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Turbine wheels and water power

Herman N. Van Devander

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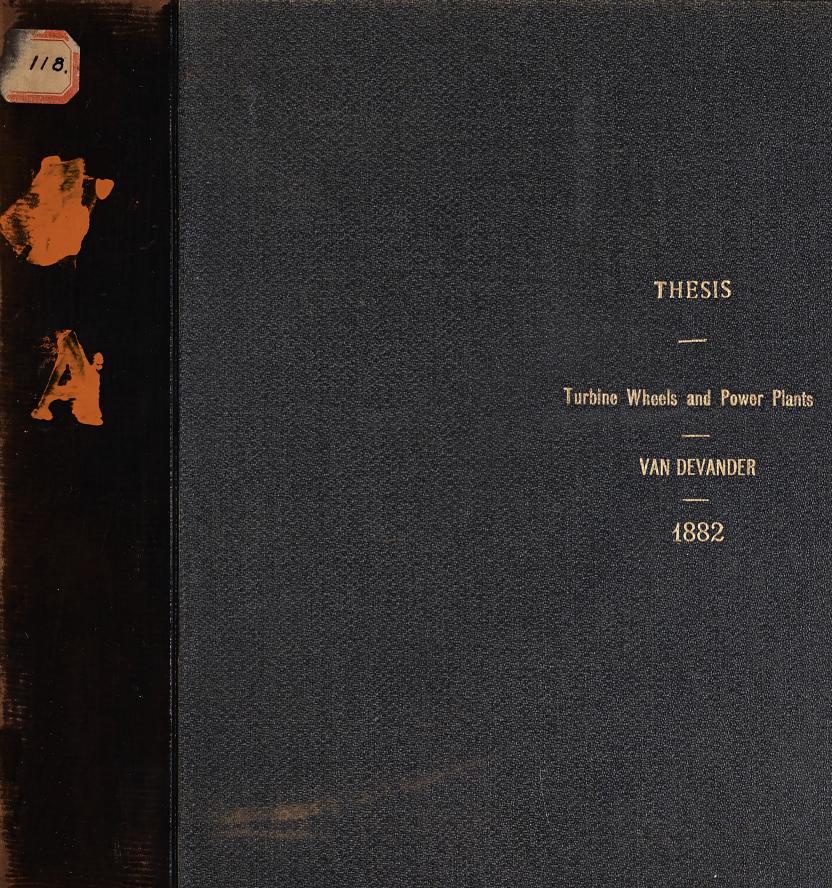
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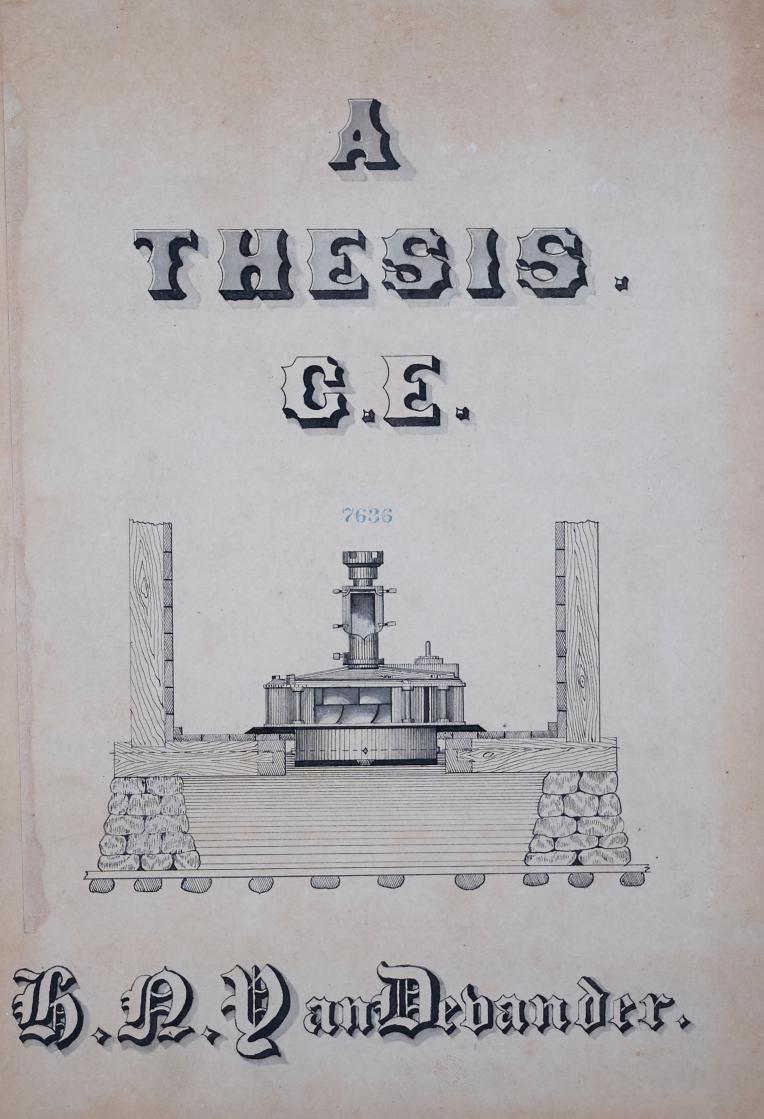
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A
Thesis
C.E.

