Water-Supply and Irrigation Paper No. 180 Series M, General Hydrographic Investigations, 18

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

TURBINE WATER-WHEEL TESTS

AND

POWER TABLES

BY

ROBERT E. HORTON

WASHINGTON
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TURBINE WATER-WHEEL TESTS AND POWER TABLES.

By Robert E. Horton.

INTRODUCTION.

This paper is not intended as a treatise on the turbine, and comprises no extensive discussion of its theory, design, or construction. It is mainly a compilation of data derived from tests and from manufacturers' power tables of American stock sizes of turbines. A bibliography has been added, giving selected references for the use of those who may wish to investigate the subject further.

The primary object of the paper has been to furnish information required in the work of the Geological Survey, where the turbine is used as a water meter in gaging streams. A secondary object has been to furnish information from which the power developed at mills can be determined from the sizes and types of water wheels used. Such information is often required in the census and other water-power canvasses. The water rights of mills can often be definitely determined only from the quantity of water used by the turbines which are or have been employed to develop the power. Some of these turbines are no longer built or catalogued, and it is believed that the manufacturers' rating tables and the record of tests of the older types of wheels will be serviceable to engineers who may be required to determine questions of water rights.

Many antiquated patterns of turbines are still on the market, and a clear presentation of the evolution of the different types of turbine water wheels should be of practical service to those who wish to know the merits and demerits of the various styles. Much of the data has been presented in graphic form. It is believed that the section treating of the selection and arrangement of turbines in power plants will be of service to all turbine users.

PRINCIPAL TYPES OF WATER WHEELS.

A water wheel may be defined as a machine that derives mechanical power from the energy imparted to falling water by gravity. Numerous modes of classification of water wheels have been used. They may be classified as follows:

(1) According to position of the plane of the wheel—whether vertical or horizontal.

(2) According to the mode of action of the water—whether by simple gravity, by pressure under head (as against a piston), by impulse or kinetic energy of a spouting jet, by reaction (illustrated by the pressure against the side of a containing vessel opposite a spouting jet), or by combined pressure and reaction.

(3) According to direction of the flow of water with reference to the axis of the wheel or to the plane of the wheel—whether tangential to the wheel, radially inward, radially outward, parallel to the axis, or a combination of two or more of these.

(4) By type—as overshot, breast, undershot, flutter, tub, Jonval, Fourneyron, Vortex, and American.

(5) As vertical water wheels, turbines, and impulse wheels. These three classes may readily be subdivided to include all the types of water wheels that have been named above.

All water wheels of the older types, including overshot, breast, Poncelet, and undershot wheels, were placed on horizontal shafts. Turbines and their prototypes, the tub wheel and the rouet volante, were placed on vertical shafts. The classification by position of shaft thus served very well to distinguish between water wheels and turbines until turbines were placed on horizontal shafts. The rouet volante or flutter wheel of the ancients consisted of flat, vertical vanes projecting radially from a vertical wooden shaft. The water jet from the feeding spout struck the vanes tangentially near their ends. Such wheels have been used for centuries in India, Egypt, Syria, and southern France. An excellent example of a rouet volante was in use until recently in a plaster mill in western New York. The rouet volante placed on a horizontal shaft becomes essentially the hurdy-gurdy of the early western miners. It may thus be considered as the prototype of the modern impulse water wheel as well as of the turbine.

Much uncertainty of meaning has arisen from the conflicting use of terms in classifying water wheels. The terms impulse and reaction, for example, have been used by different authors with opposite meanings. The conception of reaction is somewhat difficult to grasp, and as the definition of this word seems uncertain its use is to be discouraged. Its usual meaning will be explained, however, in the course of this paper, in order that its use in works of reference may be understood.

VERTICAL WATER WHEELS.

The overshot wheel is a characteristic type, although it is probably antedated historically by the bamboo varia, which was used by the Chinese, as they claim, as early as 1000 B. C. A form of inverted chain pump has been used in the Orient from time immemorial for lifting water from streams to irrigation ditches. A motor of this type has recently been patented in America, and one is in operation in Mannsville, N. Y., under a head of 23 feet, yielding abundant power to drive a grist and planing mill. Such wheels, as well as overshot wheels, operate purely by gravity, and yield theoretically a very high efficiency. The objections to this type of motor are cumbersomeness, waste of water by leakage and spilling from the buckets, inability to operate in backwater, and obstruction by ice in winter.

Overshot wheels were formerly built of great size. One at Laxey, Isle of Man, constructed about forty years ago and said to be still in operation, is 72 feet 6 inches in diameter and develops about 150 horsepower.[a] A number of overshot wheels are in use at old mills in the Catskill Mountains in New York. A firm in Pennsylvania manufactures "steel overshot" water wheels, which, it is claimed, have a high efficiency.

Breast wheels are operated partly by gravity and partly by kinetic energy, the water from the feeding chutes striking the floats or vanes of the wheel.

Undershot water wheels and current wheels operate entirely by the kinetic energy of the moving water.

Tide wheels and undershot wheels usually require a floating framework or other device to raise and lower them with fluctuation in water level.

Breast and undershot wheels never attain high efficiency, and in addition are subject to all the objections of the overshot water wheel. The labors of James Smeaton, Fairbarn, and the ingenious Poncelet, who substituted epicycloidal-curved vanes for straight buckets in wheels of these types, increased their efficiency somewhat, but such wheels were quickly superseded by the parallel-flow turbine of Jonval and the Boyden-Fourneyron turbines upon their introduction into this country. Vertical water wheels are still considerably used in Germany.

The theory of water wheels has been elaborately developed and their literature is much more profuse than that of turbines.[b]

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[a] See catalogue of the Pelton Water Wheel Company for 1898, pp. 70–71.
[b] See bibliography on pages 126–130.

CLASSES OF TURBINES.

A turbine[a] may be defined as a water wheel in which the water is admitted to all the vanes or buckets simultaneously. It is thus distinguished from vertical water wheels, which receive the water at the top or one side only, and from impulse water wheels, which receive a spouting jet or jets from nozzles directed tangentially against the perimeter of the wheel.

The component parts of a turbine are the "runner," the "case," the "gate" or "gates," and the "guides." Commonly the gates and guides are included in the "case." The runner is that portion of the turbine which revolves. It comprises the vanes, the crown plate, partition plates or rim bands, which cover, subdivide, or strengthen the vanes, and the power shaft. The term "bucket" is applied to the passage for the water in the runner. The vanes or floats are the partitions separating the buckets and forming the runner. The term "buckets" is also often used to signify the vanes. The chutes are the openings through which the water passes into the wheel, and the guides are the partitions separating the chutes The gates serve to shut off and regulate the supply.

The flow of water through a turbine may be directed either radially inward or outward or parallel to the axis, or inward and parallel, or inward, parallel, and outward. The representative types of these several classes are as follows:

Tangential flow: Barker's mill.

Parallel flow: Jonval turbine.

Radial outward flow: Fourneyron turbine.

Radial inward flow: Thompson vortex turbine; Francis turbine.

Inward and downward flow: Central discharge scroll wheels and earlier American type of wheels; Swain turbine.

Inward, downward, and outward flow: The American type of turbine.

TANGENTIAL OUTWARD-FLOW TURBINES—BARKER'S MILL.

In impulse water wheels the jet strikes or enters the buckets in a direction tangential to the circumference of the runner. In most forms of turbines the water flows outward, inward, or downward through the buckets, leaving them tangentially or nearly so.

The simplest type of tangential outflow is Barker's mill, invented in 1740. This wheel has radial arms and operates purely by reaction. Such wheels are still used on the Morris Canal in New Jersey for drawing barges up the inclined planes which serve in place of locks. The wheels have four arms of 6 feet radius, with openings at the ends 3½ inches wide by 15½ inches high.[b]

James Whitelaw, of Paisley, developed Barker's mill, which has spiral tapering arms so curved that water flows radially when the mill is running at proper speed. A wheel of this type erected on Chard Canal, 1842, for purposes of hauling boats up inclines developed 75 per cent efficiency on 25 feet fall. Owing to their large size, low speed, and inability to operate in backwater such wheels have never come into extensive use.

RADIAL OUTWARD-FLOW TURBINES—THE FOURNEYRON TURBINE.

A primitive type of water wheel, which comes under the class of turbines proper, is that of Cadiat. This is an outward-discharge turbine without guide chutes, and therefore it may be said to belong to the same stage in turbine evolution as do the tub and scroll central-discharge wheels, although the form of runner and the direction of flow are similar to those of the Fourneyron turbine. The weight of the runner is carried by a step-bearing at the lower end of the shaft. The discharge is regulated by an outside cylinder gate, probably the first one used. The buckets are curved in a vertical plane.

Fig. 1 shows a sketch in section of an early Fourneyron turbine (after Morin). The guide chamber C received the vertical pressure of water, and was suspended from above by means

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[a] From Latin *turbo*, to revolve. The etymology of the word does not sufficiently distinguish the class.

[b] Wilson, H. M., The Morris Canal and its inclined planes: Scientific American Supplement, February 24, 1883

of a hollow column surrounding the driving shaft. The discharge was regulated by a cylinder gate *G* between the guide *C* and the bucket *V*. Slits in the gate ring *G* opposite the end of each guide enabled the guides to be extended outward nearly to the vanes.

Fig. 2 shows a plan of the guide chamber and runner of this turbine. The vanes or buckets have a radial direction at their inner ends, where they receive the water. Under the mechanical conditions established the water enters the wheel with a tangential velocity

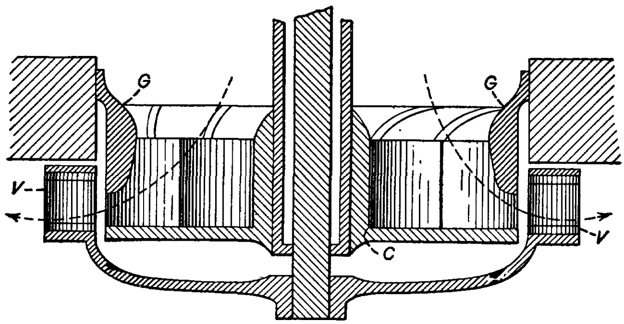


FIG. 1.—Section of the Fourneyron turbine.

equal to the velocity of the bucket, is carried outward by the radial component of its velocity, and in passing outward is deflected by the backward-curved vanes or buckets, thus doing work. Inasmuch as the tangential component of the velocity equals that of the buckets the water could do no work by impulse, hence the Fourneyron turbine is purely a pressure or reaction turbine.

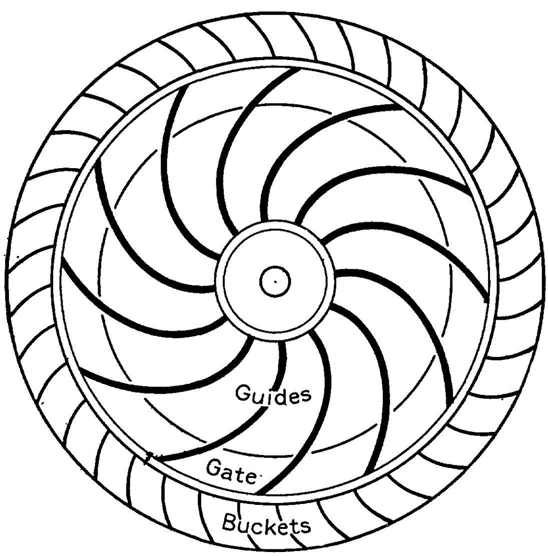


FIG. 2.—Plan of the Fourneyron turbine.

The excellence of its mechanical construction, its high efficiency, its ability to work under very great heads, and its ability to operate in backwater with good efficiency rendered the appearance of the Fourneyron turbine a notable event in the history of water power. The experiments of M. Fourneyron were begun in 1823, and his first turbine was erected at Pont sur l'Ognon, France, in 1827. It was followed by several others, operating under various heads up to 144 feet, which yielded efficiencies as high as 80 per cent.

In 1837 M. Fourneyron erected a turbine at St. Blaise, Switzerland, which operated under a head of 354 feet. The diameter of the wheel was 13 inches. The depth of the buckets was slightly less than one-fourth of an inch. This wheel made from 2,200 to 2,300 revolutions per minute, and is reported to have yielded an efficiency of 80 to 85 per cent. The water was conducted to the turbine through a cast-iron pipe conduit, and to prevent the choking of the minute apertures in the water wheel the supply was filtered before use.

