SOME NOTES ON THE PARSONS STEAM TURBINE.

Read by Mr. W. J. Newbigin, 3rd June, 1903.

Probably no one has a better conception of the truth of the first law of motion than the reformer. Every great progressive movement, whether it be social, political, or mechanical, has sooner or later to encounter that form of national inertia which is commonly called prejudice.

Progress in any direction is usually so gradual that public opinion is kept in touch with every new development without much conscious effort. It is only when the development is of an almost revolutionary character that the general objection to sudden change is made manifest.

No better illustration could be had of this than in the progress and development of the steam turbine.

The public has had over a century to assimilate the daring theories which first found practical expression at the hands of Newcomen and Watt. The process of evolution, however, from those primitive types of prime mover to the marvels of mechanical ingenuity seen to-day in our steamships and power houses has been so gradual that it has been regarded as a natural growth rather than as a mechanical revolution. The turbine enthusiast has set himself the task of endeavouring to eradicate in a decade opinions which are founded on the experience and knowledge of a century. To anyone whose whole professional life has been spent among turbines, the difficulty is in realising what first prompted the design of a reciprocating engine. A single impulse "Hero" engine was built a few years ago, which gave a steam consumption of only 40 lbs. per B.H.P., at an output of 20 H.P. A result like that from an engine which was virtually designed 2000 years ago is a striking commentary on the perversity which developed the economical use of the energy of steam along wholly different lines.

The mechanically successful steam turbine dates from about 1884, but the birth of the commercially successful one must be placed some eight years later. The Hon. C. A. Parsons and Dr. G. De Laval were both engaged on the turbine problem in the early eighties, though they attacked the question from totally different sides. Mr. Parsons was then engaged on his parallel flow multiple expansion type, while Dr. De Laval was following up Hero's original idea with a simple reaction turbine. A number of sets from both these designs were built and set to successful work, though it cannot be denied that from an efficiency point of view they left much to be desired.

The first important improvements came about 1890, when
Dr. Laval discarded the reaction type in favour of the present expanding nozzle pattern, while Mr. Parsons, with increased experience, was effecting improvements in design with a view of bringing the steam consumption within reasonable bounds.

Perhaps the real turning point in the career of the Parsons' turbine was reached in 1892, when Prof. Ewing, of Cambridge, carried out an exhaustive series of tests on a 150 K.W. alternator, directly coupled to a compound condensing turbine of about 200 B.H.P.

With 1001lbs. steam pressure, 28 inch vacuum, and a moderate superheat, the result recorded was 27lbs. steam per Kilowatt hour—equivalent to 16lbs. steam per I.H.P. in a reciprocating engine. This result is one which requires no apology to-day, but obtained as it was 11 years ago, it lifted the turbine at once into the front rank as an economical prime mover.

Following on this test, steam turbines of 150 Kilowatts and upwards were supplied to the electric power stations of Newcastle-on-Tyne, Scarborough, Cambridge, and Portsmouth, and with these larger sizes and the benefits arising from fuller knowledge, the ultimate success of the steam turbine became assured.

The development from the somewhat crude 10 H.P. turbine of 1884 at 18,000 revolutions to the 200 H.P. turbine of 1892 at 5000 revolutions, is perhaps less interesting than the more mature growth of later years. This 150 Kilowatt set was soon followed by a large number of 350 Kilowatt plants for the Metropolitan Co., while 500 Kilowatt sets were undertaken almost simultaneously.

A number of these were running before the next important increase in size took place in connection with the extensions at Elberfeld, where two 1250 Kilowatt sets were installed in 1900. Since the Elberfeld order, numerous machines of from 1000 K.W. to 3000 K.W. have been constructed and supplied, while sets of 5000 K.W., or, say, 7500 H.P. are now under construction.

Concurrently with the development of his turbine electric combination, Mr. Parsons had been experimenting along other lines, and while the original steam turbine was finding its feet, younger industries were being carefully nursed into sturdy childhood.

One of the most important of these branches was, of course, the adaptation of the steam turbine to the propulsion of vessels.

A commencement was made with the "Turbinia" in 1894, and the history of those early experiments is now well known. Engines capable of developing 2000 H.P. at about 2000 revolutions per minute were put into a hull. 100ft. x 9ft. x 3ft. draught, the total displacement being only 44 tons. The insufficiency of blade area, combined with the high speed of rotation caused cavitation troubles which rendered the experi-
ments of little value, and drastic alterations were carried out. The single turbine was replaced by one of similar aggregate power, divided into three separate cylinders, high pressure, intermediate and low; each cylinder carried its own propeller shaft, and on each shaft were mounted three propellers. The Turbinia, with her altered propelling machinery, then began a series of trials which culminated in a speed of 34\(\frac{1}{2}\) knots, with an equivalent indicated horse power of about 2300.

Thus, while the turbine alternator was justifying its existence on land, the Turbinia was marking the advent of a new era afloat. It is interesting to note that at the time of the Turbinia's trials the record for a boat of her size and displacement was 24 knots, so that she had the somewhat unusual honour of beating an existing record by over 40 per cent.

It only remains for some one to discover a cheap fuel with about 80 times the calorific value of Welsh coal per unit bulk to enable the Turbinia to bring out the English mail in 11 to 12 days.

The phenomenal run of the Turbinia at the Naval Review of 1897 did for the marine turbine what Professor Ewing's report did for the turbine alternator, and the following year the Admiralty placed an order for a 31-knot Destroyer. This boat, the "Viper," was of the same general dimensions as the usual type of 30-knot destroyers, which had a length of about 210 feet, with a displacement of 350 tons. The most striking point of difference was the fact that the turbine engines of the "Viper" were capable of developing over 12,000 horse power as against the 6000 horse power available in her sister ships. The maximum speed attained by the "Viper" was a little over 37 knots, while on her full speed trial she maintained a speed of 36\(\frac{1}{2}\) knots for one hour, a result which is yet to be surpassed.

The "Cobra," a similar vessel to the "Viper," but slightly less powerful, was subsequently supplied to the Admiralty, but as will be remembered, both these vessels were lost, through accidents in no way attributable to their method of propulsion.

The great difficulty in high-speed turbine propulsion is in providing for an economical cruising speed. The torpedo boat destroyers, while capable of very high speeds in emergency, cruise at speeds which require only a small fraction of their maximum power. With turbine dynamos the speed is independent of the output, and owing to the small "idle work" in the turbine, high efficiencies are possible even at small fractional loads. With the marine turbine the conditions are entirely different, and to run such a turbine at a speed corresponding to six or eight per cent. of its maximum output is to seriously impair its efficiency.

In more recent destroyers this difficulty is being overcome by the addition of a small auxiliary H.P. cylinder, through which the steam is taken at cruising speeds. This auxiliary
H.P. then exhausting into the main turbine cylinders, which are in communication with the condenser. This arrangement enables good economy to be obtained at all speeds up to the maximum.

At present the most important field for the marine turbine would appear to be for vessels such as mail steamers, large ferry boats, fast excursion steamers, and yachts, which are designed for continuous speeds of 15 knots and upwards. Several such boats are now completed, and under construction—including the Clyde excursion steamers “King Edward” and “Queen Alexandra,” which have lengths 250 and 270 feet, and speeds of 20 and 21½ knots respectively. The first-named was launched in 1901, and the second the following year, and both have been in regular work since with gratifying results.

The small steam yacht “Tarantula” did 25½ knots on her trials last year, and two large ocean-going yachts of somewhat less speed have recently been launched. Two fast cross-Channel boats, with a length of about 300 feet and a guaranteed speed of 21 knots, are expected to be ready for service during the ensuing summer.

Further orders have recently been placed by the Admiralty, and a second-class cruiser is at present under construction, in addition to two destroyers of similar type to the ill-fated “Viper.”

Not the least difficulty in connection with the commercial development of the steam turbine has been in the design of rotary apparatus (other than electrical machinery) for various mechanical operations previously regarded as essentially reciprocating. It is not until it becomes necessary to dispense with them that one realises the extent to which cranks and valve motions have woven themselves into the engineering fabric.

Had centrifugal pumps been better understood and positive means of driving them been available 100 years ago, it is hardly likely that the ram pump would have held the field as it does to-day.

The system of imparting velocity to an incompressible body, such as water, and then bringing it to rest and reversing its direction of motion, can only have been the work of a man at his wits’ end to make a fluid flow uphill. The complication of valves, cranks, glands, and guides is evidence enough of the difficulty that was encountered.

