INSTITUTE OF MARINE ENGINEERS,
INCORPORATED.

Patron: HIS MAJESTY THE KING.

SESSION 1928.

President: SIR ALAN G. ANDERSON, K.B.E.

VOLUME XL.

The Practical Value of the Report of the Heat Engine and Boiler Trials Committee.

BY G. J. WELLS (Vice-President),

READ

Tuesday, April 10, *at* 6.30 *p.m.*

CHAIRMAN: Mr. F. M. TIMPSON.

THE publication of this Report marks another important step in standardising the methods of conducting tests for the determination of the efficiency of Heat Engines, and the memory that this Institute shared in the Committee's deliberations is sufficient justification for spending some time in its study.

It is suggested that the best way to approach the subject is chronologically, for then the simultaneous growth of Heat Engines, and the allied physical matters may be more easily seen. Also, another aspect of some importance is thus more vividly realised. Very frequently one hears statements made, such as that "pure science is of little importance," "what is the value of considering and noting such small matters," or "he is so theoretical," and many others. The "ultra practical" man is often very ignorant, but never shows it more than when he writes down theory because it is always behind practice. It is always behind, and always must be because a theory is an hypothesis, put forward to explain some happening, to correlate individual happenings, and, if possible, to arrive at some general principle or law governing the phenomena, and thus pave the way for advance. Take as an example, the so-called practical man who has an engine giving a certain effort, but wanting, say, double that effort, he strengthens and enlarges it to gain that end. He simply doubles the diameter of the cylinder, also that of the piston rod, and other parts in like manner. Now had he possessed mathematical knowledge he would have saved himself much expense, for he would have simply enlarged the diameters by multiplying by $\sqrt{2}$ because areas are proportional to the squares of diameters. Of course it may be urged that there are not many who act thus in such a matter; and this objection is valid, but there are many other directions in which similar errors are constantly being made. Perpetual motion patents and schemes are by no means extinct, and nothing bolsters up these schemes so much as the imperfect grasp of certain fundamental laws that underlie many of the commoner concerns of our daily experiences. The production of the Report before us is evidence of the necessity that exists to guard ourselves against possible error.

An early one of some interest, described by Sir James Ewing in his work on the Steam Engine, is worth noticing. The illustration (Fig. 1) shows a floor, upon which is shown an altar, and the Sanctuary doors. The altar is connected with a reservoir beneath the floor containing water. This vessel has a pipe, with its open end beneath the water level, and its open end beneath the water surface in a second vessel. This second vessel is suspended by two ropes passing over a pulley attached to the floor, the other ends of these ropes are attached to two vertical spindles whose upper ends are attached to the Sanctuary doors forming the axes of the hinges. Two other ropes are fastened to these spindles and pass over another pully, and kept taut by a balance weight. This latter weight normally keeps the doors shut, and the suspended vessel of water raised. When the altar fire is lighted, the heated air expands, and forces some water out into the suspended water vessel, and this over balances the system, and the sanctuary doors open, showing to the worshippers that their devotions and offerings are accepted. When the altar fires die down, the air cools and therefore contracts, and the water is now drawn out of the hanging vessel, the balance weight now raises the suspended water vessel and closes the doors.

Whilst steam engines in various forms have been known for very many centuries, the first to take practical shape and to be used commercially was that known as Savery's, whose patent bears the date 25th July, 1698, and the engine is called "The Miner's Friend," for it was an "engine to raise water by fire." The Fig. 2 illustrates this engine, and Fig. 3 is a diagram which shows the arrangements of the several parts. A trial was made of one of these engines as made at Manchester in 1774 by Smeaton, and the following details were recorded. The receiver was a cylinder 2 ft. dia. by 7 ft. high. The water was delivered at a height of 19 ft. above the water surface in the well. The engine made $7\frac{1}{4}$ strokes per minute, each stroke filling the receiver to a height of 6 ft. The work done was lifting $18\frac{3}{4}$ cub. ft. of water per stroke 19 ft. and 32 cwt. of coal was burnt in 24 hours. In those times a bushel of coal of 84 lbs. was the unit employed, and the duty was therefore about 5,300,000 ft. lb. per bushel of coal. Assuming that the calorific value of coal was 14,500 B.Th.U. per lb., then the abs. efficiency was about $\frac{1}{2}$ per cent. The pump horse-power was 4·7. Some stress has been laid upon this trial, for it is a very early one and reported upon by an eminent engineer. The methods of weighing the coal, and determining the work done were very crude as measured by the standards of to-day. It

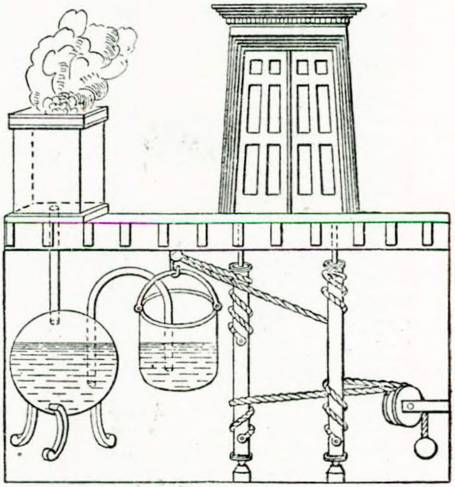

Fig. 1.

may be noticed in addition that the trial was made 76 years after the date of the patent, so that the engine was then well beyond the experimental stage. Papin, in 1705, devised a modification of Savery's engine, in which the steam was kept separate from the water in the receiver, and allowed to escape without condensation (see Fig. 4). It should be noted that the safety valve is added, a cock for the escape of the steam, and a heater to keep the steam dry. The Pulsometer (Fig. 5) is the modern form of Savery's engine.

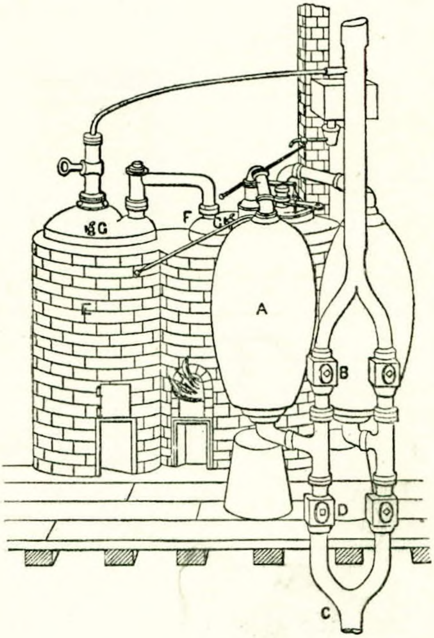

Fig. 2.

Newcomen's engine marks the next real advance in design, 1705. Fig. 6 shows in diagram form the general arrangements of this engine, in which the beam appears for the first time, and the separation of the pump and steam cylinders, also the condensation of the steam is effected internally. Smeaton designed and erected a Newcomen engine for the Chase-Water Mine in Cornwall, which had a cylinder 72 inches diameter, 9 ft. stroke, and developed 76 H.P. The pump lift was 51 fathoms; the load on the piston was $7\frac{3}{4}$ lbs. per sq. in. This engine was erected in 1775, and was then the most powerful engine in existence. This was six years after the patent was granted to Watt, but after a few years this engine was altered by Watt to his system. Until this date, and for some years later very imperfect views were prevalent concerning the nature of heat, and stirred by the development of the steam engine physicists began enquiry into the problems thus raised. For we read that criticisms were made concerning the great con-

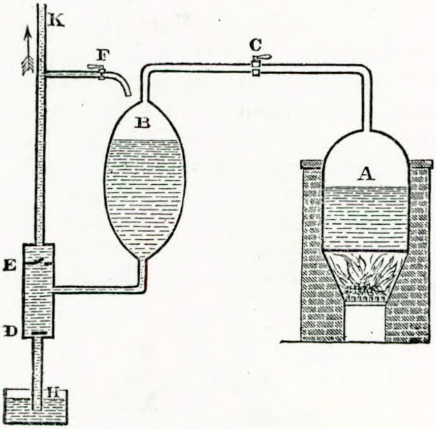

Fig. 3.

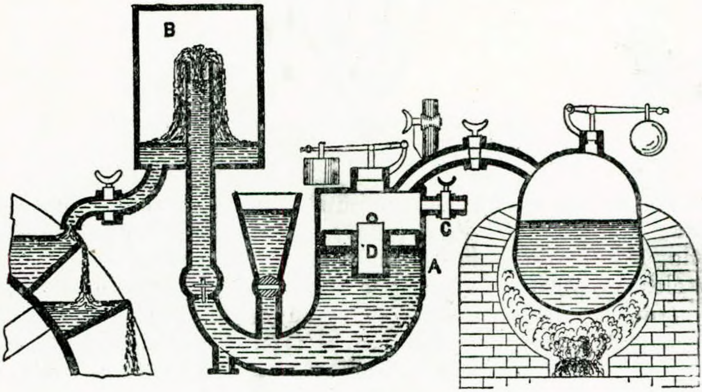

Fig. 4.

sumption of fuel of these engines, for the Newcomen engine was about the same as the Savery. The great difficulty at that time was finding out what possible return might be reasonably expected from the burning of one pound of coal.

Under the same roof with Watt at the Glasgow University was Dr. Black. After repeated efforts and experiments to make a model of Newcomen's engine work, Watt appealed to Dr. Black for an explanation of his results, and then learned of Dr. Black's experiments, which had established the doctrine (as it was then termed) of latent heat, and at once was led to the obvious course of separating the cylinder and the condenser, and so saving the enormous loss of heat per cycle. Watt's apparatus to test the value of the separate condenser is shown, Fig. 7, and it is noteworthy that a surface condenser is employed, as well as an air pump. The resulting engine is shown in Fig. 8, whilst Fig. 9 shows the valves controlling the flow of the steam to a larger scale. From this latter it is now clear that Watt had made a most substantial addition to Newcomen's engine, each of which increased substantially its efficiency. The new features are: (i) Hot cylinder; (ii) steam jacket to keep it hot; (iii) gland or stuffing box for piston rod; (iv) condenser; (v) cold water jacket to condenser and air pump; (vi) the air pump. Watt quickly added valves so that his engine became double-acting; later a connecting rod device, fly wheel, and governor, and then the engine was available for work other than pumping. Watt employed expansion, that is a cut-off valve, but curiously his steam pressure seldom

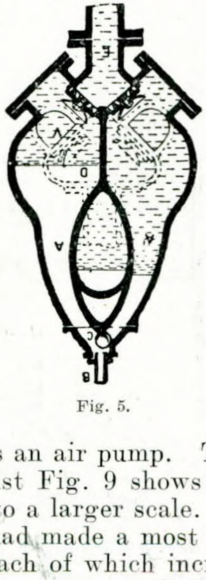

Fig. 5.

exceeded 7 lb. per sq. inch above the atmosphere. The increase of efficiency was very marked, and the Cornish pumping engine was very soon famous for its economy. In 1835 the coal per H.P. hour was about $1\frac{3}{4}$ lbs. A point of great importance that must be noticed is the rearrangement of the valves shown in Fig. 10, which was very soon made, and introduced the so-called "Cornish Cycle," thus altering the cycle employed in the "Newcomen" engine. The piston being at the top of its stroke, the valves A and C were opened, when the steam below the piston, passing out into the condenser was condensed; the reduction of pressure that ensued beneath the piston caused the steam above to force the piston down. When the piston is at the bottom of its stroke the valves A and C are closed, and B is opened, when the steam passes from above to beneath the piston, equalising the pressure, and the weight of

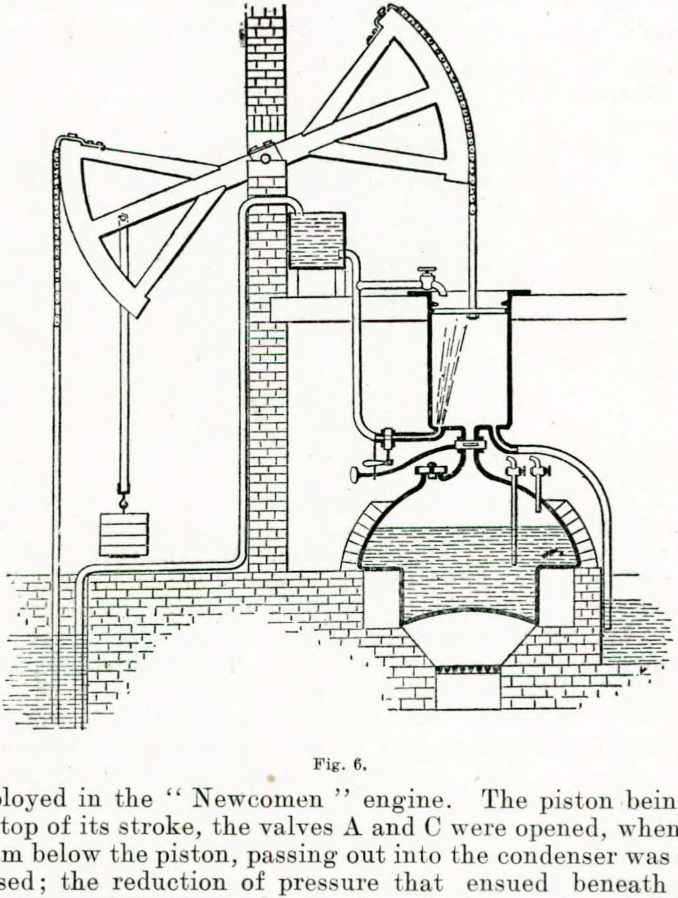

Fig. 6.

the pump-rods, etc., overbalances the piston-rod, etc., and the piston moves up again; this is position shown in the figure. In this way the temperature drops are from that of the admission steam down to that of release, and from the temperature of release to that of the condenser, which is approximately one of the effects due to compounding. Mr. Willans adopted this cycle in his well-known single-acting high-speed engines. Hotel office doors and cold rooms are amongst other modern applications of this cycle.

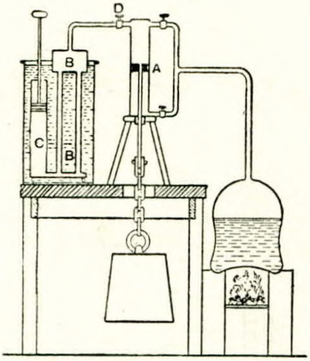

Fig. 7.

The use of steam expansively led to the patent of 1782, and here the steam engine arrived at a stage of perfection, which was only very slowly improved upon. But the actual scientific basis of testing as known to-day was not yet laid. For Count Rumford's gun experiment (1798) and Davy's ice experiment (1802) had yet to be made, showing that the older ideas of the nature of heat held by Black and others were untenable. Later, in 1824, Sadi Carnot's famous memoir, giving his well-known cycle and conclusions, was followed by Dr. Joule's work culminating in the enunciation in 1843 of the law of conservation of energy and the actual determination in 1849 of the mechanical equivalent of heat to within an error of less than 1% of the now universally accepted value. Dalton in 1802 established the laws concerning vapour pressures, and Regnault's classic experiments with steam, published in 1847, finished the provision of the necessary material for building up the Science of Thermodynamics on rigorous foundations by Clausius, Rankine and Kelvin. The work of Regnault, exhibited in the " Tables of the Properties of Steam," was of the very greatest value to Steam Engineers. Remembering the extreme difficulty of the experiments, they still remain a monument of skill and patience. The errors in the results obtained, gave rise to many schemes for smoothing them out, but the relations between pressure, temperature, volume, etc., remained empirical, until Callendar completed his researches, which culminated in rational formulæ, giving consistent results over the whole range of values within practical reach.

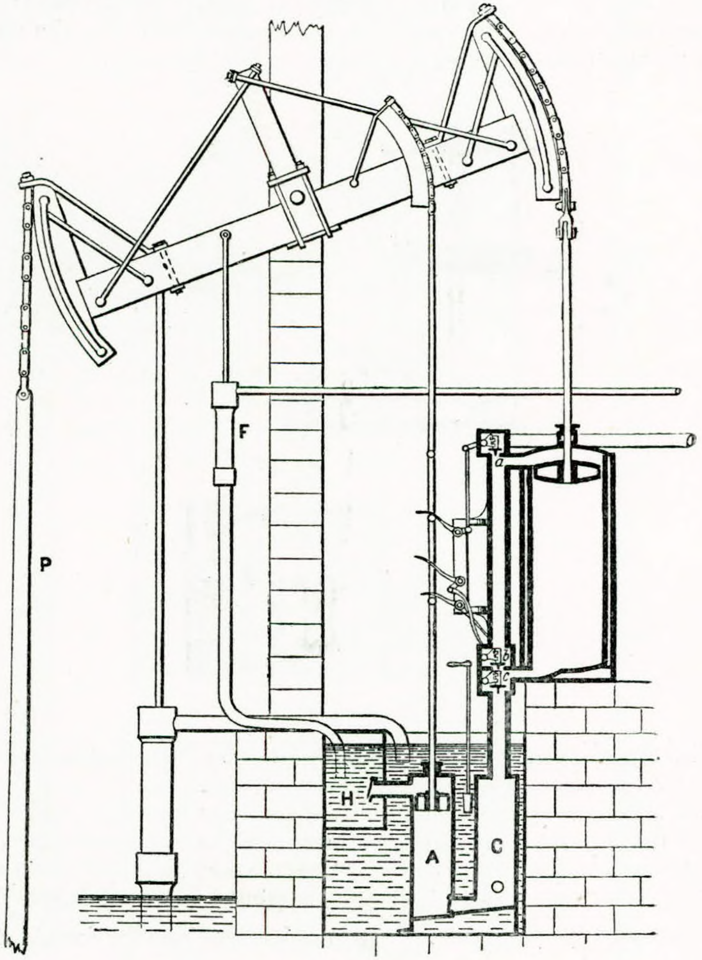

Fig. 8.

The publication in 1859 of Rankine's "Manual of the Steam Engine," marked the commencement of the new epoch in the philosophical treatment of steam engine problems. It must, however, be noted that for very many years whilst the methods given by Rankine were known and appreciated by the very few, the majority concerned in designing and testing of heat engines were profoundly ignorant of everything concerning their craft, save that in the main their engines were very close approximations as regards dimensions and arrangements of those made by their more successful competitors. By the way, this class of engineer is by no means extinct to-day.

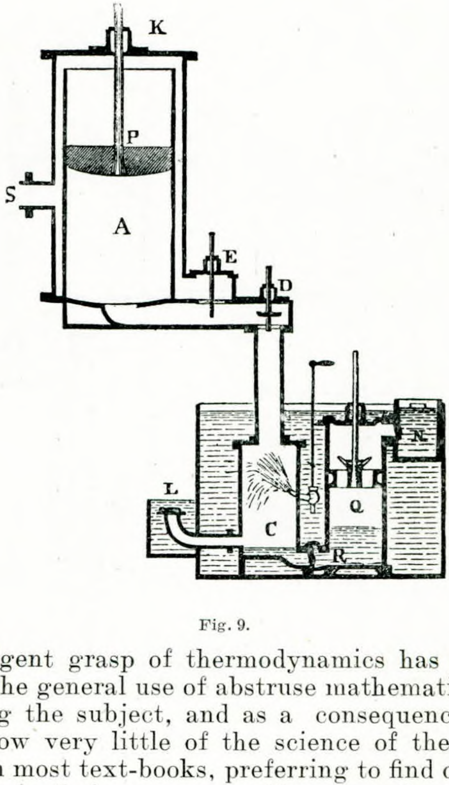

Fig. 9.

The intelligent grasp of thermodynamics has been greatly hindered by the general use of abstruse mathematics by writers when treating the subject, and as a consequence, engineers generally know very little of the science of thermodynamics to be found in most text-books, preferring to find out what they want to know in their own way. Consequently, such symbols as:—dt, δQ, $\int$, $\frac{\delta Q}{T}$; etc., form an insuperable barrier to the great majority of engineers, and it was only the select few who could gaze at them and live to draw their salaries. Macfarlane Gray, Willans and Sankey have employed the geometrical method hinted at by Wm. Gibbs in 1873, and as a result thermodynamics has become comparatively easy to grasp and appreciate. The confusion of thought, due to ignorance or the partial appreciation of thermodynamics, naturally led to much trouble in computing heat engine efficiencies.

