OUR ASTRONOMICAL COLUMN.

ASTRONOMICAL OCCURRENCES IN MARCH.

March 2.	6h.	Mercury in conjunction with moon. Mercury 4° 37′ S.
7.	23h.	Mercury at greatest elongation east (18° 16′).
8.	6h. 13m. to 7h. 3m.	Neptune occulted by the moon.
8.	9h. 31m.	Minimum of Algol (β Persei).
10.	13h. 43m. to 14h. 40m.	Occultation of *f* Geminorum (mag. 5·2) by the moon.
10.	14h. 18m. to 15h. 57m.	Transit of Jupiter's Sat. III.
11.	14h. 13m. to 15h. 6m.	Occultation of 29 Cancri (mag. 5·9) by the moon.
15.	Venus.	Illuminated portion of disc, 0·708. Mars, 0·993.
15.	15h. 20m. to 16h. 25m.	Occultation of *e* Leonis (mag. 5·1) by the moon.
17.	18h. 7m.	Transit (egress) of Jupiter's Sat. III.
21.	17h. 19m. to 17h. 33m.	Occultation of ρ Ophiuchi (mag. 5·3) by the moon.
23.	20h.	Saturn in conjunction with the moon.
23.	20h. 35m. to 21h. 46m.	Occultation of Saturn by the moon.
28.	11h. 12m.	Minimum of Algol (β Persei).
31.	8h. 1m.	Minimum of Algol (β Persei).

COMET GIACOBINI (1900*a*).—The *Astronomische Nachrichten* (Bd. 151, No. 3624) contains an ephemeris and the elements of this comet computed from the observations made on January 31, February 3 and 6, at the Nice Observatory, by M. Giacobini.

Elements.

$$T = 1900 \text{ April } 28{\cdot}2085 \text{ Paris Mean Time.}$$

$$\left.\begin{array}{rrrr} & {}^\circ & {}' & {}'' \\ \omega = & 23 & 8 & 42 \\ \Omega = & 40 & 7 & 29 \\ i = & 146 & 37 & 21 \end{array}\right\} 1900{\cdot}0$$

$$\log q = 0{\cdot}12902$$

Ephemeris for 12h. Paris Mean Time.

1900.	R.A. h. m. s.	Decl. ° ′	log Δ
Feb. 28	2 7 50	+2 19·1	0·304
Mar. 2	5 49	2 55·4	0·310
4	3 54	3 30·9	0·316
6	2 6	4 5·6	0·321
8	2 0 24	+4 39·8	0·327

METEOR PHOTOGRAPHY.—In the *Astronomische Nachrichten* (Bd. 151, No. 3623) Dr. Karl Kostersitz describes the photographic equipment which he employed at the Vienna Observatory for the detection of the Leonid and Bielid meteors in November 1899. A plate accompanies the article, showing the method of mounting the cameras, four of which were used without driving apparatus. The cameras were all fitted with rapid portrait lenses, and great care was taken to accurately orient the plates for subsequent reduction.

MOTIVE POWER. STEAM TURBINES. HIGH SPEED NAVIGATION.[1]

TWENTY centuries ago the political power of Greece was broken, although Grecian civilisation had risen to its zenith. Rome was growing continually stronger, and was rapidly gaining territory by absorbing weaker States. Egypt, older in civilisation than either Greece or Rome, fell, but two centuries later, before the assault of the younger States, and became a Roman province. Her principal city at this time was Alexandria, a great and prosperous city, the centre of the commerce of the world, the home of students and of learned men, its population the wealthiest and most civilised of the then known world.

It is among the relics of that ancient Egyptian civilisation that we find the first records of the early history of the steam-engine. In Alexandria, the home of Euclid, and possibly contemporary with Archimedes, Hero wrote his "Spiritalia seu Pneumatica." It is doubtful if Hero was the inventor of the contrivances and apparatus described in his work; it is more probable that they were devices generally known at the time. Nothing in the text, however, indicates to whom the several machines are to be ascribed. Two of these machines are of special interest. The first utilised the expansive force of air in a closed vessel heated externally, the pneumatic force being applied to the surface of water in other vessels, and the hydraulic force utilised for opening the doors of a Grecian temple, and working other pseudo-magic contrivances.

Then after describing several forms of cylindrical boilers, and the use of the steam jet for accelerating combustion, he comes to the first of a type of steam engine, the steam turbine, which is the subject of our discourse this evening.

