labour to collect this information. To all those who are engaged in water schemes perusal of the paper cannot fail to be of interest, but it will probably cause disappointment to find how little information as regards water is available in the United Kingdom in comparison with that available in some other countries.

The author concludes his paper by suggested lines of organisation in this country so as to have all matters relating to water administration under one central authority. It will probably take some time before such a complete organisation as is suggested can be attained, but there is no reason why some of the smaller suggestions should not be carried out at once. We feel sure that if the importance of the question were fully brought before the present President of the Local Government Board he would be able with very little expense and without a large supply of red tape to deal quickly with such suggestions as annual returns from all water-supply and sewage-disposal authorities, and the beginning of a hydrographic survey. If a start were once made and the importance of the matter realised, the larger details of organisation would gradually evolve themselves.

The author has added to his paper some tables dealing with the use of water in various countries, and there is also a useful bibliography. M. F.

THE COMPOSITION OF PINE WOOD.

A MONOGRAPH on the "Chemical Composition of Pine-wood," by Prof. Klason, of Stockholm, has been issued by Gebrüder Borntraeger, of Berlin, as the second of a series of "Schriften des Vereins der Zellstoff- und Papier-Chemiker." In addition to the importance of pine-wood as the chief raw material of the paper industry, this particular wood has acquired a special scientific interest from the important colour-reactions in which it has figured as a test material. Thus phloroglucinol imparts a red-violet colour to a pine splinter moistened with hydrochloric acid, aniline sulphate a yellow colour, pyrocatechol and resorcinol a red-violet, pyrogallol a grey-violet, pyrrol and indol a red, phenol a blue, α-naphthol with sulphuric acid a green, hæmatoxylin a violet, naphthylamine hydrochloride a yellow, aminoanthracene hydrochloride a red, phenylhydrazine hydrochloride a yellow, and so forth.

These reactions appear to be characteristic of a substance to which the name of "lignin" has been given; similar reactions are shown by the well-known flavouring substance "vanillin," but this is not present as such in appreciable quantities in pine-wood. Lignin is richer in carbon than cellulose, but contains the same proportion of hydrogen; it differs from cellulose in that it is not dissolved by ammoniacal copper oxide, and gives no blue coloration to zinc chloroiodide, but can be reconverted into cellulose by oxidation, and separated from it by dissolution in alkalis or by the action of sulphites, which appear to convert it into soluble sulphonates. The author has analysed the calcium sulphonate, and attributes to it the formula $C_{40}H_{44}O_{17}S_2Ca$; this corresponds with a composition $C_{40}H_{42}O_{11}$ for lignin itself, but molecular weight determinations give values above 4000. In addition to two molecules of sulphur dioxide, lignin combines with two atoms of iodine, and thus contains three double-bonds in the C_{40} complex; four methoxyl groups are present and one hydroxyl group. The substance is probably a condensation-product of coniferyl alcohol,

$$CH_3O.C_6H_3(OH).CH:CH.CH_2.OH,$$

(a substance which can be oxidised to vanillin), with an oxyconiferyl alcohol in which the substituents are grouped in the same way (1 : 3 : 4 : 5) as in gallic acid, thus

$$2C_{10}H_{12}O_3 + 2C_{10}H_{12}O_4 - 3H_2O = C_{40}H_{42}O_{11}.$$

Lignification appears to consist in embedding the pliable cellulose in a hard crust of lignin; by the action of a sulphite the lignin is dissolved out, and the clean cellulose which is left constitutes the paper pulp. The sulphite extracts, from which lignin can easily be recovered, might very possibly prove to be valuable raw material for the manufacture of artificial vanillin. T. M. L.

RECENT ADVANCES IN TURBINES.[1]

ON two previous occasions I have addressed this institution on the steam turbine. At the time of the first lecture, in 1900, the turbine may be described as having been in the "advanced experimental stage." Six years later it was meeting with "general acceptance" in certain fields. To-night I propose to review its progress from 1906 to the present time; but before doing so I shall, with the view of leading up to the subject, and at the risk of some repetition, briefly explain the chief features of interest, and recapitulate some of the earlier steps in its introduction.