H. N. VanDevander

· Jurbine while & Water Power

The utilization of the sower resident in natural water falls, ranks among The oldest of mans efforts & Escape animal power, and particularly the expenditure of his own muscular energy; and its natural cheapeness has rendered this one of the most promising fulds for the exercise of his morntor genius. From the crude apparatus used to furnish the blast for the old Catalan Iron Furnace (a column of water was allowed to fall Through a perfundicular box, perforated near the top to admit the air, which breoming entangled in the water, was carried downward to a prissure chamber at the bottom, and there to the tuyous) - and this is probably the least efficient of any method wer attempted, of obtaining work from water to the most perfect turbine of today, mu have labored, experimential, and mounted, with a slow but gradual improvement through quirations until mow they have succeeded in bringing out of the rough Catalan machinery which gave but an insignifceant fraction of the theoretical power

Turbine Wheels & Water Power

The utilization of the power resident in natural water falls, ranks among the oldest of mans efforts to escape animal power and particularly the expenditure of his own muscular energy: and its natural cheapness has rendered this one of the most promising fields for the exercise of his innovative genius. From the crude apparatus used to furnish the blast for the old Catalan Iron Furnace (a column of water was allowed to fall through a perpendicular box, perforated near the top to admit the air, which becoming entangled in the water, was carried downward to a pressure chamber at the bottom and thence to the tuyeres) - and this is probably the least efficient of any method ever attempted, of obtaining work from water. To the most perfect turbine of today, men have labored, experimented, and invented, with a slow but gradual improvement through generations until now they have succeeded in bringing out of the rough Catalan machinery which gave but an insignificant fraction of the theoretical power

of the water, machines which give to the actual performance of labor, from 60 to 90 per cent of the power resident in the water.

a turbine water-wheel is one through which the water passes, quided by channels either interior or exterior to the while its self, and the walls of these channels or guides as they are termed, are placed in such positions, as D'impings the water out the blades or while buckets at such an angle as will justis and buckets are usually curved in opposite directions, and are so placed, with regard to each other, that the water entires the while with the least possible shock. and leaves it with the least possible velocity. Durbines may be placed in any position, from a horizontal to a perfundicular, and another advantage they possessour the old style of while is, the higher the fall the smaller the while required, whereas with the over-shot wheel (the best form of old style) the reverse is the ease.

of the water, machines which give to the actual performance of labor, from 60 to 90 percent of the power resident in the water.

A turbine water-wheel is one through which the water passes guided by channels either interior or exterior to the wheel its self and the walls of these channels or guides as they are termed, are placed in such positions, as to impinge the water on to the blades or wheel buckets at such an angle as will insure the greatest efficiency. The guides and buckets are usually curved in opposite directions, and are so placed with regard to each other, that the water enters the wheel with the least possible shock and leaves it with the least possible velocity. Turbines may be placed in any position from a horizontal to a perpendicular and another advantage they possess over the old style of wheel is, the higher the fall, the smaller the wheel required, whereas with the overshot wheel (the best form of old style) the reverse is the case.

The orlocity of a small turbine under a high fall is necessarily very great, and this proves to be an advantage too, for it permits of the doing away with the heavy and expusion gearing which was necessarily used in connection with the old atyle while of great power; and it also gors a greater rigularity of motion. The turbine was first introduced into general use by Fourneyron in Grance, in 1827 and shortly after, it was used in England, and later it was introduced into the United States, by Boydur. Furbines are termed inward flow, outward-flow and parallel-flow wheels, 42to. according to the direction the water takes in passing through them. The modulus of a wheel is found as follows: The amount of water flowing through the while is found by graque, and its weight is measured by the hight of fall; The actual amount of power exerted by the wheel is ascertained by means of a dynamometer. how if we let R, represent the resistance, and V, the orlowity with which the while

The velocity of a small turbine under a high fall is necessarily very great and this proves to be an advantage too, for it permits of the doing away with the heavy and expensive gearing which was necessarily used in connection with the old style wheels of great power; and it also gives a greater regularity of motion. The turbine was first introduced into general use by Fourneyron in France, in 1827 and shortly after, it was used in England, and later it was introduced into the United States, by Boyden. Turbines are termed inwardflow, outward-flow and parallel-flow wheels, &etc. according to the direction the water takes in passing through them. The modulus of a wheel is found as follows: The amount of water flowing through the wheel is found by gauging and its weight is measured by the height of fall; The actual amount of power exerted by the wheel is ascertained by means of a dynamometer. Now if we let R, represent the resistance and, V, the velocity with which the wheel

over comes it; then RV will represent the work done in a wint of time. If we let W represent the weight of water flowing sursecond, h, the hight of fall, and, M, the modulus, we will have RV=WhM or M=RV which gives us the modulus or coefficient of afficiency. ourbines are found to give their greatest power when their orlocity is between 5/0 and 1/10 of that due to the height of the fall. The velocity of the water as it passes through the while should be kept as mearly uniform as possible, and the passages should have such a form and ara of cross-section as will insure the greatest uniformity. The orlocity of the whire should be made equal to the velocity of the while, and thus allow the water to glide our the buckets, without sudden change in orlocity, and finally, having spent all its force, morely drop from the while. Of is interesting in this advanced, stage of the world, and age of dup research, in

over comes it: then RV will represent the work done in a unit of time. If we let W represent the weight of water flowing per second, h, the height of the fall, and, M, the modulus, we will have RV=WhM or $M = M = \frac{RV}{Wh}$ which gives us the modulus or coefficient of efficiency. Turbines are found to give their greatest power when their velocity is between 5/10 and 7/10 of that due to the height of the fall. The velocity of the water as it passes through the wheel should be kept as nearly uniform as possible, and the passages should have such a form and area of cross-section as will insure the greatest uniformity. The velocity of the whirl should be made equal to the velocity of the wheel, and thus allow the water to glide over the buckets, without sudden change in velocity, and finally having spent all its force, merely drop from the wheel.