This is a veritable steam engine. The cauldron contains water, and is covered by a steam-tight cover, a globe is supported above the cauldron by a pair of tubes, one terminating in a pivot, and the other opening directly through the trunnion joint into the sphere; short bent pipes are attached to diametrically opposite points on the equator. The steam generated in the cauldron passes up into the sphere and issues tangentically from the bent pipes, and by the reaction causes the sphere to rotate.

It seems uncertain whether this machine was ever more than a toy, or whether it was used by the Greek priests for producing motion of apparatus in their temples; but from our experience within the last twenty years it appears that, with some improvements in design and construction, it could have been applied to perform useful work at the date of Hero, and further that, when so improved, it might have claimed a place among economical steam engines, even up to the middle of the present century.

A few years ago I had an engine constructed to test the capabilities of this class of reaction steam turbine, the only difference between this engine and Hero's being that the sphere was abolished, as a useless incumbrance, the arms were made of thin steel tube of oval form, so as to offer the least resistance to their motion, and the whole was enclosed in a cast iron case which was connected to a condenser. When supplied with steam at a pressure of 100 lbs. per square inch, and a vacuum in the case of 27″ of mercury, a speed of 5000 revolutions per minute was attained, and an effective power was realised of 20 horse, and the consumption of steam was only 40 lbs. per brake horse-power. By this very creditable performance, I was encouraged to further test the system, and constructed a compound reaction engine, in which the steam was caused to pass successfully through three pairs of arms on one hollow shaft, each pair being contained in a separate compartment through which the shaft passed, suitable metallic packing preventing the passage of steam from one compartment to the next. The performance of this engine was, however, not superior to that of the single two-arm Hero's engine, for the simple reason that the excessive resistance to motion of the arms in the denser steam of the compartments more than neutralised the gain from the compound form. The performance of this engine was, however, sufficiently good to have it placed on a par with many ordinary steam engines in the middle of the present century.

The great barrier to the introduction of Hero's engine was undoubtedly the excessive speed of revolution necessary to obtain economical results, and with the crude state of mechanical engineering at that time, it would have been a matter of some difficulty to construct the turbine engine with sufficient accuracy of workmanship for satisfactory results, to say nothing of the necessary gearing for applying the power to ordinary useful purposes.

The next steam engine mentioned in history, which is capable of practical and useful development, is Bianca's in 1629. It is of the simplest form, a jet of steam from a steam boiler impinges on a paddle-wheel and blows it round. This form of engine has since 1889 been developed by Dr. De Laval, of Stockholm, with great ingenuity, and is extensively used for moderate powers on the Continent. The speed is, however, necessarily very high in order to obtain economy in steam, and spiral reduction gearing is used in order that the speed of revolution may be reduced for the application of the power. The improvements that have been made in Bianca's steam turbine by De Laval are firstly, the ordinary steam jet is replaced by a diverging conical jet, which permits of the expansion of the steam before it emerges from the jet, and so transforming the

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[1] A Discourse delivered at the Royal Institution on January 26, by the Hon. C. A. Parsons, F.R.S.

potential energy of the high pressure steam into kinetic energy of velocity in the direction of flow.

Secondly, the crude paddle-wheel of Bianca is replaced by a wheel of the strongest steel, fringed round the periphery with little cupped blades of steel, somewhat analogous to the buckets of a Pelton water-wheel.

Lastly, the steel wheel is mounted on a long and somewhat elastic shaft, to allow of its easy and free motion, and on one extremity of this shaft is mounted the pinion of the spiral reduction gear.

The speeds of revolution of the steam wheels of De Laval's turbine are from 10,000 to 30,000 revolutions per minute, according to the size, involving peripheral speeds up to 1200 feet per second, or about one-half the speed of the projectile from a modern cannon. Such speeds are necessary to obtain power economically from the high-pressure steam jet, issuing at from 3000 to 5000 feet per second, as calculated by Rankine.

It is somewhat remarkable that not till a century after Bianca, the piston or ordinary reciprocating engine made its first appearance, in about the year 1705, and has since become one of the chief factors in the great mechanical and engineering growths of the last century. During this period the steam turbine seems to have been, practically speaking, neglected, which is somewhat remarkable in view of the numerous attempts of inventors to construct a rotary engine, attempts which had no practical results.