However, the elect continued their work, and a few engineers applied it. Amongst these the names of Bryan Donkin, Sir Alex. Kennedy, and Dr. Unwin are familiar. The next date of importance is 13th March, 1888, when the late Mr. Willans read his paper on "Economy Trials of Non-Condensing Engines," which he had carried out at Thames Ditton, with unparalled accuracy and skill. This was followed by a second paper on "Steam Engine Trials" on 11th April, 1893. This second paper was actually an extension of the first paper, including the effect of "Condensing" on efficiency. The criticisms of the first paper were dealt with in the second, and generally justified the conclusions drawn by the author in the first paper. So conclusive did these results appear that the Council of the Institution of Civil Engineers called into existence a committee to consider the whole matter of engine trials, and to place them upon a standard basis as far as possible. This committee reported in 1901, and in 1902 their final report was issued. This report was again revised and brought up-to-date in 1913 by a new committee, and in their report the recommendations of the Committee on Standards of Efficiency were included.

In 1903 another committee was instituted to consider the problem as applicable to "Internal Combustion Engines," and they reported in 1905. Finally, in 1922, the matter was again reconsidered by a committee, whose report has recently been published.

Up to the date of the Willans papers, each experimenter had approached the subject from a more or less special angle, and so deduced efficiencies which were not immediately comparable, with other contemporary results, the consequence being that much confusion ensued as to what constituted the real efficiency. It was generally conceded that in some way or other the Carnot standard was not a satisfactory standard of comparison. Rankine and Clausius had given a standard cycle, now known as the Rankine, but this was not strictly adhered to, so there was a slow growth of opinion, tending towards the formation of a generally acceptable standard of comparison. This being agreed to, then in order that any particular test could be accepted without question, it was very desirable that all measurements should be made with carefully calibrated instruments whose accuracy could not be questioned. It was

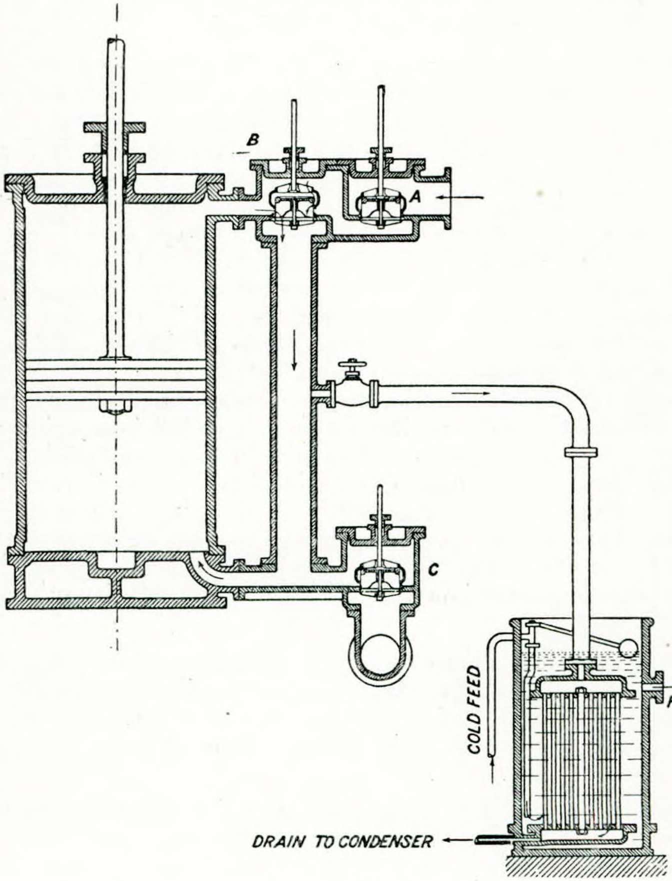

Fig. 10.

on all these points that Mr. Willans showed to the engineering world that engine testing could be carried out with great accuracy. In Fig. 11 is shown the very simple arrangement adopted by Willans for testing his engine. It will be noted that the steam from the boiler passes through the engine, and condenser into the hot well, which is actually placed upon the platform of the weighing machine. The steel yard of the weighing machine was brought together within the observer's office, so that all the essential measurements could be made immediately under the observer's eyes. The papers of Willans will well repay careful reading by all those responsible for engine testing. Now the Heat Engine Committee have ascertained standards of comparison, and framed codes by means of which, all the necessary measurements may be made.

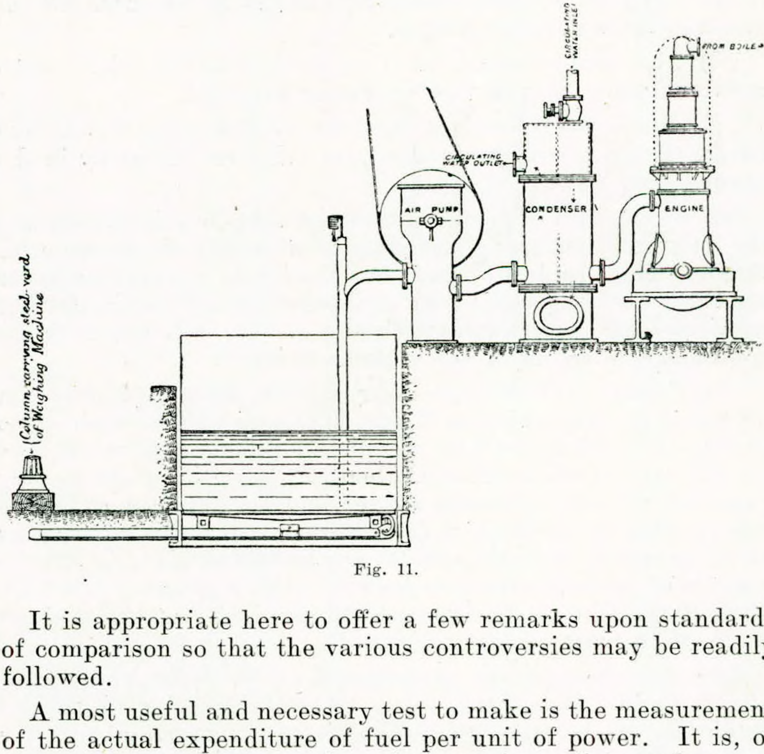

Fig. 11.

It is appropriate here to offer a few remarks upon standards of comparison so that the various controversies may be readily followed.

A most useful and necessary test to make is the measurement of the actual expenditure of fuel per unit of power. It is, of course, the result that makes the most immediate and urgent appeal to the commercial man. It is, however, when taken alone most deceptive, because it may happen that in two or three plants in which this efficiency may be practically equal, it can easily happen that one or other part of one plant may be worked far under its best performance, and therefore waste is occurring. Now, if each portion of the plant is separately tested, boilers, engines and condensers, it might then easily be discovered that a very fine engine was handicapped by a poor boiler and leaking steam pipes, etc. Many a poor result from a fine triple-expansion marine engine has been discounted by very wasteful auxiliaries. Hence, each part of a heat-engine plant should be separately tested.

(1) Boilers.—These consist of two main parts:

(i) The furnace, in which the heat latent in the fuel is liberated. This entails the measurement of the calorific value of the fuel used, of which the real crux lies in the possibility of getting a true average sample.

(ii) The determination of the total heat in the steam delivered above that in the feed water supplied.

(iii) The measurement of the heat carried away by the flue gases, the heat lost by radiation, and that carried away in the unconsumed fuel.

By means of this data, the furnace efficiency is found, and the boiler efficiency as a mechanism for getting the heat out of the hot flue gases into the water. Curiously enough the latter efficiency is fairly constant. It is the furnace efficiency that requires close and constant watching. It is customary to recognise this latter as the stoker efficiency.

(2) Engines.—Here it is necessary for the weight of steam delivered to the engine at the stop valve and its condition to be known, so that the heat supplied is known, and work done by the engine being ascertained then the ratio of the energy supplied, to that delivered by the engine at the shaft is the engine efficiency. All this is, of course, put very briefly; it is far more complicated than might appear at first sight. But the main point of controversy arises here. What proportion of the heat supplied ought to be reasonably delivered at the shaft in the form of mechanical energy?

Then this leads to the examination of the cycle, and Carnot has shown how the various processes must be conducted in order to obtain the best results. The disputes centre about the exhaust line, and the so-called toe of the diagram; the other parts of the cycle are comparatively agreed upon. It seems to be, however, obvious that if an engine for any good reason is so designed, that in its operation it departs from the best cycle, then it must pay the penalty for that departure. This loss of efficiency—because it does not conform to the ideal—is the price possibly paid for other advantages, perhaps simplicity in design, or operation, or reduced costs of production. In any event, the ideal, if it is a good one, should be aimed at, but because it cannot be attained is no reason why the ideal should be condemned.

By weighing the condensate the weight of steam utilised by the engine may be obtained if the amount of leakage at glands, joints, jacket, cylinder drains, etc., are weighed and added. Then the boiler feed will enable the losses between boiler and engine, at safety valves, etc., to be at once known.

Now a careful study of the Report will enable anyone to appreciate the very many factors there are to be taken account of in making a good test, which will command general acceptance. Just as it may be easy to see how in a business a big saving may be made in the costs of production, it is always extremely difficult to save the pence. It is the same in testing; the day has gone by when 4 or 5% error in weighing the fuel and feed water supplied during a boiler trial could be made without materially affecting the results. To-day one has got to look for almost absolute accuracy in such matters, and in addition one must infer from the methods in use what is the order of magnitude of the errors possible.

It should be a matter of considerable pride to the members of this Institute that in this work of revising and enlarging the earlier reports on heat engine testing they were represented by four members directly, and indirectly by two other members. Further, that since the report has been made a permanent committee has been formed, on which this Institute is represented by two members. It is also suggested that the Institute has reason to be proud of sharing in such an important epoch making work as the production of a standard of testing, which it is more than probable may yet become international in its operation.

DISCUSSION.

The Chairman: We have to thank Mr. Wells for giving us such an interesting paper, and for the extent to which he has dealt with the subject of steam at a time when steam is receiving more attention than it has had for many years. The paper will serve a useful object by calling the attention of the members of this Institute to the very important piece of work that was recently completed by the Committee, of which Mr. Wells was such a useful member. His association with the work of the Committee reflects a great amount of credit on this Institute.

Mr. Wells' references to Mr. Macfarlane Gray are interesting, as it is well known to many of our members that he was an important member of this Institute.

The Willans engine was a satisfactory engine. There were a great many in use in central power stations, etc., and some of them are still in service. They were to the fore up to the time of the general introduction of the steam turbine.

I am sure that Mr. Wells will be pleased to answer any questions you may wish to raise.

Mr. W. McLaren: I am sorry there are so few here to-night to receive this paper on the Report of the Committee. I doubt whether we realise the enormous amount of work which the preparation of this Report has entailed. Mr. Wells, whom we recognise as an authority on this subject, and who is a Denny Gold Medallist of the Institute, is to be congratulated on giving us his views on what the Committee has been doing.

Speaking as a practical man, I would like to refer to the recommendation that the engine and boiler should be the subject of separate tests. The first item to be considered in connection with boiler tests is the calorific value of the fuel. In connection with the recent coal conference, I am glad to hear that there were some chemists present who said that the sampling and analysis was of great importance in the selection of fuel. The practical marine engineer wants to know the calorific value of his fuel and the percentage of ash it is going to produce. Supposing that a furnace is arranged for taking a comparative test, and the results obtained vary within, say, 20%, there are allowances to be made for chimney and flue conditions which it is hardly possible to assess. When we come to the actual engine, the tests should be made under constant load. Then Mr. Wells has referred to leaky glands and so on; perhaps it is a little difficult to have an engine quite tight. One hears instructions given to slacken bearing bolts, etc. Very few engines can be so perfectly fitted as the Willans engine certainly was.

It is very appropriate that this paper should follow Mr. Hutchinson's recent paper, which dealt with a number of new types of engines which have been designed to embody the results of the latest research in steam practice, which the Heat Engine and Boiler Trials Committee has done so much to facilitate.

Mr. S. B. Jackson: I was rather interested to hear the author's remarks about the Willans' line. To me it seems that although it may have become known as the Willans' line, I think it was known long before Willans' time. It is merely a form of equation where x is the variable to y. y = a, which is a constant, plus b, which is the slope of the line, multiplied by x, *i.e.*, $y = a + bx$. I am not sure that Willans was the first to discover the use of the line. He was a very remarkable man considering that there were many able men before him. This line has recently been called the Parsons' line, and the same methods as used by Willans are adopted in power stations. Each shift, the coal consumption is plotted on a sheet of squared paper and a line drawn through, and the formula $y = a + bx$ is utilised, and by that means the line can be drawn which is exactly the same as the Willans' line. From that line one can determine quite a number of things. It is used, to my knowledge, as a method whereby the bonuses of the staff can be determined. Another application is in sub-stations, where the output can be plotted against the interval and a factor determined for the particular results which have been obtained. Although it has not yet been so used, as far as I know, I am trying to apply it to mains distribution of an electrical undertaking. I think it will be quite useful in determining what the capital cost will be for any further extensions. I was interested some time ago in boiler testing abroad, and in the question of the total heat content of steam. I used various authors' figures for determining the efficiencies of boilers. I used Mollier's figures, also Callendar's and Stodola's, and I found that there were great discrepancies at the higher range, notably above 1250 B.Th.U. per lb. There is one thing I would like to ask Mr. Wells—what is the rational standard he mentioned? I was not quite clear on that point and I would like to have it explained more clearly.

Mr. J. Ward: I do not think Willans claimed to have discovered the linear law. The linear relation between experimental quantities was known before Willans' time.

Mr. Wells: It could not have been known before Willans' experiments. Willans plotted total water used against horsepower.

Mr. Ward: I think originally against initial pressure.

Mr. Wells: No, against horse-power. You have to remember that the law is only applicable to an engine with constant cut-off.

Mr. Ward: Yes, provided you keep the cut-off constant the steam consumption is a linear function of the initial pressure since the latter is directly proportional to horse-power. Referring to the previous speaker's remarks *re* plotting experimental quantities. After an experiment of any kind one naturally plots one quantity (the dependent variable) against the other quantity (the independent variable) to see if there is a linear relation between them. If there is not a linear relation then plot logarithms of the quantities.

Mr. Wells mentions the work of Professor Callendar. I certainly think that those of us who are teachers of engineering ought to persuade engineers who work out tests to use Callendar's Steam Tables exclusively. I remember Mr. Wells, in his contribution to the discussion on Mr. Neill's paper on superheating, tried to drive home the importance of using Callendar's Tables. I think there should be copies of Callendar's Tables and Charts, including his recent tables for high pressures, in the Institute Library. Referring to Willard Gibbs, who Mr. Wells mentions in his paper, he was an American chemist of the last century and his researches were principally concerned with the application of thermodynamics to chemistry. We engineers are indebted to him because he gave us the definition of total heat: *i.e.*, $H = E + \frac{PV}{J}$. Also he gave us Gibbs' function, which can be used for determining adiabatic heat drops. Mr. Wells mentions the Rankine cycle and the arguments which took place in the early days of the first Heat Engine and Boiler Trials Committee as to whether they should adopt the Rankine cycle as the standard of comparison for the steam engine which does not have complete expansion down to the back pressure. Owing to the steam being released from the cylinder at a pressure higher than the back pressure, the toe of the Rankine P.V. diagram is cut off. Personally, I think the modified Rankine cycle was turned down owing to the greater work involved in determining the efficiency. If the modified Rankine cycle is drawn on a temperature-entropy diagram a planimeter is required to determine the areas representing heat quantities. I have found that the Callendar total-heat log-pressure diagram is the best to use for working out efficiencies on the modified Rankine cycle.

*Mr. Wells says, " Then this leads to the examination of the cycle, and Carnot has shown how the various processes must be conducted in order to obtain the heat results." Should not that read " and Rankine has shown," etc.

Mr. WELLS: No, it is quite correct.

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Mr. WARD: In the next paragraph I think Mr. Wells is optimistic when he suggests that "by weighing the condensate the weight of steam utilised by the engine may be obtained if the amount of leakage at glands, joints, jacket, cylinder drains, etc., are weighed and added." One can obtain the weights of steam used in jackets and also from the glands of a turbine, but to me it does not seem feasible to measure leakage from glands of a reciprocating engine or from pipe joints.

In connection with the Report, I was unable to attend any of the meetings except the last, when the Report was in its final form. I well remember the remarks of the Chairman, Mr. Patchell, who said that if the Report is right to-night it will be wrong to-morrow morning. It will always be open to criticism, and I criticise the inconsistency of the various Panels in their use of symbols. To give an example, one finds I used for total energy in the Steam Engine and Boiler Section and H used for total heat in another section. I rather fancy the nomenclature of the introductory matter to the Steam Engine and Boiler Section has a flavour of Professor Dalby, and if I might say so, I think he is wrong in calling I total energy. Total energy is equal to $H + \frac{v^2}{2gJ}$, H, being total heat a $\frac{v^2}{2gJ}$ the heat equivalent of the kinetic energy of the steam. Even Mollier makes this mistake when he labels the ordinate of his chart, total energy instead of total heat.

I wish the Committee had been able to deal with the reversed heat engine: *i.e.*, the refrigerator, for I think the Report of the Refrigeration Research Committee was left in an incomplete state. Their report included the thermodynamics of refrigeration by Ewing and a recommendation as to the unit of refrigeration, but did not include any information that would guide one in making and working out the results of a comprehensive trial on a refrigerating plant.

Mr. F. O. BECKETT: Mr. Wells has given us a concise history of the methods of testing from the days of our forefathers downwards, but there is one point I think we should acknowledge and for which we should perhaps excuse the earlier research workers, namely, that in carrying out his extremely delicate tests Professor Callendar has had the help afforded by modern instruments, which Kennedy, Rankine, and the others were denied. In 1926 I heard him say that he wanted to measure $780\frac{1}{2}$° F., and he had the aid of Thomson's galvanometer. In a somewhat similar manner to the use of the various numbers on the H.T. batteries of our wireless sets, so he could get the various degrees ranging upwards and downwards. It was like our early micrometers which were very difficult to graduate. I think that, apart from his great work, for which personally I am much indebted, we feel—at least I feel—that the improvements in modern workmanship have permitted the production of delicate instruments which have furthered the compilation of the present standard data in tabular form. The internal combustion engine is the result of that work.

Mr. SYDNEY A. SMITH, M.Sc. (By correspondence): I have read with interest Mr. Wells' paper, and think the author is to be congratulated on compressing the general textbook knowledge on the history of the steam engine into so few words.

In the opening paragraphs of the paper there are some rather hard things said about the ultra-practical man and with much of what the author says I am in agreement. Engineering to-day is becoming a more and more applied science, and the day of the " rule of thumb " man without fundamental principles is passing, if not already passed.

Granting this, I do think, as one engaged on the technical, as well as practical side of marine engineering, that the investigators of the past and present owe much to the practical man, and so far it has not been my misfortune to meet the man who would " double the diameter of the cylinder and piston rod " in order to double the output of his engine. I do not know if these men existed in the historical past, with which the author deals in his paper, but I am of the opinion that they would be very hard to find at the present day.

As the author deals almost exclusively with the steam engine I would like to ask what he considers the best relative efficiency basis for this type of engine. It is usual to refer the thermal efficiency of such engines to the Rankine cycle in which the ideal efficiency may be written,

$$\frac{\left(T_1 - T_2\right)\left(1 + \frac{xL_1}{T_1}\right) - T_2 \log_e \frac{T_1}{T_2}}{xL_1 + T_1 - T_2}$$

Where T_1 = Initial absolute temperature.

T_2 = Final absolute temperature.

x = Initial dryness fraction of steam.

L_1 = Initial latent heat of dry saturated steam.

and for superheated steam having a total absolute temperature T_3 we have,

Rankine efficiency =

$$\frac{\left(T_1-T_2\right)\left(1+\frac{L_1}{T_1}\right)+C_p\left(T_3-T_1\right) \quad T_2\left(\log_e\frac{T_1}{T_2}+C_p\log_e\frac{T_3}{T_1}\right)}{L_1+T_1-T_2+C_p\ (T_3-T_1).}$$

where C_p = specific heat of superheated steam at constant pressure.

