.h.p. has been reduced by the adoption of higher steam pressures and temperatures, the search for greater economy has tended to offset this advantage. Multi-stage feed heating, special arrangements for ensuring pure boiler feed, water-softening plant; expensive vacuum producing equipment; costly materials for boiler and superheater tubes, condenser tubes and turbine blading, very large airheaters; electrical auxiliaries with diesel generators; and, in some cases, economisers, all tend to increase first cost, although their adoption is fully justified by the economical results obtained. It is safe to say that the last word has not yet been said regarding the fuel consumption of modern marine steam plants, and if progress is to take the form of a steady and logical development along current lines, it is likely that complication will increase somewhat and additional outlay be necessary in order to obtain such improvement.

Diesel machinery is perhaps more fortunately placed in the matter of greater efficiency and the price paid for it in actual cash. The diesel engine is a self-contained unit and it is unlikely that greater complication will be necessary in the future in order to reduce specific consumption. Indeed, the tendency throughout the history of marine oil engine development is all towards greater simplicity of design and construction, lower first cost and better performance. It is reasonable to hold the view, therefore, that the future is likely to see the initial cost difference between steamships and motorships of the intermediate and passenger types reduced. So far as the numerically stronger cargo carrier is concerned, it seems likely that steam will continue to enjoy an advantage from the cost standpoint, particularly as the triple-expansion-engined Scotch-boilered steamer continues to be popular with so many owners. At the same time the diesel engine is not likely to be overshadowed in certain countries and services for the propulsion of cargo tonnage. The double-acting two-stroke cycle engine, or the trunk-piston supercharged airless-injection unit, seem to be the types likely to find favour and doubtless exhaust gas boilers and a fair porportion of steam-driven auxiliaries will very often be utilised for such vessels. It is doubtful, however, whether the first cost of such tonnage will ever quite equal that of the equivalent steamer.

Colloidal Fuel Development.

"The Marine Engineer and Motorship Builder", July, 1932.

The announcement that the Cunard Steam Ship Company are experimenting with a colloidal fuel consisting of a mixture of ordinary boiler oil and very finely pulverised coal in the proportion of 6 to 4 respectively has received widespread publicity. The use of colloidal fuel is not new, but its utilisation at sea has not hitherto received a great deal of attention. As will be appreciated, the secrets of success with colloidal fuel are (1) intimate mixing of the oil and coal and (2) the avoidance of settling out of the constituents during storage. In both respects the Cunard experts appear to have met with an encouraging measure of success, credit for which is given to Mr. R. A. Adam, the company's assistant superintendent engineer, and Messrs. F. C. Holmes and A. W. Perrins, the laboratory superintendent and combustion engineer respectively. Research has been carried out in the laboratory at Cunard Building, Liverpool, and in the works of the Wallsend Slipway and Engineering Company, who loaned the Cunard Company an experimental Scotch boiler for the purpose. It is interesting to note that a tank containing 1¼ tons of the new fuel was under observation from January 11 to the beginning of June without any settlement taking place.

It has been stated that the Cunard fuel, which has a specific gravity of 1·1 as against 0·96 for boiler oil, can be handled as conveniently as boiler oil, and burns in a furnace with a flame that closely resembles that of liquid fuel, although of a rather more gassy type. The difference in specific gravity between oil and the new fuel is of practical interest, for it indicates that, in the event of a fire, the latter can be dealt with by flooding with water. Moreover, when discharged overboard it will not float on the surface of the sea. How the fuel will behave in ordinary service when stored in ship's double bottom tanks is rather problematical, particularly in the case of North Atlantic service vessels in winter time. It is not outside the bounds of possibility that pumping difficulties may be encountered in such circumstances, and it is not clear how the fuel will handle if steam heated. On the combustion side the ash disposal question seems to be the most important one that will have to be considered, while it will be interesting to see how the brick-work of boilers so fired stands up in service.

We do not wish to create from these comments the impression that we are disposed to regard this new deveolpment as a retrograde step, bringing in its train considerable difficulties. There is no doubt that the points to which we have drawn attention have already been considered. They have been mentioned because we wish to remind our readers that if complete success is achieved in the near future the merits of the achievement will be of no mean order.

Propeller Theory.

"The Marine Engineer and Motorship Builder", July, 1932.

To the student of the modern vortex theory of propeller action the present paper is somewhat sensational. It forms a further contribution to what was once a very vexed question in propeller theory, namely, which particular incidence angle should the aerofoil element be considered as working at when forming part of a propeller blade? The Betz-Prandtl theory, which is now most generally accepted, regards this incidence angle as being given by correcting the apparent incidence angle by half the induced translational and rotational velocities into the propeller. According to the present author, this feature of the Betz-Prandtl theory is merely an assumption given without proof. When the complete vortex field of the propeller is considered, the author shows that full induced velocities should be used to determine the incidence angle and hence the forces induced by the circulation strength round the blade element. The influence of blade width is also of importance in modifying the true incidence angle and the necessary correction is discussed by the author.

To test the validity of the new theory as compared with the old, experiments were made upon three models. The error in the old theory is much larger than that reported by other investigators. The error in the new theory is much less, but certainly not less than previously found by other investigators from the old theory. The relation of the new theory to the prediction of pressure distribution round the blade from the standpoint of cavitation is also discussed by the author.—*Dr. R. Brard. Association Technique Maritime et Aeronautique,* May, 1932; 23 pp., 4ff.

Water-tube Boilers for small Craft.

"Shipbuilding and Shipping Record", June 30th, 1932.

In this country we generally associate the marine water-tube boiler with the modern passenger steamship, although it must be admitted that there are a few cargo vessels in which this type of steam generator has been installed. In the United States the use of the water-tube boiler on board ship has made greater strides than it has with us, and small craft such as tugs, dredgers and river vessels are equipped with the water-tube rather than the more robust tank type of boiler. And not only is the water-tube principle adopted, but in order to obtain a high efficiency the working pressure is commendably high and a considerable degree of superheat is employed. Thus, in the case of a river dredger, particulars of which have just come to hand, the two boilers are of the water-tube type, each having 2,650 sq. ft. of heating surface, the working pressure being 300lb. per. sq. in. with 100° F. of superheat. In another river vessel water-tube boilers having 1,810 sq. ft. of heating surface are installed, the working pressure being 250lb. per sq. in. Some of these small water-tube boilers have an efficiency in excess of 80 per cent. which must obviously make for highly economical operation. The fact that oil is used as fuel will, of course, be largely responsible for the choice of the water-tube type of boiler.

Piston Removal.

"Shipbuilding and Shipping Record", June 30th, 1932.

It is highly desirable that the pistons of a marine heavy-oil engine should be easy to withdraw when the engine is installed in the vessel. Not a few of the early, and certain of the more recent, designs left something to be desired in this respect. On the other hand, there are certain modern designs (for example, the Burmeister & Wain, Doxford, and Werkspoor engines) wherein the designers have clearly had a sympathetic regard for the men who would have to withdraw the pistons of their engines when they were placed on board ship. The double-acting engine is at a disadvantage, generally speaking, when it comes to this important matter of piston removal. Moreover, this usually calls for the removal of the rod as well as the piston, an operation which requires considerable clearance above the engine and also disturbs the rod packing. The Richardsons-Westgarth double-acter is unique in having an external piston rod nut and cone connection following steam-engine practice. This is a good feature that does not give trouble in service and might, with advantage, be adopted by other builders of double-acting oil engines.

Corrugated Steam Pipes.

"Shipbuilding and Shipping Record", June 30th, 1932.

