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[*]The Progress of the Internal Combustion Engine During the Last Twenty Years.

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THE most spectacular event during the period under review is no doubt the initiation and successful commercial development of the light high-speed Diesel engine, a possibility almost undreamed of twenty years ago. In the same period, the petrol or gas engine has, to all outward appearances, undergone but little change, but in this comparatively short space of time, the power output obtainable from a given size of engine has been considerably more than doubled, and with aero-engines in particular, the specific fuel consumption has been reduced to only about 60 per cent. This large increase in performance has been obtained without any radical changes in design; in fact, from the point of view of mechanical design, the petrol or aero-engine of to-day differs from that of twenty years ago only in small matters of detail design. How then has this increase been brought about? At least 70 per cent. is due to our greatly increased, though still very imperfect, knowledge of the process of combustion. This is reflected in improvements in the form and cooling of the combustion chamber, to give better control, and still more in the composition of the fuel. It is only during the last twenty years that the importance of the blending and treatment of the fuel has begun to be realised.

Until the end of the War, any petroleum distillate boiling below a certain temperature, and having a specific gravity below a certain purely arbitrary figure, was sold as petrol, and that quite regardless of the molecular structure of its component parts. To-day, all this has changed completely; now it is known that hydrocarbon molecules of a certain structure will break down easily, and give rise to detonation, which sets a hard and fast limit to the performance obtainable; it is known, too, that by certain processes in the production of petrol, the structure of these molecules can be changed in order to increase their stability, and their tendency to detonate can be further reduced by adding dopes, such as lead ethide, or by admixture in suitable proportions with alcohol or benzole.

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Hand in hand with improvements in the fuel, advantage has been taken of the higher compression, and, in some cases, of the supercharging, which their use has rendered possible. The petrol engine of to-day would give a pitiable performance on the average fuels available twenty years ago, while the aero-engine of to-day would certainly be unable to leave the ground. On the other hand, the petrol engine of twenty years ago would run no whit better on the fuels available to-day.

Detonation.

More than thirty years ago, the late Professor Hopkinson called attention to the phenomenon of detonation, and suggested that it was probably a characteristic of the fuel, but his was a voice crying in the wilderness, and his warnings had passed unheeded by all but a few of his disciples; it was not until the closing stages of the Great War, that its importance began seriously to obtrude itself. Then followed gradually the realisation that it was detonation, and detonation alone, which set a limit, and a relatively early limit, to the power output and economy of the petrol engine, for the incidence of detonation in fact determines both the weight of air which can be consumed, and the efficiency with which the heat thus generated can be converted into power.

To-day a good deal is known about the mechanism of detonation, and a little of the very complicated chemical processes which bring it about. The mechanism of detonation was soon discovered, and can be explained quite simply. When a combustible mixture of fuel and air is ignited by the passage of the spark, there builds up, slowly at first, but with a rapid acceleration, a small nucleus of flame, at first somewhat in the form of a soap bubble; this spreads outwards with ever increasing rapidity. As the flame front advances, it compresses ahead of it the remaining unburnt mixture, whose temperature is raised both by compression and radiation, until a point is reached when the remaining unburnt charge will ignite spontaneously, and almost instantaneously, thus setting up a detonation wave which will pass through the burning mixture at an enormously high velocity, such, that its impact against the cylinder wall will give rise to a ringing knock, as though they had been struck by a light hammer. During its passage, the detonation wave will compress again the already burning products, still further raising their temperature, and that of any isolated or partially insulated objects in their vicinity, such as the sparking plug electrodes, until ultimately these become incandescent, and thereby cause pre-ignition, and therefore, loss of power.

Consideration will show that the incidence of detonation depends firstly upon the amount of heating and compression which the still unburnt mixture can endure, that is upon the chemical nature of the fuel itself; secondly, upon the opportunities it has for getting rid of the heat which is being thrust at it by the rapidly advancing flame front, and thirdly, upon the absolute distance the flame has to travel from the point of ignition, for the further it travels, the faster it goes, and the more rapidly it compresses, and therefore heats up the still unburnt portion ahead of it.

The tendency to detonate can be reduced by modifying the chemical composition, or the molecular structure, of the fuel. It can also be reduced by mechanical design, by shortening the length of flame travel, that is to say, by using the smallest possible combustion chamber and by placing the sparking plug as nearly as possible in the centre, or by using two plugs. Further, it can be reduced by giving the mixture most remote from the source of ignition, every possible facility for getting rid of the heat that is being thrust into it, and it can be reduced yet again by keeping the mixture in a state of turbulence in order both to break up the flame front and, at the same time, prevent the isolation of any small pocket of unburnt mixture. All these things have been learnt during the last twenty years, and to-day it is probable that the limit of what can be done by mechanical design, has almost been reached. The limit of what can be achieved by doctoring the fuel has by no means been reached, however, for the complicated chemical processes which take place during the instant of ignition and combustion are still rather obscure, though there is a dim realisation, that to give rise to detonation, some very unstable products must first be formed, some fulminates to set off the cordite, and it is to the discovery and suppression of these that all eyes have been turned during the last few years.

According to the simple rules, a mixture of air and petrol vapour, oxygen and nitrogen, hydrogen and carbon, is compressed in the cylinder; at the appointed time, a light is set to this highly inflammable mixture; there follows an instant of violent scramble and confusion; when the clamour and the fighting are lulled, it is found that the hydrogen has mated with some of the oxygen to form steam, the carbon has embraced the rest to form carbon dioxide, while the nitrogen remains unloved, disdainful and alone.

With this simple and entirely orthodox evolution, we once were perfectly content, but inquisitive minds began to enquire what is really happening during the scrimmage itself, and more especially at, and even just before, the start of the scrimmage, and to suspect that, just possibly, every oxygen atom did not at once find its right partner, and, darkest suspicion of all, that the nitrogen's behaviour was not quite so platonic as she would have us believe. Alas, the more deeply we probe, the more scandals we unearth. We find that the fickle oxygen has formed all sorts of unholy alliances before finally settling down to a steady partnership, while even the aloof, and apparently chaste nitrogen has had at least one affair under cover of the general confusion, and a very disgraceful one at that.

In that one-thousandth part of a second or less, all kinds of unstable alliances have been formed and dissolved again, but some of them have endured long enough to exert a powerful and malign influence, while, in some cases, their very instability has itself been a source of danger.

To-day it is realised that it is not the final partnerships, but the fleeting, excitable and temporary liaisons that are the cause of all our worry, and the chief inciters of detonation; they, in fact, are the hotheads who start the rough house.

Many of these have already been identified, some few have been scotched, but many more are probably still undetected. For want of a better name, these illicit alliances are called products of partial combustion, because for the most part, they exist and have their being only during the actual process of combustion and disappear when combustion is complete, but not quite all; some, though probably only a few, are formed actually a little before the passage of the spark during the heat and confusion of compression. Thus, they are transient only, and cease to exist when combustion is complete and the oxygen atoms have found their permanent partners, but, when the wave of flame breaks on the cold shores of the cylinder walls, the process of combustion is suddenly arrested and the merry-making halted abruptly. Here, then, on the extreme outer fringes, some of these illicit couples, these products of partial combustion, may be caught embracing, for the sudden chill of contact with the cold walls has frozen them rigid before they have had a chance to disengage themselves. When we search the wide ocean nothing do we find; it is by examining the foam left behind on the shore, that their existence can be detected.

It is certain of these transient products of partial combustion, probably the unstable peroxides, that are the active instruments in the cause of detonation, and to-day we do all in our power to be rid of them; an attempt is made to discourage their formation by introducing the hydrocarbon in the form of the more stable ring molecules, rather than the loose chains of the paraffin series, or again, an oxygen atom may be insinuated in advance into the molecule to act as a chaperone, as when using alcohol or acetone. In such matters, the rôle of the chemist and the designer is that of a social reformer in an uproarious and improper nightclub. The chemist can issue the invitations, and so, to some extent at least, can choose the company. The designer can ensure that there are no secluded corners in his design of the room. In the last extreme, we descend to the rôle of the rat-catcher, and seek to poison these undesirables with dopes, such as lead tetraethide, better known perhaps as "ethyl fluid". By such means, success has been attained in reducing enormously the tendency of fuels to detonate, and thus in removing the greatest barrier to power output.

While certain of the transient products are the active instruments in detonation, some of those cast out on the fringes of the flame are the active cause of cylinder wear, for they burrow into and try to hide their shame in the walls of the cylinder barrel, like white ants in a packing case, and the colder the barrel, the more actively, and the deeper do they burrow. In this direction nitrogen's liaison is now believed to be the worst offender of all, and the most eager to hide its shame.

Mechanical Conditions.

In recent years the attempts to suppress the transient products and so reduce detonation, have met with a considerable measure of success, though the suppression of the few permanent products, has, alas, been less successful, and it has been necessary to fall back on purely defensive measures, such as the use of less easily corrodible materials for the cylinder liners, such as austenitic or high phosphorus irons or chromium plating, and the maintenance of the cylinder wall temperatures above the dew point of these destructive pests.

As regards other mechanical conditions, the vital importance of stiffness has been learnt, both in the structure of the engine itself, and in the principal moving parts in order to keep all natural frequencies as high as possible, and so avoid the incidence of synchronous vibrations. A great deal has been learnt about the torsional vibration of crankshafts in particular, and of the vibration of structures in general, and, as a result of this knowledge, it has been possible, with safety, greatly to increase the operating speed of petrol engines.

Further, a great deal has been learnt about the technique of lubrication, to deal with these higher operating speeds; the word "technique" is used, for we are still almost as far as ever from any real understanding of the fundamentals of lubrication. To-day a little oil is circulated for lubrication, whatever that may really mean, and a great deal more oil for cooling the bearings; in fact, the high speeds at which engines are operated to-day, are made possible only by lavish oil cooling of the crankshafts, bearings, etc. Some day, no doubt, the functions of lubrication and cooling will be separated, and a closed circuit will be used for the latter, for the present method, though it serves the purpose for the time being, is, at best, rather a clumsy compromise.

As a result of mechanical improvements, coupled with meticulous attention to detail design, engines to-day can be operated with equal reliability, at a piston speed at least fifty per cent. higher than twenty years ago. This increase in speed, together with the increase in mean effective pressure due to improvements in the fuels, and to the increased, though still imperfect, understanding of combustion conditions, have enabled the power output of a given size of petrol engine to be considerably more than doubled during the last twenty years.

During the same period, vast strides have been made in the technique of manufacture. The introduction of carbide cutting tools alone, has made it possible to remove material approximately three times more rapidly than was possible twenty years ago, while the introduction of what are termed "mass production methods" has compelled interchangeability, has eliminated hand fitting, and has brought about an all-round standard of accuracy such as was to be found twenty years ago only in very exceptional and extremely expensive instances.

In the last twenty years then, the power of the petrol engine has been more than doubled and its cost has been greatly reduced, while its numbers have been multiplied twenty-fold. Whether in so doing, we have acted rightly is another story; looking back, I am inclined to think that the world was, on the whole, a much pleasanter place before the advent of the petrol engine.

The Diesel Engine.

The Diesel engine made its first appearance while I was a boy, and I felt that I have grown up with it, for all my life I have followed closely its progress. For some reason this perfectly matter-of-fact heat engine contrived for many years to weave around itself an atmosphere of mysticism. Distinguished engineers were wont to speak of it with reverence and even with awe, and one was expected to stand bareheaded in its presence, while any criticism, however kindly meant, was regarded almost as blasphemy. I know not why the petrol engine has been regarded always as the guttersnipe, while the Diesel, from its birth, assumed the rôle of the proud aristocrat, but such, until recently, was the case.

I well remember, many years ago, the dark looks, and the air of shocked disapproval that greeted me, when I was once impudent enough to suggest that the Diesel engine might be persuaded to do a little slimming, and to run just a little faster. I was hustled from the presence, and told in shocked tones that I had no conception of the delicacy of its constitution, or of the complicated and difficult digestive processes it had to go through at every cycle.

To-day, the large and portly Diesel engine still preserves much of its Victorian dignity, and has progressed comparatively little during the last twenty years. It is still housed in massive brick buildings, surrounded with aspidistras and lace curtains. It has discarded, finally, I think, its attendant air-compressor—a costly luxury—and it now drinks its fuel neat, without having it diluted by high-pressure air; it has learnt to run a little faster; it has shed a little weight, but its technical progress compared with that of the petrol engine during the last twenty years has been relatively small.

It has, however, taken kindly to a sea-faring life, and is now in wide use for ship propulsion. In this service, it has been helped greatly by the use of exhaust-driven superchargers, which have added to its breathing capacity, its cooling, and to its vitality generally, but it still suffers from lack of rigidity, and it feels the heat very badly owing to the thick skin of its cylinders. Its survival to-day is due, I believe, solely to the lack of any really satisfactory method for harnessing power from a large number of small power units to a single shaft. By analogy, five hundred rabbits could haul a plough more economically than a single horse, but no one yet has succeeded in designing a suitable harness. Once this problem has been solved, the large slow running Diesel engine will, I think, adorn only our museums.

The light high-speed Diesel is a development of the last twenty years, in fact, almost of the last ten years, and is the product of an entirely new school of thought, a school which, lacking reverence, dared to question the orthodoxy of the Diesel high priests, and to press in vain for an answer to the question why the Diesel engine should not be hurried. To-day, Diesel engines are produced in their thousands which are every bit as vulgar, boisterous and lively as the petrol engine, and even more reliable, since they are free from the uncertainty of electric ignition, and the vagaries of carburettors. The amazingly rapid development of the light high-speed Diesel engine is the most outstanding single achievement in the development of the internal combustion engine; the pity is that it did not take place long ago, and in parallel with that of the petrol engine, for looking back, there is really no technical reason why it should not have done so.

Bomb experiments with petrol-air mixtures proved, thirty years ago, that the combustion process in the petrol engine required so long a period of time that, for this reason alone, such engines could not be run at more than about 300 r.p.m., but, at that very date, petrol engines on motor-cycles, were in fact, running at speeds of 2,000 r.p.m., and over, and no amount of demonstration in the lecture room could prove the contrary.

In actual fact, there is no limit in sight to the speed with which the process of combustion can be accelerated, provided the requisite temperature and air movement are ensured, nor is there any tittle of evidence in support of the dogma that the combustion process in the Diesel engine need take any longer than in the petrol engine; certainly, in neither case is the limit in sight. In both cases, the process of combustion is excessively complicated, the more complicated the deeper it is probed, and in both cases it passes through many intermediate phases, but complex though it may be, time is not the element. In both cases, the practical limit of speed is determined by mechanical conditions and by mechanical conditions alone.

Combustion in the Diesel Engine.

I have said a good deal about the combustion process in the petrol engine because it is, at the moment, a subject of renewed and very intensive study; much of what I have said applies also to the Diesel engine, but with two important differences. Firstly, the bogey of detonation is absent, and secondly, combustion is initiated, not by the passage of a spark, but by the ignition of a surface layer of vapour surrounding countless thousands of minute droplets of liquid fuel.

Apart from these two major differences, the process of combustion is much the same in either case, in that the same transient partnerships are formed and dissolved again and the same products of partial combustion are cast ashore on the cold surfaces to do their evil work.

To-day, petrols are classified in terms of their octane number, which is a measure of their tendency to detonate; the higher the octane number, the less prone are they. Diesel engine fuels are classified in terms of their cetene number; the higher their cetene number, the more readily will they ignite, and therefore with less shock, but it must be made clear that, within very wide limits, the cetene number of a Diesel fuel is, or should be, of quite trivial importance compared with the octane value of a petrol; the former affects the smoothness of running and little else, whereas the octane number of a petrol determines both the power output and the thermal efficiency of the engine.

In the early Diesel engines, liquid fuel was injected into the cylinder at the end of the compression stroke by a blast of very highly compressed air. This air served the treble purpose of pulverising the fuel itself very finely, of projecting the finely pulverised fuel to all parts of the combustion chamber and, finally, of setting up violent turbulence. Thus each particle of fuel was quickly brought into intimate contact with the air needed for its combustion. Such blast air injection served very well indeed, but was open to the objection that it necessitated the addition of a high-pressure air compressor, an expensive and delicate piece of machinery, and one, too, which absorbed a very serious proportion of the power output of the engine.

The next step was the elimination of the blast air and the substitution of what is generally, but somewhat inappropriately, termed solid injection, that is to say, the injection of fuel into the cylinder without the accompaniment of high-pressure air, by means of a small accurately timed high-pressure force pump, which both measures the quantity and decides the time of injection. With solid injection, however, it was found difficult to reconcile certain conflicting conditions.

In order to enable the fuel to reach the outskirts of the combustion chamber, and so make the acquaintance of the suburban oxygen, a high degree of penetration was essential. In order to present the largest possible surface for combustion, it was essential that the fuel should be pulverised as finely as possible. Unfortunately, pulverisation and penetration are mutually contradictory. The blast air achieved both ends, but by no amount of jiggery-pokery can an injector nozzle be made to combine the pulverisation of a scent spray with the penetration and range of a fire hose.

Other means had therefore to be found to bring the fuel and air together; all kinds of ingenuity were invoked in attempts to find a compromise between these two irreconcilables, but with only partial success. At long last, someone suggested what seems the obvious; if the fuel cannot be delivered to the suburbs, why not let the suburbanites come to town and fetch it? In other words, if it is difficult to set the fuel to find the air, then why not set the air to find the fuel? It is far easier to set air in motion and, if necessary, into very rapid motion, than to search it out with jets of finely pulverised liquid fuel; moreover, if the motion of the air is sufficiently rapid, it will help in the pulverisation.

To-day, all high-speed Diesel engines operate, to a greater or less degree, on the principle of setting the air within the combustion chamber to find the fuel. In some cases, the air is given a rotational movement as it enters the cylinder by means of baffles or guide vanes on the inlet valve; in others, it is compressed through a tangential passage into a separate spherical chamber, wherein it sets up a violent rotational swirl; in others, yet again, the sudden displacement of the air trapped between the piston and cylinder head is used to produce something in the nature of a vortex ring, but in all cases, the principle is the same, namely, that of setting the air to search out, and find the fuel.

The different methods of arriving at the same result, have each their pros and cons, hence partisan ideologists lash themselves into a frenzy of excitement over words and names. In all cases, however, the real intention is exactly the same, namely, that the air shall be constrained to pass in orderly procession across the jet or jets of fuel; the more rapidly it passes, the more rapidly is combustion completed.

Some designers favour the use of a single fire hose type jet, accompanied by very intense air swirl; others favour the use of a number of jets combined with a less intense air swirl; both methods serve the purpose well, and the choice reduces to a question of mechanical expediency, and to a number of secondary detail considerations which need not be entered into.

In general practice, the single jet and intense air swirl, on the whole, serve best in small and very high speed engines, and the multiple jet and more moderate swirl in the larger sizes; the former entails greater heat losses and therefore a slightly lower thermal efficiency, but it is possible thereby to burn considerably more fuel in a cylinder of the same size, and therefore to obtain a greater power output from a given size and weight of engine.

The Light High-speed Diesel Engine.

The last ten years has seen the application of the Diesel engine to heavy motor vehicles, at first tentatively, and now so universally, that to-day many of the large manufacturers of buses and lorries have ceased entirely to build petrol engines except for military purposes. That the sedate, comfort-loving, and neurotic Diesel engine could ever be reduced to the indignity, or could acquire the physique to haul, instead of travel in, a bus, would have seemed almost inconceivable twenty years ago; yet such indeed has happened.

The modern light high-speed Diesel engine is first cousin to the petrol engine, which it resembles closely in all its mechanical details; it bears no more relationship to its namesake than does the hare to the buffalo, the only common factor being that both share the same diet and have somewhat the same digestive processes.

The most surprising feature about this development is the ease with which it has been brought about; once the tradition, almost the article of faith, that the combustion process could not be speeded up, was broken down, and only audacity and impudence were needed to achieve this step, the problem became one of mechanical design pure and simple. Compactness and extreme rigidity, the underlying principles of petrol engine design, were found to apply with even greater force to the high-speed Diesel engine, and once these principles were adopted, the new engine was found to be just as flexible, lively and versatile as the petrol engine. In deference to the higher pressures involved, still greater rigidity was given to the crankshaft, and to the engine structure generally, but, apart from this, the design follows closely that of the petrol engine.

The rapid success of the modern high-speed Diesel engine owes much to the enterprise and initiative of the Bosch Company of Stuttgart, who, with remarkable foresight, not only developed a very neat fuel injection pump, but developed also the technique of mass production and world wide maintenance of such pumps, an enterprise requiring an enormous capital outlay and that at a time when the high-speed Diesel engine was only in the early experimental stage. It was helped also, especially in this country, by the brilliant pioneer work of Messrs. Gardner, who were the first British firm to produce a successful road vehicle engine. Thanks to exquisite workmanship and meticulous attention to detail design, the Gardner engine achieved immediate success and quickly established that confidence so essential in the initial stages of any new development.

The imposition in this country of a heavy tax on Diesel fuel used for road vehicles, has handicapped tragically the development of the Diesel engine in the smaller classes of commercial vehicle, but on the Continent, it has developed apace. To-day, for example, the Citröen Company in Paris are turning out very small mass-produced Diesel engines for taxi-cabs and light delivery vans, engines of only 1·7 litres capacity, which develop 46 h.p. at no less a speed than 4,000 r.p.m.

So far, the high-speed Diesel engine for road vehicle work has been developed only in the four-cycle edition and has followed closely on the lines of contemporary petrol engine practice. There would appear, however, to be very strong arguments in favour of the two-cycle type, more especially for the smaller class, on the grounds that by doubling the proportion of power strokes, better use can be made of the materials of construction; and, since the same equality of turning moment can be obtained with half the number of cylinders, only half the costly fuel injection equipment will be required.

The usual argument against the two-stroke cycle, namely the loss of unburnt fuel during the scavenging process, does not apply in the case of the Diesel engine, since air only is used. The efficient, light, and really high-speed two-cycle engine involves a number of very difficult mechanical problems, and a good deal of careful and methodical development work will be required ere it becomes a practical success, but it is likely to be the next development.

Aero-Engines.

The aero-engine will be treated as a subject quite apart from that of petrol engines in general, for it represents the summit of all that science and practical mechanics, acting in combination, have yet achieved; also it is in a class apart, for it is the only prime mover of really large power and extremely light weight. The average military aero-engine of to-day develops round about 1,000 h.p., and weighs little more than 1,000lb., an achievement made possible only by exquisite design and workmanship, and by utilising to the full all that the most up-to-date science can provide. Its thermal efficiency is the highest of that of any prime mover operating on a similar heat cycle and, moreover, its mechanical reliability and durability are extraordinarily high.

People are apt to look upon the aero-engine as a brilliant piece of design, but as a delicate mechanism, forever requiring skilled attention, and unable to endure for any length of time, yet the modern aero-engine, despite its high output and high average working load factor, is normally capable of covering 100,000 miles without overhaul, while many engines have a total of over 500,000 miles to their credit.

The last twenty years have seen an enormous advance in the performance of the aero-engine, an advance which, in that period, has considerably more than doubled the power output from the same size or weight of engine, while the specific fuel consumption has been reduced to only about 60 per cent. Most of this improvement has been accomplished during the last five years, and is to be attributed mainly to improvements in the fuel (due to our increased knowledge both of the requirements and how to attain them).

To-day, as I have said before, we classify fuels by their tendency to detonate, and this is expressed in terms of their octane number; the best quality fuels supplied at the roadside pump have an octane number ranging from 75 to 80. Aviation fuel to-day has an octane number of 87 and great efforts are being made to produce large supplies of 100 octane petrol. As between 80 and 87 octane petrol, the possible power output of a supercharged aero-engine is increased by about 15 per cent., as between 87 and 100 octane it is still further increased by about 30 per cent., thanks to the higher ratio of compression, and still more to the greater supercharge permissible within the limits set by detonation.

This large increase in output has been accompanied of course by a corresponding increase in the gas pressures within the cylinder, which, in turn, has been met by improved materials, and still more by improvements in detail design, more especially in the direction of avoiding any local concentrations of stress from which fatigue fractures may start, and in the careful radiusing and polishing of all fillets or corners in the highly stressed members. As an example of the lengths to which this practice has been carried, the threads of all the more important and highly stressed bolts are to-day machined by grinding, a practice which has increased the fatigue strength of a bolt of given size by about 30 per cent.

Again, the higher outputs obtainable with 100 octane fuel have, of course, increased enormously the heat flow to the cylinder walls, and more especially to the exhaust valves and pistons. In air-cooled engines this has been met by increased ribbing and better cowling, and in liquid-cooled engines by intensifying the flow of the coolant generally, and by concentration of the flow in the zones of the most intense heat flow. The increased heat flow to the exhaust valves has been met, in part by the use of hollow valve stems filled with sodium, as a medium for transferring the heat from one end of the valve to the other, and in part by facing the valves with such materials as "Stellite" or "Brightray", which maintain their hardness and wearing qualities up to very high temperatures.

The increased heat flow to the piston forms to-day the most difficult problem of all, and sets the practical limit to the output obtainable with 100 octane fuel. Oil cooling of the pistons is employed to a greater or lesser extent in all modern aero-engines; in some cases by profuse general splash, in others by aimed jets of oil directed against the underside of the pistons, but there are practical limits to the extent to which oil cooling can be carried, while the problem of getting rid of the heat thus picked up by the oil is no easy one. For the moment, it is the temperature of the piston more than all else, which is limiting the power we can obtain from individual cylinders. In the present state of the art, it would appear that about 100 h.p. per piston is the limit of power we can maintain for any length of time.

A recent development which bids fair to have very far-reaching effects, is that of the use of a single sleeve valve with combined reciprocating and rotary motion. This has some very important advantages, in that the valve mechanism no longer imposes a mechanical limit to the speed of rotation, the absence of the hot exhaust valve allows a higher compression or a higher supercharge to be used within the limits set by detonation, while the motion of the sleeve tends to transfer heat from the hot zones to other parts of the cylinder barrel. The sleeve valve aero-engine has been in the experimental stage for a good many years, but it is now coming into routine production—its possibilities are still by no means fully explored, but some quite remarkable performance figures have been obtained experimentally, considerably in advance of anything obtained with poppet valve engines on the same fuel.

Diesel Engines for Aircraft.

The question arises constantly why the Diesel engine is not used for aircraft. It is argued, and rightly, that the Diesel engine is more economical of fuel, and therefore will give a longer range of flight; that it uses a fuel which is cheaper, and above all, which frees us from the risk of fire, either in the air, or in the event of a crash; and that its reliability and durability have already been proved up to the hilt by the experience of many thousands of such engines in road service. All these are very cogent arguments and would appear to be entirely convincing, but when they are analysed quantitatively, the results are apt to be disappointing. In the first place, the modern aero-engine, using a high octane fuel, can show a specific fuel consumption so nearly equal to that of the Diesel engine, that it is only on extremely long non-stop flights that the latter can show to any real advantage, flights far longer than either ordinary military needs call for or travellers are prepared to endure.

Owing to its very high maximum pressures, the Diesel engine, in its accepted four-cycle form, is necessarily very considerably heavier than (probably nearly double) the weight of a modern 100 octane petrol engine of the same output, and this single factor over-rides all the other arguments except, perhaps, the fire risk. This latter, unfortunately, is intangible and cannot be expressed in any quantitative terms; it may be argued that the fire risk alone is so horrible that it should dominate all other considerations, but against this is the centuries old observation that the travelling public, whatever it may say, does, in fact, prefer danger to discomfort, expense or delay. As an every-day example of this, not one Londoner in a thousand will use the subways provided at certain dangerous traffic crossings; they prefer the risk of being mangled in a seething welter of cars, to the discomfort of climbing a short flight of steps. Once the first thrill and novelty have passed, flying is one of the most tedious forms of travel, and very few passengers will travel in the slower machine, even if they are assured of immunity from fire.

To the military authorities the avoidance of fire risk makes no appeal at all. The military pilot will merely say that if, owing to a heavier machine, he is in danger of being outmanœuvred and shot down by the enemy, it matters little to him whether his funeral takes the form of burial or cremation. Moreover, engine weight alone is by no means the only factor, for a heavier engine involves a heavier structure to carry it, and a greater wing area to support it, and is therefore reflected throughout the whole machine.

Five years ago, and before the great advance in power and economy due to higher octane fuel, the Diesel engine was running the petrol engine very close in the race for the air, but now the petrol engine has forged ahead, and again established a substantial lead.

In the above considerations, I have had always in mind the high compression four-cycle heavy oil engine, but there are possibilities in other directions, possibilities which are being closely watched, and on which much exploratory work is being carried out. Chief of these are the low compression but highly supercharged Diesel engines, a form which bids fair to provide as good a power weight ratio as the modern petrol engine, since it will give at least the same mean effective pressure with little or no higher maximum pressure, but, ironical as it may seem, in this form the Diesel will have a greater fuel consumption than the petrol engine. It has the advantage, however, that it involves but little departure from well tried practice.

Another possibility, also under careful consideration, is the single piston two-cycle engine; present indications are that, with this type, it may be found possible to produce an engine even lighter per horse power than the petrol engine, combined with a somewhat lower specific consumption; this, then, would appear to be the goal at which to aim, but many mechanical difficulties will have to be overcome ere it is reached.

The Germans have developed a double piston two-cycle engine which has achieved considerable success, but the construction is necessarily heavy, in that it involves two crankshafts, two crankcases, and a long train of connecting gearing for only a single line of cylinders; it is perhaps the easiest, but it is hardly likely to prove the final solution of the two-cycle problem.

Steam *versus* Internal Combustion.