With regard to the Diesel engine I have not had the opportunity of perusing the latest report mentioned by the author, but I would like him to state what he considers the best relative efficiency basis for this type of heat engine since the air standard efficiency, namely,

$$1-\left(\frac{1}{r}\right)Y-1$$

where r = ratio of compression

Y = ratio of specific heats $=\frac{C_p}{C_v}$

disregards the variation in the specific heat and the heat losses from the expansion and compression not being adiabatic.

Mr. E. W. L. Nicol. (By correspondence): As a member of this Institute whose privilege it was to represent the Institution of Gas Engineers on the Heat Engine Trials Committee appointed in 1922 by the Institution of Civil Engineers, and having attended regularly the numerous meetings of the main and certain Sub-Committees up to the time of the publication of the Report in 1927, I feel competent to offer a contribution to the discussion on Mr. Wells's interesting and instructive Paper. This claim to competence is supplemented by many years of power station experience which includes responsible participation in numerous official guarantee and regular routine thermal efficiency and fuel tests.

While I believe I fully appreciate the practical and scientific value of the Report, I am also conscious of its failure, in my opinion, sufficiently to emphasize the influence of what I regard as a factor of fundamental importance in testing steam plant, namely, the relative efficiency of fuels of similar description, but having widely different physical and chemical characteristics, as distinguished from furnace, stoker and boiler efficiency.

In the Test Codes provision is duly made for tabulating the proximate and ultimate analyses of fuels solid, liquid and gaseous; but the significance of these analyses is barely hinted at. The engineer or owner of the plant is left to draw his own conclusions, according to his knowledge and wisdom, as to the relative efficiency of, say, two steam plants similar in size and detail, but differing in the fundamental characteristics and in the physical condition of the fuel used; and as Mr. Wells has refrained from criticising the Report, and has eulogized it as an " important epoch making work," a few words of constructive criticism here may possibly add to the interest of his Paper and, conceivably, may enhance the practical value of the Report itself, to members of this Institute.

I am aware that every facility was extended to scientific bodies throughout the world to criticise the draft Report before final publication; but to my knowledge the point I wish to emphasize here has not been raised.

In Appendix V. the Report contains the following general remarks and definitions :—

" It is desired to urge with emphasis the use of the gross or higher calorific value as a basis for calculation.

" The gross calorific value of a fuel is measured by the number of B.Th.U. generated by the complete combustion of 1 lb. of that fuel, all the products of combustion being cooled to 60° Fah.

" The net calorific value (hitherto used as the basis of calculation) is measured by the gross value, less the latent heat (reckoned at 1055 B.Th.U. per lb.) of the water condensed from the products of combustion by cooling to 60° F.

" The net calorific value of the fuel can be found from the following formula :—

" Net calorific value per lb. of fuel = gross calorific value less 1055 B.Th.U. (number of lbs. of moisture plus 9 × number of lbs. of hydrogen).

" The general effect on the thermal efficiencies of boilers and I.C. engines is indicated in the following table, in which for an assumed net value the probable corresponding gross value is given :—

Fuel.		Thermal Efficiency. On net value.	Thermal Efficiency. On gross value.
Boilers	Coal	85%	81%
	Oil	85%	79%
	Coke	85%	84%
I.C. Engines	... ...	35%	32%

" When determining the thermal efficiency of a boiler or of an I.C. engine, that part of the products of combustion which is not usually utilized has often in the past been excluded; it is this part which is deducted from the gross value to obtain the net value.

" To apply this definition it has to be assumed that the whole of the hydrogen in the fuel has been burnt to water and that the percentage of hydrogen in the fuel is known.

" To obtain this information a chemical analysis is required, *and the trouble and expense thus involved is hardly justifiable in these trials for industrial purposes.*"

Mr. Wells in the course of his Paper remarks the possible adverse influence of inefficient auxiliaries upon otherwise efficient steam engines; but how much more positively adverse is the effect of inefficient fuel? Casual reading of the Report may convey the impression that one B.Th.U. is as good as another; but consideration shows that due regard must be had for the company they keep. Reference to the table quoted above shows that the difference between the net and gross calorific values may vary from 1% to 6% according to the hydrogen content of the fuel alone, while the calorific value, as determined by the calorimeter, may be identical. Therefore, every thermal efficiency test is virtually also a fuel efficiency test; but this point appears to have been, at least, not sufficiently emphasized; and in my opinion, no trouble or expense should be spared accurately to ascertain the true " availability " of the fuel by determining the hydrogen content. Purchased on a thermal value basis this potential but " unavailable " heat has to be paid for; and its adverse influence (amounting to as much as 6%) on the thermal efficiency realized should be only too apparent to both users and manufacturers of plant.

That all solid fuels are not equally efficient in the boiler furnace is a very old observation among engineers of the " ultra practical " school who know how to apply this knowledge in the best interest of their employers who, as commercial men, are interested primarily not in thermal, but in commercial efficiency, *i.e.*, the actual cost per unit of power.

As standards for comparison the Test Codes framed by the Heat Engine Trials Committee will lose much of their undoubted value if the point which I have endeavoured to make is overlooked by users of the Codes for boiler and engine testing. Theory must always, of course, follow good practice; and if one of the " select few " referred to by Mr. Wells as those who live in constant contemplation of mathematical hieroglyphics, and continue to draw their salaries, could be induced further to elucidate the question of relative fuel efficiency and to devise a system of classification and annotation of fuels according to their radiant efficiency and the difference between their gross and net calorific values, members responsible for the purchase of fuel and the operation of steam plant would, I am sure, be very grateful.

Mr. D. L. THORNTON, Member. (By correspondence): The interesting Paper by Mr. Wells urges one, as a practical engineer, to pass a few comments thereon lest some of us, and apprentice engineers in particular, receive wrong impressions concerning the foundations of our professional activities.

It may be true that the " ultra practical " man may be ignorant of some points, but the practical man is, of necessity, a reasonable interpreter of the true facts concerning the world in which he lives—otherwise, the history of the achievements of practical engineers in the past would call for serious correction. It has been my good fortune as consultant to work with practical engineers in many parts of Europe, North and South America, and I must confess that I have never experienced their want of engineering knowledge such as Mr. Wells appears to have felt when coming into contact with this group of men that forms the backbone of the structure of engineering progress. The diameter question referred to in the Paper may frequently arise in the career of students trained only in colleges—and after they have left these institutions—but one is seriously inclined to doubt its occurrence amongst even a small percentage of the mass of practical engineers.

An examination of the progress of engineering science will give rise to a feeling of doubt regarding the assertion that theory is always behind practice, for are there not very many instances where theory has preceded practice—and has even indicated the path of future progress. May I suggest a few occasions, in the sphere of natural philosophy, when the initial stages were those of pure theory and in which the subsequent and dependent practical applications had, and appear to possess, important influences on human welfare. At random, these may include: Faraday's electrical theories and their applications to motive power, Hertz's theory which revealed the possibilities of wireless telegraphy, the " porous plug " theory and its applications of the brothers Thomson, the Quantum theory of Planck which suggested the foundations of our present knowledge concerning the structure of matter, Einstein's theory of Relativity which preceded and predicted the discovery of the distortion of a light—ray (a subject not unrelated to practical astronomy), and Eddington's theory of Radiative Equilibrium of gaseous masses. This list may be extended considerably, but one feels that further examples would be superfluous at the present moment. Would it not have been more accurate for the lecturer to have said that theory and practice are but two equally legitimate aspects of engineering science and that the exclusive use of either was open to abuse? Or, are we to understand that the mind of the practical man is mainly concerned with " l'art de s'égarer avec methode "?

Is it not a distortion of terms and their true meaning to say that " a theory is an hypothesis "? From the Greek theorema (to view) we have always understood a theory to be a law of the mind applied to phenomena, and at the same time remembering that any synthesis of natural phenomena is a limitation of the realisation but not of the content of the science involved. In short, an hypothesis may be part of a theory, but in a general way one cannot further extend the connection between these two terms, for an hypothesis is a proposition merely assumed for the sake of argument.

Further, is not the Paper unduly critical of " abstruse mathematics " when we recall the fact that the monumental work of Willard Gibbs is based on foundations which were carefully and laboriously laid by the pure mathematicians of the past. I am inclined to demur to the assertion of the Paper that the intelligent grasp of thermodynamics has been greatly hindered by the general use of abstruse mathematics; is not the mathematical symbolism an inherent part of the concept of energy? Maybe, the first fault lay with the teachers of engineering in not making themselves acquainted with the mathematical instrument at their command? Let us examine the concept of entropy, which I suppose to be in the mind of the lecturer from the symbols referred to by him, in the spirit of these observations of mine. A general difficulty in the conception of entropy is due to the fact that it is not possible to define the equality of entropy of two chemically different bodies, although it is possible to compare the variations of entropy to which the separate bodies are subjected. The modern conception of entropy involves the postulate that the path of physical phenomena is, so to say, in a definite direction which cannot be reversed. This rigorous view is held by those who have examined the subject from the molecular and atomic standpoints, and connotes that the concept of the principle of increase of entropy is a statistical principle based on the laws of probability as enunciated by Gibbs and Boltzmann. In short, the entropy of a system is expressible in terms of the numerical value of the probability involved in the problem. If we are inclined to complain of the involved and complex nature of phenomena open to us as engineers, we do not bring nearer a solution of our difficulties by decrying the symbolism which adequately reveals the problem before us as practical interpreters of the sources of power open to the service of mankind.

After reading " Experimental Researches " (vol. III., p. 1), and Helm's " Die Energetik," I should, at least, be inclined to couple the name of Faraday with that of Joule as the initiator of the conception of the conservation of energy.

After all is said, is it not the duty of engineers to pay silent homage to the memory of that long procession of those to whom we are indebted by using the results of their labours in our interpretation and expression of ideas concerning the foundations of engineering science. By all means, simplify the mathematical symbolism used by these pioneers of human thought and endeavour, but do not allow this process of simplification to distort or hide the exact significance of the process under examination.

The AUTHOR'S REPLY: During the discussion much time was devoted to the " Willans' Line," and it was evident from the remarks made that the origin of this line was not correctly appreciated. Attention was first called to the matter by the late Mr. P. W. Willans in the discussion on a paper by Mr. Crompton on " Electrical Energy " (Proc. Inst. C.E., vol. cvi., p. 62) on which page is shown a diagram giving the " total water per hour," plotted against I.H.P. and E.H.P., and in explaining this diagram Mr. Willans said that the observations taken at a test of an engine " fell sensibly on a straight line," also a little later he adds that " the expansion was not varied," but " the power was altered by varying the steam pressure." That is the engine was throttle governed and ran at constant speed. On page 64 the formula proposed was—

$$W = w + S \tan \theta \, H;$$

where W = total water per hour at useful power H; w = total water per hour at zero useful power; S depended upon the relative scales of horse-power and water; and θ was the angle which the line passing through the points indicating total water consumption made with the base line. This was in April, 1891, and the next important date is April, 1893, when during the discussion on a paper dealing with the second series of "Steam Engine Trials," made by Willans, took place. In consequence of the death of Mr. Willans this paper was presented by Messrs. Robinson and Capt. Sankey, and in describing the trials, the method of plotting was mentioned (Proc. Inst. C.E., vol. cxiv., part iv.), and in his remarks at the conclusion of the paper Mr. Mark Robinson said that "undoubtedly the most noticeable feature was the straight line law of the total steam consumption which his colleague Capt. Sankey had asked him to suggest should be called the Willans' law. Later in the discussion, then Prof., now Sir Alex. B. W. Kennedy, commenced his remarks by saying a few words out of a point which Willans had made peculiarly his own—the matter of the way in which steam consumption represented itself graphically, which he was glad to hear that Capt. Sankey proposed to call the Willans' law. It was astonishing, if not even humiliating to think how long this thing has been lying straight under one's eyes and yet had not been seen. It had been customary to plot curves per I.H.P. without taking the trouble to plot the actually observed quantity—the weight of water used per hour. Thus many things escaped notice that would otherwise have been seen." Prof. John Perry in his book "The Steam Engine and Gas and Oil Engine," on page 83, writes "It is a law of great practical value to us in our calculations"; and in other places gives exercises and calculations involving the use of the Willans' law, and in paragraph 161, he shows by analysis, how from theoretical considerations the enunciation of the law might have been anticipated. But enough has been stated to show that the law was discovered by Willans from observation made during his tests made on his engines, also that it was accepted by his contemporaries as a new and valuable addition to knowledge.

Mr. Jackson seemed to put the "cart before the horse" in his references to the Willans' law. The linear law between two variables x and y, is simply a general expression in co-ordinate geometry representing simultaneously the co-ordinates of points on all straight lines, and is so far only an abstraction. "Willans' law" states a physical fact, and is in that sense unique, and not general for all facts. If Mr. Jackson turns to "Mann's Practical Mathematics," published by Longman, he will there find much useful information about the discovery of formulæ for curves resulting from experimental data; but he will soon be in trouble if he tries to fit everything to a "straight line" formula.

Some exception was taken to the example of what a Practical Engineer would do, but the critics overlooked the latter part of the author's statement, that it would be urged that there are not many who would err so palpably, and that this criticism would *be valid*. If this and the following sentences about perpetual motion patents had been read; the critics could scarcely have said as much as they did about the example given.

In making investigations into the behaviour of things, certain observations result from the experiments that are made. If these observations are quantitative in character, they may be plotted in terms of the variables. When such plottings are completed, they are usually found grouped, and apparently they lie in such way that a curve may be sketched, so as to lie evenly amongst them. Those spots that lie farthest away from this line, it may be assumed, are experiments in which an error has been made in measurement, and should be repeated to see if the recorded value is correct. When the final curve is sketched in place so as to represent the best values, the formula for that line may be computed, and the law so found is an empirical law. The reason for this is clear, as the line sketched is the result of the judgment of an individual at a particular instant. After more experience, and experiment, he may be led to reject some of his earlier data, and as a consequence will amend the position of his line, leading to a change in the value of his constants in the formula. But later the exact explanation of the phenomena under examination becomes known, so that in the light of reason, the formula may be determined exactly, experiment only being necessary to exactly determine the value of the constants involved. Such a formula is rational or reasonable. Callendar's work on the formation of steam, or possibly Prof. Dalby's "Steam Power," chapter iii., would help Mr. Jackson to realise the wonderful addition to our knowledge of the properties of steam, that has been made as a consequence of the work done by Prof. Callendar. It is this work that has made possible a rational formula for the properties of steam.

Some attention in the discussion was given to the question of fuels—Mr. E. W. L. Nicol, in particular, dwells upon this in the course of his remarks—and their suitability for use in steam raising. In the course of his remarks, he states that in his opinion the Committee in their report did not stress the effect upon the relative efficiency of steam plants, in which the chief difference was in the physical condition of the fuel used. Later on he states that the "Casual reading of the Report may convey the impression that one B.Th.U. is as good as another," and so on. Again, he states that "the actual cost per unit of power" is the item that counts.

As a member of the Committee it seems to me Mr. Nicol cannot have attended regularly the meetings, or have read closely the conclusions arrived at by his colleagues upon the points to which he refers. On page 9 it is stated explicitly that the "principal object has been to *standardize the methods of recording observations and of expressing the results.*" A few lines lower down we read "*that the trials of heat engines should be made only by fully qualified engineers, and that this Report is not intended to enable trials to be made by those not so qualified.*" These quotations have been italicised, for they virtually answer all Mr. Nicol's criticisms.

If Mr. Nicol tests a plant, and determines the several quantities relating to steam generation detailed in the Report, he will at the end of the test have the calorific value (gross) of the fuel as delivered to the furnace; its analysis complete and/or proximate, as he may consider necessary; the analysis of the flue gases, at the proper points in their passage to the chimney: the quantity and character of the ashes, collected during the test, from which it is submitted, that the competent engineer will be able to determine the exact efficiency of the furnace, because he will know as nearly as it is possible to ascertain the exact behaviour of all B.Th.U. supplied. If this result is poor then the measurements of fire-grate; its area; the area of air spaces in grate; furnace volume, character of furnace walls, heating surface, and so on, *all of which are noted*, will surely supply sufficient data, upon which to base a reliable opinion that the fuel is *unsuitable*, or that the conditions under which it is being utilised *require modification*. Surely the object of a test is to discover all the defects in the plant, to prescribe remedies for the same, and so enable the "practical man" using or designing such plants to obtain better commercial results. The Report contains special items for solid, pulverised, gas, and oil fuels, so that I think that the Committee have actually provided for all the points raised by the several speakers on this section of testing a power plant.

Mr. Thornton's contribution, which ranges over such a wide field, mentioning matters that are interesting, but touch only very remotely the subject under discussion, *i.e.*, engine testing. The early part of his remarks appear to be a very confused effort, to show that theory precedes practice, and some of his suggestions are singularly inappropriate and unconvincing. Similarly, the remarks upon the criticism of the use of abstruse mathematics in the paper, is so very wide of the mark that the only conclusion possible is that Mr. Thornton's experience and knowledge must be peculiar to himself, perhaps irreversibly isentropic?

In reply to Mr. Smith the most suitable standard of comparison for steam engines is the Rankine engine, as stated in the Report on page 13 and elaborated in the context.

It is hoped that this rather long reply has not overlooked any important points, and it only remains to add the author's appreciation of the reception of the paper, and of the subsequent spoken and written discussion, he is very grateful for the many kind things said.

The CHAIRMAN: We are very much indebted to Mr. Wells both for his paper and his reply to the points raised in the discussion.* The subject has raised an interesting discussion and I am sure it and the paper will be read with great interest by our members. I would like to propose a hearty vote of thanks to Mr. Wells.

The meeting terminated with a vote of thanks to the Chairman, proposed by Mr. W. McLaren.

———o———

Contribution from W. Brooks Sayers (Member):—

COAL. A PROPOSED SOLUTION.—The proposed solution consists in developing and financing a scheme by which every colliery coming within a determined category as regards possible economical working should be kept working at full bore, or at some ascertained most economical rate irrespective of the immediate demand for actual consumption or exportation. By the most economical rate is meant the rate at which the coal can be won and brought on to the surface at the lowest cost per ton while paying reasonably good wages to the miners and personnel and reasonable profit to owners.

Thus abundant coal at minimum cost is to be available to all industries and consumers.

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* Kindly elaborated subsequently, including the contributions by correspondence.—J.A.

Coal is to be sold without restriction except that price must not exceed a determined figure based upon actual cost of raising and transport with reasonable charges for profit.

The Government or a powerful syndicate of financiers and/or bankers is to purchase (or pay charges for storage, and/or interest on capital involved) all surplus coal beyond what is sold or consumed.

Such surplus coal to be suitably stored under seal and warrants or certificates issued for every (say) 10, 25, 50 or 100 tons stored. This surplus of "sealed" coal is not to be put on the market unless under emergency or with a predetermined period of notice.

The principle is that coal is to be steadily raised from the mines and stored upon the surface, as a *first class national asset* and requirement for industrial and economic essentials, *i.e.*, production of iron and steel, power, light, heat, transport, etc.

As a means or method of carrying out the proposal in a manner helpful to trade and beneficial in every way it is proposed that coal should be packed at the pit's mouth into iron containers that can be carried on railway trucks or directly on bogies or chassis for transport by rail or road, also lifted bodily on to shipboard. Such iron containers should be so constructed as to be available either for return produce (say from abroad) or saleable as items for building or other purposes.

They might therefore be built of standard size squares of galvanised iron with angle iron around edges and bolted together to form container of the size and capacity found most suitable in varied conditions. The tare of the container would be marked on it and weight of coal deduced from total weight.

Such iron or steel squares could be incorporated in design of steel houses such as advocated by Lord Weir.

The surplus coal going into store above ground as proposed would be in closed-up containers sealed with a Government or other seal of guarantee as to contents, and warrants issued for such containers either to be held by Government or company of financiers who would pay interest on the capital involved instead of or in substantial reduction of doles to unemployed miners or say income tax to financiers or holders of warrants.

The sealed and stored coal would be dealt with as a national asset having undoubted absolute value. The method would be tried for a limited period of years, or until sealed and stored coal reached some determined aggregate amount.

APPENDIX.

The cost of coal raising is not limited to the financial side, there is a continual toll of valuable lives. To reduce this toll it is suggested that important collieries should be provided with one or more steel carriages or a train of several, capable of being closed up air-tight with air-lock doors for ingress and egress driven either on rails or road with accumulators and motors, electrically lit, provided with compressed air and oxygen in cylinders, and equipped for exploration of conditions of mine, rescue and first aid after accident, explosions, etc.