January 1, 1843, a Fourneyron turbine, designed by Elwood Morris, who had translated the valuable experiments of Morin into English, was erected at Rockland Cotton Mills, on the Brandywine. This turbine was tested by Morris in the fall of 1843, together with a second one, located at Dupont Powder Mill, also on the Brandywine, near Wilmington, Del. These turbines gave maximum efficiencies of 70 to 75 per cent, respectively.

In 1844 a Fourneyron turbine, constructed by Uriah A. Boyden, was erected at the Appleton Company's cotton mills in Lowell, Mass. Carefully conducted tests showed that this turbine yielded an efficiency of 78 per cent. The Appleton turbine was rapidly followed by others of Boyden's design, which soon became the standard in New England, displacing the old wooden vertical wheels. The Boyden turbines were expensive, cumbersome, and gave low efficiency when operated at part gate, and "owing to the large number of buckets with small apertures they were liable to become choked by chips, leaves, and other floating obstructions, not to speak of fish. At Fall River, Mass., the first turbines are said to have been stopped by eels on their annual migrations to the sea."[a]

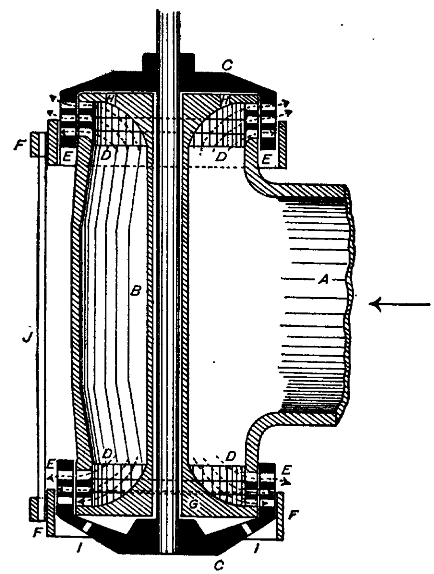


FIG. 3.—Section of penstock and runners of double Fourneyron turbine at Niagara Falls. *A*, Flume; *B*, penstock; *CC*, runners; *DD*, guides; *EE*, buckets; *FF*, gate rings; *HH*, holes in upper drum; *II*, holes in lower runner; *J*, gate stems.

The manufacture of Fourneyron turbines was taken up by a number of machine works, and several of the Boyden turbines are still in use in New England. As usually constructed this turbine has a cast-iron casing attached to one side of the flume, similar to the scroll central-discharge wheel.

The ability of a turbine of the Fourneyron type to work efficiently under very high heads was shown by the experiments made at St. Blaise. The manufacture of turbines of the Fourneyron type has been revived in recent years, owing to the demand for turbines to operate under very high heads, as at Niagara Falls and elsewhere.

Figure 3 shows a schematic cross section of the double Fourneyron turbine used in the first installation of the Niagara Falls Power Company. This was operated under a head of about 135 feet. The turbine is mounted in a globe penstock, similar to that used in early New England practice, with the exception that two wheels are used, one being placed at the top and the other at the bottom of the penstock. As shown in fig. 3 the runner *C* and buckets *E*, which are represented in black, are attached to the vertical shaft. The guides *D* and buckets *E* are subdivided into three compartments by partition plates. The discharge is regulated by outside cylinder gates *F*. The gate rings for the upper and lower wheels are connected by rods, one of which is shown at *J*. The gate rings *F* are raised and lowered in unison to shut off the outflow from or to open, one after another, the horizontal compartments, as required. The cylindrical penstock is shown in section by hachure. The disk or

[a] Webber, The Development of Water Power.

drum forming the lower end of the penstock is made solid, and holes *II* are provided in the lower runner to allow any water which may enter between the lower drum *G* and the lower runner through the clearance spaces to pass out. Holes *HH* are provided in the upper penstock drum to allow water under full pressure of the head to pass through and act vertically against the upper runner *C*. In this way the vertical pressure of the great column of water is neutralized and a means is provided to counterbalance the weight of the long vertical shaft and the armature of the dynamo at its upper end. These turbines discharge 430 second-feet, make 250 revolutions per minute, and are rated at 5,000 horsepower. A section of one of the guide rings and runners is shown in fig. 4. The guides and buckets are of bronze, and their surface curves form arcs of circles of varying radii. Except for the central thickening of the vanes, the forms of the chutes and buckets do not differ materially from those of the same parts of the early turbines of Boyden and Fourneyron.

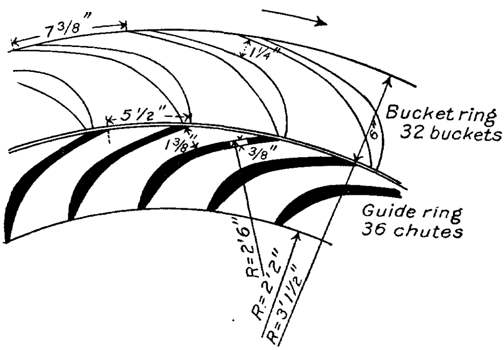


FIG. 4.—Section of guides and buckets, Fourneyron turbine, Niagara Falls.

A Fourneyron turbine similar to that at Niagara Falls has been erected at Trenton Falls, N. Y. This turbine operates under 265 feet gross head and has 37 buckets, each $5\frac{1}{2}$ inches deep and $\frac{13}{16}$ inch wide at the least section. The total area of outflow at the minimum section is, therefore, 165 square inches. How enough water can pass through so small an aggregate aperture to yield continuously 950 horsepower is a matter for legitimate wonder.

PARALLEL DOWNWARD-FLOW TURBINE—THE JONVAL TURBINE.

The idea of a parallel-flow turbine is said to have originated with Euler. M. Fontaine put it into form for practical use, and M. Jonval added the draft tube from which it bears his name.

In 1837 O. Henschel, of Cassel, invented the downward parallel-flow turbine, later known by the name of Jonval or Koechlin. The Jonval turbine closely resembles a later type of flutter wheel known as the Borda turbine, which has inclined floats and receives water from a spout directed downward. The outer ends of the vanes are inclosed in a circular curb. Thus a runner of the Jonval type was derived by easy transitions from the primitive flutter wheel. This wheel receives water at only one point on its circumference. In the Jonval wheel the spout is replaced by a ring of guide chutes, which admit water all around instead of at one point. The Jonval wheel became at once the competitor of the Fourneyron turbine. The Jonval turbine was introduced into America by Elwood Morris and Emile Geyelin, of Philadelphia, about the middle of the nineteenth century.

The tub wheel was a parallel-flow turbine without guides. This was placed in the bottom of a flume and commonly contained a number of inclined or curved vanes, the runner being similar to that of the Borda turbine in its earlier and to the Jonval turbine in its later form. Sometimes but one or two vanes were used, forming a helix or screw wheel. The tub wheel, when fitted with a cover containing guide passages to direct the currents of water against vanes, becomes essentially a Jonval turbine. The tub wheel was in common use in America at the time the Jonval turbine was introduced.

The theory of the design of the Jonval turbine forms a neat problem in applied mathematics, and is extensively discussed by various writers.[a]

[a] See bibliography, pp. 126–130.

A variation of the Jonval turbine, in which the number of buckets was reduced to two, was extensively used in sawmills in northern New York. Owing to the large openings of the buckets, ice, drift, and other obstructions could pass through this wheel without injuring it. The vanes were nearly horizontal, giving a high speed of rotation. The efficiency was very low.

In the Jonval turbine the velocity of water at the outer ends of the buckets is greater than that at the inner ends. In order to increase the capacity of the wheel without the loss of power that would result from unequal velocities in the outer and inner portions of a broad

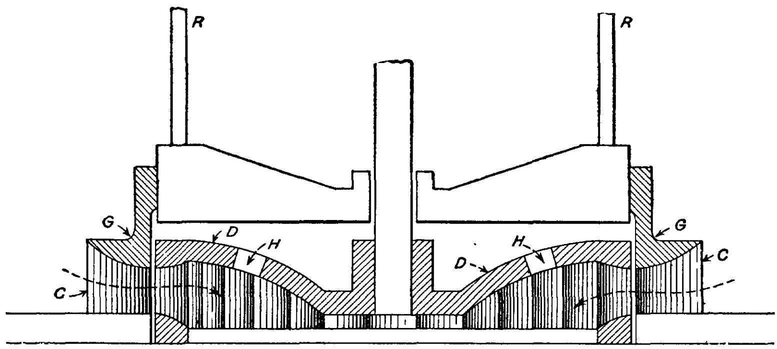


FIG. 5.—Section of Francis center-vent turbine at Booth Cotton Mills, 1849. *C*, Guide chutes; *D*, runner; *G*, inside cylinder gate ring; *H*, holes through runner disk to admit water and neutralize pressure; *R*, gate stems.

bucket annulus, the Geyelin Double Jonval turbine has been devised. This contains two rings of buckets, one within the other, the inclinations of the buckets differing, so that the angular velocity of both rings is the same; the intention being to secure a turbine of large capacity in small compass.

Jonval turbines are still manufactured by a number of American firms, and rating tables are given on pages 98–100.

RADIAL INWARD-FLOW TURBINES—THE FRANCIS TURBINE.

James B. Francis, who was intimately associated with Uriah A. Boyden in testing early American Fourneyron turbines, experimented in 1847 on a model of a center-vent turbine which was essentially a Fourneyron turbine having the relative positions of the guides and buckets and the direction of flow reversed.[a] Such a wheel had been proposed by Poncelet in 1826. A patent was issued to Samuel B. Howd, of Geneva, N. Y., in 1836 for an inward-flow turbine, some features of which were embodied in the Francis turbine.

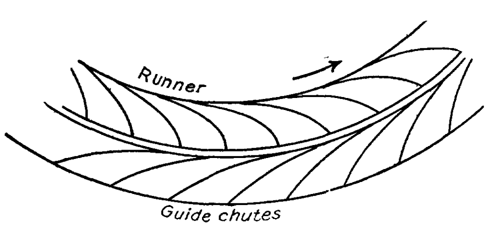


FIG. 6.—Section of runner of Francis center-vent turbine.

The inward-flow turbine was destined to supplant all others, but it was soon found best to extend the buckets downward, thus making an inward and downward flow turbine.

MIXED-FLOW TURBINES.

This class includes (A) scroll central-discharge wheels, embracing (1) turbines without guides, (2) the Burdin turbines, (3) Thompson vortex turbine; (B) early American types of turbines having double-curved buckets extended downward below the guide ring, but not protruding outward. In these wheels the runner can be lifted vertically out of the case.

[a] Francis, J. B., Lowell Hydraulic Experiments, pp. 55–60.

SCROLL CENTRAL-DISCHARGE WHEELS.

Scroll-case turbines have flat vanes, or vanes that are curved but little from a vertical plane. The action of the water is chiefly radially inward, although the discharge is both upward and downward.

The best developed turbine of the scroll central-discharge type is the Schiele, which has curved guide vanes and buckets, the latter attached to periphery of a central drum. (See fig. 7.) The discharge is controlled by a gate in the chute.

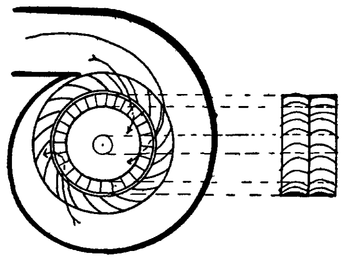


FIG. 7.—Schiele turbine.

The Thompson vortex turbine and certain American types of bulging-bucket turbines mounted in scroll cases also discharge both upward and downward. Many scroll central-discharge turbines, with no guide passages and with the controlling gate in the throat of the scroll case, are still in use. The gate is either of the sliding or of the pivoted butterfly type. Some forms of this wheel have rudimentary guide passages, two in number, opening on opposite sides of the runner, their object being to distribute the water equally around the periphery of the wheel, and to prevent a portion of the runner from "running dry.'

AMERICAN TYPE OF TURBINES.

The earliest step toward the development of the turbine in America is a patent issued to Benjamin Tyler, of Lebanon, N. H., in 1804, signed by Thomas Jefferson, for an "improvement in watei wheels." Apparently the water wheel improved is a primitive flutter wheel or rouet volante, and the improvement consisted in hooping the wheel with iron hoops and setting the wooden vanes at a specified angle.