With the gradual increase in the working pressure and the superheat temperature of the steam used on board ship, the problem of the design of the steampipe lines becomes one of considerable importance. The chief difficulty lies in making satisfactory provision for the effects of expansion, since not only does the change of temperature between cold and the maximum working temperature represent under modern conditions a considerable alteration in the length of the pipe line, but it throws considerable strains upon the pipe joints as a result of which leakage may occur. The provision of expansion bends tends to reduce the strains on the joints, but in the limited space available in the engine room of a ship it may be a difficult matter to house an expansion bend of sufficient size to take up the total expansion which must be provided for. The use of corrugated pipes for the construction of expansion bends has been found successful in overcoming this difficulty, since the flexibility of the bend made of corrugated pipe is stated to be five times as great as that of a bend of the same dimensions made of plain pipe or, alternatively, for the same degree of flexibility a much smaller bend is required. This type of pipe has already been installed on a number of steamships where high-pressure, high-temperature steam is used.

950-b.h.p. Fiat Marine Motor.

"Engineering", 1st July, 1932.

The aero engines manufactured by the Società Anonima F.I.A.T., of Turin, were well known even before the war, during which over 15,000 were manufactured for the Allies. Since the armistice, Fiat engines have been widely used in Italian and other aircraft, and a special model, the A.S. 5, was developed for the 1929 Schneider Trophy race, in which it will be recalled that the Italian machines, although not successful in securing the trophy, put up an excellent performance. This engine was a 12-cylinder water-cooled Vee model, with a normal output of 1,000 b.h.p. at 3,200 r.p.m.

The motor-boat engine illustrated in Figs. 1 and 2, is based on the A.S. 5 design, and has been developed for international competition work. As will be clear from the figures, the engine is very similar in general appearance to the ordinary aircraft engines made by the firm. The two cylinder groups are set at 60 deg. to one another. The cylinder bore is 138mm. (5·43in.) and the piston stroke is 140mm. (5·5in.), these dimensions being the same as those of the A.S. 5 engine. Owing to the arrangement of the connecting rods, the cylinders in the starboard group have a slightly smaller cubic capacity than those in the port group, the respective cubic capacities being 2,094c.c. and 2,165c.c. The total cubic capacity is therefore 25,550c.c. The cylinders are of steel, and are forged in one piece with the combustion chamber. Each cylinder is a separate forging, and is provided with a welded steel water jacket. The cylinders are bridged at the top by two aluminium-alloy casings, in which the valve mechanism is mounted. There are four valves per cylinder, and the whole of the valve gear is protected by a detachable aluminium-alloy cover. The pistons are aluminium-alloy forgings, and are fitted with two gas and one scraper ring, all three rings being at the top. The gudgeon pin is held in the small end by a riveted cotter pin, and is free to oscillate in the piston bosses. The connecting rods are of the articulated type, with wrist pins held in the big ends of the auxiliary rods also by riveted cotter pins, and working in bronze bushes fitted in the master rods. The big ends of the latter are of the normal Fiat type, lined with anti-friction metal. The crankshaft is carried in eight bearings, and is provided with a large thrust bearing of the ball type. The general construction of the crank and clutch casings, which are made from aluminium-alloy throughout, will be clear from the figures.

The overhead camshafts are driven by

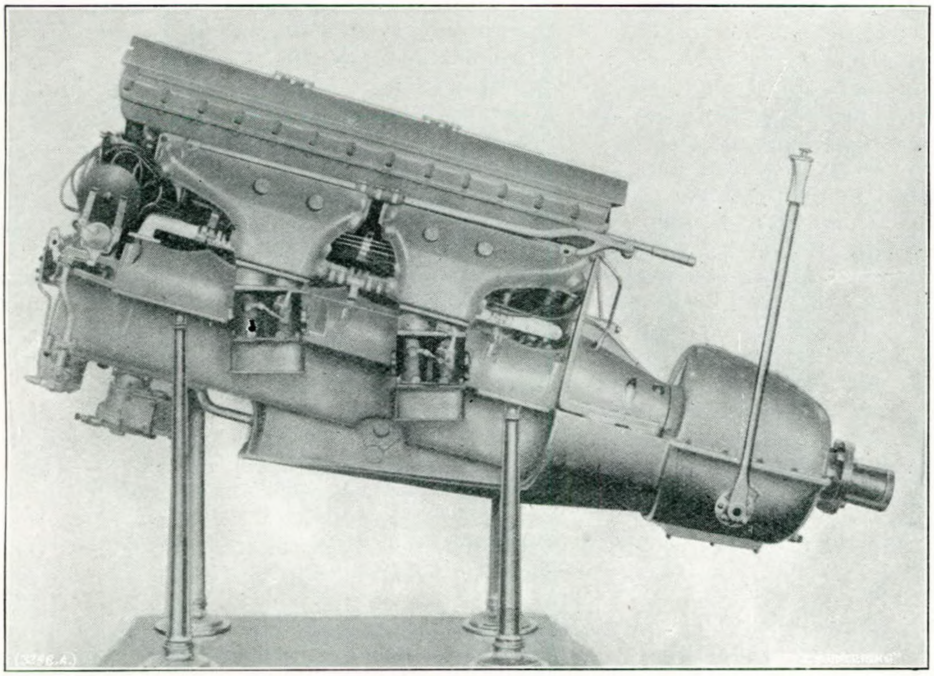


Fig. 1.

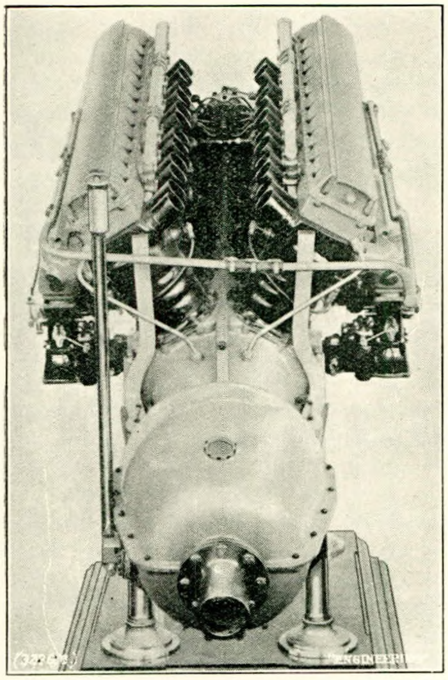
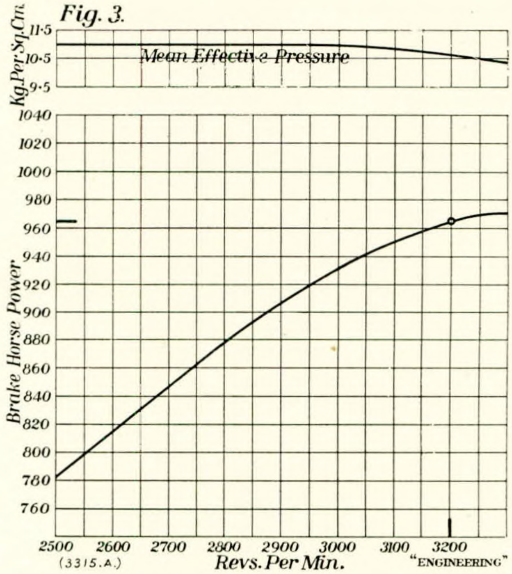


Fig. 2.

oblique countershafts from the crankshaft at the forward end of the engine. The drives for the various auxiliaries are also located at the forward end, the two magnetos being mounted on a platform with their axes horizontal and perpendicular to the crankshaft, and the water and oil pumps being mounted in a recess underneath the sump. One of the magnetos can be seen in Fig. 1, together with the water and oil pumps, the former being the larger pump to the right. The arrangement of the carburettors and inlet manifolds will also be clear from Fig. 1. The carburettors are of the Fiat double-body type. The magnetos are of the Marelli MF 7 type, and constitute two independent ignition systems. Each cylinder is fitted with two sparking plugs mounted at right-angles to the axis. The lubricating-oil pump is of the geared type and comprises three units, two to draw the oil from the sump wells and a third to deliver it under pressure to the various bearings. The water pump is of the centrifugal type. The carburettors are fed by a multiple-piston pump located at the forward end of the engine. Starting is effected by means of carburated compressed air from receivers carried on the vessel. The air is delivered to the cylinders in the correct order by a distributor driven from the engine.