In spite of the simplicity of the centrifugal pump, it has been largely neglected because of the practical difficulty of driving a high-speed rotary mechanism by means of a slow-speed reciprocating prime mover. On the principle of affinity, a rotary motor can alone make a rotary pump, a satisfactory substitute for its more positive and less simple rival. That the mechanical efficiency of the centrifugal is less than that of the ram
pump may be granted, but the commercial efficiency of the former is certainly superior. The Engineer is sometimes prone to lose sight of the annual maintenance and interest bill in the face of the weekly coal accounts. Further than this, the greater margin of inefficiency in the centrifugal makes greater improvement possible, now that scientific minds are actively studying the problem.

Given a positive rotary drive, there is practically no limit to the head available with a suitably designed centrifugal. Several makers are at present prepared to build up to 1000 ft. head, and greater heads are quite within the range of practical engineering.

A turbine-driven centrifugal consisting of three pumps coupled in series on one shaft, and running at a speed of 3700 revolutions per minute, recently delivered 1,728,000 gallons per day, against a total head of 950 feet. This gives a water horse power of 345, the steam consumption with 90 lbs. steam pressure was only 28 lbs. per water horse power, the pump efficiency being over 55 per cent. Though detailed figures are not yet to hand, it is stated that the actual water horse power is 34 per cent. of the power obtainable from a theoretically perfect steam engine working between the same temperature limits, which is a result that hardly requires to be emphasised. When it is considered that these pumps contain no valves, no plunger, or gland packings, and that the one moving part can be carried in the hand, the importance of this development will be apparent.

A similar pump has just been completed to deliver either 3½ million gallons to a height of 240 feet or 10 million gallons to a height of 80 feet, depending on whether the three pump deliveries are coupled together "in series" or "in parallel," the efficiency being practically the same in either case.

There is every reason to believe that means of usefully utilising the kinetic energy of the water leaving the runner of a centrifugal pump may yet be discovered, when a pump efficiency of 90 per cent. may be looked for. More difficult problems than this have been solved by engineers, and the advent of such a machine would give an impetus to centrifugal pumps which would have far-reaching consequences. The pumping set previously mentioned had a steam consumption of only 15½ lbs. per B.H.P., which could be easily reduced with higher steam pressure and increased superheat; such a set with a 90 per cent. efficiency pump would then have a steam consumption of, say, 17 lbs. per water horse, which for absolute coal economy would run any triple expansion three throw pump very close. The high-lift centrifugal is young as yet, and the 55 per cent. efficiency far from representing finality is merely an earnest of what may reasonably be expected.
Another type of plant which has previously been regarded as essentially of a reciprocating nature has been recently adapted to turbine driving. The steam turbine is practically reversible, and, therefore, if it is possible to rotate a shaft by the expansion of a gas, it ought to be equally possible to compress a gas by rotating the shaft. This is in effect the turbine air compressor. The steam turbine is directly coupled to a similar machine having its blades turned the reverse way, the rotation of the shaft of this second turbine enables the air to be compressed to any desired extent. The simplicity of this arrangement is not its only feature, since even with the small amount of experience gained the steam consumption compares favourably with any of the existing types of compressor.

This plant may be modified to include the whole range of air compression from, say, half inch water gauge to 120lbs. air pressure.

For ventilating purposes up to, say, 10 inch water gauge, the numerous small blades of the turbine are replaced by a screw fan or propellor, having only four or more blades, and this fan runs in the neck of a coned iron chimney. The simplicity of these fans has led to their introduction for many other purposes than ventilation; one has been running for eight years in lead fumes at a temperature of 500 deg. F., in a lead-reduction works, while another runs in the main flue to create induced draught for a battery of boilers. Of course, in both these cases the main bearings are outside the flues.

A small electrically-driven turbo blower was recently tested; the output was 3500 cubic feet of air per minute at a pressure of 2lbs., and the overall efficiency was 60 per cent. More recently a blower was supplied, having an output of 11,000 cubic feet of free air per minute at 3lbs. pressure; the combination had a speed of about 5300 revolutions per minute. The useful output of air was 61 per cent. of the power obtainable from a theoretically perfect steam engine working between the same limits of pressure and temperature.

By dividing the air cylinder into two or more stages, and providing water jackets and intercoolers, any desired air pressure may be attained. The higher air pressures, of course, requiring a greater number of rows of blades to effect the compression. A two-stage compressor of this type is now under construction for one of the South African gold mines; it will compress 4000 cubic feet of free air per minute to a pressure of 80lbs., and it is anticipated that the steam consumption will be considerably below that of the existing sets.

With these compressors, however, as with centrifugal pumps, the absence of valves and motion gear of every description is a factor of great importance, more especially where skilled men are scarce and dear, and repairs hard to effect. A compressor which is valveless, continuous in its action, and simple in its
NOTES ON THE PARSONS STEAM TURBINE.

requirements, has advantages which would outweigh even the question of absolute economy if that should ever be necessary. The machine that will do its allotted work with the smallest number of moving parts possesses one of the fundamental characteristics of success, and when efficiency and reliability are added to simplicity, the future of that particular machine should be assured.

The steam turbine of 20 years ago was little better than a toy, while the steam turbine of to-day is doing a fair share of the world's work on sea and land. When it is considered that in 17 years the turbine developed from a 10 horse power set to a 12,000 horse power set, and that about half a million H.P. are in use to-day, it is difficult to place a limit to the progress of the next decade.

That the steam turbine will completely replace the reciprocating engine seems at present unlikely, but that the turbine will encroach more and more on the others' preserve may be taken for granted.

Unfortunately, there are grave difficulties in the way of constructing a satisfactory slow-speed turbine, and all known forms of mechanical gearing have proved wanting when employed for large powers and high speeds. The only other alternative is to increase the speed of existing apparatus until it becomes suitable for turbine driving. This has already been done in the case of the dynamo, the screw propeller, the centrifugal pump, and the air compressor; and there is no reason to suppose that the list is incapable of further extension.

The increasing use of dynamos and motors as a means of transmitting energy has drawn attention to the superiority of rotary apparatus, and there seems little doubt but that except for special purposes the reciprocating engine will gradually fall into disuse. Familiarity with steam engine practice has resulted in the production of a few machine tools, such as planers and shapers, which require a longitudinal motion, but even there the reciprocating motion of the engine piston has to undergo double conversion before it can be applied to the tool.

For very large powers steam turbines can be run at speeds which render rope transmission possible. Engine power up to 2000 B.H.P. is not uncommon in large textile factories, and a turbine of that power could run very efficiently at 1000 revolutions per minute. Allowing a rope speed of 85 feet per second, we get a driving pulley of nearly 20 inches diameter, which would appear to be large enough for small pliable ropes. Of course, under these conditions a very large number of ropes would be necessary, but the other advantages of the plant might be expected to outweigh that. Apparently, about 80 to 85 feet per second is the limiting speed for large ropes, as beyond this speed the centrifugal tension increases more
rapidly than the useful power transmitted. From published data, however, it would appear that ropes of one inch diameter and under may be run economically at speeds from 90 to 100 feet per second. Common practice seems to give a minimum pulley diameter of from 30 to 40 times the rope diameter; as to whether or not this is the actual limiting size would have to be determined by experiment. Probably it would be found that smaller pulleys could be used without serious detriment to the rope, provided the ropes were pliable and of moderate diameter. Thus, for 2000 B.H.P. at 85 feet per second about 140, 1-inch ropes would be required, while less than half that number would suffice if ½ inch ropes would run on a 10 inch radius without damage.

For transmitting small powers the writer has seen cotton belts running on a 4 inch pulley at speeds up to 200 feet per second, while some of the small cream separator belts have run at speeds almost as great. Unfortunately little or no data is available as to the life of belts under these conditions.

The data given may perhaps serve to show that the turbine’s sphere of usefulness is less restricted than has been commonly supposed, and that the driving of electrical apparatus is not its only function.

The progress of the turbine has continued at an ever increasing rate of acceleration, from which it may be inferred that the resistance to motion is being steadily reduced, or that the actuating force is being augmented. Probably both these factors are contributing to the result; waning prejudice and wider production are co-operating to place the turbine in its true position.

With reference to the production, it is only necessary to study the patent records or the technical journals to see the attention which the turbine is receiving at the hands of engineers.

