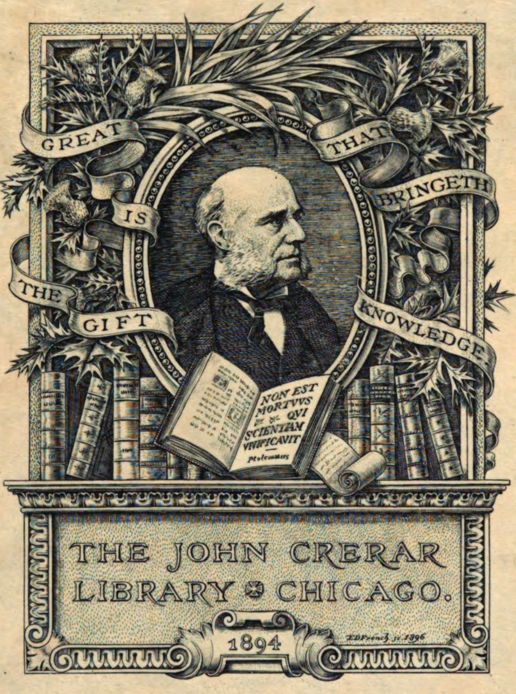
DE LAVAL
STEAM TURBINES

DE LAVAL
STEAM TURBINE CO.
NEW YORK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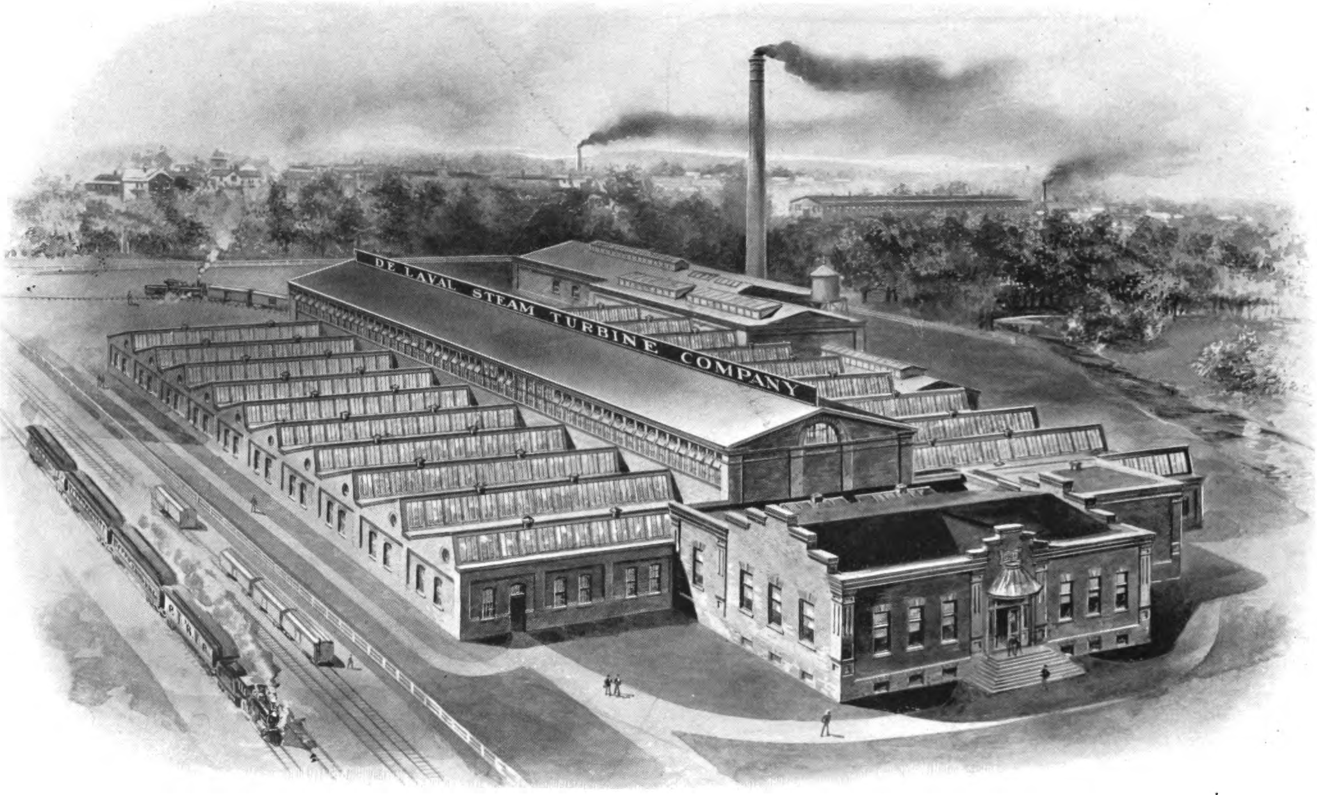
TURBINE MACHINERY.

STEAM TURBINE MOTORS,
STEAM TURBINE DYNAMOS,
STEAM TURBINE BLOWERS,
STEAM TURBINE PUMPS,
HIGH PRESSURE STEAM TURBINE PUMPS,
ROTARY FIRE ENGINES,
LOCOMOTIVE HEAD LIGHT EQUIPMENTS,
TRAIN LIGHTING EQUIPMENTS,
MARINE GENERATING SETS,
LAUNCH TURBINES,
ETC.

De Laval Steam Turbine Company,
New York.

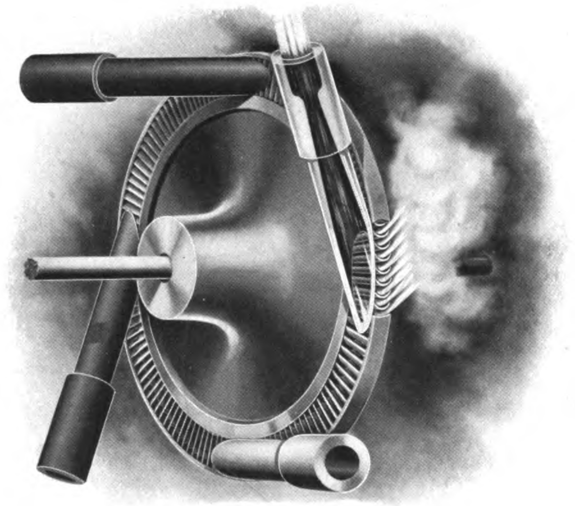


Works of the De Laval Steam Turbine Co., Trenton, N. J.

DE LAVAL STEAM TURBINES

And Turbine Machinery.

DE LAVAL



TRADE MARK

De Laval Steam Turbine Co.

GENERAL OFFICES:
74 CORTLANDT ST., NEW YORK.

AMERICAN WORKS:
TRENTON, NEW JERSEY.

Catalogue A.—Second Edition.

Sole Manufacturers Under the De Laval Patents.

DE LAVAL STEAM TURBINE COMPANY,
General Offices:
74 Cortlandt Street, New York, U. S. A.
The United States and All Colonies and Dependencies,
Mexico, Central and South America.

AKTIEBOLAGET DE LAVALS ÅNGTURBIN,
Stockholm, Sweden,
Norway, Sweden and Unoccupied Territory.

SOCIÉTÉ DE LAVAL,
48 Rue de la Victoire, Paris,
France and Colonies.

THE ENGLISH DE LAVAL STEAM TURBINE COMPANY, Limited,
Albion Works, Leeds, England.
Great Britain and Ireland, the British Colonies, Egypt,
China and Japan.

MASCHINENBAU-ANSTALT HUMBOLDT,
Kalk bei Koln,
Germany and Colonies.

The Steam Turbine.

The problem of thermodynamic energy conversion in so far as the reciprocating steam engine is concerned is to-day little nearer its solution than it was more than a century ago. Ideal in its complex construction and revolutionary in its application and achievement, the steam engine, originating with Newcomen and perfected by Watt, is, however, very far from perfect as a heat engine, and there is little prospect that future improvement will bring this type of heat motor any closer to the ideal. This assumption is to some degree borne out by the fact that the improvements ever since the days of James Watt have only been mechanical, and even though these improvements naturally have increased its efficiency, the steam engine of to-day in its ingenious and complex perfection, thermodynamically presents practically no improvement over that of Watt.

The conversion of heat energy by means of the steam engine is accomplished by allowing steam to expand behind the piston, not utilizing its kinetic energy, but subjecting it to a resistance corresponding with its pressure. The ideal efficiency of this process, and in fact the solution of the problem of thermodynamic conversion, is expressed by the Carnot Cycle represented in the formula:

$$\frac{T_1 - T_2}{T_1}$$

This means that for the highest efficiency obtainable the steam should be expanded from maximum to minimum pressure and temperature, and furthermore this expansion should be adiabatic, which, as is well known in practical operation with the steam engine, is not and never can be accomplished. The reasons for this, now so well known, need not here be enumerated.

When the science of steam engineering was thoroughly understood and the defects of and the improbability of further than mechanically improving the steam engine were realized, engineers and inventors with more or less success set about devising means for the mechanical utilization of heat energy by methods promising a closer approach to the ideal than is possible with the reciprocating steam engine.

The activity along this line of research has been most marked in the past century, and among the devices having any pretence to rivalry with the reciprocating engine has been the *rotary* steam engine. This type of engine, successful in obviating the defects due to reciprocating motion has, however, in other respects proven far inferior to the type it has sought to replace; it is especially wasteful of steam, and can therefore never be seriously considered.

The solution of the problem cannot be found here, and in fact cannot be found in mere mechanical differentiation. This has been realized, the research pursued in other directions, and the close of the century has seen the STEAM TURBINE, as proposed by DE LAVAL, brought to a state of perfection and practical application of almost revolutionary pretence.

The STEAM TURBINE in principle and even in type is not new, being in fact the *first* heat motor recorded in the history of steam engineering, as far back as 120 B.C., when Hero of Alexandria describes an apparatus for utilizing heat energy. This apparatus, a REACTION TURBINE, consisted of a spherical vessel mounted upon trunnions through which steam was admitted to finally issue from openings tangental to the sphere. Many centuries later, in 1629, the Italian, Giovanni Branca, brought out the IMPACT TURBINE, employing a jet of steam to impinge upon vanes or blades of a wheel. This latter, familiar to us in the hydraulic motors of the Pelton type, exhibits in general principle the characteristic features embodied in the present day DE LAVAL STEAM TURBINE.

Thus we see as early as 1629 the introduction of the reaction and impact TURBINE, although of imperfect form and not capable of practical application, and all attempts at perfection along these lines have, until a comparatively short time ago, proven unsuccessful; this was probably owing, however, to the interest aroused by the success of Newcomen in 1705, and later by Watt and his followers, in the development of the reciprocating engine.

The STEAM TURBINE in the form produced by DE LAVAL is characterized by the great simplicity of its construction and the directness of its energy conversion, producing adiabatic and complete expansion, ideal conditions which can *never* be attained with the steam engine. That the STEAM TURBINE, which now more than rivals the steam engine, should have been known at such an early date and yet should have been so long delayed in its perfection in a practical form, may seem astonishing. This, however, is not remarkable, for even if, as is improbable, the high efficiency of the STEAM TURBINE had been realized by Hero, Branca, and others of early times, a practical machine could not well have been produced for want of materials and tools of such refinement and quality as we to-day know are as essential to the construction of a successful STEAM TURBINE as are the principles involved. The steam engine, less exacting in this respect, has been the natural forerunner producing the favorable conditions that have enabled us to weld another link to the chain of evolutions in heat engines.

In 1883 DE LAVAL made the first successful STEAM TURBINE, using it in direct connection with the shaft of the well-known Cream Separator manufactured in this country by The De Laval Separator Company. This, his first TURBINE, in design and construction a reaction wheel, was, however, soon replaced by one of the Branca type, and of the results attained Prof. Thurston says, "The result was an astonishing efficiency in many cases of good design; and the Branca form, particularly, exhibited such satisfactory qualities as constructed by DE LAVAL for this use as to make it a permanent and standard addition to our list of prime movers."

However, satisfactory as these results were, the STEAM TURBINE was yet very limited in its application and comparatively wasteful of steam, and to successfully compete with the reciprocating steam engine it was necessary to introduce means for the complete expansion of the steam. Should the true Branca type further be retained, which was in every way most desirable on account of its simplicity as compared with a combination of the Branca and Hero types, the constructive difficulties arising out of the enormously high speed necessary would have to be overcome. This DE LAVAL aimed at and accomplished in a remarkable way. By use of the DIVERGING NOZZLE, which he patented, he secured a complete and *adiabatic* expansion of the steam and the conversion of its *entire* static energy into kinetic. Then, to overcome the impossibility of producing a wheel accurately enough balanced to revolve about its centre of gravity at a velocity sometimes as high as 1,350 ft. per second, without causing a side pressure destructive to plain bearings and a rigid shaft, he conceived the FLEXIBLE SHAFT, which he also patented.

The DE LAVAL NOZZLE, the simplest means imaginable for its great purpose, and the FLEXIBLE SHAFT, daring and ingenious in its application, may well be regarded as among the most *remarkable inventions in steam engineering*. They have placed the STEAM TURBINE in the foremost rank among heat motors. With the advent of the DIVERGING NOZZLE and the FLEXIBLE SHAFT, the DE LAVAL TURBINE has steadily progressed, thousands of machines in sizes from 3 horse-power to 300 horse-power having been built up to the present time, and outside of the United States DE LAVAL STEAM TURBINE COMPANIES are operating in Sweden, Germany, France and England.

In a properly constructed nozzle, a volume of steam of maximum pressure entering at H (Fig. 15, page 31), gradually, and—as every element of the nozzle assumes a temperature constant and equal to that of the passing steam—adiabatically expands to minimum pressure, and as this pressure is that of the surrounding medium, the steam at the point of discharge (B) issues in a solid jet without tendency of its particles to divert in any direction.

Through numerous experiments Prof. Zeuner has shown that theoretically the work of this adiabatic expansion converts the *entire* static energy of the steam into kinetic, and that the stored energy of a jet of steam issuing from a DE LAVAL NOZZLE is identical to the amount of work produced if an equal volume of steam is allowed to adiabatically expand behind the piston of a cylinder and at the same ratio of expansion—the diagram ending in a point.