The first turbine of which there is any record was made by Hero of Alexandria 2000 years ago, and it is probably obvious to most persons that some power can be obtained from a jet of steam either by the reaction of the jet itself, like a rocket, or by its impact on some kind of paddle-wheel. It is, however, not so obvious that an economical engine could be made on this principle. In the year 1888 Dr. de Laval, of Stockholm, undertook the problem with a considerable measure of success. He caused the steam to issue from a trumpet-shaped jet, so that the energy of expansion might be utilised in giving extra velocity to the steam. Recent experiments have shown that by such a device nearly the whole of the available potential energy in the steam is converted into kinetic energy of velocity in a straight line, the velocity attained into a vacuum being about 43,000 feet per second. Dr. de Laval caused the steam to impinge on a paddle-wheel made of the strongest steel, which was allowed to revolve at the highest speed consistent with safety, for the centrifugal forces are enormous. Unfortunately, materials are not strong enough for the purpose (in the large sizes the speed is nearly half that of a rifle bullet), and the permissible speed of the wheel can only reach to two-thirds of that necessary for good economy, as we shall presently explain.

Dr. de Laval also introduced spiral helical gearing for reducing the enormous speed of his wheel to the ordinary speeds of things to be driven, and we shall allude to this gear later as likely to play a very important part generally in future turbine developments.

In 1884, or four years previously, I dealt with the turbine problem in a different way. It seemed to me that moderate velocities were essential if the turbine motor was to receive general acceptance as a prime mover. I therefore decided to split up the fall in pressure of the steam into small fractional expansions over a large number of turbines in series so that the velocity of the steam nowhere should be great, and consequently, as we shall see later, a moderate speed of turbine suffices for the highest economy. This principle is now universally adopted in all except very small turbines, where economy is of secondary importance. This arrangement of compounding turbines also appeared to me to be surer to give a high efficiency, because the steam was caused to flow in a non-expansive manner through each individual turbine, and consequently in an analogous way to water in water turbines, where high efficiency at that date had been proved. I was also anxious to avoid the well-known cutting action of high-velocity steam on metal.

The close analogy between laws for the flow of steam and water under small differences of pressure have been confirmed by experiment, and the usual formula $=\sqrt{2gh}$, where h is the hydraulic head, gives the velocity of issue from a jet for steam with small heads and also for water, and we shall presently follow this part of the subject further in dealing with the design of turbines.

Having decided on the compound principle, it was necessary to commence with small units at first, and in spite of the compounding the speed of revolutions was still high.

Though, as we have said, the de Laval turbine appeared four years later, the de Laval cream separators were in use prior to 1884, and I had the advantage of seeing their beautiful means of balancing—the supporting of the bearings in elastic rubber sleeves, which at 6000 revolutions absorbed vibration and allowed the bowl containing the milk to rotate about its centre of gravity instead of its geometric centre. The first compound steam turbine

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[1] Discourse delivered at the Royal Institution on Friday, March 10, by the Hon. C. A. Parsons, F.R.S.

ran at 18,000 revolutions, and had slightly elastic bearings. The turbine teeth or blades were like cog-wheel teeth, set at an angle and sharpened at the front edge, and the guide blades were similar. Gradually the form of the blades was improved—curved blades with thickened backs were introduced. The blades were cut off to length from brass material rolled and drawn to the required section, and inserted into a groove with soft brass packing distance pieces between and caulked up tightly, and dummy labyrinth packings of various types introduced. The design was improved so as to reduce steam leakages and provide for greater expansion ratios.

The construction of a suitable dynamo to run with the turbine involved nearly so much trouble as the turbine itself; the chief features were the adoption of very low magnetic densities in the armature core and small diameters and means to resist the great centrifugal forces. The dynamo was also mounted in elastic bearings. Now that the turbine has found its most suitable field in large powers, and the speed of revolution is consequently reduced, elasticity in the bearings is less essential, and in large land plants and in marine work rigid bearings are now universal. I have said that steam behaves like an incompressible fluid in each turbine of the series, but as it is highly elastic, its volume increases with the succession of small drops of pressure, and the turbines have to be made larger and larger. This enlargement is secured by increasing the height of blade, by increasing the diameter of the succeeding drums, and by altering the angles and openings between the blades. All three methods are generally adopted to accommodate the expanded volume of one hundredfold in the condensing turbine.