For half a century, the internal combustion engine and the steam engine fought a ding-dong battle for every application where power was required; each stimulated the other to renewed efforts and unexpected achievements; it is only comparatively recently that they decided to partition territory rather than to fight over it; even to-day, the partition is not quite complete, though very nearly so; there is still war at sea, and some guerilla fighting on the railways, but elsewhere the position has become stabilised. Steam now reigns supreme in large-scale power production, while the internal combustion engine takes care of all forms of travel by road or air, and of all odd jobs requiring small power where electricity, produced from steam, is not available.

From the very nature of things this, of course, is as it should be. Steam is efficient and cheap only in very large units, while the internal combustion engine is equally efficient in all sizes, but cheap only in small units.

Personally, I feel no doubt but that, until the advent of the internal combustion turbine—not, I think, very far distant—the future of the internal combustion engine lies with the small high-speed version, growing ever smaller and running ever faster.

I regret it, as I regret much else that is passing. Gone for ever is the impressive magnificence of the large and stately steam engine, with all its romance and unhurried dignity, its gleaming muscles, and its rhythmic breathing. In its place, we have a fussy little busybody which stirs no thrill in any breast, but none the less, does all we ask of it, and does it economically and conscientiously; of such an engine we require that it shall be entirely self-supporting and reliable during its working spells, and that its capital cost shall be so low that we shall not hesitate to scrap it as soon as it becomes obsolete. We are accustomed to tell ourselves that we live in an age of rapid progress; if we really believe this, then what is the use of building engines to last more than, say, ten or fifteen years? Our forefathers were wont to boast that they built machinery to last a century, and this they accounted a virtue. In so doing, they erected impressive monuments to themselves, but left most embarrassing heirlooms for their descendants.

Low first cost, light weight and ease of transport are the needs of the present day; let us be content to supply these and to leave our successors a free hand to make use of the better knowledge and altered conditions which will be their portion.

Condenser Tube Corrosion.

We publish below two further contributions to the written *discussion on the paper entitled "Condenser Tube Corrosion—Some Trends of Recent Research", by Mr. R. May, A.R.S.M., which appeared in the TRANSACTIONS of September, 1937, Vol. XLIX, No. 8; the author's reply is appended. The Council and the author would be pleased to receive communications at any time on this subject from superintendents or seagoing engineers, as the work of the British Non-Ferrous Metals Research Association, and particularly of the author as Corrosion Investigator, will be greatly facilitated by members contributing data from their own experience.

Contribution No. 1.

PARTICULARS OF CONDENSER TUBE CORROSION.

Type of Condenser.

Three flow type, each having a total cooling surface of 1,600 sq. ft. The area of cooling water inlet to the area through the tubes is as 1 to 1·10. The power in service is approx. 1,300 s.h.p.

Temperature of sea water varies from 60° F. in winter to 88° F. in summer. (Vessels A, B, and C).

			RETUBED.			SUBSEQUENT REPLACEMENTS.			
Ship.	Date Built.	Fitted with	Date.	Work done.	Make of Tube.	Date.	Position.	No. of Tubes.	Make of Tube.
A	1921	Ordinary 70/30	1. 2.29	Entire Condr.	Chromar	17.11.36	Bottom Nest	93	Yorcalbro
						25.11.37	,, ,,	65	,,
B	,,	,,	5. 1.32	,, ,,	Alumbro	No replacements up to date of report.			
C	,,	,,	29.11.29	Bottom Nest	Chromar	9. 6.34	Bottom Nest	12	Yorcalbro
			3.10.31	Top Nest	Yorcalbro	1. 5.35	,, ,,	12	,,
						14. 9.37	,, ,,	97	,,
Temperature of sea water varies from 42° F. in winter to 88° F. in summer. (Vessels D, E, F, G, and H).									
D	1921	Ordinary 70/30	5.12.30	Entire Condr.	Cupro-Nickel	14. 6.35	Bottom Nest	39	Yorcalbro
						15. 6.36	,, ,,	5	,,
E	,,	,,	10. 3.31	,, ,,	,,	8. 6.37	,, ,,	24	,,
						1. 3.38	,, ,,	12	,,
F	,,	,,	18.12.29	Bottom Nest	Chromar				
			29.10.32	Top Nest	Alumbro	Lost in typhoon, September 3rd, 1937.			
G	,,	,,	8. 6.31	Entire Condr.	Yorcalbro	No replacements up to date of report.			
H	1922	,,	7.11.29	Bottom Nest	Chromar		ditto.	ditto.	
			12.10.33	Top Nest	Alumbro				

Prior to 1931/32 the above five vessels were operating on the same route as vessels A, B, and C.

GENERAL REMARKS.

(1) On referring to the table showing the replacements which have, so far, been effected and comparing it with that showing the make of tubes fitted at the re-tubing of the condensers, it will be observed that the greatest number of failures have occurred in the "Chromar" sections and as no failures have occurred in the case of vessel B equipped with "Alumbro" tubes and engaged in the same trade, it would seem that "Chromar" tubes are not the equal of "Yorcalbro" or "Alumbro", under similar conditions.

(2) It is of interest to note that since re-tubing no failures have occurred in vessels G and B engaged on two different trades and the inference is that neither the sphere of employment nor the difference in power have any effects on aluminium bronze tubes under the conditions prevailing in each trade.

Contribution No. 2 [from Mr. A. Spittle, Technical Director, I.C.I. Metals Ltd. (Tube Section), Smethwick].

As one who has been closely connected with the manufacture and distribution of both cupro-nickel and aluminium-brass condenser tubes since their inception, I was particularly interested in reading the paper on "Condenser Tube Corrosion: Some Trends of Recent Research", by Mr. R. May, published in the TRANSACTIONS of the Institute, September, 1937, Vol. XLIX, No. 8, and the discussion which followed, published in the March, 1938, TRANSACTIONS, Vol. L, No. 2. The paper is a very useful contribution to the literature on condenser tube corrosion and crystallises the most recent opinions on this subject. The contributions to the discussion also furnished much useful information.

There were some points in the contribution to the discussion made by Dr. S. F. Dorey which caused me some surprise, as they showed a marked difference between his experience of the behaviour of cupro-nickel tubes and my own, more particularly where Dr. Dorey implied that by comparison with aluminium-brass tubes the latter were less expensive in first cost and also superior in service. Both alloys are giving extremely good service, and I have no desire to give an impression of detracting from the merits of one by lauding the excellence of the other, but I do feel that, as written, the criticisms of cupro-nickel by Dr. Dorey may give the impression that cupro-nickel tubes are somewhat prone to failure whilst aluminium-brass tubes are not, and that this impression is likely to influence adversely opinions hitherto formed of the merits of cupro-nickel.

I have pointed out to Dr. Dorey the possible effect of this impression upon marine engineers generally, and he has agreed that the paragraph might lead to some misunderstanding of the position. It was his wish to emphasise that aluminium-brass

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*See TRANSACTIONS, March 1938, Vol. L., No. 2.

tubes are cheap in price, being but little more expensive than ordinary Admiralty brass tubes, and at the same time they are giving excellent service, in many ways comparable with cupro-nickel, which is a much more costly alloy.

When making a comparison between the behaviour of aluminium-brass and brass tubes, there is ample direct evidence of the superiority of the aluminium-brass. When used under absolutely the same conditions of service, aluminium-brass has proved to be in every sense a superior alloy to either 70-30 or 70-29-1 brass. There is very little similar direct comparison which can be brought forward by which to judge the relative merits of aluminium-brass and cupro-nickel, but such direct evidence as is available does not show aluminium-brass to be equal to cupro-nickel under all conditions of service, and I have personal knowledge of service conditions, admittedly very severe, where aluminium-brass tubes have been replaced by cupro-nickel, the former having proved unsuitable for performing the duty which the cupro-nickel tubes have subsequently performed with satisfaction. I have no knowledge of a case where the positions have been reversed.

Dr. Dorey mentioned cases of failures in cupro-nickel tubes, some from pitting and some by cracking or fractures. I gather from conversation with Dr. Dorey that these failures were not extensive or of such a nature as to necessitate re-tubing a condenser, or a substantial part of a condenser, but entailed merely the replacement of a certain number of odd tubes.

It must be recognised that many millions of cupro-nickel tubes have been put into service since they were first marketed in 1922, and there are many possible causes of individual failure having no connection with the quality of the alloy itself. Cracked or split tubes may result either from inherent defects produced in the course of manufacture, or from excessive vibration of the tubes brought about by some special cause. Oxide pitting may be only another name for deposit attack, which may bring about destruction of any tubes in a very brief period. There is no evidence to show that had the tubes of which Dr. Dorey writes been made of aluminium-brass instead of cupro-nickel they would have withstood the particular conditions of service any better than or even as well as, cupro-nickel.

Dr. Dorey quotes the excellent behaviour of aluminium-brass tubes in combination with cupro-nickel ferrules. The inlet ends of tubes are always most sensitive to impingement attack, and impingement attack often succeeds the breakdown, or partial breakdown of the ferrules. Therefore the combination mentioned is as much a tribute to the resistance of cupro-nickel as it is to the resistance of aluminium brass.

Water speed cannot be left out of consideration in reviewing the behaviour of condenser tubes, and there is evidence of a greater resistance to high speed water by cupro-nickel tubes than by aluminium brass tubes.

The first cupro-nickel tubes were put into service in 1922, and they are still in good condition.

Before aluminium-brass tubes were invented (the patent is dated 1929) many hundreds of thousands (probably more than a million) of cupro-nickel tubes were in service, and the fact that more cupro-nickel tubes are being bought to-day than ever before is a tribute to their quality in the opinions of engineers who are intimately acquainted with their behaviour.

The use of both aluminium-brass tubes and cupro-nickel tubes is growing rapidly, and it is my personal opinion that within the next few years the use of ordinary 70-30 and 70-29-1 brass for marine service will practically cease.

Dr. Dorey has perused this letter and he is quite agreeable to my sending it to you, and, should you feel so disposed, for it to be published in the TRANSACTIONS of your Institute.

The Author's Reply.

Thanks are due to the first contributors above mentioned for the useful and interesting table and notes giving particulars of condenser tube corrosion in eight of their vessels.

The absence of failures in aluminium brass tubes during periods up to seven years is certainly striking. These tubes have obviously behaved far better than the chromium-plated brass tubes installed at about the same time.

It is noticed that one of the ships, reference D, was re-tubed with cupro-nickel tubes and that a total of 44 of these were replaced 4½ and 5½ years later. As the composition of the cupro-nickel tubes is not stated, it may be that they were of low nickel content. Such a number of failures would be indeed remarkable in tubes of 70 : 30 cupro-nickel.

The Association would be very glad to be kept informed of the further progress of this important practical trial.

The author thanks Mr. Spittle for his kind remarks regarding the paper and is very much interested in the comments which Mr. Spittle makes on some of the views expressed by Dr. Dorey.

It seems to the author that in any attempt to compare the behaviour of cupro-nickel tubes with that of tubes made from other alloys, the nickel content of the cupro-nickel ought to be made clear, otherwise confusion is likely to arise. The earlier cupro-nickel tubes were of 85/15 or 80/20 composition and none of them could be expected to equal in corrosion-resistance the modern 70 : 30 cupro-nickel tubes, although many have given good service.

Also, it must not be forgotten that difficulties in the manufacture of 70 : 30 cupro-nickel tubes were not overcome at once and the interior surfaces of the early tubes of this alloy were often by no means free from score lines, microscopic cracks and surface impurities, which helped to prevent the attainment of the high corrosion resistance now known to be possible. Because of this it ought to be emphasised that odd failures of cupro-nickel tubes, or even groups of tubes, in a condenser cannot be made the basis of any conclusions unless the nickel content and other details of the tubes are known, and information is available regarding the conditions under which they were used.

With regard to the relative corrosion resistance of 70 : 30 cupro-nickel and aluminium brass tubes in marine service, the author does not think that the evidence would justify an unqualified answer. The present position would appear to be that the direct comparison of the two alloys based on practical results is possible over a certain range of the corrosive conditions encountered in marine service. Over this range, which for the present may be regarded as representing average marine conditions, both alloys have shown a remarkable freedom from consistent failures and there would appear to be little to choose between them. Outside this range the relative behaviour of the two alloys in actual practice is still an open question. For example, under the severe conditions in the high-speed North Atlantic services, and in Naval ships, 70 : 30 cupro-nickel is known to be giving excellent results, but very little has been heard about the behaviour of aluminium-brass, probably because any trials which may be in progress are not yet completed. At present, the comparative behaviour of 70 : 30 cupro-nickel and aluminium-brass tubes under the more extreme or specialised types of marine service can only be estimated in an approximate manner, and this is complicated by the fact that the relative position of the two alloys may easily be reversed by a small change in the conditions or in the composition of the alloys. The point is that outside the range of ordinary marine conditions there are certain specific circumstances in which either aluminium-brass or 70 : 30 cupro-nickel will undergo the greater attack. The general question which is the better of the two alloys therefore cannot be answered unequivocally since much will depend on the conditions encountered. A good deal of information on the specific effect of various factors on the behaviour of the two alloys is contained in Reports of the B.N.F.M.R.A. which are available to members, and further work on the subject is in progress.

INSTITUTE NOTES.

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, 5th September, 1938.

Members.

James Cattanach, 61, Cauldwell Lane, Monkseaton.
Arthur Edward Crampton, 10, Bitterne Way, Southampton.
Charles Newbold Graham, c/o Mr. Vic Burley, Simpsons Road, Bardon, W.4, Brisbane.
Frank F. Holloway, Rosewell, Meliden Road, Penarth, Glam.
Charles William Johnston, Thornholme, 1, Kirby Avenue, Swinton, Manchester.
Alexander MacCallum, Ladang Geddes, Bahau, Negri Sembilan, F.M.S.
Thomas William McDonald, 7.B, Waringah Road, Mosman, Sydney, N.S.W.
Robert Douglas Nelson, Eng. Rear-Adm'l. (ret.), O.B.E., Bessemer Grange, Denmark Hill, S.E.5.
Henry Allan Usher, 12, Heath Drive, Raynes Park, S.W.20.
John Whitehead, 39, Winn Road, Southampton.
Joseph Stephen Harry Youldon, 2nd Eng., M.V. "Sepia", c/o Anglo-Saxon Petroleum Co., Ltd., St. Helen's Court, E.C.3.

Associate Members.

John Robert Belcher, 108, Katherine Road, E.6.
Charles Stiven Russell, Telephone House, Carliol Square, Newcastle-on-Tyne, 1.
Robert Winter-Evans, Lieut. (E.), R.N. (ret.), Saint Martins, Freshwater Bay, I.O.W.

Associates.

Daniel George Alcock, 327, South Boulevard, Hessle Road, Hull.
Leslie William Brown, Park House, 270, Barking Road, East Ham, E.6.
Arthur Ernest Burnham, Southern Hay, Hinton St. George, Somerset.
Cumming A. W. Duff, China Nav. Co., Hong Kong.
Maurice Goodhind, 125, Great Queen Street, Dartford, Kent.
Lawrence John Stanley Lewer, c/o Mr. F. E. O'Reilly, 64, Priory Road, Hampstead, N.W.6.
Thomas William Miller, Homelea, Common Lane, Thundersley, Essex.
George Gustave Van Halle, 124, Rue Belle Rade, Malo-les-Bains, Nord, France.
Richard Norman Williams, 8, Green Way, Eltham, S.E.9.
James Winning, 85, Merton Drive, Hillington, Glasgow.

Students.

Victor Stanley Armstrong, 18, Roseworth Avenue, Gosforth, Newcastle.
Arthur Bedwell, Chase House, East Bay, Colchester.
Roland John Boxall, 181, Sutton Common Road, Sutton, Surrey.
Ronald Charles Brown, 125, Wellesley Road, Buckhaven, Fife.
Christopher Robert Brownless, 134, Ridgewood Crescent, South Gosforth.
John Collin, 48, Laurel Street, Wallsend-on-Tyne.

John Colville Grimmett, 65, West Bank Road, Birkenhead.

Santhanam Kasthuri, No. 11 208, E. Ganesh Baug, Matunga, Bombay.

Ronald Magill, 225, Orby Drive, Belfast.

John Winton Moore, 138, Bede Burn Road, Jarrow, Co. Durham.

Thomas Victor Otterburn, 5, Ravensworth Street, Sunderland.

Paul Patrick Shrubsole, 47, East Mount, Barrow-in-Furness.

Maurice Simmonds, 11, Chapel Road, Katong, Singapore.

Alan Foster Wilson, 30, Rosewood Crescent, Walkerville, Newcastle-on-Tyne.

Probationer Students.

Charles William Albert Andrew, 67, Helston Road, Penryn, Cornwall.

Erling Sydney Berntzen, 4, Park Terrace, Falmouth.

Ralph Alan Gilson, 11, Penrose Road, Falmouth.

Henry Thomas Morrison, Sunnyside, 4, Arwyn Place, Falmouth.

Ronald Reid, 66, Killigrew Road, Falmouth.

Dudley Vincent, 7, Marine Crescent, Falmouth.

Transfer from Associate to Member.

Alfred Menhennet, Takuapa Valley Tin Dredging N.L., Takuapa, W. Siam.

Leslie Herbert Steadman, Eng. Lieut., R.I.N., H.M.I.S. "Clive", c/o Navy Office, Bombay, India.

George William Watson, Eng. Lieut., R.I.N., c/o Navy Office, Bombay, India.

Transfer from Student to Associate.

William Webber Kerridge, 111, Eversley Avenue, Barnehurst, Kent.

Transfer from Probationer Student to Student.

Edward Cornwall, Rose Bank, Mawnan, Falmouth.

Ivor John Johns, 4, Trelawny Place, Penryn, Cornwall.

Ronald Huge Pearce, 4, New Street, Falmouth.

Cyril Lloyd Rees, Floradale, Flushing, Cornwall.

Bertram Couch Tonkin, Rozelle, Beacon Road, Falmouth.

Austin William Frederick White, 10, Berkeley Mill, Falmouth.

ADDITIONS TO THE LIBRARY.

Purchased.

Mines Department: Report of the Committee appointed to examine the possibility in the national interest of obtaining an increased use of coal for bunkering purposes. H.M. Stationery Office, 4d. net.

Board of Education: Regulations for Whitworth Scholarships, 1939. H.M. Stationery Office, 3d. net.

Guide to Current Official Statistics of the United Kingdom, Vol. 16, 1937. H.M. Stationery Office, 1s. net.

The King's Regulations and Admiralty Instructions, Vol. II, Appendices, 1937. H.M. Stationery Office, 2s. 6d. net.

Presented by the Publishers.

Transactions of the International Engineering Congress, Glasgow, 1938.

The following British Standard Specifications:—

No. 78, 1938. Cast Iron Pipes (vertically cast) for Water, Gas and Sewage, and special Castings for use therewith.

No. 96, 1938. Carbon Brushes (parallel-sided) for use on Commutator and Slip-ring Machines.

No. 806, 1938. Ferrous Pipes and Piping Installations for and in connection with Land Boilers.

No. 807, 1938. Shanks of Electrodes for Spot Welding Machines.

C.E. (ME), 8608. (Corrigenda). Steel Flanged Joints for Hydraulic Pipe Lines for Pressures up to 4,500lb. per sq. in.

C.E. (ME), 8879. (Corrigendum). Wrought Iron Chain Slings and Rings, Links alternative to Rings, Egg Links and Intermediate Links.

Proceedings of The Institution of Mechanical Engineers, Vol. 138, 1938, containing the following papers:—

"Recent Developments in Ship Propulsion", by Jones.

"Machine Tool Tests and Alignments", by Schlesinger.

"The Development of Single-bucket Excavators", by Savage.

"The Pressure Distribution in a Convergent-Divergent Steam Nozzle", by Binnie and Woods.

"The Effect of Circumferential Pitch of Steam Turbine Blades on Torque as Compared with 'Biplane Effect' on the 'Lift' of Aerofoils", by Downson.

"Aircraft Efficiencies", by Piercy.

"Exhaust Systems of Two-Stroke Engines", by Farmer.

"The Combustion Process in the Compression-Ignition Engine", by Drinkwater and Egerton.

"Power Supply for Departmental Stores", by Howes.

"Oil Engines for Tugs", by Mayor.

Engineering Economics: Book I, Elements of Industrial Organization and Management; Book II, Works Organization and Management. By T. H. Burnham, B.Sc., B.Com. Sir Isaac Pitman & Sons, Ltd., 8s. 6d. each net.

A third edition of Book I of this well-known textbook was published last year, while Book II has now appeared in a fourth edition. It has been revised, enlarged and brought completely up to date, and as it covers the broad syllabuses of those engineering institutions which include the subject of engineering economics in their examinations, the new edition seems assured of as ready a welcome as its predecessors. It is written for all who wish to specialize on the administrative side of engineering practice and meets the requirements of students preparing for the final degree examination.

The contents of Book I include elements of economics, industrial history, the commercial system, resources of Great Britain and the Empire, business organization, statistics and charts—an introduction to forecasting and budgeting, elements of commercial law, outline of industrial legislation, research and development work, organization of distribution, taxation and insurance, office administration, and the management function—psychological factors. Book II covers the management function, personnel policy and wages payment, design administration and quality control, economics of production, progress control, purchasing and materials control, factory costing, site and lay-out of works, buildings and fixed equipment, and sales organization and tendering.

Workshop Practice. By F. Johnstone Taylor. The Technical Press, Ltd., 759pp., 542 illus., 16s. net.

In the August, 1936, issue of the Transactions, page 255, we published a review of this book, which is a revised and enlarged edition of Pull's "Modern Workshop Practice"—a work familiar to engineering students of an earlier generation. In confirmation of the opinion expressed in the review that this revised edition could be strongly recommended, the publishers have found it necessary to issue a third impression. The ground covered by the book includes measurements and measuring machines; measuring tools; gauges and gauge systems; common workshop tools; bench work; materials—cast iron; wrought iron and steels; equipment of the heat treatment shop—furnaces; lathes; tool holders; lathe tools; speed and feeds; lathe accessories; turning; screws and screw cutting; turret lathes; capstan and turret lathe tools; plain and universal milling; gears and gear cutting; gear-hobbing and planing machines; boring and slotting machines; planing, shaping and drilling; plain and universal grinding; drop forging and stamping; welding.

Sea Flags: Their General Use. By Commander Hilary P. Mead. Brown, Son & Ferguson, Ltd., 52-8, Darnley Street, Glasgow, 112pp., illus., 3s. 6d. net.

Originally intended for the use of officers of the Mercantile Marine, the author feels that beyond introducing them to a few historical facts about the national colours there is not much he could pretend to teach the average Merchant Navy officer about his job. Nevertheless, he has written on various flag subjects from a viewpoint sympathetic with the Merchant Service outlook, while some of the things dealt with aspire rather to a wider claim and are intended to interest the general reader. The seagoing reader will therefore find much of interest to him in this work, the informative historical references particularly. The book is excellently produced, adequately illustrated and contains a very fine frontispiece in colour.

Problems in Electrical Engineering. By S. Parker Smith, D.Sc. Constable & Co., Ltd., 3rd edition, 267pp., copiously illus., 6s. net.

This book contains 1,319 original problems covering all grades of electrical engineering. The problems are all based on principles and do not include any descriptive questions or calculations involving purely empirical formulæ. Such a collection can only be the work of one who, like the author and those who have co-operated with him, has had a long and varied experience in teaching and examining. The book's greatest use will be found in tutorial classes, where the student may have help if needed from properly qualified demonstrators. It will also be of great use to teachers of slight experience as a help, guide and time-saver at a period when such help is most needed.

A collection of problems covering all grades and sections of electrical engineering work can only be really useful if properly indexed. This has been most successfully done in the present case by means of a "Contents" which includes a general classification of two pages, referring to a more detailed classification of 11 pages in which the problems are clearly placed under their relevant subject headings. The more elementary questions are clearly marked. A list of general data, symbols, abbreviations, etc., in standard use is given in the early pages of the book. There is no doubt that this third edition will meet with the same welcome accorded to the two previous editions by both teachers and students of the subject.

Electrical Engineering Practice, Vol. I. By J. W. Meares, C.I.A., F.R.A.S. and R. E. Neale, B.Sc., A.C.G.I. Chapman & Hall, Ltd., 780pp., 91 illus., 25s. net.

This is Vol. I of the fifth edition of a large work on electrical engineering practice written for the service of all types of engineers. That such a work has reached its fifth edition speaks for the excellence of its contents and the method of presentation. The size of the book has been increased by about 200 pages as compared with the fourth edition and it contains a comprehensive index of all three volumes of the work.

The general plan of the previous edition has been maintained in this new volume. Part I deals comprehensively with definitions, materials and measurement, Part II with the generation and sale of electrical energy, power house equipment, water power and economics of generation, and Part III with transmission and control, switchgear and protective devices. The book is decidedly of a practical nature and the authors' aim has been to present information and explanations of maximum utility to practical engineers and students of engineering practice. One need have no hesitation in stating that they have succeeded admirably. The fundamental facts and principles underlying electrical engineering practice are dealt with in detail according to their importance, and carefully selected practical examples of their application are numerous throughout the book. As far as possible the reviewer satisfied himself that all the material in the book has been thoroughly revised and the numerous technical and statistical tables which make it so valuable as a book of reference are thoroughly up-to-date.

It is impossible in a brief review to draw attention to all the good points of this large and exceptional work, but it may be sufficient to state that it is elementary enough in treatment for the ordinary student to use as a text book and as an introduction to more advanced works on the subject. It is unique as a book of reference for valuable information for those in charge of all types of generating stations, including water-driven; for those in charge of the construction and upkeep of transmission lines and installation work generally it is also invaluable. As a book of reference for civil and mechanical engineers confronted with problems in electrical work of all kinds it is unsurpassed.

Engineering Science: Vol. II, Heat and Heat Engines and Electrotechnics. By H. B. Brown, B.Sc., Wh.Ex. and A. J. Bryant, B.Sc. Macmillan & Co., Ltd., 450pp., 198 illus., 6s. net.

This book, which deals with heat and heat engines and electrotechnics, is written in the same clear and concise manner as Vol. I, which was published a year or so ago. Vol. I deals with the sections of mechanics and hydraulics.

The authors state that while the book is intended to cover the full study of the subject in the junior technical school, it is so planned that it is intensive enough for first and second year National Certificate Courses.

The approach to the subject is mainly through detailed experimental work of either a demonstrative or individual character, and, as in Vol. I, every effort has been made to bring the theory and examples into line with practice. The book is well illustrated and each section contains many worked examples which are set out in a very lucid manner, especially those which deal with the testing of engines. At the end of each chapter are some excellent examples for class work and private study. These examples are graded, and are well chosen, not only illustrating the principles involved but are mainly of a "practical" character. There are 60 to 70 such examples at the end of each chapter and answers to all numerical questions are given at the end of the book.

In general the fundamental principles are dealt with very clearly and well illustrated with line diagrams. The section of the book dealing with internal combustion engines is well planned, although the term "Diesel" is applied too freely to the various types of oil engines.

Chapter III, which deals with the steam power plant is well written and is up to date. The functions of the various auxiliaries, condensers, preheaters, etc., are very well defined. The tabular method of explaining the various parts of the steam engine and their functions, on pp. 158-161, is to be commended.

The section of the book dealing with electrotechnics follows along the usual lines adopted in the treatment of this part of the subject. The chapter headings are: electrical energy and its control, magnetism, principles of the generation of electrical energy, and electrical measuring instruments.

The book can be strongly recommended for junior technical school pupils and also for first and second year National Certificate students. In the opinion of the reviewer it will also meet the needs of students taking the first and second years of the National Certificate Course in Marine Engineering, which will be available in some technical colleges in the near future. The book is well printed and the authors and publishers are to be congratuated on producing an excellent volume at a reasonable price.

Additions to the Library.

Elementary Practical Mechanics. By the late J. M. Jameson, Ph.B., Ph.D. and C. W. Banks, C.E. Chapman & Hall, Ltd., 4th edition, 363pp., 265 illus., 13s. 6d. net.

This is the latest edition of a popular American text book first published in 1909. The primary intention of the original author was to present his subject in the light of everyday life rather than in a mathematical form, so that students who are to receive no further instruction in mechanics might be equipped for business or industrial life; incidentally, the book was to serve as an introduction to a more advanced course. Quite recently Mr. Banks set out to bring the volume up to date both from the point of the teacher and of the student. By judicious rearrangement and some additional matter he has succeeded.

The book is graded up to about the second year syllabus of the subject for the Ordinary National Certificate in this country, but it will also be found useful for marine engineers preparing for the engineering science papers of the Board of Trade examinations under the new scheme, provided sight is not lost of the fact that American symbols and phrasing prevail; be it remembered, for instance, that the American gallon is less than the Imperial gallon. The weak spot, however, is that there are no answers given for the copious problems.

Within the scope of the matter treated the best of the seventeen chapters are on (*a*) non-concurrent forces; (*b*) trusses and other structures; (*c*) forces producing motion; and (*d*) energy and momentum. One chapter only is devoted to elasticity and strength of materials while another on mechanics of fluids is virtually elementary physics with four paragraphs only dealing with orifices and pipe flow. There is also a new chapter on the elements of heat and an appendix which contrives to compress a summary of all the necessary mathematical fundamentals into the space of fifteen pages. The book is to be commended for its readability.

A Textbook of Electricity. By H. G. Mitchell, M.A., B.Sc. Methuen & Co., Ltd., 525pp., 357 illus., 10s. net.

This book provides a complete course in electricity for Higher School Certificate, Intermediate Science and University Scholarship candidates. The treatment is quite modern, and the book can be thoroughly recommended for students of electricity preparing for examinations in the subject up to pass-degree standard.

Alternative methods using calculus notation have been introduced wherever possible for the benefit of those with a sufficient knowledge of mathematics. At the end of each chapter is a series of useful exercises, many of which as indicated have been taken from recent public examination papers. The illustrations are clear and numerous, and the general production of the work is all that the reader can desire. At the end of this excellent book are given answers to the questions involving calculations and a very complete and useful eleven-page index.