It is interesting in this advanced stage of the world and age of deep research, in

view of utilizing the enormous heat that daily, comes to us from the sun, for the purpose of power, and in view of the fact, that our steam engines are so rapidly consuming the vast stores of the past energy of that lummary, as potentially represented in the coal fields, to think that the most wastiful form of water while was a more perfect machine thou the highest type of our modern steam engine, while as a sur Engine or any contrivance whereby we may convert solar heat to power for our own use. the modern water while for exceeds in perfection, any thing man can ever hope to devise or discours The existing energy of a body of water at any level, represents exactly the Equivelant of the heat of the sun expended in raising it to that level, from some other, by evaporation, and the instrument or machine by which go per cent of this latinh power can be utilized, in the doeint from this level to

view of utilizing the enormous heat that daily comes to us from the sun, for the purpose of power, and in view of the fact that our steam engines are so rapidly consuming the vast stores of the past energy of that luminary, as potentially represented in the coal fields, to think, that the most wasteful form of water wheel, was a more perfect machine than the highest type of our modern steam engine, while as a sun engine or any contrivance where by we may convert solar heat to power for our own use, the modern water wheel far exceeds in perfection, any thing man can ever hope to devise or discover. The existing energy of a body of water at any level, represents exactly the equivalent of the heat of the sun expended in raising it to that level from some other, by evaporation, and the instrument or machine by which 90 per cent of this latent power can be utilized in the descent from this level to

that at which it was waporated, is about six times more efficient, and consequently that much marin perfection, than the most efficient etam engine ever constructed. The old device, the over-shot while for a long time, stood alone, as the best means of utilizing water power, and it is only within comparatively few years that its efficiency has been approached by any other, but the turbine has reached that state of perfection, when the probabilities of its bring surpassed almost entirely disappear. The principle objections to the over shot while, are, its size, space required, cost, inapplicability to high and low falls 4to. whomas the turbine is small, requires but little space, is cheap, comparatively much stronger and is capable of utilizing zether high or low falls; and so mean theoretical perfection has this machine been brought, that now the best turbine while gives us very nearly all that eau come from the water in shape

that at which it was evaporated, is about six times more efficient and consequently that much nearer perfection, than the most efficient steam engine ever constructed. The old device, the over-shot wheel, for a long time stood alone, as the best means of utilizing water power and it is only within comparatively few years that its efficiency has been approached by any other, but the turbine has reached that state of perfection when the probabilities of its being surpassed almost entirely disappear, The principle objections to the over-shot wheel are its size, space required, cost, inapplicability to high and low falls &etc. whereas the turbine is small, requires but little space, is cheap, comparatively much stronger and is capable of utilizing either high or low falls: and so near theoretical perfection has this machine been brought, that now the best turbine wheel gives us very nearly all that can come from the water in shape

of work; of course there is a certain amount of friction of the water in pipes, conduits and upon the machine its self, which we can never hope to remove and in the majority of cases this probably distroyes 10 per ent of the power. The principle field for improvement now, is in such things as relate to cost, durability, prevention of clogging from sundry substances in the water, service in freezing, as well as in warm wrather, government of speed under variations of load, and others of less importance; while purhaps the direction open to greatest improvement, is its efficiency under a diminished flow of water or a partial gate. Of course it is not intended, here, to convey the idea, that there is no difference in turbines, and that they all reach the qualist perfection; were while working under a full gate. The results, which are given farther on, will show, that the whill that, good under the most favorable circumstances gives 80 per unt of

of work; of course there is a certain amount of friction of the water in pipes, conduits and upon the machine itself, which we can never hope to remove and in the majority of cases this probably destroys 10 percent of the power.

The principle field for improvement now is in such things as relate to cost, durability, prevention of clogging from sundry substances in the water, service in freezing, as well as in warm weather, government of speed under variations of load and others of less importance; while perhaps the direction open to greatest improvement is its efficiency under a diminished flow of water or a partial gate. Of course it is not intended, here, to convey the idea, that there is no difference in turbines, and that they all reach the greatest perfection: even while working under a full gate, the results, which are given father on will show, that the wheel that gives under the most favorable circumstances gives 80 percent of

Efficiency, is the exception and those that gor less, the rule. another point, worthy of notice, and which is deserving of particular interest, is the lack of Efficiency under a partial gate, this, although it has received a great deal of attention and improvement is still capable of greater improvement It is found that under circumstances, where the greatest efficiency is of the retmost importance is just where they are the least efficient. Where a water while is situated on a stream in which the drier seasons furnish a less amount of water than the while is competent to utilize under a full gate, it is of the greatest moment, and more than at any other Time, That all the power possible be gotten from the diminished supply, and it is most importunately true that at just such a time the best while fall short of their maximum Efficiency; thus wasting the water when it is most pricious; and what is true of the best in this repect is multiplied in the less perfect machine

efficiency is the exception and those that give less the rule. Another point worthy of notice and which is deserving of particular interest, is the lack of efficiency under a partial gate, this, although it has received a great deal of attention and improvement is still capable of greater improvement. It is found that under circumstances, where the greatest efficiency is of the utmost importance is just where they are the least efficient. Where a water wheel is situated on a stream in which the drier seasons furnish a less amount of water than the wheel is competent to utilize under a full gate, it is of the greatest moment, and more than at any other time, that all the power possible be gotten from the diminished supply and it is most unfortunately true, that at just such a time the best wheels fall short of their maximum efficiency; thus wasting the water when it is most precious: and what is true of the best in this respect is multiplied in the less perfect machine

Gate leakage is a question that demands attention, and shows considerable room for improvement. In the arrangement of machinery Hall at the Centimal Exhibition, in 1876 at Philadelphia, quiti extensive preparations were made for testing the while, placed on exhibition; and as this class of motors is now so universally in use, it may be will to give a discription of the apparatus used in testing them. a few figures well enable us to better understand it-Fig. 1 is on end alevation of the arrangements for supplying and maintaining the newsary head of water. It consists of a boilar. iron touk, supported on six iron columns, thru of which are placed on a pier built in the mainbasin. This tank when full contains about 19000 gallons. The side of the tank which extends over the main basin, has a curved form which provides for the escape of the surplus water, thus allowing the experiments to be conducted under

Gate leakage is a question that demands attention and shows considerable room for improvement.