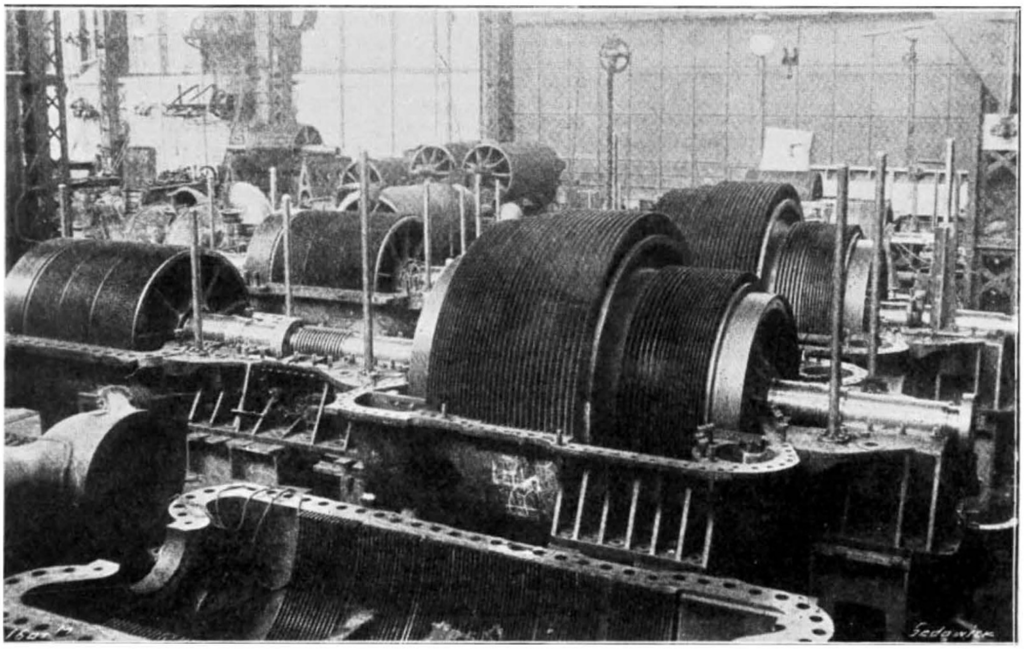

FIG. 1.—Turbines being completed. (From *Engineering*.)

Now as to the best speed of the blades. It will be easily seen that in order to obtain so much power as possible from a given quantity of steam, each individual row of blades must work under appropriate conditions. This, as has been found by experiment, requires that the velocity of the blades relatively to the guide blades shall be about one half the velocity of the steam, or, more accurately, equal to one half the velocity of issue from rest due to the drop of pressure in guides or moving blades. The curve for efficiency in relation to the velocity ratio has a fairly flat top, so that the range of velocity ratio for high efficiency is wide, and the speed of the turbine may be varied considerably about that for maximum efficiency without materially affecting the result.

In compound turbines the efficiency of the initial rows may be generally assumed as about 65 per cent., and of the latter rows at 75 to 85 per cent., and, considering the whole turbine, approximately 75 per cent. of the energy in the steam is delivered on to the shaft. The expansion curve may be expressed approximately by $pv = \log p_1/p_2$, where $p_1 - p_2$ is the drop in pressure across any turbine; pv is obviously not quite constant, but if a mean value is assumed the error is small. The expansion curve therefore lies between the adiabatic and isothermal curves for steam, but nearer the former, and the errors in these assumptions are found by experiment to be of much less importance than the errors in workmanship and imperfections of materials that are unavoidable in practical mechanics. The differential thermal expansions of the metal of which the turbine is made are the chief reason for large working clearances and loss by leakage, though every available means is taken to mitigate such loss.

In turbine design, the expression of the velocity ratio between the steam and blades may be represented by the integral of the square of the velocity of each row through the turbine, which is a coefficient called K. If K, for instance, as usual in land turbines, equals 150,000, then we know that with a boiler pressure of 200 lb. and a good vacuum the velocity ratio is 0·55, and the turbine is working close up to its speed for maximum efficiency. In large marine work, where weight and space are of importance, K varies from 80,000 to 120,000, or even to 140,000. With K = 80,000, a loss of efficiency of about 9 per cent. below the highest attainable is accepted. With K = 120,000, the deficit is only about 1½ per cent.