Credit for the scroll case is assigned by W. W. Tyler to the Parker brothers, of Licking County, Ohio, the American patentees of the draft tube in the early half of last century.[a]

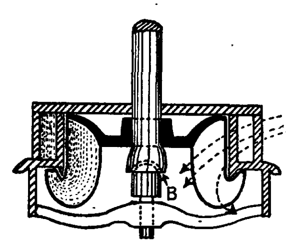
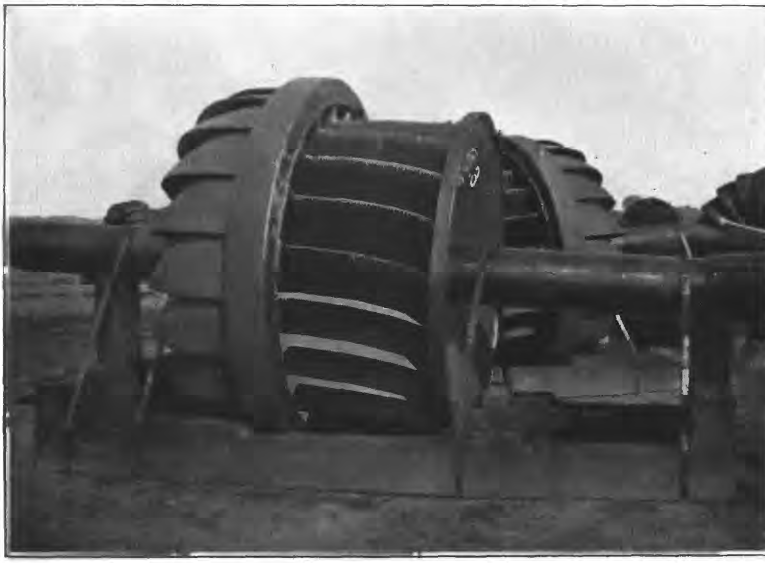


FIG. 8.—Cross section of an early turbine with deep, bulging buckets, pivot gates, and an adjustable bearing (*B*).

From 1850 to 1875 many turbines were built nearly on the lines of the Howd-Francis turbine, but with buckets curved downward to an increasing extent in successive forms. Tests of the Swain wheel in the sixties proved conclusively the merit of this type. In the same decade the pivot or wicket gate was successfully applied in the "American" and "Leffel" turbines, and thus a step in advance was taken toward improvement of the part-gate efficiency of turbines. Leffel also introduced the short draft tube, carrying the bridge tree and step bearing, giving the turbine case practically the form at present retained. The Risdon turbine having an inside cylinder gate and buckets slightly curved downward led in efficiency at the tests made at the Centennial Exposition of 1876. At this exposition much attention was also attracted by tests of the Little Giant turbine, manufactured by Knowlton & Dolan, of Indianapolis, under a patent issued to Matthew and John Obenchain. This wheel has ladle-shaped bulging buckets, and similar wheels were soon devised by John B. McCormick, from whose designs the Hercules, Hunt, Victor, and several makes of "McCormick" turbines have been developed.

In figure 8 the arrows indicate the inward and downward direction of flow of the water. Provision is made for a slight outward flow. In turbines of this type, as well as in those

[a] Tyler, W. W., Evolution of the American Type of Water Wheel.



A. RECENT AMERICAN TYPE OF WATER-WHEEL RUNNER.

B. DYNAMOMETER, HOLYOKE TESTING FLUME.

with inward and downward flow only, the buckets are commonly made of wrought iron or steel secured in a cast-iron head, as here shown, and strengthened by a band at *C*.

Clemens Herschel writes:[a]

American turbines are mostly of a complex nature, as regards the action of the water on the buckets of the wheels, and have been perfected in efficiency by test, or, as it is irreverently called, by the "cut and try" method of procedure. A wheel would be built on the inspiration of the inventor, then tested in a testing flume, changed in a certain part, and retested, until no further change in that particular could effect an improvement. Another part would then undergo the same process of reaching perfection, and thus in course of time the whole wheel would be brought up to the desired high standard of efficiency.

The American type of turbine is distinguished by the great depth of its buckets, its great capacity in proportion to its diameter, and by its high speed. It is also distinguished by the form of its buckets, which consist of a ring of curved vanes arranged parallel to the axis and inclosed within the guide ring. Below the guide ring the buckets expand downward and outward, forming large cup-shaped outlets.

The evolution of turbines having enormous capacity compared with their size is largely the result of the desire for great power in a small and consequently cheap wheel, and the desire to procure as high a speed as possible. The speed of a wheel under a given head varies inversely as its diameter. To increase the capacity of a turbine without increasing its diameter requires an increase in its depth. Thus wheels with very deep buckets have been evolved. This is illustrated in Pl. I, *A*, showing the inlet end of the runner of a deep-bucket wheel.

When a wheel is operating under low heads the lower part of a deep bucket is operating under an appreciably greater head than the upper part; hence to maintain a proper velocity of the water passing through the turbine, and to enable it to leave the runner with a low velocity, large bucket outlets are required. These could not be obtained in the narrow compass of a runner of small diameter, and to remedy this defect large cup-shaped buckets protruding downward and outward from the inlet chutes were devised. The course of the water in passing through these complex buckets is first radially inward, then axially downward, then tangential, or outward or both, thus effecting a nearly or quite perfect reversion of current direction. The large ladle-shaped vents perform another important function in that they distribute the water uniformly within the draft tube.

Recent improvements in this form of wheel have been (1) the arranging of wheels in pairs on horizontal shafts, made possible by the use of the draft tube; (2) the invention of a governor that will control the speed of the wheel with a degree of uniformity that is comparable with that effected by the best engine regulators; (3) the development of such a relation between the gate mechanism and the runner design as to give a high efficiency with a considerable range of gate opening.

American turbine practice differs from European practice in that water wheels are placed on the market in standard or stock sizes, whereas in Europe, notably on the Continent, each turbine is designed for the special conditions under which it is to operate, the designs being based on mathematical theory and following chiefly the Jonval and Fourneyron types.

Thirty years ago there were probably more establishments engaged in the manufacture of turbines than there are to-day. The keen competition of that time led to the development of better turbines, and the relatively small number of firms having the ingenuity and the facilities to meet the demand are the ones that have survived. At the present time a large majority of the turbines used in this country are built in half a dozen factories.

Having been developed by experiment after successive Holyoke tests (described on pp. 36–37), American stock pattern turbines probably give their best efficiencies at about the head under which those tests are made—i. e., 14 to 17 feet. The shafts, runners, and cases are so constructed as to enable stock sizes of wheels to be used under heads ranging from 6 to 60 feet. For very low heads they are perhaps unnecessarily cumbersome. For heads exceeding 60 feet American builders commonly resort to the use of bronze buckets and "special wheels," not designed along theoretical lines, as in Europe, but representing modifications of the standard patterns.

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[a] Cassier's Magazine, Niagara power number, July, 1895, p. 243.

TYPES OF TURBINE GATES AND GUIDES.

Practice as to chutes or guides differs widely. They are usually fewer in number than the buckets. The cogent dogma of water-wheel design is that the water should enter without shock and leave without velocity. This implies that the direction of motion of water on leaving the buckets shall be opposite to that of the buckets themselves, and that its velocity relative to the buckets shall be equal to that of the buckets. The water will then have no velocity relative to the earth. This law requires that the water shall enter the buckets at an angle at which it will glide smoothly in without shock. The guide passages are made as few in number as is reasonably consistent with this dictum. The construction of turbines without guides has also its advocates.[a]

With regard both to the efficiency and the general merit of the wheel, the gates are perhaps the most important feature. Among the different types of gates are outside register gates, inside register gates, inside cylinder gates, wicket or pivot gates.

Register gates may be of the plate or of the ring type, according as they are applied to parallel-flow or inward-flow turbines. In each class of turbines register gates are sometimes used outside and sometimes inside of the guide chutes.

Outside register gates, adapted to the Jonval type of wheels and to plain inward-flow turbines, were named from their similarity to a common hot-air register. Such wheels are of small capacity in proportion to their weight and diameter. Obstructions readily catch in the gate and chute openings and prevent the gates from being closed tightly, and the downward pressure of the water on the register ring makes it difficult to open. When the register is partially closed, the usefulness of the guide passages is in part nullified and the resulting efficiency of the wheel is diminished.

The inside register gate is placed between the chute ring and wheel runner instead of being outside of both. It is sometimes applied to wheels of the American type having inlet passages parallel to the axis as well as to Jonval wheels, in which the inlet passages are in a plane at right angles to the wheel axis.

Cylinder gates are applied to turbines of the Fourneyron and American types, but not to Jonval turbines. The cylinder gate moves over the inlet ports in a direction parallel to its axis, cutting off the supply at the top of the guide passages instead of at the side, as does a register gate.

The inside cylinder gate is the form of gate most commonly used on wheels of the American type. It consists of a cast ring having a width equal to the depth of the inlet of the buckets, supported by counterbalance weights and moved by gearing. By moving it up or down the depth of the inlet passages is increased or diminished as desired. It is commended by its ease of operation and its freedom from clogging. When it is partially closed the contraction of the water in passing the sharp metal lip of the gate causes swirls and eddies to form in the upper part of the buckets. The smooth curved form of the guide passages is fully effective only when the wheel is running with the gate wide open. In order to lead the water smoothly into the buckets at all gate openings, a set of "false guides," or garnitures, is sometimes attached to the lip of the gate cylinder to prevent the breaking or throttling of the inflowing water.[b]

Another device intended to prevent inefficient operation when the buckets are only partially filled, as at part gate, consists in the use of division plates, by which the water is entirely shut out of the upper part of the wheel when it is operating at part gate. This makes the turbine, in effect, a series of water wheels placed one above another. Such water wheels are commonly called double turbines. They may, however, be distinguished from another style of double turbines, the Leffel, in which two essentially different wheels are combined and mounted on the same shaft for the purpose of increasing the capacity of the turbine without increasing its diameter.

When an inside cylinder gate is raised, an open space an inch or more wide is left between the guide chutes and buckets. In order to avoid this and to conduct the water

[a] Tyler, W. W., The evolution of the American type of water wheel: Jour. Western Soc. Eng., vol. 3, Chicago, 1898.
[b] Webber, Samuel, Efficiency of turbines as affected by form of gate: Trans. Am. Soc. Mech. Eng., 1882.

more perfectly to the wheel, an outside cylinder gate has been devised, called a "sleeve gate," consisting of a cylindrical ring slipping outside of both runner and chute ring.

Wicket or pivot gates, as the terms are applied to the American type of turbines, are a combination of gates and guide passages. The leaves of the guide ring are so pivoted on their centers as to balance and swing by levers and gearing. Their inner ends approach or recede from one another, increasing or cutting off the supply to the wheel runner as desired. As usually constructed, all the gate leaves move simultaneously; a modification consists in a series of hinged gates, which close one after another as it is desired to decrease the power. When a gate is opened at all, it is opened full width, and the number of fractional gate openings at which the wheel can operate is determined by the number of gates.

Pivot or wicket gates are conducive to high part-gate efficiency provided they are so constructed as not to change the "entrance angle" of the water as it strikes the buckets at part gate. Cylinder-gate turbines may be so designed as to yield their maximum efficiency when running at about three-fourths gate, the depth of buckets being so great that the discharge is "choked" and some efficiency lost at full gate. In this way a good efficiency scale for part gate is obtained with cylinder-gate turbines.

Pivot gates contain many parts and are as a rule more liable to obstruction, leakage, and breakage than cylinder gates. They are, however, extensively used with very satisfactory results.

MECHANICAL PRINCIPLES OF THE TURBINE.

No attempt will be made to enter into the mechanical principles of the turbine from a mathematical standpoint, as the theoretical equations of relation are long, involved, and voluminous in development. Only a very general discussion of the subject will therefore be given.

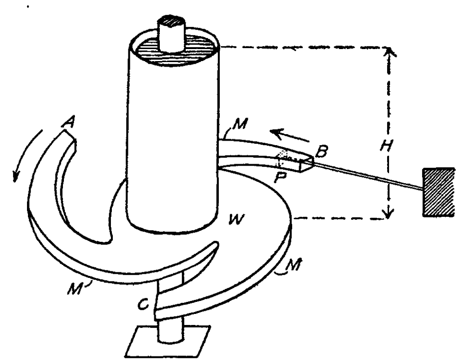

FIG. 9.—Diagram illustrating the principle of reaction. The figure represents a Barker's mill of the Whitelaw type.