In the arrangement of Machinery Hall at the Centenial Exhibition in 1876 at Philadelphia quite extensive preparations were made for testing the wheels, placed on exhibition and as this class of motors is now so universally in use, it may be well to give a discription of the apparatus used in testing them. A few figures will enable us to better understand it – Fig. 1 is an end elevation of the arrangements for supplying and maintaining the necessary head of water. It consists of a boiler iron tank, supported on six iron columns, three of which are placed on a pier built in the main basin. This tank when full contains about 19000 gallons. The side of the tank which extends over the main basin, has a curved form which provides for the escape of the surplus water, thus allowing the experiments to be conducted under

what could practically be considered a constant head. The curved form of the tank is represented at a Fig. 1, The water was forced up to the tank by two of Wis D. andrew's centrifugal pumps, B, Fig. 2, each having a discharge piper 15 inches in diameter and are sun in part at , e , Fig. 1; on the left of those is seen the purstock, I, which is 4 fut in diameter, extending downward from the bottom of the tank, and terminating at its lower end in a right angle curve where it antiro a cylindrical case 8.5 feet in diameter, and which is supported on a circular brick wall. In this case the while were placed for testing. Fig. 2 shows in hor igoutal profection, the position of the race, wir, while 4th. How the while pit it will be sun, the tail man , E, leads out to the channel between the wall of the basin and the pur, f. therin weeted. One side of this channel was closed by a brick wall, g. The water flowed around the pier and out the other side into the wir basin, which was

what could practically be considered a constant head. The curved form of the tank is represented at a Fig 1. The water was forced up to the tank by two of Wm .D. Andrew's centrifugal pumps, B, Fig 2, each having a discharge pipe 15 inches in diameter and are seen in part at C, Fig.1; on the left of these is seen the penstock, D, which is 4 feet in diameter, extending downward from the bottom of the tank, and terminating at its lower end in a right angle curve where it enters a cylindrical case 8.5 but in diameter, and which is supported on a circular brick wall. In this case the wheels were placed for testing. Fig 2 shows in horizontal projection the position of the race, weir, wheel &etc. From the wheel pit it will be seen, the tail race E, leads out to the channel between the wall of the basin and the pier, f, therein erected. One side of this channel was closed by a brick wall &. The water flowed around the pier and out the other side into the weir basin, which was

built in the main basin, and increased in width from the while toward the wring to a point about 30 fut from the wheel pit where it was 15 feet who wide, and 15 fut faritur on was placed the overflow, H, which consisted of an cast iron plate, accurately plained and brothed at an angle of 45° with the edge was but 18 of an mich thick. The inside of this plate was verticle, and the incline was placed in the direction the water was flowing. It was exactly 9 fut long, which left 3 feet of the end wall of the writ, on each side, this caused a contraction of the orm, but it was accounted for in the ealenlations. At each end of the iron plate, wooden pues, which had been cut to the exact shape of the plate, were placed with the brorlled side down stream, thus leaving on opining of exactly of the The depth of the water upon the write was determined by a quage placed in a box, which was perfor and man the bottom, to insure

built in the main basin, and increased in width from the wheel toward the weir, to a point about 30 feet from the wheel pit, where it was 15 feet wide, and 15 feet farther on was placed the overflow, H, which consisted of a cast iron plate accurately plained and bevelled at an angle of 45° until the edge was but 1/8 of an inch thick. The inside of this plate was verticle, and the incline was placed in the direction the water was flowing. It was exactly 9 feet long, which left 3 feet of the end wall of the weir on each side, this caused a contraction of the vein, but it was accounted for in the calculations. At each end of the iron plate, wooden pieces, which had been cut to the exact shape of the plate, were placed with the bevelled side down stream, thus leaving an opening of exactly 9 feet. The depth of the water upon the weir was determined by a gauge placed in a box which was perforated near the bottom, to insure

a correct level. This grade was supplyed with a vernier so so to read to Tooo of a foot, and the whole was placed back of the wrin, a distance of six fut, so as to be beyond the point at which the dipression of the surface began, and the vernier was set with reference to the edge of the wir plate as a datum plane. The head of water on the while, was determined by a guage placed in the tail race, and provided with a box, similar to the other, but this one carried a wooden rod which extended upward, and was furnished with a virnier at the top, which read to too of a foot along side of This vernier was a glass tibe guage, which was connected with the ease in which the whiles were placed, and the reading of the ormier at the level of the water in the tube gave the exact difference of level; between that due the head of water on the wheel, and the tail race or the true head of water on the while. The water

a correct level. This guage was supplyed with a vernier so as to read to 1/1000 of a foot and the whole was placed back of the weir, a distance of six feet so as to be beyond the point at which the depression of the surface began, and the vernier was set with reference to the edge of the weir plate as a datum plane. The head of water on the wheel was determined by a guage placed in the tail race and provided with a box, similar to the other, but this one carried a wooden rod which extended upward and was furnished with a vernier at the top, which read to 1/100 of a foot. Along side of this vernier was a glass tube guage, which was connected with the case in which the wheels were placed, and the reading of the vernier at the level of the water in the tube gave the exact difference of level; between that are the head of water on the wheel and the tail race or the true head of water on the wheel. The water