18/5/1928.

P.S.—I had thought that currency notes could rightly and wisely be issued in respect of 50% of value of coal raised. A brother, however, whose opinion I think to have considerable weight, approves my scheme, and thinks that coal warrants should be legal tender equally with currency notes, and that the Bank of England should be authorised when it has demands for gold to meet those demands up to 50% with coal warrants, including war debt to U.S.

W.B S.

Notes.

The following is from "Fairplay" of April 5th:—

STABILISATION OF THE WELSH COAL TRADE.—Since about the middle of last year, representatives of the South Wales coalowners have been strenuously engaged in formulating a scheme aiming at the stabilisation of the coal trade, and a few days ago what may be regarded as a partial operation of the new arrangement was introduced. It will be recalled that about a fortnight ago it was announced that the formation of the South Wales Coal Marketing Association had been completed, and that the Executive Committee, which was to administer it, was to function immediately, the measures to be adopted with a view to bringing about stabilisation being: (1) A contribution of 3d. per ton on the total output raised at each colliery in every period of four weeks; (2) compensation not exceeding 2s. per ton on output lost owing to want of trade; (3) grouping of collieries, classification of coals, and fixing of minimum prices; (4) a penalty of 2s. per ton for selling below the minimum prices; and (5) effective control by the Marketing Association of all matters appertaining to the scheme. It was then expected that the full details of the grouping of the collieries and of the minimum prices would be announced almost immediately, but apparently this is a part of the task undertaken by the coalowners which has presented many difficulties not to be easily surmounted. Anyhow, up to the end of last week the executive committee had not, so far as could be gathered, succeeded in dealing with other than the Monmouthshire group of coals, for which increases in prices ranging from 3d. to 6d. per ton in excess of those recently ruling were put into force. This arrangement, however, it is believed, is likely to prove temporary, inasmuch as it was largely the outcome of the fact that the prices ruling for some length of time for these classes of coal were relatively lower than those of other descriptions of large seams.

The method of the coalowners in dealing with only one section of the industry came in the nature of a surprise to the market, and there was a strong feeling amongst coal shippers generally that minimum prices should not have been introduced until such time as the owners were in a position to apply them to all the various grades of coal. At the time of writing it is not definitely known when the executive committee will complete its task and furnish the market with the complete list of prices which it is intended to attempt to establish, but it has been somewhat freely reported that, apart from an increase in the Monmouthshire coals referred to, very little variation in the prices at present ruling is contemplated. While it is conceded on practically all sides that the owners are fully justified in making every possible effort to put an end to the disastrous financial losses which have been incurred for so long, it is felt not only that the various descriptions of coal should have been dealt with simultaneously, but, moreover, that coal exporters should have been given a fair amount of notice as to the date on which the new scheme was to operate, if only for the purpose of acquainting their buyers abroad of the proposed changed conditions. The hope is further expressed that the owners when finally agreeing upon both the classification of the collieries and of minimum prices will bear this aspect of the question in mind. Otherwise, difficulties and delays, with a possible loss of business, are likely to be encountered at the outset, thus setting up interference with the ordinary channels of trading which may prove something more than vexatious.

Of course, the experience which has so far been gained of price control methods has been altogether too limited to enable definite and comprehensive views being formed as to the ultimate effect of such measures, but it can at least be said that the views which have been more latterly expressed in South Wales coal-exporting circles are not altogether favourable to such means being employed for the purpose of establishing prices which it is hoped will at least permit of working costs being covered. Rather, in fact, is the opinion very largely held that the more suitable, if, indeed, it would not eventually prove to be the real and only remedy for the present parlous state of the industry is to be found in co-operation and reorganisation between the owners and the miners. There is undoubtedly much to be said in favour of this view, for while control of prices may possibly in the long run prove of much benefit to the industry, the fact cannot be overlooked that it is equally possible that it will be attended with consequences that will do anything but assist in restoring the industry to its former prosperity. Thus, while the results of the measures at present contemplated are problematical, it has on the other hand been demonstrated in a very notable degree in many cases that much has been done in the direction of turning losses into profits by co-operation between the masters and the men.

A few illustrations of what has been accomplished in this respect have been provided recently by competent authorities. They are worth repeating. In one case a Welsh colliery had been closed down for thirteen weeks because a steady loss was resulting on the sale of each ton of coal. It was restarted on a co-operative basis, and in a few weeks the output was increased from an unprofitable eleven hundredweights per man to over 20 hundredweights per man. Moreover, only about half the number of the men working at this colliery in pre-stoppage days are now employed, yet they are producing more coal. In another case, a colliery was on the point of closing down when it was decided as a last hope to introduce the co-operation principle. In one week the output rose from 3,200 tons to 3,800 tons, while the average is now said to be 4,700 tons. In all, about twelve or thirteen Welsh collieries have tried the co-operation basis of working, with results which so far have proved decidedly satisfactory.

Apparently, however, the coalowners, or at least a very large majority of them, are now definitely committed to the coal price stabilisation scheme, and it will possibly be introduced in all its bearings either before or immediately after the Easter holidays. That its advent is awaited and will be followed with considerable interest there is not the least doubt. Also its influence on the general coal trade situation will be given close attention, for it is felt that such a departure from old-established methods cannot be made without at least decidedly unsettling effects. Coal exporting firms with large connections in most of the foreign markets are also somewhat concerned as to the attitude which will be adopted by buyers abroad in the event of a higher level of prices being decided upon than those now current, although for their own part they are of the opinion that, under a continuance of present conditions in the world's coal trade, the price of the Welsh commodity will eventually be determined by the world price.

A Nippon Yusen Kaisha Film.—At the invitation of the N.Y.K., a distinguished company witnessed, at the Scala Theatre, Charlotte Street, W., on Thursday evening last week, a special film prepared by the Company, showing the route followed by their vessels on their twelve thousand mile passage to and from Japan, together with life and incidents on board ship. The sights at the chief ports of call were also shown, and the chief cities and beauty spots in Japan depicted. The second half of the programme was devoted to descriptions of the chief Japanese industries. During the interval the London manager of the Company, Mr. J. Blair, thanked those present for their attendance, and said he hoped the films would show that the Far East, especially Japan, has varied attractions for the tourist. He also pointed out that the N.Y.K. fleet now exceeded 750,000 tons, in addition to a shipbuilding programme at present on hand of three new motor-vessels of 16,000 tons gross each and a speed of 18 knots, also two new vessels of 10,500 tons, for the improvement of the European mail service. Referring to the passenger business, Mr. Blair stated that there had been a steady increase of passengers since the war, and that the Mediterranean cruises during the summer season had become very popular. Illustrating the moderate cost of a first-class passage from London to Yokohama and back, he pointed out that, in a journey occupying 96 days, the cost was only £184, and suggested that, ignoring the fact that the passenger was carried 24,000 miles, the rate charged was less than the cost of staying in a first-class hotel.

The following is from "The Iron and Coal Trades Review" of April 13th:—

THE BURDENS OF INDUSTRY.—Now that the financial year has ended with an unexpected surplus, it is natural that a demand should be made for a contribution to local rates from the Exchequer. According to an admirable memorandum on the "Burden of Local Taxation," prepared by the Engineering and Allied Employers' Federation, the burdens which have to be borne by industry are becoming intolerable. Since 1913, according to the Balfour Committee, the money cost of local rates and services per unit of output has at least trebled, so the difficulty of meeting foreign competition has been correspondingly increased. In the engineering industry the cumulative load of rates and social charges payable in respect of raw or semi-manufactured materials means an addition of 9 or 10 per cent. to the selling price. The memorandum recognises that most of the social services were imposed by Parliament, and politicians are not easy to move in the direction of modifying them. But where unemployment benefit and the Poor Law relief are concerned, the case is different, "because the administration of these two services leaves much to be desired in the way of improvement and economy."

A table shows the cumulative costs of rates and social services per ton of finished steel (from coal and ore to the finished product) in the years 1913 and 1923. Five firms appear in each year; in each case the amount is given for local rates, workmen's compensation, and national insurance. Firm A (black C/A sheets) paid 2s. 5d., 1s. 5d., and 6d. respectively in 1913; ten years later the charges had risen to 3s. 6d., 2s. 6d., and 2s. 8d. respectively. Firm C (making steel rails) paid only 1s. 10d., 8d., and 4d. in 1913; ten years later it paid 5s. 9d., 1s. 5d., and 1s. 4d., a combined increase of 200 per cent. A firm making tinplates found its total expenditure increased from 3s. 5½d. per ton to 11s. 8d. per ton. We should observe that iron and steel manufacture, mining, and quarrying were not insured trades for unemployment purposes before the war. In 1913 the annual sum paid to the Unemployment Fund by employers and workpeople was about £1·6 million; in 1924-25 their contributions had risen to £36·7 million, with a contribution from the taxpayer of £13 million. Another table, printed at the end of the memorandum, shows in detail the astounding growth in the cost of social services between 1911 and 1926. Excluding £64 million for war pensions, we find that the totals increased from £63 million to £287 million; part of the too much heavier spending, with no corresponding increase is due to new services, but a large part improvement, on old services such as education.

Some interesting details regarding the cost of rates, taxes and social services in the coal, iron and steel industries are given by Lord Balfour's Committee on Industry and Trade in their volume on "Further Factors in Industrial and Commercial Efficiency," extracts from which were commenced in last week's "Review," and are continued elsewhere in this issue. It will be seen that taking 1913 as equal to 100 the cost of rates, property tax, and social charges in the mining industry during May-July, 1925, was 315. Particulars relating to the iron and steel industry abstracted from the same source are given in the following table:—

Comparative Costs of Rates, Property Tax, and Social Services in 1913 *and Post-War Years*, 1913 = 100.

	1924.
Basic pig-iron	197
Semi-finished steel	247
Sections	292
Shipplates	288
Tinplates	508
Wire	381
Wire netting	263*

Seeing that these figures relate to different periods, and include rates and property tax, they are not quite comparable with the details regarding iron and steel given by the Federation and enumerated above.

According to the memorandum, industry contributes directly not less than one-fourth of the total rates levied in Great Britain. Between 1914 and 1926 the sum raised by rates increased from £79 million to £166 million. Of course, an allowance must be made for the fall in the purchasing power of money; at the values of 1925 the rates per head would have been £3 0s. 6d. in 1914 and £3 15s. 10d. in 1926. Since that year rates have increased, and the total for 1927 may have been £180 million; of this last total something like £54

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* 1925.

million was spent on the relief of the poor. The engineering employers describe the sample analyses of the Ministry of Labour, which we gave last week, as "neither satisfactory nor conclusive"; they suggest that the Department dealing with the question is not the right body to make the analysis. They suggest a Royal Commission into the whole question of the unemployed, of unemployment insurance, and of the relation between unemployment benefit and Poor Relief. As everyone knows, the Unemployment Fund is heavily in debt (£24 million), while many Boards of Guardians have borrowed large sums from the Government. There is nothing so depressing, we are told, "as having to pay off a debt." The memorandum wants to separate the dead load of these debts from the current load.

At the annual meeting of the Amalgamated Anthracite Collieries, Sir Alfred Mond spoke strongly about the cumulative burden of local rates and railway rates. In one colliery area he found that local rates were 31s. 2d., compared with 10s 2d. in 1914. Over the whole of the A.A.C.'s collieries local rates represent about 5d. per ton; railway costs to the port of shipment are now 2s. 2½d. per ton, against 1s. 4d. per ton in 1913. Dock and loading charges are about 80 per cent. more than they were before the war. Altogether the charges over which colliery owners have no control mean a serious handicap in competing with coal producers on the Continent. In most European countries, as Mr. E. L. Hann said at the Powell Duffryn meeting, the Government helps the coal industry by means of reduced railway rates or in some other way, such as the import restrictions in Spain and in France. The Powell Duffryn Company finds that the railway charges for conveyance, tipping, and weighing work out at 2s. 2d. per ton on the average as compared with 1s. 0½d. before the war.

In spite of the increased goods rates which came into force in February, 1927, the Railway Companies are not showing as good traffics as they did a year ago, and it seems most unlikely that any of them will earn, during 1928, the standard revenue contemplated by the Railways Act of 1921, while the North-Eastern will be lucky if it can maintain the trustee status of its prior charges. There is reason to believe that the statistical foundations on which the Act of 1921 was based are sinking under the impact of road competition. The road vehicle, having to pay only a trifling licence fee for the most costly part of a transport service, *i.e.*, its permanent way, can quote rates for high-class traffic considerably below those charged by the railway companies. The Act of 1921, and, indeed, every Act fixing railway rates and fares, has been based upon a distribution of the probable traffic into various classes, the idea being that the expensive goods can afford to pay a much higher charge per ton than the cheaper goods, such as coal, ore, iron and steel, etc., which in effect, are carried at subsidised rates. But now the expensive goods are being carried by road-transport concerns, which, not being common carriers, can pick and choose their traffic, and will not take the low-rated goods. Consequently the Railway Companies try to make up their standard revenue by raising their charges on the heavy traffic, which must go by rail because the road concerns refuse to carry it.

The proposed relief in the matter of local rates which the Railway Companies are likely to secure, should be of material assistance in maintaining for them a reasonable margin of revenue, whilst enabling the coal, iron and steel, and engineering industries to benefit by a reduction in freight charges, which should be a condition of the relief, and follow automatically. If the Companies desire to render the heavy industries the much needed assistance which is imperative to enable them to recover some of their former prosperity, really substantial cuts must be made in railway rates and charges. Such a step undoubtedly would soon be justified by a greatly increased volume of traffic. For the bulk of their revenue the Railway Companies depend on the coal, iron and steel, and engineering trades; if these could be brought into greater activity by lower railway charges even at an initial though temporary loss of revenue to the Companies, a real service would be rendered to the country, and ultimately to the railways themselves.

From "The Shipping World and Herald of Commerce," April 25th:—

THE PROBLEM OF COAL PRICES.—The coal industry of Great Britain is face to face with a situation of great gravity, and a united effort by all who can help to re-establish its prosperity is necessary. It is confronted with difficulties beyond its control, such as the artificial stimulation of exports which is being adopted in Poland and elsewhere. Coal has hitherto been the great asset of this island country, and its main bulky export. For many decades prior to the war, coal-mining was a flourishing industry. In coal exports Britain had almost a monopoly, and many foreign countries depended on British mines for their supplies of fuel. Along the seaboard of the Atlantic, the Mediterranean, and the Indian Ocean as far as Colombo and Singapore, there were great depots from which ships drew their bunker supplies, and these were stocked with British coal. The war wrought a great change, and the post-war problem that confronts the industry is proving almost insoluble. For many reasons the export trade has been diminishing. The suspension of supplies during the war, the extraordinarily high prices charged for export coal when supplies again became available, as well as the irregularity with which supplies have been forthcoming in recent years owing to stoppages, taught our foreign customers to look elsewhere for their coal.—Moreover, other sources of power, light, and heat have been developed; oil has encroached on the realm of coal in many ways, and hydro-electric power has been utilised. British coal has lost the monopoly it once possessed.—In 1927 our exports to European countries were only 37,000,000 tons, as compared with 52,000,000 tons in 1913.

Some of the reasons for the falling off are of an artificial or political nature. The arrangement in the Versailles Treaty, whereby Germany was to make reparations in kind, has meant that Italy, formerly one of our best customers, has been drawing much of her coal from Germany. Again, both in France and Spain partial embargoes (of a protectionist nature) have been instituted to safeguard the coal industry. Preferential railway rates on coal intended for export are in operation in France, Belgium, Poland, and South Africa. In the case of Poland, there has been a deliberate and carefully planned effort to capture the Scandinavian market by undercutting British prices, and the effect has been very pronounced. Sweden, Norway, Denmark, and Finland each show great decreases in the amount of British coal imported, and great increases in the quantities received from Poland. The distance from the Silesian coalfield to Danzig or Gdynia is about 400 miles, and the rail rate for coal intended for export for this distance is about 3s. 6d. per metric ton, which is less than half the price charged for ordinary train loads. That this rate is of a "dumping" nature is evident from the fact that Polish exports to Austria enjoy no similar privilege. Although Vienna is much nearer than Danzig, not only are the railway charges greater, but the prices of Silesian coal are much higher. In this way the Polish coalowners are able to quote prices, f.o.b. Danzig, at figures which are very attractive to Scandinavian importers; and a recent instance is a contract with the Swedish State Railways for 93,000 tons of coal at 11s. per ton, which was far below the price quoted by Northumberland owners. In face of these difficulties, British coalowners and exporters are struggling to gain the ground that the industry has lost. It is a hard struggle, and it is not made easier by the conditions which have been imposed upon them. In many mining districts the total cost of production has greatly exceeded the sale price of the coal. The miners have protested against reductions of wages, and the disastrous strike of 1926 was a sort of blind resistance to economic law. The restoration of an eight-hour day has somewhat bridged the gap between production costs and selling prices, but the industry is still labouring under heavy difficulties. High local rates and high railway charges still exist, and have, if anything, been increased. And, all the time, competition has become keener; it is impossible to maintain high prices for export coal when foreign customers can obtain their coal from other sources or do without it altogether. Apart from readjusting burdens of taxation and rating the Government can do little to help. In a tentative manner the coalowners are endeavouring to meet the situation. The various schemes for amalgamation may aid in reducing overhead costs and in reviving the export trade. An increased use of coal in the propulsion of ships will mean a larger market, and there are hopeful indications that this market is being created. But as long as coal is sold on the Continent at artificially reduced prices, the struggle will be a hard one. However, there is always a limit to these artificial experiments, and economic law reasserts itself in the long run. The point of present interest is whether the limit can be brought nearer by diplomatic or other pressure.

CHANGED CONDITIONS.—"In years gone by, when this country had what amounted to a monopoly of manufacturing, a policy of supplying demands as they arose served us well; that policy is now insufficient and inadequate. If we do not create a demand for our goods, other nations will create it for theirs."—Sir James Martin.

MINEOWNERS AND THE COAL PROBLEM.—"Notwithstanding the increase in motorship tonnage, I, for one, do not believe we have heard the last of steam. I certainly believe there is an opening for great developments in powdered fuel systems of firing. It is time the collieries woke up. It is wrong to leave the problem of the depression in the coal trade to be solved by engineers and scientists, and the people who ought to be doing most at the moment, are doing the least."—The Duke of Montrose.

ONE-SIDED THINKING.—" The modern habit of objection to competition arises from the modern political folly of thinking of only one side of trade and industry. We insist upon concentrating the whole of our attention upon the maker of an article, and forget altogether the other person or persons whose need of the article is the only excuse for the making of it or for the existence of the maker. Without competition, no market would ever have come into being, and if the attempt to eliminate competition succeeded, every market would wither and disappear. We should thus drift into forgetting one need after another."—Sir Ernest Benn.

CREDIT AND TRADE.—" No one realises better than I the justification for criticisms against Government trading. I need make no apology for the Government export credits guarantee scheme, but I must add that if private enterprise were in a position to give this assistance which traders demand there would be no necessity for Government interference. In the fight for overseas markets, credit plays an important part. Your goods may be right, your prices keenly competitive, but the scales will be weighted against you if you do not give the same amount of credit as your competitors." Mr. Douglas Hacking, M.P., Secretary of the Department of Overseas Trade.

THE COASTER " DIAMOND.". — The coasting steamer *Diamond*, recently completed by the Burntisland Shipbuilding Company, Ltd., for Mr. William Robertson, of Glasgow, is of particular interest to marine engineers, as she is the first ship to be propelled by an engine of the Beardmore-Caprotti poppet-valve type. She is a raised quarter-deck ship with a length of 175ft., a breadth of 27ft. 9in., and a depth of 13ft. 4in. Her deadweight carrying capacity is 850 tons, with a gross tonnage of 637. Her machinery consists of a single-screw reciprocating steam engine of the triple-expansion type, supplied with steam at 200lb. per sq. in. from one large single-ended return-tube boiler. The engine was built at the firm's Coatbridge works, and although it is similar in appearance to an ordinary triple engine, it is more compact owing to the absence of the usual eccentric rod gear.