The principle of reaction, as operating in turbines, is illustrated in fig. 9. If the wheel W were held rigid, the water would spout from the orifices A, B, and C with a velocity due to the head H. If pistons similar to P were fitted in the orifices, these pistons would be driven outward by the pressure. If, now, the pistons were held rigid, but the wheel were free to revolve, the pistons would be forced outward as before relative to the wheel, but the wheel must then revolve. The water head H exerts a direct pressure on the pistons, and in accordance with Newton's second law of motion, an equal and opposite pressure or reaction is exerted outward against the back walls M, M, M of the arms A, B, and C. Similarly, if the pistons were removed, and if the wheel were free to revolve, the unbalanced pressure against the back or outer walls M, M, M of the arms would cause it to revolve and with a peripheral velocity nearly equal to that due to the head H.

The theorem of Torricelli requires that the water shall issue from an orifice with a velocity equal to that acquired by a body falling through a height equal to the head.

In the case of the Barker's mill the orifice itself is moving with this velocity and in a contrary direction. Hence the water will have the required velocity relative to the wheel, but will have no velocity relative to the earth and will drop nearly inert from the orifices. This simple phenomenon has been carefully traced out, in order that its application in the less evident example of a turbine bucket may be made clear.

Let A, fig. 10, represent a single bucket in the vane ring of an outward-discharge turbine, the inner or guide ring being removed. Assuming the bucket to be attached to the axis of the turbine by the radial arm B, the similarity of conditions to those shown in fig. 9 is obvious.

This illustration applies equally well to either an outward, inward, or downward discharge turbine, so far as reaction is concerned.

Inasmuch as the bucket A revolves, the water must enter the bucket, if at all, with a tangential velocity equal to the velocity of the bucket and in the same direction. Guide chutes facilitate the action by properly directing the current of water in entering the bucket, as indicated at C, fig. 10.

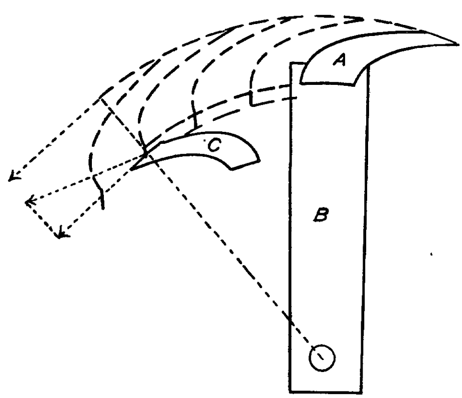

FIG. 10.—Diagram illustrating impulse against curved vanes.

Action by impulse against a moving vane takes place as follows:

First consider the vane V, fig. 11, as stationary. The jet from a guide chute enters the bucket in the direction $A\ B$ and leaves it in the direction $C\ D$, so that its direction of motion is changed through the angle $B\ E\ C$.

If the water spouting from the guide chute A would have reached B at the same time that it actually reaches C, then $A\ C$ would represent the resultant velocity. The line $A\ C$ comprises two components—(1) the initial velocity $A\ B$ and (2) a velocity imparted by the vane V. From the parallelogram of forces we find graphically for the latter the value $B\ C$. This force is exerted as a push against the vane, tending to rotate it on its axis. It can do work by causing the vane to move forward or to revolve against resistance, and the amount of work done will be represented by a component of the force $B\ C$ (modified by the motion of the vane) parallel to the line of motion and acting through the distance v where v is the velocity of the vane—i. e., the velocity of rotation of a turbine.

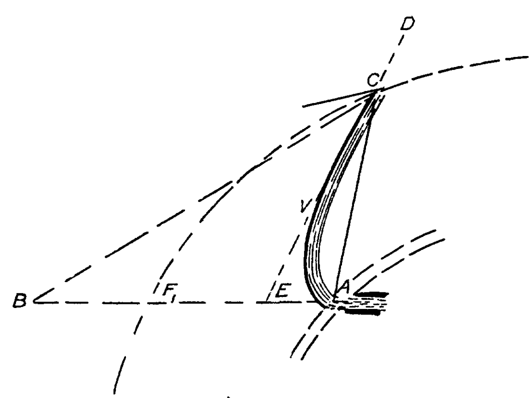

FIG. 11.—Diagram illustrating theory of moving vanes.

If the vane V were properly curved and moved with such velocity relative to that of the jet that the jet left its outer end with a backward velocity equal to the forward velocity of the wheel, then the jet would have no velocity relative to the earth and would drop inert, its entire energy having been imparted to the vane.

With most forms of gates the size of the jet is decreased as the gate is closed, the bucket area remaining unchanged, so that the wheel operates mostly by reaction at full gate and by impulse to an increasing extent as the gate is closed. Hence, the speed of maximum efficiency varies as the gate is closed. The ratio $\frac{\text{peripheral velocity}}{\text{velocity due head}}$ for maximum efficiency for a 36-inch Hercules turbine is given in the subjoined table.

Velocity at various gate openings for a 36-inch Hercules cylinder-gate turbine.

Proportional gate opening.	Maximum efficiency.	Peripheral velocity. / Velocity due head.
	Per cent.	
Full.	85.60	0.677
0.806	87.1	.648
.647	86.3	.641
.489	80	.603
.379	73.1	.585

Centrifugal force also plays an important part in turbine action. The complete theory of the turbine, including consideration of friction and centrifugal force, involves intricate mathematical analysis. The principal results to which it leads are as follows:

Given the head and quantity of water and speed required, theory indicates the diameter of wheel and the initial and terminal angles of the vanes. It does not determine the form of the vanes, the curved surfaces of which are usually made up of circular arcs for simple inward-, outward-, and downward-flow turbines. Neither is the number or the depth of the buckets determined, except that their normal sections shall be such as to give the water the required velocities in passing through.

Theory does not indicate the numbers of guides or buckets most desirable. If, however, they are too few, the stream will not properly follow the flow lines indicated by theory. If the buckets are too small and too numerous, the surface-friction factor will be large.

It is customary to make the number of guide chutes greater than the number of buckets, so that any object passing through the chutes will be likely to pass through the buckets also.

In a Jonval turbine the guide ring and bucket ring have equal radii. In the Francis, Thomson, and American types the radius of the guide ring is larger, requiring oftentimes the thickening of the guide partitions in order to give the water the proper initial velocity where it enters the buckets.

HORSEPOWER AND EFFICIENCY OF TURBINES.

The energy or capacity for doing work resulting from a weight W falling through a height H is—

$$\text{Energy in foot-pounds} = W\ H.$$

A horsepower was defined by James Watt as the capacity to perform work at the rate of 33,000 foot-pounds of energy expended per minute.

If the weight of a cubic foot of water is w and the flow of a stream is Q cubic feet per minute, then the theoretical horsepower will be—

$$\frac{W\ H}{33{,}000} = \frac{Q\ w\ H}{33{,}000}$$

Taking w, the weight of water, at 62.4 pounds per cubic foot, the factors for obtaining the theoretical horsepower are the following:

$0.1135 \times H \times$ cubic feet per second.

$0.00189 \times H \times$ cubic feet per minute.

$0.000253 \times H \times$ U. S. gallons per minute.

$0.3643 \times H \times$ U. S. gallons per 24 hours.

$0.00227 \times H \times$ California miner's inches (=0.02 second-foot).

$0.00295 \times H \times$ Colorado miner's inches (=0.026 second-foot).

$0.000789\sqrt{2g} \times H^{\frac{3}{2}} \times V$ (vent in square inches).

$0.00632 \times H^{\frac{3}{2}} \times V$ (vent in square inches).

The horsepower of a stream decreases about one-fourth of 1 per cent with a variation of the temperature of the water from 40° to 75° F.

For precise calculations the exact weight of pure water may be useful.

Weight and dimensions of distilled water at stated temperatures.[a]

[Weight in pounds.]

Temperature, degrees Fahrenheit.	Relative density.	Weight per cubic foot.	Weight per cubic inch.	Weight of column 1 inch square, 1 foot high.	Weight per U.S. gallon.	Cubic feet per ton.	Weight per cubic yard.
32	0.99987	62.416	0.0361	0.4334	8.345	32.043	1,685.232
[b]39.3	1.00000	62.424	.0361	.4335	8.3454	32.039	1,685.448
50	.99975	62.408	.0361	.4333	8.3433	32.047	1,684.908
60	.99907	62.366	.0361	.4330	8.3383	32.069	1,683.882
70	.99802	62.300	.03607	.4326	8.3295	32.103	1,682.100
80	.99669	62.217	.03602	.4320	8.3184	32.145	1,679.859

[a] Smith, Hamilton, Hydraulics. [b] Maximum density.

In practice the theoretical power is always to be multiplied by an efficiency factor E to obtain the net power available on the turbine shaft as determinable by dynamometrical test.

Manufacturers' rating tables are based on efficiencies usually between 75 and 85 per cent. In selecting turbines from a maker's list it is often important to know the rated efficiency. This may be obtained by the following formula:

E=tabled efficiency.

H. P.=tabled horsepower, and

Q=tabled discharge (C. F. M.) for any head H.

$$E=\frac{33{,}000\times H.P.}{62.4\times Q\times H}=528.8\,\frac{H.P.}{Q\times H}$$

The tabled efficiencies for a number of styles and sizes of turbines are shown in the accompanying table.

Rated efficiency of water wheels.

From manufacturers' power tables.]

Name of wheel.	Diameter in inches.	Percentage of efficiency at 10-foot head.	Percentage of efficiency at 40-foot head.
Hercules	24	81.520	79.856
Do	48	79.855	79.856
Samson	20	80.800	80.800
Do	45	80.754	80.887
United States (Camden)	24	79.877	79.944
Do	48	79.869	79.931
Smith-McCormick	24	80.004	79.913
Do	48	79.945	79.907
New Success	24	80.000	79.906
Do	48	79.937	79.907
Lesner No. 1	22	80.110	79.841
Do	44	80.010	80.126
New American	25	79.830	79.890
Do	48	79.905	79.776
Victor	24	79.914	79.936
Do	48	79.914	79.933

The efficiency at which wheels are rated by the builders varies slightly with the size of the wheel, as well as with the head, in many cases. Owing to the different weights of water assumed, etc., the efficiencies of wheels intended to be rated at 80 per cent differ slightly from that amount where computed from the manufacturer's power tables.

Prior to the classical experiments of James B. Francis on the flow of water over weirs in 1852 at the lower locks in Lowell, the diversity of formulas used for calculating flow through turbines makes the results of early tests incomparable one with another, and the accuracy of some later experiments preceding the building of the present Holyoke testing flume is somewhat in doubt.

It can hardly be said that there has been a progressive growth in the efficiency of turbines, as the following outline of the results of successive series of tests will show:

In 1759 James Smeaton reported tests of 27 undershot water wheels showing efficiencies varying from 28 to 32 per cent. Similar tests of 16 overshot wheels showed efficiencies varying from 76 to 94 per cent.[a]

In 1837 M. Morin tested several Fourneyron turbines. One at St. Blaise showed an efficiency of 85 per cent under 354 feet head. For another, under a lower fall, 88 per cent efficiency is claimed.[b]

In 1843 Elwood Morris introduced and tested Fourneyron turbines in the United States. Turbines in Rockland mills and Dupont powder mills, Wilmington, Del., showed 70 and 75 per cent maximum efficiency, respectively.

In 1844 Uriah A. Boyden built at Lowell the first Fourneyron turbine used in New England, which showed on completion an efficiency of 78 per cent.[c] It is claimed that some of Boyden's later turbines showed an efficiency, on test, of 88 to 92 per cent.

In 1859 and 1860 competitive tests of 19 wheels at Fairmount Park waterworks showed efficiencies as follows:

Results of tests of turbines at Fairmount Park, Philadelphia, Pa., in 1859–60.