It is well known, however, that this ratio of expansion is for practical reasons *never made use of in the reciprocating engine.*

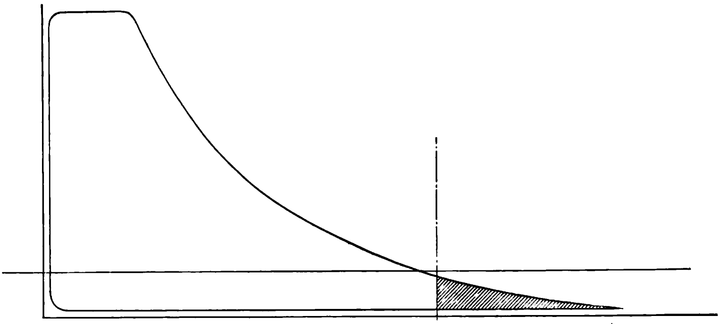


Fig. 1.

The shaded portion of the diagram (Fig. 1) thus represents a loss due to incomplete expansion.

The energy of a jet of steam per unit weight is:

$$E. = \frac{V^2}{2g}$$

Where V is the velocity of the effluent steam, and assuming this velocity to be 4,000 ft. per second, which is nothing unusual, we have:

$$E. = \frac{4000^2}{2g} = 248{,}500\ ft.\text{-}lbs.$$

The velocity of efflux given, and with the nozzle at an angle of 20° to the plane of motion of the buckets, the velocity of the

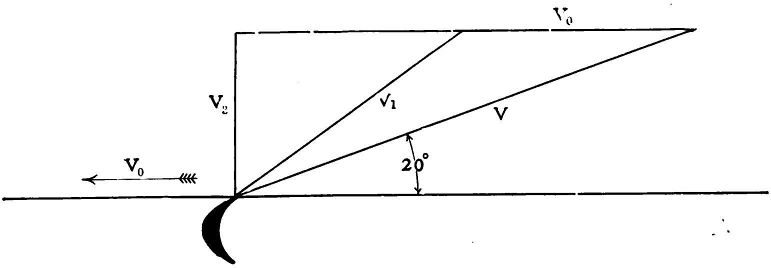


Fig. 2.

turbine wheel for the maximum of efficiency should be 47 per cent. the velocity of the steam. The absolute velocity of the steam leaving the buckets is then 34 per cent. of the initial, and we find the energy absorbed by the turbine wheel to be 88 per cent. of that expanded, or referring to Fig. 2:

With V 4,000 ft. per second, we have the horse-power per hour, per lbs. of steam.

$$H.P. = \frac{V^2 - V3^2}{2g.550.3600} = 0.11$$

And the steam consumption per theoretical horse-power per hour.

$$\frac{2g.550.3600}{V^2 - V3^2} = 9.1\ lbs.$$

The speed of the DE LAVAL TURBINE WHEEL, which for V 4,000 ft. and for the maximum of efficiency should be about 1,880 ft. per second, or about 21 miles per minute, is, however, much lower, as it has been found difficult to produce a material for the wheels that with ample margin of safety would withstand the strains produced by the centrifugal force at this high speed. At the present time the speed does not actually exceed 1,350 ft. per second, which in the above case would give a steam consumption of 9.8 lbs. per theoretic horse-power.

The diagram (Fig. 3, page 10), gives the energy of a jet of steam in foot-pounds per unit weight and at different initial and terminal pressures.

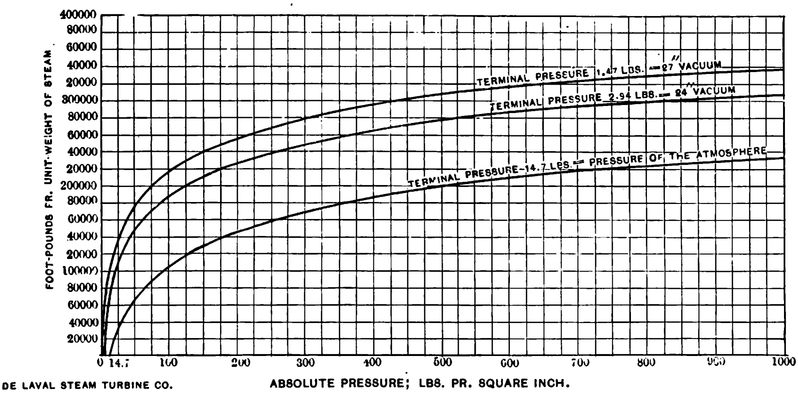


Fig. 3.—Energy of a Jet of Steam at Various Initial and Terminal Pressures.

At an initial pressure of 150 lbs. per square inch absolute, it will be seen that the energy of a jet issuing at a terminal pressure of 14.7 lbs. absolute is 130,000 ft.-lbs.; at a terminal pressure of 2.97 lbs. it reaches 210,000 ft.-lbs.; and if issuing at 1.47 lbs. absolute, equal to 27 in. vacuum, the energy is 240,000 ft.-lbs.

The curves in the diagram (Fig. 4, page 11), show the steam consumption per *brake* or effective horse-power per hour, as actually obtained in practice with the De Laval Steam Turbine.

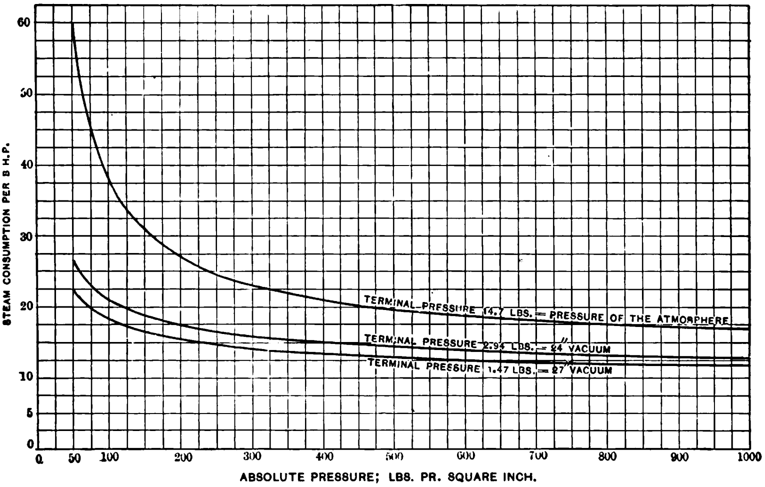


Fig. 4.—Actual Steam Consumption Pr. B. H. P. De Laval Steam Turbine.

The importance of a high steam pressure and a good vacuum when operating the Steam Turbine is clearly shown by the above diagram. Not that the Steam Turbine cannot, as far as the mechanical results are concerned, be operated equally well with low pressures and non-condensing, and even then successfully compete with the reciprocating engine, but whenever the *very best* economy in operating is sought for, high pressure and a condenser should be used, and as the difference and gain in economy in the case of the Steam Turbine is more marked than in the reciprocating engine it will be found in many cases, even in comparatively small sizes, of advantage to operate condensing, and even to do so in places where the scarcity of water would render the employment of a cooling tower necessary.

A characteristic feature of the De Laval Steam Turbine is that none of its running parts are subject to the full pressure of the steam, as the steam is fully expanded in the nozzle before it reaches the turbine wheel. This feature, which will not be found in *any other* heat motor, is of great value and promising future in the direction of using high pressures with resultant increase in economy of fuel. The restriction as to the steam pressure that can be used is found only with the boiler, and as far as the Steam Turbine itself is concerned, it has been operated successfully with a pressure as high as 3,000 lbs. per square inch.

Further, a considerable increase in economy can be obtained by using superheated steam, for which the De Laval Steam Turbine is particularly well adapted, it having no rubbing parts requiring lubrication, or packing glands in contact with the superheated steam, and as in the case of high pressure even here the limit exists alone with the boilers.

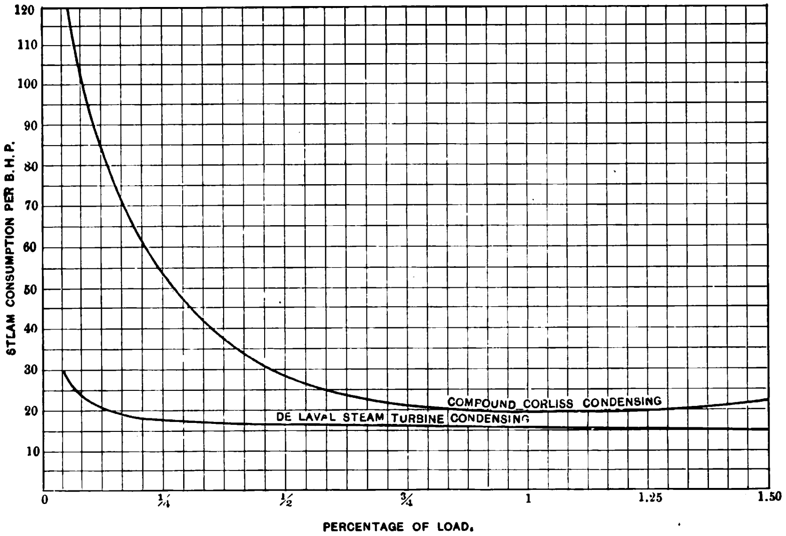


Fig. 5.—Comparison of Efficiency at Various Loads.

The De Laval Steam Turbine.

The De Laval Steam Turbine is a high speed rotary steam engine, in design and construction adapted for all purposes where the common reciprocating steam engine is now used, and for many other purposes where for various reasons no other type of engine meets hitherto impossible conditions. This is especially the case where great efficiency, great uniformity of rotation, and close regulation are important, as when used in connection with electrical machinery, centrifugal pumps, fans, blowers, etc. Its

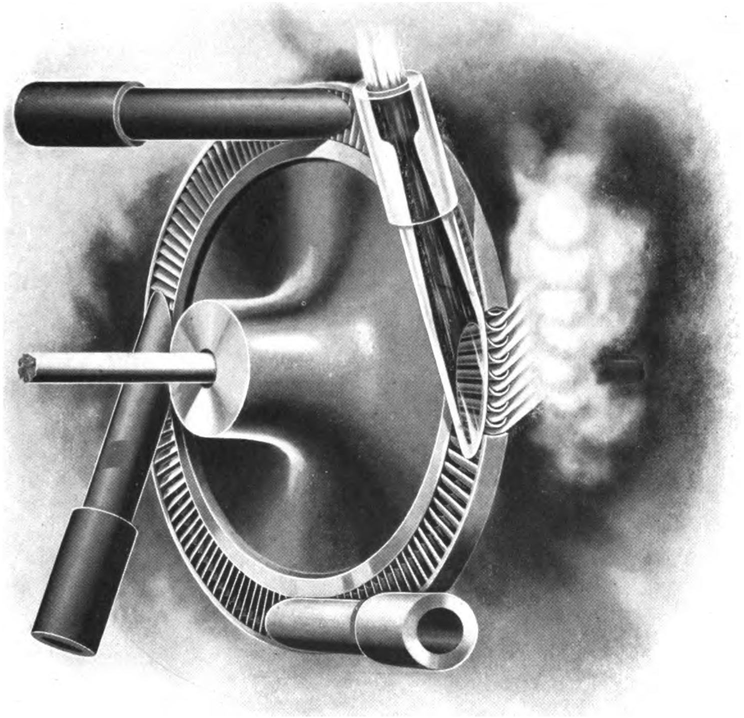


Fig. 6.—The De Laval Turbine Wheel and Nozzles.

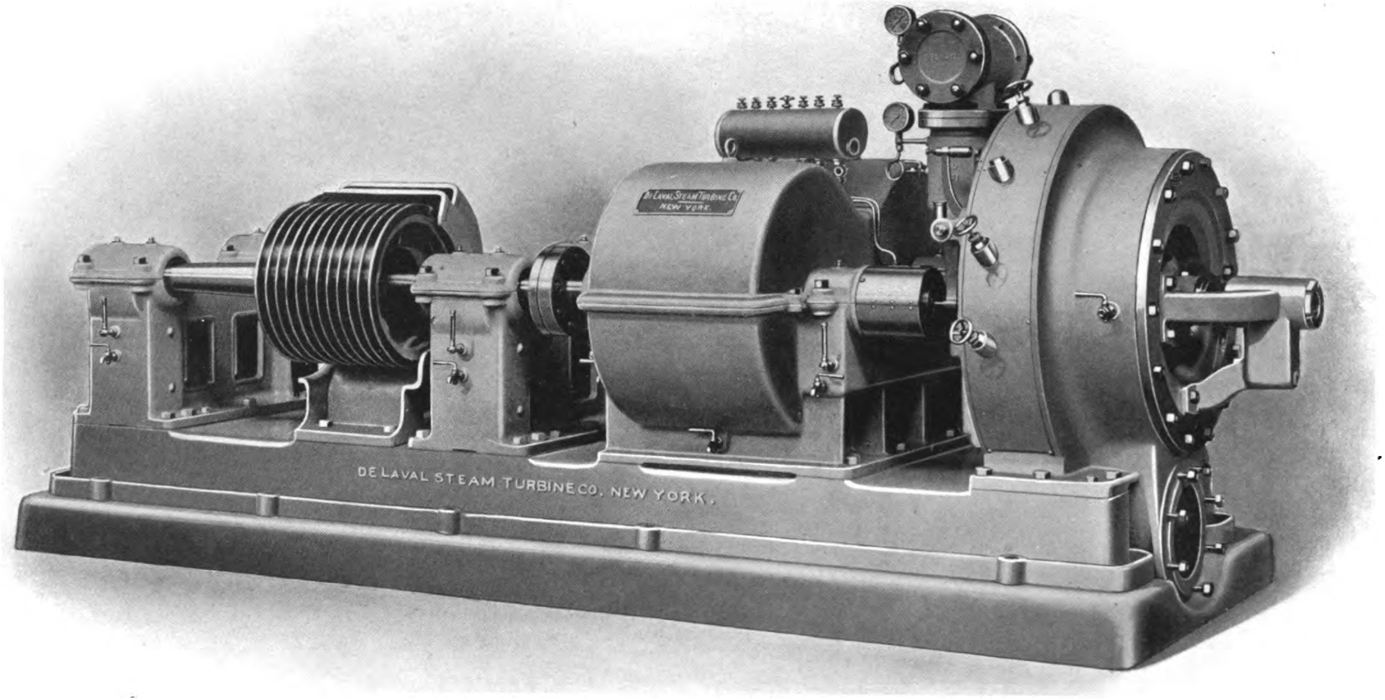


Fig. 7.—De Laval Steam Turbine Motor, 300 H. P.

high speed and the directness of its energy conversion decreases the dimensions and weight, and simplifies the construction without impairing its efficiency, advantages which do not exist with the modern steam engine where great bulk and complexity are features indispensable to highly efficient operation. Its principal advantages are:

NO LEAKAGE FROM WEAR,
NO BEARINGS TO ADJUST,
SMALL FRICTION LOSS,
HIGH EFFICIENCY WITH VARIABLE LOADS,
NO MOVING PARTS UNDER PRESSURE,
CLOSE SPEED REGULATION,
SIMPLICITY OF CONSTRUCTION,
PERFECT BALANCE—SMALL FOUNDATIONS,
SMALL SPACE OCCUPIED,
EASE OF ERECTION,
AUTOMATIC OILING,
NO DANGER FROM WATER,
AND LONG LIFE.