The Westinghouse Co., of Pittsburg, who hold the Parsons’ patents in America, have already supplied a number of turbine sets of 1500 K.W. and upwards, while more recently the British Westinghouse Co. have made extensive provision at their Trafford Park Works to build Parsons’ turbines on a large scale under license. Messrs. Brown, Boveri and Co., of Baden, as the Continental licensees, are also turning out Parsons’ turbines of large size, combined with their well-known electrical plant. This firm has supplied sets of 2000 Kilowatts and larger ones are under construction. The hold that the turbine has obtained over the electrical industry is further evidenced by the fact that many of the largest electrical firms are now placing steam turbines on the market. Among these may be cited the turbine of Professor Stumpf, of Berlin, which is being manufactured by the Allgemeine Co. This turbine is similar in general design to that of Dr. De Laval, and consists
of a number of conical jets discharging against the rim of a disc carrying buckets not unlike those of the Pelton water wheel.

The Curtis steam turbine is another which has been only recently placed on the market by the General Electric Co. of America. Many other turbines are at the present time either complete or in process of development, amongst them being the Seger, the Ratteau, the Brady and the Marsh. Most of these are variants of either the De Laval or the Parsons, the multiple expansion type of De Laval perhaps claiming the larger proportion.

It is, perhaps, too early to speak of the gas turbine, since it has not materialised as yet, although many minds are engaged on the problem. If, however, future improvement is to be looked for in the elimination of the steam boiler from our power stations, it is not likely that the turbine will be found wanting. Its property of maintaining its cylinder walls at constant temperature for constant loads should make it the most suitable type of prime mover in a system which essentially requires high initial and low terminal temperatures. A gas engine without a water jacket and without cylinder lubrication should possess a commercial efficiency unknown to-day.

Though it is not in the engineer's province to prophesy, there seems little doubt that in future, where high speed or even moderate speed rotary motion is required it will be generated and transmitted in that form, and the reciprocating engine will be relegated to those special duties for which its great weight, slow speed, and somewhat erratic motion so eminently fit it.

**Table I.**

**Approximate Weights and Sizes, etc.**

**Standard Parsons Steam Turbines.**

<table>
<thead>
<tr>
<th>Normal Output B.H.P.</th>
<th>Average Speed (Revs. per minute)</th>
<th>R.H.P. per square foot of floor space</th>
<th>Total Weight in lbs. per B.H.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4,000—5,000</td>
<td>2.7</td>
<td>67</td>
</tr>
<tr>
<td>250</td>
<td>3,000—4,000</td>
<td>4.6</td>
<td>36</td>
</tr>
<tr>
<td>500</td>
<td>2,500—3,000</td>
<td>6.3</td>
<td>25</td>
</tr>
<tr>
<td>1,000</td>
<td>1,800—3,000</td>
<td>8.0</td>
<td>24</td>
</tr>
<tr>
<td>2,000</td>
<td>1,000—1,500</td>
<td>10.0</td>
<td>22</td>
</tr>
<tr>
<td>4,000</td>
<td>750—1,200</td>
<td>16.0</td>
<td>18</td>
</tr>
<tr>
<td>7,000</td>
<td>750—1,200</td>
<td>19.0</td>
<td>16</td>
</tr>
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</table>
## Table II.
### Various Steam Consumption Tests.
**Parsons Turbo Dynamos and Alternators.**

<table>
<thead>
<tr>
<th>Rating of Machine in K.W.</th>
<th>Dynamo or Alternator</th>
<th>Speed in Revs. per Minute</th>
<th>Steam Pressure lbs. per sq. inch.</th>
<th>Vacuum at Turbo Cylinder.</th>
<th>Supersat in degrees Abs.</th>
<th>Load at time of test.</th>
<th>Steam used in lbs. per Kilowatt.</th>
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</thead>
<tbody>
<tr>
<td>24</td>
<td>Dynamo</td>
<td>5,000</td>
<td>80</td>
<td>28.8</td>
<td>0</td>
<td>24.7</td>
<td>28.8</td>
</tr>
<tr>
<td>50</td>
<td>Alternator</td>
<td>5,000</td>
<td>126</td>
<td>28.0</td>
<td>0</td>
<td>52.7</td>
<td>28.0</td>
</tr>
<tr>
<td>100</td>
<td>Dynamo</td>
<td>3,700</td>
<td>100</td>
<td>28.8</td>
<td>84°</td>
<td>119</td>
<td>24.3</td>
</tr>
<tr>
<td>200</td>
<td>Dynamo</td>
<td>3,000</td>
<td>129</td>
<td>27.6</td>
<td>58°</td>
<td>226</td>
<td>22.0</td>
</tr>
<tr>
<td>500</td>
<td>Alternator</td>
<td>2,500</td>
<td>133</td>
<td>27.3</td>
<td>66°</td>
<td>507</td>
<td>21.1</td>
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<tr>
<td>750</td>
<td>Dynamo</td>
<td>2,300</td>
<td>115</td>
<td>26.5</td>
<td>0</td>
<td>800</td>
<td>21.9</td>
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<tr>
<td>1,500</td>
<td>Alternator</td>
<td>1,200</td>
<td>196</td>
<td>27.4</td>
<td>76°</td>
<td>1,440</td>
<td>18.0</td>
</tr>
</tbody>
</table>

## Table III.
### Showing Value of Vacuum in Expansive Engines.
**Steam Pressure 100 lbs. (Gauge). Temperature 338° F.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Final Pressure Vacuum in inches</th>
<th>Final Temperature Degrees Fah.</th>
<th>Heat Efficiency of Perfect Steam Engine between Temperatures</th>
<th>Steam Consumption, lbs. per B.H.P. per hour in a perfect Engine.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>Absolute Zero 32°F</td>
<td>100 per cent.</td>
<td>2.14</td>
</tr>
<tr>
<td>2</td>
<td>29.8</td>
<td>32°F</td>
<td></td>
<td>6.3</td>
</tr>
<tr>
<td>3</td>
<td>29.5</td>
<td>60°F</td>
<td></td>
<td>7.07</td>
</tr>
<tr>
<td>4</td>
<td>29.0</td>
<td>80°F</td>
<td></td>
<td>7.7</td>
</tr>
<tr>
<td>5</td>
<td>28.1</td>
<td>100°F</td>
<td></td>
<td>8.45</td>
</tr>
<tr>
<td>6</td>
<td>26.6</td>
<td>120°F</td>
<td></td>
<td>9.3</td>
</tr>
<tr>
<td>7</td>
<td>24.2</td>
<td>140°F</td>
<td></td>
<td>10.2</td>
</tr>
<tr>
<td>8</td>
<td>20.4</td>
<td>160°F</td>
<td></td>
<td>11.3</td>
</tr>
<tr>
<td>9</td>
<td>14.7</td>
<td>180°F</td>
<td></td>
<td>13.4</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>212°F</td>
<td></td>
<td>17.0</td>
</tr>
</tbody>
</table>
Discussion.
June 3, 1903.

Mr. G. A. Turner (president) said that the thanks of the Institute were due to Mr. Newbigin for describing so well the possibilities and limitations of the turbine. There was no doubt that there was a great field for high-speed agents, especially if at high efficiency.

Professor Kernot pointed out that Mr. Newbigin had said nothing on the question of reversing. But without some means of reversing, it put him in mind of a person on a bicycle with a "free wheel" going down a steep hill, without a brake. He had said that the loss of the "Viper" and "Cobra" was not due in any measure to the method of propulsion. He (the Professor), however, did not agree with this, as he considered that had the "Viper" had better powers of stopping, it might have escaped the rocks. It was all very fine to travel at forty (40) miles an hour, but he would like to have a better power of pulling up, and this seemed to be the difficulty with these fast turbine boats. They seemed to be in the same position as the railway trains were in in the early days—without a proper brake. Possibly some brake might be devised independently of the engine. It might be possible to project blades at right angles to the vessel. Another question not dealt with by Mr. Newbigin was the application of the turbine to the locomotive. Locomotives have been dealt with electrically by the transmission of the power from the steam cylinders to the wheels, such as the Heilmann. Suppose, for example, that there was on one carriage a boiler and a turbo generator, and electric motors distributed over a sufficient number of wheels on the train, with the supply of electricity from the engine. The turbine would not need to be stopped at ordinary stoppages at stations. Then you could work on a series parallel system. Would not that be an arrangement worth considering? The whole question was extremely interesting. Our old friend, the reciprocating engine, had done great service, but it seemed to be seriously threatened by the new power. The day when steam boilers would be universally discarded in favour of gas turbines, however, seemed a long way off. The use of the turbine might act on locomotives very well where the traffic was very dense, but on lines where the traffic was very intermittent it would be a long time before it was generally used.
Mr. Geo. Turner said there was, perhaps, no subject at the present time more important than that which Mr. Newbigin had brought up. The development of the turbine was remarkable. The point that appealed most to one in examining the Parsons Turbine at work was this: It took up so little space; it consumed practically no stores, and its mechanical efficiency was very much greater than any other form of steam engine, that is taking the mechanical efficiency apart from the thermal efficiency. The fact that the exhaust steam is free from oil was also a very important point. He would like Mr. Newbegin to say what was Mr. Parsons' latest move in the turbine as regarded going astern with steamers? In the case of the turbine steamers "King Edward" and "Queen Alexandra" on the Clyde River, the proprietors were enabled to charge double rates owing to the absence of vibration and the regularity of speed.