Examples in Applied Mechanics. By the Education Department of the Admiralty, published by authority of the Lords Commissioners of the Admiralty. H.M. Stationery Office, 204pp., copiously illus., 4s. net.

The examples in applied mechanics in this book have been classified into six main parts as follows: I measurements, II statics, III kinematics, IV kinetics, V hydrostatics and hydraulics, and VI stress, strain and elasticity. Each part has been divided into sections, and while the book is not a text book these sections have been generally briefly prefaced by a resumé of the basic principles by which the problems in the particular section may be solved. This is one of the commendable features in the book. The examples in part I, while they might have been more aptly included in a work on practical mathematics, are most instructive, those in section I of this part especially impress on the mind that most physical measurements are at best approximate. In part V section 3 there are several instructive and comprehensive problems in theoretical naval architecture.

To attempt an exposition of each part in detail is impossible here, hence summarizing the questions generally it is no exaggeration to say that they are a unique collection of very sound problems, many of which have a definite vocational atmosphere. It is this latter characteristic of these problems which, with their tang of the sea, will provide that feeling of a job well done to those readers who, on their own initiative, succeed in obtaining the correct solutions.

The Department state in their preface that the problems have been selected from the courses taken by specialist officers in the Royal Navy, hence the examples generally are of an advanced character. The standard and vocational bias of the examples in the aggregate make the book an invaluable asset to the progressive students of The Institute, and it should be welcomed by engineers preparing for the Board of Trade, Extra First Class Engineers' Examination. All young engineers who work through this book will not only be indebted to the Department for its publication, but will themselves have greatly enhanced their potential status as true professional marine engineers.

The Elements of Ferrous Metallurgy. By J. L. Rosenholtz, Ph.D., and J. F. Oesterle, Ph.D. Chapman & Hall, Ltd., 2nd edn., 258 pp., 140 illus., 15s. net.

The authors, who are obviously fully conversant with their subject, are to be congratulated on the compiling of the second edition of this text book, especially in respect of the very valuable additions which have been made. For the student and apprentice it contains a wealth of practical information, each process being dealt with in a comprehensive manner. The criticism is perhaps not justified that descriptions in several instances could with advantage have been treated a little more fully, when data usually spread over several volumes has been put into one book. The reviewer feels, however, that the Whiteheart malleable cast iron and cast iron sections could have been, with advantage, slightly amplified. This book is a really worth while addition to the book shelves of anyone requiring a knowledge of iron and steel metallurgy.

ABSTRACTS OF THE TECHNICAL PRESS.

Ascertaining the Most Favourable Pressure of Exhaust Steam from Auxiliary Machinery.

It is known from foreign journals that one of the most economical war vessels, a certain destroyer, has a big drawback in the machinery installed due to the intricacy of the system of multi-phase heating of the feed water with the exhaust steam from the main turbines (apart from utilizing the exhaust steam from the auxiliary machinery). It would therefore be of interest to make a detailed analysis of the conditions for heating the feed water only by the exhaust steam from the auxiliary machinery. From the expression for the specific consumption of fuel for steam installations :—

$$G_T = \frac{i_K - i''}{\eta_K \, Q_p^H} G_\pi$$

Where :— G_T = consumption of fuel kg./p.h., G_π = consumption of steam kg./per hr.;

i_K = heat content of the steam at boiler, cal./kg.;

i'' = heat content of feed water, cal./kg.;

η_K = coefficient of efficiency of boiler;

Q_p^H = 10,000, the calculated calorific value of oil fuel in cal./kg.

It is evident that all other conditions being equal, the consumption of fuel depends on the temperature of the feed water, and the influence of preheated feed water is greater the lower the coefficient of efficiency of the boiler.

Assumed :—

P_K = Steam pressure at the boiler = 36 atm.

t_K = Temperature of steam at the boiler = 380° C.

$\eta_K = 0{\cdot}8$.

P_1 = Steam pressure before entering turbine = 32 atm.

t_1 = Temperature of steam entering turbine = 360° C.

P_2 = Steam pressure beyond the turbine = 0·08 atm.

η_B = Coefficient taking into account the loss due to the line of shafting.

η_π = Coefficient of efficiency of the gear transmission = 0·98.

η_M = Mechanical coefficient of efficiency of the turbine = 0·99.

η_{3x} = Coefficient taking into account the losses due to rotation in the economical stages and the astern turbine = 0·98.

η_i = Internal coefficient of efficiency of the turbine = 0·76; and by the Mollier diagram :—

i_K = heat content of the steam at boiler = 759 cal./kg.

i_1 = heat content of the steam at the turbine = 749 cal./kg.

i_2' = heat content of the steam at the end of process beyond the turbine = 504 cal./kg.

We obtain the specific consumption of steam of the main engines :—

$$G_\pi' = \frac{632{\cdot}3}{(i_1 - i_2')\sqrt{\eta_B \times \eta_\pi \times \eta_M \times \eta_{3X} \times \eta_i}} = \frac{632{\cdot}3}{h_a \times \eta_e}$$

$$= \frac{632{\cdot}3}{(749 - 504)\ 0{\cdot}99 \times 0{\cdot}98 \times 0{\cdot}99 \times 0{\cdot}98 \times 0{\cdot}76}$$

= 3·61 kg./h.p. per hour.

The specific consumption of fuel for the main engines without preheating of feed water (i'' = cal./kg.)

$$G_T' = \frac{759 - 41}{0{\cdot}8 \times 10{,}000} \times 3{\cdot}61 = 0{\cdot}324 \text{ kg./h.p. per hour.}$$

The dependence of the consumption of fuel for the main turbine on the temperature of the feed water is shown in *Table 1 and Fig. 1. The heating of the feed water under marine conditions is effected by the exhaust steam from the auxiliary machinery. For the purpose of further utilizing the heat of the exhaust steam, condensate from the feed water heater is mixed with the water passing to the feed pump.

η_{in} = Coefficient of efficiency of the gear trans-

Assumed for the auxiliary machinery :—

mission = 0·96.

η_M = Mechanical coefficient of efficiency of the turbine = 0·97.

η_i = Internal coefficient of the turbine = 0·60.

We obtain the mean specific consumption of steam from the auxiliary machinery, for P_2'' = 0·80 atm. (relative to its power) :

$$G_\pi'' = \frac{632{\cdot}3}{(i_1 - i_2')\eta_\pi \times \eta_M \times \eta_i} = \frac{632{\cdot}3}{(749 - 504)0{\cdot}56} = \frac{1130}{245}$$

= 4·61 kg./h.p. per hour.

The consumption of fuel for the auxiliary machinery only (relative to its total power) :

$$G_T'' = \frac{i_K - i''}{\eta_K \times 10000} G''_\pi = \frac{759 - 41}{8{,}000} 4{\cdot}61 = 0{\cdot}415 \text{ kg./h.p.}$$

per hour.

Increase in the temperature of the feed water necessitates an increase in temperature and therefore an increase in pressure of the exhaust steam used in the feed water heater. An increase of pressure of the exhaust steam indicates an increase of consumption of steam for the auxiliary machinery, in the first place at the expense of the heat content

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*This and other tables and illustrations not reproduced.

of the exhaust steam. In accordance with the above conditions, Table 2 is drawn up, also the graph shown in Fig. 2 is constructed, relative to $G_\pi'' = (\phi P_2'')$. By differentiating the total consumption of fuel from the consumption of fuel for the main engines, and the consumption for the auxiliary machinery, Table 2 and graph Fig. 3 are constructed, showing the changes in the consumption of fuel for the auxiliary machinery, relative to its total mean power, depending on the guaranteed temperature of the feed water. The final economical effect is characterized by the total consumption of fuel, which is expressed by the value:—

$$G_T = G_T' + \alpha G_T'' = \frac{G_\pi (i_K - i'')}{\eta_K \times Q_p^H}$$

where $G_\pi = (G_\pi' + \alpha G_\pi'')$ kg./h.p. per hour = total specific consumption of steam relative to the power of the main engines, kg./h.p. per hour, $\alpha =$ the ratio of the total power of the auxiliary machinery and the main engines for $P_2'' = 0{\cdot}08$ atm.

$$G_\pi = 3{\cdot}61 + \alpha \times 4{\cdot}61.$$

Denoting the total consumption of steam of the installation by D kg./p.h. and the power of the main engines by N_e h.p. the value α is determined:

$$\alpha = \frac{D - N_e G_\pi'}{N_e G_\pi''} = \frac{\frac{D}{N_e} - G_\pi'}{G_\pi''}$$

Designating by "*y*" the proportion which the total consumption of steam of the auxiliary machinery bears to the total consumption of steam of the main engines, we obtain:—

$$y = \frac{\alpha N_e G_\pi''}{N_e G_\pi'} = \alpha \frac{G_\pi''}{G_\pi'} \text{ or } y = \frac{D - N_e G_\pi'}{N_e G_\pi'} = \frac{G_\pi}{G_\pi'} - 1$$

for $P_2'' = 0{\cdot}08$ atm.

$$y = \alpha \frac{4{\cdot}61}{3{\cdot}61} = 1{\cdot}28\alpha.$$

The dependence of the total steam consumption on the back pressure of the auxiliary machinery and the temperature of the feed water is shown for different values of α and y by the graph Fig. 4 (constructed on the basis of Table 3). The limit for the heating of the water depends on the temperature of evaporation at the boiler pressure. In Fig. 5 are shown the values of the specific heat of water and the heat content of steam in cal./kg., depending on the pressure, and in Table 4 the specific heat of the feed water is given as a percentage of the heat of the exhaust steam. It will be seen that with increase of pressure the specific heat of water rises, while the value of the latent heat of evaporation decreases. At 1 atmosphere, 1 kilogram of dry saturated steam by condensing will heat 101·8 kg. of water 5° C. At 92 atm. 1 kg. of steam will heat, at the expense of its latent heat of evaporation, only 7·4 kg. of water 5° C. In graph Fig. 6 a curve is drawn on the basis of Table 3 showing the changes in the consumption of steam of the auxiliary machinery, working with back pressure, as a percentage of the quantity of steam passing into the main condenser for the different values of α (*i.e.*, for different ratios of the total power of the auxiliary machinery to the power of the main engines, on the assumption that all the auxiliary machinery is working with back pressure) depending on the back pressure P_2''. On the same graph (Fig. 6) is also shown a curve of specific heat of the condensate of the main condenser, as a percentage of the quantity of condensed exhaust steam from the auxiliary machinery; the curve is drawn in accordance with Table 4, taking into account that the initial temperature of the condensate is 41° C. As is seen by Fig. 6, in cases where the specific steam consumption lies above the curve, there will always be a surplus of exhaust steam. The maximum value of the exhaust steam from auxiliary machinery, which could be utilized for a single-stage heating of the feed water would be $\simeq$14 per cent. The optimum pressure of exhaust steam lies within the limits of 1·6 to 2·0 atm. With a small consumption of steam from auxiliary machinery working with a back pressure, the optimum values of back pressures are defined by the points of intersection of the curves of steam consumption with those of the specific heat of feed water. For determining the total specific consumption of fuel in relation to the power of the main engines for the following conditions:— $Q_p^h = 10{,}000$ ca./kg., $\eta_K =$ 80 per cent., $P_K = 36$ atm., $t_k = 380°$ C., $y = 6{\cdot}4$ per cent., we obtain for a single stage heating Table 5 and graph Fig. 7. It will be seen that for the conditions assumed, the maximum fuel consumption will correspond to a back pressure $P_2'' = 1{\cdot}8$ atm. With two-stage heating, increasing the back pressure is more advantageous, as will be seen from Table 6 and graph Fig. 7, as only a part of the machinery is working with an increased back pressure. With the waste steam from the main turbines and three-stage heating, when increasing the heating and consequently the pressure of the waste steam the consumption of fuel decreases. Where there is evidence of a surplus of exhaust steam, the character of the curves of Fig. 6 show that it is not expedient to increase the back pressure of the exhaust steam beyond 2·0 to 2·5 atm.; it is also not desirable in cases where the exhaust steam utilized in preheaters of less than 14 per cent. of the quantity of condensate to switch over even part of the auxiliary exhaust to the condenser. It is evident that the change of the initial variables of the steam and the coefficient of efficiency of the auxiliary turbines would mean certain alterations in the character of the relative values obtained, but in such a small way that it would not be harmful to extend the deductions made in this article to other closely related cases. In case of a considerable deviation from the values obtained, it is advisable to carry out check calculations with the assistance of the methods proposed.—*"Soudostroienie", No. 1, 1938.*

Welded Pressure Vessels and Pipe Flanges.

In the past forge-welding has been preferred for steel vessels in larger sizes, *e.g.*, a railway waggon with capacity 12 tons of liquefied gas. A detailed examination is now being made of steel pressure vessels fabricated by oxy-acetylene, electricity and forge-welding, and welded joints in steel plates ¼-1½in. are to be subjected to comprehensive mechanical and metallurgical tests. Further, the density and vapour pressure of propane and butane, singly and in admixture, are being studied, to deduce data for safe filling. Under service conditions the tension induced by screwing up a joint leads to creep of bolts and flanges with deterioration of tightness, and maximum life is obtained when relative plastic deformations are matched with the initial elastic strains, so that total overall extension remains constant. An apparatus in which an assembly of four flanges is compressed in a very rigid frame and simultaneously heated at temperatures up to 600° C., is described. A new building to house two new creep-testing units of high sensitivity, remote from machine vibrations, is projected. —*Report on N.P.L. Research, "Engineering", 15th July, 1938, p. 64.*

The Building of Ships—A British Survey.

The author is gravely concerned by the apparent lack of attention by British statesmen to the importance of the export trades in general, and export shipbuilding in particular. Comparing two five-year periods, to 1901 and 1931, he points out that in percentage of world mercantile tonnage launched, Great Britain's share, while still in the first place, has fallen from 65 to 40, that of Germany has increased from 9 to 15 and of Holland from 1·5 to 5·5, while surprising jumps are shown by Japan from 0·6 to 15, and by Scandinavia from 2·5 to 15. While welcoming the adoption of a tariff policy in 1932, he deprecates the incidence of direct taxation to the extent of 25-50 per cent. of the entire industrial income, and praises the efficiency of the machinery for disposing of redundant shipyards. He would welcome a reversal of the continuous transfer of people from basic exporting industries to others. While paying a tribute to technical and managerial staffs, the paper shows that costs of building are now the ruling consideration, since no centre has outstanding design or construction to offer and materials cannot differ substantially in price from one country to another. In particular the author is indignant at the cost of the non-producer—he cites too widespread education and the unemployed operative, and advocates "a judicious pruning of those social services which have outstripped the bounds of healthy growth" with the object of some sacrifice by certain favoured sections of the community for the benefit of others exposed to the full blast of foreign competition; and "national assistance . . . . . to make up money demanded by the community from certain sections of industry whose circumstances preclude them from the possibility of earning it".—*J. Lithgow, "The Engineer", 1st July, 1938, pp. 4-5.*

Transient Flow in Pipes.

In general, pressure is transmitted through a fluid by a wave of known velocity, and according to both theory and experiment, boundary reflection takes place. The subject is of fundamental importance in engineering, *e.g.*, in oil engine and hydraulic installations subject to water-hammer, to cite only two instances. At a given moment account must be paid to the initial circumstances and the then position of the wave front, *i.e.*, oscillatory motion can be investigated by expressing velocity and pressure as functions of time and position. The resulting equations are conveniently solved by a treatment devised by K. J. De Juhasz (see *Journal of the Franklin Institute, 223*), three axes in an isometric chart representing the variables. Pipe, pump, nozzle, etc., are shown on either a velocity-pressure or a time-distance graph, the pipe being identified with the tangent to the velocity pressure line, and by a time interval on the time-distance graph. Several factors may be shown on a single diagram. After the characteristic factors for all parts have been found, the solution depends on obtaining the point of intersection of two curves associated with two different parts, together with conditions of flow at any instant. If A and C are connected by B, then the characteristic curve of B will connect two points on the curves for part A and part C. Although the finished chart appears complicated it is constructed by a succession of simple steps within prescribed limits of time and distance. With one or two charts the engineer may trace the disturbed motion from end to end of the system, and the same treatment might be applied to a wide range of mechanical problems.—*"Engineering", 24th June, 1938, p. 713.*

Effect of Circumferential Pitch of Steam Turbine Blades on Torque.

Most turbine blades have much greater curvature than aerofoils, so that aerodynamics cannot be applied directly. On account of length, not more than 80 stages can be adopted to discharge a 300,000ft. head, and blade discharge and inlet angles cannot greatly exceed 20° and 90° respectively, and may be even less; the nominal outside angle is therefore not obtuse as in aerofoils, but a right angle or less. (See *Proc. Inst. Mech. Engrs., Vol. 130, 1935, p. 45*). A biplane is said to have less lifting effect than the same wing surface in a monoplane owing to "crowding", and the author investigates whether the same effect may occur in turbines. A small axial-flow pressure compounded turbine, with 7 reaction pairs of rows of radial clearance blades of identical profile throughout, was used. The mean nominal diameter was 6⅞in. and the nominal length (assuming zero tip clearance) ⅞in., four experimental blade types being used. Measurements were made of (1) initial steam pressure (maintained constant at 27·2in. with 0·2in. exhaust), and temperature (initial superheat of about 40° F., the steam remaining superheated throughout); (2) final steam pressure; (3) torque or dynamometer weight; (4) r.p.m. was determined by a 50:1 worm and wheel; (5) consumption; (6) mechanical and frictional losses; (7) blade-tip clearance losses. As the small expansion was spread over 14 rings of blades, the jet velocity was about 140 f.p.s., and the fluid was treated as though non-expansive. B.h.p. was measured by a 5 b.h.p. Froude water dynamometer, and consumption by measurement of the condensate—about 104lb. at 70° F. in 6 min. Corrections were applied for mechanical losses, a blank turbine runner sleeve of equal weight being (*a*) driven by an electric motor, (*b*) uncoupled and allowed to run down, a dynamical calculation being made subsequently; meanwhile a steam atmosphere was maintained, and concordant results were obtained by the two methods. Blade-tip clearance loss was determined for each portion representing 1 per cent. of clearance area. Coefficient of discharge over the tips (not knife-edged) enabled consumption at zero clearance to be calculated. To obtain corresponding torque curves corrections were applied for reduced consumption at zero leakage, and increase in efficiency due to undisturbed flow. Efficiency was calculated from :—Total h.p.$=2{\cdot}545/Qh$. Steam consumption curves showed that the steam-jet velocity of discharge was *not* independent of speed, contrary to expectations. Probably this is due to carry-over of kinetic energy at low velocity ratios, but where maximum efficiency occurred, this was practically balanced by losses in the blade passages. Comparisons with the four-blade types were made at equal angles of approach (involving differences in the velocity of approach) since this is known to influence the lift in aerodynamics. After all necessary corrections have been applied the results are shown graphically, and may be summarized as follow—If total driving force were unaffected by circumferential pitch p, the force per blade would vary as p. Actually a curve is obtained which approaches a limit, so that the *biplane effect does occur,* and is relatively more important in the turbine where the whole of the energy in the steam should be exploited. The optimum power is obtained with $p=0{\cdot}23$, far below that necessary for the maximum lift per blade, *i.e.,* when the steam is properly guided there is some form of interference which reduces the lift per blade below the maximum. Lanchester shows that for a "pterygoid" aerofoil the Newtonian law of momentum will hold [see *Proc. Inst. Auto. Engrs., Vol. 9, 1915, p. 171*], under certain conditions. From a conjectured peak, the proportion of steam usefully employed there may be estimated at 62 per cent., the ratio (peripteral area/annular area) being 79 per cent. These figures seem to prove that wide separation is required to secure maximum force per blade. Despite the approximations introduced, it seems clear that lift per blade increases to a limit as with widely spaced aerofoils. The efficiency of the Kaplan water turbine seems to be due to wide blade-spacing, so that Newtonian momentum laws do not necessarily apply to this practical prime mover any more than to aerofoils, and vortex mechanics are necessary for a true interpretation of either.—*R. Dowson, "Engineering", 24th June, 1938, pp. 722-724.*

Relief of Internal Stress in Castings.

Test pieces of the materials investigated, carefully machined, were fitted into a stirrup, separated by distance pieces at the ends, and annealed in a thermostated furnace. The straightening which occurred on dismantling was taken as a measure of the residual stress. The authors' conclusions may be summarized as follows: Substantial stress relief is obtained by annealing Admiralty gun metal at 400° C., high tensile bronze at 500° C., cast iron at 550° C. (if this is much exceeded growth occurs), carbon steel at 600° C.; molybdenum steels show carbide spheroidisation if annealed much above 650° C. with deterioration of creep strength, the property for which they are particularly valuable. Time of annealing is of secondary importance, since stress relief-temperature curves are steep, but care must be taken to ensure uniformity of temperature throughout the whole casting, if large. *In iron and steel castings no stress-relief occurs on ageing at room temperature or 150° or 350° C.* Cooling from the suggested annealing temperatures may itself induce stress, if too rapid; furnace cooling is therefore recommended down to 100° C. for large castings, or non-uniform sections. Some of the objectionable internal stresses may be due to rapid cooling following the anneal at 600 - 650° C. customary after rough machining; the authors deprecate this entirely and lay stress on the *importance of slow final cooling* whether from 900° or 600° C. With iron castings the need for annealing depends on the tolerable internal stress and the uniformity of temperature that can be maintained during foundry cooling from 550-350° C. Many are never annealed. It is believed that internal stresses even much higher than those chosen for the investigation would be dissipated at substantially the same temperatures.—*L. E. Benson and H. Allison, "The Engineer", 1st July, 1938, pp. 23-24.*

Engineering Wages.

The paper discusses wage costing, with special reference to "incentive". On an average, both day and piecework wages have approximately doubled since 1914, the following special rates being usual—the first two hours' overtime at 1¼, thereafter 1½; night allowance of 1 if sent home after midnight, or 1½ if after 2 a.m., of the time up till 6 a.m.; coupling-up time at 1¼; night-shift at 1 1/6 plus overtime if applicable, special rates being allowed for double shift work; Sundays and local holidays at 2. In 1914 about 30 per cent. of employees were piece workers, in 1927 about 50 per cent., to-day the percentage is much higher for skilled workers, especially where the job is suitable for piece measurement, *e.g.*, machine work. Once agreed, piecework figures should be mutually respected, except for (1) error in calculation, (2) change in material, production or quantities, (3) a new agreement. An average hand should earn at least 25 per cent. over the time rates (indeed the management cannot afford that he should earn less), day-work time-rates should be guaranteed, and no debit should be carried beyond the agreed limit. Piecework on a price and time basis is discussed. Tables are given showing *inter alia* earnings, wages, bonus per cent. and true bonus per cent. for a basic wage of 1/- per hour, cost of living bonus of 18/- per 47-hr. week for an estimated 12-hr. job on the basis of 100 per cent., 50 per cent., and 33 per cent. of the savings being returned to the workman. The author concludes that the premium bonus is not sufficient "incentive" to sustained effort and discusses the conditions necessary for satisfactorily merging cost of living bonus with basic wage. Finally he suggests that the executive should study bonus rates in their relation to machine hour rates, but stresses the need for extreme caution in making any change.—*E. R. Briggs, "The Engineer", 24th June, 1938, pp. 698-701.*

Properties of Engineering Materials.

The work is concerned with the exact mechanism of deformation and fracture in metals, in which investigation is limited by the range of the high power microscope, X-ray diffraction patterns being studied. With normalised steel a progressive deterioration of structure occurs no matter what type or combination of stresses is applied, and eventual fracture is associated with partial or complete breakdown into grains or crystallites much smaller than the original ones. Fifty per cent. cold-rolled mild steel was subjected to (*a*) static stresses, (*b*) reversed cyclical stresses below, at, and above the safe fatigue range, being photographed periodically at exactly the same spot. It is found that fatigue stress produces lattice distortion within the crystallites; the prior process (with rise in hardness and strength) is perhaps a first stage towards total disruption, a stable structural stage which enables the metal to resist further distortion until completely work-hardened. Beyond this, under sufficient stress, lattice distortion proceeds to a second limit at which fracture occurs. Thus if the cyclical stress is too low to produce fracture no lattice distortion can occur, and indeed no change is visible from the original diffuse ring of the cold-rolled steel. With an unsafe stress progressive reduction in the intensity up to 14 per cent.—indicating continued lattice distortion—is observed. No further sub-division of the crystallites—shown by radial spreading—occurs, nor does any preferred orientation. Attention is drawn to work on alloyed ferrous castings, some of which are available with strengths of 60 tons/in.^{2} after heat treatment, and to the effect of surface finish on fatigue strength, of importance in aircraft materials. Research on frettage in hardened steel, stainless steel, brass, nickel, chromium and an aluminium alloy, shows that it is least when a hard and a soft metal are in contact, and that lubrication minimizes but does not entirely prevent it. Corrosion-fatigue values for the following materials used in aircraft have been determined—(1) cold drawn 0·5 per cent. C steel wire, (2) corrosion-resisting 15 per cent. Cr steel, (3) stainless 18 :8 Cr :Ni steel, (4) corrosion-resisting 17 :1 Cr :Ni steel, (5) duralumin, (6) magnesium alloyed with 2½ per cent. aluminium. [See *Journal of the Iron and Steel Institute, Vol. 135, 1937, p. 293*]. A Haigh machine was used, the specimen being subjected to a spray of 3 per cent. common salt in distilled water. The results are given as graphs. On the whole the effect of variation of mean stress is much as in air, and the fractures show no special features although for the more readily corroded materials they were serrated.—*Report on N.P.L. Research, "Engineering", 15th July, 1938, pp. 62-64.*

Marine Applications of High-Pressure and High-Temperature Boilers.

The writer observes that in recent years naval architects and marine engineers have come to the conclusion that the advantage of the modern high-pressure and high-temperature boilers, viz. reduced weight per lb. of steam and per horsepower, makes them specially suitable for marine installations. He points out that while the various types of such boilers differ in their layout and construction, the fundamental principle on which their design is based is throughout the same, namely the combustion of a maximum of fuel in a minimum of space and time. These new boilers in which efficiencies of 90 per cent. and more have been obtained are in reality steam generating machines, in the operation of which the qualified engineer must take the place of the fireman. Their development which is based on the progress of research relating to the influence of fluid circulation on the transfer of heat and to the phenomena of radiation, of necessity presupposes a parallel development in metallurgy providing boiler and turbine materials capable of standing up to the pressures and temperatures involved which range respectively from 20 to 225 kg. per sq. cm. (285 to 3,200lb. per sq. in.) and up to about 500° C. (about 930° F.). The writer gives brief particulars of the La Mont, Velox, Loeffler, Benson, Sulzer, and Schmidt-Hartmann boilers of which he notes the distinguishing characteristics as follows :—The *La Mont* boiler with its steam collector, circulation pump, economiser, and superheater occupies an intermediate position between the type of boiler fitted in the "Queen Mary" and the

"Normandie" and the latest type and has been adopted in British destroyers. A working pressure of 20·4 kg. (290lb. per sq. in.) 365° C. (690° F.) steam temperature, 48 tons hourly output of steam and 73 per cent. efficiency represent typical characteristics. The novel feature of the *Velox* boilers consists in the substitution of a compressor for the low-pressure forced draught fan, so that sufficient air can be provided for a greatly increased rate of combustion; air and gas speeds of 200 metres per sec. (656ft. per sec.) and a heat transfer of 100,000 B.Th.U. per sq. ft. are obtained. A Velox boiler supplying 34·5 tons of steam per hour, at a pressure of 48 kg. per sq. cm. (683lb. per sq. in.) and a temperature of 450° C. (840° F.) has been fitted in the steamer "Athos" of the Messageries Maritimes. In the *Loeffler* boiler the aim of the designer has been to arrange the water-steam circuit in such a manner as to place the tubes containing steam in the zone of the highest temperature of the combustion gases. Boilers of this type, one of which has been fitted in the "Conte Rosso", supply 68 tons of steam per hour at a pressure of 130 kg. per sq. cm. (1,850lb. per sq. in.) and at a temperature of 500° C. (930° F.). In the *Benson* boiler, on the other hand, no tube containing steam only is exposed to the maximum radiation temperature of combustion gases. It has been fitted in the North German Lloyd steamer "Uckermark" and subsequently in the German Africa Line steamers "Pretoria" and "Windhuk", but the maximum pressure of 225 kg. per sq. cm. (3,200lb. per sq. in.) employed in the former has not been retained in the later boilers which supply 40 tons of steam per hour at a pressure of 81 kg. per sq. cm. (1,150lb. per sq. in.) a temperature of 450° C. (840° F.) and 91 per cent. efficiency. In the Monotube *Sulzer* boiler the feed water enters the mono-tube element and after reheating passes to the tube nests surrounding the combustion space. It has been fitted in the steamer "Kertosono" where 20 tons of steam per hour are supplied at a pressure of 60 kg. per sq. cm. (853lb. per sq. in.) and a temperature of 380° C. (684° F.). The *Schmidt-Hartmann* boiler consists of a direct-fired primary boiler operating in a closed circuit which supplies heating steam to a secondary boiler in which the working steam is generated, the condensed heating steam being returned to the primary boiler. The first installation of this type was fitted in 1937 in the Germany steamer "Altair".—*Journal de la Marine Marchande", Vol. 20, No. 1009, p. 1176, August 4th, 1938.*

Fabricated Gear Units.

Two interesting examples of welded units are illustrated. A large worm reducing gear for the paddle wheels of a 125ft. Nile sternwheeler has been built up from steel plates with cast steel bearing units, with tee stiffening ribs at the points of maximum stress. The case is made in halves, accurately machined so that the top can be lifted clear without disturbing wheels and bearings. It is sufficiently robust to withstand shock from river obstructions such as crocodiles and half-submerged logs. The rolling mill drive case is built up entirely from steel plates and rolled sections, and designed to eliminate projections, and relieve stress; it is braced to reduce resonance. It is claimed that the housing will comfortably withstand the severe shocks and heavy loads it is likely to meet in service. *—"The Engineer", 22nd July, 1938, p. 101.*

Problems Before The Engineering Profession.