No Leakage from Wear.

Unlike the reciprocating engine and *other Turbines* the De Laval Steam Turbine has no stuffing boxes, no glands, no packing joints, and no working parts under pressure, which entirely eliminates the question of loss from leakage, in this respect differing from *all* other steam motors. The efficiency of a steam engine as given in a *shop testing room* may be of the very best, but after running, the leakage constantly *increases* and the efficiency *decreases*, while the Turbine throughout its entire life remains absolutely constant in this respect, and a test made in the shops at the time a Turbine is shipped would hold good for the same Turbine after years of operation.

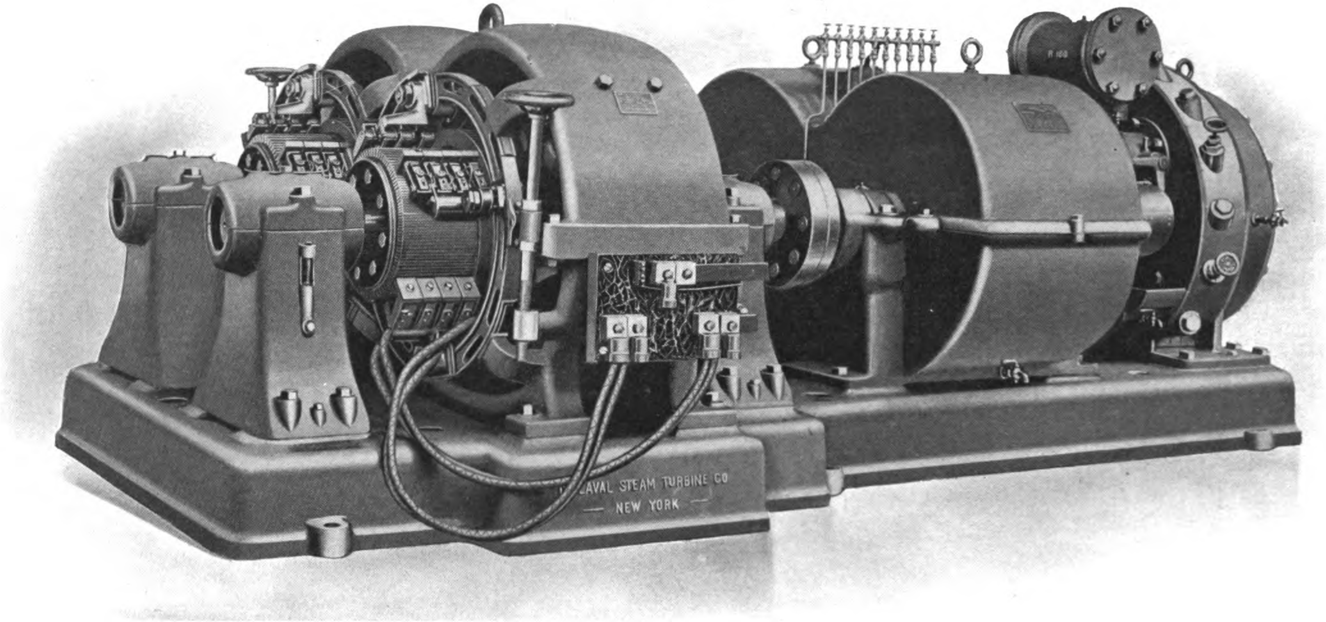


Fig. 8.—De Laval Steam Turbine Dynamo, 300 H. P., 200 K. W., Direct Current.

No Bearings to Adjust.

As the motion of the TURBINE is entirely rotative, no adjustment of bearings whatever is necessary, and even should these become considerably worn, no bad effects will result. However, the pressure exerted on the various parts is so slight that the wear is surprisingly small, being *much less*, in every case, than with a steam engine used under the same conditions. Many DE LAVAL TURBINES have been in constant operation in Europe for periods ranging from five to seven years without requiring the renewal or adjustment of a single bearing, and at the end of this time not showing any appreciable wear.

Small Friction Loss.

There is practically no friction loss to contend with in the TURBINE, while in the reciprocating engine the loss caused by poor or improperly adjusted packing and by piston or valve rods worn out of parallel is often considerable, and a surprising difference in efficiency is often shown from these causes in a number of tests made with the same engine.

High Efficiency with Variable Loads.*

While the DE LAVAL STEAM TURBINE running condensing will give a *better efficiency than a compound condensing Corliss Engine*, there is the additional advantage in favor of the TURBINE that the efficiency of the reciprocating engine is given for its full *rated load* and the steam consumption per horse-power largely *increases* with every *increase* or *decrease* of the load, while with the TURBINE the efficiency is *practically the same from 25 per cent. load to a 20 per cent. over-load.* See diagram page 12. It is undoubtedly a fact that in nearly every case a steam engine is running *under-loaded* rather than over-loaded throughout many of its working hours. This is particularly so with an electric light plant, where the peak of the load lasts for a very short time, and during the balance of running time the engine must

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* All efficiency tests or diagrams of steam consumption for the DE LAVAL STEAM TURBINE are based on the actual or brake horse-power and not on the indicated. The difference in favor of the TURBINE in rating should be about 10 per cent.

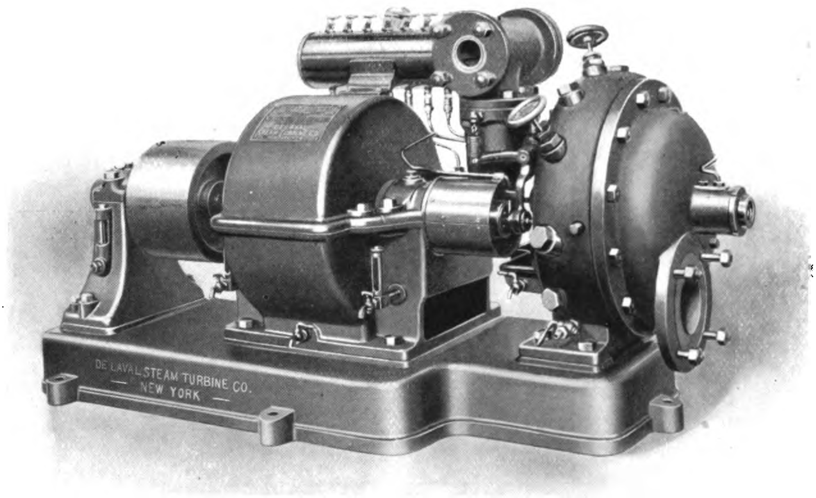


Fig. 9.—De Laval Steam Turbine Motor, 30 H. P.

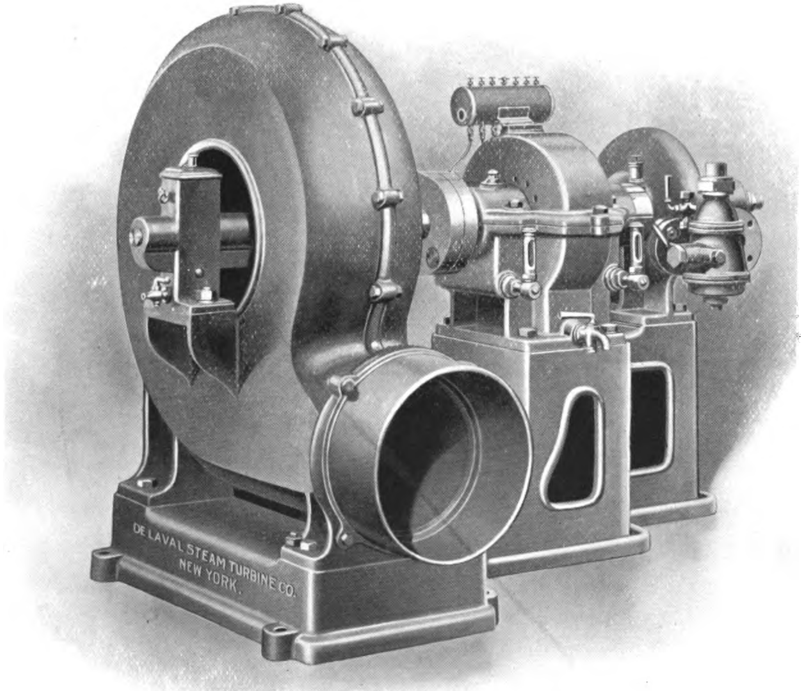


Fig. 10.—De Laval Steam Turbine Blower, 10 H. P., 2,300 Cubic Feet per Minute, 18 Lbs. Pressure.

necessarily be operating at a great loss, in many cases more than doubling the quantity of steam used per horse-power hour. In other words, the total amount of fuel required to operate a reciprocating engine at *half-load* is almost equal to the quantity required for a *full-load*, while with the TURBINE the steam consumption is nearly proportionate to the amount of work being performed. Fuel cost is beginning to assume an important aspect in this country, and this, coupled with the close competition in most lines of manufacture, necessitates taking advantage of every means of fuel-saving known. Nothing offers a better opportunity for thus economizing than the DE LAVAL STEAM TURBINE. It is undoubtedly the excessive cost of fuel in Europe that has led to the general adoption of the STEAM TURBINE for all classes of power work so far in advance of its introduction into the United States. While as a general proposition Americans are in the lead in machine designing and construction, it is freely admitted that in steam engine practice Europeans lead the world.

No Moving Parts Under Pressure.

As steam under pressure does not come in contact with *any* moving part in the TURBINE a very high pressure can be used with a considerable increase of economy as shown in diagram, page 11. This feature is also of great importance when using superheated steam, as it removes the difficulties of lubrication at high temperatures. It is undoubtedly with superheated steam that the greatest future improvement can be looked for in the reciprocating engine, but a limit is soon reached on account of the great difficulty of lubrication. With the DE LAVAL STEAM TURBINE the saving is equally as great, but the allowable temperature and pressure is entirely a question of the steam boiler used and is not in any way limited by the TURBINE.

Close Speed Regulation.

The speed regulation is unexcelled. The high speed, the simple and direct connection of the governing mechanism, and the exceedingly sensitive governor insure a perfect and, under

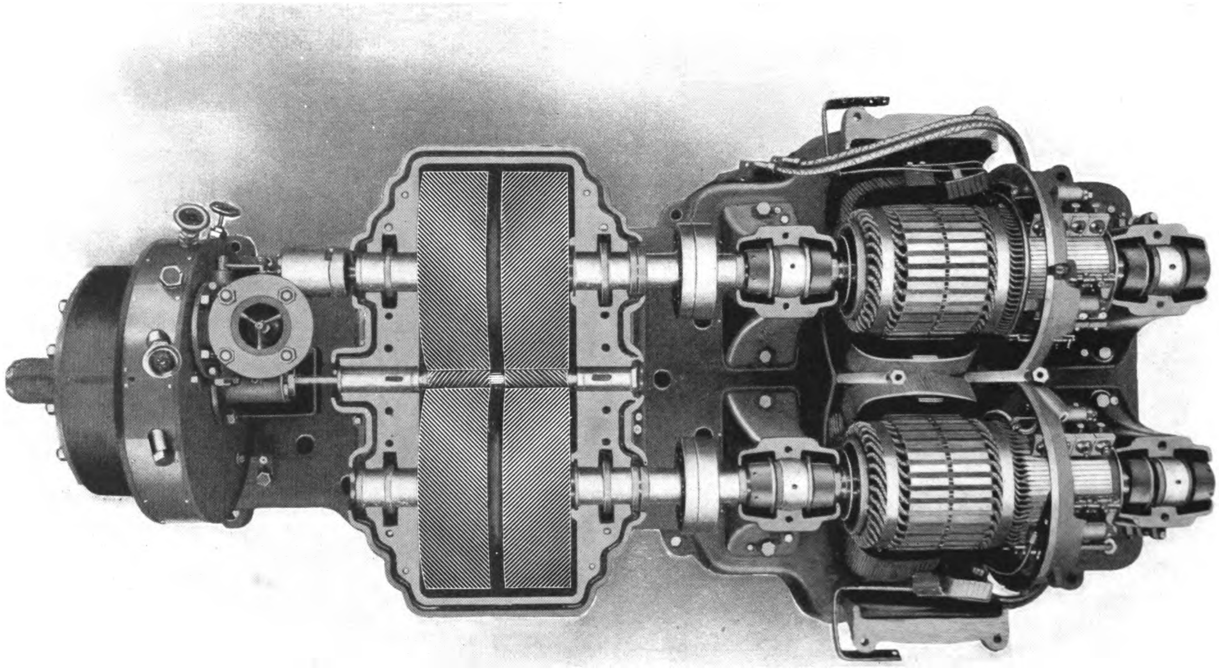


Fig. 11.—110 H. P. Turbine Dynamo—Upper Half of Gear Case and Field Frame Removed.

all conditions, safe control of the speed of the TURBINE, at the same time keeping the variation within very small limits. The value of this cannot be over-estimated, especially where a machine is used for driving electrical apparatus, where the full load is often thrown off or on at once, a happening which has proven destructive to many a steam engine. The DE LAVAL STEAM TURBINE is particularly adapted for operating alternating machines in parallel, as there is an entire absence of variation in angular velocity, which is responsible for so much trouble with reciprocating engines. The diagrams, page 28, show the excellent control of the DE LAVAL STEAM TURBINE as compared with other motors.