Prof. Kernot thought the method of governing the turbine by having a series of puffs of steam, the duration of which varied, was a very peculiar one. The early turbines had the character of being great steam-eaters, and that reputation proved a considerable obstacle later on. He would like to know whether information could be given as to what was the steam consumption of the old turbines with the flat blades compared with the modern turbines with blades very carefully designed; also as to whether there was any further improvement in the direction of economy with the modern turbine, or was there a vista of further improvements. Was the turbine forging ahead and leaving other engines behind? And was it likely that we could get a turbine working with 7lbs. of steam per horse power per hour?

Mr. Schoder, in reply to Prof. Kernot's question as to the method of governing the turbine, said that one of the reasons for using the intermittent admission of steam was to prevent any possibility of the governor sticking. He thought Mr. Newbigin would bear him out in this. As regards the argument brought forward that governing by a simple throttle valve would be more economical, it seemed to him that when the valve was closed no steam could be consumed, and therefore a certain saving was gained.

Mr. Stone said that at a recent test conducted by him at their works, with one of the turbines, the steam was superheated to between 70 and 80 degrees, and the steam consumption was about 11 per cent. less than previously when tested with saturated steam. The steam consumed was a little over 28lbs. per Kilowatt hour. There were many points of advan-
tage which the turbine possessed, he thought, over the ordinary reciprocating engines. The President had mentioned the question of internal lubrication. The absence of internal lubrication in the turbine was a very great advantage. Engineers at the present day are recognising the advantage of keeping oil out of the boilers. The absence of oil in the turbine was not only an advantage so far as the boiler was concerned, but also as far as the condenser was concerned. The condenser quickly lost its efficiency when used with engines requiring internal lubrication; though in new reciprocating steam plants taking the boilers, engines and condensers together, as good results might possibly be obtained as with turbines. He thought it was extremely doubtful whether a reciprocating plant with internal lubrication would retain its high efficiency as the turbine did. The portions of turbine which affect the steam economy are not subject to wear (i.e., of the Parsons type). In the case of the turbines which had been in use at Newcastle for 13 or 14 years, constantly working, the engineers stated they could detect no sign of wear on the blades. Another advantage of the absence of internal lubrication in the turbine was that the steam could be used highly superheated. In the Parsons turbine the grain of the metal of which the blades are made is in the best possible direction to give it the greatest strength, thus permitting the use of high superheat. There was another important feature in connection with turbines, and that was that they could utilise the energy of exceedingly low pressure steam. They could be designed to utilise the pressure of the steam down to the pressure in the condenser. If we tried to do that in the reciprocating engine the dimensions of the low pressure piston must be enormous. No matter how high the steam pressure in the turbine it did not affect the pressure on the bearings and the wearing surfaces. The lubrication bearings, etc., of the turbine had been often called in question. He had shown several engineers in the turbines at the Spencer-street works that the lubrication was exceedingly good, as evidenced by the electrical insulation of the rotating parts from the bed plate. In eighteen months’ almost continuous running the wear on the journal measured only .001 inches. Another advantage of the turbine was its moderate size and weight. In a reciprocating engine there is often sufficient metal in the fly-wheel to make a couple of turbines of equal power. There was not the least difficulty in getting any degree of accuracy of governing that was required. With regard to the matter mentioned by Prof. Kernot about the intermittent admission of steam, and the blast dying out inside the turbine close to the inlet end. If the load were light the puffs would pass right through the turbine, and be distinctly visible from the top of the exhaust pipe. But when there was a reasonable load on, the fluctuation of pressure must be exceedingly small, at the exhaust end.
August 5, 1903.

Mr. George Turner (President) said that before asking members to join in the discussion, he would like to ask Mr. Newbigin for further information. Was there any chance of a vane breaking in the Turbine? either by becoming loose, or through undue expansion. Also what was the clearance between the revolving vanes and fixed vanes, because it appeared to him that if this was very minute, it would vary to some extent when the Turbine started. He would also like to know whether the thermal efficiency of the Turbine was the same at all ranges of temperature.

Mr. Geo. Higgins was glad the matter of the Turbine had been brought so well before the Institute. No doubt a lot of questions suggested themselves to many of the members, and there were a few that he would like to ask. On page 8 of Mr. Newbigin's paper he noticed, in reference to the "Turbinia," that, originally it had one steam turbine and one propeller, and afterwards had three cylinders, three shafts and three propellers on each shaft, nine in all. He saw by recent reports that in the case of the Channel steamer "Queen," Mr. Parsons had reverted to the system of having one propeller on each shaft. Perhaps Mr. Newbigin could inform them whether any alteration in the shape of the propeller had been made which had led to the change in the number of propellers.

On page 11 Mr. Newbigin referred to a Turbine driving a Centrifugal Pump, which latter had a periphery speed of 11,630 feet a minute, which was very high. He was sorry, however, to see that the method adopted of testing these Pumps was the same as that of M. Rateau, which he (Mr. Higgins) thought very unsatisfactory:—the water was not actually lifted but was throttled, and a pressure gauge was employed to indicate the head. This is not an accurate test.

It would be interesting if Mr. Newbigin could show them some illustrations of this pump; for instance, it would be interesting to know to what extent whirling space had been introduced, and what means had been adopted for reducing the velocity,—by gradually enlarging the delivery pipe, or otherwise.

No doubt, some of the members would know that he (Mr. Higgins) was personally interested in pumps that dealt with gravel, stone, sand, etc.; and when turbines came under notice he endeavored to find out to what extent they could be
applied to such pumps. For small powers the speed of the Tur-
bine was very high. Quite recently he had occasion to go into
the question in a case where a large power was required, and to
show the result of his attempts to adopt a Parsons turbine to a
gravel pump, he had brought with him a blue print (which was
perused by members) of a pump to be driven by one of the
Parsons Turbines. The passages in the pump were large enough
to admit stones of the dimensions of 9 x 9". The rock was broken
up partly by a bucket dredge and partly by cutters. In this
particular case, so far as dredging capacity was concerned, he
would have been satisfied with the application of say 2,000 indi-
cated horse power to the pumps; but he found that a Turbine,
developing this power only, would be very inefficient unless
running at a rate that would make it necessary to employ a
pump so small that it would be impossible for these stones to
pass through it. Therefore he proposed to employ more power
and slower speed. He arrived at a certain size of pump that
could be run at 700 revolutions a minute, and at the same time
the pump was not too small to allow of the stones passing through.
The brake horse power was to be 2,760, corresponding to about
3,200 indicated. The pipes through which it was proposed to dis-
charge this material were to be 36" in diameter, 6,000 ft. long, but
he divided this suction pipe in two branches having a bell-mouthed
inlet in common. The turbine was to drive 2 pumps, and the
delivery pipes were to unite again some distance from the pumps.
He described how the vanes were dished, i.e., curved in two
directions. He explained how the dimensions of the whirling
chamber had been calculated, and how the delivery-pipe was very
gradually enlarged so as to reduce the velocity gradually and
thereby avoid loss of head.