The designed output of the unit is 650 i.h.p., and the cylinders have diameters of 13½in., 22in., and 37in., respectively, with a stroke of 26in. Double-beat balanced poppet valves control the steam admission and exhaust on the Beardmore-Caprotti principle, and they are worked from a rotary cam gear which is neatly arranged near to the cylinders at the back of the engine. The valve lifts are constant, and the stop valve is always kept full open, the speed of the engine being regulated by varying the cut-off. An economy of 10 per cent. compared with an ordinary triple installation is claimed for the new valve gear, which gain, it is hoped, may be doubled in a larger installation of, say, 3,000 i.h.p., to which an exhaust steam turbine, working on the same shaft, might with advantage be fitted.

SUPERCHARGING IN DIESEL ENGINES.—Mr. Henry R. Sutphen, president of the National Association of Engine and Boat Manufacturers in the United States, recently expressed the opinion that supercharging would receive more attention from now on than any other feature of the Diesel engine, inasmuch as it opens the way for obtaining increased power at much less cost than would be involved in adding to the size of the engine. The addition of supercharging equipment, he pointed out, offers a practical means of increasing the power output of marine Diesel engines without increasing either maximum pressure or maximum temperatures and without incurring any great additional cost.

The adoption of supercharging certainly is becoming more popular among marine engine builders abroad, but it has not been taken up to any great extent in this country. The three Brazilian motorships *Itapé*, *Itaquicé*, and *Itanagé*, built by Messrs. William Beardmore and Co., Ltd., Dalmuir, are fitted with supercharged Beardmore-Tosi engines, but they are the first British-built marine engines in which supercharging has been adopted. A notable foreign ship with supercharged engines is the Cosulich liner *Saturnia*, which is equipped with two double-acting four-stroke cycle Burmeister and Wain type engines, each developing 9,000 b.h.p., which may be raised to 10,000 b.h.p. with the aid of superchargers. Mr. Sutphen stated that in small engines the power output can be increased about 15 per cent. by supercharging.

The following is from "The Power Engineer of August, 1927:—

LOW-TEMPERATURE CYCLES. (A Provocative Discussion of some New Ideas resulting from Recent Research. By C. W. Olliver, B.A., B.Sc., E.S.C. (Paris).—The increasing demand for power, which is a natural result of the world's industrial development, has brought about within the last decades an extraordinary rapid evolution of power-producing plant. But this evolution, remarkable though it may be, has been restricted to the study and improvement of the heat engine, based on high-temperature cycles, and depending on the combustion of fuel. The efficiency of such an engine is limited by well-defined laws, though, as we shall see, even these may need modification in view of recent research. But the efficiency is a minor item when the fact is once grasped that the world's fuel resources are rapidly decreasing, whereas its power requirements are increasing just as rapidly. To make matters clearer, by using a simile, we may state that the world is expending its capital to produce power, and such capital must necessarily come to an end.

There are other methods by which power may be produced than that of using up such stores of energy as natural fuels. Water power has been developed to some extent, and increasing attention is being given to the harnessing of tides. Methods such as these depend not on capital but on revenue; the power derived does not correspond to a definite destruction or waste of energy, but on an expenditure of potential energy, which is being constantly restored by natural forces, and which will, therefore, always remain at our disposal, so far as can be foreseen. Apart from the more obvious natural forces which can be utilised, there are many others to which little attention has been paid as yet, but which are, perhaps, the more important. Such sources of energy as the wind or the sun are, unfortunately, irregular, and as such not wholly utilisable, but when we realise that the average heat given out by the sun, after allowing for atmospheric absorption, represents some 510,000,000,000,000 H.P. over the whole of the earth's surface, it is not hard to understand that, could even a small portion of this be turned into mechanical power, a very great problem would be solved.

This enormous supply of energy cannot be used as such on account of its irregularity, but if a machine can be devised to operate with reasonable efficiency—firstly, on a moderate temperature drop, and secondly, on a low initial temperature—conditions such as these are constant and regular, and power could be produced, not very efficiently, perhaps, but without any expenditure of fuel.

The Laws of Thermodynamics.—Before attempting to describe the results achieved by means of low-temperature cycles, it is necessary to examine the laws of thermodynamics, on which the theory of all heat engines is based, and see to what extent recent research may have modified what have always been considered as fundamental axioms. We may state at once, for the reader's peace of mind, that the modifications are slight, but they may, nevertheless, have far-reaching effects.

It would seem as though the laws of thermodynamics were no longer in keeping with the facts in that, among other things, they do not take into account the heat absorbed by the internal molecular work, which, moreover, varies with the substance employed. Taking, for instance, Lord Kelvin's postulate that "It is impossible, by means of a machine, to produce mechanical work with a given stuff by cooling this stuff below ambient temperature." This is now seen to be incorrect, since a compressed-air motor will produce mechanical work with an exhaust at a temperature of —140° C. Lord Kelvin's postulate could be correctly stated as follows: "Any natural phenomenon, chemical or physical, occurs in such a way that the sum of the entropies of the bodies concerned is increased. In the limit case of reversible phenomena, this sum remains a constant quantity." This conception that the total entropy cannot decrease is a true expression of Kelvin's law. If it were possible to produce work by cooling stuff below the ambient temperature, its entropy would decrease without any corresponding increase of the entropy of any other stuff. Conversely, if we admit that it is impossible to convey heat from a cold body to a warm one, then, obviously, the entropy cannot decrease.

During adiabatic expansion, since there is no exchange of temperature, and we assume the phenomenon to be reversible, the entropy remains constant. The expansion is produced at the expense of the heat of the vapour expanding. Supposing we let into a steam engine cylinder carbonic acid gas at a pressure of 22 kg. per square centimetre, and a temperature of

—10° C., and let it expand adiabatically, according to Kelvin's law, the piston should not move. But, in point of fact, it will move until the pressure inside the cylinder reaches that of the atmosphere, by which time the temperature of the vapour will have reached—79° C.

A similar argument may be applied to Joule's principle of the mechanical equivalent of heat. Joule stated that there is a definite relation between the work produced and the heat absorbed, and *vice versa.* But if we take into account the internal molecular work, the principle needs modification, and, moreover, this quantity will vary with the nature of the substance, which is again contrary to Joule's principle. When a gas is compressed, the heat produced is greater than the equivalent of the work put in by an amount that corresponds to internal molecular reaction at the expense of the intrinsic internal energy of the substance and, conversely, on expansion, this internal action will result in a greater absorption of heat than corresponds to the work produced. It has been proposed, therefore, to modify Joule's principle as follows:—" When a gas is compressed or expanded the heat produced or absorbed is equal to the sum of the calorific equivalents of the external and internal work. The heat developed during compression or absorbed during expansion varies according to the nature of the gas."

Carnot's Principle.—The real crux of the matter is reached when we examine Carnot's fundamental law, and it is here that the whole question of low-temperature cycles and the utilisation of ambient temperature resolves itself.

Carnot states that the ratio between the maximum quantity of heat utilised, Q—q, and the quantity Q drawn from the source of heat, does not depend on the nature of the substance, but merely on the temperature of the hot source and that of the cold body to which heat is rejected. The efficiency of a heat engine is based on this conception, $\frac{Q-q}{q} = \frac{T-t.}{T}$ According to recent ideas this is incorrect. In the first place, it is wrong to compare the heat absorbed by expansion with the total heat removed from the source. The true efficiency is the ratio between the heat utilised and the heat absorbed. The error arises from the assumption that the heat " rejected " to the cold body is lost, whereas in reality it is a potential source of power. Taking as a concrete example the case of a steam engine for

1 H.P., absorbing 6,000 calories from the boiler, and rejecting 5,000 calories to the condenser.

According to Carnot's law, the efficiency would be $\frac{6{,}000-5{,}000}{6{,}000} = 0{\cdot}16$, whereas really it is $\frac{632}{1{,}000} = 0{\cdot}63$.

Moreover, according to Carnot's law the efficiency varies with the initial temperature of the cycle. When a gas is expanded adiabatically the work produced is

$$T = A\ c\ (t_1 - t_2),$$

where A is the mechanical equivalent of work, c the specific heat of the gas, t_1 the initial temperature, and t_2 the final temperature. The work depends, therefore, in the case of a gas on the temperature drop, but is independent of the initial temperature. Let us consider, for instance, the case of a cycle to be obtained with air between 30° C. and 0° C. From Carnot's law, the maximum efficiency would be $R = \frac{T-t}{T} = \frac{30}{300} = 0{\cdot}099$ (absolute temperature).

Now, the specific heat of air is 0·168 calorie. The heat required to raise 1 kg. of air from 0° to 30° C. will be $30 \times 0{\cdot}168 = 5{\cdot}04$ calories (constant volume). The final pressure will be $1 + (0{\cdot}0037 \times 30)$ or 1·111 atmosphere or 1·148 kg. per square cm. If the air is allowed to expand adiabatically until the original temperature is reached, the work produced will be

$$W = R\frac{(t-t_1)}{\gamma-1} = \frac{29{\cdot}27 \times 30}{0{\cdot}41}$$

that is, 2,141 kg. ms., or 5·04 calories. The efficiency will be $\frac{5{\cdot}04}{5{\cdot}04}$, or unity instead of 0·099.

If the same cycle is reproduced for various temperatures, the result will be the same, and one must conclude that with a gas the thermal efficiency is equal to unity and independent of the initial temperature of the cycle.

Practical Applications.—In order to utilise low-temperature cycles on a commercial basis the following principles must be applied:—(1) Some such substance as carbonic acid must be vaporised by means of the ambient heat instead of heating it by fuel combustion, and (2) the substance, once vaporised, must be condensed.

The second point is the whole difficulty of the problem; the cycle must be closed and the substance liquefied ready for further evaporation.

The evaporation can be obtained by means of a tubular "boiler" immersed in the surrounding atmosphere. The vapour thus produced is then allowed to expand in the cylinder of a suitable engine, and the expanded vapour must then be condensed for the cycle to be closed. It is at this point that the modification of the laws of thermodynamics become significant.

The whole principle of low-temperature cycles rests on the following statement: *A vapour may be condensed by absorption of heat, and this absorption of heat may be brought about by the production of work.* The methods that have been so far successful have not reached the industrial stage, but they are technically true and correct, and however inefficient, it is now proved that work can be produced and, incidentally cold, without any fuel expenditure whatsoever.

The principle is as follows: The engine operates with adiabatic expansion and partial consequent condensation of the vapour, which is then drained off and returned to the evaporator. The remaining vapour is compressed on the return stroke and used in the following expansion with the addition of the vapour obtained from the previous condensation. Theoretically, the work during compression is 0·176 of that during expansion, but practically, owing to mechanical losses, this is not correct. If the total efficiency of the compressor is 80%, the motor will produce 0·80 – 0·76 = 4% of actual power. That is to say, if the compressor is rated at 1 H.P. the power available will be 0·04 H.P. Under such conditions, and with a perfectly constructed machine, the boiler evaporator, if placed in a confined space, will produce cold without any exterior source of power and produce enough energy to supply the auxiliary requirements of a refrigerating plant.

If a vapour is adiabatically expanded, we will obtain a partial condensation that is sufficient to ensure a complete cycle. Such a cycle has been patented by Prof. Guarini. The cycle, then, consists of the following stages:—

(1) Saturated vapour at—10° C. is introduced into the cylinder.

(2) The vapour is allowed to expand adiabatically up to the extreme attainable limit. After this, the condensed liquid is drained off.

(3) The remaining vapour is compressed in the cylinder on the return stroke and the condensate is returned to the boiler for readmission to the cylinder.

It has been found that under the most unfavourable conditions the condensation amounts to 22%. There remains, therefore, a difference of 22% between the motive power and the work of compression, which represents 1·514 kg. meter per kilogramme of carbonic acid gas expanded.

Conclusions.—The conclusions that have been drawn from research along these lines may be summed up as follows. Ambient heat can be utilised by means of a refrigerating engine when the hot source is at a temperature such that condensation can be brought about by means of cold water. But cycles based on the direct utilisation of the sun's heat or on the utilisation of heat accumulated in water, etc., are not always available, and are but a partial solution of the problem. Low-temperature cycles based on the adiabatic vaporisation of volatile liquids, or on the adiabatic expansion of the vapours of such liquids are possible both from the thermodynamics and practical points of view although they have not yet reached the stage of industrial realisation.

The most complete and most economical solution of the problem of utilising ambient heat for power production simultaneously with cold production, the latter without absorption of power, lies in the realisation of refrigerating low-temperature cycles applied to the condensation of vapours exhausting from refrigerating machines working with volatile liquids. Such a cycle has been briefly described in this article; it is as yet imperfect, but however paradoxical it may seem, it works. Machines of this type have been built and operated in laboratories, and it is merely a question of time and further research before the low-temperature cycle becomes an industrial *fait accompli*.

From "The Power Engineer" of October:—

TAMED THERMODYNAMICS. THE ELEMENTS OF THE SUBJECT ARE CONSIDERED FROM THE SIMPLEST POINT OF VIEW.—The word "Thermodynamics" has put a great number of people off the study of what is really a very simple science, when only a practical knowledge of its fundamental axioms is required. The whole of the theory of thermodynamics rests on two such axioms, better known as the first and second laws, and a clear comprehension of these should dispel much of the obscurity that surrounds the subject and remove a number of very common misconceptions connected with the generation and application of steam.

The trouble with these principles is their very simplicity; in order to keep them on a par with the more intricate mathematical aspects of the problem, they have been stated in such a form that the truisms they contain are veiled by the use of a phraseology such that the average student gets out of his depth at the very start. This is immediately followed by an outbreak of differential calculus and the non-mathematical reader closes the book in despair. If would-be students could only realise the childish simplicity of the calculus, things would not be so bad, but until this fact has been recognised, we must try and express the fundamental principles involved without mentioning its dreaded name.

Work and Heat.—The term "heat engine" is vague and conveys little meaning to the average reader, and we prefer to state the object of thermodynamics as the study of the best way in which we may obtain *work* from *heat*. Both work and heat are manifestations of energy, but what we require is mechanical energy, *i.e.*, something that will do work. Heat is produced by the combustion of fuel, and the heat engine is a device for converting this heat energy into mechanical energy or work.

All readers are familiar with the reverse process, or conversion of mechanical energy into heat; indeed, they are probably constantly doing their best to avoid its occurrence. Mechanical energy is converted into heat, and consequently lost, or wasted, by friction. We are not interested in the conversion of mechanical energy into heat, since the former is immediately available to do work, whereas the latter, although it is still energy, is a step further removed and not available without reconversion.

Mechanical energy is valuable as it stands; we have in fact originally obtained it by conversion from heat, in some form of prime-mover, and we are not prepared to let any of it slip back again to its former state.

The First Law.—This possibility of converting one form of energy into another, work into heat, or heat into work, is a very important one, and constitutes what is known as the first law of thermodynamics, which states that there is a definite relation between the amount of heat expended and the amount of work produced in the process, or between the amount of mechanical energy lost and the amount of heat produced in the reverse process.

There is nothing mysterious or complicated about this law; it is quite simple and obvious. If, for instance, we consider a bearing which is heating for any reason, we should expect a decrease in the efficiency of our machinery which would be proportional to the amount of heat developed in the bearing. The reverse case is equally obvious, the amount of work we can get from a steam engine, for instance, must depend on the amount of coal we burn under the boiler, that is, on the amount of heat available for conversion into work. In other words, an amount of heat converted corresponds to a certain amount of work produced, and *vice versa;* an amount of work converted, by friction for instance, corresponds to an amount of heat produced. This relation is known as the mechanical equivalent of heat, or Joule's equivalent, from the name of the scientist who first measured it experimentally.

The first law of thermodynamics, therefore, tells us that we may obtain a certain definite proportion of energy in the form which we call mechanical energy from a certain given amount of energy in the form of heat, or similarly, heat energy from mechanical energy. In other words, we can get heat to do work, and by doing work we can produce heat, and moreover, we get a definite amount of work in exchange for a given amount of work, and a definite amount of work in exchange for a given amount of heat.

The Second Law.—So far, we have only considered quantities or amounts of heat, which are expressed, as we know, in *thermal units*. But there is yet another consideration, the temperature. Our heat may be very hot heat, so to speak, or moderately hot heat, and the temperature is an all-important consideration. This leads us to the second law of thermodynamics. This has been stated in a variety of forms, but the best way of grasping its true meaning is to lead up to it gradually. The French scientist, Carnot, who laid the foundations of thermodynamics, was very fond of stating this second law as follows:—"One cannot heat an oven with snowballs." This statement may appear absurd at first sight, but a close examination of it will enable us to understand just what is meant by this second law.

Snow contains heat, just as a mass of molten metal does, but is is unavailable to us in the case of snow because we cannot get it out without first providing a body at a still lower temperature. In other words, we can only utilise such forms of heat as are at a temperature greater than the ambient or surrounding temperature, for heat can only be abstracted for conversion by allowing the temperature to drop, and obviously it must have some lower temperature to which to drop.

*If we took liquid air, for instance, and brought it into contact with our snowballs, it would boil furiously, and work could be performed in a suitable engine; the snowballs being at a much higher temperature than liquid air, heat would be transferred from the former to the latter. But we would have had to expend energy to produce the cold liquid air in the first place, much more in fact than we could recuperate in this way, and the whole process would result in an expenditure instead of a production of work. Our heat energy must therefore be at a higher temperature than the ambient temperature if it is to be available for conversion into work, and moreover, the efficiency of the conversion will depend on the temperature drop, that is, the higher the initial temperature, and the lower the final, the better the efficiency. Taking the ratio $\frac{\text{Heat converted into work}}{\text{Heat supplied to engine}}$ as representing the efficiency of conversion, if this were perfect it would be equal to unity, that is, the heat converted into work would be exactly equal to the heat supplied. In actual fact it is not so. This perfect efficiency, unity, has to be decreased by a certain amount, and clearly the smaller this decrease, the nearer to perfection, or unity, will the efficiency become. Now this amount which has to be deducted is itself a ratio, that of the initial to the final temperature of the "stuff" used in the engine, whether it be steam, air, or gas. It is

$$\frac{\text{Final temperature.}}{\text{Initial temperature.}}$$

We have just seen that this ratio should be made as small as possible for good efficiency. Obviously, this can be done in two ways, by increasing the initial temperatures, or decreasing the final temperature.

In the case of a steam engine, the final temperature is that of the condenser, and is therefore slightly above the average

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* An interesting demonstration to witness.—J.A.

temperature of river water. In this direction, therefore, we find a definite limit below which we cannot go. Our efforts must turn to increasing the initial temperature, that is, the temperature at which the steam is generated, at which the heat is supplied. Here, however, we are faced with a further difficulty. When steam and water are present simultaneously in a vessel, there is a definite relation, though it is a complex one, between the temperature and the pressure. The more we raise the temperature, the more the pressure rises, and we are soon limited in our efforts to increase the initial temperature by the very high pressures involved, these pressures being the more difficult to deal with since the temperature is high. Thus, the second law of thermodynamics, which states that the efficiency of conversion of heat into work depends on the values of the initial and final heat temperatures, gives us the explanation of the trend of modern power-production practice which aims at high pressures, and consequently obtains high temperatures. Another form of this second law which immediately results from the preceding remarks, is that heat cannot be conveyed from one body to another which is at a higher temperature.

It should be very clearly understood that the initial temperature referred to is that at which steam is generated from water. Superheating steam, after its generation, adds comparatively little to the dynamic properties of the steam; its main object is to avoid losses through condensation during the passage of the steam through pipes and through the engine, and in the case of turbines, to avoid undue erosion of the blades through the presence of water in the steam.

There are other considerations which limit the efficiency of the heat engine. When steam or gas is allowed to expand, in a cylinder for instance, it may do so in two different ways. If the cylinder is properly jacketed, and fairly impervious to heat, then, during expansion, the gas will neither lose nor gain any heat. Such expansion is called *adiabatic*. During adiabatic expansion, since the gas cannot draw heat from any exterior source, its temperature drops. In other words, in addition to the energy converted into work by the expansion of the gas behind the piston, there will be a definite quantity of energy lost, or more exactly degraded, that is rendered less available for further conversion, by the very fact of the gas expanding. The other form of expansion is known as *isothermal*. In this case, during expansion, the gas is allowed to draw a corresponding amount of heat from some hot source, and its temperature consequently remains constant during expansion.

We are not immediately concerned with isothermal expansion, the conditions in the steam engine being very nearly adiabatic. From the definition we have given of adiabatic expansion it follows that the work which a substance does when it is expanding adiabatically is all done at the expense of its stock of internal energy.