Efficiency.	Number of turbines.	Efficiency.	Number of turbines.
50 per cent or less	1	70 to 75 per cent	4
50 to 55 per cent	2	75 to 80 per cent	3
55 to 60 per cent	0	80 to 85 per cent	2
60 to 65 per cent	4	Over 85 per cent	1
65 to 70 per cent	2		

In 1876 Centennial tests showed maximum efficiencies as follows for 17 wheels:

Results of tests of turbines at Centennial Exposition, at Philadelphia, in 1876.

Efficiency.	Number of turbines.	Efficiency.	Number of turbines.
60 to 65 per cent	1	75 to 80 per cent	5
65 to 70 per cent	3	80 to 85 per cent	4
70 to 75 per cent	4	Over 85 per cent	1

The large majority of turbines sold at the present time are made at the shops of five or six builders whose wheels have been frequently tested. The average full-gate efficiency shown in recent Holyoke tests of standard patterns is close to 80 per cent.

Some early wheels showed very high efficiencies, but prior to the building of the Holyoke flume the large majority were of low efficiencies.

[a] Evans, Oliver, Millwright's Guide, Philadelphia, 1853, pp. 131–154.
[b] Journal Franklin Institute, October to December, 1843.
[c] Francis, J. B., Lowell Hydraulic Experiments.

During the past thirty years the general standard of efficiency of turbines has been steadily raised, although the maximum attained may not exceed that of some early forms. The uniformity of each maker's wheels, as well as their strength and durability, has increased. This increase in uniformity and durability has been accompanied by a marked development in capacity and by the production of good part-gate efficiencies.

From 15 to 25 per cent of the gross power of the water is wasted by the better class of turbines. This waste is due to the following causes:

1. Shaft friction.
2. Skin friction on the guide and bucket surfaces.
3. Leakage through clearance spaces, etc.
4. Terminal velocity of the water on leaving the wheel.
5. Production of swirls, or vortices, in the water within the turbine, some of the energy of the water being thus converted into internal motion, which is ineffectual in producing power. How this occurs is illustrated in figure 12 (after Vigreux).

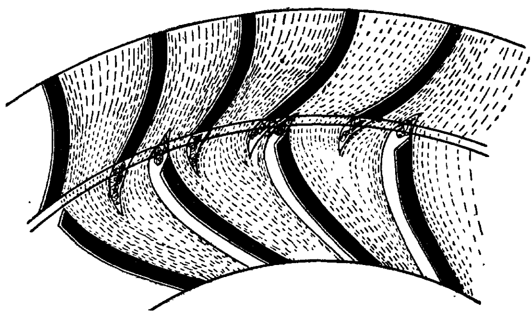

FIG. 12.—Diagram showing interference and formation of eddies in a turbine. (After Vigreux.)

Unwin classifies the lost energy of turbines as follows:[a]

Classification of lost energy of turbines.

Character of loss.	Per cent.
Shaft friction and leakage	10–15
Unutilized energy	3–7
Friction and shock in guide and wheel passages (i. e., skin friction and internal motion)	10–15
Total	26–37

There appears to be little probability of further marked increase in turbine efficiency. Compared with steam engines or other forms of prime movers, water wheels yield a larger percentage of the gross power available than any other type of machine or power-yielding medium. The accompanying diagram (fig. 13) shows the efficiency of various prime movers.

TURBINE TESTING.

GENERAL REVIEW.

The testing of water wheels may be considered to have begun with the work of James Smeaton, whose results of tests of undershot and overshot water wheels were communicated to the Royal Society of London in May, 1759.

The next important results are those of General Morin, in 1837, from early turbines of the Fourneyron type. General Morin's experiments represent a very high grade of scien-

[a] Unwin, W. C., On the Development and Transmission of Power, p. 104.

tific research and have formed the pattern for later work. These results have been translated into English by Elwood Morris, and are worthy of examination by students of hydromechanics.[a]

Tests of American Fourneyron turbines were made by Elwood Morris in 1843. From 1844 to 1851 important tests of Fourneyron and Francis turbines were made by Uriah A. Boyden and James B. Francis. These tests included Boyden-Fourneyron turbines con-

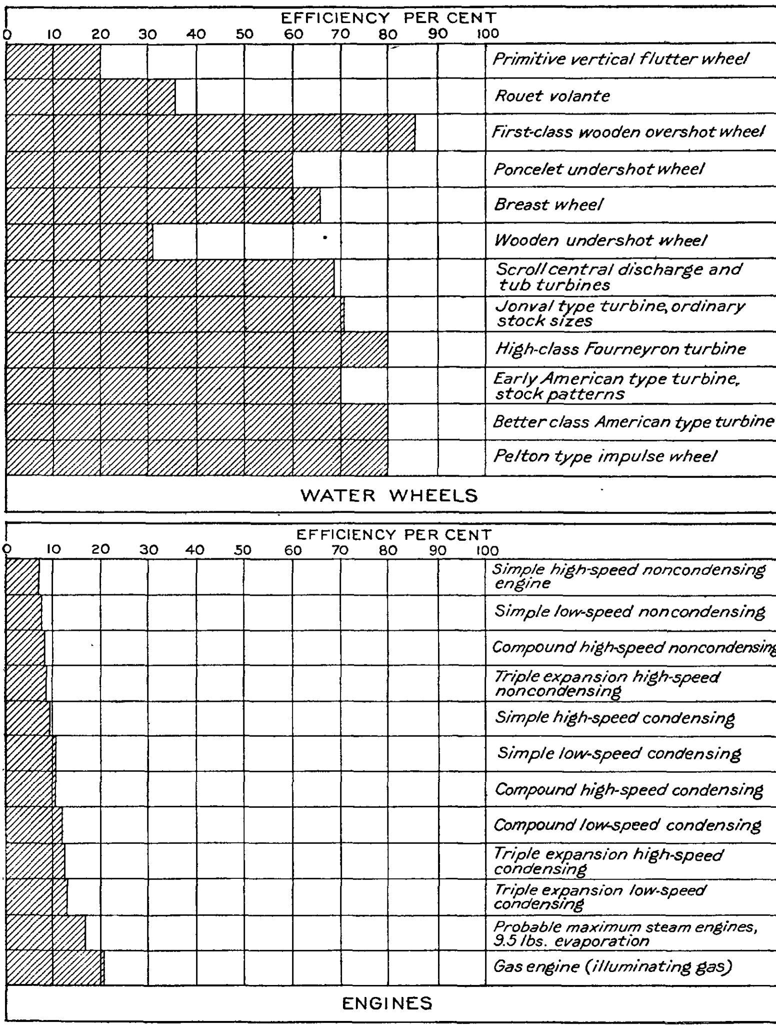

FIG. 13.—Diagram showing efficiency of various prime movers.

structed for the Appleton Mills in 1846, under an agreement in which Mr. Boyden was to receive a bonus of $400 for every 1 per cent of power in excess of 78 per cent efficiency. The computations of these tests were made by James B. Francis, who found a mean maximum efficiency of 88 per cent. Mr. Boyden was accordingly awarded $4,000 premium.

In 1859 and 1860 a series of competitive tests was carried out by the city of Philadel-

[a] Journal Franklin Institute, October to December, 1843.

phia at Fairmount waterworks, by Henry P. M. Birkinbine, chief engineer. The wheels tested were chiefly of the scroll, spiral, and Jonval types. Efficiencies from 47 to 82 per cent were obtained, with the exception of one wheel of the Jonval type, reported to have yielded 88 per cent.

Before the development of turbine testing at Holyoke is considered, mention may be made of the Centennial tests of 1876, results of which are given on pages 25–29. These tests did much to stimulate improvement in general efficiency and enlargement of capacity of American type turbines.

In 1868 a testing flume was constructed by A. M. Swain at Lowell from designs by James B. Francis. James Emerson was engaged to construct a Prony brake and conduct the tests. Tests of the Swain wheel were also made by Mr. Boyden and Mr. Francis and the Lowell flume was opened to the public, under the charge of Mr. Emerson, who conducted it as a personal enterprise, paying for the water used.

In 1871 and 1872 a new testing flume was erected at Holyoke, and continued under the charge of James Emerson until about 1880. An important series of tests was made in this flume by the Holyoke Water Power Company in 1879 and 1880 under the personal supervision of Theo. G. Ellis, Samuel Webber, and James Emerson. The wheels tested at this time were chiefly of the early American type, having both inward and downward discharge.

In 1882 the present testing flume of the Holyoke Water Power Company, designed by Clemens Herschel, was completed. The growth of the water-wheel testing at the Holyoke flume is illustrated by the following table, from data furnished by A. F. Sickman, hydraulic engineer of the Holyoke Water Power Company:

Growth of turbine testing at Holyoke testing flume.

Year.	Serial number of first test.	Number of wheels tested during year.	Year.	Serial number of first test.	Number of wheels tested during year.
1881	36	43	1893	650	84
1882	79	52	1894	734	80
1883	131	96	1895	814	69
1884	227	67	1896	883	87
1885	291	19	1897	970	99
1886	310	38	1898	1069	96
1887	348	48	1899	1165	57
1888	396	45	1900	1222	94
1889	441	25	1901	1316	72
1890	466	41	1902	1388	54
1891	507	54	1903	1442	59
1892	561	89			

CENTENNIAL TURBINE TESTS.

A series of 22 tests, a résumé of which is given in following tables, were obtained at the United States International Exhibition, Philadelphia, 1876, under direction of Samuel Webber.[a] The effective head utilized in these experiments was about 30 feet, and therefore greater than that used at Holyoke or elsewhere. Many of the turbines were of types that have since come into general use. The results of the tests, therefore, give valuable information relative to the capacity under partial and full gate of a variety of old-type turbines under as great heads as were commonly used thirty years ago.

The water supply for the tests was pumped into an overhead tank of 19,000 gallons capacity by means of two Cataract centrifugal pumps. From this tank it was conducted

[a] See Reports and Awards, U. S. Centennial, vol. 6, pp. 327-367; also Scientific American Supplement, February 17 and March 13, 1877.

to the flume in which the turbine was contained by a vertical wrought-iron pipe 4 feet in diameter, having a quarter turn at its lower end where it entered the flume. The flume was of wrought iron, 8 feet in diameter and 6 feet in height. The discharge was measured by means of a thin-edged weir placed across the lower end of the brick tailrace. The depth of overflow was determined by means of a hook gage and stilling box 6 feet upstream from the weir, and the discharge was computed by means of the Francis formula. The power was measured by means of a friction dynamometer. Each experiment comprised a record of the water used and of the speed and power at a given load and setting of the gate, covering a period of one or two minutes. Allowance was made for leakage of the flume in the reduction of the experiments.

The water supply was limited to about 1,860 cubic feet per minute, which was found insufficient for proper testing of the Cope and Hunt turbines. Most of the wheels were tested as they came from the shop, without special finish or preparation.

The results of the tests are probably consistent among themselves, although the general accuracy of the tests has been questioned.

Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876.

20-INCH BARBER & HARRIS.[a]

[Tested September 18, 1876.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horse-power.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	4	31.21	354	330.5	343.6	330.5	13.622	35.677	76.08	73.43
.875	1	31.27	380.5	380.5	380.5	380.5	12.855	33.484	73.62	73.62
.75	2	31.425	299	267.5	283.25	299	9.924	23.73	71.30	68.69
.50	2	31.64	271.5	227.5	249.5	271.5	6.767	14.603	71.77	60.23

30-INCH RISDON.[b]

[Tested September 21, 1876.]

1.000	3	30.37	266	252.5	259	266	27.763	82.84	87.68	86.56
.875	2	30.59	257	247	252	257	23.446	69.53	86.20	85.60
.75	2	30.835	248	238	243	248	20.148	57.33	82.41	81.83
.50	3	31.03	269	258	263.16	258	15.949	41.78	75.35	74.55

24-INCH KNOWLTON & DOLAN.[c]

[Tested September 23, 1876.]

1.000	6	30.763	333.5	282.5	307.75	333.5	25.281	67.47	77.43	76.68
.875	3	30.863	299.5	283.5	291.83	299.5	22.581	58.323	73.34	72.69
.50 } .625 }	4	31.19	270.5	233	250.88	233	15.929	34.99	62.73	62.24

[a] Made by Barber & Harris, Meadford, Ontario.
[b] Made by T. H. Risdon & Co., Mount Holly, N. J.
[c] Made by Knowlton & Dolan, Logansport, Ind.

Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876—Continued.