Mr. J. A. Smith called attention to a copy of "Engineering"
(July 3rd, 1903, page 32) just to hand. The New South Wales
specification for a combined steam turbine and centrifugal pump-
ing plant contained a clause as follows:—"The first set to be
capable of raising 4,500,000 gallons per day, 240 feet, on tem-
porary work, and eventually 1,500,000 gallons per day, 700 feet,
on permanent work." The conditions were very diverse, and
would seem to tend to prevent tenderers designing for the best
results; they would be compelled to rest satisfied with a moder-
ate performance at either extreme. The results given for four
tests conducted by Professor Goodman (for 700 feet lift) gave
efficiencies of 35.0 31.0 31.1, and 32.6 per cent. The pump
efficiency was taken to be about 56 per cent. A point upon
which he (Mr. Smith) desired information was this—when a
heavy mass in rapid rotation was supported by a light shell or
structure possessing a motion of translation, what would be the
resistance to an impact tending to change the plane of rotation?
[Mr. Smith here illustrated the question by an experiment with
a gyroscope. A mass of about 1 lb, capable of being put into rotation was supported by an axis running in gymbals permitting unconstrained motion in any direction; with the mass at rest a touch caused alteration of plane; when rotating about 1,000 revolutions per minute to resistance to slow change of position was appreciable, but when subjected to a sudden blow the system resisted almost as a solid mass]. Was there any existing solution when the factor of impact was concerned? Mr. Smith was aware that the problem of gradual change of plane had been discussed.

Mr. Michell thought that the question of superheating in connection with the Turbines was a very interesting subject. The loss avoided by superheating was usually considered to be frictional but seemed more likely to be thermodynamic. He referred to Mr. B. A. Smith's paper of Sept. 1900, in explanation. He would like to know whether, the use of a thin steel belt had been considered for high speed gearing. (He put the matter merely as a suggestion). The belt would be about the size of an ordinary surveyor's chain for 100 horse-power. The belt would be rolled from a ring of shear steel, or spring steel, and without a joint. It would be necessary to roll the belts to standard lengths and some means of adjusting the tension would be required while in use.

Mr. W. Fyvie: I think the institute is highly indebted to Mr. Newbigin for this valuable contribution to its proceedings, and in bringing this very important subject of Steam Turbine before its members at the present time, with the large amount of up-to-date information he has laid before us.

Referring to the use of the turbine for the propelling of ships and other crafts; to provide for an economical cruising speed, is certainly a very difficult problem. If a suitable feathering propeller could be constructed by which the pitch could be altered so that any intermediate speed could be got with constant speed of the turbine, and if we could carry this a little further so that we could reverse the blades, from a right to a left-hand propeller, or vice versa, the necessity of reversing the turbine would be got over. A wide field is open here for the inventive genius, and so make the marine turbine a practically perfect apparatus for the purpose.

Re the driving of rotary pumping gear, the turbine is certainly well suited for this work, and in conjunction with the centrifugal pump it may come to beat the old type of deep mine pump, but they have a long way to go yet. I hardly think that the difference between a positive drive and that of a belt drive, can possibly account for the difference between a 50 per cent. efficiency and an efficiency of 75 per cent. I admit a belt is far from an ideal drive for high speeds, but hardly so bad as that.
The author says: "Given a positive rotary drive, there is practically no limit to the head available with a suitably designed centrifugal." This may be so, but the strength of the delivery pipe on very high lifts comes to be a question of some importance, and to overcome this the power would have to be split into sections as in most deep pumping plants at present.

The author lays considerable stress on the absence of valves and motion gear of every description, "more especially where skilled men are scarce and dear, and repairs hard to effect." This is doubtless a very laudable and important feature, but on the other hand there is a much greater multiplicity of individual parts in its construction than any type of motor with which I am acquainted. And suppose one blade was to get broken or displaced, I am afraid the result would be disastrous, and would put the question of repairs absolutely beyond anyone but an expert blade-fitter, whereas with the reciprocating engine, it is a pretty serious breakdown that the ordinary country blacksmith and fitter could not fix up to hold out for a time till better provision could be made.

I would like to ask what the experience is with highly superheated steam, say, up to 500deg. or 600deg. F.? Does the co-efficient of expansion due to this great range of temperature have much effect on the different materials of which the revolving part is made? Have the blades any tendency to become loose under these conditions? I have experienced some considerable trouble where steam of this temperature has been used with the gunmetal seats of ordinary stop valves getting unseated and following out the valve when opened, and this with valves by the very best makers, and special means had to be adopted to overcome this trouble.

With regard to the driving of machinery where much slower speeds are required, I think it would be found better to reduce the speed in the first place by gear running in an oil bath or box (like the De Laval) to a speed that would be more suitable for rope or belt transmission. The results would be more satisfactory from an efficiency and maintenance point of view. I am afraid with the dia. of pulley and speed suggested by the author the efficiency would not be very high with ropes or belts.

It would be interesting to have some figures of efficiencies given by the turbine at part load; some very good figures are given on Table II, but those are all under full load conditions.

Regarding the weight and floor space occupied, the weight is not of so much importance (except for marine purposes), but the space is sometimes of considerable consequence. The figures given on Table I are certainly very good as to the total weight per B.H.P. I presume this does not include the condensing apparatus. In that case the total weight would hardly compare with so much advantage against well-designed
NOTES ON THE PARSONS STEAM TURBINE.

reciprocating plant, as I understand that the very low tempera-
ture necessary in the condenser to produce the high effi-
ciencies given, would require a much heavier plant than is
usually necessary with the reciprocating engine. As to floor
space occupied, a well-designed, quick speed reciprocating en-
gine of equal power can be placed in less floor space than
that given in the table referred to; the approximate floor space
occupied by Belliss and Morcom engines being as follows:—

<table>
<thead>
<tr>
<th>B.H.P.</th>
<th>B.H.P: per sq. ft. floor space</th>
<th>Total weight in lbs. per B.H.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>6.5</td>
<td>53</td>
</tr>
<tr>
<td>250</td>
<td>6</td>
<td>70</td>
</tr>
<tr>
<td>500</td>
<td>7</td>
<td>79</td>
</tr>
<tr>
<td>1000</td>
<td>9</td>
<td>70</td>
</tr>
<tr>
<td>2000</td>
<td>13</td>
<td>85</td>
</tr>
</tbody>
</table>

In regard to Mr. Stone's remarks, where, "he thought it was
extremely doubtful whether a reciprocating plant with inter-
nal lubrication would retain its high efficiency as the turbine
did" (as for the results of the boiler and condenser falling off
through dirty surfaces, they must be cleaned, which is not a
very serious matter.) I give some results here of different en-
gines that had been running practically continuously from
three to five and a half years, after which they were tested
under similar conditions and found to give practically the
same results as when tested new, and also records of the
amount of wear on the different parts after those periods of
constant work.


This engine was set to work in May, 1896, in a chemical
works, and has, therefore, been running nearly four years,
almost continuously day and night since.

In one year it ran 99.77 per cent. of the total hours, the
longest run without stopping being from the 1st July to the
30th November, during which time the combined steam
dynamo made 85,000,000 revolutions without stopping. The
engine still runs absolutely noiselessly, and has required prac-
tically no repairs or adjustment. The records show that there
have been no hot bearings or failure of the oil supply. The
steam cylinders were last opened out for inspection 12 months
ago. They have just now been again examined, and found
in perfect condition, the cylinder surfaces being extremely
good. The wear on the working parts that were measured
was found to be extremely small, and fully bears out a similar
report taken some months ago on the Taunton E.C.-8 engine.
NOTES ON THE PARSONS STEAM TURBINE.

Report Concerning No. 572 Dynamo Engine, E.C., 10 size Engine, after 5 Years' running at Cheltenham Corporation Electricity Works.

This engine was returned to us for alteration, as it was proposed to use it for traction instead of lighting conditions, a different dynamo being connected to it.

Before the alterations were taken into hand the engine was very carefully gauged and tested, but it was found that the amount of wear throughout the engine was practically a negligible quantity. On none of the principal bearings, including main and cross-head bearings, did the wear exceed one-half of a thousandth of an inch in any direction, the bearings, including the cross-head bearings, being truly round and cylindrical within the above limit. The amount of wear on the brasses could not be so readily determined as on the journals, but was so slight that it was impossible to say whether any wear had taken place or not.

The foregoing facts are borne out by the statement of the engineer of the station, who, on being referred to, reported that no adjustments had been found necessary or had been made to the engine during the four years it had been at work.

The reduction in diameter of the piston rods by wear amounted to only six-thousandths for the H.P. and four-thousandth for the L.P., whilst the valve rod, which is the part which in careless hands (in our experience) usually suffers most, had been reduced in diameter only fourteen-thousandths, say, one sixty-fourth, of an inch.

The condition of the cylinders and the valve chambers was equally satisfactory, indicating no appreciable wear, and the Rowan piston rings were in excellent condition.