There are many forms of turbines now on the market, but we need only consider four chief types, which are:—

First, the compound reaction turbine, with which we have been dealing, representing more than 90 per cent. of all marine turbines in use in the world, and about half the land turbines driving dynamos.

Secondly, the de Laval, which is only used for small powers.

Thirdly, the "multiple impulse compounded," or Curtis, which has been chiefly used on land, but which has been fitted in a few ships.

Lastly, the compound reaction type, with one or more "multiple impulse elements" added to replace the reaction blading at the high-pressure end.

We may dismiss the numerous other types as simply modifications of the original type, without any scientific interest.

Let me explain the latter types. The multiple impulse principle is the only substantial innovation since the compound reaction and the de Laval turbines came into use. It was proposed by Pilbrow in 1842, and first brought into successful operation by Curtis in 1896. A little consideration should be given to it as involving some characteristic points of difference from what has been said about reaction blading. It will be seen that Curtis used the de Laval divergent nozzle, and that he also uses compounding, but generally only 5 to 9 stages as compared with 50 to 100 in the compound type. The same principles as regards velocity ratio apply, but owing to the repeated transfer of the steam between fixed and moving buckets at each velocity-compounded stage, the best velocity ratio in a four-row multiple impulse is only one-seventh, and the best obtainable efficiency 44 per cent., and therefore much lower than reaction blading under favourable conditions.

The good points of the multiple impulse type are that there is very little loss by leakage, and that therefore, in spite of its low efficiency, one or more multiple impulse wheels can in certain cases usefully replace reaction blading at the entry to the turbine, because in slow revolution turbines of moderate power the blades are short at the commencement, and there is consequently much loss by leakage through the clearance space. As a rule, one multiple impulse wheel is generally preferred, and is followed by reaction blading; the expansion ratio on to the wheel is about threefold, and it generates about one quarter of the whole power. Occasionally several wheels in separate chambers are placed in front of the reaction blading, but there are serious practical drawbacks to this arrangement. The multiple impulse wheel at the commencement has a further advantage in that, when highly superheated steam is used, the temperature is much reduced by expansion and work done before it passes to the main turbine casing.

The highest efficiency yet attained by land turbines has been with the pure compound reaction turbine of large size, where the high-pressure portion is contained in a separate casing of short length and great rigidity; the working clearances can then be reduced to a minimum.

The first turbine imported into Germany in 1900, of 2000 horse-power, was on this principle, and also the latest turbines, of 12,000 horse-power, which generate current for the Metropolitan Railway in London.

In marine work the same arrangement has been almost universal since 1896, when the original single turbine of the *Turbinia* was replaced by three turbines in series (on the steam) on different shafts.

Here there is the additional advantage that, owing to the power being subdivided over three shafts, smaller screws are admissible, and the speed of revolution may be increased in the ratio of 1 to $\sqrt{3}$.