in the tail race, in all eases was backed up to the level of the draft but of the wheel. The vilouties of the wheels were determined by a "slow motion" server, attached to the while chaft and connecting with a train of wheel work which Terminated in a dial point. This indicator could be connected or disconnected at a mounts notice, and the the speed read off from the dial. most of the suns were made for about two minutes, all other observations bring made every half minute. The testo land for each while lasted about two hours, or until the owner expressed him self satisfied. The Time principly depended on the number of fractional gate tisto disired. The apparatus used in determining the power of the while is shown in Figs. 344. Fig. 3 represents the ordinary pony brake, but its direction of effort is in a horizontal plane, and the figure is a horizontal projection of the

in the tail race, in all cases was backed up to the level of the draft tube of the wheel. The velocities of the wheels were determined by a "slow motion" screw, attached to the wheel shaft and connecting with a train of wheel work which terminated in a dial point. This indicator could be connected or disconnected at a moments notice, and then the speed read off from the dial. Most of the runs were made for about two minutes. All other observations being made every half minute. The tests lasted for each wheel lasted about two hours, or until the owner expressed him self satisfied. The time principally depended on the number of fractional gate tests desired. The apparatus used in determining the power of the wheel is show in Figs. 3 & 4. Fig 3 represents the ordinary pony brake, but its direction of effort is in a horizontal plane, and the figure is a horizontal projection of the

brake. a hollow cylinder, c, is keyed to the shaft of the water wheel, and is 37.44 inches in diameter, with a face of 18 inches; this runs within two sumicircular straps, one of which terminates in the lover arm, L, the straps were arranged for perfect lubrication, and the pressure was regulated. by the tension cerus, b. Fig. 4 is a frame upon which is supported a horizontal lover, L. pivoled at its center, f. The pivot is a knife edge, and resto in hardened iron chairs, at the enter of this lover, is placed an upright piece, a, securely braced, and made faist one half the length of the lover arm, L, the top of this was by means of a cord or rod attached to a knift edge eye-bolt, which was bolted to the end of the lover , L, Fig. 3 - From one and of the lover L', a seale platform was suspended. at the other end a rod extended down ward terminating in a plunger which served to present vibration. The weights used were of the

brake. A hollow cylinder, C, is keyed to the shaft of the water wheel, and is 37.44 inches in diameter, with a face of 18 inches; this runs within two semi-circular straps, one of which terminates in the lever arm, L, The straps were arranged for perfect lubrication, and the pressure was regulated by the tension screws, G. Fig. 4 is a frame upon which is supported a horizontal lever, L, pivoted at its center, f,. The pivot is a knife edge and rests in hardened iron chains; at the center of this lever, is placed on upright piece, a, securely braced, and made just one half the length of the lever arm, L, the top of this was by means of a cord or rod attached to a knife edge eye-bolt, which was bolted to the end of the lever, L, Fig. 3- From one end of the lever, L, a scale platform was suspended. At the other end a rod extended down ward, terminating in a plunger which served to prevent vibration. The weights used were of the

21, 5. stoudard and were furnished by Jairbanks Heor The wright of the apparatus was calculated to be about the came as the graning usually attached to the where when in use, and was therefore omitted in the determination of power. The length of the arm, L, was 10,5 fret or Equal to the radius of a circle whose circumfrine was 66 fut, and was made of this lingth to facilitate computation. now, remembering that the liver arms, L, are to, a, in the proportion of two to one and representing the weight on the scale par by W, the velocity of the while by, V, this circumfrance of the circle due to the arm, L, as a radius, by c, = (66 feet) Ele have the following 2WV2 = WY = Horse kower To find the korse power of a while, it was only necessary to multiply the product of the wright and revolutions by 4 and point back three decimal places. now while this method of testing a while appears very

U.S. standard and were furnished by Fairbanks &Co.. The weight of the apparatus was calculated to be about the same as the gearing usually attached to the wheel when in use, and was therefore omitted in the determination of power. The length of the arm, L, was 10.5 feet or equal to the radius of a circle whose circumference was 66 feet and was made of this length to facilitate computation. Now, remembering that the lever arms, L', are to, a, in the proportion of two to one, and representing the weight on the scale pan by, W, the velocity of the wheel by, V, the circumference of the circle due to the arm length, L, as a radius, by, c, =(66 feet). We have the following $\frac{2WVC}{33000} = \frac{WV}{250} = \text{Horse power.}$ To find the horsepower of a wheel, it was only necessary to multiply the product of the weight and revolutions by 4 and point back three decimal places. Now while this method of testing a wheel appears very

simple and should appearantly yild reliable risults, it is found by manufacturers and practical mill owners, to be altogather unreliable, as an indicator of the amount of work the while will perform. In a great many instances, it has been found that different while. when mader test and giving about the same per ent of efficieney, differed greatly when in practical use; some of them loosing about one half their supposed power. after all, this testing sums to be of but little value; it searely shows more than the madiquacy of such tisto, to rival the true murito of the while. In 1860 There was a competitive test of water while at the Fairmount Water Works in Philadelphia, and a great many while gave marly go per ent of power, and it was afterwards found in their practical opporations, that the whiles which had goven the most flathering

simple and should apparently yield reliable results, it is found by manufacturers and practical mill owners, to be altogether unreliable, as an indicator of the amount of work the wheel will perform. In a great many instances, it has been found that different wheels when under test and giving about the same per cent of efficiency, differed greatly when in practical use; some of them loosing about one half their supposed power. After all this testing seems to be of but little value; it scarcely shows more than the inadequacy of such tests to reveal the true merits of the wheel. In 1860 there was a competitive test of water wheels at the Fairmount Water Works in Philadelphia, and a great many wheels gave nearly 90 per cent of power, and it was afterwards found in their practical opperations that the wheels which had given the most flattering