The average degree of slackness between the slide valve rings and the valve chamber amounted to about seven-thousandths, which, allowing for two thousandths originally slack, indicates a wear of five-thousandths. That this degree of slackness has not been sufficient to prejudice the water consumption is shown by the results of special trials we have made, the engine placed on a test plate as soon as possible after receipt here without the cylinders being opened or any adjustments made. Under these conditions consumptions were registered varying between 17.39 and 17.96 lbs. per B.H.P., depending upon the initial steam pressure and the temperature of the steam, which figures compare very favorably with the average consumption of new engines of the same size, which our records show to be about 18 lbs. under similar conditions, and also with the results attained on the original official trial of the engine in 1897, when 19.76 lbs. per E.H.P., say, 18.31 lbs. per B.H.P., was recorded.
### No. 486 as Tested at Maker's Works, 1896.

<table>
<thead>
<tr>
<th>Range Press</th>
<th>4/4</th>
<th>1/2</th>
<th>1/4</th>
<th>Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>154</td>
<td>154</td>
<td>142</td>
<td>147</td>
</tr>
<tr>
<td>Chest Press</td>
<td>140</td>
<td>100</td>
<td>62</td>
<td>32</td>
</tr>
<tr>
<td>Steam Tempr.</td>
<td>377.5°</td>
<td>368.7°</td>
<td>372°</td>
<td>361°</td>
</tr>
<tr>
<td>Vacuum</td>
<td>25 3/4&quot;</td>
<td>26 1/2&quot;</td>
<td>26 1/2&quot;</td>
<td>26 1/2&quot;</td>
</tr>
<tr>
<td>Revolutions</td>
<td>364</td>
<td>360</td>
<td>360</td>
<td>359</td>
</tr>
<tr>
<td>B.H.P.</td>
<td>218.4</td>
<td>162</td>
<td>107.7</td>
<td>53.8</td>
</tr>
<tr>
<td>I.H.P.</td>
<td>245.5</td>
<td>184.5</td>
<td>126.9</td>
<td>65.63</td>
</tr>
<tr>
<td>Efficiency</td>
<td>89%</td>
<td>87.7%</td>
<td>84.8%</td>
<td>82%</td>
</tr>
<tr>
<td>Water per B.H.P.</td>
<td>19.4</td>
<td>19.9</td>
<td>21.3</td>
<td>22.9</td>
</tr>
<tr>
<td>Water per I.H.P.</td>
<td>17.3</td>
<td>17.48</td>
<td>18.08</td>
<td>18.7</td>
</tr>
</tbody>
</table>

Table of results taken from engine No. 486, as it was received from Croydon in 1902, without any overhauling, compared with original sizes and performances.

We give here a table showing in parallel columns the results obtained on the test of a 250 horse-power compound engine, first, as shown by the original work’s trials, and, secondly, as re-tested after 5 1/2 years’ regular work in a central electric light station. We may state that the results on both these tests were independently verified, and that the re-trial was made on the engine in exactly the condition it was returned to us without the cylinders being even opened up for examination, and, further, that on the engine being opened up all parts were found to be in splendid condition, the wear on the journals, as carefully measured by micrometer gauges, being as follows:

### No. 486 as Tested at Maker’s Works, April, 1902.

<table>
<thead>
<tr>
<th>Range Press</th>
<th>Full</th>
<th>Full</th>
<th>Full</th>
<th>3/4</th>
<th>1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest Press</td>
<td>138</td>
<td>139</td>
<td>138</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>Steam Tempr.</td>
<td>378°</td>
<td>368°</td>
<td>368°</td>
<td>382°</td>
<td>372°</td>
</tr>
<tr>
<td>Vacuum</td>
<td>27.8&quot;</td>
<td>27.8&quot;</td>
<td>27.8&quot;</td>
<td>27.8&quot;</td>
<td>27.8&quot;</td>
</tr>
<tr>
<td>Revolutions</td>
<td>360</td>
<td>360</td>
<td>360</td>
<td>360</td>
<td>360</td>
</tr>
<tr>
<td>B.H.P.</td>
<td>218</td>
<td>218</td>
<td>218</td>
<td>162</td>
<td>162</td>
</tr>
<tr>
<td>I.H.P.</td>
<td>230</td>
<td>231.5</td>
<td>232</td>
<td>174.1</td>
<td>173</td>
</tr>
<tr>
<td>Efficiency</td>
<td>94.7%</td>
<td>94.1%</td>
<td>94%</td>
<td>93%</td>
<td>93 7%</td>
</tr>
<tr>
<td>Water per B.H.P.</td>
<td>19.2</td>
<td>19.4</td>
<td>19.4</td>
<td>19.1</td>
<td>19.5</td>
</tr>
<tr>
<td>Water per I.H.P.</td>
<td>18.2</td>
<td>18.25</td>
<td>18.23</td>
<td>17.75</td>
<td>18.29</td>
</tr>
</tbody>
</table>
Amount of Wear on Working Parts after about 5½ years running.

<table>
<thead>
<tr>
<th>Part</th>
<th>Wear Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Bearings</td>
<td>about 0.0025&quot;</td>
</tr>
<tr>
<td>H.P. Crank Pin</td>
<td>0.005&quot;</td>
</tr>
<tr>
<td>L.P. Crank Pin</td>
<td>0.009&quot;</td>
</tr>
<tr>
<td>H.P. Crosshead Pin</td>
<td>0.0035&quot;</td>
</tr>
<tr>
<td>L.P. Crosshead Pin</td>
<td>0.008&quot;</td>
</tr>
<tr>
<td>Eccentric Sheave</td>
<td>0.008&quot;</td>
</tr>
<tr>
<td>H.P. Piston Rod</td>
<td>0.0111&quot;</td>
</tr>
<tr>
<td>L.P. Piston Rod</td>
<td>0.005&quot;</td>
</tr>
<tr>
<td>H.P. Valve Rings</td>
<td>0.012 Slack (.002 Original) = 0.0055</td>
</tr>
<tr>
<td>L.P. Valve Rings</td>
<td>0.012 Slack (.002 Original) = 0.010&quot;</td>
</tr>
</tbody>
</table>

Cylinders and Valve Chest in excellent condition, wear being practically negligible, Piston Rings in excellent condition.

No. 486 Dynamo Engine Cyls. 12" & 20" Table of Results taken from Engine as it was received from Croydon without any overhauling compared with original sizes and performance.

Recent trials with Belliss' triple expansion engines, working with a pretty high superheat, on a consumption at full load of 11.51 lbs. B.H.P. = 16 lbs. per K.W. hour, and consumption at half load of 11.61 lbs. B.H.P. = 17.71 lbs. per K.W. hour.

I think it is a point that is pretty well conceded all round that if we can get a fairly perfect system of supplying the lubricant in a continuous and positive manner, so as to insure that at all times we can keep a film of lubricant between the bearing surfaces and thus prevent them making metallic contact, we can reduce the tear and wear in a remarkable degree, but if we depend on a hit or miss, such as the splash system of lubrication, with the very high speeds that are the usual practice now, we run great risk of getting into trouble at any moment. Should the supply of lubrication be defective for only a very short period, the results may, and sometimes are, of a very serious nature before the defect is discovered by the attendant, and often leads to extensive and costly repairs, not to speak of time lost and inconvenience caused by such stoppages.

The difficulties experienced in properly lubricating the bearing surfaces of single acting engines are much greater than that of double acting engines, due to the pressure on the bearing, being always in one direction; there is greater difficulty in getting the lubricant between the surfaces.

The very great success that has been attained and maintained by the “Belliss” quick revolution double acting engines is largely due to the very excellent system of positive or forced...
lubrication which they introduced at an early stage, and can insure such remarkable results of continuous running on a very small amount of wear on the bearings as given above.

Mr. Arnot said that in connection with the feathering of propellers blades he had had some experience. He was recently on a turbine driven boat in Sydney which had the blades feathered, and it seemed to act very well as far as the stopping of the boat was concerned, so much so that he was thrown into the bottom of the boat, which stopped in about 30 feet. Some 20 years ago he had the pleasure of making some tests of a steam turbine in Glasgow, and the speed was between 10,000 and 12,000 revolutions per minute. The most satisfactory arrangements arrived at there was friction gear, and the speed 10,000 revolutions was so exceptional that he thought anything else would have been a failure. Some four years ago he inspected a great many of the turbines in use in England, and he came to the conclusion that they were undoubtedly the prime mover of the future. The use of oil could be eliminated entirely by the use of the turbine, a point very much in its favor. The vibration of the reciprocating engine was a very great nuisance.