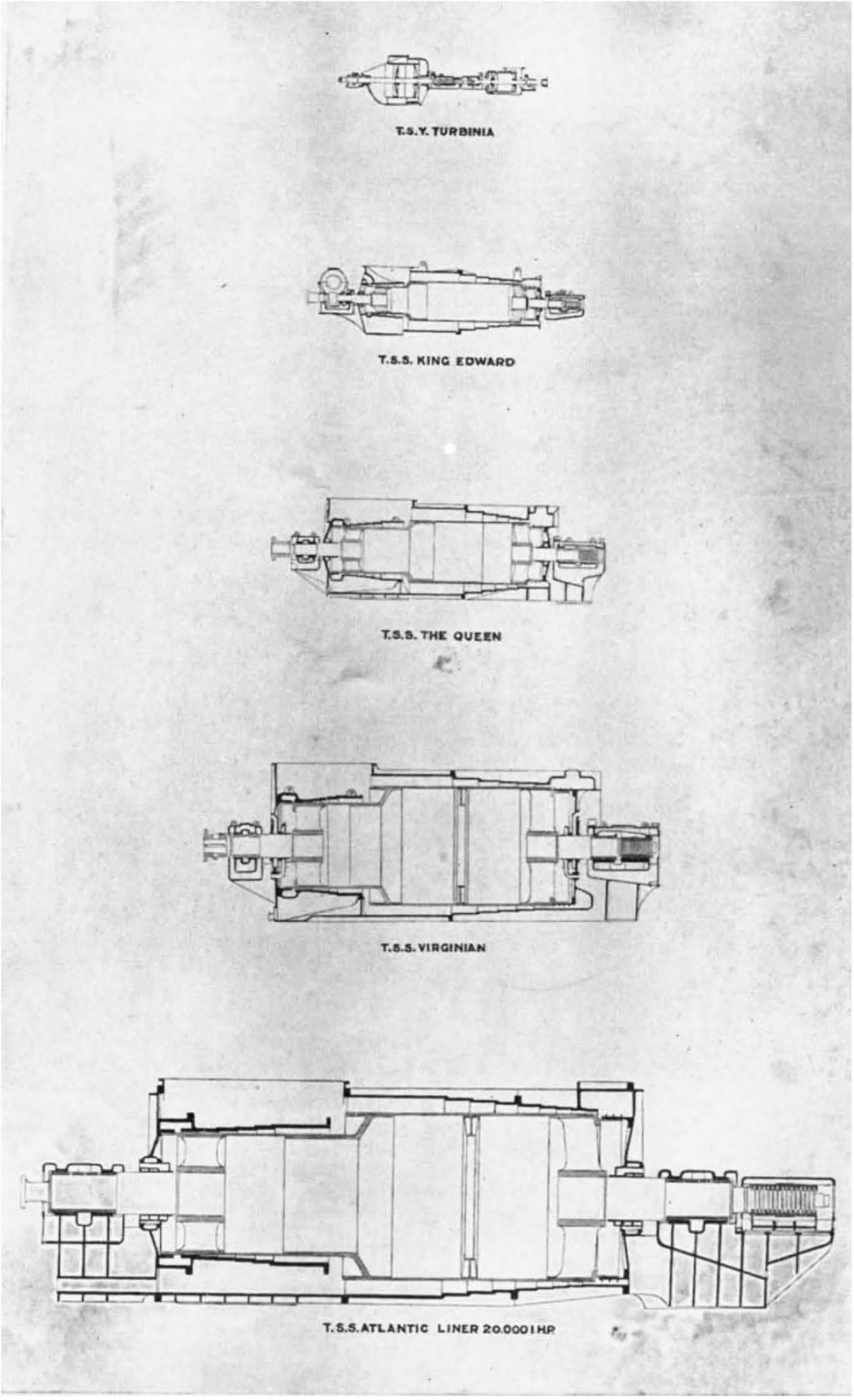

FIG. 2.—Progress in size of turbines. (From *Engineering*.)

Generally, the turbines are placed two in series, as in cross-Channel boats, the *Mauretania* and *Lusitania*, torpedo craft, battleships and cruisers, or sometimes three in series, as in the liner *La France* and the latest and largest Cunard liner now building. Four in series have been proposed, but not constructed.

The war vessel in commission is working at reduced power for most of the time, and on long voyages economy of fuel is of great importance. For this purpose, additional turbines are fitted in front of the main full-power turbines. They are naturally of small size, and may be in separate casings, or the main high-pressure turbine may be lengthened by the addition of a cruising portion added on in front. All these cruising turbines or cruising elements are more or less by-passed, according as additional power is required, and at full speed they are entirely by-passed, and when in separate casings are connected to the condenser and rotate in vacuum. In some instances of modern naval construction one or more multiple impulse wheels have constituted the cruising element.

Before passing to the consideration of other applications of the turbine, I should like, with your permission, to repeat an experiment which illustrates the phenomenon of cavitation. The chief difficulty in applying the turbine to marine propulsion arose in the breaking away of the water, or the hollowing out of vacuous cavities in the water when it was attempted to force the screw above certain limits.