The clutch is of the dry-plate multiple-disc type, made up with alternate flat steel and asbestos-lined plates. The engine is direct coupled to the propeller shaft, and two engines, revolving in opposite directions, are fitted in the motor boat. The horse-power and mean-effective pressure curves are shown in Fig. 3. It will be noticed

Fig. 3.



that the engine develops about 946 b.h.p. at 3,200 r.p.m., and that the mean effective pressure is constant at 11 kg. per square centimetre from 2,500 r.p.m. to 2,900 r.p.m., falling to 10·6 kg. per square centimetre at 3,200 r.p.m.

Macquorn Rankine.

Abstract from
Memorial Lecture by Sir James B. Henderson, D.Sc.
"The Engineer", 24th June, 1932.

Thermodynamics.

No one present here to-day will remember the time when conservation of energy was not one of the fundamentals, if not the fundamental principle, underlying all physical phenomena, or the famous discussion as to whether the kinetic energy of a body is represented by mv^2, or by $\frac{1}{2}mv^2$, a point which could be settled by any schoolboy of to-day. Having been brought up "in the faith", we find it difficult to imagine the state of mind of the scientist before the "faith" existed.

In Newton's time heat was regarded as a kind of ethereal substance called caloric, which bodies could absorb to produce a rise in temperature, while the heat evolved by friction between two bodies was regarded as due to a reduction in the absorptive powers of the bodies which caused caloric to be squeezed out. The classic researches at the end of the eighteenth century by Count Rumford on the heat generated in the boring of cannon, and by Sir Humphry Davy on the melting of ice by friction, killed the caloric theory and introduced the idea that heat was a mode of motion of some sort. The researches of Joule, Kelvin, Clausius, and Helmholtz in the 'forties of last century definitely established the conservation of energy and introduced the word "energy" for the first time. It is significant that in his famous essay in 1848, "Die Erhaltung der Kraft", Helmholtz does not use the word "energie", although the essay deals with the conservation of energy. The indestructibility of energy became the first law of thermodynamics.

Another great law of nature discovered in Rankine's time and to which he contributed greatly, now known as the second law of thermodynamics, is of even greater importance than the first law, in that it has contributed much more to further discoveries.

The first law merely states that the total energy is constant, that we cannot do work without the expenditure of energy, or that perpetual motion is impossible.

The second law states that even with inexhaustible sources of heat in the air, earth and sea, it is impossible to have perpetual motion without a condenser or sink of heat at lower temperature, into which some of the heat abstracted from the inexhaustible source must be exhausted before the heat in the source can be available. A parallel case in dynamics is that of a water turbine driven by water from the sea and exhausting down a mine shaft. Sooner or later the mine shaft will become full of water and the turbine will cease to function, and the sea will no longer be a source of power. So it is also with the heat in the sea—it cannot be used in heat engines unless there is a sink of heat at lower temperature than that of the sea.

The second law, however, has a much wider application in nature as it provides a means of measuring the stability of any natural state, and indicates the direction in which all natural changes will take place.

The foundation of this law was lying dormant in an essay written by Carnot in 1824 relating to heat engines, wherein we have an example of one of the wonders of science—that a discovery in a limited field may prove to have wide ramifications in all processes of nature. In his essay on "Heat Engines", Carnot devised a cycle of operations for the working substance, since known as Carnot's cycle, which he proved to be the ideal of efficiency to be aimed at by engineers in any heat engine. Viewed simply as an ideal of accuracy the Carnot cycle was a great discovery, but no one at that time could have had any idea of the colossal discoveries to which it would lead. These discoveries arose from Carnot pointing out two facts : first, that the efficiency of his ideal engine depends only upon the two temperatures at which heat is taken in and exhausted, and secondly, that this efficiency is independent of the working substance.

I have already indicated that physicists of the first half of the nineteenth century were groping in the dark for a mechanical hypothesis of the constitution of the molecule which would explain some, if not all, of the complex phenomena of nature, because further progress in physics seemed impossible without it. The great importance which has gradually become attached to Carnot's discovery by physicists is due to the fact that it provides a means for studying molecular physics in the bulk without any hypothesis as to the constitution of the molecule, and also provides a measure of stability of any condition in nature. The secret lies in the fact that the efficiency of the Carnot cycle is independent of the working substance, so that by putting different substances, or the same substance in different conditions, through a Carnot cycle and writing down the efficiency, one cannot fail to make a discovery with respect to the substance.

It is strange that this fact was overlooked for over twenty years; in fact, Carnot's essay was forgotten for over ten years and Glasgow University took a prominent part in its exhumation and republication. Clapeyron, in 1834, and Lewis Gordon, Rankine's predecessor, in 1842, drew attention to the essay; then Kelvin, Clausius, Helmholtz, James Thomson and Rankine all contributed to its application and advancement. Kelvin derived from it the variation of latent heat with temperature, an absolute scale of temperature independent of any material, and he also applied it to thermoelectricity. Helmholtz worked out the temperature coefficient of the E.M.F. of an electric battery; James Thomson derived the effect of pressure on the melting point of ice. Rankine became a disciple of Carnot, and wrote voluminously on the application of the Carnot cycle to heat engines of different types, and in his essay on "Energetics", he applied it to his earlier theory of molecular vortices with some remarkable results.

It is strange that no physicist of Rankine's time applied the Carnot cycle to chemical combinations by taking as the working substance a mixture of two elements which combine. Had they done so the development of modern chemistry would have been greatly accelerated. A remarkable paper by Willard Gibbs in 1876 led the way, and the work of Clausius, van t'Hoff, Helmholtz, Planck and Nernst laid the foundations of modern thermodynamic chemistry, which is based upon the stability of a combination as determined by the Carnot cycle. The test of stability is made by what is known as Carnot's function, to which Clausius gave the name of entropy, and in any stable state the entropy must be a maximum.

It is well known that at ordinary temperatures hydrogen and oxygen combine with explosive force to form water, yet the spectroscope shows us that at the temperature of the sun water dissociates into hydrogen and oxygen. The Carnot cycle applied to this problem explains the apparent anomaly, and shows us that at every temperature there is a definite stable mixture of hydrogen, oxygen and water, the mixture varying with the temperature.

In his essay on "Energetics", Rankine showed that the second law of thermodynamics is only a particular case of a still wider law applicable to other sciences in which energy is stored in bodies in other forms than that of heat, such as magnetism, electricity, light, etc. It would be easy to make a claim for Rankine's foresight in this respect and to consider this wider law as the second law of energy, or Rankine's law, but such a claim might, in the light of future progress, prove to be extravagant. For nearly forty years after Rankine's essay no such development as was conceived by him took place, and entropy was considered to apply only to thermo-dynamics. In the wider application Rankine called the two factors of energy corresponding to temperature and entropy the metabatic and metamorphic functions. The first step along the path indicated by Rankine was not taken until 1900, when Planck applied entropy to electro-magnetic theory, and gave to it a new interpretation and physical meaning. In the 'nineties of last century the Reichsanstalt, which is the National Physical Laboratory of Germany, was engaged in the investigation of the distribution of energy in the spectrum of incandescent bodies, and after years of work obtained beautiful curves giving the energy in the spectrum of a luminous black body and its variation with temperature. Professor Wien then derived an equation which represented the whole family of curves almost entirely within the limits of experimental error. Professor Planck then tackled the problem theoretically, and searched for a function in the radiation which would represent the entropy. He pointed out that the entropy in any state is simply a measure of the probability of that state, the logarithm of the probability being proportional to the entropy. The simplest function which he found gave him Wien's equation, but he could only derive the function by assuming that energy is not infinitely divisible, but that there must be a fundamental indivisible unit, which he called a quantum. He thus discovered the quantum theory, and the quantum, which, in at least one theory, is now known as the electron, has revolutionised modern physics. Incidentally, Planck introduced a function which simplified his equations considerably and brought them into line with those of thermodynamics, and this function he called the temperature of the radiation. It is probable that further developments on these lines will follow in other sciences, throwing light upon our ignorance, and that by similar arbitrary definitions of temperature the second law of thermodynamics may survive as a general law applicable to all branches of physical science. It will obviously be more convenient if so arranged than to have different names for the factors of energy in different sciences.