In the year 1884, the advent of the dynamo-electric machine, and development of mechanical and electrical engineering, created an increased demand for a good high-speed engine. Engineers were becoming more accustomed to high speeds of revolution, for the speed of dynamos was at this time from 1000 to 2000 revolutions per minute, of centrifugal pumps from 300 to 1500, and wood-working machinery from 3000 to 5000; and Sir Charles Wheatstone had made a tiny mirror revolve at a speed of 50,000 revolutions per minute for apparatus for measuring the velocity of light. The problem then presented itself of constructing a steam turbine, or ideal rotary engine, capable of working with good economy of steam at a moderate speed of revolution, and suitable for driving dynamos without the intervention of reduction gearing. To facilitate the problem, the dynamo was also considered with the view of raising its speed of revolution to the level of the lowest permissible speed of the turbine engine. In other words, to secure a successful combination, the turbine had to be made to run as slowly as possible, and the dynamo speed had to be raised as much as possible, and up to the same speed as the turbine, to permit of direct coupling.

In 1884 preliminary experiments were commenced at Gateshead-on-Tyne, with the view of ascertaining by actual trial, the conditions of working equilibrium and steady motion of shafts and bearings at the very high speeds of rotation that appeared to be essential to the construction of an economical steam turbine of moderate size. Trial shafts were run in bearings of different descriptions up to speeds of 40,000 revolutions per minute; these shafts were about 1½ inches in diameter and 2 feet long, the bearings being about ⅜ inch in diameter. No difficulty was experienced in attaining this immense speed, provided that the bearings were designed to have a certain small amount of "give" or elasticity; and after the trial of many devices to secure these conditions, it was found that elasticity, combined with frictional resistance to transverse motion of the bearing bush, gave the best results, and tended to damp out vibrations in the revolving spindle. This result was achieved by a simple arrangement; the bearing in which the shaft revolved was a plain gun-metal bush with a collar at one end and a nut at the other; on this bush were threaded thin washers, each being alternately larger and smaller than its neighbour, the small series fitting the bush and the larger series fitting the hole in the bearing block, these washers occupying the greater part of the length of the bush. Lastly, a wide washer fitted both the bush and block, forming a fulcrum on which the bush rested; while a spiral spring between the washers and the nut on the bush pressed all the washers tightly against their neighbours. It will be seen now that, should the rotating shaft be slightly out of truth (which it is impossible to avoid in practice), the effect is to cause a slight lateral displacement of the bearing bush, which is resisted by the mutual sliding friction of each washer against its neighbour. The shaft itself being slightly elastic, tends to centre itself upon the fulcrum washer before mentioned, under the gyrostatic forces brought into play by the rapid revolutions of the shaft and influenced by the frictional resistance of the washers, and so the shaft tends to assume a steady state of revolution about its principal axis, or the axis of the mass, without wobbling or vibration. This form of bearing was exclusively used for some years in turbine engines aggregating some thousands of horse power, but it has since been replaced by a simpler form fulfilling the same functions. In this later form the gun-metal bush is surrounded by several concentric tubes fitting easily within each other with a very slight lateral play; in the interstices between the tubes the oil enters, and its great viscosity when spread into thin films has the result of producing great frictional resistance to a rapid lateral displacement of the bearing bush; the oil film has also a centring action, and tends under vibration to assume a uniformity of thickness around the axis, thus centring the shaft, and like a cushion damping out vibrations arising from errors of balance. This form of bearing has been found to be very durable and quite satisfactory under all conditions.

Having tested the bearings up to speeds above those contemplated in the steam turbine, the next problem was the turbine itself. The laws regulating the flow of steam being well known (which was not the case in Hero's time), various forms of steam turbine were considered, and it appeared desirable to adopt in principle some type that had been both successful in the water turbine, and also easily adapted to a multiple or compound formation, a construction in which the steam should pass successively through a series of turbines one after the other.

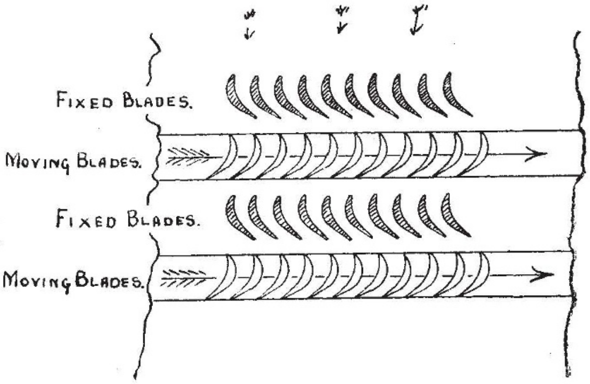

Fig. 1.—Fixed and moving blades of turbine.

The three best known of water turbines are the outward flow, the inward flow, and the parallel flow, and of these the latter appeared to be the best adapted for the multiple of compound steam turbine, for reasons which will afterwards appear.