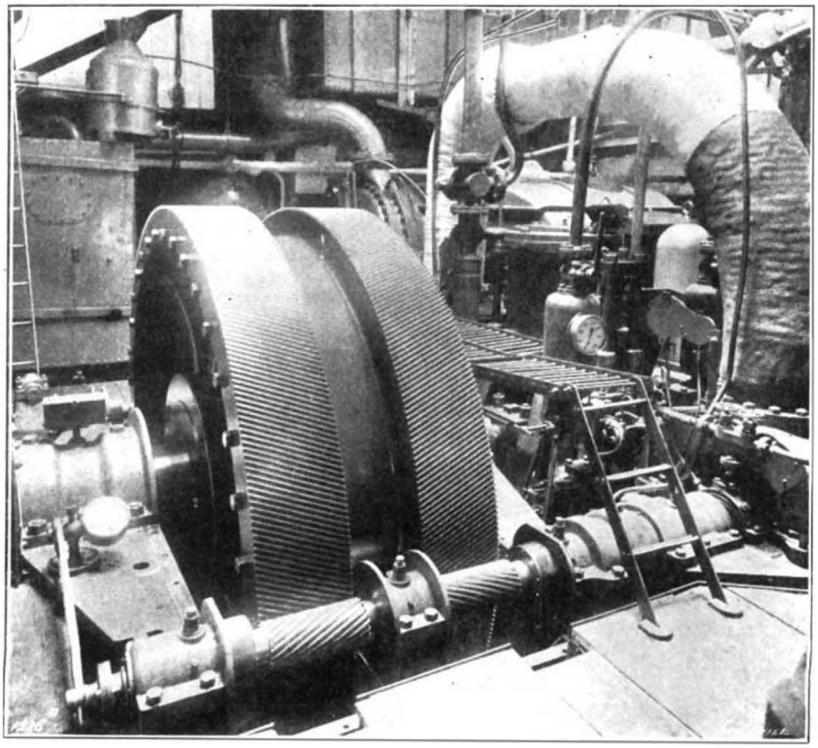

FIG. 3.—The gearing of the *Vespasian*. (From *Engineering*.)

The phenomenon was first observed by Sir John Thornycroft and Mr. Sydney Barnaby. In order to avoid cavitation, which involves great loss of power, propellers in all fast vessels are now made with very wide blades covering about two-thirds of the disc area, which gives a very wide bearing on the water, and prevents its giving way under the force.

In models, and in vessels of moderate speed, the forces are not sufficient to tear the water asunder, but if the pressure of the atmosphere is removed, a model screw will cavitate at a comparatively moderate speed.

The marine turbine, with the modifications we have so far described, is only suitable for vessels of more than 16 knots sea speed, and to make it suitable for the remaining two-thirds of the tonnage of the world has been our constant aim. The first plan to this end to be adopted is somewhat in the nature of a compromise, and is called the combination system, because the reciprocating engine is used to take the first part of the expansion and the turbine to complete it. From what we have said it will be apparent that this coalition of the reciprocating engine and turbine is a good one, because they each work under advantageous conditions. The reciprocating engine expands the steam to about atmospheric pressure, and the turbine carries on the expansion with high efficiency down to the pressure in the condenser. Now, though a large and high-speed turbine deals with the high-pressure portion of the expansion as economically as a reciprocating engine, a slow-speed turbine cannot be made to do so; but, on the other hand, a slow-speed turbine expands low-pressure steam much further and better than any reciprocating engine. In this system the turbine develops about one-third of the whole power.

About fifteen years ago I filed a patent for the system, but, with the exception of fitting the British Admiralty destroyer *Velox* in 1902, few steps were taken towards its application until the turbine had become firmly established for fast vessels, because we feared the technical public would say, "You are trying to bolster up a failure of the turbine." About three years ago Messrs. Denny, of Dumbarton, who in 1901 built the first mercantile turbine vessel, the *King Edward*, built the first combination vessel, the *Otaki*, of 9900 tons dead-weight capacity and 13 knots sea speed. She has ordinary twin screws driven by triple-expansion engines exhausting into a turbine driving a central screw. The initial pressure at the turbine is 9 lb. absolute, and it generates one-third of the whole power. The combination vessel was found to consume 12 per cent. less coal on service than her sister vessel *Orari* on the same service, fitted with quadruple reciprocating engines.