It is not obvious why the entropy should be connected with probability, since the laws of probability only apply to incidents or units when repeated millions of times, but in the particular case of the partition of energy in the spectrum, Planck points out that if we consider only a very narrow band of the spectrum, one millionth of the width of the visible spectrum, there are still five hundred million frequencies in it among which the energy has to be distributed. The connection between a stable distribution and probability thus becomes clear.

Rankine's contribution to thermodynamics Professor Tait described as his greatest work. He laid the foundation of the mathematical science as it is known to-day, he applied the second law to heat engines of all kinds, steam engines, air engines and explosive engines, while in the steam engine he introduced the cycle now known as the Rankine-Clausius cycle, which is used as the ideal for engines and refrigerators employing vapours as the working substance, and he pointed out that this law is only a particular case of a wider law applicable to all sciences.

The final state to which the Universe is drifting was a subject which interested both Kelvin and Rankine. Kelvin pictured all energy being gradually transferred to its lowest form of heat and dissipated by radiation and conduction until the whole universe would be at one temperature, and that a very low one. Life, of course, would cease long before that final state could be attained —truly a pessimistic picture. Rankine was much more optimistic, and pointed out that if the outer confines of space were perfect reflectors the radiation would be concentrated in foci, and that any celestial body drifting into one of these foci would soon be raised again to a temperature sufficient to start its life over again as a new star or sun. Hence, the present type of distribution of energy in our celestial system might be repeated indefinitely by cyclical processes. The same idea has recently been advanced by Sir James Jeans on a similar theory of radiation concentrated in foci, but with the difference that Jeans accounts for the concentration, not by reflection from the outer confines of space, but by Einstein's curvature of space. We are, therefore, free to adopt whichever theory best suits our individual tastes and aspirations.

Hydrodynamics.

Rankine's work on hydrodynamics has been of the greatest value to engineers and naval architects. The mathematical theory of hydrodynamics is so very abstruse and so limited in its application to practical problems that it is repugnant to most practical men as the physics of the problem is lost in a maze of symbols and equations. Rankine showed how wave motion in deep water, which the naval architect must understand, can be studied from the physical standpoint and with only the simplest mathematical tools.

Incidentally, Glasgow University, and the Professor of Engineering in particular, owes much to this part of Rankine's work. He was a man of great geniality and many friends, and in his period as Professor in Glasgow two of his closest friends were James Napier and John Elder, both of whose names are still household words on the Clyde, and, in fact, throughout the whole world of shipping. Rankine seems to have helped both of them in many problems of shipbuilding and construction, and in all probability he was able to draw on their experience in the writing of his book on shipbuilding. His salary as Professor was only £275 a year, but when John Elder died and Rankine commemorated their close friendship by writing his biography, which was published in 1872, Mrs. Elder, as a memorial to her late husband and as a tribute to his biographer and friend, handed over to the University the much-needed funds for the further and adequate endowment of the Chair of Civil Engineering and Mechanics.

When confronted with a problem, evidently set by John Elder, of determining the best form of streamlines for a ship's hull, Rankine made a most ingenious use of Kelvin's artifice, used in problems of heat conduction, of combining sources and sinks by purely geometrical methods. In the two-dimensional problem he combines a source with a sink of equal magnitude and obtains lines of flow like the magnetic lines round a bar magnet. Combining these with a parallel flow he obtains by a graphic process one streamline, which is an oval figure, and all outside it are ship-shape lines. He shows how the dimensions of the oval may be varied, and under what conditions a stream-line due to one oval may be chosen for the forward part of a ship and that from another oval for the after part. This is an excellent example of scientific use of the imagination to solve a difficult practical problem by purely hypothetical conceptions.

Another problem which was set him by James Napier was the estimation of the power required to drive a ship of given lines at a given speed with no previous knowledge derived from experience or experiments with models. This seemingly impossible conundrum he tackled in a very original way, which may be briefly described as follows. Imagine the ship moving forward at the required speed. Imagine now that the ship is lifted bodily out of the water, but that the cavity in which it formerly rested does not fill up but continues to move forward as a wave depression. In order to do so the velocity of each particle of this wave surface must obey the laws of wave motion and can be easily ascertained. This velocity constitutes a rubbing velocity against the ship's surface and the total power so lost in friction is thus obtained. The results obtained by this ingenious method were so good that Napier objected to its publication as he wanted to keep a monopoly of the method. Rankine protested, but finally compromised by publishing it in the "Philosophical Magazine" in the form of an anagram, which no one seems to have been able to solve until the answer was found in his papers after his death.

In Rankine's day the speeds of ships were generally low and the power was nearly all consumed in overcoming friction. The increase of speed in recent years has greatly increased the wave resistance of a ship, due to the systems of waves in echelon diverging from both bow and stern, and the system of transverse waves between them which makes the wave resistance a periodic function of the ship's length and of the speed. Our present knowledge of these complicated phenomena is mostly due to the work of W. and R. E. Froude, and the whole science is now based on model experiments with apparatus which was not available in Rankine's day.

Of Rankine the man, a study of his bust in the possession of the University gives a much better idea than any I could possibly convey in words. An old friend and former colleague of mine, Professor Waghorn, who is now 84 years of age, remembers Rankine coming to the Royal School of Naval Architecture at South Kensington to examine the students of his year. He describes Rankine as looking like a farmer, and although all the students were very much afraid of him as an examiner, they were more than surprised by the simplicity of the papers which he set them.

I referred earlier to Rankine's study of music as a boy. Therein he seems to have acquired the same proficiency which he showed in more serious walks of life, and the lighter side of even technical matters he committed to songs and verses, some of which have since been collected and published. At the dinners of the "Red Lions", following the annual meetings of the British Association, he was in great demand, and in 1871, when the Association met in Edinburgh, he was elected Lion King. None of these convivial evenings was complete until Rankine had been called to the piano, where he would sit and sing, to his own accompaniment, a song almost always composed by himself, and generally a humorous skit on some scientific question of the day.

To conclude this address, I think I cannot do better than quote a few sentences written by one who knew Rankine intimately. In his preface to Rankine's "Miscellaneous Scientific Papers", the late Professor Tait, of Edinburgh, writes:

> "Of the man himself it is not easy to speak in terms which to a stranger, would appear unexaggerated. His appearance was striking and prepossessing in the extreme, and his courtesy resembled almost that of a gentleman of the old school. . . . His conversation was always interesting, and embraced with equal seeming ease all topics, however various. He had the still rare qualification of being a

good listener also. The evident interest which he took in all that was said to him had a most reassuring effect on the speaker; and he could turn without apparent mental effort from the prattle of young children to the most formidable statement of new results in mathematical or physical science. . . . He was ambitious, but he was the very soul of honour in respect to giving all credit to others, and in never attempting in anything, small or great, to go a hairbreadth beyond the line of right as to his own claims. He showed a particularly good and generous temper in cases of difference on scientific questions—a temper which proved the true metal, unalloyed by any mean quality".