The object in view being to obtain a good coefficient of efficiency from the steam with a moderate speed of revolution and diameter of turbine wheel, it becomes essential that the steam shall be caused to pass through a large number of successive turbines, with a small difference of pressure urging it through each individual turbine of the set, so that the velocity of flow of the steam may have the proper relation to the peripheral velocity of the turbine blades to secure the highest degree of efficiency from the steam, conditions analogous to those necessary for high efficiency in water turbines. A large diameter of turbine wheel, it is true, would secure a moderate speed of revolution, but this may be dismissed at once for the simple reason that the frictional resistance of such a disc revolving at the immense peripheral velocity, in the exhaust steam, would make it a most inefficient engine.

In the year 1884, a compound steam turbine engine of 10 horse-power and a modified high speed dynamo were designed and built for a working speed of 18,000 revolutions per minute. This machine proved to be practically successful, and subsequently ran for some years doing useful work, and is now in the South Kensington Museum.

This turbine engine consisted of two groups of fifteen successive turbine wheels, or rows of blades, on one drum or shaft within a concentric case on the right and left of the steam inlet, the moving blades or vanes being in circumferential rows projecting outwardly from the shaft, and nearly touching the case, and the fixed or guide blades being similarly formed and projecting inwardly from the case and nearly touching the shaft. A series of turbine wheels on one shaft were thus constituted, each one complete in itself, like a parallel flow water turbine, but unlike a water turbine, the steam after performing its work in each turbine passed on to the next, preserving its longitudinal velocity without shock, gradually falling in pressure on passing through each row of blades and gradually expanding. Each successive row of blades was slightly larger in passage-way than the preceding, to allow for the increasing bulk of the elastic steam, and thus its velocity of flow was regulated so as to operate with the greatest degree of efficiency on each turbine of the series (Fig. 1).

All end pressure from the steam was balanced by the two equal series on each side of the inlet, and the revolving shaft lay on its bearings revolving freely without any impressed force except a steady torque urging rotation, the aggregate of the multitude of minute forces of the steam on each blade. It constituted an ideal rotary engine; but it had faults. The comparatively high speed of rotation that was necessary for so small a size of engine as this first example, made it difficult to prevent, even with the special bearings described, a certain spring or whipping of the massive steel shaft, so that considerable clearances were found necessary, and leakage and loss of efficiency resulted. It was, however, perceived that all these defects would decrease as the size of the engine increased, with a corresponding reduction of rotational velocity, and consequently efforts were made towards the construction of engines of larger size, which resulted, in 1888, in several turbo-alternators of 120 horse-power being supplied for the generation of current in electric lighting stations, and at this period the total horse-power of turbines at work reached in the aggregate about 4000, all of which were of the parallel flow type and non-condensing.

In 1889, in consequence of partnership difficulties and the temporary loss of patents, the radial flow type of turbines was reluctantly adopted. This type of turbine consists of a series of fixed discs with interlocking flanges at the periphery, forming, when placed together, a cylindrical case with inwardly projecting annular discs. On the shaft are keyed a similar set of discs, the faces of the fixed and moving discs lie a short distance apart. From the faces of the fixed discs project the rows of guide-blades which nearly touch the moving disc, and from the moving disc project the rows of moving blades which nearly touch the fixed disc.

The steam is admitted into the case between the balance piston on the left and the first fixed disc, and passes outwards through the rows of fixed and moving blades between the first fixed and moving discs; then inwards towards the shaft at the back of the first moving disc, then again outwards between the second fixed and moving discs, and so on to the exhaust; the action being the same as in the parallel flow type.

In 1892, this type was the first to be adapted to work in conjunction with a condenser. The first condensing turbine of the radial flow type was of 200 horse-power, and at a speed of 4800 revolutions per minute, drove an alternator of 150 kilowatts output. It was tested by Prof. Ewing, and the general result of the trials was to demonstrate that the condensing steam turbine was an exceptionally economical heat engine. With a steam pressure of 100 lbs., the steam being moderately superheated, and a vacuum of 28 inches of mercury, the consumption was 27 lbs. per kilowatt hour, which is equivalent to about 16 lbs. of steam per indicated horse-power. This result marked an era in the development of the steam turbine, and opened for it a wide field, including some of the chief applications of motive power from steam. At this period turbine alternators of the condensing type were placed in the Newcastle, Cambridge and Scarborough Electric Supply Company's Stations, and soon afterwards several of 600 horse-power of the non-condensing parallel flow type were set to work in the Metropolitan Companies' Stations, where the comparative absence of vibration was an important factor. Turbine alternators and turbine dynamos of 2500 horse-power are now in course of construction in England and the United States, and larger sizes are in prospect.