The next combination vessel was the *Laurentic*, of 20,000 tons, built by Messrs. Harland and Wolff, a sister vessel, the *Megantic*, being fitted with quadruple engines, and on service at the same speed the saving in coal by the combination is 14 per cent.

Messrs. Harland and Wolff are also fitting the combination system in the White Star liners *Olympic* and *Titanic*, of 60,000 tons displacement, and some other companies at home and abroad are also adopting the combination system.

There is another alternative solution which promises to extend the field of the turbine further over that of the reciprocating engine. We mentioned before that de Laval had in the 'eighties introduced helical tooth gear for reducing the speed of his little turbines. For twenty-three years it has worked well on a small scale. Recent experiments, however, have led to the assurance of equal success on a large scale for the transmission of large powers of many thousand horse.

After some preliminary experiments some years ago on helical reduction gear, which showed a mechanical efficiency of more than 98 per cent., a 22-feet launch was constructed in 1897; the working speed of the turbine was 20,000 revolutions per minute, which was geared in one reduction of 14 to 1 on to the twin-screw shafting driving twin propellers at about 1400 revolutions. The speed attained was 9 miles per hour, and this little boat was many years in use as a yacht's gig.

The next step was the purchasing of a cargo boat in 1908, the *Vespasian*, of 4350 tons displacement, and triple expansion engines of 900 horse-power. After thoroughly overhauling and testing her existing machinery for coal and water consumption, the engines were replaced by geared turbines, the propeller, shafting, and boilers remaining the same. On again testing for economy a gain of 15 per cent. was shown over the original machinery, and subsequent minor alterations have increased this gain to 22 per cent. There are two turbines, a high pressure and a low pressure, each driving a pinion at 1400 revolutions, gearing into a main wheel on the screw shaft making 70 revolutions per minute. The gearing is entirely enclosed in a casing, and is continually sprayed with oil by a pump. Ordinary centrifugal governors on the turbines control the speed, and because of the enormous angular momentum of turbines (some fifty times that of an ordinary marine engine) the acceleration is so slow that the governors have time to act, and consequently no racing has ever occurred in the heaviest weather, and it is certain that if geared turbines come into use there will be no more cases of broken screw shafting as has hitherto been common with reciprocating engines.

The vessel has now been carrying coal from the Tyne to Rotterdam for about a year, and has covered about 20,000 miles and carried 90,000 tons of coal across the North Sea. The pinion on the lecture table was specially removed from the vessel last week for this lecture, and shows a wear on the teeth of under 2/1000″ in this time, and its life will therefore be equal to or greater than that of a vessel.

Gearing promises to play an important part in war vessels for increasing the economy at cruising speeds. We explained the difficulty in obtaining good economy at the high-pressure end of marine turbines, and in replacing such portions by geared high-speed turbines we have a complete solution. The Turbinia Company are now constructing two 30-knot destroyers of 15,000 horse-power, wherein the high-pressure portion and cruising elements are geared in the ratio of 3 to 1 and 5 to 1 respectively to the main low-pressure, direct-coupled turbine. Their use will increase the radius of action of the vessels at cruising speed to a very considerable extent over that of any similar destroyer without gearing. Similar gearing is proposed for warships, with similar prospective advantages.

Gearing may also find a place in cross-Channel boats and liners for the high-pressure portion of their turbines, but the greatest material gain will be in extending the use of turbines to vessels of slow speed.

Gearing enables very high coefficients to be used in marine work at full speed, and good coefficients at all speeds without much increase in weight, and under such conditions a geared high-speed reaction turbine is much more efficient at the high-pressure end than the multiple impulse wheel or wheels we have considered, and will probably dispense with their use generally. Gearing in marine and land work promises to give to the turbine a level consumption curve like that of the gas and oil engine. Half a century ago nearly all screw vessels had mechanical gearing, one element being composed of wooden teeth, for gearing up the speed of the engine. Subsequently the speed of engines was increased, and gearing abandoned. Now a very slow-speed turbine is an impossibility, and accurately cut steel gearing seems to be a permanent and satisfactory solution.

Low-pressure turbines worked by the exhaust steam from other engines are coming into general use on land under the name of "The utilisation of exhaust steam," for they utilise what was formerly a waste product, the exhaust steam from non-condensing engines.