A New Self-Cleaning Strainer.

"The Engineer", 24th June, 1932.

Owing, possibly, to the increased use of the oil engine, the lubricating and fuel oils for which must be very carefully strained, there has been a tendency of late years towards the production of self-cleaning strainers. We have described several types in our columns at various times. The strainer illustrated by the line engravings accompanying this article has recently been developed by D. M. Shannon. It is claimed for it that it has marked advantages over other types. As in other self-cleaning strainers its self-cleaning action depends upon a high-pressure reverse flow, but the method by which this flow is brought about is novel.

Referring to the drawing, Fig. 1, it will be seen that the filter itself is mounted upon a drum, which is capable of rotation upon spigots in the end covers. The drum is equipped with internal teeth which engage with those of a pinion supported in plain bearings at each end and capable of being rotated by means of an external handle. The axis of the drum is horizontal and the pinion is set a little off the centre line of the filter box at the bottom of the drum. The liquid enters from the top or any other convenient point and passes inwards through the filter drum towards the centre, so that dirt, grit, etc., is deposited on the outer face of the strainer. By rotating the pinion the oil trapped between two teeth of the internal teeth of the drum is forced outwards, carrying any adhering dirt with it. Thus, it will be seen that the filter is cleaned section by section. In the majority of the filters made by the company three turns of the handle are sufficient to clean the whole filter. In the larger sizes, however, the gearing has a lower ratio. It is claimed that by thus cleaning the filter by sections, the action is more efficient. When a whole filter is subjected at one time to reverse flow there is a tendency for the oil to seek the easiest path—that is, to pass through those parts of the strainer upon which least matter has been deposited. In this filter it will be seen that each separate section receives individual attention.

A fault that must be guarded against in all strainers that depend for self-cleaning action upon reverse flow, is that of re-picking up the material released, as soon as normal flow is re-established. If time is not given for the matter in the oil to settle re-deposition may easily occur. In the strainer under consideration special measures have been taken to guard against any such happening.

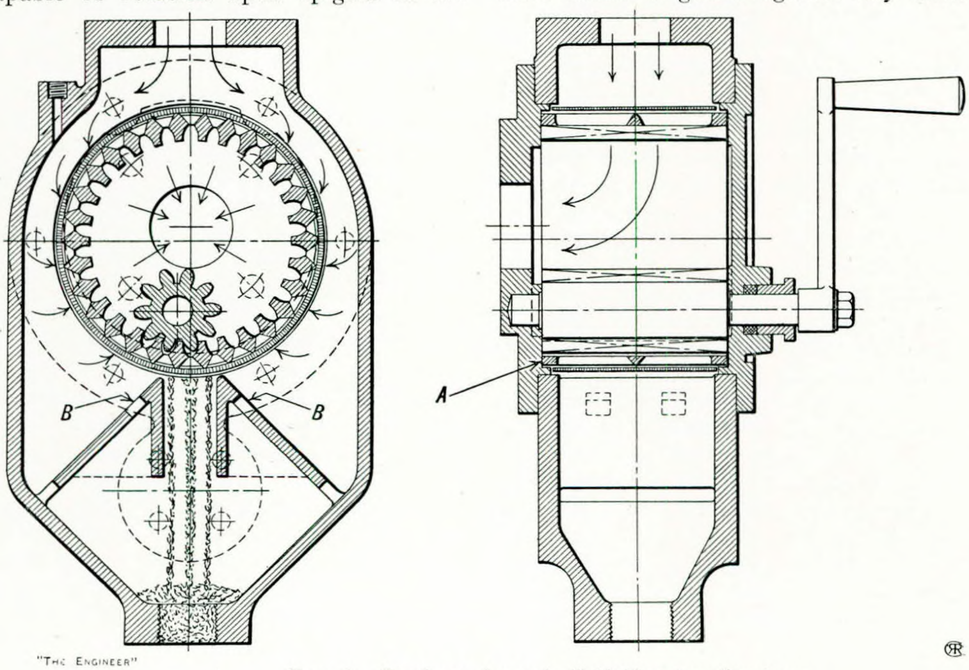


Fig. 1.—Sections through Self-Cleaning Strainer.

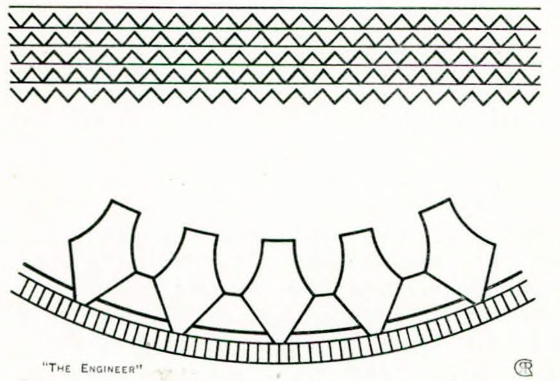


FIG. 2.—Indestructible Filter Cartridge.

Referring again to the drawing—Fig. 1—it will be seen that the box housing the filter is divided into two compartments. The oil displaced by the action of the cleaning pinion is forced outwards and downwards into the lower of these compartments, from which it cannot pass back through the filter owing to the sealing effect of the pinion teeth. The section of this lower compartment is very similar to that of an old-fashioned, unspillable ink bottle, with the exception that passages are provided in its sides to allow the oil to pass from it into the upper compartment. The volume of the compartment is very much greater than that of the oil displaced by a rotation of the pinion. In consequence, the dirt and grit in the oil displaced from the filter has plenty of time to settle out before the oil passes back through the holes B into circulation again.

The makers also fit, where desirable, a special indestructible filtering cartridge. A thin and narrow strip of material of square or rectangular section has V grooves of a depth corresponding to the fineness of straining required, rolled transversely into one side. The strip is then wound closely together on a mandrel of about the same diameter as the strainer drum in such a way that the V grooves are radial. The construction can be seen in Fig. 2. It is claimed that the strainer so formed can be constructed with spaces finer than the finest gauze cloth, and that it is at the same time very much stronger and not liable to be damaged by grit or carried away by excess pressure.

The makers term the new filter the Rotoklene strainer. It is suitable for paints, size, dies, inks, chocolate, etc., besides lubricating and fuel oils, and is built in various sizes. Two or more may be arranged axially in line in the same box, if desired, to form a duplex arrangement, which calls for a slight modification of the design of the settling compartment.

Internal Combustion Engine Nomenclature.

"Engineering", 24th June, 1932.

TO THE EDITOR OF ENGINEERING.

Sir,—During the last few years I have had to correct students for writing Diesel with a "d", and I have frequently been told by them that a capital letter is not used in the technical periodicals or in some of the proceedings of the engineering institutions. By all means, let us give credit to Dr. Rudolf Diesel for his pioneer work on his Rational heat motor by writing his name with a capital letter. In my student days the gas burner used in the chemical laboratory was known as a Bunsen burner, and now everybody refers to it as a bunsen, and consequently the inventor has been lost sight of. In some cases the replacement of the capital by the small letter is either excusable or necessary, e.g., boycott, bowdlerise, pasteurise, gudermanian, and the names of electrical units.

There is now a tendency for the general public to refer to all engines running on heavy oil as "diesels", whereas the same people would look surprised if one asked them if they had a good "otto" in their car. I realise that we live in an age when the saving of words is important, and "diesel", by some, would be preferred to such a verbal construction as four-stroke cycle, single-acting, air-injection, internal-combustion engine (the German equivalent of this would look really dreadful). In the adoption of the word "diesel" for the heavy-oil engine the work of the late H. Akroyd Stuart would be forgotten.

I am aware that a special committee of the Institution of Mechanical Engineers spent a lot of time on this question of oil-engine nomenclature, and that many letters on this subject have appeared in the technical Press, so I apologise for taking up your valuable space, but I should be pleased to have the opinions of your readers on "d" or "D", and also on the use of the "diesel" applied to all heavy-oil engines.