The author discusses the position in U.S.A. with special reference to cultural and sociological standpoints. He emphasizes that each member of a profession must undergo a test for admission, and should maintain a code of ethics and assume social responsibility, placing human and professional interests above his own; the engineer is a specialist in his own subject, but should not therefore neglect broader educational interests. He should have a better appreciation of the co-ordination of technology and economics and should think, write, and talk more on social matters, in which his normal straightforward thinking and devotion to facts would be of value. If professional people are unwilling to subdue their rights and individuality under dictatorship, they must take an active interest in public affairs; in the long run the good citizen is even more important than the expert engineer since without good government engineering contributions to society will be lost. Professor Potter then deals with the American Engineering Council, formed to present a united professional front in matters of interest to the government and the people, as a clearing house for public questions, and to advise the authorities in connection with special engineering problems. He emphasizes the importance of united action, which in no sense entails a diminution in the value or utility of technical or sectional societies. Recent changes in U.S.A. may result in retarding technological advance by restricting individual initiative, and greater unity and better solidarity amongst engineers in general are very necessary.—*A. A. Potter, "Mechanical Engineering", July, 1938; reproduced in "The Engineer", 22nd July, 1938, pp. 103-104.*

The New "Mauretania".

Apart from propelling machinery, there are some important technical differences from the original "Mauretania" [*see "Engineering", Vol. 134, 1907*], and Merseyside is justly proud of having launched the biggest ship ever constructed in England. Many features reminiscent of "Queen Mary" are found, with particularly pleasing lines:

Length	772 ft.
Breadth extreme	89 ft. 6 in.
Draft	30 ft. 9 in.
Cargo space	390,000 cu. ft.
Cargo space refrigerated	75,000 cu. ft.
Gross tonnage	approx. 34,000
Height of pole masts above keel ...	211 ft

The hull is divided by 13 main transverse bulkheads, 11 with hydraulic watertight doors; water, feed water, oil, reserve fuel, and ballast are to be stored in the 37 compartments of the double bottom, and about 70 cars can be carried in the 'tween decks, with access through hatches 4 and 5. Parsons geared turbines, each comprising a high-, intermediate- and low-pressure stage, are being constructed for use with superheated steam at 425lb., each stage being geared to an 85 ton wheel. Each shaft runs in self-lubricating plummer blocks, has a total length of 243ft. and weighs 156 tons; each manganese bronze propeller weighs 25 tons. A closed circuit system is to be used for condensate and boiler feed, through three-stage heaters using exhaust and bled steam from the turbines. Six oil-side-fired water-tube double-flow Yarrow boilers will deliver steam at 725° F., each evaporating 68,500lb./hr. and having a 54in. steam drum, superheater, and three water drums, all solid-forged with riveted ends. Fire tubes are 2in., others 1½in. in diameter and their connections to the various drums are explained. Dust collectors are fitted to the two funnels which are elliptical with axes 34 and 24ft., and reach 56ft. above the sports deck. Electrical plant comprises four 800-kW. 225-volt self-contained compound turbo-generators with underslung condensers, pumps and closed feed equipment, driven through single-reduction double-helical gears; an emergency 75-kW. Diesel set is carried on B deck, and a 220-volt battery can maintain essential services for half-an-hour. In the cable installation fire-risk is eliminated as completely as possible, the total load being about 5,000 h.p. Particular attention is given to the ship's amenities, to include observation lounge, hall, library, children's playground, dance floor, swimming pool, gymnasium, hairdresser's shops and hospital. Cabin passengers will be carried on B deck, tourists and thirds on A, B and C decks. Fans or motors near air ducts are to be sound-insulated. Extensive wireless equipment including three transmitters and four receivers will be installed, permitting trans-Atlantic communication in either direction. 24 double-teak diagonal-plank lifeboats will be carried, 2 motor driven, 14 others with auxiliary motors, 18 in gravity davits above the sun deck, 6 in quadrant davits on the promenade deck aft. Other equipment includes an 18in. searchlight, electric telegraphs for intercommunication, three bower anchors weighing 9 tons each, with 3⅜in. stud-link cable weighing 96 tons, twin capstan heads, 2 warping and 22 boat winches. The hull was launched on 28th July and the first sailing from London is planned for early summer 1939.—*"Engineering", 29th July, 1938, pp. 121-124.*

Ship's Motor Lifeboat in Stainless Steel.

The craft, with length 28ft., beam 8ft. 9in. and moulded depth amidships of 3ft. 10in., built to B.O.T. requirements for a Class I passenger liner, is on view at the Glasgow Empire Exhibition. A 24 h.p. airless injection engine is fitted, and a compact wireless set receiving or transmitting over 200 miles, searchlight and small morse lamp, are operated from accumulators. An interesting method of hull construction is used—stainless 18/8 Cr. : Ni steel plates of 14 s.w.g. are flanged inwards and welded both inside and outside in the V, while keel, stem and stern are also welded from plate and forgings; further the propeller and shaft are of the same alloy. In this lifeboat the resistance of the well tried alloy to marine corrosion has been exploited to the full.—*"Engineering", 5th August, 1938, pp. 154-155.*

Glandless Parallel Plug and Controlled-Ball Bowler Valves.

The glandless lubricated valve, of simple construction, is designed for a wide variety of products, *e.g.* oils, acids, gas, water, air at temperatures not exceeding 365° F. (185° C.), and pressures up to 3,000lb./in.^{2}. It is made in sizes from ½in. to 12in., in cast iron for ordinary work but in steel castings of tensile strength 35-40 tons/in.^{2} for pressure work. The plug may be coated with stainless steel, nickel or aluminium for corrosive fluids. Stresses are relieved by previous annealing. Normally, wrench operation is used up to 1½in. and worm or bevel gearing above this. In the new bowler stop valve a stainless steel ball replaces the usual mushroom or disc; this finds a new face after each operation, and the stainless steel seating can also move laterally, ensuring a perfect closure despite any movement of the pipeline, and avoiding leakage. The valve can be repacked while open and under pressure, and the stainless steel is hard enough (500 Brinell) to crush adventitious impurities, *e.g.* scale, without damage. The handwheel has large radiating surface and the gland is packed with moulded asbestos rings. The valves are recommended for heavy duty applications and are on view at the Empire Exhibition.—*"Engineering", 5th August, 1938, p. 155.*

50,000 kW. Turbo-alternators at Dalmarnock.

Each of the two units has maximum continuous capacity of 50,000 kW. and 20,000 volts operating at 1,500 r.p.m. on steam at 600lb. (gauge) and 825° F., and exhausting at 29in. vacuum. Pure reaction two-cylinder single-exhaust design is used, with 48 pairs of blade rows in the high-pressure section and 28 in the other; before fitting, the stainless iron blades are centrifugally stressed beyond the yield point. The longest blades are 26in. long with tip-speed of 852 f.p.s. Pure labryrinth glands, packed with live steam which is subsequently condensed, are used. Each turbine rotor has a pivoted pad thrust-block of white metal-faced steel, adjustable within limits and separately lubricated. A single governor valve and combined runaway-stop valve control the steam supply up to 40,000 kW., the most economical load, when a second governor comes into action; normally the valves are operated by oil pressure, and on failure of this they shut automatically, but do not reopen when this is restored until manually set; further, the turbine cannot be started unless the auxiliary oil pump is working. An emergency trip-valve is also fitted. For starting, a motor turning gear in conjunction with a 2,000lb./in.^{2} oil pump to float the rotors are used, but when the heating steam drives the machine faster than the motor, the latter cuts out. As regards the generator, the welded steel stator and segmental construction of the core are described in full; end-shields are of non-magnetic non-conducting material, to reduce eddy-current losses. The rotor is machined from a solid forging, axially trepanned and test pieces are taken from the core; after manufacture it was dynamically balanced at various speeds and tested at overspeed; electrical stability is ensured by a pilot exciter at constant voltage. Ventilation is by motor-driven fans, being split up so that the centre is cooled as efficiently as the ends; exciter and split rings are also included. Should a predetermined exit air temperature be exceeded, a horn sounds.—*"The Engineer", 15th July, 1938, pp. 60-62.*

Heat Transfer by Turbulent Flow in Pipes.

The extended Prandtl equation holds over a wide range from gases to thick fluids if a suitable temperature is chosen.

$$N=\frac{\alpha d}{\sigma}=\frac{0{\cdot}0395\ R^{\frac{3}{4}}\ P^{\frac{7}{8}}}{1+\frac{3}{2}R^{-\frac{1}{8}}(P-1)}$$

α being heat transfer, d diameter, σ thermal conductivity, N, R and P the Nusselt, Reynolds and Prandtl numbers. For convenience logarithmic graphs with N as ordinate, P as abscissa and R as parameter are used. Over limited values the following simplified formulæ may be used :—

For $P=0{\cdot}6$ to $1{\cdot}7$ $N=0{\cdot}0393\ R^{0{\cdot}75}.\ P^{0{\cdot}56}$
$P=1{\cdot}7$ to 14 $N=0{\cdot}0237\ R^{0{\cdot}81}.\ P^{0{\cdot}39}$
$P=14$ to 300 $N=0{\cdot}0216\ R^{0{\cdot}86}.\ P^{0{\cdot}23}$

These formulæ hold only for $l/d>200$ [*see E. Eckert, Zeitschrift des Vereines deutscher Ingenieure, Vol. 80, 1936, p. 137*] and for isothermal flow, and will hold for heating or cooling conditions only if the flow resistance is identical in both cases. The effective temperature of the fluid can be derived from the expression

$$\left\{\ \theta_m-\left(\frac{0{\cdot}1\ P+40}{P+72}\right)(\theta_m-\theta_w)\ \right\}$$

[*see E. Hofmann, Zeitschrift ges. Kälteindustrie, Vol. 44, 1937, p. 99*]. Other equations proposed are *'ten Bosch's extension of Prantl's expression*—

$$N=\frac{0{\cdot}0395\ R^{\frac{3}{4}}\xi P}{1+B.R^{0{\cdot}1}.\ P^{0{\cdot}185}\ (P_g-1)}$$

where $\xi=1-0{\cdot}007\ (\theta_m-\theta_w)$ for water, B is 1·4 for heating and 1·2 for cooling, P_g the "mean temperature in the boundary layer" [*see "Wärme übertragung", Berlin, 1936, pp. 127 and 135*];

$$\left\{\begin{array}{l}N=0{\cdot}024\ R^{0{\cdot}8}\ P^{0{\cdot}37}\text{ for heating}\\N=0{\cdot}024\ R^{0{\cdot}8}\ P^{0{\cdot}31}\text{ for cooling}\end{array}\right\}$$

being Kraussold's extension of Nusselt's expression [see Forschungen Ingenieur Wesen, Vol. 4, 1933, p. 39], mean liquid temperature being used; and that of *Merkel "Hütte", 26th edition, Vol. 1, p. 500*] valid for water alone

$$\alpha=1{,}755\left(1+0{\cdot}015\ \theta_{effective}\ \times\frac{w^{0{\cdot}87}}{d^{0{\cdot}13}}\right)$$

$$\text{where } \theta_{effective}=0{\cdot}9\ \theta_m+0{\cdot}1\ \theta_w$$

θ_m and θ_w being temperatures of liquid and wall respectively. Obviously with high wall temperatures there are notable variations in the values obtained in these different formulæ. Of those quoted, the last approaches the first most closely.—*E. Hofmann, "V.D.I. Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 18th June, 1938, pp. 741-742.*

Early History of the U.S.A. Navy.

The author gives an historical review of progress during the nineteenth century, this being, in effect, an account of the introduction of steam. "Demologos", built in 1814, was the first steam warship ever constructed but was never in action, and with peace interest rapidly died out. In 1837 "Fulton 2nd" easily made 12 knots, outdistancing the "Great Western". Intense hostility was shown to the young engineer corps and after the civil war in U.S.A. the amazing decision to return to sail was reached. Meanwhile "Princeton", equipped with propellers, ran very successfully in 1883 and the cruiser "Wampanoag" reached the unheard-of speed of 18 knots in 1867; in the same year oil-firing was tried, with conspicuous failure. In 1883 five new ships were constructed, entirely of domestic steel, and this period saw the development of the "Bureau of Engineering" which took over electrical equipment also; five years later speeds of 19 knots were being guaranteed by builders. "Vesuvius", the first U.S.A. warship with vertical triple-expansion engines, attained 21·65 knots in 1888; she was equipped with dynamite bombs thrown by compressed air. An unusual craft was the torpedo boat "Ericsson" with length 137·5ft., beam 15ft., displacement 105 tons, ram bow and overhanging stern; on a 3-hr. run at 22·5 knots she burned 2lb. coal per i.h.p. hr. In 1891 three 9,000-ton 15-knot battleships were authorized; about the same time the triple screw became popular; some accidents occurred through replacement of cast iron by cast steel, and speed premiums and penalties were introduced. The author discusses the history of boiler corrosion, of smoke pipes, and of the increased frequency of steam-pipe bursts, as pressures rose. He traces the variation in steam-raising equipment through a variety of vessels, and mentions with pride the naval performance of the "Oregon" on a 14,500-mile run with only eight stops, coaling at five. U.S.S. "Trenton" was the first warship in the world to be electrically equipped, even though crudely by present standards; electrical gunfire control was introduced in 1896 and in "Kearsarge" the first American three-wire system was used, at 160 volts. About this time water-tube boilers, particularly those of French and British design, excited considerable interest. Engineering and industrial progress went hand-in-hand, particularly in the machine tool and metallurgical fields. Bessemer steel was first permitted in 1891 and the tensile strength of steel castings rose consistently from 18 to 27-31 tons/in.^{2}; simultaneously alloy steels and armour plate gained ground.—*H. M. Neuhaus, Journal of the American Society of Naval Engineers; reproduced in "The Engineer", 29th July, 1938, pp. 130-132.*

Friction at Moderately Rough Surfaces, Especially of Ships.

In high speed watercraft a substantial part of the power is used in overcoming surface friction, so that finish is of importance. Fortunately resistance relations for tubes and plates are transformable, but unfortunately the inside and outside of a tube are not usually identical in surface. Results for a number of plates prepared by commercial methods are reported, but since the range of Reynolds number was insufficient to substantiate the resistance law [*see Jahrbuch schiffbautechn. Gesellschaft, Vol. 39, 1938*] data by *Bauer and Galavics* [*Mitt. Fernziehkraftwerks Eidg. Tech. Hochschule Zürich, Feb., 1936*] are used. Both for the author's plates and for tubes of different sand roughness investigated by *Colebrook and White* [*Proc. Royal Society, Vol. 161A, p. 367*], comparable results are obtained. The author gives charts of $\tau\rho/2v^2$ and $2W/\rho v^2\ x$ plotted against log (Reynolds number) for various conditions, x being plate length in cm. To obtain agreement with the resistance diagram of *Prandtl and Schlichting* [*Werft, Reederei, Hafen, Vol. 15, 1934, p. 1*] the "equivalent sand roughness" is introduced as a parameter in the square law region, for the Swiss authors' surfaces $k=0{\cdot}01537$mm. It implies the grain size which in the square law region gives the same resistance as a tube of equal bore. For smooth surfaces, not attained in the tests described, the Reynolds law holds but the difficulty can be overcome by the new method of determining equivalent sand roughness, with results summarized below. For rough surfaces the relation of *Prandtl and Schlichting* holds approximately, but there are still difficulties in the treatment of corrugated surfaces [*see L. Hopf, Zeitschrift angew Mathematik und Mechanik, Vol. 3, 1923, p. 329*]. [Paint colours will be according to German nomenclature].—*F. Schultz-Grunow, "V.D.I. Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 18th June, 1938, pp. 756-758.*

Research on Materials and Modern Design.

When technical development has reached a certain level, increased output of machines is substantially a question of the constructional material since the *form* of the component parts has been established by experience, or if the output is fixed, of how a suitable machine can be made from the least possible amount of material. Particularly is this true for motor cars and aircraft, where reduction of weight leads to increases in speed, load and other desiderata. Not only the material but often the *shape* of the member can be improved. The following types of load can be distinguished: (1) dead, (2) fluctuating, (3) starting impact, (4) applied deformation, (5) non-uniform heating; but even in purely static constructions the time factor enters. Fluctuating stresses are not easy to determine, but sharp bends, if not every notch effect, can be avoided by suitable design. With pure tensile stresses, which are rare in practice, a notch hinders plastic flow and the area of fracture is therefore greater in a notched bar, and further the possible stress changes according to the nominal stress at the notch. The higher the yield point, the higher the stress that can be chosen; high tensile steel can be used with advantage and any methods of artificially raising the yield point, *e.g.*, cold working or heat treatment, should be exploited to the full. With fluctuating loads, fracture ensues from gradual breaking down, leading to an incipient crack. Very high local stress concentrations do not, however, produce their full effect. In design, the strength at every point should be utilized as fully as possible, and use of the strongest steels is favourable only with proper design and surface configuration. This is illustrated by the advantage of a hollow cast crankshaft with bowl design for the web. Impact stresses increase greatly with increasing rigidity while static stresses decrease, so the manufacturer must choose his middle way. In motor car driving shafts fracture occurs when the ability of single softer spots to deform is exhausted, the entire angle of torsion being very small, and *such steels should not be heat-treated to the utmost.*

No.	*Surface.*	*Ground coats.*	*Weathering in days.*	*Coats after weathering.*	*Equivalent sand roughness.*
1.	Rusted	Two coats red anti-rust paint one coat ship's paint III	14 in marine conditions	One coat ship's paint I, one coat ship's paint III.	0·0318
2.	Rusted and galvanised	ditto	ditto	ditto	0·0318
3.	Rusted	ditto	42, then scratch-brushed	Two coats ship's paint II.	0·0195
4.	Rusted and galvanised	ditto	ditto	ditto	0.0195
5.	Rusted	ditto	42, then thoroughly chipped, etc.	ditto	0.0195
6.	Rusted and galvanised	ditto	ditto	ditto	0·0195
7.	As rolled	——	——	——	0·0543

Professor Thum points out that machine parts which must inevitably have limited life (*e.g.*, those exposed to wear or corrosion) need not be designed to carry the maximum stresses for an unlimited time, and goes on to discuss fluctuating stresses in relation to frequency. He inserts a further curve, the "damage line" in the Wöhler diagram on the base of Russell and Welcker's work on rotary bending. The interval between this and the Wöhler curve shows the region in which overload decreases the fatigue strength. *With pure alternating stress, after a few fluctuations the damage line exceeds the fatigue line by little, if at all, and this holds even for notch-free specimens.* Welding, also, may introduce internal stress concentrations not visible externally. At high temperatures notched bars have lower nominal creep-stress than plain bars, and sooner or later the deformation at fracture ceases to be evident. For a steel with 0·2 per cent. C, 0·8 per cent. Cr, 0·9 per cent. Ni, 0·95 per cent. Mo, the fatigue resistance of the smooth bar was 36 kg./mm.^{2} (23 tons/in.^{2}), hot tensile strength 66·4 kg./mm.^{2} smooth, 67·5 threaded, and 75 notched (42·2, 42·9, 47·6 tons/in.^{2} respectively); at 500° C. the fracture was intercrystalline. Normally a fatigue fracture is quite distinct, but in the hot tensile test it appears to be transcrystalline. For bolts, for continuous exposure to high temperature (*e.g.*, in boiler pipe flanges), the author suggests (1) reduced shank, (2) stronger thread, (3) shaft not to be too long, (4) infrequent removal, (5) rounded base of thread, though this may become uneconomic. —*A. Thum, "Engineering", 29th July, 1938, pp. 143-146.*

Strength of Metal Panels and Ships' Plates.

For metal sheets under end loading satisfactory agreement is obtained between theoretical and test conclusions, and recently the difficulty of transmitting a concentrated load to monocoque structure where strength and weight requirements conflict, has been solved theoretically. In test three integrating structures have been used, but give conflicting results. A similar structural problem also solved theoretically is the stability of a plane rectangular grid of stringers subject to uniform compressive loading, and ribs; this fails by buckling. A ship's plate of ¼in. mild steel 80in. high and 40in. wide, stiffened along edges by angles, and at corners by gusset plates, gave a slight curvature up to 7 tons, then a linear relationship up to 21 tons both during loading and unloading. Within the maximum load of 50 tons available the stiffened edges did not buckle. If the torsional rigidity attributable to the longer angles is neglected, from the formula 3·6 E h^2/d^2 the panel should have failed at 1·89 tons/in.^{2}, 26 tons on 13·75in.^{2} of cross section. Actually a gradually increasing curvature occurred over the range 21-31 tons, actual buckling being reached at 29 tons, after which stiffness fell to about one-third. The behaviour was thus in close agreement with theory.—*Report on N.P.L. Research, "Engineering", 5th August, 1938, pp. 151-152.*

Oil-Engined Picket Boat for the Royal Navy.

It is claimed that this is the first naval oil-engined picket boat with speed exceeding 20 knots. She has standard dimensions—length 45ft., breadth 10ft., draft 2ft. 6in., and weighs about 8 tons, but is nevertheless strong in view of the special hull construction. Two diagonally planked mahogany skins are separated by oiled canvas, the timbers being fashioned and bent under heat, then clenched inside with copper nails. Forward is a small wheel-house and officers' accommodation, aft is the men's cabin with provision for fitting anti-aircraft equipment. With 45 persons the boat can attain 15 knots, or 10 knots when towing a similar one. Machinery consists of twin-screw 6-cyclinder Diesel engines with bore 4¾in. and stroke 6½in., the designed h.p. per engine being 95 to 145 at speeds 1,200 to 1,800 r.p.m. respectively. Fuel cost is said to be only one-fifth that for a petrol motor of similar power, with increased radius of action (150 sea miles) on account of smaller fuel consumption; moreover, fire risk is practically eliminated. The control mechanism is described—gauges showing oil pressures, circulating water temperatures and engine speeds; manageability, sea-keeping qualities and general comfort are good.—*"The Engineer", 29th July, 1938, p. 129.*

The Four-Ball Top.

The apparatus consists of a half-inch hard-steel ball rotated under a heavy load in the cavity formed by three other steels spheres clamped within a cup containing the liquid under test. It is normally employed for investigating lubricants for use at extreme pressures as in gears [*see "Engineering", Vol. 144, 1937, p. 2*]. Frictional torque set up by rotation, or time necessary for seizure, or mean diameter of the circular impressions on the balls, may be measured. Recently common lubricants have also been investigated, with interesting results. Load is applied and the upper ball rotated at 1,500 r.p.m. for one minute; the magnitude and duration of the frictional force associated with seizure and recovery which usually occur within a fraction of the first minute's run are recorded. It is almost certain that no fluid film capable of supporting a load exists, so that "oiliness" alone acts, uninfluenced by the viscosity of the lubricant. Up to 300 tons/in.^{2} extreme pressure lubricants are superior to oils containing zinc oxide or castor oil, and especially over common mineral oils, but there is no sharp division. Golden syrup behaved as though in the former class. Additions of colloidal graphite and water in small amount were slightly deleterious, but in larger amount led to an increase in breakdown load. Oleic acid and rape oil additions had slight beneficial effects at high pressures. A new transmission dynamometer of double bevel-gear type is also described, so arranged that the power actually transmitted by the belt greatly exceeds that of the driving motor. Many difficulties and inconsistencies in belts have been encountered, some of which are not yet solved; these are too great to be fortuitous or experimental, and are not connected with atmospheric humidity. The formula $\mu = 0{\cdot}125 + 0{\cdot}707s/(7{\cdot}54 + s)$ is in very good agreement with experimental results over a wide range for a 2in. × $\frac{1}{4}$in. leather belt in contact with one quadrant of a 2ft. diameter cast-iron pulley, where s is the slip in f.p.s. This explains the unsuitability of leather belting for low speeds and the difficulty of starting belt-driven machinery from rest. It should hold for the range of slip commonly encountered.—*Report on N.P.L. Research, "Engineering", 22nd July, 1938, pp. 107-108.*

The Graphoid Layer on Bearing Surfaces.

If a bearing which has been run-in with oil containing colloidal graphite is washed free from oil and subsequently run dry, seizure takes place much later than with a bearing similarly treated with a non-graphited oil, this property of non-seizure during temporary breakdown of the oil film being most valuable. The graphite layer formed is so thin, 10^{-6} cm., as sometimes to escape detection even by the sensitive electron diffraction method, although its effect on corrosion and dry-running is marked. Stuart [see *"Engineering", Vol. 145, 1938, p. 73*] found that the layer was oriented with the slip planes parallel to the surface, and acts as a boundary film resistant to high temperatures and pressures and also to corrosion. The authors have tested flat discs of mild steel, lead, copper and two widely differing bearing metals by running them against a mild steel disc until a smooth reflecting surface was obtained, medicinal paraffin with 20 per cent. of a graphite-oil suspension being used as lubricant. Each metal acquired a graphoid layer a few atoms thick; after further running with the lubricant without graphite, halo patterns characteristic of the Beilby flowed layer resulted, with disappearance of the graphite pattern, nor did hand polishing cause its reappearance. Gentle etching or abrasion and subsequent polishing, however, gave a clear graphite pattern. In some cases, two or three such treatments were necessary to remove this graphite, the penetration being greatest with lead and the soft white metal, and least with mild steel. The authors explain this phenomenon by actual occlusion of graphite by "rolling-in" while the Beilby layer is being formed.—*G. I. Finch and E. J. Whitmore, "Engineering", 22nd July, 1938, p. 91.*

Dry Multiple-Disc Clutch.

The discs in the outer coupling are of compressible material threaded on a continuous ring of machine-cut teeth, the inner metal discs being threaded on the inner coupling. This arrangement gives an even torque round the discs and also provides for shaft expansion. To the outer metal disc a pressure plate is screwed in such a way that there is enough play to allow them to be separated under the force of springs when the clutch is disengaged. A sleeve screwed on to the coupling carries several levers, each provided with two rollers, one in contact with the pressure plate, the other with the inner surface of a sleeve which is keyed to another sleeve and carries the operating yoke. A torsion spring wound round the fulcrum pin of the lever keeps the upper roller in contact with the sleeve. When the clutch is engaged the inner conical portion of the sleeve comes into line with the upper roller, which under the influence of the torsion spring, moves radially outwards; the lower roller moves away from the pressure plate, which, however, follows it on account of the expansion springs. Thus the pressure is taken of the discs and the coupling ceases to transmit power; the springs transmit no torque but allow gradual engagement. The locking device and grip adjustment are described, and the mechanism may be used with a pulley or a gear-wheel instead as one of a pair.—*"Engineering", 22nd July, 1938, p. 115.*

1,000 H.P. High-Speed Diesel Marine Engine.

The unit, characterized by a high power/weight ratio, is particularly intended for high speed lighter naval craft, now becoming of tactical importance. Lateral stiffness is essential, and since the engine is more rigid than the hull, a semi-flexible mounting is necessary. Accessibility is also important, on account of restricted space; in a recent test all 16 pistons were withdrawn for examination and replaced within 9 hrs. To minimise time out of commission stellite facings for valves and seatings are used. Fuel pumps are located within the 60° V of the cylinders, which have bore 7in., stroke 7$\frac{3}{4}$in., and develop 300 b.h.p. at 1,006 r.p.m. and 1,000 b.h.p. at 1,750 r.p.m., with corresponding mean effective pressures of 51 and 95lb/in.^{2}. In manufacture great attention is paid to accuracy of machining, balancing and matching. Pearlitic liners with good resistance to wear and corrosion are used in the cylinders; the heads are of machined alloy cast-iron and carry the vertical air and exhaust valves. The lower throat of the Ricardo III combustion chamber is of heating-resisting steel, and the chamber as well as the cylinder head are cooled by a rapid water stream to reduce scaling. Die-cast aluminium pistons are fitted with four pressure rings and two oil control rings, the upper ones being fitted with high-expansion iron inserts cast in the piston, to reduce wear in the grooves. Ground, case-hardened, fully floating gudgeon pins and matched heat-treated drop-forged steel connecting rods, with phosphor-bronze eye-bushes, are used. The crankshaft, 4$\frac{1}{8}$in. in diameter, is machined from a single forging of heat-treated Ni—Cr steel of tensile strength 55 tons/in.^{2}. Valves and camshaft are of alloy steel. The centrifugal spring-loaded continuously-lubricated governor operates on the fuel-pump control, and is driven from the camshaft through bevel gearing. The dry-sump lubrication system is described in detail. Forward gear ratios of 1·7 and 1·16 and a reverse ratio of 2·4 are used; normally they will be operated from the bridge, but can also be handled directly.—*"Engineering", 22nd July, 1938, pp. 111-112.*

The Problem of Air-conditioning in Vessels.

Conditions in vessels make it necessary to arrange for a number of enclosed spaces and in some cases the spaces are hermetically closed; this introduces the problem of guaranteeing the requisite condition of the interior air. The characteristics for intensifying the ventilation are the values indicating the average theoretical number of times per hour the air is renewed in a given compartment. The usual accepted values are given in *Table I for the various compartments in a vessel. The wide range of the given values is due to the unequal requirements in connection with the ventilation and to the necessity of securing the renewal of the interior air without knowing the particulars of the service conditions. From the standpoint of the effect on human organs under seagoing conditions, it is necessary to take into consideration the temperature, humidity, and the CO_2 content of the air. The possible entry of injurious gases, etc., should be excluded from normal conditions. Particulars are furnished of the effect of various temperatures, humidities and CO_2 contents on a human being. Formulæ and tables are given for calculating the quantity of air required in the different compartments, viz., living, and the main and auxiliary machinery spaces. Formulæ are also given for calculating the heat transmitted through bulkheads, the number of times the interior air should be renewed, on the basis of particulars indicated in Table III, and for verifying the quality of the air. Artificial air-conditioning is also discussed and various information and coefficients are provided in this connection. The article concludes with the following observations:—

(1) Previous to prescribing standard values for renewing the air it is advisable to obtain the particulars of the service conditions.