It follows from the above remarks that the availability of heat for transformation into work depends essentially on the range of temperature through which the heat is let down, from that of the hot source to that of the cold body into which heat is ejected; it is only in virtue of a difference of temperature between bodies that conversion of any part of their heat into work is possible. No mechanical effect could be produced from heat, however great the amount of heat present if all bodies were at a dead level of temperature. Again, it is impossible to convert the whole of any supply of heat into work because it is impossible to have a body at the absolute zero of temperature as the " sink " into which heat is rejected.

The following letter appeared to " The Mechanical World " of November 4th :—

MATHEMATICS AND THE ENGINEER.—Sir,—There has been considerable controversy in the past on the value of a sound knowledge of mathematics to the practical engineer, and it would appear to be impossible to present any new aspect of the subject without repeating much that has already been said. It is, however, possible, by drawing on one's personal experiences, to introduce new material and present old facts in a new light. It has been the writer's privilege to have through his hands during the last fifteen years considerable numbers of pupils, apprentices, and students, many of whom presumed to a fair knowledge of mathematics, and it has been interesting to observe the varying degrees of success with which they applied this knowledge to ordinary every-day practical problems.

It may be stated at the outset that mathematics can never be a substitute for sound practical experience, and mathematical ability alone is almost useless in a modern industrial works, and but poorly recompensed.

On the other hand, it should be observed that a fairly extensive knowledge of the subject is necessary if one is to follow intelligently the proceedings of the various engineering institutions and societies, and to read the standard treatises which are published from time to time, together with a systematic perusal of the current engineering periodicals.

It is unfortunate that the teaching of mathematics has been largely done by professional mathematicians and theorists, and whilst the results may be satisfactory from an examination point of view, they leave much to be desired from the practical standpoint, and it is no doubt largely due to the uninteresting way in which this subject is usually introduced that it has become the *bête noir* of the student.

We are all agreed that calculation is a very necessary part of an engineer's training, and no matter how practical his work may be, he will at some time or another have to fall back on his own resources in this respect. The majority of such calculations are, however, of an elementary nature, involving nothing more than mensuration, the evaluation of formula, and the calculation of simple stresses.

It is when we get to the question of design that we really come to grips with the problem, and it is not stressing the matter too far to say that a thorough knowledge of mathematics is highly desirable if one is to be able to work expeditiously and efficiently, but the practical side must always predominate, excepting in the case of research, when the mathematical and scientific sides are, of course, pre-eminent.

It might be argued that an extensive literature on almost any conceivable technical subject is available, and that by reference to standard works one may gain sufficient information to enable their meagre knowledge of mathematics to adapt or transpose the information so gained to suit the problem in hand. In some cases this may be so, but it is a practice to be strenuously avoided, for apart from the possibility of misprints—many cases of which have come under the writer's notice—there is the additional objection that one is working in the dark, as certain conditions may have been assumed in obtaining the given formula which may not apply in the case under consideration; further, it is possible to deal more intelligently with a problem when one is familiar with the theory of the subject and capable of following the argument step by step up to the final result.

As an instance we may cite such subjects as the " whirling speeds of shafts " and the " strength of rotating discs," both of which are of importance, due to the tendency to higher and still higher speeds. Both these subjects are treated in Morley's " Strength of Materials " very thoroughly, and from time to time in the various engineering journals, and it is essential that such contributions should be read if one desires to have a thorough understanding of the subject.

When considering the question of mathematics one naturally asks what degree of knowledge is necessary, and to this question no direct answer can be given. It will obviously depend upon one's natural inclination and the ultimate aim in view, but it may be stated quite definitely that a thorough knowledge of fundamentals is of far greater value than a mere acquaintance with an extensive syllabus, and this is where our present methods of teaching are at fault. The average student is not mathematically inclined, yet he is rushed through a syllabus drawn up to comply with the requirements of certain examination authorities, who will at the end of the term signify their approval, or otherwise, of his work, which in most cases means that he has dealt with a few set questions in a satisfactory or unsatisfactory manner, and in the former case he will proceed to a more advanced stage. But does success in such cases imply a sound working knowledge of the past term's work? In most cases it does not! What it really means is that the poor student has been well and efficiently crammed, that that last minute revision helped a lot, and that he was perhaps a little more fortunate than his fellow students with regard to the questions suiting his particular knowledge.

This is exemplified by many instances which we have all experienced from time to time when passing on some simple calculation to a junior who has probably reached the stage of mathematical ability implied by the study of differential equations, and who will produce, in the majority of cases, an incorrect answer to our simple question. What has really happened is that he has acquired a facility in handling certain stereotyped mathematical expressions, but has not had sufficient practice in constructing his own problems for other conditions.

It is now the practice to introduce the elementary calculus at a much earlier stage than previously, and this is all to the good, as a large proportion of this most useful branch of mathematics is extremely simple and of considerable assistance in the study of kindred subjects, such as thermodynamics, the strengths of materials, alternating currents, and hydraulics. It would appear to be a better way of introducing the technical student to such expressions as the " radius of gyration " and "moment of inertia," and he will find that a sound grounding in mathematics will enable him to understand the underlying principles of much that he will have to learn, and will enable him to check and, if necessary, deduce expressions which would otherwise mystify him.

Apart from its intrinsic and obvious value, the study of mathematics constitutes a very fine training, inasmuch as it develops the power for logical reasoning, careful and methodical work. Loose thinking and slip-shod methods will never make a mathematician, and for this reason alone is its study worth while.

W. S.

London, October 26th.

The Duke of Montrose advocated some months ago a closer combination and fellowship between engineering and shipbuilding firms with a view to a co-operative study of the ways and means which might be adopted to reduce costs on output both on the commercial side and on the workshop.

Sir Alfred Mond advocated a similar line of thought and action, and the following shows that the opinions have gained ground and brought forth a course of action termed Rationalisation of Industrial Projects:—

*The following is from " System, the Magazine of Business " for November, 1927:—

A new industrial policy that is visualised by Sir Alfred Mond, the head of the great combination, Imperial Chemical Industries, Ltd. In urging it in October " System, The Magazine of Business," he described its evolution under three headings: (1) Amalgamation—of smaller industrial units into huge combinations; (2) Rationalisation—the full application of science and scientific method to industry; (3) Imperial Economic Union—to counter foreign cartels and trusts operating against Greater Britain.

Sir Alfred's article has aroused enormous interest. Representative views are here expressed by business leaders.

Amalgamation justified, If— (Sir William Plender, Bart., C.B.E. Deloitte, Plender, Griffiths and Co.).—Amalgamations

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* Reprinted by courtesy of " Business "– the Journal for the man of affairs.—J.A.

in the generally accepted meaning of the word are in some particular industries not only desirable, but a necessity if trade is to be successfully operated and kept in this country.

The pooling of knowledge and experience, a concentration of effort, the elimination of waste, and a better and more economical adaptation and use of plant and machinery must bear fruit in well-devised, properly-organised, and well-administered combinations. Amalgamations without co-operation, both of the management and of the workmen, cannot achieve their object. Unless there be on the part of all concerned—employees as well as employers—mutual trust and confidence, the advantages which theoretically attach to amalgamations will only be very partially realised.

A common purpose to produce the measure of consumptive needs, as opposed to unrestricted production, and at as low a cost as possible, combined with well-directed and active aggressive salesmanship, must benefit customers, workers and the providers of the capital. Amalgamations will then be justified.

Progression Demands— (Sir William MacKenzie, G.B.E., K.C., formerly President Industrial Court).—I am in entire accord with Sir Alfred Mond. Small units in industry have in the past been responsible for the development of British industries, and no one can look back but with admiration and pride at the vital part they played in building up Greater Britain. We are now in a transition period. We see in progressive industries, whether at home or abroad, a strong movement towards larger establishments, necessitated by the ever-changing requirements of industry in new and improved plant, in research, in more enlightened management and in more intensive salesmanship. Large units mean improved conditions and better pay for labour, the elimination of waste and cheaper products.

We have within the four corners of Greater Britain all the raw materials necessary for industry. The out-lying parts of our Empire have in the past been much neglected and in a large measure are still awaiting development. We have in Greater Britain a consuming public steadily increasing and capable in time of absorbing the bulk of our products. Our ultimate aim should be to make the British Empire one economic unit.

There are many obstacles in the way of adopting some such scheme, but that should not daunt us; it should only be a stronger reason for pressing on to achievement.

Smaller Unit Efficiency (T. Birkett, General Manager Midland Electric Manufacturing Co., Ltd).—Sir Alfred Mond's vision of a Rationalised Imperial era of industrialism is a fascinating one, and there is certainly some evidence that the trend of social evolution is at present in that direction. But there are other forces at work, and much political propaganda remains to be done before progress can be said to be definitely set in the direction desired by Sir Alfred Mond and those who think with him.

Australia is pledged to high import duties,clearly arranged to protect inefficient industries and to keep out of that market the products of more highly developed countries. And when protective duties are sufficiently high as to be very near total prohibition, British preference is of small advantage. Canada, in spite of a powerful imperial sentiment, is very largely under the influence of American technical practice and financial interests. South Africa has at present a powerful anti-British element, and thus the present and immediate future does not look favourable for the early development of the active Imperial complex.

At home, amalgamations and large industrial combines have not invariably been successful. In some cases actual disintegration has set in.

The predominance of Britain as a manufacturing country was built up by the strength of many solitary personalities, and it is permitted for one to wonder whether the great industrial combines desired by Sir Alfred Mond are quite suited to the peculiar genius of British people. Efficiency is a personal virtue, and there is some doubt whether an era of dictatorship would be any more effective in creating personal efficiency than the smaller units with which we in Britain are more familiar.

The doubt is not unmixed with a haunting fear of a regimented existence, which might have re-actions on national character, not altogether desirable. Evolution is a slow process, and it may well be, that ultimate fitness to survive, may be found in the personal element with high character and high efficiency; which doctrine, although somewhat unfashionable at the moment, is not entirely without its disciples.

The Combine and Output Adjustment (J. M. Keynes, Chairman, The National Mutual Life Assurance Society).—I agree with Sir Alfred Mond's general philosophy of what British industry should be to-day, so far as the basic industries are concerned.

When an industry is a new one, and going ahead at a great pace so that plant and machinery and skilled labour have their work cut out to keep up with demand, the perplexing problems of over-production scarcely arise. Apart from the cyclical depressions, which were sharp while they lasted but were soon over, many of our greatest industries were almost continuously in this stage of development through the nineteenth century.

Nowadays, the problem of adjusting output to demand in an old-established industry cannot be avoided even in the most go-ahead countries. Some of our industries have learned this lesson. Others have not learned it, or are learning it far too slowly.

I have had some experience lately of an industry which has signally failed to solve the problem of potential over-production—the section of the Lancashire cotton industry which spins American cotton. Sir Alfred Mond writes as the head of an industry which has solved it as completely as it can be solved, and has built up on these foundations one of the most splendidly equipped producing organisations in the world. Units of different size are appropriate to different industries. I do not say that all industries should imitate the scale of Imperial Chemical Industries, Ltd., which Sir Alfred Mond tells us is a combination of what were originally 113 independent firms. Indeed, I am sure that there are many important industries in which the unit of maximum efficiency falls far short of this.

But, whether the right unit is a relatively large or a relatively small one, no industry to-day can afford to neglect altogether the adjustment of the capacity to produce to the probable scale of consumption—an adjustment to be deliberately thought out by the industry coming together as a whole.

It may be true that a great combine like Imperial Chemical Industries might, in conceivable conditions, become a dangerous monopoly. There ought to be some suitable machinery for watching it from this point of view.

But as regards efficiency of production and control, which is after all an essential ingredient of national success in industry, it seems to me absolutely undeniable that a concern like Sir Alfred Mond's has reached a level which is a very great deal higher than the level of those industries which are still trying to carry on with innumerable small independent units mainly engaged in trying to cut one another's throats.

The following report of an experience is from "The Engineer and Iron Trades Advertiser," Glasgow, of February 21st:—

BREAKDOWN THROUGH WATER IN AN ENGINE CYLINDER.—When a breakdown occurs through water obtaining access to the high-pressure cylinder of an engine, the usual assumption is that it has, for some reason or other, been carried over with the steam, but a breakdown recently reported in *Vulcan* presented some unusual features. The engine was of the horizontal tandem compound condensing type, the admission valves to both cylinders being of the drop type. The accident occurred at stopping time. The steam was shut off in the usual manner, and the cylinder drain cocks opened, when almost immediately the smash took place. Fortunately, the damage was not extensive, but on examination it was found that the high-pressure front-end admission valve seat was broken, the cotter securing the high and low-pressure piston-rods was sheared and the main crosshead cotter slightly bent. On ininvestigation it was found that the drains from the high-pressure cylinder had an outlet in the vicinity of a pond, and that, owing to a flood, the water level in this pond had been raised abnormally and had completely submerged the free end of the drain pipe. Consequently, as soon as the engine stop valve was closed and the cylinder drain cocks opened, a vacuum was created in the pipes, and water was thus drawn from the pond into the cylinder, instead of draining from the cylinder into the pond.

At the Annual Dinner of the Glasgow University Club, London, held on May 25th, Sir Donald MacAlister, K.B.E., M.D., LL.D., the Principal of the University, in his address, referred in eulogistic terms to the interest that all the heads took in the University, its aims and aspirations, encouraging all concerned to devote themselves to advance each and all sections of the work for the common good. The students had enthusiastically taken up the work and followed the course with spirit, manifesting their desire to pave the ways leading to the different fields. In their loyal and generous co-operation they had learned lessons other than set lectures could teach them about conduct of practical business, the handling of men, and the team method of working together harmoniously for a common end.

The attention of all on the roll of membership is directed specially to the invitation to contribute Papers for reading at meetings, contributions from experience or Essays on set subjects for Awards. Those who gave capital sums for the apportioning of awards did so in appreciation of the good which would be gained by the writers who committed their views to writing, and in doing so, discovered weaknesses and wants which called for mental exercise and investigation on their part, thus leading to advancement in knowledge and experience.—J.A.

In the "Marine Journal," New York, of March 1st, there is a descriptive article on an internal combustion boiler for which economy and adaptability in regard to steam engines—land and marine—is claimed. A sample boiler is in course of manufacture for testing with a triple expansion engine, the test carried out on a smaller sample having proved satisfactory. It is further proposed to install one in a tugboat capable of supplying steam for 1,000 H.P. The boiler is stated to be of light construction, about ·5 of the weight of the Scotch—3 tons is given as the weight of the 1,000 H.P. one, and to be readily placed in the engine room of a ship, where it would occupy much less room than the ordinary type, added to which, as the economy claimed brings the steam engine fitted with it to a higher ratio for economical service than the internal combustion engine, the tests will be interesting to watch the results. As several members have been interested in the internal combustion boiler of the Brunler type, attention is directed to the American one. The inventor is A. Schwartz, Internal Combustion Boiler Corp., U.S.A.

The following is from the "Foundry Trade Journal" of March 15th:—

FATHER OF THE IRON TRADE. BICENTENARY OF GREAT INDUSTRIAL FIGURE. By T. B. Fowler.—No man, it is safe to say, contributed more to the great industrial development attendant upon the improvement of the processes of manufacturing iron than John Wilkinson, whose bicentenary occurs this year.

Justly called "The Great Ironmaster," says Smiles, and "The Father of the Iron Trade," standing head and shoulders above the majority of his contemporaries in mechanical acumen and practical inventiveness, he was beyond all question one of the most conspicuous industrial figures of his day.

He was closely linked to Birmingham by family as well as by business associations. His sister, Mary, was the wife of Dr. Joseph Priestley, the famous scientist, and it is recorded as one of the redeeming features of an adamantine character, relieved by few glimpses of human softness, that when Priestley's property was destroyed in the Birmingham riots, Wilkinson came forward with substantial assistance for his brother-in-law. For upwards of twenty years he was identified with the growth of Boulton andWatt's engineering business at Soho. He not only contributed castings of a better quality than could be obtained elsewhere, but it was his discovery of an improved apparatus for boring cylinders that helped Watt to overcome the final difficulties that had prevented him from perfecting his invention.

Neighbours' Prophecies.—Never throughout his life had Wilkinson any profound respect for orthodoxy. The very circumstances of his birth at Clifton, Cumberland, in 1728 were unusual. His father, Isaac Wilkinson, himself a skilled iron-worker of keen discernment, at the time kept a small farm, and John was actually born in a common market cart used by his mother for taking the produce to a neighbouring market. The event, we are told, caused no little sensation, among the simple-minded people of the locality, and more than one prophetically said that "John sum tyme wod bee a girt man."

Schooled first in the academy of Dr. Caleb Rotherham, at Kendal, and later in the forges of his father at Blackbarrow, near Furness, and at Wilson House, near Lindale, in Cartmel, Wilkinson, when little more than twenty, following the failure of his father's last venture, set out to make a business career for himself.

He found employment at Wolverhampton. Then he became manager for the New Willey Company at Broseley, near Coalbrookdale. Full of eager ambition, thrustful and charged with dynamic energy, a grim, determined man who made light of obstacles, he had by 1763 gained sole control of the works. Seven years later he set up a furnace at Bradley, near Bilston, and almost simultaneously he and his brother, William, secured possession of the Bersham works, near Wrexham.

The incessant wars of the period stimulated the demand for ordnance, and Wilkinson's discovery of a new method of boring cast-iron cannon, ensuring greater accuracy and effectiveness, enabled him to outrival all his competitors. Orders for howitzers, mortars, swivels and shells poured in, and the works were kept going at top speed.

The furnace at Bradley had just been established when Watt's friend, Small, heard of " an eminent caster " (Wilkinson) who had " settled during the summer at Bilston," and it was out of the communications then exchanged that Wilkinson's relationships with the inventor of the steam engine originated.

Wilkinson's restless temperament was expressed in repeated experiments. He anticipated James Beaumont Neilson, the Scottish gas engineer, in exploring the possibilities of the " hot-blast " for smelting the ore and producing the pig-iron. It is exactly a hundred years since Neilson took out his patent for heating the blast by passing it through pipes exposed to the flames of subsidiary furnaces before its entry into the smelting furnace. Long before, Wilkinson had experimented at Bradley with a leather " gooseneck," which connected a blast furnace with a cylinder in which the blast was heated. But as the leather was charred and rendered useless, he abandoned the idea, when the substitution of a metal for a leather connection would have solved the difficulty.

Against this failure, however, are to be set many practical achievements of the greatest value. He first applied mineral coal to the smelting and puddling of iron ore in Staffordshire in place of wood charcoal; he was one of the first to use the engines supplied from Soho, applying them to the blowing of improved bellows at a new forge at Broseley; he was chiefly instrumental in casting the parts for the first iron bridge in the country, that over the Severn between Madeley and Broseley; he built the first large steam engine in France for the waterworks at Paris; he brought out a patent for making lead pipe; he harnessed steam to the tilt hammer and the threshing machine; and he built the first iron barge to carry castings down the Severn from his works at Coalbrookdale.

The latter innovation seems to have afforded him particular satisfaction. When the boat was successfully launched he wrote: " It answers to my expectations, and it has convinced the unbelievers, who were nine hundred and ninety-nine in a thousand."

James Watt thought so highly of the work done at Coalbrookdale that in 1784 he sent his son to study there.

But Wilkinson was at all times a difficult man to work with. He quarrelled bitterly with his brother, of whose growing friendship with the Soho partners he was passionately jealous. Matters were not improved in this respect by the marriage of his brother's daughter to Boulton's son. "His was a dominating, assertive nature, almost titantic in the force of its elemental passions, in its ambitions, its inflated egotism, and its capacity for hatred and revenge," says Thomas S. Ashton in his "Iron and Steel in the Industrial Revolution." "When differences arose, whether with his rivals, with customers or with employees he was relentless in his bitterness and blind to all consequences."

To do him justice he was perfectly conscious of his own deficiences. "Peace is a most desirable thing," he once wrote to one of his friends, "and the more so to one of my constitution, who cannot be angry by halves. Resentment with me becomes a matter of business and stimulates to action beyond any profit."

It was this hot, overmastering and tempestuous spirit that led to the complete rupture of his relations with Soho. He had conceived quite exaggerated ideas of the indispensability of the part he had played in the perfection of the steam engine, and presuming on this, and upon a concession, granted to him at his own urgent request, to make the all-important "nozzles" at Bersham, he did not scruple to infringe Watt's patents in wholesale and barefaced fashion.