Yours faithfully,

J. WARD, M.I.Mar.E.

Technical College, Huddersfield.

June 15, 1932.

Ball and Roller Bearings for Reciprocating Motion.

"Engineering", 24th June, 1932.

Ball and roller bearings are employed to a very wide extent in modern machinery for shaft journals, and also to resist thrust, but hitherto they have not been suitable for sliding or reciprocating mechanisms except in such elementary forms as the ball castor. The Hoffmann Company, whose association with the development of the usual types of anti-friction bearings is too well known to require comment, have now, however, introduced a new type of bearing to fill this important gap. Three examples of the new bearing, which is known as the Sun and Planet Friction Eliminator, are illustrated in Figs. 1 to 4 on the next page. The principle is the same in all three bearings, and consists in providing a ball or roller with which the reciprocating surface makes contact, and which rests on a raceway or track, itself on ball bearings, the whole forming a self-contained oil-retaining unit.

The design shown in Fig. 1 forms one of a series of bearings suitable for carrying loads of

Fig. 1.

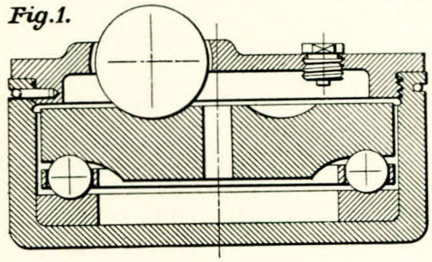


Fig. 2.

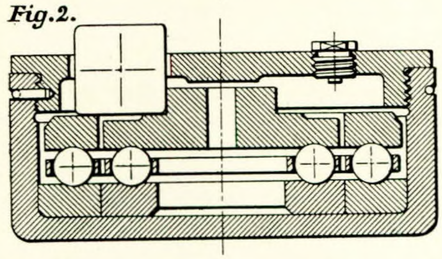


Fig. 3.

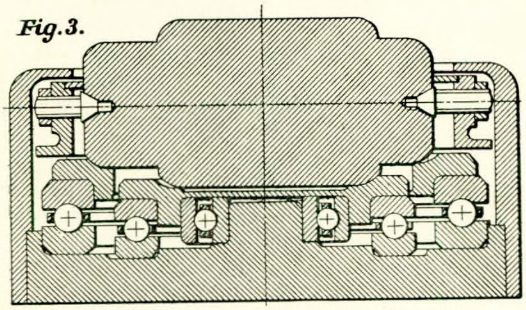
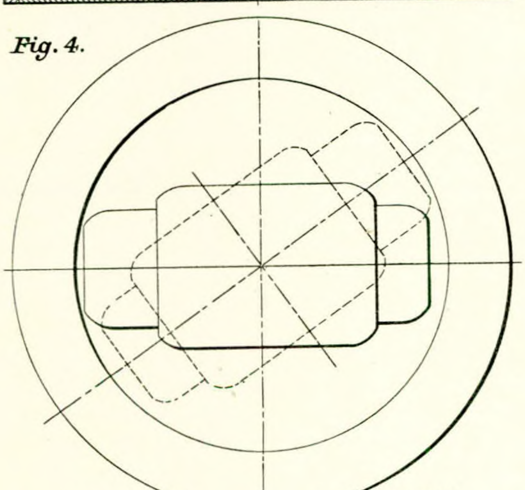


Fig. 4.



(3307) "ENGINEERING"

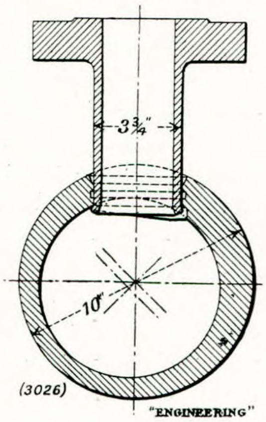
from 250lb. to 6,000lb. In this case, the reciprocating surface is carried on the large ball shown, and may be either flat or provided with a suitable grooved track. As will be clear from the figure, the ball is mounted eccentrically with respect to the track, which is itself mounted on a ring of balls running on a fixed raceway. All the elements are contained in an oil-retaining housing with a removable plate or cover, the latter being provided with a suitable opening for positioning the contact ball. The bearing shown in Fig. 2 is one of the simpler forms of the roller type, and is designed to carry loads of from 1,500lb. to 7,500lb. In this type, the contact roller is eccentrically mounted above, and in contact with, two rotating tracks which are concentric with one another. These tracks revolve on two rings of balls running on fixed raceways, and it will be clear that the tracks revolve in the same direction at different speeds. As in the ball type illustrated in Fig. 1, the elements are all enclosed in an oil-retaining casing. The third bearing, illustrated in Figs. 3 and 4, is designed to meet cases where a relatively large contact surface is desirable, such as on the tables of heavy planing machines. It will be noticed that the ends of the contact roller are reduced in diameter, and that one reduced end rests on the outer track, while the shoulder at the other end of the roller rests on the inner track. The tracks revolve in opposite directions at different speeds. As a certain amount of end thrust arises at the shoulder of the roller, a central ball race of the ordinary type is provided. A special feature of this bearing is that the roller is free to swing round on a vertical axis through its centre, so that it is self-aligning.

Several other types of bearing embodying the same principle have been evolved, of which two are of particular interest. The first of these consists of a bearing of the type shown in Fig. 1, formed integral with an eccentrically disposed anti-friction turntable, the combination constituting a castor which allows of multi-directional movement. The second type of special interest is one in which a ball-type bearing is mounted in a tubular housing containing a stiff spring, the top of the housing being covered by a cap with an opening to expose the free portion of the ball. These spring-mounted bearings can be used for a number of purposes, but are of particular value where heavy castings or forgings have to be accurately located before clamping in position. A number of the bearings, for example, can be inserted in the lower faces of bolsters on presses, the top of the contact ball being just proud of the surface. A bolster so fitted can be easily moved into its correct position under the tool, and on tightening down, the balls are pressed into their housings to allow the surfaces to make contact. Various other applications could be quoted, such as turntables and conveyors, and the sliding parts of machine tools, but enough has been said to indicate the wide potentialities of the bearings. We understood that the various types have been exhaustively tested by the makers, and that they have proved fully as reliable and frictionless as the ordinary types of ball or roller bearings.

Boiler Explosions.

"Engineering", 3rd June, 1932.

Explosion from a Superheater Header.—Report No. 3127, dealing with an accident from a superheater header at the works of Messrs. Synthetic Ammonia and Nitrates, Limited, Billingham, is of more than usual interest, as the accident occurred in a high-temperature, high-pressure plant working at 800lb. per square inch and 800° F. There are eight boilers in the plant, each of which includes a superheater supplied by Messrs. The Superheater Company, Limited, constructed of



drums, etc., made to their order. The superheater headers are of forged steel machined all over, and are 23ft. 2¾in. long and 10in. external diameter. The thickness varies as shown in the accompanying sketch, and each header is fitted with branch pipes or nozzles 3in. internal diameter for carrying the safety valves and stop valves. The holes into which the nozzles fit are serrated, and after being put into position each nozzle was expanded and bell-mouthed. Every precaution was taken in the manufacture of the parts; during the construction of the headers they were inspected by representatives of the owners and of the Vulcan Boiler and General Insurance Company, Limited, and they all successfully withstood the specified hydraulic tests. It had, however, been found necessary to re-expand a few of the nozzles, and it was one of these which failed. Soon after midnight this particular nozzle, on the header of boiler No. 33, was forced out of its seating, the steam pressure then being 675lb. per square inch. The escaping steam made it difficult to shut off the boiler, but apart from the displacement of the nozzle and the attached safety valve and escape steam pipe, which were held suspended by the supports 2ft. away from the header, there was no structural damage. The inquiry which followed the accident showed that the serrations in the header had not been filled when the nozzle was expanded, while the bell-mouthing may have not been sufficient. A contributory cause of the accident may have been the bending of the nozzle slightly owing to the proximity of an overhead steel joist fouling the escape-steam pipe. A test of a nozzle subsequently made by Messrs. Synthetic Ammonia and Nitrates, Limited, showed that the joint would leak before the serrations had failed, and also that after the serrations had failed and the nozzle had moved to the extent of giving an opening of $\frac{12}{1000}$in. on one side and $\frac{15}{1000}$in. on the other side, the bell-mouthing was practically intact.