(2) When carrying out calculations for ventilating arrangements it is desirable to make sure of the methods and characteristic values as set forth in the article (previous to correcting these on the basis of experimental data). It is advisable to verify the accuracy of the given values for leakage of steam and heat transmitted by heated surfaces.

(3) When designing ventilating installations the distribution of the various ventilating stations and the technical resources should be considered; also the air currents (both in a horizontal and vertical direction) should be taken into account. The number and distribution of the ventilators should be arranged so as to guarantee a reserve and the possibility of working with a moderate rate of ventilation.

(4) On the basis of experimental investigations, the advantage of some system of cooling arrangement should be contemplated, including the possibility of utilizing it for thermal heating.—*"Soudostroienie", No. 2, 1938.*

The Construction of Producer Gas Driven Vessels in the U.S.S.R.

It has been proved in practice that marine motors may be driven by gas produced from coal and wood equally as well as by oil. A number of producer gas driven vessels were built some years ago and have given satisfactory results in service; therefore there should be no difficulty in organizing mass production of these craft. There is no need to emphasize the great importance of building motor craft of the producer gas type using gas generated in particular from wood, as many distant places with a network of rivers and lakes would greatly benefit by the introduction of a fleet of small craft using local fuel supplies; unfortunately, up to 1937 only 52 boats have been built out of 500 proposed. There is still no definite constructive plan for the fulfilment of this most important programme. Normal conditions should be set up for satisfying the need for these vessels. In order to make this possible it is suggested that a special organization of builders of small river craft should be formed; such organization should be included in a special sub-department of the Machine Building Department.—*"Soudostroienie", No. 2, 1938.*

Calorizing as a Method of Increasing the Heat-resisting Capacity of Metal.

In the construction of boilers and sundry fittings, and in the production of special articles, it is of great importance to obtain a metal capable of resisting high temperatures; in most cases up to the present, very expensive heat-resisting steel has been utilized for this purpose. There exists, however, a very simple and cheap method of increasing the heat-resisting power of ordinary carbon steel. This process is called "calorizing" and consists of impregnating the surface layers of iron or steel articles with aluminium under a high temperature. Aluminium is capable of forming a solid solution with the metal. It has been established that an iron-aluminium alloy with an aluminium content of about 33·8 per cent. gives a solid solution which melts at a temperature of 1,230 - 1,530° C. Experience has shown that the solution most difficult to melt is that with an aluminium content of about 30 per cent.; with a content exceeding 60 per cent., the solution is easily melted. This condition has been widely utilized by American and German industries in imparting to iron and steel articles greater heat-resisting powers. The basic process is as follows: The articles are placed in a hermetically closed box in such a manner that the spaces between them are

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* This and other tables and formulæ are not reproduced.

equal; these spaces are fitted up with a special powdered mixture consisting of Al and Al_2O_3 (alumina), with an aluminium content from 30 - 40 per cent. It is necessary that the powder closely surrounds the articles; for this purpose it must be thoroughly rammed. The box is then hermetically closed and placed in an annealing furnace with a temperature up to $\simeq$ 1,050° C., so that the articles will have a temperature within the limits of 980 - 1,000° C. Under this temperature they remain in the furnace for a period of about 20 hours, and are then allowed to cool down with the furnace to 400° C. When the articles have entirely cooled down they are removed from the furnace, taken out of the box and cleaned. They will now have a surface layer consisting of a solid solution of the basic material with aluminium which has penetrated the metal to a depth of 0·5 to 1 mm.; this layer is very difficult to melt and forms a protection against high temperatures. The solution used for calorizing steel tubes at certain works in the U.S.S.R. consists of powdered aluminium-oxide 49 per cent., powdered ferro-aluminimum 49 per cent. (60 per cent. Al. and 40 per cent. Fe.) and ammonium chloride 2 per cent. The tubes remain at a temperature of 950° for 22 hours. The temperature is controlled by means of a thermo-electric pyrometer and a ferric pyrometer installed on both sides of the furnace; the temperature is also controlled by an optical pyrometer, "Pyropto". *Fig. 1 shows the tubes being placed in a special box, and the furnace in which the calorizing is carried out. Samples cut from the tubes were ground, polished and afterwards treated with the usual reaction for steel, 2 per cent. HNO_3 and 4 per cent. picric acid, which acts on the material of the tubes but not on the surface layers infused with aluminium. Fig. 2 shows the sample after corrosion; the dark edges on the inside and outside surfaces are the aluminium layers. It may be seen that the layers are quite equal both on the inside and outside, their depth being from 0·5 to 0·7 mm. Fig. 3 shows the structure at the surfaces of a calorized tube, the corroded part showing a ferrite-pearlite structure, the usual material for tubes; the layer which shows no sign of corrosion represents the material of the tube infused with aluminium. In order to test the heat-resisting properties of the tubes they were placed in an electric furnace and heated to a temperature of 950° C. for 25 hours; the calorized tubes were found afterwards to be quite clean, whereas the non-calorized tubes which had been placed in the furnace under the same conditions were covered with a thick layer of scale. There is a wide range of fittings in boiler construction, etc., in which the heat-resisting properties would be greatly improved by being calorized. According to data issued by the calorizing department of certain large steel works, calorized articles have 50 to 20 times the fire-resisting powers at a temperature of 850° C. as compared with non-calorized articles, 15 to 10 times at 900°, 8 to 7 times at 950°, and about 5 times at 1,100° C. The mechanical properties of calorized fittings depend on the depth of the aluminium layer and the latter is dependent on the time occupied in the process. A table is furnished giving the results of some mechanical tests of calorized material in comparison with that non-calorized; a second table shows the results of several technological tests on the original material and also after calorization. On the basis of the results given in Tables 1 and 2, the following deductions are made:—

(1) Calorizing slightly reduces the strength and toughness of the material; this depends on the duration of the calorizing process, but nevertheless both the strength and toughness are quite satisfactory and increase after normalizing.

(2) The layer impregnated with aluminium offers less resistance to deformation than the original material.

In accordance with the results of the tests it follows that: (*a*) Tubes should be bent, where required, previous to being calorized; (*b*) Before calorizing, the ends of tubes which have to be expanded should be insulated; (*c*) Normalizing should be effected after calorizing; (*d*) During the process of normalizing, care should be taken to prevent as far as possible warping of the tubes and undue alteration in their shape.

Details.

The preparation of the mixture consists of mixing fireclay in a baked state and powdered aluminium in the necessary proportion in a special ribbed drum. After the mixture has been used once it loses 6 to 8 per cent. of Al., but if the necessary quantity of aluminium is added the mixture may be utilized again.

In the preparation of the articles, all material previous to being calorized should be pickled in a 30 per cent. solution of sulphuric acid and afterwards washed and the surfaces scrubbed with steel brushes. The parts which do not require to be calorized may be insulated with asbestos or may be coated with fireclay dissolved in liquid glass. The articles are placed in a hermetically closed box in such a manner as to leave sufficient space for the mixture. The space between each article should not be less than 100 mm.; this is filled in with the mixture and carefully rammed. After the articles have been packed in the box and the mixture carefully rammed, the remaining open spaces should be filled in with fireclay. Any small openings in the cover after being bolted down on asbestos packing should also be filled up with clay in order to prevent air penetrating into the interior of the box.

The box is then placed in the furnace, the temperature of which is gradually increased until it reaches 1,000° C. inside the box. The articles are kept in the furnace from 14 to 22 hours; the furnace is then cooled down together with the articles to a temperature of 300 to 400° C. The box is then

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* None of the illustrations referred to is reproduced.

withdrawn from the furnace and the articles are taken out. The majority of the fittings after being calorized should be normalized by being heated to a temperature of about 850 to 900° C. and then permitted to cool down in the atmosphere.—*"Soudostroienie", No. 2, 1938.*

An Interesting Boiler Mishap—Effect of Soot Blowers.

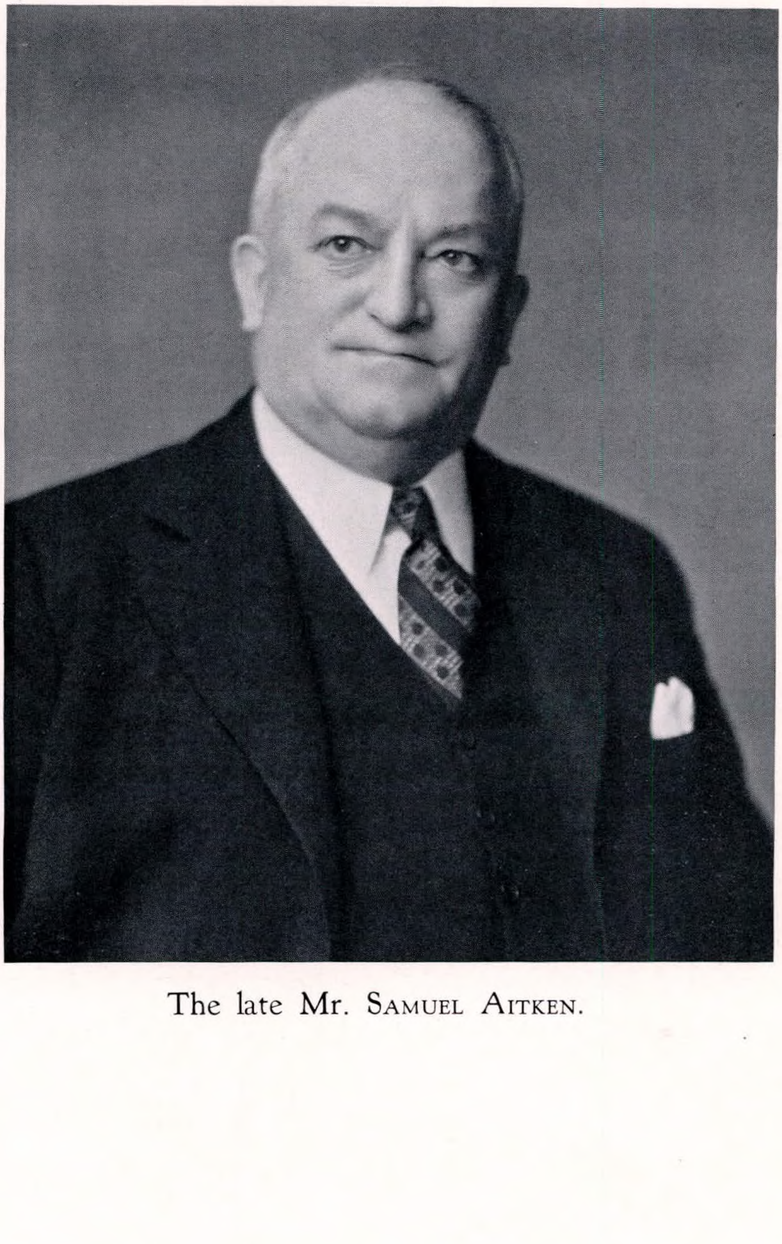
On March 4th, 1938, a tube failed through splitting over 5ft. 6½in., in an Ilford chemical works, having been examined by an insurance company six months before. According to B.O.T. Report 3310 the cause was "thinning of the material . . . . owing to external erosion. The principal factors were probably the position of the steam nozzle of the furnace soot blower and the angle of the rear edge of the jet orifice . . . being such as to cause scouring of the refractory lining. The impingement on to the tube of the grit steam . . . . together with the floating grit normally present in the furnace, caused abrasion and consequent thinning . . . . ". With multi-jet blowers care is taken in their design, location, and look-out for any obstructions. At sea blowers are operated nightly, in power stations once every eight-hour shift. This particular boiler was fired with coke breeze and bird-nesting of the ash occurred. A single nozzle blower was installed to deal with this, operated every four-hours by being advanced into the furnace and simultaneously rotated through 101°; the whole operation lasted a minute and proved very effective. Owing to distortion of the mounting the jet became directed on the brickwork where it picked up grit, and then on to the tubes, thus acting as a sand blast. With steam at pressures up to 600lb./in.^{2} the jets should be examined more frequently than once a year, and soot blowers might receive more attention than heretofore.—*Leader, "The Engineer", Vol. 166, 12th August, 1938, p. 177.*

Trends in Shipbuilding.

Since 1920 there has been little change in average length (400 - 410ft.) and depth (30ft. for full scantling and 36ft. for shelter deck vessels), but there has been a gradual increase in breadth from $12{\cdot}5+{}^{L}/_{10}$ to $(16+{}^{L}/_{10})$; probably this is associated with increase in speed. More powerful engines create severe stress conditions, especially in ballast voyages; during the last 15 years for a 400ft. ship the average increase is 1·2 knots for steamers and 1·6 for motorships. At present 27 testing tanks exist; that in Rome is 902ft., in Hamburg 1,150ft., in Leningrad 1,810ft. with a high speed carriage (65ft./sec.), and each improvement in design creates its own problem. In general there is a tendency, especially abroad, to place more responsibility on drawing office and moulding loft. Pneumatic riveting and drilling are increasing, as well as flame cutting. Tankers show uniform expansion in average principal dimensions; those in U.S.A. are broader and deeper than others, and there is a tendency to speed standardization for each particular company. In Japan speeds of 16 knots are common. There is some tendency to standardization of tanker design particularly for the central part between bow and stern. Modern steel produced in a fast running mill has a more adherent scale coat, but the steel plates themselves seem substantially unchanged in quality. The author deals with steels containing Si, Mn, Cr and Cu in small amounts, but emphasizes the economic factor, and the presence of sea salt. Welding is increasing rapidly especially in U.S.A. and is particularly welcome in tankers. Automatic arc welding requires modified design, but is very rapid, with regular and smooth surface of excellent Izod figures. The author considers that welding is successful only in association with pre-construction, and that each case can be decided separately on its merits. Generally the saving in weight is about 10 per cent. Hatch proposals and U.S.A. freeboard regulations are discussed. The rod-chain steering gear is disappearing from 47 per cent. of 1930 built cargo vessels, to 19 per cent. in 1937, even for small vessels; in 1937 the proportion of cast steel to wrought iron in cables was 1 : 3. Since the war the oil engine has gained rapidly at the expense of steam, and electric propulsion (Diesel-electric or turbo-electric) is also making progress.—*J. Montgomerie, I.M.E.-I.N.A. Conference Paper, reproduced in "Engineering", 15th July, 1938, pp. 84-87.*

Fundamentals and Experience in Corrosion Research.

Despite 10,000 scientific investigations, no simple and complete theory of corrosion exists, partly owing to the extraordinary complexity of the process which is markedly affected by slight external influences, some of which are self-contradictory, but partly also to insufficient insight into the exact mechanism. Professor Müller discusses the electrochemical theory, especially the work of *Kohlschütter* (*Korrosion und Metallschutz, Vol. 12, 1936, p. 118*), electrolytic cells of two elements, the electrolytic behaviour of hydrogen, corrosion of single-phase materials (*see U. R. Evans, Metallic Corrosion, Passivity and Protection, London, 1937*), protective coatings with reference to porosity, repair and breakdown, effect of inhibitors and other external additions. He surveys the various results obtained for excitation of small currents by local action and fundamental measurements with the help of wireless valves. For minimizing corrosion he recommends the combating of local action by all possible means, *e.g.* removal of oxygen, inhibition of hydrogen iron precipitation, addition of inhibitors, prevention of galvanic action through alloying of metals and use of polished surfaces, and above all through protective coatings, paint, enamel, etc. Finally he emphasizes the importance of high purity in all metals used. A valuable bibliography of 78 references is included.—*F. Müller, "V. D.I. Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 16th July, 1938, pp. 841-846.*



The late Mr. Samuel Aitken.

Portrait by] *[H. J. Whitlock & Sons.*

OBITUARY.

Mr. Samuel Aitken.

It is with deepest regret that we record the death of Mr. Samuel Aitken who, at the age of 56, passed away suddenly on Friday, 12th August, 1938, at New York.

Born at Belfast of a seafaring family, Mr. Aitken was educated at the Grammar School, the High School and the Technical College in that city. His apprenticeship was served with Messrs. Harland & Wolff, Ltd., and on its completion in 1902 he joined the White Star Line as a junior engineer. In due course he became a chief engineer with this Company, in whose service he remained until 1915 when he was appointed assistant superintendent of Messrs. Moore & Scott's Shipbuilding Works, San Francisco. In 1917 he was appointed by the United States Shipping Board as superintendent engineer of the United States Emergency Fleet, a post he relinquished in 1919 to become marine superintendent of Messrs. Moore & McCormack Co., Inc. In 1923 he became vice-president in charge of operations of this Company, a post which he still held at the time of his death.

Mr. Aitken was president and director of a number of companies, including the Coastal Freight Handlers Co., the Tampa Stevedore & Wharf Co., Inc., Tidewater Stevedore & Wharf Corpn., the Drag Eliminator Corpn., and the Anchorage Tung Oil Corpn. He was also vice-president of the American Scantic Line, Inc., Mooremack Gulf Lines, Inc., Mooremack Lines, Mooremack Coastwise Carloading Co. and the American Caribbean Line, Inc. In 1935 he was appointed by the President of the United States as the United States Delegate, representing employers, to the Tri-parte International Maritime Labour Conference in Geneva, and in 1936 by Governor Leyman of New York State as Member of the Board of Visitors, New York State Merchant Marine Academy. He was also appointed by the Department of Labour to the New York District Joint Board of Mediation and Conciliation. Mr. Aitken, who was also a member of a number of American clubs, including the New York Engineers' Club and the Propeller Club of the United States, was chairman of the Personnel Committee of the American Steamship Owners Association, a civil member of the American Society of Naval Engineers and the American Society of Military Engineers, and a member of the American Society of Mechanical Engineers and the Society of Naval Architects and Marine Engineers.

On the death of Mr. James Milne in 1936, Mr. Aitken was appointed as The Institute's Vice-President for the New York district, an office to which he was re-elected at the last Annual General Meeting. During this period his energetic representation and devotion to the interests of The Institute have been of inestimable value and earned the keenest appreciation of the Council.

Mr. Aitken's many friends both on this side of the Atlantic and in America will extend the warmest sympathy to his wife and his son, Mr. George Robert Aitken, by whom he is survived.

Effect of Oil-hole Reinforcement on the Fatigue Stress of a Hollow Crankshaft Journal.

Test pieces were prepared from rods 8 cm. in diameter, with the following dimensions—40 cm. long, 7·5 cm. in diameter for a length of 10 cm. at each end and 6 cm. in the middle portion, an oil hole 0·5 cm. in diameter being bored across the centre. A hole is bored axially through the test-piece, but in the case of the reinforced specimens the diameter of this is reduced to 2·0 cm. for a distance of 1 cm. on either side of the axis of the oil hole. The surface was polished. Six Cr-Ni-Mo steels, mostly with low contents of alloying elements especially of Ni, were investigated. Reinforced shafts showed a rise of 26 - 30 per cent. in Wöhler values. For test pieces superficially hardened by the oxy-acetylene flame process, the fatigue stress at 17 kg./mm.^{2} was definitely lower than that of the original heat-treated test-piece at 21 kg./mm.^{2} (10·8 and 13·3 tons/in.^{2} respectively); probably this weakening is due to an internal zone which has become softened as a result of annealing during the superficial hardening. In general, for heat-treated test pieces, the increase as a result of superficial hardening was slight when the steels after heat-treatment were soft; with steels which were hard after heat-treatment there was even a marked diminution. The effect of superficial hardening by electrical heating of controlled duration is being investigated with the object of preventing this diminution. For nitrided specimens the Wöhler curve is very flat. After the superficial oxy-acetylene hardening Brinell numbers of 600 - 625, according to the composition of the alloy steel, were obtained; after nitriding about 450.—*H. Cornelius and F. Bollenrath, "V.D.I. Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 23rd July, 1938, pp. 885-889.*

Corrosion-, Acid- and Heat-Resisting Steels in Shipbuilding.

The author reviews the essential characteristics of the principal corrosion-, acid-, and heat-resisting steels which are already being employed in marine engineering and which may be made available for shipbuilding purposes in the form of "plated" materials. The development of corrosion-resisting steel dates from the discovery, made in 1912, that in steel containing 12·5 per cent. of chromium the corrosive attack would, in the case of a highly-polished surface, result in the formation of a protective layer of chromium oxide, while an increase of the chromium content to 16 per cent. would protect the material of surfaces smoothed by simple grinding or machining. In the same year, an alloy steel containing 18 per cent. of chromium and 8 per cent. of nickel was first produced, and the addition of small percentages of other elements, such as molybdenum and titanium, has since then resulted in the development of corrosion- and acid-resisting alloy steels of mechanical and chemical properties suitable for a great variety of practical purposes. Chromium steels contain 14 and up to 17 per cent. of chromium with varying carbon contents yielding mechanical properties covering the range from constructional mild steel to tool steel, and they are employed in marine engineering for turbine blading. These alloys also offer some resistance—rising with the chromium content—to acid attack, which is materially increased in the chromium-molybdenum alloy steels containing 18 per cent. of chromium and 2 per cent. of molybdenum. High acid resistance characterizes the chromium-nickel alloy steels which are for this reason widely employed in the chemical industries and are acquiring importance in marine transport, viz. the piping of refrigerating systems, blubber boilers of whale factories, etc. The alloys fall into two groups: (1) Chromium-nickel alloys containing 18 per cent. Cr. and 8 per cent. Ni.; (2) alloys containing the same percentages of Cr. and Ni. together with 2·5 per cent. to 4·5 per cent. of molybdenum. Other constituents, such as titanium and tantal may be added to prevent intercrystalline corrosion due to annealing and welding operations. The addition of chromium also promotes the heat resistance of the resulting alloy steel, and materials suitable for the temperatures up to 1,500° to 2,000° F. required in high superheat boiler work are obtained by the addition of silicium and aluminium together with small percentages of manganese in varying combinations, the chromium-nickel alloy steels thus treated yielding superior mechanical properties. Referring to modern methods of "plating" iron or steel by casting or rolling processes, the author discusses the possibilities of employing mild steel "plated" on one side with a layer of chromium-nickel alloy steel having a thickness equal to 10 per cent. of the mild steel plate in question, for the shell plating of ships, more particularly in small vessels of very high speed, in which coats of paint rapidly wear away. In such vessels corrosion-resisting aluminium alloys are at present employed, but owing to their low strength heavy thicknesses are required. The adoption of the proposed corrosion-resisting "plated" materials would thus enable paint coverings to be dispensed with while returning to the lower steel scantlings.—*Dr. Ing. H. Hougardy, "Werft, Reederei, Hafen", No. 15, 1st August, 1938, p. 227.*

Aluminium Lifeboats.

Light alloy lifeboats are being constructed by Cantieré Riuniti dell' Adriatico for the trans-Atlantic liner "Stockholm"; these are of the Fleming type similar to those constructed in Birmingham for "Nieuw Amsterdam". The weight is 1·5 tons less than that of the normal type, representing a saving of 33 tons deadweight on the latter ship, apart from improved manageability, greater capacity (99 persons) and increased speed of launching of the boats themselves. Savings in maintenance costs are also anticipated. With the continued improvement in the technology of aluminium alloys the author anticipates an ever-growing use in naval construction, especially for specialised purposes. The article is illustrated with five photographs, showing the construction. — *"Aluminio", March/April, 1938; pp. 93-94.*

A Standard Atlantic Liner.

Four centuries ago all ships carried cargo, and most were available, on occasion, for warlike purposes; a century later warships became a specialised type and have remained so; up to a century ago merchant ships were ready to take passengers "if inducement offered" to the limit of their accommodation and the travellers' endurance. Such incidental traffic has almost vanished under governmental regulation, and need for a quick "turn round" restricts the cargo-carrying capacity of *ad hoc* passenger ships. Denny once drew a line between *Cargo*-passenger and *Passenger*-cargo vessels. Like "Berengaria" and "Aquitania" the new "Mauretania" is definitely in the latter class, "Britannic" and "Georgic" might be designated *Passenger-Cargo* and older intermediate ships like "Ascania", "Andania", "Alaunia" belong definitely to the first class. For many new trans-Atlantic ships ("Aquitania", "Paris", "Columbus", "Nieuw Amsterdam") as well as for the new "Mauretania" and a new U.S.A. ship to replace "Leviathan", the ratio $V/\sqrt{L}$ lies between 0·76 and 0·82; express liners vary between 0·87 and 0·97; "Normandie" is actually higher, approaching a modern warship. The secret information on the relation between capital and running costs on the $V/\sqrt{L}$ basis would be very interesting; "Aquitania" (0·81) was designed to give the same return as the old "Mauretania" and "Lusitania", together with the subsidy of £150,000 *p.a.* paid to the latter ships. The editorial concludes that the "express" liner should be regarded as something above and beyond normal rather than as a new standard on a higher plane. It suggests a new North Atlantic type, in the sense of the "Strath——" ships, recent ships of the Orient line, and the uniform type on the Cape run. It foresees "conference" difficulties, points out the benefits to harbour authorities, and suggests the existence of a critical speed (about 24 knots?) above which open-deck travel is trying and more amenities below are required. Less than half the size of "Queen Mary" (although the largest ship yet built in England) "Mauretania" has greater choice of ports and her speed is competitive. High-speed traffic cannot expand indefinitely, but why should not general traffic so expand as in time to employ a fleet of "Mauretanias"? — *Editorial, "Engineering", 5th August, 1938, pp. 163-164.*

German Mercantile Construction in 1937.

During the year German yards have worked almost to capacity, orders being one-sixth greater than in the previous year at 1,141,108 gross registered tons, about equally divided between home and export markets. Launchings were 400,000 tons, of which 182,600 was for domestic use. A chart of launchings since 1900 shows pronounced jags, particularly since the war, peaks occurring in 1906 (300,000) 1914 (380,000), 1922 (610,000), 1929 (350,000) and 1937, while valleys occur in 1909/1910 and 1932/1934 (50,000 tons only). Export orders run a rather similar, but lower, course; since the war the proportion has increased consistently. At the end of the year the mercantile fleet, at 4,160,000 gross registered tons, stood at 80 per cent. of pre-war strength, representing about 6¼ per cent. of world tonnage. It increased rapidly between 1920 to 1927, since which date it has remained fairly close to four million tons. Particular attention is drawn to the passenger and cargo ship "Windhuk", 16,662 g.r.t., with Benson boilers and high-pressure turbines of 14,200 s.h.p., the whaling factories "Unitas" of 21,846 and "Walter Rau" of 13,751 g.r.t., the twin-screw air depôt-ship "Friensenland" [see ABSTRACTS, *May, 1938; p. 30*] and two Nazi cruising ships of 25,400 g.r.t. of which the first "Wilhelm Gustloff", is already in service.—*"V.D.I. Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 23rd July, 1938, p. 878.*

Atmospheric Corrosion and Specification Testing of Galvanised Iron Wire.

Results of tests carried out over 5½ years by the Post Office Research Station on 17 samples of wire by electrode-potential measurement, metallographic, chemical and physical examination, and by field observation, are reported. Previously such wire was subject to B.S.S. 182/184—1927, but as this was found too lax, a new specification 443—1932 has been drawn up, including a wrapping test followed by a copper sulphate dip, requiring a more ductile coating. It is found that laboratory tests are not of great value in assessing corrosion resistance in actual use; the Preece copper sulphate dip test is also of little value, but either of two stripping tests gives good correlation with experience. Until the zinc coating is destroyed and rusting of the iron begins, there is no appreciable loss in strength. The smallest thickness of coating that will pass the specification is 0·5oz./ft.^{2} and by increasing this to 1·2oz./ft.^{2} (the thickest coating commercially available) a saving in cost of 23 per cent. over 30 years results from the longer life of the wire. A good thickness is about 0·95oz./ft.^{2}, giving savings of 19 per cent. and 14 per cent. in industrial and rural areas respectively, while not being thick enough to cause brittleness. Even though the wire must be severely worked after galvanising it is generally *not* good policy to increase flexibility of the coating at the expense of thickness, but with marine exposure a continuous zinc envelope may be more important. For 8 s.w.g. wires the life in an industrial and a rural area are $1{\cdot}6 + 2{\cdot}78t$, and $3{\cdot}8 + 15t$ respectively, where t is the thickness of the coating in oz./ft.^{2};

for 14 s.w.g. corresponding relations are $1{\cdot}0 + 2{\cdot}42t$ and $1{\cdot}3 + 4{\cdot}69t$. Where the rate of corrosion is very high, substitution of stainless steel wire may even be a practicable proposition.—*C. E. Richards, "Engineering", Vol. 146, 1st and 8th July, 1938, pp. 27-28 and 54-56.*

Accident Statistics of World Mercantile Tonnage in 1937.

For 1937 accidents represented a ratio of 0·7 per cent. Weather, grounding and stranding, and collision, each represent a little over 20 per cent. of the losses, fire about 4 per cent. and ice 1 - 2 per cent., the remaining causes being unknown; the latter proportion has risen in recent years from warlike activity in the Far East and the Mediterranean. For the German mercantile fleet there has actually been a diminution in the attributable damage and a complete absence of total loss from fire during 1937; further the ratio of total loss to mercantile tonnage is about 20 per cent. less than the world index quoted. This increases linearly from 0·1 per cent. for vessels 1 - 5 years old to about 1 per cent. at 30 - 35 years.—*"V.D.I. Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 23rd July, 1938, p. 878.*

High Pressure High Velocity Centrifugal Pumps.