Simplicity of Construction.

Simplicity of construction is one of the most important features of the DE LAVAL STEAM TURBINE. The wearing parts are few, practically being limited to the bearings. These are plain and simple in construction, and like all the other moving parts are made interchangeable and can therefore be cheaply and quickly replaced, no fitting whatever being necessary.

Perfect Balance—Small Foundations.

The entire absence of reciprocating motion and the light weight and perfect balance of all revolving parts removes the necessity of foundations, except such as are required to sustain the weight of the larger sized machines, and as this is much less than the weight of reciprocating engines of the same capacity, the saving in cost of foundations is an important item. In the smaller sizes *no foundations whatever* are necessary, and TURBINES of *any size* may be placed in the upper stories of high buildings without any preparation other than strength enough to sustain the dead load.

Small Space Occupied.

As compared with a steam engine of equal power the space occupied and the weight of the TURBINE are both extremely small. A large part of the metal in a reciprocating engine is used to absorb the *shock*, which is entirely absent in the TURBINE, but a sufficient quantity of metal is used in the TURBINE wherever necessary to withstand any strains it may be called upon to resist, and a large factor of safety is allowed. The saving in space occupied, cost of building, transportation and erection, as well as weight and cost of repairs when needed, are items well worth consideration.

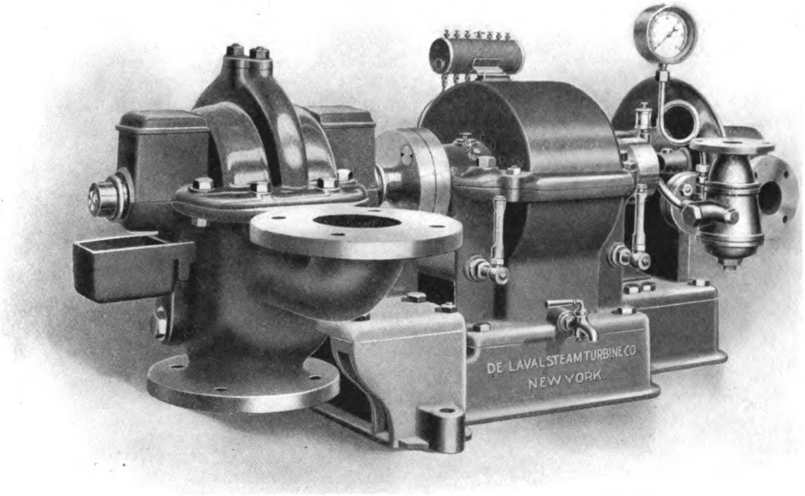


Fig. 12.—15 H. P. Steam Turbine Pump.

Ease of Erection.

All TURBINE machinery is mounted upon a substantial bedplate, and owing to its light weight and small size is shipped completely assembled, and the erection easily and quickly made. In the construction of the DE LAVAL STEAM TURBINE particular attention has been paid to the accessibility of all parts and the design is such as to make assembling or taking apart extremely simple.

Automatic Oiling.

The main shaft and dynamo bearings are ring oiling and require no attention other than an occasional refilling with oil. The bearings on the turbine shaft are fed from a common reservoir holding enough oil for a day's run, and a receptacle is provided in the base which collects all of the drip oil. This can be filtered and used over and over again. The oil reservoir is a closed one and can be connected with an elevated tank. By pumping the drip oil to tank after passing through a filter the system becomes automatic. The quantity of oil consumed under all conditions is much less than that used by a steam engine. Only one grade of oil is required for all parts of the TURBINE, and as this is of extremely light weight and low in cost, the entire expense of lubrication is very slight, and the quantity of oil consumed under any conditions is much less than that used by a reciprocating engine.

No Danger from Water.

There is absolutely no danger from water being carried over into the motor as there are no valves and no clearance spaces where damage could result therefrom, the only affect of a large body of water being a slight slowing down of the wheel until the water is disposed of. It is well, however, in all cases to use a separator close to the governor, as wet steam slightly decreases the efficiency of the TURBINE.

Long Life.

An experience extending over a period of about eight years, during which time there have been placed on the market from the European factories upwards of *four thousand* STEAM TURBINES, has demonstrated that the wear in every case is very much less than any reciprocating engine. Some of these machines have been in operation during the entire time with practically no repairs, and at the most it has been only a matter of renewing some interchangeable babbitt bearings which can be removed or replaced *without lifting the* TURBINE *shaft or the gear shaft from its position*, and in an extremely short space of time. Unlike another well-known make of TURBINE there are no studs or pins about the governor or any other part of the DE LAVAL TURBINE; these always give more or less trouble, and in the governors and valve motions of all types of reciprocating

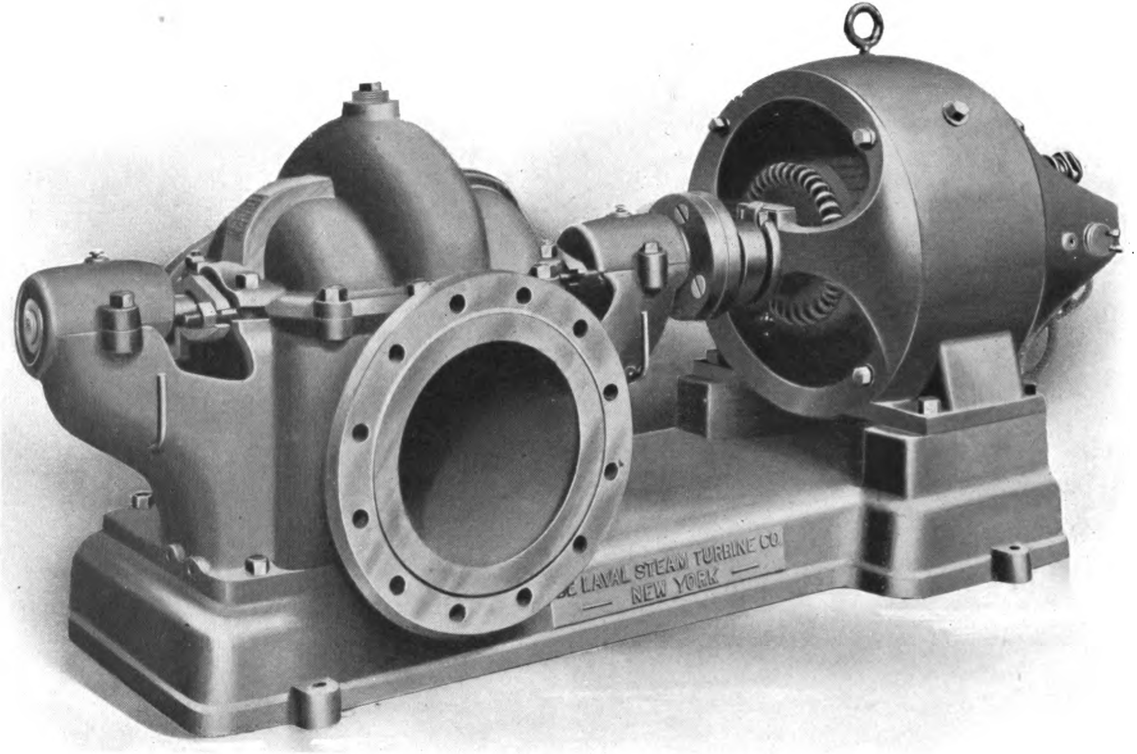


Fig. ~~31~~ 13.—20 H. P. Electro Motor Pump. Capacity, 2,400 Gallons per Minute, 30 Feet High.

engines, where the centrifugal force makes them difficult to lubricate, they are soon worn flat on one side. In the TURBINE there is no valve motion to wear, as in the steam engine, or to cause excessive friction and consequent loss in efficiency, which is a considerable item even in the best *so-called* balanced valve engine. It is of course necessary that nothing but the very best of materials and workmanship should enter into the construction of the TURBINE and nothing has been left undone to make the DE LAVAL STEAM TURBINE long-lived and free from accident.

Direct Connected Units.

The DE LAVAL STEAM TURBINE is particularly well adapted for direct connection to dynamos, centrifugal pumps, blowers, fire engines, etc. All such units are built and tested in the Works, which is a decided advantage over the old method of buying an engine from one place, a generator or a pump from another, and having them fitted together on the ground where used, oftentimes with great expense and delay and probably a poor piece of work as the result. All machines are ready when taken from the car to be set down and operated wherever convenient, nothing being necessary but the connection of steam and exhaust, and switch-board connections in case of dynamos.

High Speed.

High speed, while objectionable in some classes of machinery, is certainly not in the TURBINE; the parts being so small, so perfectly balanced, and so well lubricated, are more durable than those of even a slow moving reciprocating engine. While the speeds used in the DE LAVAL STEAM TURBINE may seem excessive when applied to a steam engine, they are common practice in other lines of work where the conditions imposed on them are more severe than with the TURBINE.

The De Laval Separator Company has during the last twenty years placed on the market over *two hundred and fifty thousand* centrifugal cream separators, which are running at speeds once considered absolutely out of the question. Moreover, these machines have been placed in operation on *farms* and in *creameries* where they are handled by the *cheapest class of help*, and oftentimes with practically *no* attention and almost no repairs. In addition to these many thousands of other makes of separators have been sold and are in operation every day at speeds varying from *six thousand* to *twenty-five thousand* revolutions per minute. They are set up with poor foundations, or none at all, and frequently where care is not taken with the engine governor the speed even exceeds these figures. Aside from a rare accident, caused by the grossest carelessness, these machines are never heard of by the engineering public. If working under such conditions and at such speeds these separators give satisfaction, as they undoubtedly do, there should certainly be no question in the mind of a steam user as to the durability of the DE LAVAL STEAM TURBINES, with their wonderful simplicity of construction and used as they are where all conditions are infinitely better, and where in the majority of cases they are in the hands of intelligent operators.

A Comparison.

Compared with another Steam Turbine now being experimented with in this country the contrast is even greater than with the most complicated steam engine. Taking a 300 horsepower machine as a basis, the DE LAVAL STEAM TURBINE has about three hundred and fifty buckets in the wheel against *thirty one thousand and seventy-three* in the other Turbine of equal capacity. Aside from this the other has a very great complication of parts, a large number of pins and studs in the governor, a valve motion allowing the steam to be admitted intermittently as in a reciprocating engine, a number of steam-packing joints, and several balancing cylinders; in one case the efficiency being produced by high speed and simplicity of parts and the other by a somewhat lower speed and a very great complication of parts.

In Conclusion.

IN THE DE LAVAL STEAM TURBINE RUNNING NON-CONDENSING, THE CONSUMPTION OF STEAM PER HORSE-POWER HOUR IS LESS AT FULL LOAD THAN IN ANY SIMPLE NON-CONDENSING STEAM ENGINE. CONDENSING, THE CONSUMPTION IS LESS THAN IN ANY COMPOUND CONDENSING ENGINE. UNLIKE THE STEAM ENGINE, HOWEVER, THE EFFICIENCY IS NEARLY THE SAME THROUGHOUT ITS ENTIRE WORKING RANGE. IT HAS FEWER PARTS, IS LESS LIABLE TO GET OUT OF ORDER, REQUIRES LESS OIL, LESS CARE, AND, TO USE THE WORDS OF PROFESSOR R. H. THURSTON, IT IS "THE STEAM ENGINE OF MAXIMUM SIMPLICITY AND HIGHEST THERMAL EFFICIENCY."

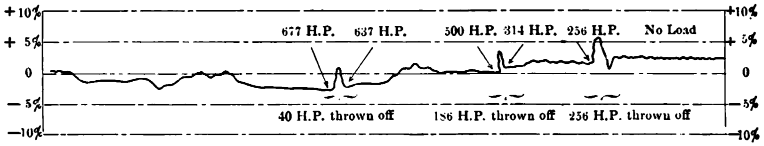
Speed-Diagrams Taken by Horn's Self-Registering Tachograph.

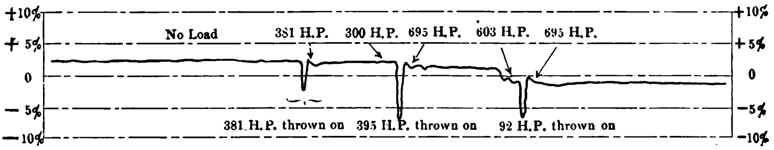
(*The space between two adjoining horizontal lines represents 5 per cent. variation of speed.*)

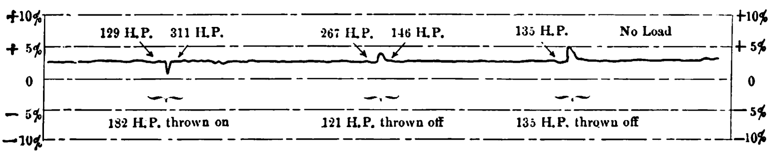
1. Speed variations observed at delivery-test of a *Triple-Expansion Condensing Corliss Engine* directly coupled to a continuous current dynamo for electric lighting.

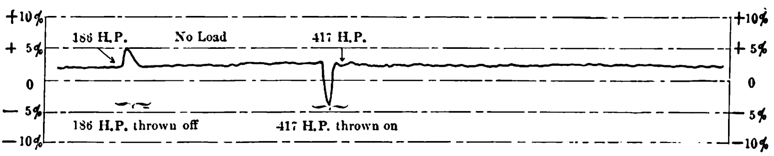
Normal load *500 horse-power.*

Normal speed *100 revolutions* per minute.