24-INCH WOLFF.[a]

[Tested September 25, 1876.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute. Maximum.	Revolutions per minute. Minimum.	Revolutions per minute. Mean.	Revolutions per minute. At maximum efficiency.	Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency. Maximum.	Percentage of efficiency. Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	7	30.58	305	266	290.07	297	27.349	68.12	72.75	72.03
.75	2	30.81	297.5	276.5	287	276.5	21.911	53.83	71.50	70.30
.50	1	31.08	287.5	287.5	287.5	287.5	15.256	34.50	64.90	64.90
.333	2	31.425	282.5	272.5	277.5	272.5	12.024	25.51	60.22	59.75

24-INCH WOLFF[a] (SECOND TEST).

[Tested October 15, 1876.]

1.000	7	30.15	320	267.5	296.21	320	25.451	64.423	74.80	73.62
.75	2	30.5	300	298	299	298	19.430	49.03	74.00	72.75
.625	1	30.83	284	284	284	284	15.028	34.08	65.00	65.00
.50	2	30.89	290	271	280.5	290	12.996	28.01	61.60	61.54

24-INCH NOYES & SONS.[b]

[Tested September 26-27, 1876.]

1.000	8	30.976	325	269	301.812	317	16.035	35.29	65.66	62.80
.875	1	31.16	317	317	317	317	14.326	32.97	65.46	65.46
.75	3	31.206	314	289	301	289	13.657	28.83	61.27	59.94
.625	1	31.29	293	293	293	293	11.237	25.78	64.80	64.80
.50	3	31.28	289.5	256.5	272.83	256.5	10.787	19.55	52.52	51.34

30-INCH E. T. COPE & SONS.[c]

[Tested October 19, 1876.]

1.000	13	29.88	274	223	250.08	258	27.605	65.75	78.7	70.07

25-INCH TAIT.[d]

[Tested October 23, 1876.]

1.000	10	31.038	331	243	288.7	288.5	15.939	44.198	82.03	79.28
.75	3	31.32	322.5	292	305.67	292	11.6297	29.26	72.6	70.8
.50	3	31.44	277.5	258	266.83	258	9.59	22.387	66.2	65.43
.25	3	31.537	268.5	245	259.51	265	6.541	12.423	54.5	53.1
.20	2	31.595	255	235	245	255	4.824	7.33	46.9	44.95
.125	2	31.61	277	266	271.5	266	4.702	5.96	37.7	35.3

[a] Made by A. N. Wolff, Allentown, Pa.
[b] Made by John T. Noyes & Sons, Buffalo, N. Y.
[c] Made by E. T. Cope & Sons. West Chester, Pa.
[d] Made by Thomas Tait, Rochester, N. Y.

Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876—Continued.

36-INCH GEYELIN DUPLEX.[a]

[Tested October 31, 1876.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
.50	13	30.235	260	181	221.3	190	17.189	39.980	71.4	67.78

36-INCH GEYELIN DUPLEX.[a]

[Tested November 2, 1876.]

1.000	9	29.547	223.5	185.5	200.9	217.5	26.52	68.24	78.1	76.77

36-INCH GEYELIN SINGLE.[a]

[Tested November 3, 1876.]

1.000	7	29.58	213.5	190.5	204.93	213.5	24.837	66.196	83.3	79.41

24-INCH RODNEY HUNT.[b]

[Tested November 9, 1876.]

1.000	6	29.282	328	276	302.67	295	30.754	79.60	78.7	77.95
.50	3	30.25	312	287.5	299.83	312	21.395	50.31	68.72	68.57
.75	4	29.655	306	278	292.75	298 / 289	27.849	66.65	71.40	71.22
.333	4	30.455	266	223	245.25	266	18.507	32.227	51.30	50.35

30-INCH STOUT, MILLS & TEMPLE.[c]

[Tested November 10, 1876.]

1.000	7	29.464	245.5	201	226.143	231	27.95	63.091	68.4	67.53
.50	4	29.59	259	230	245.75	230	22.784	50.922	69.13	66.56
.25	3	30.95	204	181	189	182	11.619	24.072	59.91	59.03

27-INCH GOLDIE & McCULLOUGH.[d]

[Tested October 2, 1876.]

1.000	9	30.198	320	281.5	299.44	281.5	27.419	73.452	82.2	78.28
.75	2	30.14	285	280	282.5	280	22.848	55.36	71.93	70.96
.625	2	30.59	352	350	351	350	22.425	39.305	54.10	50.65
.50	2	30.65	325	312	318.5	312	19.980	40.715	60.5	58.6

[a] Made by R. D. Wood & Co., Philadelphia, Pa.
[b] Made by Rodney Hunt, Orange, Mass.
[c] Made by Stout, Mills & Temple, Dayton, Ohio.
[d] Made by Goldie & McCullough, Gault, Ontario.

Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876—Continued

30-INCH TYLER.[a]

[Tested October 4, 1876.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.00	8	30.05	294	251	276.69	257	27.143	71.648	79.55	77.31
.875	1	30.10	286.5	286.5	286.5	286.5	24.017	66.47	81.09	81.09
.75	3	30.413	261	246	254.5	261	20.943	52.96	79.85	73.66
.50	2	30.62	260	247	253.5	247	18.432	42.535	77.10	66.55
.333	1	30.80	240	240	240	240	14.2595	34.56	69.50	69.50

30-INCH TYLER[a] (SECOND TEST).

[Tested October 24, 1876.]

1.000	6	30.345	294	262	276.5	281	27.491	69.520	74.10	73.55
.875	1	30.50	280	280	280	280	24.92	62.72	72.15	72.15
.75	2	30.42	268	255	261.5	268	21.2672	50.31	73.00	69.00
.625	2	30.59	262	218	240	262	18.1905	39.45	64.20	62.30
.50	2	30.715	247	242	244.5	242	16.4572	34.22	60.30	59.65

26½-INCH BOLLINGER.[b]

[Tested October 10, 1876.]

1.000	4	30.302	310	292.5	300.62	292.5	23,004	54.68	70.4	69.25
.875	2	30.46	300	290	295	290	21.49	50.72	68.6	68.3
.75	3	30.617	306	290	298.67	300	18.40	40.577	63.8	62.9
.50	2	30.805	290	274.5	282.25	274.5	15.647	32.71	60.2	59.95
.375	2	30.55	291	263	277	263	12.895	24.265	57.2	54.3

27-INCH YORK, NO. 2.[b]

[Tested October 12, 1876.]

1.00	12	30.504	312	232	274.375	246.5	20.2244	48.755	73.6	69.65
.875	2	30.60	318	300	309	300	18.4685	41.95	67	65.5
.75	2	30.71	290	280	285	280	17.229	39.88	67.45	67.0
.50	2	30.85	277	268	272.5	268	15.6415	35.95	67.5	66.7
.375	2	31.015	300	285	292.5	285	13.555	29.22	62.01	61.33

27-INCH YORK, NO. 3.[c]

[Tested October 13, 1876.]

1.000	9	29.972	265.5	212	247.28	235	22.685	45.677	66.9	59.41
.75	4	30.42	264	233	247.5	233	16.822	32.592	60.58	56.58

[a] Made by Putnam Machine Company, Fitchburg, Mass.
[b] Made by York Manufacturing Company, York, Pa.
[c] Made by National Water Wheel Company, Bristol, Conn.

Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876—Continued.

25-INCH NATIONAL.[a]

[Tested October 18, 1876.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	11	30.186	330.5	226.5	276.13	279	21.809	60.15	83.7	80.63
.75	2	30.685	312	292	302	292	17.076	40.995	70.5	68.9

24-INCH CHASE.[b]

[Tested November 6-7 1876.]

1	2	3	4	5	6	7	8	9	10	11
1.000	11	29.725	399	304	356.18	355	25.794	54.802	68.30	62.99
.75	5	29.47	435	325	366	360.[a]	23.505	51.801	67.6	65.74
.50	3	30.073	372.5	328	350.17	328	18.747	36.30	57.3	56.6

24-INCH WILLIAM F. MOSSER.[c]

[Tested October 6, 1876.]

1	2	3	4	5	6	7	8	9	10	11
1.000	1 *a*	30.56	....	....	300	....	19.396	50.40	....	75.09
1.000	1 *b*	30.58	....	....	289.5	....	19.741	50.95	....	74.60
1.000	1 *c*	30.58	....	....	276	....	19.972	50.78	....	73.40
1.000	1 *d*	30.60	....	....	312.5	....	19.664	50.00	....	73.43
1.000	1 *e*	30.60	....	....	326.5	....	19.189	49.63	....	74.62
1.000	1 *f*	30.62	....	....	342	....	18.978	49.25	....	74.80
1.000	1 *g*	30.65	....	....	356.5	....	18.676	48.48	....	74.39
1.000	1 *h*	30.67	....	....	365	....	18.523	46.72	....	72.68
1.000	1 *i*	30.90	....	....	310.5	....	15.808	39.74	....	71.63
1.000	1 *j*	30.95	....	....	323	....	15.488	38.76	....	71.48
1.000	1 *k*	31.00	....	....	335	....	15.169	37.52	....	70.50
1.000	1 *l*	31.02	....	....	347	....	15.028	36.09	....	68.2
1.000	1 *m*	31.03	....	....	355	....	14.747	34.08	....	65.74
1.000	1 *n*	31.10	....	....	312	....	13.334	29.95	....	63.80
1.000	1 *o*	31.00	....	....	343	....	13.029	30.18	....	65.8
Mean.....		30.79	....	....	326.23	....	17.116	42.835	....	....

[a] Made by National Water Wheel Company, Bristol, Conn.
[b] Made by Chase Manufacturing Company, Orange, Mass.
[c] Made by William F. Mosser, Allentown, Pa This test has been included in full in order to show the range in variation in discharge resulting from variation of the load and speed, the head and gate opening remaining nearly the same throughout the test.

TURBINE TESTS BY JAMES EMERSON, AND THE HOLYOKE HYDRODYNAMIC EXPERIMENTS OF 1879-80.

James Emerson was a man of great mechanical skill and ingenuity, but of limited education. A seaman in early life, he took up water-wheel testing by a mere accident of circumstances, and developed testing flumes at Lowell and Holyoke which were forerunners of the present Holyoke testing flume. The results of his tests, covering the period from 1869 to 1880, may be found in his treatise on hydrodynamics, etc.[a]

As a rule, the proportion of full-gate opening for wheels running at part gate is omitted in his reports. Many of the wheels tested were experimental, but a number of selected tests of types of wheels which have continued in use to the present time are given in the following tables. Cases are very rare where tests of the same turbine are given under widely varying heads. The following data from Emerson's Hydrodynamics are of interest:

Tests of a 30-inch Rodney Hunt wheel under two heads.

Mean head in feet.	Number of tests.	Mean revolutions.	Mean discharge in second-feet.	Ratio of—		
				Square roots of heads.	Revolutions.	Discharge.
18.35	9	170.39	24.36	1.000	1.000	1.000
12.16	10	145.78	19.75	.814	.855	.811

The discharge is very nearly proportional to the square root of the head, indicating practically constant bucket and guide discharge coefficients throughout this range of heads.

Comparative tests of a 30-inch Tyler wheel, set in a scroll case and in an inside register-gate case, are also of interest. These tests also show the great reduction in efficiency that may result from poor finish, friction, or imperfect balancing of the buckets.

Tests of the Case National wheel show the effect on discharge and power which results from cutting off the supply successively from one-fourth, one-half, and three-fourths of the circumference of the wheel.

The Holyoke competitive tests of 1879–80 [b] were carried out in response to a circular issued to turbine builders by the Holyoke Water Power Company, William A. Chase, agent, requesting them to submit turbine water wheels for testing. The tests were made under the general supervision of James Emerson. Check observations were made by Samuel Webber and the computations were submitted to him for verification on the part of the water power company. Theodore G. Ellis represented the interests of the turbine builders. These results are probably more accurate than those hitherto obtained.

A number of tests were made of Victor, American, Hunt, Leffel, Hercules, and other types of turbines from the same patterns as wheels still in use at many places. The most complete of these tests are included in the following tables, together with earlier tests by James Emerson.

Tests of similar wheels have been grouped together for convenience. Results obtained in the Holyoke competition of 1879 and 1880 can be distinguished by date. The tests of a 15-inch Victor wheel, set in a flume, and also with various sized draft tubes, are of interest as being the first recorded tests of this character. They also show the importance of using a draft tube of ample size, perfectly air-tight.