According to *Beck* [*Dissertation Technische Hochschule Karlsruhe 1934*], the efficiency of a centrifugal pump should theoretically be improved by a change from the usual multi-stage lower velocity pump, to a single stage of high velocity, say 6,000 - 20,000 r.p.m. To prevent cavitation under these conditions a pressure of 5 - 20 atm. must be applied by a slower-running backing pump, and there is an optimum ratio of speeds. Meanwhile quick-running apparatus has been developed industrially on a practical scale without theoretical basis, having the advantages of higher efficiency, compactness, lower weight and saving of materials, but in general these are two-stage designs in which better axle balancing is possible. For such equipment the author quotes the following performance figures—80 per cent. efficiency at 7,500 r.p.m. with capacity 300 ton/hr., another with 60 per cent. efficiency at 16,000 r.p.m. with capacity 38 ton/hr.—*R. Dziallas, "V.D.I., Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 23rd July, 1938, pp. 893-894.*

Royal Research Ship "Research".

Designed to continue the investigations of U.S. yacht "Carnegie" (lost by fire in 1929) into terrestrial magnetism and atmospheric electricity, the vessel is almost free from ferromagnetic material. Even in the 4-cylinder, 2-stroke, 160 b.h.p. direct air reversing Diesel engine bronze has been substituted for steel as far as possible, and the crankshaft is of non-magnetic steel. At 6½ knots the 14 tons of bunkers will give a cruising radius of 3,000 miles, but the vessel is brigantine-rigged with 12,000 sq. ft. of sail. Two 9 h.p. and one 18 h.p. auxiliary Diesel engines drive two 4kW. 115-volt dynamos, and a large winch for oceanographical work via line shafting and fluid flywheel. Waterline length is 142ft. 6in., breadth moulded 34ft., draft 13ft. 2in., loaded displacement 770 tons; 20 tons of ballast lead are attached to the keel and 60 tons disposed in the bilges. The false keel is of Canadian rock elm, the composite hull of teak planks on brass frames; keel, stem and stern posts as well as the 37½-ton water tanks, are also of teak. Anchors, cables and wire rigging are of aluminium bronze. Elimination of magnetic material has extended to pots and pans, the typewriter, nails, preserved food and tobacco containers, and even razor blades! After launching in February, 1939, the vessel will proceed to Washington in October, then cruise in the South Atlantic, the Indian Ocean and near Mauritius; Durban will be reached in a year from sailing. Her complement is six officers, 22 petty officers and men and 4 scientific officers.—*"Engineering", Vol. 146, 19th August, 1938, p. 226.*

The Theory and Practical Calculations of the Kort Nozzle Propeller.

The great attention which is at present paid in different countries to the Kort nozzle propeller is due to the efficiency of this type of ship propulsion. The absence of sufficient experimental data does not as yet permit full reliance being placed on the present methods of calculation. Latterly the calculations have been mainly based on the work of Gutsche, who takes as the fundamental value the coefficient of suction, the ratio δ, the value of the reaction S_d developed by the nozzle, to the value of the thrust of the propeller S_p (taken at their absolute values).

$$\delta = \frac{S_d}{S_p} \qquad (1)$$

The pressures S_d and S_p are easily obtained from the expressions :—

$$S_d = \frac{P}{2} V_o^2 F \left(\frac{C_a}{V_o}\right)^2 \qquad (2)$$

and

$$S_p = \frac{P}{2} V_o^2 F \left[\left(\frac{C_a}{V_o}\right)^2 + 2\frac{C_a}{V_o}\right] \qquad (3)$$

where V_o = speed of vessel (or the incoming flow), C_a = the augmentation of the speed set up by the work of the propeller, F = disc area. In accordance with these designations, the speed behind the propeller disc will be $V_a = V_o + C_a$ or $C_a = V_a - V_o$. As the expressions (2) and (3) are rather inconvenient for analysis, $V_a : V_o$ may be designated by α. By simple transformation the formulæ (2), (3) and (1) may be written in the form of :—

$$S_d = \frac{P}{2} V_o^2 F (\alpha - 1)^2 \qquad (3a)$$

$$S_p = \frac{P}{2} V_o^2 F (\alpha^2 - 1) \qquad (4)$$

$$\delta=\frac{a-1}{a+1} \tag{5}$$

The value a is the value of the compression of the incoming flow. Consequently the effect of the nozzle is assumed to be attained in accordance with the compression of the stream, flowing under given conditions to the propeller nozzle system, and to drive through it the same quantity of water as flows into it. The part aft of the propeller is assumed to be cylindrical as also is the stream thrown off by the propeller. If the coefficient of the thrust of the propeller nozzle system is designated by σ, then

$$\sigma=\frac{S_p+S_d}{\frac{P}{2}FV_o^2} \tag{6}$$

or, substituting in (6) the values (3) and (4) we obtain :—

$$\sigma=2a\,(a-1) \tag{7}$$

whence the dependence of a on σ :—

$$a=\frac{1+\sqrt{1+2\sigma}}{2} \tag{8}$$

As the ideal coefficient of efficiency equals :—

$$\eta=\frac{2}{a+1}$$

then if the expression (8) is inserted we obtain the efficiency of the system :—

$$\eta=\frac{4}{3+\sqrt{1+2\sigma}} \tag{9}$$

Comparing the expression (9) with the efficiency of the free propellers :—

$$\eta=\frac{2}{1+\sqrt{1+\sigma}}$$

we obtain the coefficient of improvement ϵ :—

$$\epsilon=\frac{\eta_1}{\eta}=\frac{2\,(1+\sqrt{1+\sigma})}{3+\sqrt{1+2\sigma}}$$

which within the limits when σ tends to ∞ gives $\epsilon=1{\cdot}41$, i.e. the pull of the propeller within the nozzle per unit of power is 41 per cent. greater than with a free propeller. Therefore with a nozzle it is possible to attain within limits either 41 per cent. economy of power or 41 per cent. increase in pull, but not greater (some authorities claim an improvement of 50 per cent. and higher). We have a thrust coefficient of the propeller nozzle system in the expression (7); for a free propeller it would be :—

$$C=a_1^2-1$$

and the compression of the flow of the free propeller :—

$$a_1=\frac{1+\sqrt{1+C}}{2} \tag{10}$$

$$\text{As } C=\frac{S_p}{\frac{P}{2}FV_o^2} \text{ and } \sigma=\frac{S_p+S_d}{\frac{P}{2}FV_o^2}$$

then by the expression (8) the compression of the flow with a nozzle is always greater than with a free propeller, i.e. $a>a_1$. These indisputable theoretical data compel the calculation methods to agree with them, and it is here the difficulty arises. Gutsche's equation and its variations as here described are derived from the coefficient of the compression of the flow. A theoretical transition from the compression of the flow to the compression of the nozzle is not mentioned; experimental work on the subject is also not furnished. Gutsche by his method of calculation does not solve this problem; he only gives a criterion for an approximation of the coefficient of expansion of the nozzle to the value a of the flow. This incomplete criterion is the nozzle resistance as a function of the coefficient of its expansion ($F_e : F_p$). In the well-known graph of Gutsche's, with an alteration in the expansion of the nozzle from 1·0 (cylinder) to 2·0, the resistance changes approximately from 0·05 to 0·5, i.e. with a twofold alteration in the expansion the resistance changes ten times. On the assumption that the expansion of the nozzle should follow the expansion of the flow, practically such a relation does not take place, since whatever the choice of $F_e : F_p$ corresponding to the value a, the resistance of the form remains constant, only the frictional resistance changing, which in practice it is impossible to increase ten times. If the flow (Fig. 1) creates a compression in a given nozzle with a certain a, then we may use nozzle II (Fig. 1) where $F_e : F_p=a$; we may also utilize nozzle III in which $F_e : F_p\neq a$ (with a nearly constant a) or the whole of the intermediate variations of nozzles corresponding to the compression of the flow, but with different lengths. In place of nozzle III, retaining its length, construct a nozzle with a larger opening and a larger coefficient of

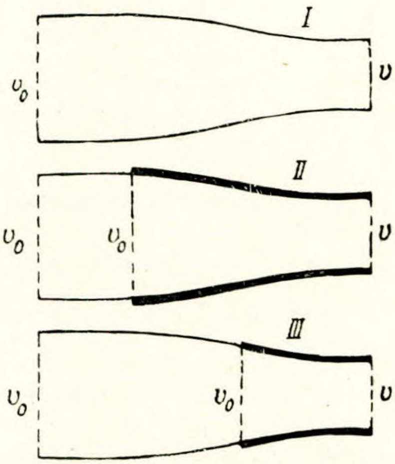


FIG. 1.—With a given σ the axial section of the flow is as shown in (I). The nozzle may have the section (II) where $F_e : F_p=a$ or may have the section (III) where $F_e : F_p\neq a$.

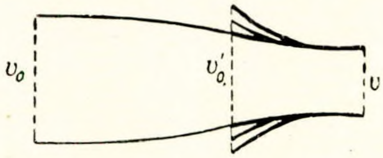


FIG. 2.—Fan nozzles. Only one has an expansion corresponding to the value a.

expansion, thus effecting a sudden increase in the resistance by creating a thrust; by decreasing $F_e : F_p$ a compression is produced, i.e. another increase in the resistance; both nozzles will not conform to the flow produced by the propeller. Gutsche's curve refers to the fan (Fig. 2) nozzles not dependent on α of the flow. The minimum resistance of the nozzle itself serves as a criterion of the conformity of the compression of the flow and the compression of the nozzle, but the ascertaining of this minimum is not an easy task. We are obliged to take a nozzle end of the shortest possible length, but we have not yet found $\sigma = f\ (F_e : F_p)$, and Gutsche's criterion is to such an extent approximate that he himself stated that the calculation of the nozzle (in accordance with his formulæ) invariably gave very high values, and in practice very often led to a decrease in the efficiency as compared with a free propeller. B. M. Lavrentieff's method apparently does not release us from these errors. The empiric graph of Gutsche's is constructed on the variations of $F_e : F_p$ with a constant length of nozzle, which changes the resistance of the nozzle simultaneously with the alteration of α in the flow, whereas σ at a given pull and speed in the first approximation has a constant value and an initial one at all subsequent calculations of the elements of the nozzle. The second problem which requires consideration consists in utilizing the egress expansion of the nozzle. The strict conclusion of Gutsche's equations (3 and 4) arises from the assumption that the nozzle abaft the propeller has a cylindrical form and that the flow behind the propeller disc is also cylindrical. The utilization of a diffuser (in accordance with Betz's research work) as used in this case contributes to decrease the efficiency of the propeller; the rational use of an expansion of the egress section of the nozzle requires special proof and it is feared this will be difficult to prove. No doubt half the failures in the research work of the Italian engineer Stip may be attributed to the fitting of a diffuser. Finally, and this may be the most important side of the problem, what form of propeller working in a nozzle will answer all the conditions of the system? If the velocity at the disc of a free propeller is denoted by V_1 and of a propeller working in a nozzle as V_2, the corresponding outflow by Q_1 and Q_2, and the pressure by H_1 and H_2, it is not difficult to prove that these values will be in the following form :—

$$\frac{V_2}{V_1} = \frac{Q_2}{Q_1} = \frac{1 + \sqrt{1 + 2\sigma}}{1 + \sqrt{1 + \sigma}} = \frac{\alpha_2}{\alpha_1} > 1 \qquad (11)$$

and

$$\frac{H_2}{H_1} = \frac{C}{\sigma} < 1 \qquad (12)$$

Thus at one and the same speed and pull on the towing hook with a nozzle propeller, the velocity, outflow and compression will be greater and the pressure less than with a free propeller. These are the only indisputable data which are available, and the only initial figures for the calculation. But these are not sufficient for the calculations of an Admiralty propeller; the search for an equivalent propeller working in a nozzle requires the determination of the speed of the variation of the propeller. For this purpose the semi-empiric formulæ (at present three) are employed, but it is well known that this method leads to an increase of the hydraulic efficiency of the propeller from 0·47 to 0·80; also to a drop of 50 per cent. in the efficiency. Kort and other investigators make only one deduction relative to propellers; since the output of the propeller in a nozzle increases, then the pitch for the same shaft power may also be increased, but to what extent still remains unknown. Therefore careful designers construct the propeller with variable pitch which can be regulated when in motion. With a 55 h.p. motor a pull of 2,300 kg. is said to have been developed, i.e., 41 kg. per h.p.; our results so far have not exceeded 16 kg. With the exception of Gutsche's formulæ, German theoretics have nothing further to reveal; they do not depend on these formulæ, but prefer the empiric method to the theoretical one. This way is evasive but leads to positive results (and greatly differs from the theoretical). A reliable basis for the transference of the calculation of a free propeller to one working in a nozzle is not yet available. The author is of the opinion that the search in this direction leads us from the direct solution of this problem. The velocity of the propeller disc, pressure, outflow and pull, give sufficient data for the calculation of the suction. The Kort propeller is a pump and sufficient complete methods of calculation of a propeller pump open up all possibilities for constructing a propeller with a hydraulic efficiency reaching in practice to 87 per cent. The manner of calculating this in principle is very simple; with a given coefficient of pull, α of the flow is determined; by its help the pressure outflow and velocity at the propeller disc are calculated. The theory connecting these values is indisputable; experience has shown the closeness of these calculated values to those obtained in practice. It is difficult to imagine what motive there is in rejecting the exact fundamental course which leads to positive results. There remains the theoretical and experimental methods of determining the resistance of the nozzle itself (a problem not yet clearly formulated) and the dependance between the compression of the flow and the compression of the nozzle; the latter has very nearly been elucidated. The problem of Kort's nozzle propeller still remains a difficult proposition and it is somewhat early to claim that the problem has been fully solved; it shows the necessity of carrying out research work to permit this system being largely adopted for tugs, trawlers and cargo vessels.—*"Soudostroienie", No. 2, 1938.*

Equation of State for Steam.

Dr. Jůza reviews the astonishing progress made since 1932 as a result of international cooperation for the purpose of establishing generally acceptable steam tables. It is [2]desirable to have an equation in the form $v=f\,(p\mathrm{T})$ from which formulæ for enthalpy and entropy can readily be derived, but with steam the problem is complicated by molecular aggregation. Eventually the following form was chosen

$$v=\frac{\mathrm{RT}}{p}-\left[a_0+a_1\left(\frac{p}{10^6}\right)+a_2\left(\frac{p}{10^6}\right)^4+a_3\left(\frac{p}{10^6}\right)^{16}\right] \quad \ldots\ \ldots\ \ldots\ \ldots\ \ldots\ \ldots\ \ldots\ (1)$$

in which R is the gas constant=47·05m. per °C., p is pressure in kg./m.^{2}, v is specific volume in m.^{3} per kg. From this enthalpy may be calculated from

$$\left(\frac{\delta i}{\delta p}\right)_{\mathrm{T}}=-\mathrm{AT}^2\left(\frac{\delta\frac{v}{\mathrm{T}}}{\delta \mathrm{T}}\right)_p \ldots \quad \ldots\ (2)$$

where A=1/427 Cal./kg.m., is the mechanical equivalent of heat. By substituting (1) in (2)

$$i=i_o-\left[b_o\left(\frac{p}{10^6}\right)+b_1\left(\frac{p}{10^6}\right)^2+b_2\left(\frac{p}{10^6}\right)^5+b_3\left(\frac{p}{10^6}\right)^{17}\right] \quad \ldots\ \ldots\ \ldots\ (3)$$

where i_o is enthalpy at zero pressure. At Prague[1] enthalpy was measured at 1kg./cm.^{2} (14·22lb./in.^{2}) absolute. The specific heat obtained by extrapolation to zero pressure agrees well with that calculated from the quantum theory so that a single empirical relation suffices.

$$c_{po}=0{\cdot}4402+0{\cdot}0095(t/100)+0{\cdot}00072(t/100)^2 \ldots\ (4)$$

It is assumed that 1 (int.) kW. hr.≡860 I.T.Cal. Values for specific heat at zero pressure thus obtained are tabulated at 100° intervals from 0-700° C., together with the experimental results of Justi[6] and of Keenan and Keyes[7]. In the range 100° - 600°C. the difference does not exceed ±0·0002; at 0° it is about 0·5 per cent. By integration[8] of (4)

$$i_o=597{\cdot}7+0{\cdot}4402t+0{\cdot}475(t/100)^2+0{\cdot}024(t/100)^3 \quad (5)$$

By comparison of some 300 points for different properties, the coefficients a_0, a_1, a_2, a_3, *and* b_0, b_1, b_2, b_3 are given very accurately *as functions of T*, the simple relation $a_0=k\mathrm{T}^n$ *not* being applicable. Charts comparing Prague measurements and computed values at 48 points show a maximum deviation of 1·9 I.T. Cal./kg., the average being 0·1 per cent.; in comparison with U.S.A. measurements of specific volume the average deviation is 0·026 per cent.; these are obviously very accurate especially at low volume and special attention has been given to eliminating wall effect.

By differentiating (3) with respect to T, specific heat at constant pressure is obtained.

$$c_p=c_{po}+\left[c_0\left(\frac{p}{10^6}\right)+c_1\left(\frac{p}{10^6}\right)^2+c_2\left(\frac{p}{10^6}\right)^5+c_3\left(\frac{p}{10^6}\right)^{17}\right] \quad \ldots\ \ldots\ \ldots\ (6)$$

and the values of c_0, c_1, c_2, c_3, c_4 are given as functions of (100/T). In comparison with *Koch's* experimental values[9, 10] and U.S.A. values[5] the former seem high, and there seems to be a 1 per cent. uncertainty in specific heat determinations[3] at present. From the enthalpy equation (3) the Joule-Thomson effect is obtained by differentiating:—

$$\mu=\left(\frac{d\mathrm{T}}{dp}\right)_{\mathrm{i}}=\frac{-\left(\frac{\delta i}{\delta p}\right)_{\mathrm{T}}}{\left(\frac{\delta i}{\delta \mathrm{T}}\right)_p}=-\frac{\left(\frac{\delta i}{\delta p}\right)_{\mathrm{T}}}{cp} \quad \ldots\ (7)$$

These values show an average deviation of 1·17 per cent. from the 41 results of *Davis and Kleinschmidt*[5]. The paper contains nine charts and eight valuable tables.

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—J. Jůza, "Engineering", 1st and 8th July, 1938, pp. 1-3 and 34-36.

Gear Performance.

Gear performance is made up of working life, efficiency and quietness; temperature rise is no criterion of efficiency, and quietness depends largely on external factors. Sudden premature failure is more dangerous than excessive wear; it may be due to defective material, bad profile, insufficient accuracy, imperfect alignment, distorted mounting or defective bearings, overheating, overloading from excessive torque, torsional vibration, shocks from unsatisfactory couplings, or external loads. Breakage from a sudden load is rare, but repeated application may cause similar breaks in successive teeth from fatigue. Smooth corners and grooves are very important, since maldistribution of a safe load may cause dangerous stress concentration. Double-helical gears sometimes "fight". Overheating may so weaken the material, especially bronze, as to cause failure; usually lubrication and not inadequate cooling is at fault. Sideways creep of a shrunk-on rim may cause jamming. Surface failure is due either to poor lubrication or to superficial stress; irregularities normally become smoothed out and subsequently wear is negligible, but occasionally the teeth are polished down to knife-edges without fracture. *Scuffing* consists of tearing or scoring from localised film failure, especially in heavily strained car-gears. Pressure lubricants permit increased wear at high spots and prevent local welding during running in, afterwards an ordinary oil may be used. *Ridging* is aggravated scuffing caused by ductile flow. *Pitting* consists of detachment of flakes of material; according to WAY it is caused by hydrostatic oil pressure within an initial crack (*see Transactions A.S.M.E., Vol. 57, 1937, A 49*); but it is not much affected by lubrication. *Cracking* occurs in brittle materials and may be due to overheating, bad grinding, incorrect hardening or unsuitable material. *Flaking* may be due to maximum load below the surface, slag inclusions, or residual stress and incipient cracks from flame hardening.

The *strength factor* Y is the tangential force which applied to unit face width of unit pitch, will produce unit stress (see *"The Engineer", Vol. 162, Oct. 16th and Sept. 25th, 1936*). Normally about 1·7, with earlier cutters the stress concentration is about 2.

$$Y=y^2\cos\psi/(6x\cos\phi+y\sin\phi)$$

With increased depth or smaller pressure angle the load will theoretically aways be shared by more than a single pair of teeth, but in practice cutting errors may prevent this. With full depth, and pressure angle of 14½°, a strength factor ¾ of that for the corresponding 20° combination is usually taken. In *helical* gears, after somewhat drastic assumptions, which from other considerations appear reasonable,

$$Y=\frac{r_c}{1\cdot5}\left(\frac{y^2\cos\psi_n}{6x\cos\phi+y\sin\phi}\right)$$

unless spiral and pressure angles are simultaneously high. Strength factors for *bevel gears* are identical with those for corresponding "virtual spur" or helical gears, but if neither contact ratio nor (face width/axial pitch) is integral, the length of contact fluctuates, so that for small angle spirals or narrow faces the gain on substituting helical for spur teeth may be illusory. However since the lost contacts are only lightly stressed, the actual loss is not so great. For a 30° spiral, an odd fraction z of an axial pitch has effectiveness reduced by $30(1-z)\%$. Bevel gears are particularly liable to longitudinal load maldistribution. ALMEN (*Automotive Industries, 25th Sept., 1937, p. 426*) points out the danger of overhang at the end of a spiral tooth, so that chamfering is well founded.

For a worm wheel tooth on certain assumptions

$$F_a=1\cdot25\ S_b m l_r\ \cos\lambda,$$

l_r being found by drawing, or from the equation $l_r=2r\sin^{-1}(x/r)$ in radians; usually a case-hardened worm runs in conjunction with a bronze wheel, from design particularly sensitive to sharp corners under heavy loads. With bronze rims, correct proportioning is very important, and in shrunk-on rims, residual stresses are increased approximately in the ratio (initial/final area) on cutting.

For involute helical worm shafts

Torsion stress $S_t=16M_p/\pi i^3$, and

Bending stress $S_b=5\cdot08M_p\ s_p/d_o\ i^3$.

For routine calculations $S_t=16M_p/\pi i^3\ m^3$

and $S_b=16M_p\ s_p/\pi d_o\, i^3\ m^4$.

These expressions hold for most designs, in which $\psi_n=20°$. Deflection is not sensibly different from a plain shaft of the same root diameter,

$$\Delta=\frac{2\,M_p\,s_p^{\,3}}{48\,\mathrm{E\,I}\,d_o}=\left(\frac{2\cdot83}{d_o\,i^4}\right)\left(\frac{M_p\,s_p^{\,3}}{10^8\,m^5}\right)$$

and should not normally exceed 0·0025 per inch of pitch diameter. Separating force is found to be $(2\tan\psi_n\sec\lambda)\ M_p/t\,m$. Values of the various coefficients are tabulated.

According to HERTZ' classical treatment of elastic bodies in point or line contact

$$w=3\cdot04\ \sqrt{F_i\,R_r/E_e}$$

$$S_{max.}=0\cdot418\ \sqrt{F_i\,E_e/R_r}$$

for (*a*) isotropic materials, (*b*) statically strained, (*c*) within the limit of proportionality, (*d*) with only a small portion of surfaces in contact; (*a*) and (*c*) certainly do not hold in gears. By similarity, the load per inch of contact might reasonably be proportional to radius of curvature; from experience this is modified empirically to $S_c=F_i/R_r^{0.8}$. For pure rolling WAY finds that the film carries only a tenth of the load. If this amount is ignored entirely $S_{max.}=1{,}870\sqrt{S_c}$, if $S_c>20{,}000$ as with case-hardened car gears, maximum pressure is about 140 tons/in.²

For spur gears $F_i=S_c\,Z$, where $Z=R_r^{0.8}\cos\psi$, is the *"zone factor"*; where $r_c>2$ a ratio of 3/4 is probably pessimistic. For other than unit pitch $F_i=S_c\ Z/P^{0.8}$, the denominator being the *"pitch factor"* $=K_p$ (say), then torque referred to the pinion will be $M_p=\frac{1}{2}\ S_c\ Z\ f\ t/P\ K_p$. For helical gears

$$Z=\frac{S_c}{F_i}=\left\{\frac{r_c\ (R_{rt}\sec^2\sigma_o)^{0.8}}{1\cdot5}\right\}$$

For bevel gears (introducing the maldistribution factor K_d) at the pitch radius of the back cone,

$$F=S_c\,Z\,f\,(C\text{-}f)/C\,K_p\,K_d.$$

For worm gears

$$F_a=S_c\,l\cos\lambda_o(\tfrac{1}{2}\,D\sin\lambda)^{0.8}.$$

Over a wide variety of involute helicoid worms

$$\{l\cos\lambda_o(\tfrac{1}{2}\sin\lambda_o)^{0.8}/f_{ew}\}$$

does not vary greatly, so that $F_a=0\cdot36\ S_c\,f_w\,D^{0.8}$.

Spiral gears are found empirically to have one-tenth the capacity of similar worm gears.

Various factors entering into gear design are discussed, and values tabulated for 22 materials; in general the basic strength is 0·22 × tensile strength. The best-known speed factor is $X_b=600/(600+V)$; of this there are modifications; actually changes in size introduce self-compensating variables. In worm gears there is relatively much sliding and a separate wear factor must therefore be introduced. Pitch factors are tabulated. A "reasonable life" is 25,000 working hours, but no accurate estimate is possible; for short-life gearing (as in aircraft or racing cars) endurance is the limiting factor. For motor car gearing (helical and bevel) ALMEN finds life to be inversely proportional to the seventh power of the bending stress. Allowances for overloading, varying speed and torque, separately and together, are discussed. B.S.I. basic racks

(436-1932) have been widely adopted, but corrections may be applied. For internal gears the strength factor should be multiplied by $(1+3T)$ or accurately calculated. For 30° helical gears generated from a 20° basic rack, it is practically the same as for corresponding spur gears; for other angles multiply by $1{\cdot}33\cos^2$ (spiral angle). For spiral bevel gears it should be derived from a large-scale generated tooth outline.

Charts of the zone factors between 10 and 100 teeth are given; above 100, strength is usually the determining consideration. Service factors are discussed, the actual choice of dimensions is very wide and may be determined wholly by external requirements.

Power loss is made up of (1) sliding friction which varies with the load, and (2) oil churning, which can easily be determined by running light, and is substantially constant. The problem is often that of heat dissipation. With a rated (theoretical) efficiency of $n\%$, probable limits of error are $+0\%, -\{1+(100\text{-}n)/10\}\%$, with a worm gear; and 0·5 to 2% with others. Churning losses are usually 1-3% but may be higher. Efficiency usually increases during "running-in", μ being 0·06-0·08 for steel gears. A chart showing the connection between λ and tooth loss between 0·01 and 0·14 is given. μ depends on materials, accuracy, finish, lubricant (castor oil being the best), sliding velocity, surface stress, velocity of contact line relative to the surfaces. The best combination of metals is phosphor bronze/case-hardened steel. Factors for cast iron/bronze, hardened steel/aluminium, and steel/steel, are 1·15, 1·33, 2·0 respectively.

In general, gear operation is favourable to lubrication, and sliding velocities as high as 116ft./sec. have been used successfully. Rolling-velocity ratios favourable to lubrication deserve further investigaton, but no ingenuity of thread design will overcome unsuitable materials, inaccurate manufacture or assembly, non-rigid mounting and inadequate lubrication. Theoretically, worm gears are irreversible when lead angle does not exceed the angle of friction, say 3-4½°. However, μ decreases with increasing speed, and the hoist may run away; further, the static value is reduced appreciably by vibration. On principle the use of irreversible worm gears as brakes is to be deprecated. The paper is illustrated with 41 drawings and graphs, 9 tables, and 10 photographs of broken gears.—*H. E. Meritt, "The Engineer", 1st, 8th, 15th, 22nd, 29th July; 5th, 12th, 19th Aug., 1938; pp. 2-4, 32-34, 58-60, 84-86, 110-113, 138-140, 166-168, 190-191.*

Senate Report 184 and the Design of Merchant Ships.

Two main causes of disaster treated rather casually at the 1929 Convention are (1) stability when damaged, (2) fire, but recent spectacular fires on "Georges Philippar", "L'Atlantique", "Morro Castle", "City of Baltimore", have focussed attention on the latter question. Chapter I groups ships into five classes, Chapter II deals with hull materials and strength. Chapter III is concerned with stability when damaged and proposes new subdivision formulæ with special reference to the importance of coastal shipping in U.S.A.; usually these vessels are 375 - 400ft. long, with about 400 passengers mainly above the bulkheads, the lower spaces being used for cargo; normally they do not exceed a 200 mile limit. The following new formulæ are suggested :—

$$\text{Factor ``A''}\quad \frac{190}{L-160}+0{\cdot}18 \text{ for } L>392$$

$$\text{Factor ``B''}\quad \frac{94}{L-85}+0{\cdot}18 \text{ for } L>200$$

$$\text{Criterion numeral } 60\left(\frac{M+2P}{V}\right)+30{,}000\left(\frac{N}{L^2}\right)$$

After complete flooding, metacentric height should be at least neutral, and sufficient to limit the heel to 10°, 15° or 20° after damage to 1, 2, or 3 compartments. Water ballast is permitted up to 50 per cent. of liquid capacity. Maximum metacentric height is limited by the formulæ for ships with beam >50ft.

$$GM=0{\cdot}06B-\frac{350}{(B/10)^4}$$

In this, the reduction factor is proportionately more effective in small ships, and special treatment is required for the Atlantic liner. All doors (except for shaft access) below the bulkhead deck are required to be sliding and power-operated. Fire-control was investigated in detail in the "Nantasket" tests which developed non-combustible materials previously not available, new methods of erection and fire limiting bulkheads; to utilize the conclusions to the full some standardization of the setting out within the rooms must be adopted. Chapter V deals with engineering and is divided into 9 parts; it gives rules of design and periodical inspections, but carefully refrains from hampering future developments by burdensome restrictions, and proposes tests for welders. Formulæ are given for certain engine parts and auxiliaries; astern power should be at least 40 per cent. of ahead power; protective devices and boat handling winches are also covered. In regard to fire extinguishing, definite nozzle and pump pressures for the "two powerful jets of water" are laid down; such fire pumps must not be used for oil pumping. Cast-iron and bronze valves, fittings, etc., are to be prohibited in machinery spaces for fuel oil, and fuel oil piping should be kept as remote as possible from high pressure or superheated steam; alarms and shut-off apparatus for steam is to operate in the event of a dangerous drop in steam pressure. Emergency electric supply and life-saving equipment are also dealt with, particular attention being given to the type and number of lifeboats. A separate report deals with living conditions for the crews.—*H. L. Vickery with W. G. Esmond, J. E.*

Schmeltzer and S. B. Crosby, I.M.E.-I.N.A. Conference Paper, reproduced in "Engineering", 22nd July, 1938, pp. 116-118.