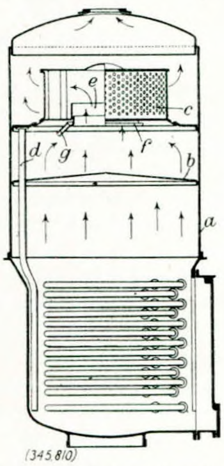
Explosion of a Steam Pipe in S.S. "Roseric".—Considering the stresses in ships and their machinery due to heavy weather, it is perhaps remarkable that accidents to steam pipes are so few. Anyone familiar with the vibration of a ship when the vessel is pitching badly and the engines are racing, will realise that it is only due to the provision for adequate support and for expansion and contraction that fractures are avoided. The S.S. "Roseric", however, appears to have been unusually unfortunate, and one accident to her steam pipes led to the death of one of her coal trimmers. Report No. 3126, which deals with the accident, is dated from Newcastle-upon-Tyne, June 26th, 1931, but the accident occurred about a year previously, when the vessel was trading between Eastern ports and Australia. Built in 1910, the "Roseric", owned by the Bank Line, Limited, was of 4,738 tons. She was propelled by a set of triple-expansion engines supplied with steam at 180lb. per sq. in. from two marine boilers. The main steam pipes were of solid drawn copper and were annealed and tested in 1923. In May-June, 1928, they were also inspected by one of Lloyd's surveyors. That same year, in August, at Osaka, Japan, a small crack was found in the main steam pipe near the flange at the engine stop valve, and the pipe being sent on shore for repairs, was cut and refitted. In February, 1930, at Ocean Island, another crack was found at the same place and at Auckland, the pipe was repaired again. Four months later, in June, 1930, a crack was found at the boiler stop valve end of the pipe, and this was repaired at Bombay, and a little later on at Aden the brazing at the flange and the sleeve which had been inserted, was reinforced. This however, did not prove very effective, for on July 11th, while on voyage from Aden to Colombo, the starboard main steam pipe broke off without warning at the boiler stop valve end, and for a time the vessel was helpless. After the steam from both boilers had cleared away, the broken pipe was taken down, blank flanges were fitted, and the vessel proceeded on her voyage, using steam from the port boiler for the main engines and steam from the starboard boiler for the auxiliaries. A new pipe fitted at Colombo fared little better than the old one, and other repairs were necessary at Fremantle and Calcutta.

After the arrival of the vessel home a new steel pipe, having bends to give greater flexibility was fitted and provided with suitable supports. "Previous partial failures of this pipe", says the engineer surveyor-in-chief, "should have warned those responsible that it was insufficiently flexible to accommodate the expansion and vibration to which it was subjected in service, but two of the repairs made were such that the original flexibility was decreased and the pipe thereby subjected to increased stresses".

Improved Evaporator.

"Engineering", 10th June, 1932.

345,810. G. & J. Weir, Limited, of Glasgow, and J. G. Weir, of Glasgow, March 21st, 1930.—The invention consists in an evaporator having a baffle which extends horizontally across it above the frothing level, a centrally-disposed door-port, a perforated plate or diaphragm extending horizontally across the steam space of the vessel and not far below the baffle and a collection gutter around the central port of the baffle. The perforated plate is



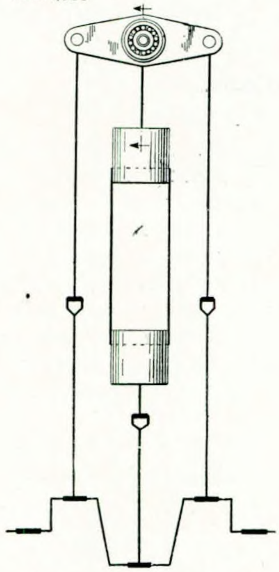
slightly conical to be higher in the centre than at the circumference. The drain pipe from the top of the baffle extends through the perforated plate. A small drain pipe is provided from the collection channel to lead the water away. *a* is the casing of the evaporator, *b* the perforated plate or diaphragm, *c* the baffle, *d* the drain pipe therefrom, *e* the central port of the baffle, *f* the gutter, and *g* the drain pipe from this gutter. (*Sealed*).

A Doxford Improvement.

"The Engineer", 10th June, 1932.

371,889. April 29th, 1932.—Opposed Piston Engines, W. Doxford and Sons, Ltd., and K. O. Keller, Pallion Yard, Sunderland.

It is stated in this specification that there is a tendency for the cylinder liner in which the top piston works to wear excessively on account of vibrations transmitted to the piston by its yoke and connecting-rods. In consequence, the inventors replace the usual yoke with a simple pin bearing by a



double yoke, which has roller bearings to connect it with the piston-rod.—*April 29th*, 1932.

Relativity and a Hole!

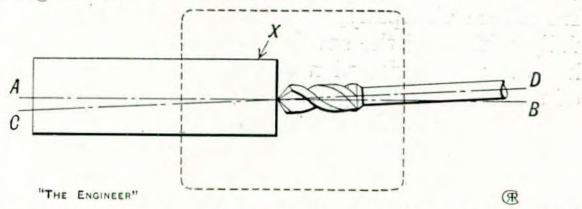
"The Engineer", 3rd June, 1932.

Sir,—The classical relativity illustration of the apparent difference of path of a stone dropped from a railway carriage window, as observed from the carriage or from the track, has suggested to the writer an interesting paradox connected with the drilling of a hole through a shaft.

Let A B be the axis of a shaft and C D that of a drill, as nearly as possible, but for practical reasons not quite co-axial.

It is, of course, well known that if the drill revolves and the shaft remains stationary, the result will be a hole emerging at C, whereas if the shaft is made to revolve and the drill is stationary the hole will be true with the axis of the shaft and emerge at A.

Now an observer located on the shaft at X, having no other frame of reference than the drill,



can only appreciate the *relative* motion of the drill and shaft, it being entirely immaterial and indeterminate which moves.

How, then, can he account for the different results in the two cases which, unlike the illustration of the path of the stone, which is one of appearance only, is in this case one of actuality?

Any solutions forthcoming would be appreciated at an early date, as the writer is anxious to get on with the job.

R. Stanley Lewis.

Ipswich. May 20th.

The Services of Aircraft to Shipping.

"Schiffbau", 15th May, 1932.

The ability of aircraft to establish communication by the most direct route and in the minimum time with places which cannot be reached by other forms of transport renders it peculiarly valuable for emergency services.

In numerous cases ice-bound vessels have been supplied with provisions, fuel and mails, and much work has been done by the German Luft Hansa in the use of aeroplanes to search for missing vessels; they have also carried provisions and mail to islands in the Baltic when sea transport has been interrupted by ice. The survey aircraft have also come to the assistance of sailing vessels in difficulties due to weather; for example, a yacht was found in serious difficulties between Kalmar and Travemunde, and a wireless message to Warnemund brought a motor boat to its assistance in time to save it from being wrecked. Some time ago the crew of a cargo vessel that had run ashore in the Gulf of Aden were sighted in open boats and taken on board by seaplanes. In the polar regions provisions have been taken to fishermen and others isolated on ice flows, and in many cases they have been brought back to land by aeroplanes.