Had genial Matthew Boulton had his way an eleventh-hour peace would have been patched up, but Wilkinson's intractable conduct rendered this impossible, and, like other pirates, he had to pay the penalty. But he never forgot or forgave the humiliation he had suffered. He exhibited his rancour in the closing of the works at Bersham and the dismissal of the employees, thus cutting off the supplies of cylinders for Soho.

Undismayed, Boulton and Watt determined to undertake the casting and boring of their own engine parts, and with the immediate erection of the Smethwick Foundry they entered the ranks of constructive as well as consultant engineers.

Wilkinson combined farming with other interests, and is said to have run a five-hundred acre farm at Brymbo, near Wrexham, with success. To other personal idiosyncrasies he added the reputation of being an atheist and disciple of Tom Payne, and in Staffordshire, Shropshire, and on the Welsh border his fame was sung in many a quaint piece of native doggerel.

He was a profound believer in iron, and as one who helped to lay the foundations of a new era in the industry, there was something entirely fitting in the fact that when he died at Bradley on July 14th, 1808, he should be buried in an iron coffin.

The circumstances attending his internment were no less remarkable than those associated with his birth. He was buried four times, and one of the men engaged in the work used to say that he buried John Wilkinson four times and disinterred him thrice. He was first interred at his seat of Castleford, near Ulverston, but his remains found their final resting-place within the church at Lindale, amidst scenes familiar to him in his youth and early manhood.

[Wilkinson must have travelled abroad considerably, because we have encountered souvenirs of his industry at the works of Schneider et Cie, at Les Creusot, and again at the Decazeville Works (in the very South of France), of the Commentry Fourchambault concern.—EDITOR.]

MALLEABLE IRON FITTINGS.—Records showed that iron pipes were first used for conveying coal gas about 100 years ago, and that with their use came the need for various angle and branch fittings, said Mr. H. R. Hiscott at a meeting of the Institution of Heating and Ventilating Engineers, held at Caxton Hall, Westminster, S.W.1, on March 7th.

These, he continued, were made from bent tubes or from pieces of plate cut, forged to shape and welded. With the progress of casting methods it was possible to produce a much larger variety of fittings, but owing to the lack of ductility of ordinary grey iron castings, due to the high carbon-content, research was carried out to provide a specially constituted iron for malleablising, in which the carbon was almost wholly "combined." This research on malleable iron took a considerable amount of time, but there exist to-day high-grade malleable iron fittings which can quite safely hold their own within certain limits, which, by reason of their cleanness of finish and accuracy of screwing, strength and other physical properties, are well suited to the engineer's requirements for general use and also heat and pressure.

In his interesting paper, Mr. Hiscott gave a general description of the processes through which a malleable iron fitting had to pass between its raw and finished states, including the annealing process on which the malleability of the fitting depends. In the operation of screwing, accurate fitting demanded that all outlets should not only be screwed to perfect gauge diameter to make satisfactory joints, but connections made with them should be perfectly square and in line with the fitting. Constant testing during operation was essential to provide fittings which under tensile stress showed from 45,000 to 56,000 lbs. per square inch. On the question of cost they now compared with wrought iron, gas and steam qualities.

"The British Legion Journal" of March contains many contributions from different sources as to the fine personality of the late Field Marshall Earl Haig of Bemersyde. The tributes paid to him by contributors who knew him and the work he had done during the war and since, in endeavouring to help ex-Army men, are worthy of historic note, and they are fittingly recorded in the magazine of the British Legion, of which he was President.—J.A.

The following is from "The Shipbuilding and Shipping Record" of April 5th:—

CAVITATION IN SCREW PROPELLERS.—The importance of investigations into this phenomenon cannot be overestimated, for, apart from the effect pronounced cavitation has on the power and speed of ships, its presence accounts for the very serious erosion observed on the propellers of many ships now in commission. Occasionally, it has been found necessary to dry-dock vessels shortly after their having been placed on service, and builders have been astonished at the condition of the screws through the baneful action of cavitation. Mr. Tutin's paper on this subject, read at the recent I.N.A. meetings, suggests a method of predicting its presence in any particular case. When this subject was brought before the shipbuilding world very high-speed ships were comparatively rare and the late Mr. Barnaby was surprised at the performances of the *Daring* and the peculiar features of her trials. He arrived at the conclusion that the limitation of thrust pressures was the proper method of obviating the appearance of cavitation, and, within limits, his suggestions are practically sound. In many cases, however, it is evident that cavitation is taking place even when the pressures are well below the limits accepted. The theory put forward by Mr. Tutin may help in such cases. Unfortunately, it may be the case that the very high powers now being put through screws with high rotational velocities simply cannot avoid the zones which bring about excessive erosion. Up to the present time the ability to overcome this difficulty has not been made evident.

The following are from "The Electrical Review" of April 6th : :—

Electric Propulsion of Ships.—In a paper he recently read before the Rugby Engineering Society, Mr. W. J. Belsey, M.I.N.A., dealt with the electric transmission of power for propelling ships. He emphasised the fact that practically all recent vessels, whether propelled by steam or internal combustion engines, depended on the reliability of electrical machinery for their operation, and machines on which the safety and running of the ship depended, such as steering gear, scavenge blowers, circulating and lubricating pumps, etc., were driven electrically. Therefore, if its reliability was accepted for those vital duties, why not for the main propulsion where the machinery was of large capacity and therefore much easier to insulate and make reliable than was the case with smaller electrical machines? He believed that there were very many types of vessel where electric transmission could be used with very great advantage on account of its extreme flexibility both in operation and in location.

Liquid Fuel from Coal.—At a recent meeting of the Diesel Engine Users' Association, Mr. David Brownlie read a paper on the above subject, in which he dealt in detail with its importance from a national standpoint, stating that the production of liquid fuel from bituminous coal and other carbonaceous material was a vital matter to those in Great Britain who were connected directly or indirectly with the development of the Diesel engine, either as stationary power plant or for locomotive purposes. Instead of selling British coal at ridiculous prices, it would become compulsory to treat the coal on scientific lines, including the production of liquid fuel. The author made a brief reference to some 30 of the more important low-temperature processes that at the present time actually had large scale plant in more or less continuous operation. An indication that the time was rapidly becoming ripe for low-temperature carbonisation was the remarkable advance made during the past few years in pulverised-fuel firing, the solid carbonised product from any process being eminently suitable for this method of furnace operation.

PULVERISED FUEL.—Comments have been made regarding possible danger arising from spontaneous combustion and the necessity of arranging for the carriage of the fuel in safeguarded compartments, apropos of which attention is directed to the following letter from "The Journal of Commerce Engineering Supplement" of May 10th:—

PULVERISED FUEL.—Sir,—The correspondence on the above subject in your most valuable paper has been most interesting and enlightening, and it is a subject with great possibilities in store, but it would be unwise to jump to the conclusion that this system of burning coal will be a panacea for the ills and discomforts of the coal trade in the near future as far as shipping is concerned.

Even if the efficiency of the system is all that its advocates claim, there are other aspects which must be considered by the shipowner before he will consent to alter his existing arrangements for raising steam, the benefits and defects of which he is fully conversant with. "Better the devil you know," etc.

The bulk of the coal bunkering business is done with cargo vessels, most of which trade with many ports in various parts of the world and often do not call at the same ports on two consecutive voyages. The owner, therefore, would require to be assured that his vessel could bunker pulverised fuel at a reasonable wide range of ports on the prospective voyage, or run the risk of serious delays and expenses. This for the tramp steamer would mean that a very large number of pulverised fuel plants would have to be installed throughout the ports of the world; otherwise the pulverised fuel system on board would curtail the ship's sphere of work or cramp its style, as our golfers would say. It would seem that a considerable time must elapse before this eventuates.

Again, the bunkering of pulverised fuel is likened to oil fuel, but it is obvious that double-bottom tanks are no suitable places for stowing pulverised fuel, though freely used for oil fuel. Also, it is stated that by fluffing the bunkers with inert gas from the ship's funnel all risk of spontaneous combustion is eliminated, but it remains to be seen what view underwriters would take of this if the system became general; and an owner must carefully avoid incurring increased insurance premiums.

Alternatively, if the ship carried her own pulversing plant, and so renders herself independent of shore supplies of pulverised fuel, there is the weight and space occupied by the plant to be considered, and consequent reduction of cargo capacity and earning power, in addition to the heavy initial expense. There must undoubtedly be heavy wear and tear on machinery dealing with such gritty material, and in order to avoid serious delays due to breakdowns and replacements of worn parts it would be necessary to carry duplicate machines and a host of spare parts, the cost of which would make the scheme prohibitive.

I do not wish to appear a pessimist, but the above aspects will indicate to the optimists that a certain period of time must elapse under the most favourable circumstances before the use of pulverised fuel on board ship can appreciably ameliorate the troubles of the coal trade.

Recognising and ventilating the difficulties is surely the best way of seeking to overcome them, and the achievement of the Mercer should inspire the pioneers with courage.

Yours, etc.,

T. Currie.

Messrs. Flannery and Given,
21, Water Street, Liverpool.
May 4th, 1928.

From "The Times," May 10th:—

Science and Coal.—Sir,—Your correspondent Mr. Murray Stuart is to be congratulated upon having drawn attention in your columns to the all-important question of low-temperature distillation. That there is a big future for the industry is now beyond doubt. His word of warning, however, to proprietors of various processes to give more authentic guidance to non-technical men and would-be purchasers is certainly both apropos and timely.

The Institute of Fuel, of whose council I have the honour to be chairman, is doing great work in the encouragement of technical and non-technical discussion of the problems of coal distillation. At its periodical meetings impartial and disinterested debate is conducted by those whose standing in the realm of science and industry entitles them to be heard with profound respect. The scientific papers and subsequent critical analysis to which they are subjected would narrow down the possibility of error on the part of purchasers of so-called commercial plant, provided that those undertakings sincerely interested in fuel problems would see that their own technical advisers took advantage of data made available to them by this and kindred institutions.

Then, again, the merits of respective processes are much more likely to be understood by the public if their proprietors would see to it that purely technical differences were first of all thrashed out and accepted by their scientific and technical men themselves within the *milieu* of their own societies. The British public has no taste for purely technical squabbles. It is always anxious to learn about and support new processes when they promise to be of real national value. A little less bickering about the merits of one process over another, and just a little more concentration upon the vital importance of getting the maximum value out of our own coal resources, and the whole movement will have a great fillip and earn a lasting benediction from our countrymen. Those processes which cannot stand the strain of commercial competition will inevitably go under. Time will see to that. But the public must understand the main purpose or objective of the systems as a whole.

Mr. Winston Churchill's Budget has helped more than anything else to enlighten the public mind as to the objects to be achieved by coal distillation. He did not expatiate upon the merits of any particular process. Knowing of the vast accumulation of scientific experience in coal treatment, of the great pioneer efforts made by the fuel technologists, and of the nearness to a scientific revolution in the coal industry, he courageously proffered real help to all those who have set themselves the task of making Britain less dependent upon imported motor spirit. It is a fact of which the Chancellor was fully aware—namely, that coal is a source of heavy and light oils, and that if the claims of science were realised he was taking one great step forward to re-create the British coal industry. It was worth while to give small financial assistance now in the painful days of travail. The birth will be easier, and the babe will have a greater opportunity of survival.

Commercial low-temperature distillation comes upon the scene at an opportune moment. If it had come earlier it might not have survived. No scientific discovery is a failure; the worst that can be said of it is that the discovery was made too soon. It comes now, not only to make coal yield up its oil, its spirit, its gas, and leave its bones as semi-coke, but at a moment when oil and spirit are urgently required, when gas can be boosted and pumped through an undreamt-of length of pipe-line, and, above all, when the science and practice of combustion have reached a point where the semi-coke residual is not only used for steam-raising but demanded in a pulverised or milled form in the many powdered-fuel installations established on land, and, we hope, soon to be established in ships at sea as well.

Thus the aim, first, is to conserve every particle of value of our great national treasure, coal, to realise its intrinsic worth, to make it yield up its power elements more cheaply and abundantly to our industries. Secondly, the aim is to inject the red corpuscles of economic health into our great basic industry, coal, and thus create real grounds for hope and prosperity, where now exist grey gloom and hopelessness. Thus is our true objective stated, and with it the explanation why many of us have diverted our energies from the more turbulent currents of activity into this steady stream of national creative work.

Yours truly,

FRANK HODGES.

31, Buckingham Gate, S.W.1.
May 8th.

From "The Machinery Market" of 11th May, 1928:—

THE RATIONALISATION OF INDUSTRY*.—The recent improvement in trading conditions, welcome though it is, should not be allowed to obscure the difficult problems with which some sections of industry are still faced. These difficulties are most prominent in certain basic industries, but they are also in evidence, in greater or lesser degree, in a few of the less important activities. Broadly speaking, the position is most acute in industries which have to bear the full brunt of foreign competition, the problem of meeting which is, perhaps, one of the major issues with which British manufacturers have to

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(* Reprinted from the "Monthly Review" of Barclays Bank Ltd.)

deal. In a number of countries abroad costs of production are lower than in Great Britain owing to lower wages, lighter taxation, and other factors. For various reasons it is very difficult to make an exact comparison of the wage levels in different countries, but the following table, although admittedly subject to many reservations, offers some approximate indication of the relative levels of real wages of adult male workers in certain occupations and cities:—

TABLE SHOWING THE RELATIVE RATES OF HOURLY WAGES PAID TO WORKMEN IN THE VARIOUS CITIES NAMED, TRANSLATED INTO UNITS OF FOODSTUFFS. (*a*).

(Prepared by International Labour Office.)

City.	Relative real wages as at Oct. 1st. 1927.
Amsterdam	86
Berlin	68
Brussels	50
Copenhagen	107
Dublin	106
Lisbon	30
Lodz	44
London	105
Madrid	57
Ottawa	170
Philadelphia	199
Prague	52
Riga	55
Rome	51
Stockholm	87
Vienna	45
Warsaw	42

Even before the war, British wages were usually above the Continental level, and yet we had no great difficulty in meeting foreign competition, but in all probability the wage disparity is much greater to-day than it was in 1913. The comparatively low level of production costs on the Continent enables manufacturers there to quote attractive prices for their products, and the problem facing many British producers is to decide what steps can be taken effectively to meet this competition. To reduce British wages to the Continental level is impractic-

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(a) In the case of Stockholm, the figures are based on wages in the building, furniture-making, and printing industries only. For other cities, the metal industry is also included.

able, even if it were desirable. The experience of the United States shows that, given certain essential conditions, high wages and commercial prosperity may go hand in hand. At the same time, if a high level of wages is not compensated by those other factors, its maintenance will be impossible. It is not only in wages that Great Britain demands a higher standard than the Continent, but also in certain classes of profit, in Government expenditure, and in social services, although in these days, sanitary and health administration cannot be said to be more efficient in Great Britain than in many other countries. To assume that British origin alone is sufficient to sell our goods is to labour under a delusion, especially as in actual efficiency we are no longer so far in advance as previously. This country's reputation for quality of production and honesty of dealing serves us in good stead, but it would be very unwise to assume that we have a monopoly in these directions.

There are various possibilities by which British industry may improve its competitive power and the maximum success in this direction will only be achieved by tackling the problem from all angles, but perhaps the most substantial results are likely to accrue from developing a sane policy of unification of interests, which forms part of the rationalisation of industry. In an address delivered to the shareholders of this bank last year Mr. F. C. Goodenough stated that " it seems to be clear that in cases where there are sound reasons the amalgamation of undertakings identical in character should be capable of producing increased efficiency, together with economy of administration. I am not suggesting that there should be any further development of a practice which has been too common in the past with industrial and commercial undertakings, of amalgamating such as have only some more or less distant affinity, but which are really of diverse character; but I would advocate strongly the amalgamation of like with like, with the above object in view."

In some industries the development of a policy of greater concentration is necessary in order to keep pace with the similar movement which, for some years past, has been in evidence abroad, while in other cases it is necessary to offset those disadvantages from which British industry suffers as a result of lower costs of production elsewhere. Although, however, the desirability of amalgamations may be theoretically admitted, the practical difficulties of giving effect to them are formidable, evidence of this fact being found in the slow progress made. The explanation is not far to seek. The real benefit of a merger should lie in the reduction of overhead charges, the concentration of production in the most efficient and modern units, economy in administration and selling expenses, and the scrapping of that part of the organisation which is found to be redundant or inefficient. There is, however, a natural reluctance to take such drastic steps, and a disposition to assume that a change of fortune is bound to come, the fact that many of our post-war difficulties have been due to causes beyond our control having encouraged this attitude. It is not usually an attractive proposition to dispose of a business at a time when it is in a state of depression, with the consequence that, however much an owner may be convinced that amalgamation is the ultimate solution, he will prefer to wait a more favourable opportunity for selling his assets. In addition amalgamation and re-organisation often require considerable capital, and capital is not readily secured by a depressed industry. Not infrequently, therefore, the tendency is to concentrate upon economies, such as wage reductions; but wage reductions naturally meet with resistance from the workers, who rightly claim that it is unfair to expect them to accept reduced standards unless everything possible is being done to bring the industry to a state of efficiency. Factors of this kind tend to create a position of stalemate, with the consequence that the re-organisation which, in some directions, is admittedly desirable, is unduly delayed. It is clear, however, that little is to be gained by a policy of hoping for the best, even though it is true that certain factors are working in our favour. In countries like Great Britain, where the currency was stabilised in April, 1925, at the pre-war parity, the starting-point of wages and other production costs was above the normal world level, and therefore downward adjustments had to be made, whereas countries which stabilised by permanently writing down the gold value of their currencies usually commenced with wages and production costs below the normal world-level. In many European States the stabilisation of currencies has led to a marked upward tendency in wages and prices, and as this tendency still continues it is not unlikely that the disparity between British wages and other costs of production and those prevailing on the Continent will tend to narrow, but it should not be assumed that this movement will alone prove sufficient to maintain and improve our existing standards. The solution seems to lie in taking every possible step to make British industry super-efficient, irrespective of conditions elsewhere, as only by such methods can full prosperity in this country be expected. It is true that such a policy may involve parting with many preconceived notions and entail considerable initial sacrifices, but in the long run it should greatly strengthen our industrial organisation and increase our competitive power in the markets of the world. On the other hand, if industries which cannot effectively compete with foreign countries delay the necessary measures of re-organisation, they can scarcely expect to receive any more than the orders which cannot be satisfied from other sources of supply, and such a state of affairs must, if continued indefinitely, lead to the decay of the industries in question. During the past few years British industry has made remarkable progress from the difficulties caused by the war, while substantial headway has also been made in promoting social measures designed to improve conditions for the general body of workers. Further progress should result from the general tendency of British and Continental costs of production to draw closer to each other, but a full measure of prosperity can only be obtained by bringing our industrial organisation to the highest possible pitch of efficiency.

In " The Syren and Shipping " of June 13th, it is good to note, in memory of him who has gone, that special reference is made to the question of nomenclature in connection with the Internal Combustion Engine, which was mentioned in a Paper read at the Centenary Celebration Congress of the Institution of Civil Engineers. Both Mr. Geoffrey Porter and Prof. Hawkes alluded to the pioneer work of the late Herbert Akroyd Stuart, who unquestionably first conceived and put into effect the idea of the engine. He took out a Patent for the Engine Cycle 38 years ago and three years later Dr. Diesel produced an engine which bears his name, he being backed up to an extent which carried it through, and H. Akroyd Stuart's name was not associated with the engine in the public view, although credit was due to him for initiating the design. He died in Western Australia February 19th, 1927. See May Issue, 1927. The references made by Mr. Porter and Prof. Hawkes emphasize the importance of having a Paper on the subject as soon as possible based upon the title given under the legacy left for Awards to be made as per the Notices issued.—J.A.

The Student Graduate Examination in April was attended by 16 candidates: Cardiff 1, Newcastle 12, Leyton 2, London 1.

Seven passed in all subjects and the following obtained first places in the subjects as undernoted, and prizes will be awarded to them, books, instruments or class fees, according to choice.

Theoretical Mechanics: Equal 1st, D. Tagg (Newcastle), L. J. P. Lively (Newcastle), W. T. Stevenson (Leyton).