Elastic Limit of Steels Under Prolonged Loading.

"Slip-limit" (*Gleitgrenze*) is defined as the alternating load at which heat evolution occurs from slipping. With an alternating load above the slip limit f_E, the value of the latter falls; with a load still higher but not exceeding the fatigue tenacity f_D, it first drops and later rises as the number of revolutions increases. For a particular steel $f_E = 18{\cdot}5$ and $f_D = 23$kg./mm.^{2} (14·7 and 11·7 tons/in.^{2} respectively). This holds for all repeated stresses in which the slip limit is exceeded in only one direction, *e.g.* in tension. With fine-grained, heat-treated and alloy steels, the slip limit falls more slowly, and in relation to the initial time-stress, less than with coarse-grained steels. [see *Forschung auf Gebiet Ingenieur Wesen, Vol. 9, 1938, p. 14*]. These results confirm and amplify those of *Bauschinger* [*Mitteilungen mech.-techn. Labor. der Techn. Hochsch. München, Vol. 13, 1881*]. This anomalous behaviour is explained by the existence of two opposing processes, strengthening and weakening of cohesion. The former induces a rise in slip resistance and elastic limit; with occurrence of slip, cohesion is weakened and the slip limit falls. With stress alternating about a dead point, the second effect predominates. By annealing for 2 - 3 hr. at 150 - 200° C. (300 - 390° F.) the cohesion weakening induced by alternating stress is removed, and subsequently the first (strengthening) effect is shown by a slip limit exceeding the initial value. Fatigue phenomena appear after the slip limit has been exceeded. Recently by X-radiation [see *Zeitschrift V.D.I., Vol. 82, 1938, p. 28*] it has been possible to detect structural changes far below the time stress. The interference pattern changes for only a few crystals, presumably those in which the slip-limit has been exceeded in the direction of their slip planes. Separation strength (the force normal to the slip planes required to cause fracture without deformation) falls with slip, but rises with increasing cohesion. In the first place shear stresses are responsible for fracture; without the strengthening that occurs time-stress would be identical with the initial slip limit, *i.e.* the difference between these two values is a measure of the strengthening capacity. Internal damping depends on the alteration of the slip limit and the resistance to deformation; it increases with the fall in the slip limit and decreases with the recovery of the slip limit and with rising resistance to deformation. With unsymmetrical loading from alterations in cross section, strain concentration occurs owing to the prevention of plastic deformation of the highly stressed parts after the slip limit is exceeded. As a result the peak strain is lowered and the slip limit is attained only at a higher mean load. With sharp notches and small sections the effect is greater; the similarity principle does not hold. With loads equal to the time-stress and geometrically similar notches the decrease in tension was proportional to the plastic portion of the strain. —*H. Buchner, "V.D.I., Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 25th June, 1938, pp. 781-782.*

Italian Banana Carriers "Ramb I" and "Ramb IV".

Designed essentially for banana transport, the vessels have two small holds (35,000 cu. ft.) at bow and stern for general cargo and petrol, and accommodation for 12 passengers. Their particulars are:

Water-line length	367ft. 6in.
Length between perpendiculars ...	354ft. 5in.
Breadth at water-line	49ft. 11in.
Height to upper deck	95ft. 8in.
Mean draft at full load	59ft. 10in.
Gross tonnage	3,500 tons
Deadweight carrying capacity ...	2,300 tons
Displacement light 2,900 tons; loaded	5,200 tons
Refrigerated capacity	141,000 cu. ft.
,, ,, for bananas ...	900 tons
Trials speed	18·5 knots
Service speed	17 knots

Tonnage openings have been designed so as to reduce Suez Canal dues to a minimum. Propulsion is by two single-acting, two-stroke, direct-reversing, airless-injection 9-cylinder Diesel engines of bore 520mm. (20·5in.) and stroke 820mm. (32·3in.), each developing 3,600 b.h.p. at 195 r.p.m.; the cast iron cylinders are interchangeable and bolted together. Four 150 kW. 400 r.p.m. auxiliary generators are driven by 4-stroke 6-cylinder engines, and there is a 5 kW. emergency set on an upper deck. Electricity is used for winches, windlass, steering gear, CO_2 compressors, as well as for cooking and heating. 46,000 cu. ft. of air to the forward hold, and 32,000 to the after hold, is circulated per minute over the 15,600 sq. ft. of cooling surface, 565,000 cu. ft. of new air being taken in each day; to overcome crate resistance a pressure of 1½in. water is maintained by the four fans, requiring 82 h.p. Indicators for CO_2 content, temperature and humidity are installed in each hold. Cooling capacity of the two twin-cylinder multi-stage compressors is 350 cal./hr. —*"Engineering", Vol. 146, 19th Aug., 1938, pp. 216-217.*

The Changing Outlook of Engineering Science.

Notwithstanding a very respectable pedigree, engineering science was not admitted to the universities till 1840 and the honours degree came much later. Professor Southwell, in his address as President of Section C of the B.A. at Cambridge, deprecates any intensification or actual or virtual lengthening of the honours course, which will always be limited by the quantity of instruction which can be assimilated. Industrial leaders require men of personality who take wide views and have a real and ready knowledge of engineering principles. Such men are as likely in the second class as the first, and it is "undergraduate activities" which develop them. An honours degree is no criterion of ability in research, since this is something which cannot be taught. University training and industrial apprenticeship should not be regarded as wholly distinct phases, and industrialists might be called in to scrutinise university syllabuses closely, with advantage to both sides. Fundamentally the difference between the attitude to research of the engineer and the physicist is that the former must solve the problem as given (*e.g.*, strain in a crankshaft), even if only approximately, while the latter is free to eliminate disturbing factors. The author roundly attacks mathematical-physicist criticism of "19th century model-making", citing the magnificent achievements which resulted, and counsels the avoidance of humility. Indeed the very theories of orbits, wave motions, etc., provided by these "model makers" are used to-day by men who do not understand them or even seek to do so, but rely on intermittent experimental verification; a very sound line to follow in a fog, but no cause for self-congratulation. In practice data are always erroneous to some extent; in theoretical work one starts with the assumption of absolute certainty. In relation to the community the scientist is hardly to blame for the abuse of invention in warfare. By joining political discussions unlabelled he might provide a leaven of "trained common sense" sorely needed in the social and political administration of to-day.—*R. V. Southwell, "The Engineer", Vol. 166, 19th Aug., 1938, pp. 194-196.*

Giant D.C. Compressor for Refrigerating Plant.

The 1½ million cal./hr. two-cylinder compressor has been so carefully designed that material consumption is reduced to 1 kg. per 100 cal. Casing and cylinders are of cast iron, the crankshafts having several bearings and passing through stuffing boxes with pressure lubrication. Long pistons are used with the object of reducing load, and working oil is prevented from entering the cylinder. The spring-loaded flap valves were chosen for permanence of close fit and fatigue resistance, and are almost noiseless even at high speeds. Entry valves are arranged in the piston bases, where correct opening and closing is helped by the motion of the piston itself. The cylinder head is elastically mounted and pressed heavily against the ground surface by springs; it can move slightly upwards under fluid-hammer so that damage to the cylinder is avoided. Forced lubrication of the bearings by a pump driven from the crankshaft is employed; of the two filters, one is constantly in operation. The apparatus is well set-out, compact, and uses little current.—*J. Heinrich, "V.D.I. Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 13th Aug., 1938, pp. 964-965.*

Passenger Steamer with Added Velox Boiler.

The machinery of the Bremen-built French twin-screw passenger steamer "Athos II" originally consisted of a two-stage 10,000 h.p. turbine installation, steam being generated at 14 atm., giving a speed of 14 knots. To improve this a 1,030 h.p. high-pressure turbine and a 1,370 h.p. low-pressure turbine were added to each set, the power being conveyed to the shafts by two-stage gearing (5,500/880 r.p.m.) and a liquid coupling. Steam for the new turbines is generated in a Velox boiler at 55 atm. and 450° C. (842° F.), which increases the total production by about 60 per cent. In the new high-pressure turbine this steam is expanded down to 14 atm; 40 per cent. then passes through the new low-pressure turbine, and the remaining 60 per cent. is mixed with steam from the old boilers and passes with it through the old turbines. The new turbines fall out of use when the engines are put into reverse, having no reverse gearing.—*"V.D.I. Zeitschrift des Vereines deutscher Ingenieure", Vol. 82, 13th Aug., 1938, pp. 965-966.*

The Newest German Cruiser.

On 22nd Aug., 1938, the cruiser "Prinz Eugen" is to be launched at Krupp's Germania Yard, Kiel, by the wife of the Regent of Hungary—Admiral Horthy. Two previous ships of the same class, "Admiral Hipper" and "Blücher" were launched in 1937. They are Washington Treaty vessels, of 10,000 tons, with 8in. guns and well developed A.A. armament, designed essentially for mercantile protection. Since this type was first constructed, its armament outside Germany has remained substantially unchanged, but armour plating has been much improved with the object of improving the known vulnerability to a direct hit. This entails a sacrifice of record 36-37 knot speeds, and recent non-German ships are capable of 31-33; to compensate for this, however, the protection of the new ships is comparable with the pre-war "Scharnhorst" class of cruisers, *i.e.* rather inferior to that of a battle cruiser, against the mere splinter-proof deck of previous non-German ships. The ship resembles the French "Algérie", and the recent trend is towards excellent under-water partitioning. Criticism of the type has been based on the loss of the Spanish rebel "Baleares", but "according to investigations recently made by a British naval officer", the ship was not at fault. This, as well as "Canarias" is comparable with the "County" class and cannot therefore be regarded as quite up-to-date. Unless forced by Russian construction, Germany does not intend to exercise her right to build further similar ships, although Britain possesses 15, France and Italy 7 each. Two other "medium heavy" cruisers, of 10,000 tons with 5·9in. guns, which type is not restricted, are now under construction, while Russia is building a number of heavy cruisers.—*"Rhein Front", 22nd Aug., 1938, No. 195.*

Supercharging Marine Oil Engines.

Supercharging allows an increase in power in service ranging up to 40 per cent. without appreciable increase in maximum cylinder temperatures or pressures, whilst on the test bed as much as 100 per cent. increase has been carried. Various methods of increasing the pressure of the air in the cylinder at the beginning of the compression stroke are or have been employed, notably, for four-stroke engines, a turbo-driven blower utilizing the exhaust gases. Electrically-driven blowers have also been used, and at the present time many engines are being fitted with blowers driven from the engine crankshaft. In single-acting engines the underside of the piston may be used to compress air for supercharging, and certain engines which were originally double-acting have been converted to this system. With the compound-admission system, air enters the cylinders from ports uncovered at the bottom of the stroke, i.e., twice per cycle of operations. Another four-stroke system, which has not yet been applied to marine engines, is that involving throttling of the suction during the first part of the stroke, so that the subsequent rush of air, when the throttling is abandoned, has a supercharging effect. This may be combined with the blower system. Supercharging of two-stroke engines is a more recent development, involving the provision of an additional air supply at a suitable pressure of about 9lb. per sq. in., and a special mechanically-operated inlet valve, in addition to the usual ports.—*"The Motor Ship", August and September, 1938, pp. 168-70 and 219-21.*

Aluminium in Marine Construction.

The application of various aluminium alloys and of aluminium paint on board ship is discussed. For external work, involving a high degree of corrosion risk, manganese, magnesium and silicon alloys are found suitable. The aluminium-silicon group, mainly in the form of castings, is the most useful, possessing medium strength. Pure aluminium may be used in sheet form, but the manganese alloy is stronger and has equal resistance to corrosion by sea water. This also applies to manganese-magnesium alloy, which in the half-hard condition has a proof stress of 12 tons per sq. in., which may be increased to 15 tons with a higher magnesium content. Usually, painting is desirable as a protection against corrosion, and the resistance to attack is further increased if the material is subjected to anodic oxidation in the first instance, the oxide coat forming a good base for the paint. Certain alloys, such as NA.57S., which contains magnesium, need not be anodically treated, but the surface should be prepared for painting, *e.g.* by sand-blasting. Aluminium paint is suitable for these alloys, as well as to replace lead paint on steel and woodwork. An important saving in weight is realized the weight per gallon being only 10lb. against 20 to 25 for leaded paint. The use of light alloy for superstructures, particularly of passenger ships, is suggested. Aluminium has been employed for lifeboats, and other applications are for side-scuttles, heating, cooling and ventilating fittings, and internal decorative work. Apart from the question of weight-saving, aluminium fittings and furniture replacing wood minimize the fire risk. For internal partitions and bulkheads, composite panels comprising slag wool or asbestos between aluminium sheets have the necessary insulating properties and are non-inflammable. For insulation of refrigerated and other spaces, aluminium foil is much lighter than cork. In cargo ships, comparatively little light alloy has been used in the engine-room, but for naval work many minor engine and auxiliary parts are of aluminium alloy, and Diesel engine pistons up to 400lb. are being supplied. Other naval uses include lockers, miscellaneous internal and electric fittings. The use of light alloys in place of mild steel for structural purposes is forecast.—*"Syren & Shipping", 6th July, 1938, pp. 41-5.*

Welding in Machinery Construction.

Welding, originally used mainly for repair work, has extended to new construction in nearly all branches of engineering, as the technique improved, and greater confidence was gained. Ship construction and structural engineering, including bridges, are notable examples. The building-up by welding of such parts as engine bed-plates and condenser shells is an established practice which has largely superseded the use of cast iron. Other applications to machinery and boilers have been somewhat restricted, but two recent exceptions are cited. In one case the complete cylinders and valve chests of a foreign locomotive were fabricated. Steel plate, 0·8in. thick, was used for the cylinders, 24in. in diameter, and for the piston valve chests, rings being welded on at the ends to take the cover studs. Ports were cut in the cylinders and the steam and exhaust passages built up with welded plates, and brackets to secure the cylinders in place were welded on. A hydraulic test pressure of 285lb. per sq. in. was applied. In the other case, a complete steam pipe line for a power station was welded. The working pressure was 1,900lb. per sq. in. and the superheat temperature 930° F.—*"Shipbuilding and Shipping Record", 7th July, 1938, p. 5.*

Alternating Current on Board Ship.

The tendency of marine practice to follow land practice as regards the type of current used is noted, and this is stated to apply particularly to America, where a large turbo-electric tanker, the "J. W. Van Dyke", has been completed, using nothing but alternating current. The main propulsion motor, of 5,000 s.h.p., is of the synchronous-induction type, the voltage being 2,300. When the ship is at sea the auxiliary machinery is supplied from the main generator, through a transformer, at 440 volts. This arrangement gives a very low fuel consumption. For harbour and manœuvring purposes, there is an auxiliary turbo-generator. The centrifugal cargo oil pumps, delivering 15,000 gallons per hour, which enable the ship to discharge in about 10 hours, are driven by vertical explosion-proof motors, situated on deck. All electric wiring, even for lighting, is excluded from the pump-room. The windlass has electro-hydraulic drive from a 75 h.p. motor below the forecastle deck.—*"Shipbuilding and Shipping Record", 21st July, 1938, p. 69.*

Three-point Suspension.

Flexible three-point suspension of the engine-clutch-gearbox unit is fairly common in automobile practice. Similar suspension, but of a rigid type, has recently been employed on the Continent for a fairly powerful marine geared-turbine installation, consisting of turbines and gears forming a stiff monobloc unit, with underslung condenser attached. This arrangement is stated to simplify and cheapen the work, and to relieve the machinery of stresses transmitted from the ship structure in a seaway or when the vessel is aground. For this reason it appears suitable for coasters and river craft. The principle of flexible suspension might also be introduced, at any rate for small units, and should result in steadier running and a more comfortable ship.—*"Shipping World", 10th August, 1938.*

Examination of Engineers for Board of Trade Certificates.

Board of Trade notice No. M.162, giving preliminary information as to the proposed revision of the examination regulations, in accordance with the recommendations of the Departmental Committee, is summarized. The subject-matter and standard of the examinations will not be changed, but there will be alterations in the details of the syllabus, and in the arrangement of the papers. Part A of the examination for both first and second class certificates will comprise papers on general engineering science, heat and heat engines, and Part B electrotechnology, naval architecture, engineering knowledge, and orals; in addition Part A of the second class examination will include drawing. The holding of approved degrees, diplomas or certificates, such as the National Certificate in Mechanical Engineering, provided it covers the appropriate subjects, will exempt from Part A of both examinations. Part A of the second class examination can be taken as soon as the prescribed workshop service has been completed, and Part A of the first class as soon as a second class certificate has been obtained, but Part B must follow the period of sea service in each case. In order to facilitate the change-over from the old system to the new, the two will be operated concurrently at the various examination centres, for a period starting from September, 1938. Attendance at a recognised technical school or college will continue to exempt candidates from part of the necessary period of workshop service, and suitable marine departments of technical schools will similarly be recognised for the purpose of remission of part of the qualifying sea-time. The list of recognised schools is being revised.—*"Shipbuilding & Shipping Record", 7th July, 1938, p. 8.*

Deflection of Turbine Rotors.

The critical speed of a turbine rotor, in general difficult to calculate, is given by the expression $R_k = 187\sqrt{\Sigma Wy/\Sigma Wy^2}$ where y is the deflection at any load W. The bending moment at each load is obtained in general form at the load W_z where z may have any integral value up to n. From this

$$M_z = \frac{b_z}{L}\sum_1^z Wa + \frac{a_z}{L}\sum_{z+1}^n Wb$$

From the principle of virtual work

$$\int_0^L \frac{Mm}{EI}dx - 1y_z = 0$$

where m is the bending moment due to unit load acting alone at section z. In view of the shape of the rotor, a very close approximation is obtained if integration is replaced by summation, so that

$$y_z = \sum_1^n \frac{Mm}{EI}\delta x \text{ (approx.)}$$

in which average values for M, m and I are taken over short lengths. Now the bending moment (a) at any section from unity to z can be written $m = a\, b_z/L$, (b) at any section from $z+1$ to n can similarly be written $m = b\, a_z/L$, and therefore

$$y_z = \frac{b_z}{EL}\sum_1^z \frac{a\,M\,\delta x}{I} + \frac{a_z}{EL}\sum_{z+1}^n \frac{b\,M\,\delta x}{I}$$

This form is suitable for tabulation, but in practice as many as fifty load elements must be used, and a shortened example is given. For a 25-element division, the results agreed with those given by Moir's semi-graphical method, for the middle 14 elements, to within the 2½ per cent. error normally allowed. The tabular method seeks only to save the labour and eliminate the drawing errors of graphical methods.—*S. J. E. Moyes, "Engineering", 12th Aug., 1938, pp. 181-182.*

Neither The Institute of Marine Engineers nor The Institution of Civil Engineers is responsible for the statements made or the opinions expressed in the preceding pages.

EXTRACTS.

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

Direct Reading S.H.P. Meters.

New instruments which enable constant readings to be obtained.

"Shipbuilding and Shipping Record", June 9th, 1938.

The accurate determination of shaft horsepower developed by propelling machinery during a voyage has, up to the present, been a matter of difficulty to the marine engineer, as such data could only be obtained from intermittent observation, and was at the best only approximate, especially as regards averages.

By means of a new instrument recently placed on the market, however, the average shaft horsepower may be recorded with precision equally for the day's run and for the complete voyage. Accurate comparison between power developed, voyage conditions and fuel consumption thus becomes possible, some of the resulting information being:

1. Consumption per shaft horse-power hour with different fuels.
2. Power developed under adverse weather conditions.
3. Extent to which full power is actually used.
4. Power required for various screw speeds.
5. Reduction in power due to ballast conditions.
6. Economy arising from clean bottom, change of propellers, streamlining of rudders, etc.

One of the electrical interrupters.

Known as the White-Fox Powermeters, two types of instrument are available, one operating on electrical principles and the other by purely mechanical means. Both patterns function continuously, being permanently connected to the shafting they meter. In each case a shaft horse-power dial and a shaft horse-power-hour counter are fitted. The dial is calibrated in horse-power direct and the counter records the accumulated total of horse-power-hours developed. From the difference of any pair of readings shown by the counter, the average shaft horse-power maintained over the corresponding period is immediately ascertainable.

It is interesting to note that the powermeters combine the factors of shaft speed and shaft torsion in such a way that no separate observation of revolutions is required. The actual power being transmitted by the shafting from moment to moment is accurately indicated by the pointer of the dial, even when the fluctuations caused by a heavy sea are incessant.

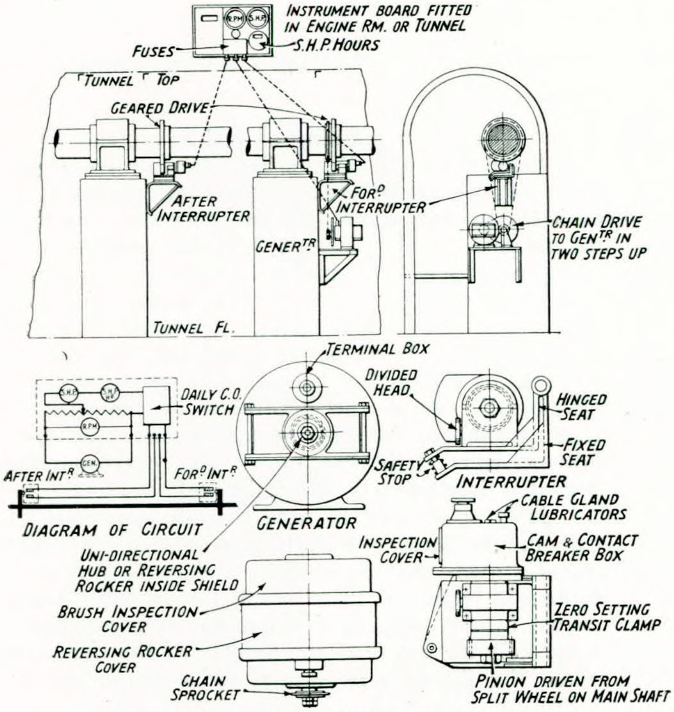
In the electric powermeter, the equipment consists of a pair of interrupters with suitable gearing for driving them from separate points on the main shaft, a small permanent field generator of White-Fox patent multi-magnet design (also driven by the main shafting), an instrument panel and the necessary connecting cables. The arrangement of these parts is shown in the diagram.

The electric circuit is also shown. It will be observed that it is entirely self-contained, no connection to the ship's mains being required; consequently, the powermeter operates whether the ship's generator is running or not.

Operation.

Each interrupter is fitted with a cam, actuating one or more contact breakers about 25 times per second at full speed. The zero setting is such that if the shafting were revolving in an idle condition, the closing of the forward contacts would occur at the same moment as the opening of the after contacts. The actual slight twisting of the shaft that occurs when power is being transmitted results in a period of overlap being established between the interrupters. The angle of overlap is considerable, due to the gearing ratio, and will, of course, vary in exact proportion to the twist in the main shaft. During the overlap, current passes through the metering circuit.

The generator delivers to the metering circuit an electric current of which the voltage is proportional to the speed of the main shafting. The quantity of electricity passing through the circuit per second varies with the overlap and with the voltage, and is therefore proportional to both twist



Arrangement of electrical powermeter.

and speed, *i.e.,* to the same product as that on which the horse-power transmitted depends. Standard electrical meters are placed in the circuit to read the quantity of electricity per second and also the total quantity that passes in a given time. The resistances of the circuit and calibration of the meters are such that their readings give shaft horse-power direct.

The mechanical type installation, which is likely to be preferred for single-screw vessels of moderate power, comprises the powermeter instrument, mounted parallel to the main shafting and at the centre of the base length utilised for metering, together with two countershafts extending from either side of the powermeter to the ends of the base, where they are connected to the main shafting by suitable gearing. The gearing is arranged to step up the speed of each countershaft, and to reverse the direction of rotation of the after one, as indicated in the diagram.

Details of mechanical unit.

The powermeter consists of a triple bevel gear with right- and left-hand spindles connected to the countershafts, and with the axis of the crown wheel vertical. This gearing is located within a tilting box provided with trunnions, and mounted in ball bearings fitted between the two halves of the split main case.

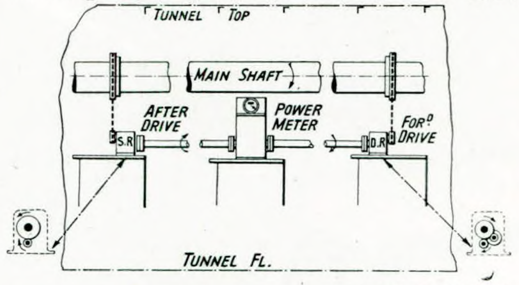
The main vertical spindle is hollow and fitted with epicyclic gearing operating an inner vertical spindle at reduced speed. This spindle extends to the outside of the tilting box and is fitted with a spherical dome. In contact with the dome is a standard size tracking wheel and above this is mounted a metering wheel, the diameter of which is adjusted to suit the power transmission characteristic of the installation. A small flexible shaft is connected to the metering wheel and drives a recording head for indicating speed and recording the number of revolutions of the metering wheel.

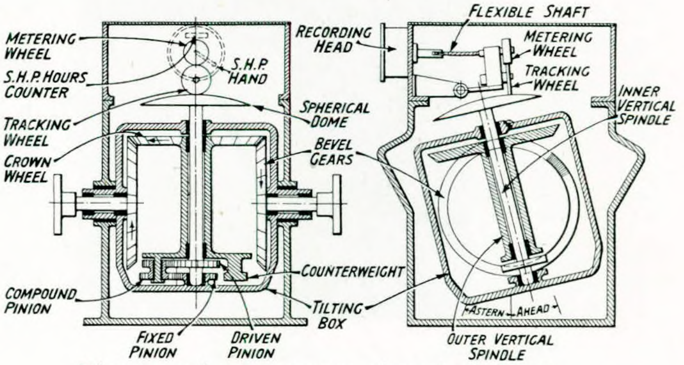
In operation the countershafts rotate the right- and left-hand bevel gears of the powermeter in opposite directions at a speed proportional to the main shaft. The crown wheel is rotated and controlled in tilt by the right- and left-hand bevels; therefore while its speed varies with that of the bevels, relative lead or lag of one of them over the other (due to twist in the main shaft) results in the axis of the crown wheel becoming displaced out of the vertical. Thus the connected dome rotates with angular velocity proportional to the main shaft speed, and takes up an angle of tilt proportional to the main shaft twist.

The tracking wheel contacts initially with the centre of the dome, but when the main shaft is running loaded, contact takes place on a circular track of radius proportional to the twist and with angular velocity proportional to that of the main shaft, and therefore with peripheral speed proportional to the product of main shaft angular speed and twist. The proportions of the measuring components of the powermeter are arranged so that the dial of the recording head can be marked in shaft horse-power direct, and its attached counter in shaft horse-power-hours.

A comparison.

It is interesting to note that on trials of the steamship "Llanashe" carried out in November,





Diagrammatic arrangement of mechanical unit.

1936, both a mechanical and an electrical White-Fox powermeter were installed for experimental purposes.

Both instruments were in action throughout the trials and functioned without attention. Records observed are shown in the table below.

MEASURED MILE SHAFT HORSE-POWER

Hour	Mechanical	Electrical	Mean
8.34 a.m.... ...	1,040	1,040	1,040
9.07	930	940	935
9.28	1,190	1,200	1,195
9.55	1,130	1,140	1,135
10.25	1,440	1,420	1,430
10.51	1,430	1,400	1,415
11.16	1,620	1,620	1,620
11.47	1,610	1,610	1,610

Readings were usually the mean of three in the course of the run.

CONSUMPTION TRIAL SHAFT HORSE-POWER
(Single Readings)

2.0 p.m.	1,240	1,245	1,242
2.30	1,190	1,210	1,200
3.0	1,340	1,300	1,320
3.30	1,320	1,315	1,317
4.0	1,130	1,190	1,160
4.30	1,250	1,245	1,252
5.0	1,270	1,270	1,270
6.0	1,170	1,155	1,162
6.30	1,180	1,165	1,172
7.0	1,200	1,155	1,177
7.30	1,300	1,280	1,290
8.0	1,170	1,235	1,202
Means	1,231	1,230	1,230
Average power as obtained from the aggregate or integrating gear was	1,227	Not observed	1,227

The mechanical powermeter was installed between the couplings of a single length of tunnel shafting, the actual base being 19ft. 10½in. The electrical powermeter was fitted on a base of 93ft., which included five lengths of shafting and therefore four shaft couplings.

The Largest Sirron Engine.

A Seven-cylinder 700 b.h.p. Unit for a British Coaster.
New Features of Design.

"The Motor Ship", August, 1938.