A turbo-alternator manufactured at Heaton Works, Newcastle-on-Tyne, for the Corporation of Elberfeld in Germany, was tested a few days ago by a committee of experts from Germany, Prof. Ewing being also present, with the following remarkable results. At the full load of 1200 kilowatts, and with a steam pressure of 130 lbs. at the engine, and 10° C. of superheat, the engine driving its own air pumps, the consumption of steam was found to be at the rate of 18·8 lbs. per kilowatt hour. To compare this figure with those obtained with ordinary piston engines of the highest recorded efficiencies, and assuming the highest record with which I am acquainted of the ratio of electrical output to the power indicated in the steam engine, namely 85 per cent., the figure of 18·8 lbs. per kilowatt in the turbine plant is equivalent to a consumption of 11·9 lbs. per indicated horse-power, a result surpassing the records of the best steam engines in the production of electricity from steam.

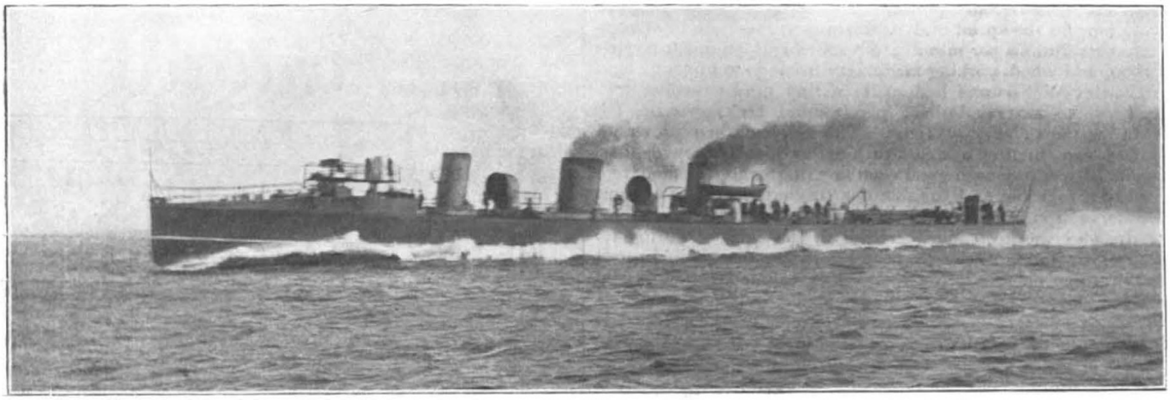

FIG. 2.—The *Viper*.

Turbine engines are also used for generating electrical current for the transmission of power, the working of electrical tramways, electrical pumping and coaling, and similar purposes. They are also used for coupling directly to and driving fans for producing forced and induced draught for general ventilating purposes, also for driving centrifugal pumps for lifts up to 200 feet, and screw pumps for low lifts.

The most important field, however, for the steam turbine is undoubtedly in the propulsion of ships. The large and increasing amount of horse-power and the greater size and speed of the modern engines tend towards some form which shall be light, capable of perfect balancing and economical in steam. The marine engine of the piston type does not entirely fulfil all these requirements, but the compound turbine engine, as made in 1892, appeared to be capable of doing so, and of becoming an ideal marine engine. On the other hand, an element of uncertainty lay in the high speed of the turbine engine, and to couple it directly to a propeller of ordinary proportions would have led to failure.

In January 1894, a pioneer syndicate was formed to explore the problem, those chiefly associated in the undertaking being the Earl of Rosse, Christopher Leyland, John Simpson, Campbell Swinton, Norman Cookson, the late George Clayton, H. C. Harvey, and Gerald Stoney. It was deemed expedient, for reasons of economy and also of time (as many alterations were anticipated), to build as small a vessel as possible, but not so small as to preclude the attainment of an unprecedented high speed in the event of success. The *Turbinia* was constructed, her dimensions being 100 feet in length, 9 feet beam, 3 feet draught of hull, and 44 tons displacement. She was fitted with a turbine engine of 2000 actual horse-power, with an expansive ratio of a hundred-and-fifty-fold, also with a water-tube boiler of great power, of the express type, with small tubes. The turbine engine was designed to drive one screw shaft at a speed of from 2000 to 3000 revolutions per minute.