risults, were of comparationly little value; while others which stood low in the apprimental scale, provid to be for superior. The very while which gave the greatest satisfaction in the Hairmount test, was found to be so inefficient, when put to practical use, that it was finally abandoned by the maker, and in its stead, he adopted one of the class that gave the lowest peremeage at that time, and is now engaged in its manufacture with much better results. The Gairmount tests were conducted with the greatest skill, and was superintended by the best engineering talinh in the country. do avoid any error in measuring The water by the use of the weir, (which is heable to arrowous results) an absolutely certain was adopted, The water bring eaught in a large Tank and measured with perfect accuracy. These deception results are certainly discouraging, but may be accounted for, by the variation of the load the while are required

results, were of comparatively little value; while others which stood low in the experimental scale proved to be far superior. The very wheel which gave the greatest satisfaction in the Fairmount test was found to be so inefficient, when put to practical use, that is was finally abandoned by the maker and in its stead, he adopted one of the class that gave the lowest percentage at that time and is now engaged in its manufacture with much better results. The Fairmount tests were conducted with the greatest skill, and was superintended the best engineering talent in the country.

To avoid any error in measuring the water by the use of the weir (which is liable to erroneous results) an absolutely certain was adopted, the water being caught in a large tank and measured with perfect accuracy. These deceptive results are certainly discouraging, but may be accounted for by the variation of the load the wheels are required

to move. This of course directly affects the wheel." The motion, especially in woolin, cotton and saw mills, is ever changing, exceedingly unsteady, and these changes by no means in a uniform degree, and of course discharging for each interval of time different quantities of water than where the conditions are uniform and favorable in the test flum. On the following page will be found in tabulated form. a few of the results of the tests, made at the centinial Exhibition; showing per ent of efficiency under fractional gatio.

The Victor and Leffel while are not found in this table; though they are probably the most popular while at present. The Victor is manufactured by Stilwell & Bierce of Day ton, Ohis - and the Leffel while by James Leffel of Springfield Ohis. The Victor 10 inch while, runder a 10 foot head, gives 5.58 horse power, and uses 348 cubic fut of water, while the deffel 10 inch while made a 10 foot head, gives

to move. This of course directly affects the wheel. "The motion, especially in woolen, cotton, and saw mills, it ever changing, exceedingly unsteady, and these changes by no means in a uniform degree, and of course discharging for each interval of time different quantities of water than where the conditions are uniform and favorable in the test flume. On the following page will be found in tabulated form, a few of the result of the tests, made at the centenial exhibition: showing per cent of efficiency under fractional gates.

The Victor and Leffel wheels are not found in this table; though they are probably the most popular wheels at present. The Victor is manufactured by Stilwell & Bierce of Dayton, Ohio and the Leffel wheel by James Leffel of Springfield, Ohio. The Victor 10 inch wheel, under a 10 foot head, gives 5.58 horse power and uses 348 cubic feet of water while the Leffel 10 inch wheel under a 10 foot head gives

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Exhibitor	363	age al	man n	343	120	season m	3/63	inst
Cyhibitor	8 3	rich	Swort min	Hor Hor	Head	ne ser	How Eta	是
O. H. Risdon		-	266	82.99	30,36	34.66	94.87	87-56
"	"	3/4	248	67,53	30,84	"	69,73	82,66
11	"	/2	258	42,31	31.00	"	56,22	75,26
noye 45 ons	26"	/	269	36,58	3/,/0	34.66	58,57	62,45
""	"	3/4	289	30.05	31,24	11	49.01	6/,3/
//	"	1/2	269,5	20,52	3/,28	//-	39,12	53,45
Barber & Harris	20"	/	330,5	37.01	31,18	53,40	48,55	76,23
11	11.	3/4	299	23,92	31.45	"	33,60	71,19
. "	"	1/2	271,5	17.37	31,62	"	24,23	71.68
Goldie & The Galloch	27"	/	281,5	78.82	30,05	34,66	96,01	82,09
"	11	3/4	280	56,00	30,14	11	77.79	71.99
11	11	1/2	325	39,00	30.65	"	68,70	58,22
Putman mach. Co.	30"	/	287	74.01	30,05	14.35	93,09	79,50
//	//	3/4	26/	58,46	30.25	"	73,23	79,83
11	//	1/2	24/	43,47	30,60	"	64,86	67,02
Thos. Fait	25	/	288,5	46,16	31,00	14,35	56.27	82,03
<i>II</i>	//	3/4	292	30,37	3/,32	"	41,76	72.72
· i	11	1/2	258	22,70	31,44	"	33,91	66,94
11	11	1/4	235	7,52	31,59	11.	17,47	43,05
"	//	1/8	266	6,38	31,61	//	16,92	37.7/
Rodny Hunt	24"	/	276	79.48	29,25	14,35	101.79	78-08
Rodny Hunt, mach. Co.	11	3/4	289	67.04	29,60	//	93.69	71.55
//			3/2	49,42	30,25	"	72,56	68.79
<i>"</i>		1/3	238	32,37	30,44	//	64,26	50,35
						Lina?	1.	
						1944		
	30	1	266		30,36	34,66	94 78	8756