Mr. Newbigin (in reply to Professor Kernot): The question of reversing with the Marine Steam Turbine has been widely discussed at different times, and the difficulties in connection therewith have been not uncommonly exaggerated. The problem is one of commercial expediency rather than mechanical difficulty. It is, no doubt, quite possible to make a turbine driven steamer go full speed astern, provided the hull and machinery are primarily designed for that purpose, but in practice such an arrangement would be costly and complicated and the advantages would ordinarily be negligible.

Reversing seems to be required for three purposes:—
1st. To give a maximum of retardation when stopping.
2nd. To improve the turning effort in twin screw boats.
3rd. To give a reasonable speed astern when required.

With regard to the first, it must be remembered that the skin friction of high speed boats is enormously in excess of that of slower vessels. In a paper read before the Institute of Engineers in Scotland, referring to the retardation of the new Cross Channel steamers, Mr. Parsons said: “By calculation, assuming steam to be suddenly shut off from the engines when at a speed of 25 knots, the vessel would slow down to a speed of 18 knots from her hull resistance alone in about 200 yards, so that the only difference required in bringing a 25 knot boat into harbour over an 18 knot boat would be, that in the case of the former, steam would be shut off 200 yards from the pier head, assuming that the reversing turbines were not used. If, however, they were used, full speed could be held till within 100 yards of the
NOTES ON THE PARSONS STEAM TURBINE.

piers, and loss of time from reduced speed over that distance would not amount to more than two seconds; whereas the saving of time from five extra knots speed would be about 12 minutes; neglecting the saving of time at the starting of the vessel on the commencement of the passage, arising from the more powerful machinery and the more rapid starting power of the steam turbine machinery."

The resistance alone of the Turbinia was sufficient to bring her to rest from full speed in about 550 feet, while with the reversing turbines in use she could be brought to rest in about half that distance. The Viper, on her Admiralty trials at Portsmouth, was brought to rest from 36 knots in the same time as the standard 30 knot destroyers, and even then full steam was not admitted to the reversing turbines.

The new Cross Channel steamer Queen, with a length of about 300 feet and a speed of 21 knots, started on regular service at the beginning of last month. On her official trials on the Clyde she proved to have exceptionally great manoeuvring and reversing power.

When steaming continuously astern she was capable of maintaining a speed of nearly 13 knots. When running ahead at a speed of 19 knots, she was brought to a dead stop in one minute seven seconds after the telegraph order was rung through to the engine room. The distance travelled in this time was only equal to about 2½ times her length.

With regard to manoeuvring in narrow waters the fact that the two outer shafts are reversible enables the turning effort to be effectively and promptly increased.

The third point, i.e., the speed astern, is also readily arranged in turbine vessels. The requirements of the Admiralty are that half the guaranteed speed shall be obtainable astern. The guaranteed speed of the Viper was 31 knots, and 16 knots was obtainable when running astern; this astern speed could have been increased had there been anything to gain by so doing. Professor Kernot mentioned the greater possibilities in this respect with marine engines, but it is doubtful if many fast vessels are capable of running astern at more than half speed, while in the case of open-fronted engines with short connecting rods going astern for long periods is not at any time devoid of difficulty.

It is by no means certain that reciprocating engines are more readily reversed than turbine marine sets, and the latter, as at present constructed, are quite capable of developing as much power astern as shipowners are prepared to pay for or likely to require.

The modern reversing turbine does not increase the space required, since it is now telescoped inside the low pressure ahead turbine. This arrangement not only simplifies construction, but also lessens the cost of manufacture, and there
is ample room for all the reversing power required for ordinary purposes.

Professor Kernot's suggestion that the Viper might have been saved had she possessed greater retardation is possibly true, but as she had stopping power in excess of that usual in similar engine-driven boats, her loss cannot be attributed to the turbine. It must be remembered that there was a heavy fog at the time of the accident, and probably a retardation sufficiently great to have stopped the Viper after the rocks became visible would have proved more disastrous to the crew than the rocks themselves.

To follow Professor Kernot's own analogy of the brakeless train, it may be pointed out that the retardation due to a collision is considerably in excess of that due to any of the brakes at present in use, but the latter method of stopping though less rapid is certainly more comfortable.

Professor Kernot also raises the question of the application of the turbine to a modified Heilman locomotive. This is a matter which has not so far received attention, but the advantages to be gained are not very apparent. A turbine generator large enough to develop sufficient energy to drive a modern express train would not be a very handy thing to carry on a locomotive, and if the motors, etc., were taken into account the weight would be considerable. In addition to this, condensing would be practically impossible, and there would be double transmission losses, so that the economy of the combination would not be materially better than at present, while the capital cost would be very much greater. Little has been heard of the Heilman locomotive of late, and beyond the original experimental one the author has no knowledge of them being used commercially.

(In reply to Mr. Turner.)

The previous reply covers Mr. Turner's remarks as to the reversing of turbine steamers. With regard to his remarks as to the Cunard captains requiring full speed astern, the author would like further particulars, preferably from the engineers, as the captain usually only sees the telegraph dial, and full speed on the bridge is not always full speed in the engine room. Perhaps there is some misunderstanding as to the meaning of "full speed astern." The writer has used it in the sense of a speed astern equal to the maximum obtainable when going ahead. It hardly seems reasonable to expect the same efficiency from propeller, hull and lines, when running in either direction.

(In reply to Mr. Smith.)

The blades of the turbine are not symmetrical when regarded as part of a reversible machine.

(In reply to Professor Kernot.)

In reply to further remarks by Professor Kernot on the steam consumption of the early flat bladed turbines the writer
is loth to disinter any of the earliest tests from the decent obscenity in which they are buried. It is sufficient to say, that the first sets were all very small, and consequently the clearance was a large percentage of the diameter. The blades also were not of the best shape, and the method of construction did not lend itself to the same degree of accuracy as is obtainable to-day. As far as future improvement is concerned, one must look forward only to slightly less consumptions, due to minor improvements. The Steam Turbine has a thermal efficiency to-day which precludes the possibility of any extensive reduction in steam between present temperature limits. The road to coal economy lies along the line of higher initial and lower terminal temperatures, and that is a road the turbine is singularly well adapted to follow. As will be seen from Table III. to get down to Professor Kernot's ideal, 7lbs. per horse-power with 100lbs. steam, a perfect steam engine would require a vacuum of at least 29½ inches.

The intermittent steam admission for governing is convenient, but not essential. The blasts practically merge at full load, so that the admission is only cut off between the blasts at intermediate loads. This type of governor is very convenient at light loads, since when running condensing there is great difficulty in so adjusting a double beat valve as to pass only the small amount of steam required. It is easier to admit the steam in puffs under these circumstances than to work with a valve almost closed. There is, of course, also the additional advantage at light loads of a greater ratio of expansion, while at all times the valve being constantly in motion is much less liable to stick.

(In reply to Mr. G. Turner.)

With regard to the question of blades breaking, there is no doubt that with the early turbines when the blades were cut out of the solid, breakages did occasionally occur, but the risk of this has been reduced to a minimum in more recent machines, where the blades are all drawn from bars composed of a strong ductile alloy. The writer can call to mind no case of broken blades during the last five or six years, which has not been due to gross carelessness. Practically speaking, broken blades can only occur through two causes. 1st. Excessive bearing wear; 2nd, excessive thrust wear. In ordinary working the wear of these thrust blocks or bearings is so infinitesimal, that there is no excuse for allowing them to be worn down below their safe limits. Even if a blade should go, due to some accidental flaw, the chances of it carrying any other with it are somewhat remote.

The clearances on the tops of the blades vary so widely that it is impossible to give any general figures for their value. The clearances, of course, are a minimum with short blades and small diameters, increasing with the length of
blade, and also with the increase of spindle diameter. Owing to
the eccentricity of the main bearings, the clearances, as originally arranged, are smaller at the top than they are at
the bottom to allow for wear of bearings. In the case of the
Victorian railways' machines after nearly four years contin-
uous running, the clearances at the bottom of the spindles are
still in excess of those at the top, showing the small amount
of wear which has taken place in that time.