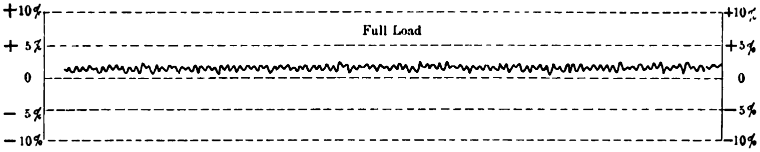




2. Speed variations observed at a *Compound Condensing Engine* with two cranks at 90 degrees driving a cotton mill.

Constant load *350 horse-power.*

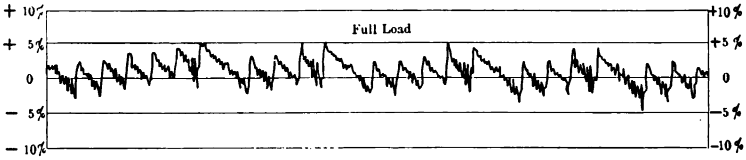
Normal speed *60 revolutions* per minute.



3. Speed variations observed at a *Gas-motor* with two fly-wheels driving by belting a dynamo for lighting purposes.

Constant load *35 horse-power.*

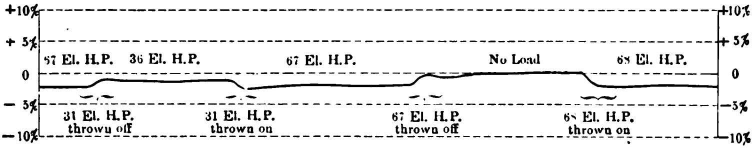
Normal speed *175 revolutions* per minute.



4. Speed variations observed at a *De Laval Steam Turbine Dynamo* working non-condensing.

Normal load *135 Electrical horse-power.*

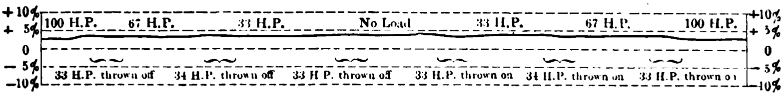
Normal speed *1,050 revolutions* per minute.



5. Speed variations observed at a *De Laval Steam Turbine Motor* working condensing.

Normal load *100 eff. horse-power.*

Normal speed *1,050 revolutions* per minute.



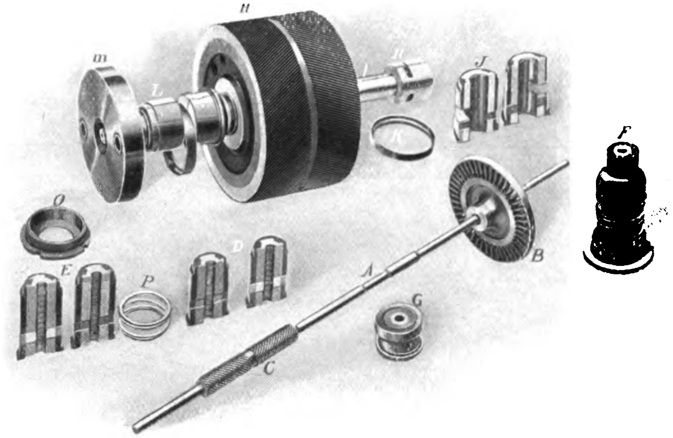


Fig. 14.—Working Parts of the De Laval Steam Turbine.

A.—Turbine shaft.
B.—Turbine wheel.
C.—Pinion.
D.—Pinion bearing, two parts.
E.—Pinion bearing, two parts.
F.—Wheel bearing with spring.
G.—Flexible bearing.
H.—Gear wheel.

I.—Gear wheel shaft.
J.—Gear wheel bearing, two parts.
K.—Oil ring.
L.—Gear wheel bearing in position.
M.—Coupling.
N.—Centrifugal governor.
O.—Gland adjusting nut.
P.—Adjusting nut for flexible bearing.

General Description.

The general construction of the De Laval Steam Turbine will be clearly understood from the sectional plan and elevation (Figs. 16, 18 and 21), and the halftone showing the different parts (Fig. 14). The construction of the Turbine it will be seen presents no extraordinary departure from every day engineering practice. However, the workmanship and material used, owing to the high speed employed, must be of the very highest quality.

Referring to (Fig. 14), B is the turbine wheel mounted upon the slender flexible shaft A, and in such position relative to the wheel case as to revolve entirely free, liberal space being allowed on each side as shown. The wheel case and the wheel case cover are so shaped as to form "safety bearings" around the hub of the wheel for the purpose of catching and checking its speed in case of an accident to the shaft.

The steam after passing through the governor valve C (Fig. 21) enters the steam chamber D, where it is distributed to the various nozzles. These, according to the size of machine, range in number from 1 to 15. They are generally fitted with shutting off valves E (Fig. 15), by which one or more nozzles can be cut out when the Turbine is not loaded to its full capacity. This allows steam of boiler pressure to be almost always used, and adds to the economy on light loads.

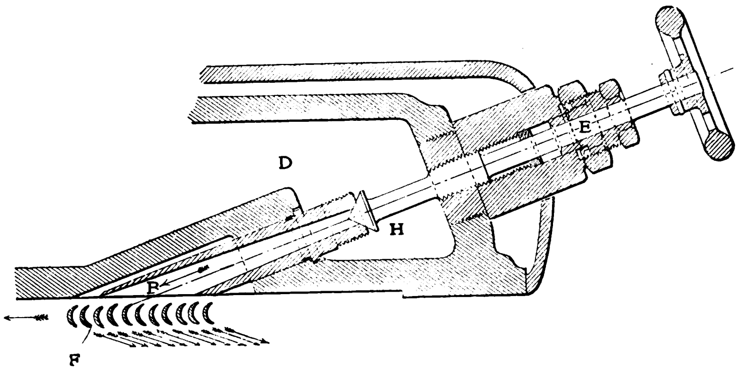


Fig. 15.—De Laval Nozzle.

After passing through the nozzles, the steam, as elsewhere explained, is now completely expanded, and in blowing through the buckets F (Fig. 15), its kinetic energy is transferred to the turbine wheel. After performing its work the steam passes into the chamber G (Fig. 16), and out through the exhaust opening H (Fig. 21).

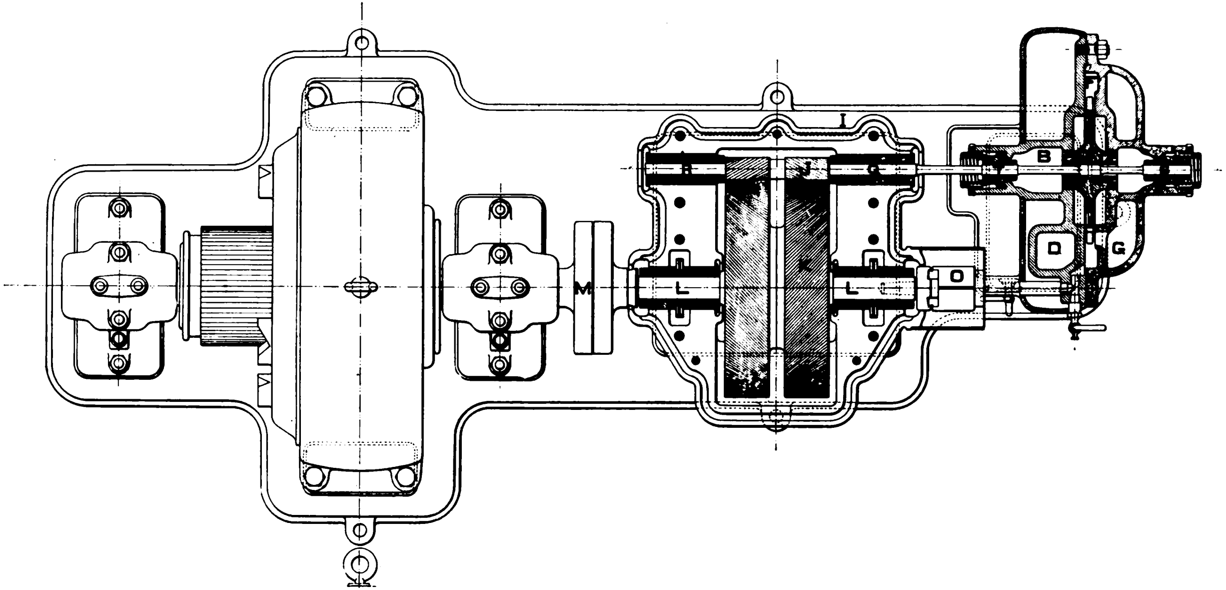


Fig. 16.—Sectional Plan De Laval Turbine Dynamo, 30 H. P.

The velocity of the turbine wheel and shaft, in most cases too great for practical utilization direct, is considerably reduced by means of a pair of spiral gears, usually made 10 to 1. The gear is mounted and enclosed in the gear case I (Fig 16). J is the pinion made solid with the flexible shaft and engaging the gear wheel K. This latter is forced upon the shaft L, which with couplings M, connects to the dynamo or is extended for pulley. O (Fig. 21) is the governor held with a taper-shank in the end of shaft L, and by means of the bell-crank P operates the governor valve C.

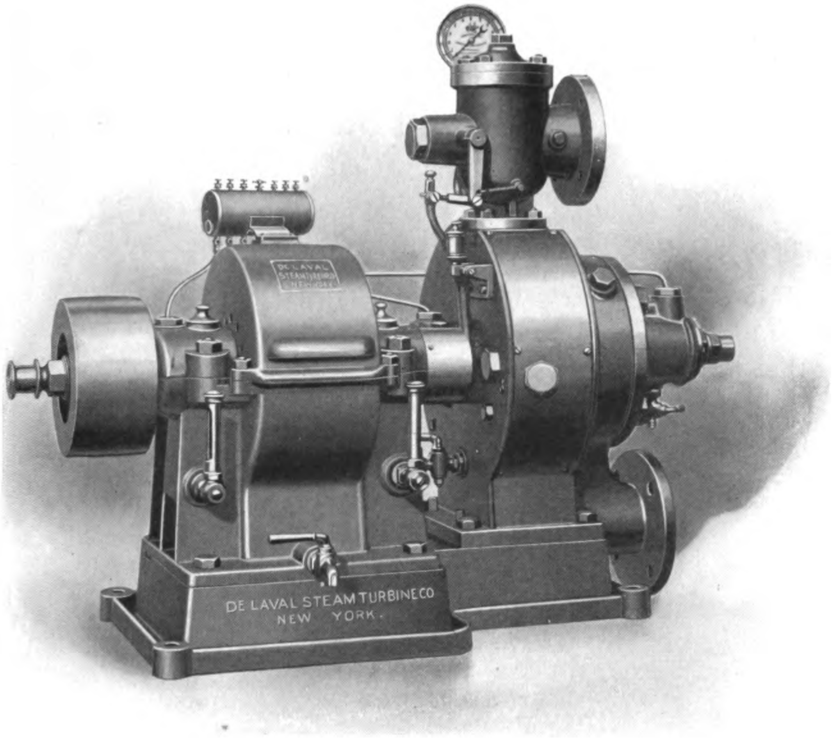


Fig. 17.—De Laval Steam Turbine Motor, 15 H. P.

Bearings.

The flexible shaft is supported in three bearings (Fig. 16). Q and R are the pinion bearings and S is the main shaft bearing

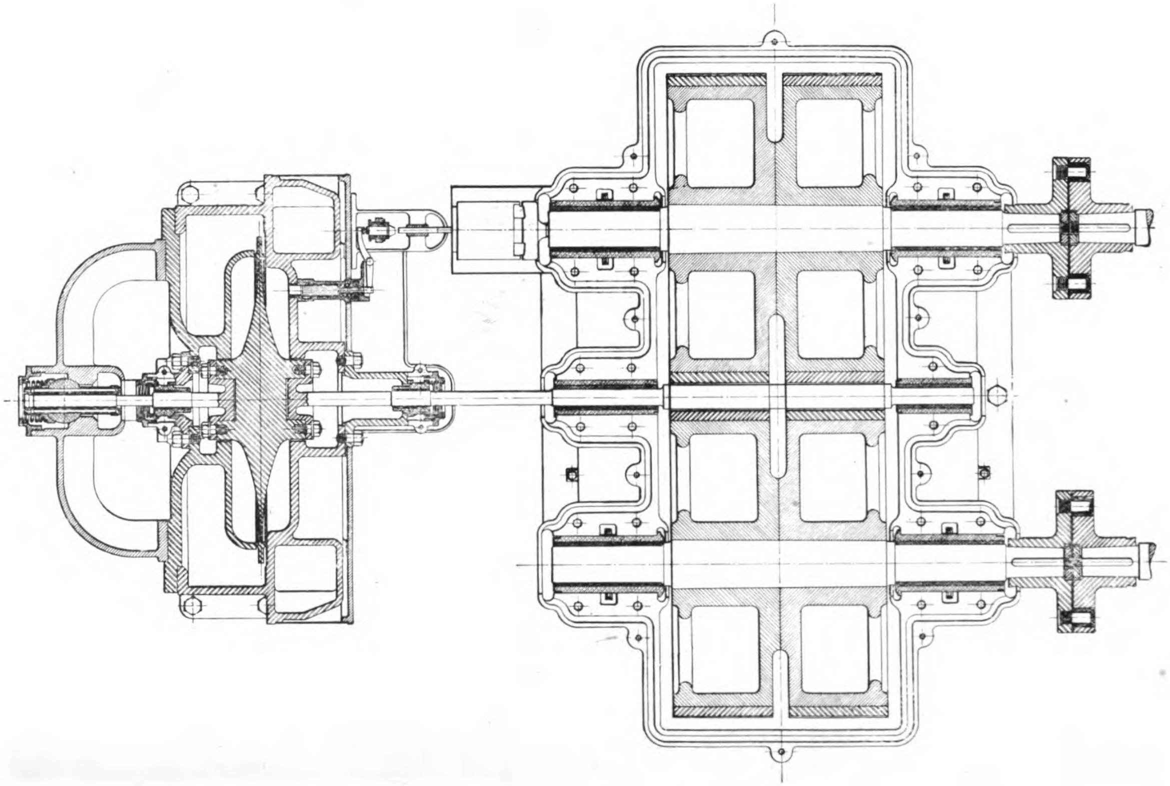


Fig. 18.—Sectional Plan De Laval Turbine, 300 H. P.

which carries the greater part of the weight of the wheel. This latter bearing is self-aligning and is held to its seat by the spring and cap shown. T is the flexible bearing. This bearing is entirely free to oscillate with the shaft, and its only purpose is to prevent escape of steam when running non-condensing, or air from entering the wheel case when the TURBINE is running condensing. All the bearings of the flexible shaft, as well as the gear wheel, are lubricated from a central oil reservoir U (Fig. 21), mounted upon the gear case; all other bearings are self-oiling. The bearings are plain and simple in construction, and made in two halves, so as to easily be taken out and examined. They are lined with the best quality anti-friction metal, are reamed true, round, and to exact size, and have the outside surface ground to insure perfect fitting and alignment. The bearings even in the largest sizes are removed and replaced without raising the shaft from its seat.