It has been said of Emerson's tests that they frequently showed unaccountable irregularities. Many tests obviously abnormal have been omitted in the present publication. Others are retained chiefly because they give the only available record of the capacity of types of wheels which have been extensively used.

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[a] Emerson, James, Treatise Relative to the Testing of Water Wheels and Machinery.
[b] Complete results will be found in "Holyoke Hydrodynamic Experiments," published by Holyoke Water Power Company, Holyoke, Mass., 1880.

Summary of James Emerson's tests of turbine water wheels.

40-INCH LEFFEL, PIVOT GATE.[a]

[Tested October, 1869.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum. efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	7	14.272	147.1	124	136.2	132.6	37.435	....	79.7	76.0
.93	7	14.132	131.4	129.5	130.5	131.4	35.496	....	79.6	79.0
.875	1	14.21	128.9	128.9	128.9	128.9	34.536	....	78.9	78.9
.827	1	14.285	126.2	126.2	126.2	126.2	32.533	....	78.3	78.3
.818	3	14.201	128.4	125	127.2	125	33.277	....	79.6	79.9
.80	2	14.251	127.6	126.3	127	127.6	32.904	....	78.4	78.4
.751	2	14.251	123.1	115.8	119.4	123.1	30.920	....	78.7	78.7
.747	3	14.011	126.1	124.4	125.3	125.3	30.358	....	79.4	79.2
.56	5	14.642	139.9	121	130.5	121	23.523	....	72.0	69.56
.373	1	14.938	129.2	129.2	129.2	129.2	16.422	....	67.5	67.5

30-INCH LEFFEL.[a]

1.000	14	15.40	201	135.5	167	175	24.396	28.80	74.3	68.9
.75	1	15.65	161	161	161	161	18.446	21.95	66.4	66.4
.50	1	16.037	165	165	165	165	10.624	13.13	59.1	59.1

20-INCH CASE NATIONAL, REGISTER GATE.[b]

[Tested August 22, 1872.]

1.000	4	18.695	342.5	237.2	269	237.2	11.905	18.50	76.3	73.3
.75	4	18.84	254.5	237.5	248.2	237.5	9.291	13.23	71.2	65.9
.50	4	18.955	248.5	247	247.6	247	6.506	8.01	60.4	56.4
.25	4	19.112	249	197.5	232.9	249	3.266	2.74	43.8	38.4

24-INCH CASE NATIONAL, REGISTER GATE.[b]

[Tested September 27, 1872.]

1.000	4	15.58	655.1	139.5	291.2	655.1	12.455	10.745	49.5	47.6

30-INCH CASE NATIONAL, REGISTER GATE.[b]

[Tested August 19, 1872; 16 chutes, 4 closed at a time.]

1.000	1	18.35	133	133	133	133	24.627	30.23	61	61
.75	1	18.61	153	153	153	153	15.006	18.43	58.3	58.3
.50	1	18.78	154.5	154.5	154.5	154.5	9.817	10.53	50.5	50.5
.25	1	18.19	141	141	141	141	5.613	4.16	37.7	37.7

[a] Made by James Leffel & Co., Springfield, Ohio.
[b] Made by National Water Wheel Company, Bristol, Conn.

Summary of James Emerson's tests of turbine water wheels—Continued.

40-INCH CASE NATIONAL.[a]

[Tested January 21, 1872; 16 chutes, 4 closed at a time.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	1	17.76	163.5	163.5	163.5	163.5	32.914	48.30	72.9	72.9
.75	1	18.40	158	158	158	158	35.179	32.31	61.6	61.6
.50	1	18.85	158	158	158	158	17.192	17.59	47.9	47.9
.25	1	19.26	156	156	156	156	10.304	4.6	20.5	20.5

50-INCH CASE NATIONAL.[a]

[Tested August, 1873.]

1.000	6	16.36	114	92	103.5	97	79.73	109	74.86	73.84

20-INCH AMERICAN, PIVOT GATE.[b]

[Tested November 12, 1873.]

1.000	1	18.85	253.5	253.5	253.5	253.5	10.109	14.97	69.38	69.38

25-INCH AMERICAN.[b]

[Tested November 11, 1873.]

1.000	1	18.23	212	212	212	212	19.304	28.91	72.44	72.44

36-INCH AMERICAN, PIVOT GATE.[b]

[Tested November 13, 20, 1872.]

1.000	2	18.63	146.5	144	145.2	144	28.382	45.5	76.8	75.9

42-INCH AMERICAN, PIVOT GATE.[b]

[Tested September 29 and October 6, 1873.]

1.000	2	17.91	118	112.5	115.2	112.5	42.549	60.18	70.95	69.88

48-INCH AMERICAN, PIVOT GATE.[b]

[Tested January 29, 1874.]

1.000	13	12.82	107.8	83	94.1	107.7	48.591	54.27	83.14	75.40

60-INCH AMERICAN, PIVOT GATE.[b]

[Tested August 5, 1873.]

1.000	7	15.24	88.1	70.5	78.4	80	99.621	121.41	73.94	69.87

[a] Made by National Water Wheel Company, Bristol, Conn.
[b] Made by Stout, Mills & Temple, Dayton, Ohio.

Summary of James Emerson's tests of turbine water wheels—Continued.

30-INCH NEW AMERICAN, PIVOT GATE.[a]

[Tested July 2, 1880.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	8	17.74	209.3	163	190.7	207.5	41.29	63.26	78.03	76.42

30-INCH NEW AMERICAN, PIVOT GATE.[a]

[Tested July 7, 1880.]

1.000	4	17.65	210.4	201.5	205.85	201.5	41.678	64.88	78.21	77.84
.819	3	17.70	209.5	200.5	204.33	200.5	39.325	62.66	79.64	79.49
.764	3	17.74	208.5	200	203.66	208.5	38.076	60.62	79.83	79.21
.708	2	17.77	207	201.2	204.1	207	36.770	59.35	80.27	80.08
.653	3	17.81	206.7	198	202.9	204	35.712	56.45	80.42	78.32
.597	3	17.85	208	201	204.7	201	33.684	55.77	79.89	78.93
.542	2	17.91	206	204	205	204	31.580	49.84	78.69	77.75
.486	3	17.96	207	203	204.7	203	29.309	45.57	77.00	76.38
.431	2	18.04	203	197	200	197	27.258	41.58	74.82	74.76
.375	2	18.12	206	203	204.5	206	24.391	36.71	73.58	73.38
.32	3	18.16	285.5	200.5	235.3	200.5	21.316	31.11	71.92	70.89

48-INCH NEW AMERICAN, PIVOT GATE.[a]

[Tested October 14, 1879, and January 3, 1880.]

1.000	8	16.33	110.5	101.5	106.5	108.3	92.843	132.80	77.83	77.02
1.000	9	13.14	109	99.0	101.2	105	98.419	111.11	77.23	75.82

30-INCH ECLIPSE, REGISTER GATE.[b]

[Tested 1878.]

1.000	5	19.02	184.5	165	171.9	184.5	16.849	24.01	76.28	63.94

15-INCH VICTOR, CYLINDER GATE.[b]

[Tested March 26, 1878.]

1.000	1	18.34	323	323	323	323	16.233	29.36	87.05	87.05

[a] Made by Stout, Mills & Temple, Dayton, Ohio.
[b] Made by Stillwell & Bierce Manufacturing Company, Dayton, Ohio.

Summary of James Emerson's tests of turbine water wheels—Continued.

15-INCH VICTOR, REGISTER GATE.[a]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	[b]6	17.98	355	300.5	335.33	347.5	16.269	30.24	92.58	91.22
[c]1.000	7	17.78	338.5	291.5	323.8	345	15.968	27.79	87.99	86.00
[d]1.000	5	17.89	365	309	337.9	354	16.023	26.53	82.64	81.64
[e]1.000	7	17.86	376	296	334	336	14.991	22.61	75.84	74.64
[f]1.000	5	17.82	369	325	348.6	356	16.723	28.52	85.59	84.35

20-INCH VICTOR, CYLINDER GATE.[a]

[Tested July 26, 1877, and February 21, 1878.]

1.000	2	18.17	266.5	246	256.2	266.5	22.914	38.02	83.63	77.77

25-INCH VICTOR, CYLINDER GATE.[a]

[Tested July 25, 1877, and March 26, 1878.]

1.000	2	18.02	209	200	204.5	209	38.092	62.72	85.84	80.58

30-INCH VICTOR, CYLINDER GATE.[a]

[Tested October 29, 1878.]

1.000	1	11.65	144.5	144.5	144.5	144.5	19.671	52.54	86.76	86.76

35-INCH VICTOR.[a]

[Tested September 5, 1879.]

1.000	9	17.11	156	126.6	142.5	150	83.32	132.46	83.34	82.04

30-INCH TYLER FLUME WHEEL, NO GATE.[g]

[Tested April, 1876.]

1.000	3	18.56	215	168	195.3	215.3	20.29	33.61	91.27	79.05

[a] Made by Stillwell & Bierce Manufacturing Company, Dayton, Ohio.
[b] Used in draft-tube experiments; tested in the ordinary way.
[c] With draft tube 23 inches in diameter and 10.33 feet long.
[d] With draft tube 19 inches in diameter and 10.33 feet long.
[e] With draft tube 15 inches in diameter and 10.33 feet long.
[f] With draft tube 21 inches in diameter, submerged 6.83 feet in backwater
[g] Made by John Tyler, Claremont, N. H.

Summary of James Emerson's tests of turbine water wheels—Continued.

30-INCH TYLER, INSIDE REGISTER GATE.[a]

[Tested August 1, 1879.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	8	18.27	218	180	201	198.5	23.32	38.60	82.25	80.01

42-INCH TYLER FLUME WHEEL, NO GATE.[a]

[Tested October 13, 1877.]

1.000	2	18.06	146.5	146	146.2	146.5	43.38	67.30	77.5	75.79

60-INCH TYLER, INSIDE REGISTER GATE.[a]

[Tested October 8, 1879.]

1.000	4	16.92	102.5	98	100.3	103	79.19	121.57	80.3	80.06

18-INCH LESNER, INSIDE REGISTER GATE.[b]

[Tested April 17, 1879.]

1.000	10	18.29	335.3	280	269.6	296	10.74	16.41	75.61	73.87

15-INCH HERCULES, CYLINDER GATE.[c]

[Tested March 5, 1880.]

1.000	6	17.9	375.5	298	342.7	356.5	18.03	29.44	82.94	81.87

33-INCH HERCULES, CYLINDER GATE.[c]

[Tested November 4-11, 1879; Runner of McCormick type; partial division plates.]

1.000	11	17.05	184.5	130	156.9	154.5	78.41	119.88	80.31	79.09
1.000	5	16.68	159.2	148.7	153.2	152	77.46	116.45	79.95	79.56

[a] Made by John Tyler, Claremont, N. H.
[b] Made by William B. Wemple Sons, Fultonville, N. Y.
[c] Made by Holyoke Machine Company, Holyoke, Mass.

Summary of James Emerson's tests of turbine water wheels—Continued.

48-INCH HERCULES, CYLINDER GATE.[a]

[Tested January 10, 1880.]

Gate opening (proportional part).	Number of tests.	Mean head in feet.	Revolutions per minute.				Mean discharge in second-feet.	Mean horsepower.	Percentage of efficiency.	
			Maximum.	Minimum.	Mean.	At maximum efficiency.			Maximum.	Mean.
1	2	3	4	5	6	7	8	9	10	11
1.000	9	11.51	94.5	75.2	84.65	93.2	135.53	138.24	82.86	78.13
.927	1	11.73	70.3	70.3	70.3	70.3	131.54	130.5	78.66	78.66
.878	1	11.70	81.5	81.5	81.5	81.5	129.17	130.89	76.43	76.43
.830	3	11.55	83.5	78.5	80.66	83.5	124.06	124.60	77.48	76.31
.781	1	11.20	81.8	81.8	81.8	81.8	116.67	114.02	77	77
.732	2	11.43	87	83.2	85.1	87	112.38	110.82	76.19	76.14
.683	2	11.65	85.7	85	85.35	85.7	108.62	109.91	76.74	76.54
.634	1	11.69	83	83	83	83	103.95	105.63	76.72	76.72
.586	1	11.6	82.5	82.5	82.5	82.5	97.36	98.20	76.59	76.59
.537	2	11.36	81	80	80.5	80	89.34	85.37	74.59	73.87
.488	1	11	82	82	82	82	80.88	74.54	73.94	73.94
.439	3	11.72	88.5	84	86	88.5	75.41	70.31	70.68	70.18

36-INCH HUNT.[b]

[Tested May 19, 1880.]