With regard to the thermal efficiency of the turbine, it is, as might
be expected, a little better when working on a back pressure, than
when working with a high vacuum. This, of course, being due
to the increase of latent heat with decreasing pressure. The
variation in thermal efficiency, however, is a very small item
when compared with the great economy at high vacua, due
to the increased energy of the steam. Of course this vari-
ation in thermal efficiency only refers to the results obtained
between the stated temperatures, the absolute thermal effi-
ciency being necessarily a maximum when the terminal tem-
perature is a minimum.

(In reply to Mr. G. Higgins.)

Mr. Higgins draws attention to the fact that in the newest
turbine steamer, "Queen," only one propeller is used on each
shaft, whereas in the earlier boats, there were commonly two
propellers on each of the wing shafts. The only object of the
multiple propellers on one shaft was to increase the available
blade area in order to keep the pressure per square foot down
to a reasonable limit. The turbines of the "Queen," however,
run at a very much slower speed than those of the "Turbinia,
and it is therefore possible to use propellers of larger dia-
meter, and consequently to get sufficient blade area without
duplication.

The question raised by Mr. Higgins as to the accuracy of
using pressure gauges to determine the head in high lift
centrifugal pumps, is a very interesting one, and the writer
would welcome any data showing the probable percentage of
error. From results which have been obtained in actual
working with pumps originally tested by means of a pressure
gauge, the error cannot be very great. When the N.S.W.
Government erects the centrifugal pumps recently supplied
to them, it may be possible to get comparative figures. The
design of the high lift centrifugal pumps supplied to the
N.S.W. Government is not widely different to that previously
employed for this class of work, although an interesting inno-
vation has been introduced in dividing the pump casing longi-
tudinally parallel to the axis of the shaft. Whirling cham-
bers are introduced round the runner in the ordinary way, so
as to ensure a gradual reduction of the velocity with a con-
sequent increase in the static head. Small propellers are also
introduced on either side of the pump runner to give the water
some initial velocity on entering the eye of the pump.
NOTES ON THE PARSONS STEAM TURBINE.

(In reply to Mr. J. A. Smith.)

Mr. Smith has not clearly understood the arrangement adopted by Messrs. Parsons to obtain the wide range of pressure and volume required by the N.S.W. Government. Each of the three pumps is designed to give an output of 1½ million gallons of water per day against a head of 240 feet, i.e., when the pumps draw from a common suction the total discharge will be 4½ million gallons per day against a head of 240 feet, while if the delivery of one pump is carried to the suction of the next, there will be a cumulative head, and the total output will then be 1½ million gallons per day against a head of 720 feet, and both turbine and pumps will work at practically their best efficiency under either set of conditions.

The efficiencies quoted by Mr. Smith, that is 31 per cent., 32 per cent., and 35 per cent. are not the overall mechanical efficiencies, but the overall thermal efficiencies. The gross horse-powers given in the table from which Mr. Smith quotes are those theoretically obtainable from a perfect engine, and not the equivalent indicated horse-powers, as Mr. Smith seems to infer. A gross thermal efficiency of 35 per cent. for a centrifugal pump plant is a very good result, when it is remembered that the pump efficiency was only about 55 per cent. Under these conditions the thermal efficiency of the turbine used was 64 per cent., which is a better figure than that usually obtained in triple expansion reciprocating engines of equal output.

The question of gyroscopic action in marine work, is one which has been discussed at various times, but as far as the writer is aware, proof is still wanting that it has the detrimental effect referred to by Mr. Smith. In fact, there is not much evidence to show that gyroscopic action has any effect at all on the free movement of the hull.

(In reply to Mr. A. G. Michell.)

Mr. Michell points out that, though the economy due to superheat is about the same in reciprocating engines and turbines, the cause of the increase in efficiency is generally stated to be different in the two cases. The exact thermo-dynamic effect of superheat is difficult to understand in either case, but probably as far as the turbine is concerned a considerable percentage of the saving is due to the lesser skin friction of the more perfect gas. It is possible also that some benefit is derived from the fact that in that portion of the turbine in which the steam continues superheated, there are no losses due to condensation and subsequent evaporation, such as must take place when saturated steam is used. With high degrees of superheat, the conductivity of the metal in the turbine itself, must also play an important part.

The question of gearing, also introduced by Mr. Michell, is one of very great importance in connection with steam turbines. Up to
the present the only really reliable high speed gearing, is electrical. This method of gearing, whether from low speed prime movers to high speeds, or from high speeds to low, is becoming daily more common, and there seems little doubt that it will ultimately take the place of all the present mechanical high speed gears. Rope driving for turbines, though suggested in the paper, is perhaps almost outside the pale of practical mechanics, except under very special conditions. Helical, spur, and worm gearings have all been tried, and found wanting, when used with high speeds and large powers, and as far as one can see where rope driving is not possible, electric transmission is the only alternative. The steel belt transmission mentioned by Mr. Michell is certainly novel, but the mechanical difficulties, first, of all in getting such a belt, and secondly, in keeping it in good order, would appear to be very great.

(In reply to Mr. W. Fyvie.)

Mr. Fyvie has drawn attention to the use of feathering propellers for obtaining economical cruising speeds. The feathering propeller has, of course, been used fairly widely in small oil launches, but it does not seem a promising piece of mechanism, where large powers are concerned. After all, cruising speeds are only required in the case of war vessels, and, perhaps, subsidised cruisers. All passenger or cargo steamers practically travel continuously at almost their maximum rate of speed. The special conditions required by war vessels can apparently only be met satisfactorily by the use of special machinery. It has recently been suggested in a paper before the Institution of Naval Architects that subsidised cruisers might be fitted with an additional engine carrying a special housing propeller, which could be used when extra high speeds were required. Possibly something of this sort may ultimately be adopted in turbine-driven warships. If special boilers are carried for full speed only, there can be no objection to carrying special engines for the same purpose.

Mr. Fyvie draws attention to the comparatively poor efficiency of centrifugal pumps as compared with the old Cornish pattern. There is no doubt that the centrifugal has not at present quite so high an efficiency as the Cornish pump, but its efficiency is being rapidly improved, and there is every reason to hope that it will yet reach a figure at which the Cornish cannot compete even in the matter of absolute coal consumption. In comparing the relative efficiencies of the two classes of pumps, the items of first cost, sinking fund, maintenance and attention cannot be neglected, and even to-day, there are many cases in which high lift centrifugals will lift water at a cheaper rate than is possible with Cornish pumps, and this even with a coal consumption considerably in favour of the Cornish. Mr. Fyvie mentions the multip-
licility of parts in the turbine, which is certainly a novel objection to this type of plant. No matter how many individual parts originally enter into the construction of the turbine, the machines when erected are certainly homogeneous. Practically speaking, the steam turbine has only one moving part, since the blades are as much part and parcel of the spindle as the end plates of a boiler are of its shell. Steam turbines are devoid of all these minor mechanisms, which tend to add so much to the maintenance costs of the reciprocating engine, and it is their simplicity in this respect which is one of their most valuable features.

Mr. Fyvie further points out the general fear that repairs to the turbine when necessary at all are likely to present many difficulties. This fear in the writer's opinion is quite unwarranted. The steam turbine is an ordinary piece of mechanism, and as such is as easily repairable by ordinary mechanics, as any other high-class machinery. The putting in of new blades, should that ever be necessary, is an operation which requires no more skill than the scraping down of a valve face, or the caulking of a boiler seam. There is no doubt that, as Mr. Fyvie says, engineers in general have had more experience of engine breakdowns than they have had of turbine breakdowns, but that is hardly a fault that can be laid at the door of the steam turbine.

Up to the present time very high degrees of superheat have not been used with the Parsons' turbine, about 120 deg. Fahr. being the most that has so far been tried commercially. The question, however, is now under consideration, and when reliable figures are available, the writer will be pleased to lay them before the Institution. With regard to the helical gears referred to by Mr. Fyvie, it may be mentioned that from exhaustive experiments which have been carried out this type of gear, no matter how carefully manufactured, has proved wholly unsuitable for large powers. The teeth require to be of such fine pitch that it is almost impossible to get them to stand, and the noise of such large gears even when running in enclosed oil baths is in itself sufficient to preclude their use. Mr. Fyvie also mentions that the floor space of quick revolution vertical engines is less than that given for turbines in Table 1. The height, however, of such engines is very much greater than that of turbines, and had the figures been given in cubic feet instead of square feet, the comparison would have been very much more favourable to the turbine.

In conclusion, the writer is gratified that the subject has caused so much discussion, and he has to thank those members who have so kindly shown their appreciation of the importance of the question by taking the trouble to criticise the paper.
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