Many trials were made with screw propellers of various sizes and proportions, but the best speeds were quite disappointing, and it was clear that some radical defect lay in the propellers. This was corroborated by dynamometric measurements. The excessive slip of the propellers beyond the calculated amount, and their inefficiency, indicated a want of sufficient blade area upon which the thrust necessary to drive the ship was distributed, in other words, the water was torn into cavities behind the blades. These cavities contained no air, but only vapour of water, and the greater portion of the power of the engine was consumed in the formation and maintenance of these cavities instead of the propulsion of the vessel. This phenomenon was first noticed in the trials of the torpedo boat *Daring*, by Messrs. Thornycroft and Mr. Barnaby, shortly before the commencement of the trials of the *Turbinia*, and was named "cavitation" by R. E. Froude.

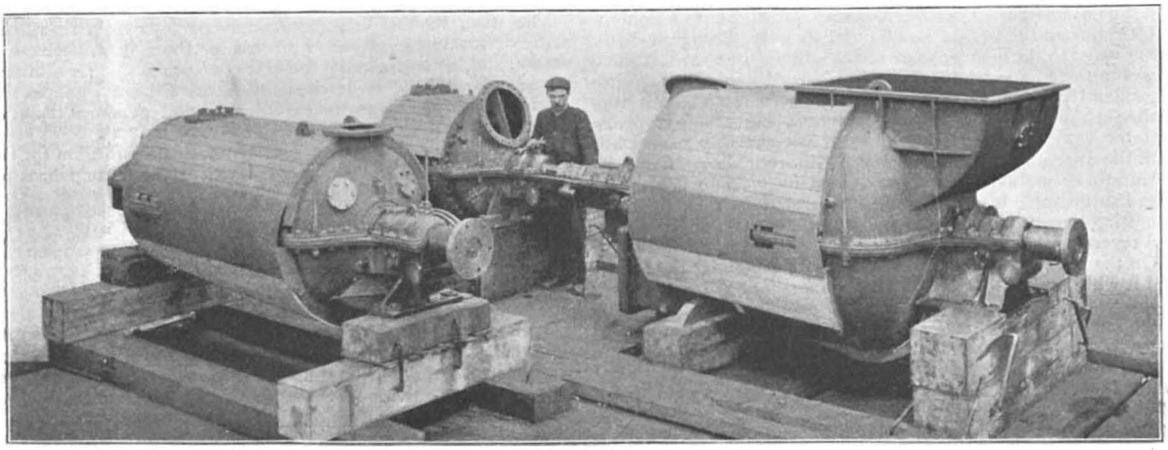

FIG. 3.—Turbine engines of the *Viper*.

This phenomenon has been investigated experimentally with propellers of small size working inside an oval tank, so as to represent approximately the conditions of slip ratio customary in fast ships. To enable the propeller to cause cavitation more easily the tank is closed, and the atmospheric pressure removed from the surface of the water above the propeller by an air-pump, glass windows are fitted for observation and illumination. Under these conditions the only forces tending to hold the water together and resist cavitation are the small head of water above the propeller, and capillarity. The propeller is 2 inches diameter and 3 inches pitch; cavitation commences at about 1200 revolutions and becomes very pronounced at 1500 revolutions. Had the atmospheric pressure not been removed, speeds of 12,000 and 15,000 revolutions per minute would have been necessary, rendering observations more difficult.

The arrangement we have now was kindly suggested by Mr. Heath, and is a decided improvement, the revolving disc with narrow slots synchronising approximately with the revolutions of the propeller. The propeller is now seen to rotate very slowly, it also permits of the projection of the phenomenon on the screen, which was not possible with my previous arrangement. The permanence of the vortices behind the blades is very striking. The inference to be drawn from these experiments seems to be that for fast speeds of vessels, wide thin blades, a coarse pitch ratio, and moderate slip, are desirable for the prevention of cavitation, and in order to obtain the best efficiency in propulsion of the vessel.

To return to the *Turbinia*, a radical alteration was deemed necessary. A new turbine engine was made, consisting of three separate engines, high pressure, intermediate pressure, and low pressure, each of which drove one screw shaft, the power of the engine was distributed over three shafts instead of being concentrated on one, and three propellers were placed on each shaft. The result of these changes was marvellous. The vessel now nearly doubled her speed, 30 knots was soon reached, and finally $32\frac{3}{4}$ knots mean speed on the measured mile authenticated, or the fastest speed then attained by any vessel afloat. The economy of her engines was investigated by Prof. Ewing, assisted by Prof. Dunkerly, the consumption of steam per indicated horse-power for all purposes at 31 knots speed was found to be $14\frac{1}{2}$ lbs., or in other words, with a good marine boiler the coal consumption would be considerably under 2 lbs. per indicated horse-power, a result better than is obtained in torpedo boats or torpedo-boat destroyers with ordinary triple expansion engines.