Name	Diameter	Fraction	Revolution	Horse	Head	Flow duct	Horse	Percent
of	of	of	per	power	on	leakage	power	of
Exhibitor	Wheel	Gate	Minute	of	Wheel	per	of	Efficiency
				Wheel		Minute	Water	
F.H. Risdon	30"	1	266	82.99	30.36	34.55	94.87	87.06
66	66	3/4	248	57.53	30.84	66	69.73	82.66
66	"	1/2	258	42.31	31.00	66	56.22	75.26
Noye & Sons	26"	1	269	36.58	31.10	34.66	58.57	62.45
66	"	3/4	289	30.05	31.24	66	49.01	61.31
44	"	1/2	265.5	20.52	31.28		39.12	53.45
Barber & Harris	20"	1	330.5	37.01	31.18	53.40	48.55	76.25
66	"	3/4	299	23.92	31.45	66	33.60	71.19
44	"	1/2	271.5	17.37	31.62		24.23	71.68
Goldie &	27"	1	281.5	78.82	30.05	34.66	96.01	82.09
McCulloch								<u> </u>
"	66	3/4	280	56.00	30.14	66	77.79	71.99
"	46	1/2	325	39.00	30.65	66	68.70	58.22
Putnam Mach. Co	30"	1	257	74.01	30.05	14.35	93.09	79.50
66	"	3/4	261	58.46	30.25	66	73.25	79.83
66	"	1/2	241	43.47	30.60	66	64.86	67.02
Thos. Fait	25"	1	288.5	46.16	31.00	14.35	56.27	82.03
66	"	3/4	292	30.37	31.32	66	41.76	72.72
66	"	1/2	258	22.70	31.44	66	33.91	66.94
66	"	1/4	235	7.52	31.59		17.47	43.05
"	"	1/8	266	6.38	31.61	66	16.92	37.71
Rodney Hunt,	24"	1	276	79.48	29.25	14.35	101.79	78.08
Mach. Co								
"	46	3/4	289	67.04	29.60	66	93.69	71.55
"	"	1/2	312	49.42	30.25	"	72.56	68.79
"	"	1/3	238	32.37	30.44	66	64.26	50.35

2,00 horse power and uses 122 cubic fut of water. It will be sun from this that the Victor" gives marly three Times as much, power as the "Liffel", but at the Rame Time it will be sun that it requires more water, in about the same proportion. In order to make a judicious accledion between these two whiles, it would be mussary to take into consideration the amount of water available, as the diffil while would be better capable of retilizing a limited quantity than the Victor. In order to utilize very high falls, it is necessary to have come thing stronger than the ordinary wooden pustock, and to This end an iron ease has bren introduced, which is capable of withstanding any pressure that might come upon it. The where bring placed in this casing, any height of fall may be utilized. at Ithaca, how york, there is a 11/2 inch while operating under a head of 95 fut. The water is

2.00 horse power and uses 12.2 cubic feet of water. It will be seen from this that the "Victor" gives nearly three times as much power as the "Leffel" but at the same time it will be seen that it requires more water, in about the same proportion.

In order to make a judicious selection between these two wheels, it would be necessary to take into consideration the amount of water available, as the Leffel wheel would be better capable of utilizing a limited quantity than the Victor. In order to utilize very high falls, it is necessary to have something stronger than the ordinary wooden penstock, and to this end an iron case has been introduced, which is capable of withstanding any pressure that might come upon it. The wheel being placed in this casing, any height of fall may be utilized.

At Ithaca, New York, there is a 11 ½ inch wheel operating under a head of 95 feet. The water is

carried to the wheel through an iron pipe 500 fut long where it is attached to a Globe ease, in which the while is placed. This wheel gives about one hundred horse power-In regard to setting the durbine where, the first thing dimanding attention is the head race or conduit Care should be taken to have this of sufficient size, and this is Especially necessary where the once is of considerable length, and a large quantity of water is to pass through it. The water should never flow faster than from 60 to 120 fut per minute. It has been noticed in long races, that after The wheel has been running a free hours, the water draws down from 1 to 3 fut. The effect of this is the same as if the dam had bren lowered an equal amount, and the result is a loss of power, which might have been saved by making the race duper and wider. The next point of importance is the wheel pit, and to obtain the

carried to the wheel through an iron pipe 500 feet but long where it is attached to a globe case, in which the wheel is placed. This wheel gives about one hundred horse power.

In regard to setting the turbine wheel the first thing demanding attention is the head race or conduit. Care should be taken to have this of sufficient size, and this is especially necessary where the race is of considerable height, and a large quantity of water is to pass through it. The water should never flow faster than from 60 to 120 feet per minute. It has been noticed in long races, that after the wheel has been running a few hours, the water draws down from 1 to 3 feet. The effect of this is the same as if the dam had been lowered an equal amount and the result is a loss of power, which might have been saved by making the race deeper and wider. The next point of importance is the wheel pit and to obtain the

best results from the wheel, it must be of the proper depth, which depends on the size of the wheel, and varies from 2 to 7 but. The pit should be so made, as to allow about 2 fut of water to stand in it, when the wheel is not running. In all eases, eare must be taken, a prevent the water from backing up into the while when in motion, as part of the power would be expended in forcing it away. On making the pit, if there is a sandy or mud-bottom, mud-sills must be put down to privent the foundation from washing out, and Thise sills should be covered with heavy plank. a rock bottom does not require mud-sills or plank, but must be blasted out so as to give the disired disth of standing tail water. The tail race should always have, at least , foot of dead water in it, and should have a cross section some what larger than that of the head race.

best results from the wheel, it must be of the proper depth, which depends on the side of the wheel and varies from 2 to 7 feet. The pit should be so made as to allow about 2 feet of water to stand in it when the wheel is not running. In all cases, care must be taken to prevent the water from backing up into the wheel when in motion, as part of the power would be expended in forcing it away. In making the pit, if there is a sandy or mud-bottom, mud-sills must be put down to prevent the foundation from washing out and these sills should be covered with heavy plank. A rock bottom does not require mud-sills or plank, but must be blasted out so as to give the desired depth of standing tail water. The tail race should always have, at least 1 foot of dead water in it and should have a cross section some what larger than that of the head race.