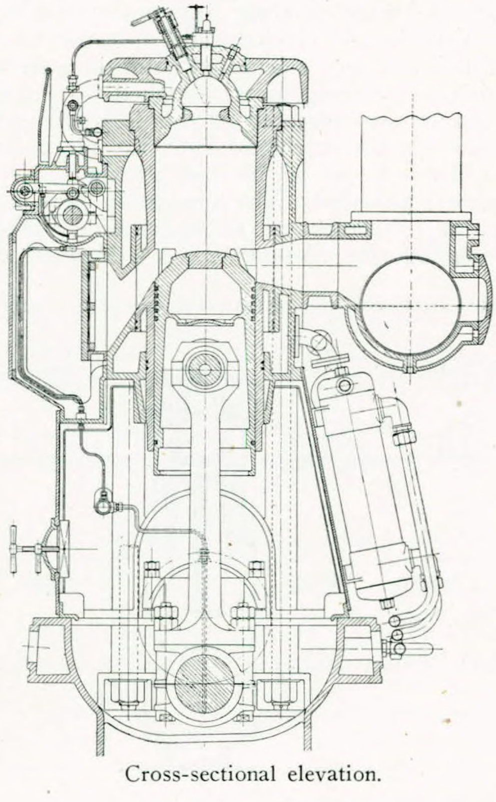
The most obvious alteration is the employment of a reciprocating scavenging air pump in place of the rotary blowers formerly used, while the control station, which is now moved to the after end of the engine, embodies some additional mechanism, to which we shall refer. The bilge and circulating pumps are now horizontal instead of vertically placed, and the fuel-injection pumps are located at the top of the engine, their previous position being about midway between the top and the bottom.

The new engine, which we inspected on the test bed last month and had the opportunity of noting its satisfactory performance under load and whilst reversing, is for a coaster named "Sodality", nearing completion for Messrs. F. T. Everard and Sons at the yard of the Goole Shipbuilding and Repairing Co. She was originally built (with the intention of making her a steam-engined vessel) at Workington; the Goole concern, however, launched the ship and towed her round to their yard for the purpose of finishing the vessel as a modern Diesel-engined coaster, and she will be numbered among the largest in the Everard fleet. She has a length of 188ft. 2in., a breadth of 30ft., and a moulded depth of 14ft. 7in. The machinery will be installed aft and a 37-ton deep tank for fuel is located at the forward end of the engine-room.

Through-bolt construction.

The cylinder diameter of the engine is 320 mm. (12·6in.) and the piston stroke 426 mm. (16·76in.). Normally the maximum speed is 300 r.p.m. A twin-cylinder tandem-type scavenging-air pump is fitted forward, the engine being of the two-stroke trunk-piston design. Airless-injection of fuel is employed, in conjunction with Bryce fuel pumps and injectors. The pumps are mounted separately in front of each cylinder head and the injectors are centrally arranged in the covers. The scavening-air pump has a capacity of about 1·35 times that of the working cylinders and the air is drawn into the pump through a Disco filter.

The bedplate is in two sections; it carries the frames on which rest the entablatures, each cylinder having its own. These entablatures are castings into which are inserted the cylinder liners, and the practice is to run through-bolts between the joints,

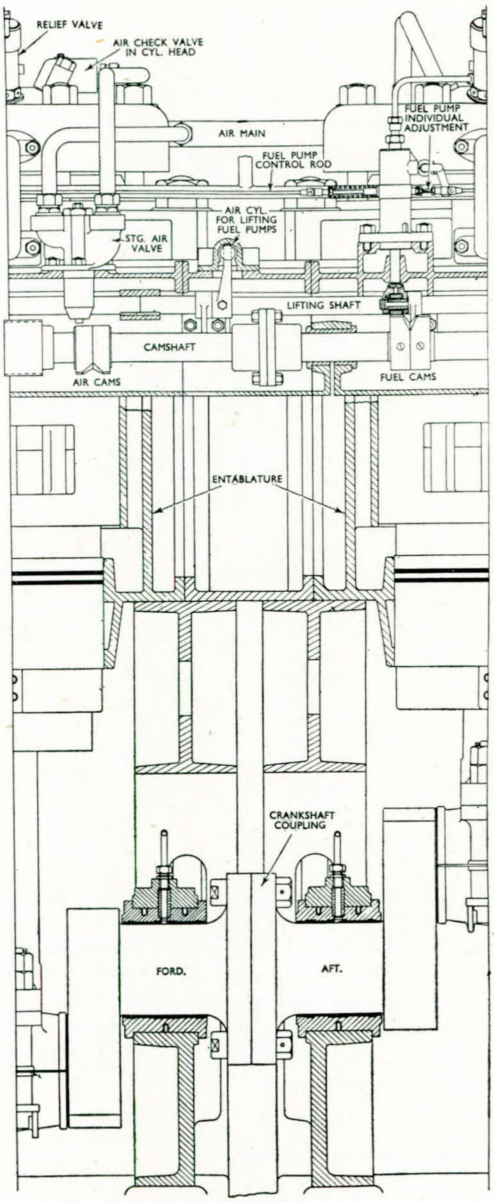


Cross-sectional elevation.

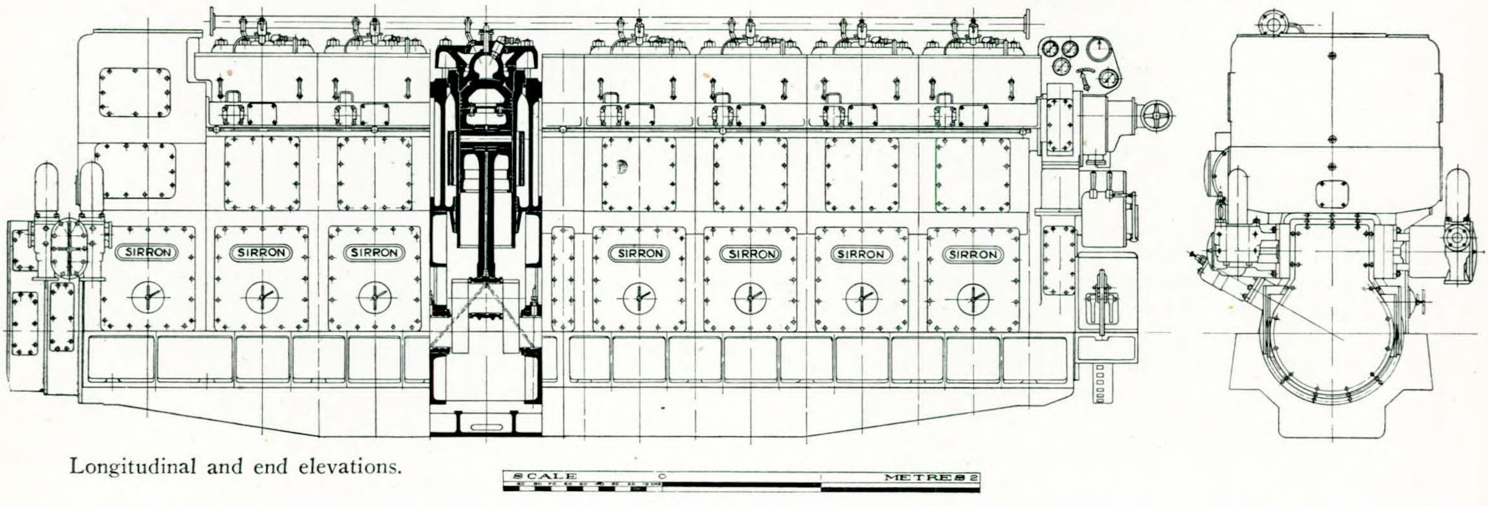
there being four half-holes near each corner corresponding with those in the adjacent parts. The through-bolts pass from the top of the entablature—it may be considered as a complete rigid structure, since all are bolted together—to the bedplate and, as usual, take the loads due to combustion. The cylinder liner is flanged and jointed in the manner shown clearly by the accompanying cross-sectional elevation, forming a central belt for the scavenging air admission and exhaust-gas outlet ports. Between the air ports and the scavenge trunk non-return strip valves are provided.

The cylinder cover is in two main parts and a restriction at the neck of the combustion chamber is formed by a separate ring. Four explosion rings are fitted in the piston and there is a scraper ring at the lower end; the piston top comprises a plug in the crown and a plate below (immediately above the top of the connecting rod), its shape at the commencement of the curve of the crown being such as to allow the piston to be lifted by special tongs, so that it is unnecessary to drill and tap the crown for the accommodation of an eyebolt. This relatively small modification to the shape of the piston crown is not clearly shown in the drawings.

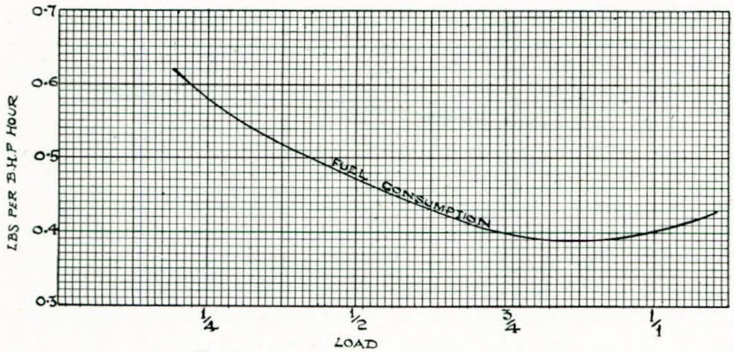
Lubricating oil is supplied under pressure to all the important bearings, the pump being an external, removable unit at the after end, designed so that no pipe joints need to be broken when it needs removal for any reason. This pump is driven by the same chain that drives the engine camshaft on the opposite side. Two Auto-Klean strainers are provided, and there is a hand-priming oil pump with a Vokes filter. A Wakefield mechanically operated lubricator is fitted, and this is actuated from the governor-shaft drive. Starting air is supplied by a single-stage compressor mounted at the forward end of the engine on the starboard side, the air pressure being 350-400 lb. per sq. in. An automatic unloading device is provided. The lubricating oil is passed through an oil cooler and all the auxiliary plant is self-contained with the engine. A half-speed shaft



(Right) Sectional side elevation at centre of engine.



Longitudinal and end elevations.



Fuel consumption curve.

at the forward end drives the twin bilge pumps through gearing, and opposite these is the water-circulating pump.

Three levers are arranged at the control station. The largest is for moving the camshaft in a fore-and-aft direction, and once it is in the correct position for ahead or astern, as the case may be, it is locked in its proper location by oil pressure. There are two pairs of cams for each cylinder, i.e., the ahead and astern cams for the operation of the fuel pump and a corresponding pair for the air-starting valve. Between the fuel-pump cam and the bottom end of the pump plunger is a roller carried on an eccentrically pivoted lever; this lever has an extension at the inner end (adjacent the roller) adapted to engage a catch moved by a fore-and-aft shaft which is turned a few degrees by the piston of an air cylinder during reversal, so that when the camshaft moves longitudinally all the pump plungers are raised from the cams.

The safety device, which Mr. H. Kent-Norris, the designer of the engine, introduced some time ago, for allowing the fuel-injection pump control rod to move, even if a pump plunger seizes or sticks temporarily, has proved a success and is retained with the new engine. The control is effected by twisting the plungers to vary the amount supplied, and for this purpose a series of racks is employed. The control rod is spring-connected to the racks and normally moves them as if they were actuated by a solid rod. If any resistance should be set up by any one plunger, the appropriate spring is merely compressed and the remaining plunger controls are unaffected. Further, the rod also has a means of giving a fine individual adjustment to each pump.

Of the two small levers at the control station, one is for air-starting purposes and the other for fuel control. Each has four positions, those for the starting lever being for stop, air to all cylinders, air and fuel together and, finally, fuel alone, while the fuel-control lever has a stop position, one giving a range of slow speed, the full-speed position and one for allowing an overload. It is possible to set the controls so that when the engine is started it runs at a suitably low rate of revolutions instead of taking, first, the full amount of fuel momentarily, and then being set for slow speed. Above the levers is a small handwheel for setting the engine governor at the maximum speed required, and adjacent is a cock with twin pipes leading to the main lubricating-oil strainer. When the cock is turned one way it enables a gauge to show the oil pressure on the delivery side of the strainer and a quarter-turn in the other direction places the gauge pipe in communication with the suction side.

The pressure gauges above the controls are for scavenging air, cooling water, lubricating-oil and starting air, an additional dial being that of the revolution counter. The engine was started in our presence and when it was running at 300 r.p.m. on load (a Heenan and Froude brake being used for the test-bed trials) the scavenging-air pressure was 2 lb. per sq. in., the cooling-water pressure 6 lb. per sq. in., and the lubricating-oil pressure 11 lb. per sq. in. The shaft is fitted with a vibration damper at the forward end and a Michell thrust block is to be fitted in the ship. Our own impressions of the running of the engine were of a favourable character; the unit is a clean, well-designed marine installation and shows many signs of attention to detail in its construction.

Machinery of Passenger Liners.

"The Motor Ship", September, 1938.

As we anticipated, the new 21,000-ton passenger liner for the Rotterdam Lloyd ordered last month is to be a twin-screw vessel, and this adds still further interest to the unending controversy regarding the most satisfactory system of propulsion for high-powered passenger liners. An examination of the engines installed in various passenger ships of between 21,000 tons and 27,000 tons gross and with machinery of from 20,000 b.h.p. to 32,000 b.h.p., recently built or under construction, reveals how varied are the views held by the technical advisers to the various owners.

The 27,000 b.h.p. Rotterdam Lloyd ship will have four engines geared to two propeller shafts. The "Oranje", the Netherlands Steamship Co.'s vessel with engines of about 30,000 b.h.p., is to be propelled by three units direct coupled to the shafts, whilst the "Dominion Monarch" (32,000 b.h.p.) has four engines, also direct coupled. The "Stirling Castle" (24,000 b.h.p.) and her sister ship have but two engines, with direct drive, but the "Stockholm" (21,000 b.h.p.) follows the lines of the "Oranje" with three engines coupled to the shafts. The "Oslofjord" is the only geared Diesel passenger liner with machinery comparable in power to that of the Rotterdam Lloyd ship, and we were informed last month that her four engines, developing 18,000 b.h.p., geared to two shafts, have given complete satisfaction in their transatlantic service. In the case of the Rotterdam Lloyd ship, however, we understand that A.S.E.A. electro-magnetic couplings will be utilized for the first time in a big liner, and the new ship will, in any case, be by far the highest powered motorship with gearing. The main object of its employment is to reduce the height of the machinery and thus gain the advantage of an extra passenger deck.

Variable-Pitch Propellers.

"The Motor Ship", September, 1938.

The utilization of variable-pitch propellers in a motorship with an engine of 4,000 h.p. seems a somewhat revolutionary proposal. Such an arrangement may be adopted in a vessel now under construction on the Continent, with the two-fold object of avoiding frequent starting and stopping when manœuvring (and the consequent ill-effects of the introduction of cold air into the hot cylinders) and of enabling complete control of the ship to be effected from the bridge, although there will be duplicate controls in the engine-room.

Designs have been prepared, and in reply to those who might object to the innovation from the standpoint of its experimental nature, it is claimed that the problem involved is not so difficult, nor are conditions so onerous as is found in connection with the building of variable-pitch blades for water turbines in powers up to 40,000 b.h.p.

Home-produced Marine Diesel Fuels.

"The Marine Engineer", July, 1938.

With commendable enterprise Lever Bros. and Unilever Ltd. have carried out a series of tests in connection with the running of transport-type Diesel engines on fuel oils obtained from soya beans, palm oil, cotton seed, groundnut oil, and a wide variety of other vegetable and animal oils. There is no doubt that this question of an indigenous fuel oil supply is as important to the road transport industry of Great Britain as it is to Germany and other countries, where this problem has been vigorously tackled for several years. The majority of heavy commercial goods vehicles and buses now being turned out of British factories are Diesel-driven and it is encouraging to find private enterprise having the foresight to undertake tests at their own expense on the important subject of alternative fuel supplies for possible use in times of war. These tests have, it would seem, been carried out very thoroughly and carefully, and it is to be hoped that the results will be published in the form of a paper before some scientific body. Let us also hope that it will encourage other enterprising British users of Diesel engines to tackle this important problem.

Equally urgent is the need for tug owners, owners of Diesel-engined fishing vessels, and the like to give consideration to this question, and it is to be hoped that encouragement will be given to work in this direction by such bodies as the Diesel Engine Users' Association and the Institute of Marine Engineers. The employment of soya bean oil as a Diesel fuel is, of course, far from new but, so far as we are aware, until the tests sponsored by the two large British concerns above-mentioned were put in hand no firm in this country had done any practical work of much importance in connection with the utilisation of this fuel.

In the very general Press reports on these tests it was stated that the Unilever interests expected to make good use of vegetable oils as fuels in their vessels operating on the West Coast of Africa. Further work in this connection will be watched with interest because there is no doubt that in the event of war the bulk of our petroleum supplies would be needed for the Navy. The soya bean grows very well in English soil and it would be an excellent plan if the lead given by Mr. Henry Ford, who has cultivated the soya bean on his farm in Hertfordshire, were followed elsewhere. It would be patriotic and really long-sighted if our great oil companies were to investigate this matter so as to ensure an adequate supply of soya bean oil for various non-combatant purposes in wartime. We have no doubt that if such an alternative Diesel fuel could be produced cheaply and in sufficient quantities many of our large motorship owners would feel distinctly happier about the future, while we should imagine that the Government would not be lacking in practical co-operation and encouragement.

A Velox Boiler Installation.

"The Shipping World", 31st August, 1938.

A passenger steamer fitted with an oil-fired Velox boiler—the first installation of this kind in Finland—was recently launched for service between Abo and Stockholm. She is named the "Bore II" and the small dimensions of her "fuel valve" boilers were indicated by the fact that they could be lowered into the vessel through the apertures made for the funnel. There are two generators, each having an output of 8 tons of steam at 16 kgs. per square centimetre absolute and 320 degrees C. Fuel oil is used and the steam so generated is supplied to a double compound steam reciprocating engine direct coupled to the screw. The whole outfit is extremely compact, and presents a striking arrangement. Two Velox units are at the forward end of the engine room, and are inter-connected to an ordinary Scotch boiler which is also used for port. The condenser is on the port side of the double compound main engine, where there is also an evaporator. On the starboard side are two generator sets, one large and one small, and also an evaporator. This is the first occasion on which a Velox boiler has been used in conjunction with a steam reciprocating engine, a previous similar arrangement being on the Messageries Maritimes passenger vessel "Athos II", where it was used in conjunction with an ordinary boiler and engine room.

Oil in New Zealand?

"The Shipping World", 17th August, 1938.

It is reported that boring for oil is to begin under Government auspices in New Zealand. Following on favourable reports from geologists, the Government has granted powers to a specially-formed petroleum company to conduct prospecting operations. Both British and American capital is involved. An expert field-drilling staff, transferred from the Persian Gulf oilfields, and heavy modern drilling gear capable of reaching a depth of 10,000 feet, have already arrived in the Dominion.

Non-Destructive Testing.

"Ice and Cold Storage", August, 1938.

The joint committee on Materials and Their Testing is organising a meeting which will be held on November 25th under the auspices of the Institution of Electrical Engineers for the discussion of the subject of non-destructive testing. The subject has been divided into three sections, namely:—Magnetic and electrical methods; X- and gamma-rays; acoustical and general methods, and each section will be dealt with by authors representing respectively Great Britain, the Continent of Europe, and the United States.

Nickel Steel Rivets.

"Shipbuilding and Shipping Record", 14th July, 1938.

It is well known that even a slight variation in the chemical composition of a metal when subjected to exposure in sea water is sufficient to set up galvanic or electro-chemical action which leads to rapid corrosion. Interest, therefore, attaches to the measurement of the magnitude of the electrical potential developed between the rivet material and the ship plating which was made during the course of an investigation into the possibility of using nickel steel for the manufacture of the rivets. Actually, using a low-carbon steel containing about 2 per cent. nickel, it was found in the laboratory that the potential of this metal in sea water is about 90 millivolts lower than that of mild steel, while practical tests in sea water at various locations have confirmed the fact that there is a definite protection afforded to the nickel steel rivets by the surrounding mild steel plate, as well as an absence of accelerated corrosion of the plate itself. Incidentally, in addition to eliminating the trouble and expense due to the sea-water deterioration of rivets made of ordinary carbon steel, it has been found that the mechanical properties of nickel steel rivets, both as regards strength and ductility, are equal to those of carbon steel, while the driving technique employed for carbon steel rivets can be used without modification for rivets of nickel steel. It may be noted that both Lloyd's Register of Shipping and the United States Bureau of Shipping have approved this new type of rivet for use in hull construction to their respective classifications, the specification for the bars from which the nickel steel rivets are made being: Tensile strength, 29 tons per sq. in.; yield point, 20 tons per sq. in.; elongation on 2in., 28 per cent.; reduction of area, 55 per cent.

BOARD OF TRADE EXAMINATIONS.

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

Name.	Grade.	Port of Examination
For week ended 7th July, 1938:—		
Anderson, John C. B.	1.C.M.E.	London
Bray, Charles F. A.	1.C.M.E.	,,
Filshie, James F.	1.C.M.E.	,,
Jones, Owen H. L.	1.C.M.E.	,,
Kirkwood, Robert C. C.	1.C.M.E.	,,
May, Harry G.	1.C.M.E.	,,
Snowdon, James L.	1.C.M.E.	,,
Larter, Frank A. J.	1.C.S.E.	,,
Butcher, George F.	1.C.S.E.	Liverpool
Wallace, Daniel C.	1.C.M.E.	London
Brown, Leslie W.	1.C.	,,
Craib, Charles	1.C.	,,
Kent, Frank	1.C.	,,
Miller, Leslie F.	1.C.	,,
Wood, Robert	1.C.	,,
Beetles, Hubert J.	1.C.M.	,,
Simmons, George D.	1.C.M.	,,
McMurray, James A. C. D.	1.C.M.	Liverpool
Wilkinson, George L.	1.C.M.	,,
Carmichael, Thomas E.	1.C.	Glasgow
Coskry, John M.	1.C.	,,
Smith, William E.	1.C.	,,
Stewart, James	1.C.	,,
Campbell, Peter	1.C.M.	,,
Cowper, Edward C.	1.C.	Newcastle
Walker, James W.	1.C.M.	,,
Wood, Harry G.	1.C.M.	,,
Weston, Henry W. H.	1.C.M.E.	London
Ridyard, Clement J.	1.C.M.E.	Liverpool
Smedley, Reginald W.	1.C.M.E.	,,
Guthrie, John	1.C.M.E.	Glasgow
Leith, Allan B.	1.C.M.E.	,,
Rawling, Ernest	1.C.M.E.	Newcastle
Stephenson, John N.	1.C.M.E.	,,
Williamson, Harold G.	1.C.M.E.	,,
For week ended 14th July, 1938:—		
Olsen, Sigurd W.	2.C.M	Liverpool
Priest, Benjamin H.	2.C.M.	,,
Shackleton, James H.	2.C.M.	,,
Lindsay, John	2.C.	Glasgow
Whitelaw, George M.	2.C.	,,
McArthur, John	2.C.M.	,,
Penny, Lawrence J.	2.C.	Hull
Wallace, George J.	2.C.	,,
Cummings, Henry A.	2.C.M.	Newcastle
Seaman, William D.	2.C.	Cardiff
Burnham, Arthur E.	2.C.	London
Fenner, Martin W.	2.C.	,,
Goodhind, Maurice	2.C.	,,
Curry, Frederick S.	2.C.	Newcastle
Stokeld, George S.	2.C.	,,
Bates, Arthur S.	2.C.M.	,,
Johnson, John M.	2.C.M.	,,
Taws, Fred	2.C.M.	,,
Telfer, Robert	2.C.M.	,,
Choyce, Charles N.	2.C.	Liverpool
Foulis, David M.	2.C.	,,
Grant, Charles	2.C.	,,
Alderson, John R.	2.C.M.	,,
Johnson, Joseph L.	2.C.M.	,,

Name.	Grade.	Port of Examination.
For week ended 21st July, 1938 :—		
Holloway, Frank F.	1.C.M.E.	Cardiff
Aird, Andrew W.	1.C.M.E.	Glasgow
Varian, Thomas L.	1.C.M.E.	Cardiff
Taylor, George H.	1.C.M.E.	Liverpool
Sharer, Philip S.	1.C.M.E.	Newcastle
Swain, James R.	1.C.S.E.	Liverpool
Rundle, John E.	1.C.S.E.	London
Campbell, Peter	1.C.S.E.	Glasgow
Treliving, Harold	1.C.M.E.	Newcastle
Gilbertson, John G. D.	1.C.M.E.	"
Price, Rees W.	1.C.M.E.	Cardiff
Papworth, Frank H.	1.C.M.E.	Glasgow
Moore, Quintin	1.C.M.E.	"
Third, Charles	1.C.M.E.	London
Farquhar, John M.	1.C.M.E.	"
Roberts, Mostyn	1.C.M.E.	Liverpool
Milligan, Andrew B.	1.C.M.E.	"
Jones, Herbert V.	1.C.M.E.	"
Green, Leslie N.	1.C.M.E.	"
Johnson, Tom	1.C.M.E.	Hull
Dryden, Robert	1.C.M.E.	"
Cain, William L.	1.C.	Liverpool
Miller, Alexander	1.C.	"
Whitburn, Leomonde L.	1.C.	"
Frayn, Clifford C.	1.C.M.	"
Wainwright, Kenneth M.	1.C.M.	"
Butcher, John A.	1.C.	Hull
Fowler, John	1.C.	London
McIntosh, Douglas B.	1.C.	Glasgow
Chalmers, John	1.C.M.	"
Gracey, William	1.C.	Cardiff
Miles, Edwin	1.C.M.	"
Fox, James G.	1.C.	Newcastle
Nicholson, John H.	1.C.	"
Thompson, Wilfred	1.C.	"
Wood, Thomas C.	1.C.	"
Taylor, Joseph W.	1.C.M.	"
For week ended 28th July, 1938 :—		
Balmer, George K. C.	2.C.	Glasgow
Findlay, John M.	2.C.	"
Harley, Frank	2.C.	"
Lewer, Lawrence J. S.	2.C.	"
Martin, Kenneth McK.	2.C.M.	"
Crockett, John H.	2.C.	Leith
Dick, George S. F.	2.C.	"
Barlow, James R.	2.C.	Liverpool
Donaldson, Maurice	2.C.	"
Foreman, William J. L.	2.C.	"
Green, Harry	2.C.	"
Ross, Frederick M. McG.	2.C.	"
Sinclair, William G. MacP.	2.C.	"
Small, Joseph	2.C.	"
Thomas, John H.	2.C.	"
Williamson, George	2.C.	"
Charlton, Cyril R.	2.C.	London
Hawkins, George R.	2.C.	"
Olding, Leonard A.	2.C.	"
Russell, Thomas F.	2.C.	"
Maxwell, Donald P.	2.C.M.	"
Catchpole, Charles	2.C.	Newcastle
Chalk, Thomas	2.C.	"
Donald, George	2.C.	"
Duplock, Ernest F. J.	2.C.	"
Lee, Walter T.	2.C.	"
Parker, John W.	2.C.	"
Robinson, Tom L.	2.C.	"
Halcrow, Ben H.	2.C.M.	Newcastle
Lillico, James	2.C.M.	"
Robson, George W.	2.C.M.	"
Everett, Robert	1.C.M.E.	"
For week ended 4th August, 1938 :—		
Millar, James B.	1.C.	Glasgow
Ritchie, Steven S.	1.C.M.	"
Cormack, Daniel J. F.	1.C.	Leith
Farquhar, Percival	1.C.	"
Mason, John C.	1.C.	"
Edmonds, Albert F.	1.C.M.E.	Liverpool
Whitburn, Lemonde L.	1.C.M.E.	"
Brown, L. W.	1.C.M.E.	London
Cartwright, Edward	1.C.M.E.	"
Coleman, Edgar H.	1.C.M.E.	"
Gargett, Ralph S.	1.C.M.E.	"
Lee, John S.	1.C.M.E.	"
Rischmiller, Charles A.	1.C.M.E.	"
Fox, James G.	1.C.M.E.	Newcastle
Stevens, William	1.C.M.E.	"
Wood, Daniel S.	1.C.M.E.	"
Evans, Jack	1.C.	Liverpool
Johnston, Angus McArthur	1.C.	"
Lane, Raymond Thomas	1.C.	"
Masters, Douglas W. C.	1.C.	"
Rippon, Charles H.	1.C.	"
Taggart, Robert Stanley	1.C.	"
Watson, Albert Edwin	1.C.M.	"
Williams, Henry Tudor	1.C.M.	"
Coombe, George	1.C.	London
Fidele, John Francis	1.C.	"
Holtum, Richard R.	1.C.	"
Armstrong, Thomas	2.C.M.	Belfast
Arnold, William	1.C.	Newcastle
Gibson, John G.	1.C.	"
Hetherington, Victor J.	1.C.	"
Fleuret, Bernard C.	1.C.M.	"
For week ended 15th September, 1938 :—		
Snadden, James	2.C.M.	Glasgow
Brown, Norvel K.	2.C.	London
Clark, John A.	2.C.	"
Johnson, Sidney C.	2.C.	"
Maundrell, Henry B. H.	2.C.	"
Parker, Philip R.	2.C.	"
Rashwan, Ahmed R.	2.C.	"
Bishop, Denis	2.C.M.	"
Jones, Thomas J.	2.C.M.	"
Griggs, Robert	2.C.	Newcastle
Malone, Charles J.	2.C.	"
Welch, William F.	2.C.	"
Craig, John R.	2.C.M.	"
Beckerleg, James T.	2.C.	Liverpool
Birkhead, Thomas L. L.	2.C.	"
Kirkham, James	2.C.	"
Taggart, George H.	2.C.	"
Croft, Norman	2.C.M.	"
Smith, Hugh L.	2.C.M.	"
Campbell, Alexander N.	2.C.	Glasgow
Docherty, James	2.C.	"
Hall, Charles S.	2.C.	"
McLeman, Lewis	2.C.	"
McNair, William S.	2.C.	"
Montgomery, James A.	2.C.	"
Towers, Walter	2.C.	"
Hutchison, George	2.C.M.	"
Shanks, Charles	2.C.M.	"