Gear Wheels.

The gear wheels are made of solid cast steel, or of cast-iron with steel rims pressed on. The teeth in two rows are set at an angle of 90° to each other. This, while insuring smooth running, at the same time checks any tendency of the wheel and shaft to move lengthwise, thereby making a troublesome trust bearing unnecessary. The gears are cut on automatic machines designed specially for this purpose, and a degree of accuracy has been attained not heretofore approached in gear wheel production. Owing to the high speed of the gears and their perfect alignment, the stress on the teeth is extremely small, and gears which have been examined after continuous operation for seven or eight years show no appreciable wear.

Flexible Shafts.

The flexible shaft is mainly supported on each side of the pinion by main bearings Q and R, the shaft is at the same time made very slender, which gives it a certain amount of flexibility and allows the Turbine wheel, when the so-called critical speed is

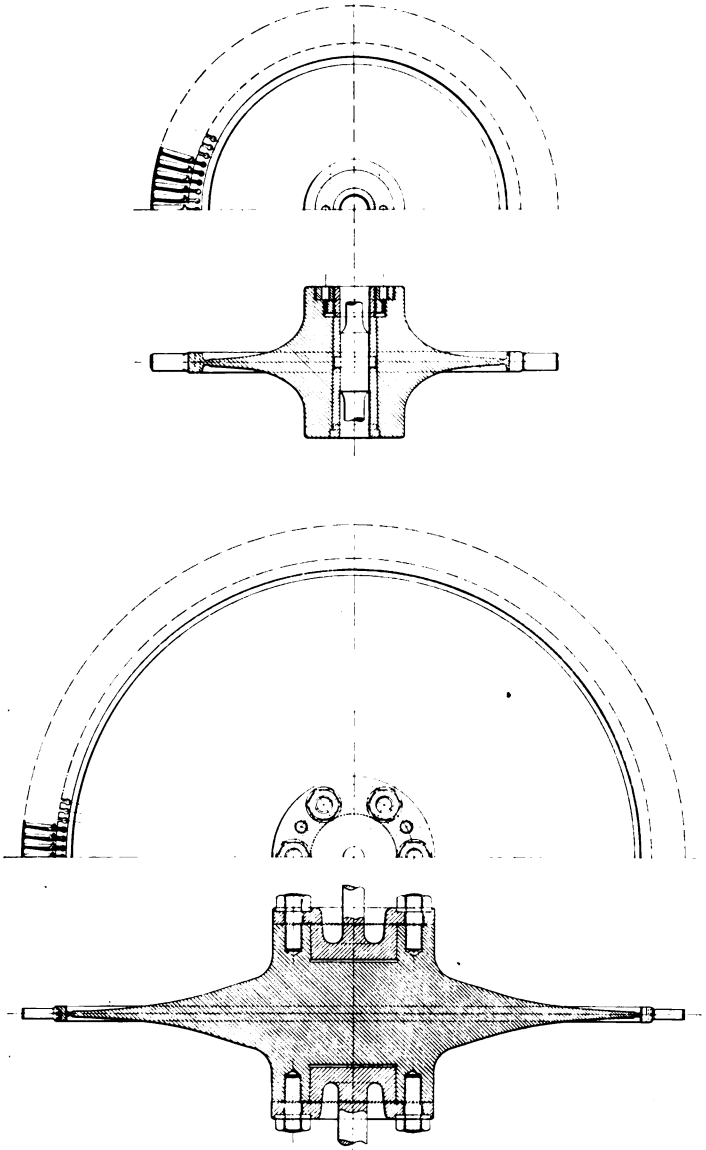


Fig. 19.—De Laval Turbine Wheels, 15 and 300 H. P.

reached, to revolve around its true centre of gravity. This critical speed, dependent upon the flexibility of the shaft, occurs well below the normal speed of the TURBINE and marks the disappearance of all vibrations.

Turbine Wheel.

The Turbine wheel is by far the most important part of the DE LAVAL STEAM TURBINE and is in its present form the result of numerous experiments both as to shape and material. It is made of forged nickel-steel, and will withstand more than double the normal speed before showing any signs of distress. In the smaller sizes the Turbine wheels have a hole through the centre and are forced upon a taper sleeve shrunk on to the shaft (Fig. 19). The larger wheels are made solid, with the shaft in two pieces screwed to the flanges of the wheel (Fig. 19). The buckets are drop forged and made with a bulb shank fitted in slots milled in the rim of the wheel. By this method the buckets can easily be taken out and new ones inserted, should occasion require, without damage to the wheel.

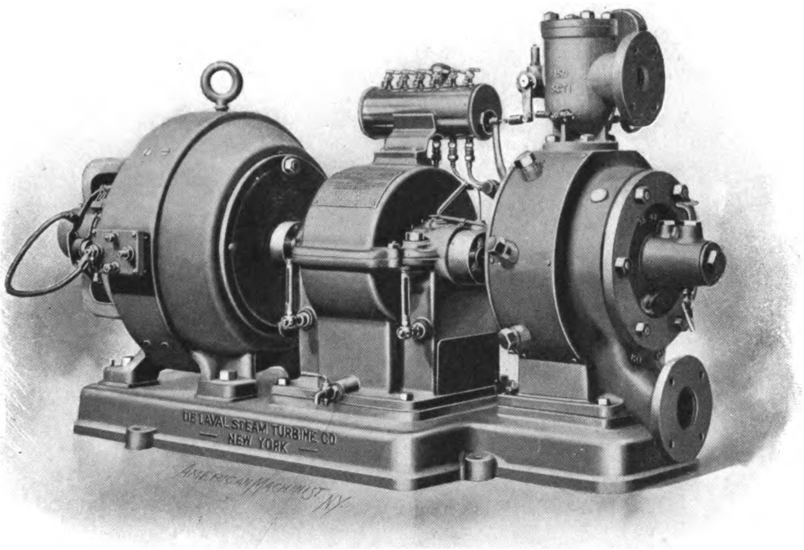


Fig. 20.—De Laval Steam Turbine Dynamo, 10 H. P., 6.6 K. W.

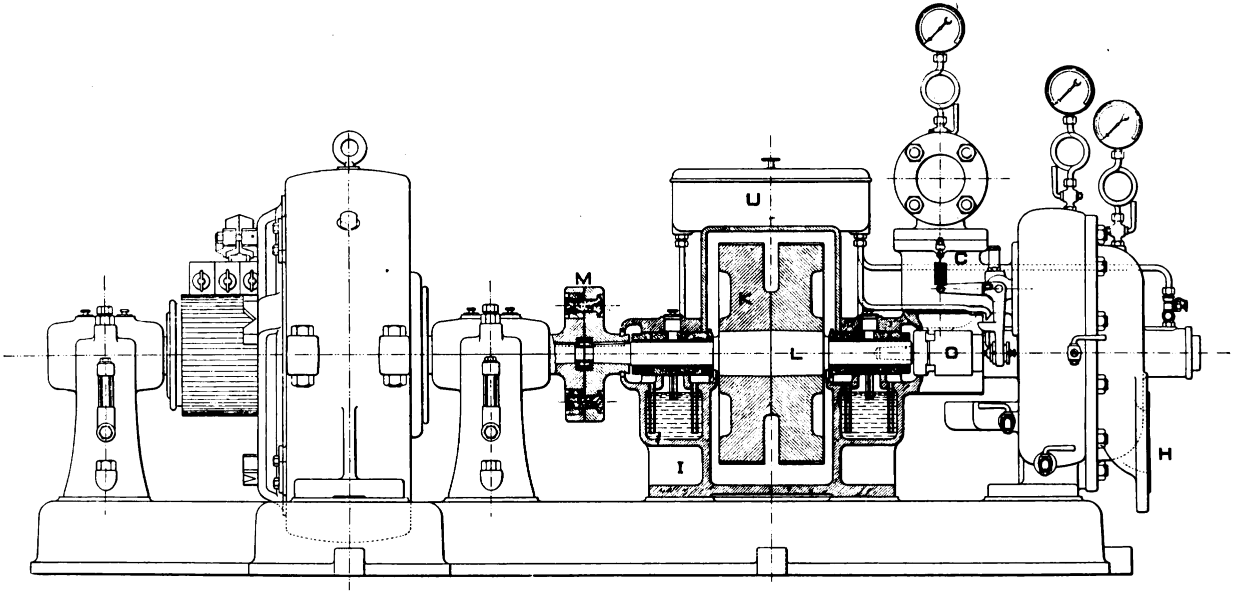


Fig. 21.—Sectional Elevation De Laval Turbine Dynamo, 30 H. P.

Governor.

With the high speed employed in the De Laval Steam Turbine a governor of small dimensions, and yet very effective, can be used. The governor shown in detail (Fig. 22), is compact and simple in construction. The two weights, B, are pivoted on knife edges A, with hardened pins C bearing on the spring seat D. E is the governor body, fitted in the end of the gear wheel shaft K, and has seats milled for the knife edges A. It is afterwards reduced in diameter to pass inside of the weights, and is in its outer end threaded for the adjusting nut I, by means of which the spring and eventually the speed of the Turbine is adjusted. When the speed exceeds the normal, the weights, affected by the centrifugal force, spread apart and, pressing on the spring seat D, push the governor pin G forward, cutting off part of the flow of steam.

Vacuum Valve.

The vacuum valve is only necessary when running condensing, as in this case it has been found that the governor valve alone is unable to hold the speed of the Turbine within the desirable narrow limit during sudden and great changes in the load. The function of the vacuum valve is as follows:

The governor pin G actuates the plunger H screwed into the bell-crank L, however, without moving the plunger relative to said crank. This is on account of the spring M being stiffer than the spring N, whose purpose is to keep the governor valve open and the plunger H in contact with the governor pin. When a large part of the load is suddenly thrown off the governor opens, pushing the bell-crank in the direction of the vacuum valve T. This closes the governor valve, which is completely shut off when the bell-crank is pushed so far forward that the screw O barely touches the valve stem J. If this is not sufficient to check the speed, the plunger H is pushed forward in the now stationary bell-crank and opens the vacuum valve. This allows the air to rush into the space P, where the Turbine wheel revolves, effectually checking its speed.

Applications of the De Laval Steam Turbine.

The De Laval Steam Turbine is adapted for all classes of work now performed by reciprocating engines and many others where such engines have proven impracticable or impossible. It is particularly suited for driving high speed machinery of all kinds where low steam *consumption* and *perfect regulation* are required. It is manufactured in the following types:

STEAM TURBINE MOTORS,

From 1½ to 300 Horse-Power Condensing and Non-Condensing.

DIRECT CONNECTED STEAM TURBINE DYNAMOS,

From 1 K. W. to 200 K. W. Direct or Alternating Current.

STEAM TURBINE PUMPS,

HIGH PRESSURE STEAM TURBINE PUMPS,

For Water Works.

ELECTRO-MOTOR PUMPS,

STEAM TURBINE BLOWERS,

MARINE LIGHTING SETS,

ROTARY FIRE ENGINES,

TRAIN LIGHTING EQUIPMENTS

AND

LOCOMOTIVE HEAD-LIGHT EQUIPMENTS.

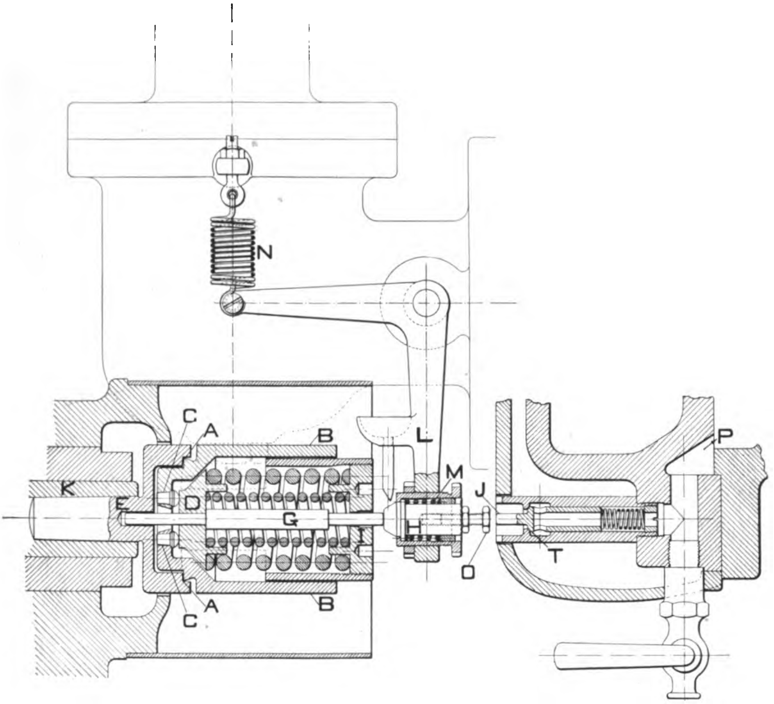


Fig. 22.—De Laval Governor and Vacuum Valve.

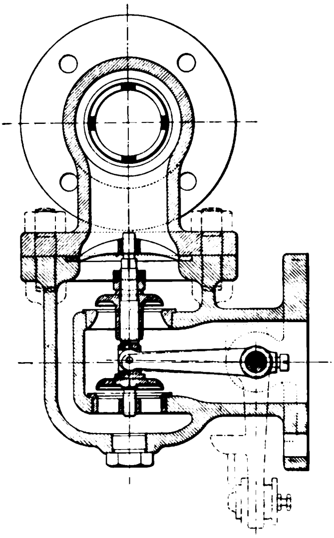


Fig. 23.—Governor Valve.