Heat and Heat Engines: 1st, D. Tagg.

Machine Construction and Drawing: Equal 1st, J. Henderson (Newcastle), J. P. Reid (Newcastle), J. H. Tiplady (Newcastle), L. J. P. Lively (Newcastle), E. O. Stockman (Newcastle).

Applied Mechanics: 1st, J. Henderson.

Mathematics: 1st, J. P. Reid.

English: 1st, D. Tagg.

Electrical Engineering: 1st, J. Henderson.

Gross Total Marks: 1st, D. Tagg.

The Newcastle candidates attended the Rutherford Technical College and the Leyton candidates attended the Leyton Technical Institute.

The Lloyd's Register Scholarship Examination in May was attended by 16 candidates: Cardiff 2, Crewe 1, Sunderland 2, Glasgow 2, Edinburgh 1, Newcastle 8. The three who gained highest aggregate marks were J. D. Pearson, Cardiff; E. Foster, Crewe; and T. S. Harker, Sunderland. Further examination, conducted by two representatives of Lloyd's Register of Shipping and by two representatives of The Institute has been made of the three candidates who attended at the Institute, and their merits were carefully considered before the scholarship was awarded. The Report of the Board of Representatives was submitted to the Committee of Lloyd's Register of Shipping and the Scholarship was awarded to J. D. Pearson.

Boiler Explosion Acts

REPORT NO. 2868. S.S. *Seaforth.*

The *Seaforth* is a vessel 145ft. long and 349 gross tons, fitted with one boiler 11ft. 6ins. diam. x 10ft. 6ins. long; 2 furnaces 3ft. 4 5/16th ins. diam, shell plates 23/32nd ins. thick, furnaces 21/32nds ins. thick, combustion chamber back plate 19/32nds ins., tube plate $\frac{7}{8}$ins., and the bottom plate 31/32nd ins.

On July 17th at about 7.30 p.m. when the vessel was en route to Pentewan from Par, an explosion took place in the port furnace. It was not violent and it was possible to keep up the water level until port was reached, when the boiler was emptied and examined. It was then found that the furnace was seriously pitted in several places on the water side and wastage on the fire side. Thus leading to a hole through which the water and steam escaped.

The circumstances were investigated and the report prepared by Mr. R. Lewis, Board of Trade Surveyor, Falmouth, who found that in April the boiler was overhauled and repaired. The port combustion chamber back plate was reinforced in way of one stay end; a short length of furnace plating, 12ins. x 3½ins. was built up and four rivets in furnace and combustion chamber joint built over by the electric welding process. Joints of wrapper plate on starboard and port sides were caulked, starboard combustion chamber back plate reinforced in way of one stay and one rivet in flange of back plate at bottom built over, pitted places in landing (caulking) edge of furnace end; also short length of landing (caulking) edge of furnace plating built up and two rivets in furnace afterend bottom built over by electric welding process. Starboard wrapper cross seam caulked, taking in joints of wrapper and extending up the chamber back plate and tube plate.

It had been the custom to empty and clean the boiler once in about three months. This was done at Par on July 15th, the furnaces being then scaled as well as time would allow. The repairs carried out in April evidently did not cover all the defects in the plates, and closer observation then would have revealed the defects which led to the explosion and its results in delaying the ship. A piece 12ins. long x 36ins. circumference was cut out of the bottom of the furnace and combustion chamber, and a patch of ½in. thick steel riveted on. The hydraulic test of 160 lbs. per sq. in. was applied and proved satisfactory, so also the steam test.

The observations of Mr. Laslett, Engineer Surveyor-in-Chief were that it appears that certain repairs to the furnaces and combustion chambers of the boiler were effected recently, but the defective condition of the furnace plate where the hole developed was not noticed at that time. The case directs attention to the importance of making close examination of boilers and particularly of those parts where serious wastage is likely to occur.

REPORT NO. 2842. S.S. *Clydeburn*.

This deals with an explosion on board of the *Clydeburn* on December 16th, 1926, when off Wicklow Piers. The investigation of the circumstances and preparation of the report were made by Mr. J. H. Morgan, Board of Trade Surveyor, North Shields. The cause of the explosion, which was not of a violent nature, was due to a crack about 3ins. long developed in an old patch on the bottom of centre combustion chamber, through which contents of the boiler escaped. The crack was caused by the plate having become so thin by corrosion that it was unable to withstand the pressure in the boiler—160 lbs.

The boiler, single-ended, 13ft. diam. x 9ft. 6ins. with three plain furnaces, 3ft. 5½ins. diam, was overhauled and a patch was fitted to the bottom of centre combustion chamber prior to 1922, on which date the vessel changed owners. In February, 1923, a few rivets in this combustion chamber were renewed and the wrapper plate welded. In March, 1924, rivets and seams were caulked in port and centre furnaces and a number of tubes expanded. The back of the centre combustion chamber was renewed and the patch which was much wasted by corrosion was built up to the original scantlings. The boiler was then tested by hydraulic pressure. In March, 1925, one centre combustion chamber stay was renewed and others caulked. Some rivets were caulked and the saddle seams of centre and starboard furnaces were also caulked. The seams of tube plate and wrapper in the centre furnace were welded in Sept., 1925. A number of tubes were expanded and rivets and seams caulked on February 6th, 1926, and the manhole doors refitted and 30 tubes expanded in April, 1926. The part that gave way was found to be reduced in 1/32nd inch, and the bottom plate of the combustion chamber was renewed.

The observations of the Engineer Surveyor-in-Chief were that the boiler was 24 years old and owing to wastage of one of the plates forming part of the centre combustion chamber, a large patch had been fitted at some time previous to 1922. At various times later, owing to wastage, a process of electrically building up the plates was resorted to, but some parts thinned on the chamber bottom were overlooked apparently and were so reduced that about the time of the explosion the local thickness was only about 1/32nd in. The vessel was disabled by reason of the explosion and had to be towed into port. It is always difficult to examine thoroughly such parts as these and even more difficult to build up the thinner plate in such a position efficiently. The use of electric welding should only be resorted to when the parts can be thoroughly examined after repair.

Election of Members.

List of those elected at Council Meeting of June 11th, 1928:—

Members.

Yoshiatsu Akaba, Eng.-Comdr. I.J.N., Imperial Japanese Navy, Broadway Court, Broadway, Westminster, S.W.1.

Percy Robert Brooker, M.B.E., Eng.-Lt., R.N., 5, Cleave Road, Gillingham, Kent.

William Fearon Brown, 5, Craven Road, Addiscombe, Surrey.

John George Christie, Anglo Saxon Pet. Co., St. Helen's Court, Leadenhall Street, E.C.3.

John Francis Cowlin, Surveyors' Dept., Trinity House, Tower Hill, E.C.3.

Paul Henry Farmer, Apt., 7, Scarsdale Court, 950, Decarie Boulevard, Montreal, Canada.

Frank Edgar Mattocks, 140, Westwood Road, Goodmayes, Essex.

Duncan Cameron McMillan, Yamba, 25, Chelmsford Avenue, Willoughby, Sydney, N.S.W.

Andrew Paul, *c/o* Stewart, 6, Brachelston Street, Greenock.

Alan Grant Richardson, 65, Eldon Street, Greenock.

John William Roche, 22, Lilac Gardens, Low Fell, Gateshead.

William Thomas Raine Scott, 10, Addison Road, Fairview, Dublin.

James Young Shanks, Myrtledene, 24, Ramsay Park, Broughty Ferry, Dundee.

Edmund Victor Telfer, D.Sc., Ph.D., 11, Chelsea Grove, Newcastle-on-Tyne.

Associate Member.

Edward Rupert Etches, SS. *Philip T. Dodge*, *c/o* Lambert Bros., Ltd., 85, Gracechurch Street, E.C.3.

Asosciate.

Walter Richard Moitie, Marine Engineering Works, New Street, Guernsey, C.I.

Transferred from Associate Member to Member.

Cecil Francis Ivanson Batt, Ferndale, Walton Road, Clacton-on-Sea.

George J. Hatch, *c/o* John Swire and Sons, Shanghai, China.

J. L. Pedrick, 2, Victoria Road, Millbay, Plymouth.

Charles E. Peel, S.S.Y. *Sea Belle II*, Singapore, S.S.

Transferred from Associate to Member.

William Edward Mallett, 46, Orchard Hill, Lewisham, S.E.13.

Board of Trade Examinations.

List of Candidates who are reported as having passed examination under the provisions of the Merchant Shipping Acts.

For week ended 5th May, 1928:—

NAME.	GRADE.	PORT OF EXAMINATION.
Miles, Harry	1.C.M.E.	Southampton
Cowburn, Thomas H.	2.C.	London
Hoult, Aubrey E.	2.C.	,,
MacDougall, John...	1.C.M.	,,
Allan, Harold R.	1.C.	Glasgow
Miller, John	1.C.	,,
Speirs, John	1.C.	,,
Wilson, Frederick H. M.... ...	1.C.	,,
McWillie, Donald M.	2.C.	,,
Campbell, Robert	1.C.M.	,,
Watson, James C....	1.C.M.E.	,,
Macadam, John K.	1.C.M.E.	Liverpool
Brown, Cyril K. L.	1.C.	,,
Gow, Edward A.	2.C.	,,
Jones, Edward	2.C.	,,
Jones, Harold	2.C.	,,
Jones, Herbert V.	2.C.	,,
Preston, James K....	2.C.	,,
Serjeant, William N.	2.C.	,,
Taylor, Herbert	2 C.	,,
Ditchfield, Charles F.	2.C.M.	,,
Shotton, William C.	1.C.	North Shields
Brown, Ernest	2.C.	,,
Jackson, Charles	2.C.	,,
Mordue, Arthur	2.C.	,,
Waugh, William G.	2.C.	,,
Lisle, John...	2.C.M.	,,

For week ended 12th May, 1928 :—

NAME.	GRADE.	PORT OF EXAMINATION.
Hayward, Sidney G.	2.C.M.E.	London
Neall, Alfred G.	2.C.M.E.	,,
Hunter, John T.	2.C.M.E.	Glasgow
Muirhead, William	1.C.	,,
France, Robert P.	2.C.	,,
Gifford, Archibald McL.	2.C.	,,
Robertson, Nicol	2.C.	,,
Sinclair, Alexander B.	2.C.	,,
Butter, Edwin A.	2.C.M.	,,
Collins, George C. M.	1.C.	Hull
Greenaway, Thomas P.	1.C.	,,
Porter, Tom	1.C.	,,
Wright, Harold	1.C.	,,
Graham, William	2.C.	,,
Haykin, Sydney	2.C.M.	,,
Duff, Alexander	1.C.	Liverpool
Hutchinson, Edward J.	1.C.	,,
McKenzie, Duncan	1.C.	,,
Satterthwaite, William	1.C.M.E.	,,
Dalziel, George A.	2.C.	,,
Fryer, Algernon, M.	2.C.	,,
Roberts, Thomas N.	2.C.	,,
Tempest, James F.	2.C.	,,
Wright, Edward	2.C.	,,
Wynn, Francis K.	2.C.	,,
Berryman, George W.	1.C.	North Shields
Gerner, Robert H.	1.C.	,,
Muckle, William P.	1.C.	,,
Worrall, Thomas R.	2.C.M.	,,
Bassett, Roger S.	2.C.	London
Hannan, James A.	2.C.	,,
McKnight, William J.	2.C.	,,
Tucker, Frank W. G.	2.C.	,,
Sim, James	1.C.	Sunderland
Walker, Enoch D.	1.C.	,,
Young, Hugh	1.C.	,,
Robson, Matthew	2.C.	,,
Shotton, George B.	2.C.	,,
Craggs, Charles	1.C.M.	,,
Harvey, William H.	1.C.M.E.	,,
Hogg, Frederick S.	1.C.M.E.	,,

For week ended 19th May, 1928 :—

Thomas, Benjamin C.	1.C.M.E.	Cardiff
Baker, Francis C. W.	1.C.	,,
Child, Thomas H.	1.C.	,,
Deslandes, Edward H.	1.C.	,,
Ewer, Percy S.	1.C.	,,
Harries, David J. I.	1.C.	,,
Kipling, Arthur	1.C.	,,
Richards, Ronald M.	1.C.	,,
Richards, William G.	1.C.	,,

For week ended 19th May, 1928—*continued*—

NAME.	GRADE.	PORT OF EXAMINATION.
Taylor, John S. D.	1.C.	Cardiff
Amos, Hedley A.	2.C.	,,
Osmond, Colin W.	2.C.	,,
Lochhead, David Mc G.	1.C.	Glasgow
McArthur, Donald	1.C.	,,
Brown, Alasdair L.	2.C.	,,
McNay, William W.	2.C.	,,
Monteith, William	2.C.	,,
Hunter, John T.	1.C.M.E.	,,
Jarvie, David Mc K.	1.C.M.E.	,,
Alexander, Charles J.	1.C.	Liverpool
Bailey, Thomas W.	2.C.	,,
Bolger, James F.	2.C.	,,
Gobie, William	2.C.	,,
Greenop, William	2.C.	,,
Palmer, George A.	2.C.	,,
Richardson, George E.	2.C.	,,
Barrow, Thomas J. E.	1.C.M.	,,
Bunn, Sidney C.	1.C.	London
Roberts, Robert	2.C.	,,
Verrall, Walter C.	2.C.	,,
Prest, Sydney A.	1.C.M.E.	,,
Woods, Thomas	1.C.M.E.	Southampton
Martin, Graham W.	1.C.	,,
Pirie, Norman	1.C.	,,
Bass, James A.	2.C.	,,
Moore, Clarence K.	2.C.	,,
Craigen, Robert M.	1.C.M.E.	Leith
Baillie, John P.	1.C.	,,
Harris, James M.	1.C.	,,
Penman, James	1.C.	,,
Bamber, William J.	2.C.	,,
McDonald, Cecil W.	2.C	,,
Ross, Arthur A.	2.C.	,,
Mortimer, John D.	2.C.M.	,,
Webster, Robert	1.C.M.E.	,,
Adamson, Robert	1.C.	North Shields
Gair, George	2 C.	,,
Gibbon, Charles E.	2.C.	,,

For week ended 26th May, 1928 : -

Campbell, George McC.	1.C.	Glasgow
Earl, Robert J. C.	1.C.	,,
McLaren, Thomas	1.C.	,,
Porter, John S.	1.C.	,,
Cameron, William P.	2 C.	,,
Begbie, James	1.C.	Liverpool
Donaghy, Chris A. D.	2.C.	,,
Ewing, John C.	2.C.	,,
Johnson, Thomas	2.C.	,,
Roberts, John	2.C.	,,
Scragg, Godfrey B.	2.C.	,,
Simpson, Hector S.	2.C.	,,

For week ended 26th May, 1928—*continued*—

NAME.	GRADE.	PORT OF EXAMINATION.
Stewart, John S.	2.C.	Liverpool
Bridge, Ernest W.	2.C.M.	,,
Marks, Harold W. R.	2.C.M.	,,
Dalgliesh, Ernest V. C.	1.C.M.E.	,,
Batt, Cecil F. I.	1.C.	London
Hill, Gerald D.	1.C.	,,
Wheeler, Harry P.	1.C.	,,
McCarraher, Alan J.	2.C.	,,
Jones, Norman F.	2.C.M.	,,
Dorward, Alexander S.	1.C.M.E.	,,
Hayward, Sidney G.	1.C.M.E.	,,
Cromarty, Robert W.	1.C.M.E.	North Shields
Milne, John	2.C.M.	,,
Goodram, Charles	1.C.	Sunderland
Butterworth, Arthur	2.C.	,,
Carter, William	2.C.	,,
Coates, William G. R.	2.C.	,,
Inman, Frederick E.	2.C.	,,

For week ended 2nd June, 1928:—

Sellar, Peter W.	1.C.	Belfast
Maxwell, John G.	2.C.	,,
Shannon, William P.	2.C.	,,
Prigg, John W.	1.C.	Cardiff
de la Mare, Edgar G.	2.C.	,,
Hayes, Charles E.	2.C.	,,
Rees, Brinley	2.C.	,,
Taylor, Kerwin F.	2.C.	,,
Goodfellow, Henderson M. M.	1.C.	Glasgow
Huggan, Robert E.	1.C.	,,
McLaren, James W.	1.C.	,,
Rodgers, Herbert C.	2.C.M.E.	,,
Dunbar, John	2.C.	,,
McColm, William	2.C.	,,
Brash, Matthew P.	2.C.M.	,,
Milne, George H.	2.C.M.	,,
Torrie, George	1.C.	Leith
Strachan, John S.	2.C.	,,
Rosine, John L.	2.C.M	,,
Paul, Douglas	2.C.	Liverpool
Solly, Henry W.	2.C.	,,
Burdis, John H. M.	1.C.	North Shields
Smith, William G.	2.C.	,,
Simkins, Clarence R. P.	1.C.	London
Howieson, Nicol Mc C.	2.C.	,,
McMurtrie, William A. S.	2.C.	,,
Cartmell, John	1.C.	Southampton
Ransom, Jack	2.C.	,,
Whittaker, Thomas D.	2.C.	,,

For week ended 9th June, 1928:—

Sedgwick, Stanley	1.C.M.E.	Sunderland
Martin, Charles J.	1.C.	Glasgow
Scott, David H.	2.C.	,,

For week ended 9th June, 1928—*continued*—

NAME.	GRADE.	PORT OF EXAMINATION.
Moncrieff, Christopher J.	1.C.	Hull
Jones, John O.	2.C.	,,
Smith, Fred	2.C.M.	,,
Butler, Richard G....	1.C.	Liverpool
Wright, Eric	1.C.	,,
Jones, James M.	2.C.	,,
Scott, James R.	2.C.	,,
Nettleton, Albert J.	2.C.M.	,,
Hall, Charles E.	1.C.M.	,,
Owen, John E.	1.C.M.E.	,,
Ritchie, David	1.C.M.E.	London
Christian, Alexander A.	1.C.	,,
Haggarty, James A. R.	2.C.	Sunderland
Lawrence, Charles J.	2.C.	,,
Oliver, John	2.C.	,,
Jones, Ronald D.	2.C.	North Shields
Smith, James	2.C.	,,
Still, Andrew N.	2.C.	,,
Corlett, William A.	1.C.M.E.	,,

Ex. 1.C.	Extra 1st Class.	1.C.M	1st Class Motor.	2.C,M.	2nd Class Motor.
1.C.	First Class.	2.C.	2nd Class.	M.E.	Motor Endorsement.

Samples of questions to Candidates for Board of Trade Certificates. Reprinted by permission of H.M. Stationery Office:—

SECOND PAPER.

What is acceleration and how is it measured? A body is projected vertically upward with a velocity of 1,200ft. per second. Find the greatest height to which it will rise, and the time taken.

A mild steel tie-bar is 18ft. long and is made of angle bar 3·5 ins. x 2·5 ins. x 0·42 ins. If the total pull on the bar is 19 tons, find the stress in lbs. per sq. inch and the extension of the bar. Take E = 13,500 tons per sq. inch.

The thickness of the shell plating of a cylindrical boiler is $\frac{7}{8}$ inch, the diam. of the boiler is 8ft.; the strength of the joint compared with the solid plate is 74%, and the tensile strength of the plate is 28 tons per sq. inch. What would be the factor of safety with a working pressure of 155 lbs. per sq. inch?

FOR ORDINARY EXAMINATION.

The boilers of a vessel contain 218 tons of water and at the commencement of a voyage they were filled with fresh water. At the end of that voyage, owing to a leak in the condenser the density of the water in the boilers was $\frac{3\cdot75}{32}$. If the average density of the water in the hot-well had been $\frac{0\cdot15}{32}$, how many tons of water had been evaporated during the voyage?

What is meant by mean referred pressure? The diameters of the cylinders of a triple expansion engine are respectively 25ins., 46ins. and 60ins. and the mean effective pressures are respectively 56·2, 21·1, and 10 lbs. per sq. inch. Find the mean pressure referred to the L.P. cylinder, and the I.H.P. with a piston speed of 820ft. per minute.

Steam is admitted to a cylinder at a pressure of 185 lbs. per sq. inch by gauge and the cut-off takes place at 0·37 of the stroke, the clearance being = 4·9 of the stroke volume. Find the *absolute* pressure when the piston has passed through 0·86 of its stroke, taking the effect of clearance into consideration.