The vessel's reversing turbine gave her an astern speed of $6\frac{1}{2}$ knots, and she could be brought to rest in 36 seconds when running at 30 knots speed, and from rest she could be brought up to 30 knots in 40 seconds.

The *Turbinia* cruised from the Tyne to the Naval Review at Spithead, where she steamed on the day of the Review at an estimated speed of $34\frac{1}{2}$ knots. These results represent about 2300 indicated horse-power, and may be said to have been obtained without a very abnormal performance as regards the boiler; its total heating surface being 1100 square feet, and an evaporation of about 28 lbs. per square foot at the speed of $34\frac{1}{2}$ knots.

These speeds were not obtained by bottling up the steam and opening the regulating valve on coming to the measured mile, but were maintained for many miles together with constant steam pressure, and as long as the fires were clean. On the other hand, the endurance of the engines themselves seems to be unlimited, all heavy pressures, including the thrust of the propellers, that would in ordinary engines came on the bearings, being counterbalanced by the steam pressure acting on the turbines.

It seems clear that the results obtained in the case of the *Turbinia* were almost entirely due to the economy in steam of the turbine engines, and the unusually small weight of the engines, shafting and propellers, in proportion to the power developed.

It may also be said that generally speaking every part or the machinery was as substantial as in naval vessels of the torpedo-boat class, yet she developed 100 horse-power per ton of machinery, and 50 horse-power per ton of total weight of vessel in working order.

The results of the *Turbinia* having been found satisfactory, the original company which built her was merged into a large company under the same directorate for carrying on the work on a commercial scale. At Wallsend-on-Tyne, the Parsons Marine Steam Turbine Company erected works, and in 1898 contracted with the Admiralty for a 31-knot torpedo-boat destroyer, the *Viper* (Fig. 2), which is of the same dimensions as the usual 30-knot vessels of this class, viz. 210 feet length, 21 feet beam, and about 350 tons displacement, but with machinery of much greater power than usual in vessels of this size; they also contracted with Sir W. G. Armstrong, Whitworth and Co. for machinery for one of their torpedo-boat destroyers.

The turbine engines of these vessels are similar to those of the *Turbina*, but are in duplicate, and consist of two distinct sets of engines on each side of the vessel. There are four screw shafts in all, entirely independent of each other, the two on each side being driven by one high and one low-pressure turbine respectively of about equal power; the two low-pressure turbines drive the two inner shafts, and to each a small reversing turbine is also permanently coupled, and revolves idly with them when going ahead. The screw shafts are carried by brackets as usual, and two propellers are placed on each shaft, the foremost in each case having a slightly lesser pitch than the after one. The thrust from the screw shafts is entirely balanced by the steam acting on the turbines, so that there is extremely little friction.

The boilers, auxiliary machinery and condensers are of the usual type in such vessels, but their size is somewhat increased to meet the much larger horse-power to be developed, and to compensate for the lesser weight of the main engines, shafting, propellers, as well as the lighter structure of the engine beds. The boilers are of the Yarrow type, with a total heating surface of 15,000 square feet, and grate surface of 272 square feet, and the condensers have a cooling surface of 8000 square feet. The hull and all fittings are of the usual design.

Let us consider the machinery on one side of the vessel only: the steam from the boilers is admitted directly through a regulating valve to the high-pressure turbine driving one shaft, it then passes to the adjacent low-pressure turbine, driving its shaft independently, thence it flows to the condenser, and both the shafts then drive the vessel ahead; the reversing turbine revolves with the low-pressure shaft, and being permanently connected with the vacuum of the condenser no appreciable resistance is offered to its motion under these conditions. To go astern the ahead steam valve is closed and the astern steam valve opened, admitting the steam from the boilers to the reversing turbine, and reversing the direction of rotation of the inner screw shaft.

On the other side of the vessel the arrangement is the same, and it will be seen that she can be manœuvred as an ordinary twin-screw vessel, and with great facility and quickness.

On her second preliminary trial about three weeks ago, the mean speed of four consecutive runs on the measured mile reached 34·8 knots, and the fastest run was at the speed of 35·503 knots, which is believed to be considerably beyond the recorded speed of any vessel hitherto built. The vessel was scarcely completed at the time of this trial, and it is anticipated that still higher speeds will be realised on subsequent and official trials. The speed of 35·5 knots, or nearly 41 statute miles, represents about 11,000 indicated horse-power in a vessel of 350 tons displacement, as compared with 6000 to 6500 developed in the 30-knot destroyers of similar dimensions and 310 tons displacement.