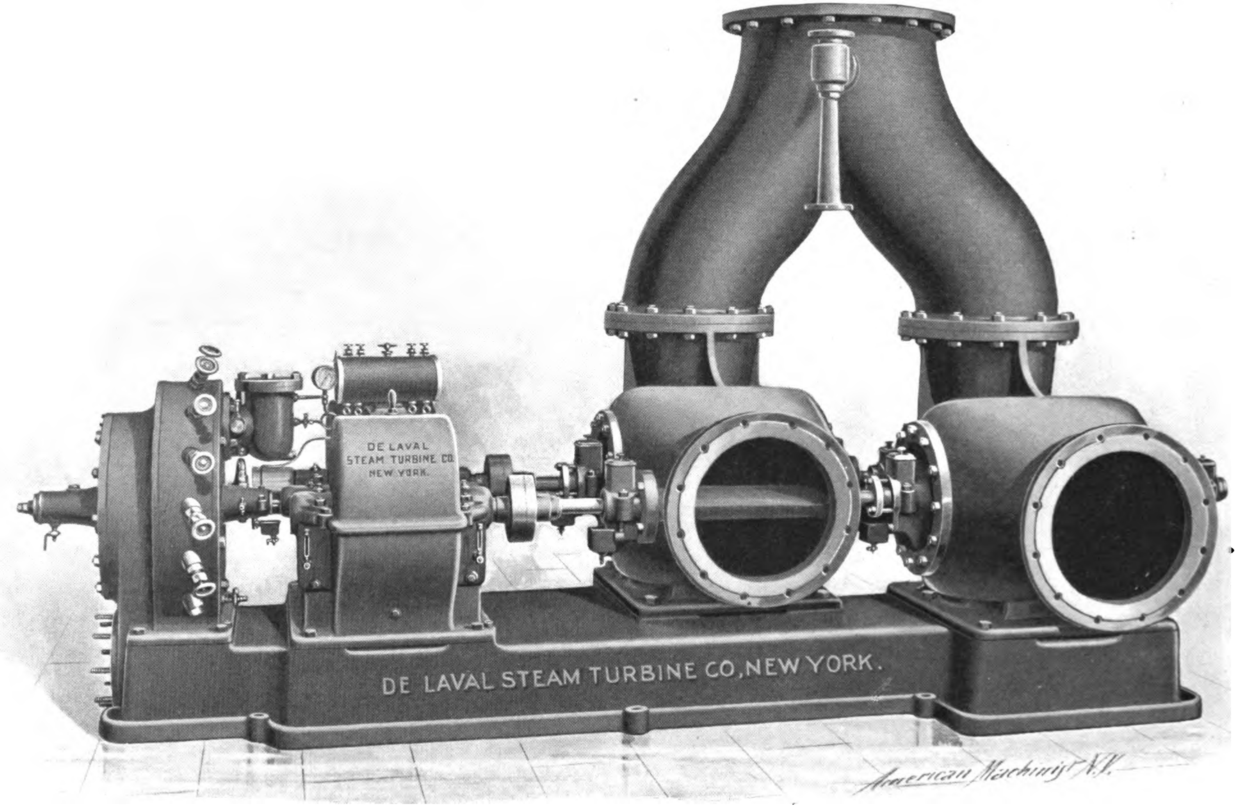


Fig. 24.—De Laval Steam Turbine Pump, 16,000 Gallons per Minute, 15 Feet Head

The De Laval Steam Turbine Company of America.

The reason that the De Laval Steam Turbine has not been sooner introduced in America has been the fact that the parent company wanted a very great sum for the patent rights and other privileges, which it was unable to realize until the economy and practicability of the Steam Turbine was as thoroughly demonstrated and generally accepted as its theoretical principle. This has been accomplished through years of experiment and considerable improvement by the parent and other European companies, and by the crucial test of practical use of hundreds of machines put into operation during the past seven years in various parts of Europe.

The American Company has now been organized, through the combination of the parent Company with competent American interests providing ample capital for the enterprise, thus acquiring the Steam Turbine and allied machinery rights for the United States and its colonies and dependencies, Mexico and Central and South America. This arrangement brings into co-operation the all important European experience with the best of American trade knowledge, engineering ability and shop practice. The new shops of the Company have been located at Trenton, N. J., and are considered one of the two or three best of modern American machine works. They are of the saw-tooth type with centre nave crane section, equipped throughout with the most modern of everything contributing to perfect work and economical shop operation. The power is supplied by Steam Turbines and the plant is electrically driven. The cranes are electric traveling ones and many of the larger tools are individually motor-driven. The complement of machine tools was selected by an expert purchasing agent only after a careful study of the best up-to-date shop practice, both at home and abroad, and many of them have been specially designed for their particular purpose.

The name De Laval has long since come to stand for the best that is possible in a machinery way. The Turbine Company will strive to raise the De Laval standard still higher. Nothing but the best of materials and the highest class of workmanship enters into the construction of De Laval Machinery. All work is made with jigs and templates, is absolutely interchangeable, and is subjected to the strictest inspection.

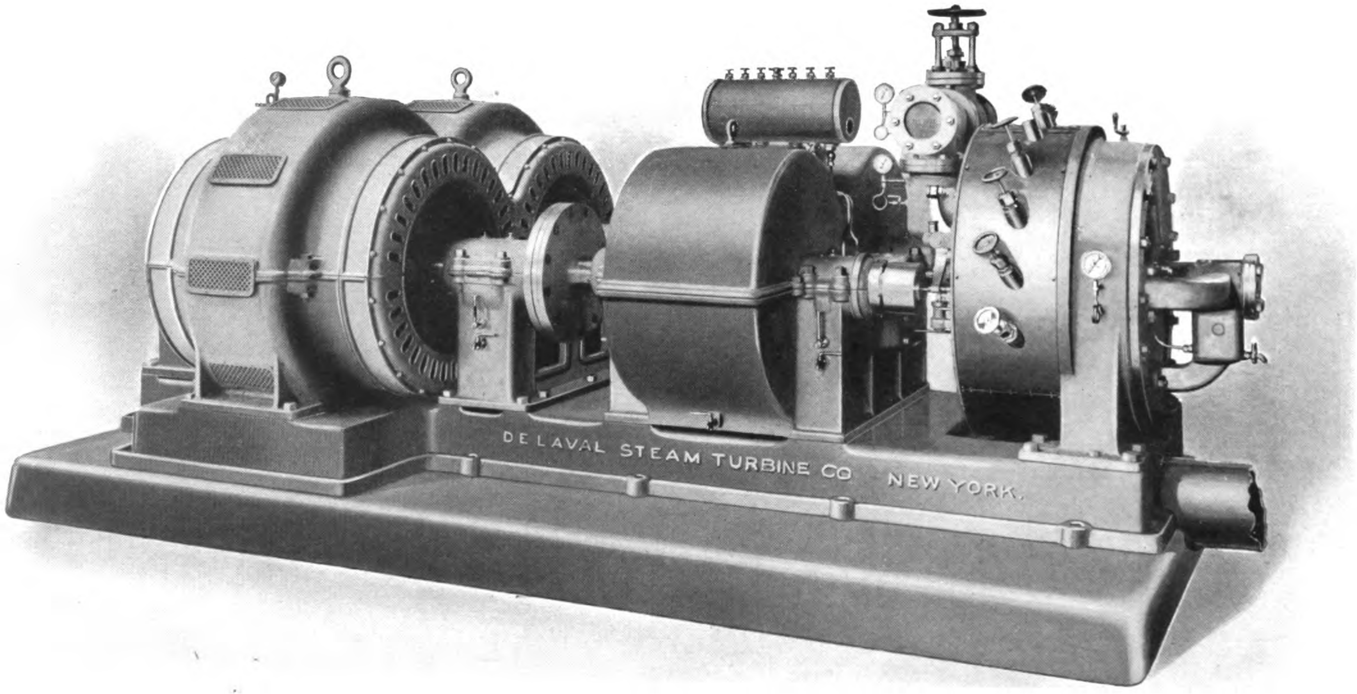


Fig. 25.—De Laval Steam Turbine Alternator, 300 H. P., 200 K. W., Two Phase.

Guarantees and Tests.

Every machine shipped bearing the Company's name has been carefully tested as to accuracy, capacity and efficiency, and a full record of such test will be furnished with each machine. It is guaranteed against defective workmanship or material for a period of one year. It will conform to specifications in all particulars and will operate successfully if used according to instructions.

The factory testing room is supplied with all modern appliances for both electrical and steam efficiency tests, and an opportunity is afforded every purchaser of making, or having made, before shipment, a complete test of any machine purchased. This removes all uncertainty as to guarantees, as the purchaser may *accept* or *reject* machines on such tests *without* the expense and loss of time occasioned when tests are made after *foundations* are built and *erection* completed. It is well known among engineers that many guarantees are made which are impossible of fulfilment, the builder relying on the fact that the purchaser will not order a machine taken out after going to the expense of erecting and connecting it. This method of testing a machine *before shipment* is undoubtedly the fairest both to purchaser and builder, and we recommend it in all cases.

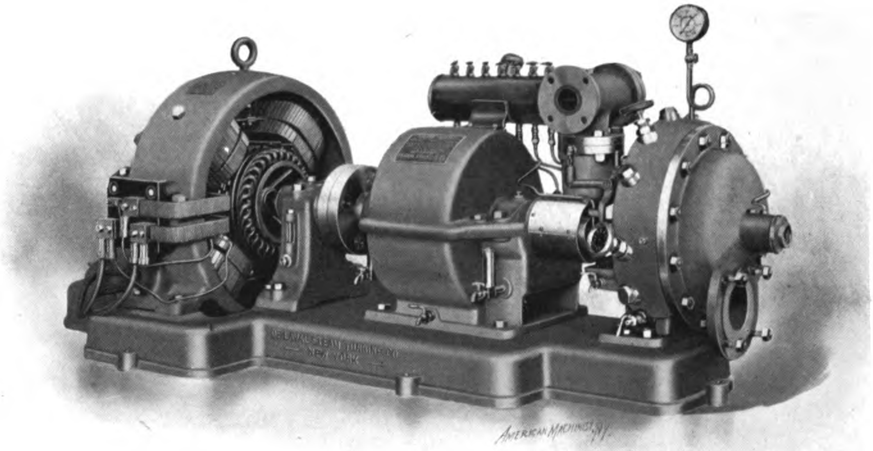


Fig. 26.—De Laval Steam Turbine Dynamo, 30 H. P., 20 K. W., Direct Current.

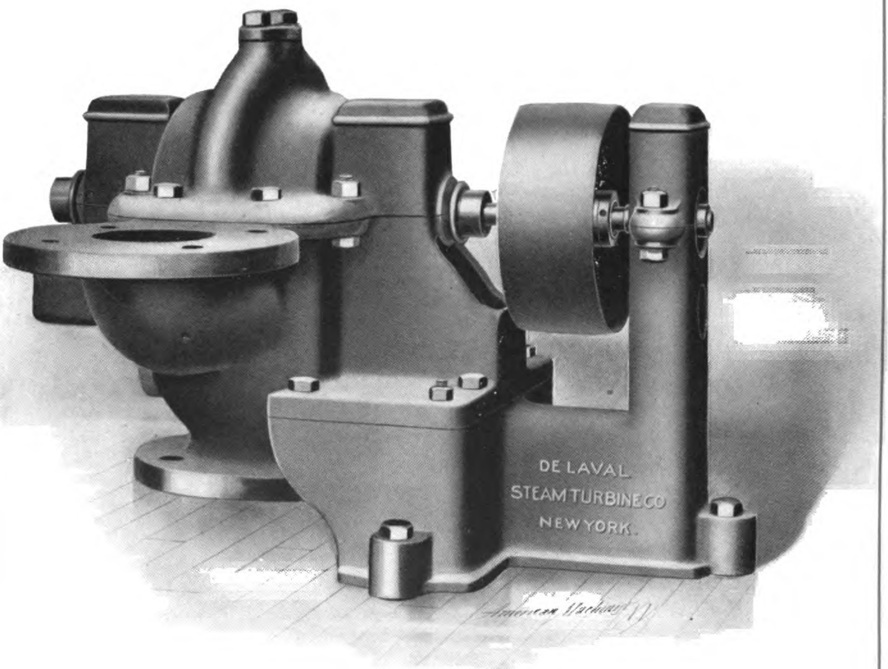


Fig. 27.—De Laval Belted Centrifugal Pump.

Reports

UPON TESTS OF A 300-BRAKE HORSE-POWER DE LAVAL STEAM TURBINE AT THE WORKS OF THE DE LAVAL STEAM TURBINE CO., TRENTON, N. J.

De Laval Steam Turbine Company,
74 Cortlandt Street, New York, N. Y.

Gentlemen:

On May 21, 22, 23 and June 10, 1902, we conducted several trials under various conditions, of a 300-brake horse-power De Laval Steam Turbine, which is in operation at your factory in Trenton, N. J.

The Turbine shaft is geared into two other shafts, instead of one as is frequently the case with De Laval Turbines, and on each of the latter shafts there is a direct current electric generator, both revolving in the same direction, and operating in series.

The current generated is used for driving the tools in the machine shop where Turbines are manufactured, but the capacity of the shop is not at present sufficient to utilize the whole power of the Turbine or generators. The excess load over the shop requirements was taken up by a water rheostat, which also served the purpose, by frequent adjustment, of maintaining a uniform load. The load could not be kept strictly uniform, but was sufficiently so for all practical purposes. The three-nozzle test on June 10 was made in the evening and the load was all absorbed by the rheostat and was uniform.

Steam was supplied to the Turbine by a 250 horse-power Babcock & Wilcox boiler, with the same company's superheater attached, and operated at a pressure of about 200 lbs. by the gauge. There were two of these boilers in the room, but that supplying steam to the Turbine was separated from the other by disconnecting steam, feed, blow-off and drain pipes, and blanking them in such a way that there were no losses or gains of water from leakage. All work in the shop by steam, independent of that done by the Turbine under test, was carried on by another boiler.

Several of the tests were made with superheated steam and several without, as stated in the detailed results of the tests. This could be conveniently done, as the Babcock & Wilcox superheater can be thrown out of use at any time and the pipes forming it filled with water so as to add to the water heating surface of the boiler.