Aeroplanes have been used with great success to help fishing vessels find the best fields to trawl. It was found during the war that objects under the water could easily be observed from aircraft. Trials of this method of locating fish were first made in England and later in Norway, and during recent years a regular service has been established in Iceland during the herring season. Aeroplanes patrol the fishing grounds and report by wireless to those trawlers which are equipped with receiving sets, while for those not so equipped a shore station provides information each time they are in harbour. After the service was established experimentally, it was found that the value of fish landed was increased by 500,000 kronen in the first month. A regular service is now maintained by the Icelandic Government and is paid for by a small tax on all herrings landed.

Geared Four-stroke Engines for Liner Propulsion.

"The Motor Ship", July, 1932.

A good deal of interest has been shown and a certain amount of criticism expressed at the retention of a geared high-speed Diesel drive with four-stroke single-acting machinery in the 14,000-ton passenger liners built recently for the Hamburg South American Line. It is evident, however, that the owners are satisfied with this system (utilising four 1,750 b.h.p. high-speed engines driving two slow-running propellers), for in a lecture which Mr. Müller, the chief superintendent engineer of the Hamburg South American Line, recently delivered, he remarked that the machinery installation of the "Monte" ships (there were four) has thoroughly satisfied all demands in regard to efficiency and safety. The Hamburg South American Line would, he added, adhere to this system of propulsion, even with higher-powered ships.

During the course of his lecture Mr. Müller stated that 15·2 per cent. of the heat in the exhaust gases was recovered by the use of exhaust gas boilers, and the thermal efficiency of the propelling engine was increased from 43·6 to 58·8 per cent.

Research on Propeller Shapes to reduce Cavitation.

"V.D.I.", 28th May, 1932.

In the construction of fast running propellers, centrifugal pumps or water turbines, a serious problem—cavitation—is caused by uneven pressure distribution on the back of the blade. This trouble cannot be avoided without a detailed knowledge of the actual variation of pressure round blades of various sections, and to provide information on this subject a series of tests has been made in the wind tunnel at Danzig. The relative pressures are similar with air or liquids, although the absolute values are different.

The above-mentioned researches showed that in general the normal propeller blade section with flat face and symmetrical back indicates a pressure distribution less liable to cause cavitation than the majority of unsymmetrical sections (i.e.,, aerofoil sections). The sharp entering edge of the normal blade section did not show the most satisfactory pressure distribution, and a slight modification with a rounded entering edge reduces the liability to cavitation. A shape known as the Betz profile which has been determined on theoretical considerations of pressure distribution showed on test a very low liability to cavitation. Tests were also made on the influence of the superficial shape of the blade and it was found that blades of which the leading edge was canted back showed very high peaks of under pressure and were, therefore, liable to cavitate badly.

Increasing the speed of the T.S. "Slamat".

"Bulletin Technique du Bureau Veritas", May, 1932.

A number of ships built shortly after the war are to-day unable to maintain a competitive service due to their speed being too low. In the case of the larger mail boats re-engining may be justified and, in fact, a number of vessels of this class have been fitted with new machinery of increased power, the "Albert-Ballin" and "P. C. Hooft" being cases where this course has been adopted. The cost of complete new machinery is very high and cannot be justified for intermediate class vessels such as the "Slamat" of the Rotterdam Lloyd Company, and on this vessel, which had become too slow for the service to the Dutch East Indies, other and cheaper means of increasing the speed had to be looked for. The increase required was from 15 knots to 17½ knots.

The boilers of the "Slamat" had been designed for alternative coal or oil firing, and the turbines designed for the coal-fired output. When running on oil considerably more steam could be generated than the turbines could take, and by the addition of supplementary nozzles it was possible to increase the machinery output by 25 per cent. This increased power still left the vessel far short of the desired speed and a number of alterations to the hull were undertaken, the work being carried out by the Wilton Shipyard at Rotterdam. After tank tests had been made on various proposed modifications. it was decided to make the following changes in the hull:—

(*a*) The length of the vessel was increased about 16ft. at the water line by remodelling the bows over a length of nearly 100ft. The new bow lines were of the Maier form.

(*b*) New propellers were fitted which were better suited to the hull.

(*c*) A stream line rudder was fitted.

(*d*) The shape of the bilge keels was altered and their area reduced.

(*e*) The bossing was modified.

According to the tanks tests these modifications should reduce the power required to drive the vessels at 17½ knots from 12,900 to 8,100 b.h.p.

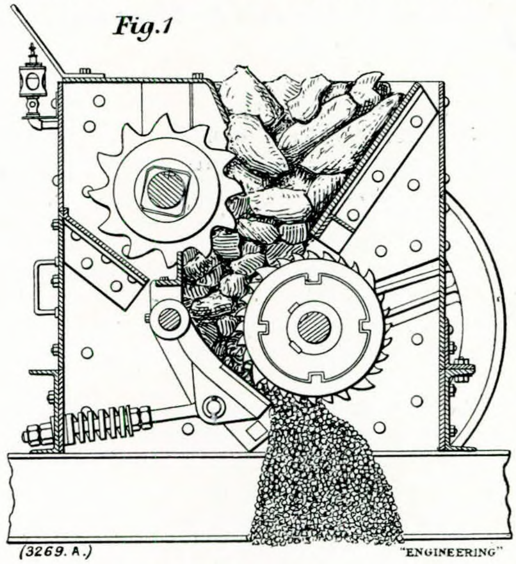
The whole work had to be completed without withdrawing the vessel from service for more than three months, and to make this possible it was decided to build the new bow ready to fit to the vessel, and to cut off the old bow after the ship had been dry-docked, a 120 ton crane being used to handle the sections. Actually the vessel was in dock for only eight weeks.

Three-stage Coal Breaker.

"Engineering", 17th June, 1932.

A new type of coal breaker has recently been introduced by Messrs. Hadfields. The breaker will deal with "run-of-mine" coal and will reduce it to ¾in. cube or less, thus effecting a reduction for which it is usual to employ two machines working in series. The construction of the machine is shown in Fig. 1, an inspection of which will make it clear how the very large reduction is obtained. In a sense, the machine may be said to constitute three breakers in one. As will be seen, it contains two crushing rolls arranged with their shafts parallel, but with the upper roll offset diagonally in reference to the lower. The upper roll is built up of circular claw cutters threaded on a square shaft, while the lower consists of a hollow roll with small teeth fitted on a cast-iron centre. The

Fig.1



rolls run in opposite directions, the lower at a considerably higher speed than the upper. This is necessary owing to the much smaller space separating the roll from the breaker plate in the case of the lower roll. The rolls are gear-driven, the gear wheels of toughened cast-steel having machine-cut teeth.

As will be clear from the figure, the upper breaker plate is fixed. The large pieces of coal fed to the machine are gripped by the teeth of the top roller and forced downwards and broken against the fixed plate. The coal then passes between the two rollers where it is further reduced to a size sufficiently small to enable it to be carried forward by the lower roller and reduced to final size against the lower breaker plate. It will be seen that this lower plate is pivoted and provided with strong compression springs. The long bolt with its regulating nuts allow the position of the plate and, consequently, the size of the product to be adjusted. The rollers and other parts subjected to abrasion by the coal are made from Era manganese steel.

ERRATUM: JUNE ISSUE.—With reference to the abstract commencing on page 238 of the June Transactions, entitled "Dew Point Recorder for Flue Gases", after the words "between the anode and grid potentials" at the bottom of colume one, page 240, continue reading at paragraph two, column one, page 244 "the thyratron anode . . . . ".

The abstract entitled "Marine Steam-Engine Efficiency", commencing on page 240 ends with paragraph one, column one, page 244.