They are generally employed in the generation of electricity or in the working of blast-furnace blowers and centrifugal pumps and gas forcers, but recently an exhaust turbine of 750 horse-power has been applied to driving an iron plate mill in Scotland. The turbine revolves at 2000 revolutions per minute, and by a double reduction of helical gears drives the mill at 70 revolutions. A flywheel of 100 tons weight revolving at the same speed as the rolls equalises the speed. During each rolling the turbine and flywheel collectively exert 4000 horse-power, the maximum deceleration at the end of each roll being only 7 per cent.

So satisfactory has gearing proved up to the present on a small and also comparatively large scale that it seems probable that by its use turbines will be more widely adopted in the future for power purposes generally.

There are at the present time just above 6,000,000 horse-power of marine turbines completed and building, and also an equal horse-power of land turbines of the compound reaction type.

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE Australasian Association for the Advancement of Science held its thirteenth meeting at the Sydney University on January 9–14 inclusive. In a short article in our issue of February 23 last (vol. lxxxv., p. 558) a brief outline of the proceedings at the meeting was given. We have now received from Mr. J. H. Maiden, the permanent honorary secretary of the association, an extended account of the meetings and presidential addresses delivered in the various sections, and are glad to publish a fuller report of what proved an important and successful gathering of Australasian men of science and their friends.

The president for the year, Prof. Orme Masson, F.R.S., professor of chemistry in the University of Melbourne, presided over the meeting, which was attended by more than 500 members, the membership being above 800. Every State in the Commonwealth was represented, and also the Dominion of New Zealand.

The president gave a garden-party in the afternoon of January 9, and delivered his address in the evening in the Great Hall of the university. His Excellency the Governor, Lord Chelmsford, was in the chair.

The work of the meeting was divided among eleven main sections, each with its own president, vice-president, and secretary. The following is a list of sections with the name of the presidents:—

Section A, Astronomy, Mathematics, and Physics: Prof. T. H. Laby, professor of physics in Victoria College, Wellington, N.Z. Section B, Chemistry, Metallurgy, and Mineralogy: Prof. B. D. Steele, professor of chemistry in the University of Queensland, Brisbane. Section C, Geology: Prof. P. Marshall, professor of geology in the University of Otago, Dunedin, N.Z. Section D, Biology: Mr. F. M. Bailey, Government botanist at Brisbane. Section E, Geography and History: Prof. G. C. Henderson, professor of history in the University of Adelaide. Section F, Anthropology and Philology: Mr. Edward Tregear. Section G—two departments, (1) Social and Statistical Science: Mr. E. W. H. Fowles; (2) Agriculture: Prof. W. Angus, late director of agriculture in Adelaide. Section H, Engineering and Architecture: Mr. Ellwood Mead. Section I, Sanitary Science and Hygiene: Dr. W. Perrin Norris, Commonwealth Director of Quarantine, Melbourne. Section J, Mental Science and Education: the Rev. E. H. Sugden.

Prof. Masson spoke first of the earliest attempts to bring about a visit of the British Association to Australia. In 1909 the matter was brought under the notice of the Australasian Association, of the universities and scientific societies of Australia, and of the Federal and States Governments. All united in cordial support of the proposal, and old financial difficulties were dispelled by the far-sighted generosity of the political rulers. The Government of the Commonwealth, acting officially for all Australia, sent a formal invitation, which was unanimously accepted by the British Association for the year 1914. Prof. Masson said it was his good fortune to attend the Sheffield meeting last September, and to speak there with the High Commissioner as the inviting deputation; and he bore testimony to the hearty feeling that prevailed and to the strong desire shown by many of Britain's most distinguished men of science to profit by this opportunity of seeing Australia, to study its science on the spot, and to play a part in what will surely prove a great event in the history of imperial unity.

He went on to describe recent advances in chemistry. He dealt first with the atomic theory, and proceeded to explain with great clearness ionic dissociation, conductivity through gases, molecular collision, the periodic law, radioactivity, and the transmutation of metals. Towards the end of his address he referred to the theory of the spontaneous transformations of the atom, whereby new kinds of atom, both electrical and material, are produced, some of the latter having but a short life before they in turn