At all speeds there was very little vibration. Her speed astern is guaranteed to be 15½ knots.

The *Viper* has surpassed the *Turbinia* in speed, and is at the present time the fastest vessel afloat.

In regard to the general application of turbine machinery to large ships, the conditions appear to be more favourable in the faster class of vessels, such as cross-Channel boats, fast passenger vessels, liners, cruisers and battleships; in all such vessels the reduction in weight of machinery, and economy in the consumption of coal per horse-power, are important factors; in some the absence of vibration is a question of first importance, as affecting the comfort of passengers, and, in the case of ships of war, permitting of greater accuracy in sighting of the guns.

The model exhibited represents a proposed cross-Channel boat for the Dover and Calais or Newhaven and Dieppe routes. She is 270 feet length, 33 feet beam, 1000 tons displacement, and 8 feet 6 inches draught of water. She has spacious accommodation for 600 passengers, and with machinery developing 18,000 horse-power would have a sea speed of about 30 knots as compared with the speed of 19 to 22 knots of the present vessels of similar size and accommodation.

It is perhaps interesting to examine the possibilities of speed that might be attained in a special unarmoured cruiser, a magnified torpedo-boat destroyer of light build, with scanty accommodation for her large crew, but equipped with an armament of light guns and torpedoes. Let us assume that her dimensions are about double those of the 30-knot destroyers, or of the *Viper*, with plates of double the thickness, and specially strengthened to correspond with the increased size and speed, length 420 feet, beam 42 feet, maximum draught 14 feet, displacement 2800 tons, indicated horse-power 80,000, there would be two tiers of water-tube express boilers, these, the engines and coal bunkers, would occupy the whole of the lower portion of the vessel, the crew's quarters and armaments would be on the upper decks. There would be eight propellers of 9 feet in diameter, revolving at about 400 revolutions per minute, and her speed would be 44 knots. She could carry coal at this speed for about eight hours, and she would be able to steam at from 10 to 14 knots, with a small section of the boilers and supplemental machinery, more economically than other vessels of similar size, and of ordinary type and power, and when required all the boilers could be used, and full power exerted in about half an hour.

In the case of an Atlantic liner or a cruiser of large size, turbine engines would effect a reduction in weight of machinery, and also increased economy in fuel, tending either to a saving in coal on the one hand, or, if preferred, to some increase in speed on the same coal consumption per voyage.

In conclusion, it may be remarked that in the history of engineering progress, the laws of natural selection generally operate in favour of those methods which are characterised by the greater simplicity and greater economy, whether these advantages be great or small.

The work in this undertaking has perhaps been slow, but many difficulties were met with besides those of a mechanical nature, and, as is generally the case, the success so far attained has been largely due to devoted colleagues and staff, and in the marine developments to the enterprising and generous financial assistance.

My thanks are due to the officials of this Institution for the kind assistance they have afforded me in the arrangement of the apparatus.

ADVANCEMENT OF ELECTRICAL CHEMISTRY.

ON reviewing the science of electro-chemistry and its application to modern manufacturing processes, one is struck with amazement at the enormous strides which have been made within the last ten or twenty years. On studying works on chemistry little more than ten years old, hardly a reference is found to the use of electricity in metallurgy, still less in regard to the manufacture of metallic salts, or of the non-metals, and absolutely none in reference to the preparation of organic chemical bodies, at any rate on a large scale.

We are told that in 1808 Sir Humphrey Davy discovered the metals—sodium and potassium—by the electrolysis of their moist hydroxides; we are then informed that they are now manufactured by the much cheaper method of heating the carbonates with charcoal and chalk, or the hydroxides with carbide of iron. To-day we find a retrograde step has been taken, and that they are manufactured by the vastly cheaper method of electrolysing their chlorides or hydroxides.

Notwithstanding that Faraday and others early in the nineteenth century had shown that metals could be deposited, from the solutions of their salts, upon other metals by means of an electric current, and Faraday had, in 1833, formulated his law that "The amount of any substance liberated is proportional to the total quantity of electricity passed through the solution," and that "the amount of different substances liberated by the same quantity of electricity are in the ratio of their chemical equivalents"; electricity until quite recently was not used as an adjunct to chemical analysis. Within the last few years electro-chemical analysis has been very much studied, and now most laboratories *abroad* are fitted with special apparatus for this class of analysis. It is to be feared that in this country we are hardly so advanced.

Within the last thirty years the process for depositing metals from their solutions, and so obtaining moulds for casting, &c., has not undergone any very radical changes, but the means at our disposal for carrying out the work have enormously improved.