The prosperity of the how England Slates, is, in a quat measure due to water power. not that water is more abundant there than in other parts of the United States but more of it has brew profitably utilized. The South is better provided with water power than any other section of the country. This is premiarly so of the attentie plope, The four states of Virginia, north Carolina, South Carolina and Georgia, having water power Equivabout to 14 000 000 horse power, four Times that of all the stiam engines in the world. The Yadkin word of n.C. alone has sufficient force to turn 12 000 000 spindles. In the northern part of the South en states, there is an elwated region of more than one hundred, Thousand square miles, in which There is a vast amount of water power, and bring in the extron region, with a fine, healthy climate, its only needs, are rail roads, capital and population, to make it the qualist manufacturing

The prosperity of the New England States, is, in a great measure due to water power. Not that water is more abundant there than in other parts of the United States but more of it has been profitably utilized. "The South is better provided with water power than any other section of the country. This is peculiarly so of the Atlantic slope, the four states of Virginia, North Carolina, South Carolina, and Georgia, having water power equivalent to 14 000 000 horse power, four time that of all the steam engines in the world. The Yadkin river of N.C. alone has sufficient force to turn 12 000 000 spindles."

In the northern part of the Southern states, there is an elevated region of more than one hundred thousand square miles, in which there is a vast amount of water power, and being in the cotton region, with a fine, healthy climate its only needs are railroads, capital, and population to make it the greatest manufacturing

section in the Union -The utilization of the magara falls, is at present, bring considered, and although it is the greatest trutur, that Hydraulie Engineers have yet made, it is not imperatable that it may prove to be a feasible project. The binal result, in case of the anews of this sehum, can hardly be confectured. What can be accomplished by a force of from two to three million horse power, combined at one point, is almost bryond comprihusion.

section in the Union.

The utilization of the Niagara Falls, is at present, being considered and although it is the greatest venture that Hydraulic Engineers have yet made, it is not improbable that it may prove to be a feasible project. The final result in case of the success of this scheme, can hardly be conjectured. What can be accomplished by a force from two to three million horsepower, combined at one point, is almost beyond comprehension.

Rolla, May, 9-1882

Rolla, May 9, 1882

Fig. 1

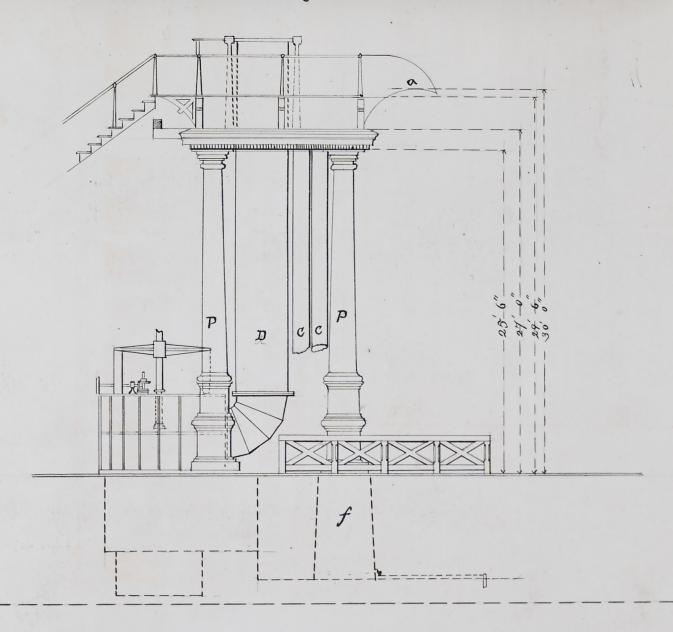
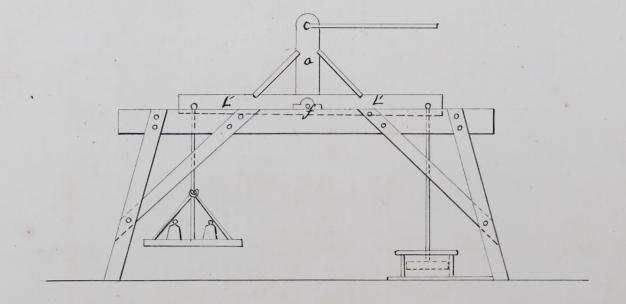


Fig. 4



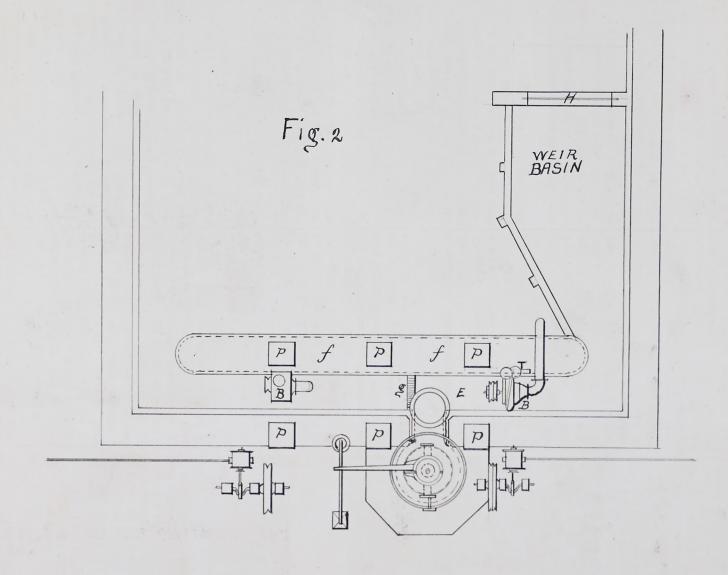
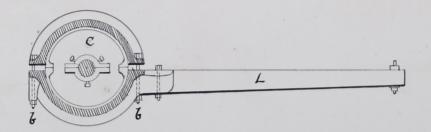
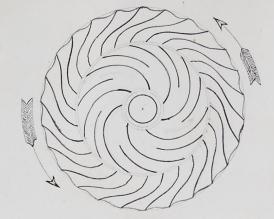


Fig. 3





PLAN, OUT WARD FLOW TURBINE



PLAN, INWARD FLOW TURBINE