THE DE LAVAL TURBINE.

The De Laval Steam Turbine consists of a single disc with properly formed buckets on the circumference, against which steam impinges at a proper angle. The steam enters a ring shaped chamber surrounding the casing of the Turbine and cast in one piece with it, and from this it enters several nozzles that convey the steam to the Turbine buckets. These nozzles are formed in a way that has been found to be most suitable for the purpose, the interior being tapered with the large end towards the buckets. The steam in passing through the nozzles freely expands, thereby acquires velocity, gives up its work by impact upon the buckets, and thereby rotates the Turbine wheel. It is apparent from this brief description of the process of obtaining the energy from the steam, that if the means of converting the energy of the impact into useful work are sufficiently good, the efficiency of the machine will be high. There are many sources of loss to which the reciprocating engine is subject that are not present in the steam Turbine, and, of course, to some extent, *vice versa*. In the case of the Turbine the nozzles are not in contact with the Turbine buckets, and therefore if economy once exists it will be maintained indefinitely.

The power of the Turbine depends upon the number of nozzles in action, and these nozzles can be opened or closed by a hand wheel on each. The machine tested had twelve nozzles, but seven gave the rated capacity. It will be seen from this that the Turbine is capable of great overloads.

Regulation of speed is accomplished by a throttling valve operated by a centrifugal governor.

In connection with economy of steam and the ability to throw nozzles into and out of action, it is at once apparent that each nozzle performs its function as perfectly when operating alone as when any other number of nozzles is in operation. For this reason the Turbine does not change its economy of steam per indicated horse-power, if such could be determined, as does a reciprocating engine. There is no "range of temperature" of any importance in the Turbine to cause condensation of steam. The principal cause of diminished economy with the lighter loads than the rated load is the fact of constant friction with all loads. At overloads there is even greater economy than with the rated load for the reasons that the extra nozzles are of maximum economy and the friction losses are constant.

The Turbine exhausted into a Worthington injector condenser, and the vacuum was measured by means of a mercury column connected into the exhaust chamber of the Turbine.

The Turbine rotates very rapidly and the speed is reduced by the employment of a spiral spur pinion on the Turbine shaft gearing into one or two spiral gears, as the case may be, depending upon whether the power is desired on one or two shafts. The pinion and gears are both double with the teeth inclined in opposite directions so that there will be no end thrust to either shaft.

THE WATER MEASUREMENTS.

The water used by the boiler to make steam for the Turbine was weighed in a barrel resting upon an elevated platform scale, and from the barrel it was emptied into a barrel below. From the lower barrel the water was forced into the boiler by an injector which was worked by steam from the same boiler, correction for the overflow when starting the injector being made.

The height of the water when starting a test was noted by tying a string around the water glass, the height of which was measured in order to re-establish the height when desired.

The water quantities were determined for each hour separately during the tests, and with such uniformity in amounts, that one hour would have been sufficient to approximately establish the rates of consumption of the Turbine if such had been necessary. From the tables, however, it will be seen that longer periods were employed. The hourly quantities are given because it is a matter of interest to know with what degree of uniformity hourly results can be obtained. The final averages, however, should only form the means of judging of the economy of the Turbine.

When superheated steam was used the amount of superheat was determined by a bare stem Green thermometer inserted in a well of cylinder oil in the steam pipe between the throttle and governor valves. When saturated steam was used, the amount of moisture therein was determined by a Peabody throttling calorimeter, drawing steam from the same place. The calorimeter discharge was weighed and deducted.

A separator was located in the line of steam pipe near the Turbine. When superheated steam was used no condensation was weighed from the separator, but when saturated steam was used a quantity was continually discharged. This was weighed and was deducted from the Turbine consumption. There was a drain from the chamber which supplied the Turbine nozzles, but it was considered that such steam, having once entered the apparatus undergoing the test, should not be deducted from the water weighed. It accordingly was trapped and the discharge allowed to waste.

There was a slight drip from a small pipe at the bottom of the main steam pipe. This was of little consequence, but was nevertheless caught and deducted from the weighed water.

THE ELECTRICAL TESTS.

The power, the measurement of which was desired, was the brake horsepower of the Turbine, as it might have been measured by some form of friction brake simultaneously applied to each shaft on which the electric generators were secured. For this purpose the generators might have been disconnected by means of a flanged coupling in each shaft, but as the electrical power was needed for operating the shop, the generators were used and their efficiencies determined.

The electrical measurements were made by nice instruments and their errors were determined by taking them to the works of the Weston Electrical Instrument Co., Waverly Park, N. J.

The efficiencies of the generators were ascertained for each load carried. The friction of generators was determined by driving them as motors by another generator. Other resistances were computed by well-known methods and under the actual conditions of temperature, speed and out-put. Into these features of the tests this report does not enter, as the steam consumption per brake horsepower, only, is desired.

The electrical data was taken simultaneously by one of our assistants and by the electrical engineer of the De Laval Steam Turbine Co. The computations for powers, efficiencies and brake horse-powers were made by Messrs. Stone & Webster of Boston, and by the De Laval electrical engineer.

REGULATION OF SPEED.

No tests were made to ascertain the instantaneous effect in speed of change of load or to see how quickly the normal speed was regained after a change. In regard to the permanent effect of change of load on speed, this can best be observed from the data given in the tables of results farther on. The speeds and loads are here tabulated for convenience with percentages of variation of load and speed referred to these with eight nozzles in operation.

Table of Different Loads and Speeds.

WHEN USING SUPERHEATED STEAM EXCEPT WITH THREE NOZZLES.

Number of Nozzles. Open.	Loads. H. P.	Relative Loads.	Speeds. R. P. M.	Differences in Speeds.
8	352	100 per cent.	750	
7	298	85 "	756	$+\frac{8}{10}$ of 1 per cent.
5	196	56 "	745	$-\frac{7}{10}$ of 1 "
3	119	34 "	751	$+\frac{1}{10}$ of 1 "

Relative Economies for Different Loads.

These are shown by inspecting the tables of results, but the loads and economies are here given.

TABLE OF RELATIVE STEAM CONSUMPTION FOR DIFFERENT LOADS, PER BRAKE HORSE-POWER.

Number of Nozzles. Open.	Loads. B. H. P.	Relative Loads.	Steam per Brake H. P. Lbs.	Increase for Diminishing Loads, Referred to Maximum Load.
		Superheated Steam.		
8	352	100 per cent.	13.94	
7	298	85 "	14.35	2.9 per cent.
5	196	56 "	15.53	11.4 "
		Saturated Steam.		
8	333	100 per cent.	15.17	
7	285	86 "	15.56	2.6 per cent.
5	195	59 "	16.54	9.0 "
3	119	36 "	16.40	8.1 "

EFFECT OF SUPERHEATED STEAM.

By comparing the results of the tests with superheated and saturated steam, the saving by the use of the former can be determined for the particular amount of superheating existing. As the tables show, the superheat steadily diminished as the load became lighter. This was caused by the fire and draft being very light with the lighter loads. The superheat for the eight-nozzle load averaged 84° F. while that for the five-nozzle load only averaged 16° F. There is, therefore, scarcely any propriety in making a comparison for the effect of superheat, except with eight and seven-nozzle loads.

TABLE SHOWING THE SAVING BY THE USE OF SUPERHEATED STEAM FOR EIGHT AND SEVEN-NOZZLE LOADS.

Number of Nozzles in Use.	Amount of Superheat.	Load with Superheated Steam. H. P.	Load with Saturated Steam. H. P.	Steam Used per Brake H. P. with Superheated Steam. Lbs.	Dry Steam Used per Brake H. P. with Saturated Steam. Lbs.	Saving by Use of Superheated Steam.
8	84° F.	352	333	13.94	15.17	8.8 per cent.
7	64° F.	298	285	14.35	15.56	8.4 per cent.

In all of the statements made in this report of the consumption of superheated steam, the actual consumption without reduction to dry saturated steam as a standard, is given. This is customary, while with the results with superheated steam the moisture is deducted.

The Results.

TESTS WITH SUPERHEATED STEAM.

Number of nozzles open, eight (8).
Average reading of barometer, 30.18 in.
Average temperature of room, 83° F.

Date, 1902.	Hour.	Weight of Steam Used Per Hour. Lbs.	Pressure Above Governor Valve. Lbs.	Pressure Below Governor Valve. Lbs.	Vacuum In.	Superheat Above Governor Valve.	Revs. Per Minute of Generators.	Brake Horse-Power.	Steam Used Per Brake Horse-Power Per Hour. Lbs.
May 22	8- 9 a.m.	4833	208.3	200.6	27.2	81° F.		356.6	13.55
May 22	9-10 a.m.	4936	207.5	199.3	27.2	86° F.		355.7	13.88
May 22	10-11 a.m.	5083	207.7	202.1	27.2	91° F.		357.8	14.21
May 22	11-12 a.m.	4976	208.3	199.4	27.2	88° F.		354.1	14.05
May 22	12- 1 p.m.	4841	207.5	194.3	27.3	82° F.		343.5	14.09
May 22	1- 2 p.m.	4768	206.9	195.6	27.2	75° F.		344.4	13.84
Independent Average.	8- 2 p.m.	4906	207.0	198.5	27.2	84° F.	750	352.0	13.94

Number of nozzles open, seven (7).
Average reading of barometer, 30.07 in.
Average temperature of room, 90° F.

May 22 May 22	2.10 p.m. 3.10 p.m.	4316	207.5	196.2	27.4	67° F.		299.8	14.39
May 22 May 22	3.10 p.m. 4.10 p.m.	4248	207.3	197.9	27.4	61° F.		297.3	14.29
Independent Average.	2.10 p.m. 4.10 p.m.	4282	207.4	197.0	27.4	64° F.	756	298.4	14.35

Number of nozzles open, five (5).
Average reading of barometer, 29.79 in.
Average temperature of room, 89° F.

June 10 June 10	8.45 a.m. 9.45 a.m.	3068	199.2	196.5	27.6	8° F.		195.3	15.71
June 10 June 10	9.45 a.m. 10.45 a.m.	3010	201.5	197.2	27.4	12° F.		197.3	15.26
June 10 June 10	10.45 a.m. 11.45 a.m.	3020	201.4	196.1	27.4	10° F.		196.5	15.37
Independent Average.	8.45 a.m. 11.45 a.m.	3033	200.7	196.6	27.5	10° F.	743	196.5	15.44
June 10 June 10	1.45 p.m. 2.45 p.m.	3107	201.4	196.7	27.4	13° F.		194.8	15.95
June 11 June 10	2.45 p.m. 3.45 p.m.	3054	203.1	199.0	27.3	15° F.		197.9	15.43
June 10 June 10	3.45 p.m. 4.45 p.m.	3025	202.7	197.5	27.4	19° F.		194.7	15.54
Independent Average.	1.45 p.m. 4.45 p.m.	3062	202.4	197.7	27.4	16° F.	747	196.0	15.62
Average of both tests - - - - - - - - -							745		15.53

TESTS WITH SATURATED STEAM.

Number of nozzles open, eight (8).
Average reading of barometer, 29.92 in.
Average temperature of room, 90° F.

Date, 1902.	Hour.	Feed Water Weighed Per Hour. Lbs.	Condensation from Separator. Lbs.	Moisture in Steam at Throttle by Calorimeter.	Dry Steam entering Turbine. Lbs.	Pressure above Governor Valve. Lbs.	Pressure below Governor Valve. Lbs.	Vacuum In.	R.P.M. of Generators	Brake Horse Power.	Dry Steam Used Per Brake H.P. Per Hour. Lbs.
May 23	8.15 a.m. 9.15 a.m.	5289	70	2.15 %	5107	204.7	196.2	26.7		332.2	15.37
May 23	9.15 a.m. 10.15 a.m.	5073	70	2.15 %	4896	206.2	196.2	26.6		332.4	14.73
May 23	10.15 a.m. 11.15 a.m.	5286	70	2.15 %	5104	207.2	196.3	26.6		332.2	15.37
May 23	11.15 a.m. 12.15 a.m.	5283	70	2.15 %	5101	207.4	198.9	26.6		334.9	15.23
Independent Average.	8.15 a.m. 12.15 m.	5233	70	2.15 %	5052	206.4	196.9	26.6	747	333.0	15.17

Number of nozzles open, seven (7).
Average reading of barometer, 29.90 in.
Average temperature of room, 97° F.

May 23	12.45 p.m. 1.45 p.m.	4675	60	2.15 %	4516	207.0	196.6	26.8		284.4	15.88
May 23	1.45 p.m. 2.45 p.m.	4499	60	2.15 %	4344	207.7	196.4	26.8		285.2	15.23
Independent Average.	12.45 p.m. 2.45 p.m.	4587	60	2.15 %	4430	207.3	196.5	26.8	746	284.8	15.56

Number of nozzles open, five (5).
Average reading of barometer, 29.83 in.
Average temperature of room, 97° F.

May 23	3.00 p.m. 4.00 p.m.	3483	51	2.15 %	3358	207.5	196.5	27.3		194.8	17.24
May 23	4.00 p.m. 5.00 p.m.	3219	51	2.15 %	3100	207.8	195.1	27.4		195.6	15.85
Independent Average.	3.00 p.m. 5.00 p.m.	3351	51	2.15 %	3229	207.6	195.8	27.35	751	195.2	16.54

Number of nozzles open, three (3).
Average reading of barometer, 29.81 in.
Average temperature of room, 80° F.

June 10	6.35 p.m. 7.35 p.m.	1996	33	2.15 %	1921	201.1	196.5	28.1		115.0	16.70
June 10	7.35 p.m. 8.35 p.m.	2098	33	2.15 %	2021	201.6	198.9	28.1		122.0	16.57
June 10	8.35 p.m. 9.35 p.m.	1984	33	2.15 %	1909	201.7	198.4	28.1		121.5	15.71
Independent Average.	6.35 p.m. 9.35 p.m.	2026	33	2.15 %	1950	201.5	197.9	28.1	751	118.9	16.40

All barometer readings are reduced to 32° F.

Respectfully submitted,

DEAN & MAIN.

SOUTH PUB. CO., N. Y.