1.000	8	17.55	165	145.5	155.4	155.5	39.44	65.16	84.84	83.80
1.000	15	17.69	179	139.5	162.2	160	40.89	68.4	84.61	83.3

24-INCH REYNOLDS CHAMPION.[c]

[Tested October 13, 1879.]

1.000	9	18.3	313	243.7	275.6	276.7	17.87	28.7	78.57	76.72

[a] Made by Holyoke Machine Company, Holyoke, Mass
[b] Made by Rodney Hunt Machine Company, Orange, Mass.
[c] Made by Bloomer & Co., Ellenville, N. Y.

TURBINE TESTS BY HOLYOKE WATER POWER COMPANY.

GENERAL DISCUSSION.

The conditions under which turbines are tested at the Holyoke flume are described in the following circular issued by the Holyoke Water Power Company:

We are prepared to test turbines on vertical shaft, of any of the usual diameters (the pit is 20 feet square), and of any power up to 300 H. P.

The measuring weir has a capacity of about 230 cubic feet per second.

Small wheels may be tested under any head from 4 to 18 feet. Larger sizes, 11 to 14 feet.

The price of test and report is based on the amount of water drawn by the wheel when giving its best efficiency at full gate. But on account of variation of heads the quantity drawn will be computed for a head of 17 feet, and on that the charge will be 66⅔ cents per cubic foot per second, but no test for less than $30, the sender to pay freight and cartage.

Scroll wheels or wheels set in iron cases may cost $10 to $15 or more in addition.

A test will consist of five or six settings of the gate; additional settings will be charged extra.

We can also test small and medium sizes, singly or in pairs, on horizontal shaft, under certain conditions, details of which will be sent on application. Price of horizontal test, from $50 up, depending on the amount of labor necessary to erect the wheel.

All results are kept strictly confidential, report being made only to the party ordering the test.

Duplicate reports, typewritten, or in India ink for blue printing, will be furnished at $2 each.

HOLYOKE WATER POWER COMPANY.

HOLYOKE, MASS., *November 1, 1898.*

The Holyoke flume serves three principal uses:

1. The testing of all wheels installed in conjunction with the water power at Holyoke, in order that their discharge capacity may be determined and used as a means of estimating the quantity of water taken by the several mills.

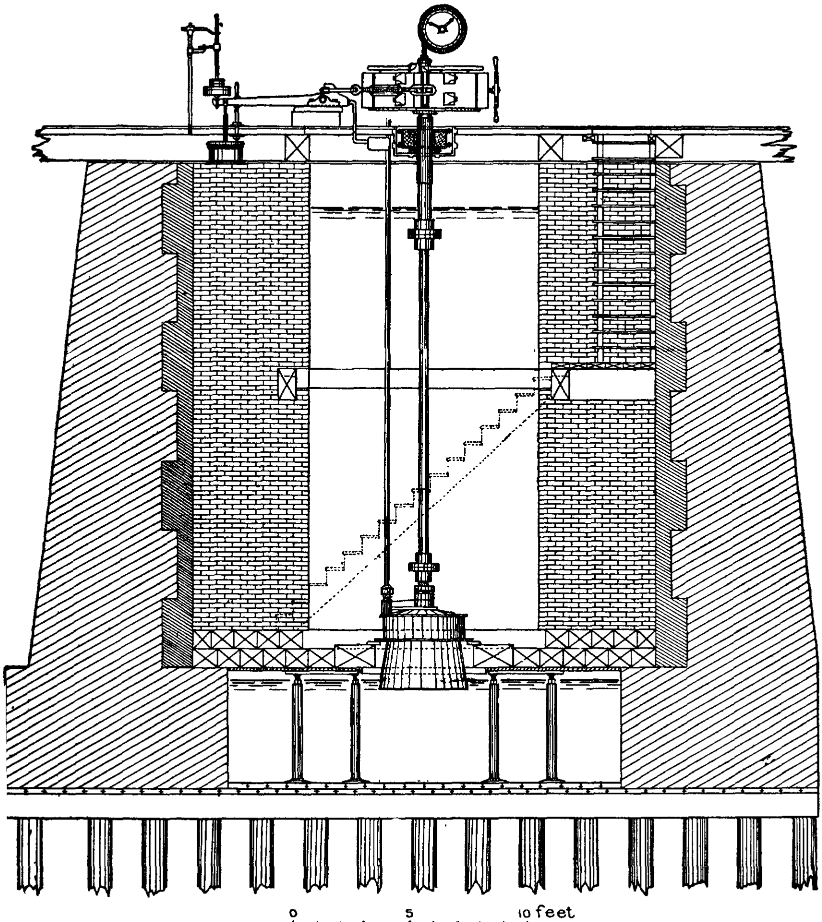


FIG. 14. Cross section of Holyoke testing flume.

2. The testing of experimental wheels with a view to their improvement. Many of the wheels tested, especially in the early years, have been of this class, and the results are of no general interest.

3. Testing of standard patterns of American type turbines which are to be installed in new plants. The results of such tests are of general and permanent interest.

A few complete tests have been published by Thurston[a] and in the catalogues of tur-

[a] Thurston, R. H., The systematic testing of turbine water wheels in the United States: Trans. Am. Soc. Mech. Eng., vol. 8, pp. 359-420.

bine builders. The policy of the Holyoke Water Power Company has been to treat the results of the tests as the property of their clients, and they have never been made public without the permission of the parties for whom they were made. In the preparation of this paper application was first made to the Holyoke Water Power Company, and afterwards to a number of the leading turbine builders, for the results of Holyoke tests of standard patterns of wheels. As a result, complete reports of tests of a considerable number of turbines have been obtained for publication with the mutual consent of the Holyoke Water Power Company and the turbine builders.

Acknowledgment is due to Mr. A. F. Sickman, hydraulic engineer of the Holyoke Water Power Company, and to the Holyoke Machine Company, Worcester, Mass.; the S. Morgan Smith Company, York, Pa.; the James Leffel Company, Springfield, Ohio; J. & W. Jolly,

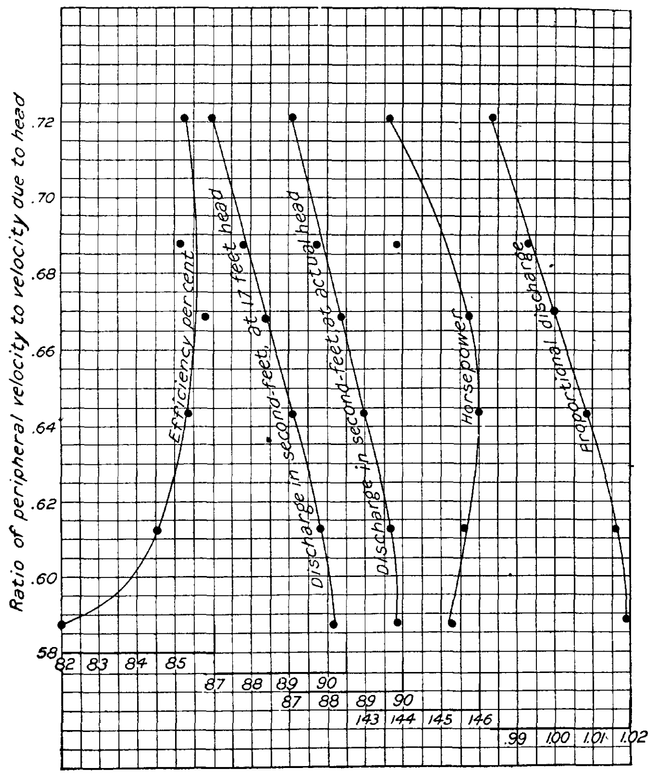


FIG. 15.—Log of test of 36-inch right-hand Hercules, full gate, test No.190, October 13, 1883.

Holyoke, Mass.; the Stillwell-Bierce and Smith-Vaile Company (now Platt Iron Works), Dayton, Ohio, and the Dayton Globe Iron Works, Dayton, Ohio.

The quantity of water used in the Holyoke tests (see tables, pp. 43–76) is determined by means of a thin-edged weir, with or without end contractions, according to the volume of flow. The discharge is computed by the Francis formula, and is given in column 7 of the tables. The power is determined by a friction dynamometer (see Pl. I, *B*), and is given in column 8 of the tables. Each wheel is tested under several positions of speed gate, commonly varying from about one-third to full gate. A varying number of tests at each gate is made, the load being so adjusted as to cover the ordinary range of speeds, both greater and less than that at which the maximum efficiency occurs. The net head acting on the wheel in feet is determined by means of hook gage readings, and is contained in column 4 of the tables. The measured gate opening, head, speed, discharge, and power constitute the basic data of the experiments. The efficiency for each experiment is computed from

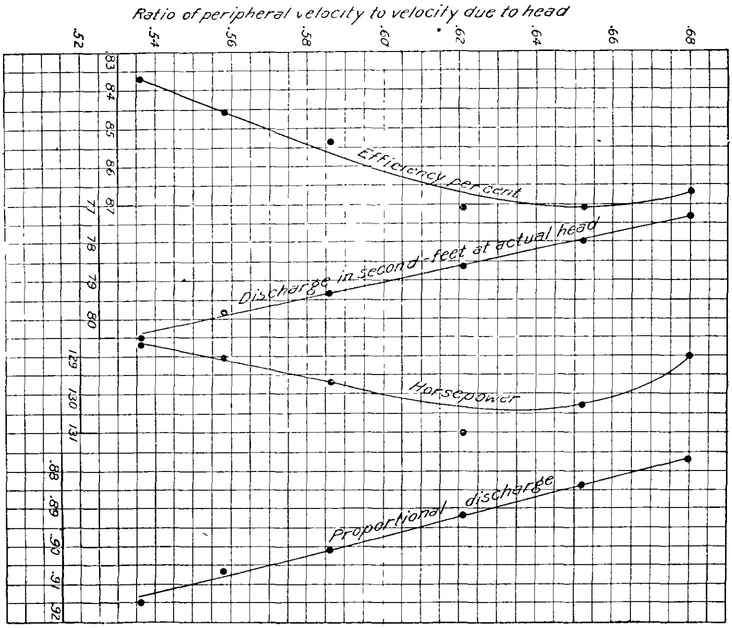


FIG. 16.—Log of test of 36-inch right-hand Hercules, 0.806 gate, test No. 190, October 13, 1883.

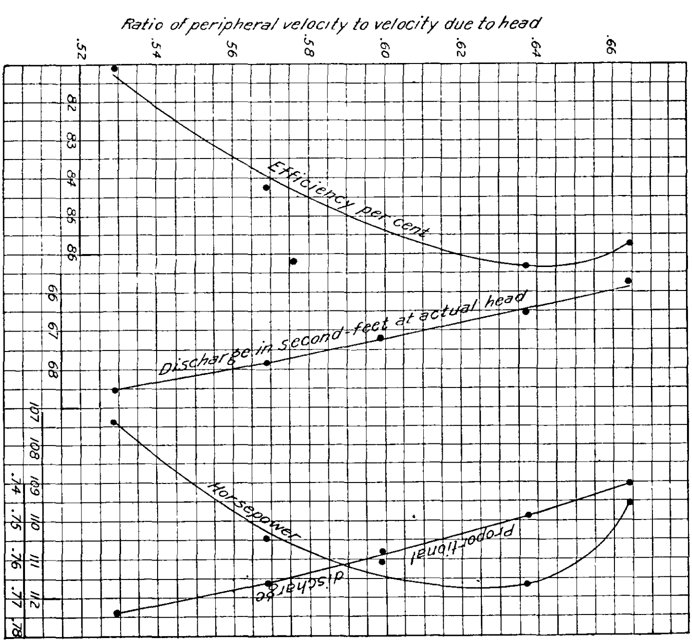


FIG. 17.—Log of test of 36-inch right-hand Hercules, 0.647 gate, test No. 190, October 13, 1883.

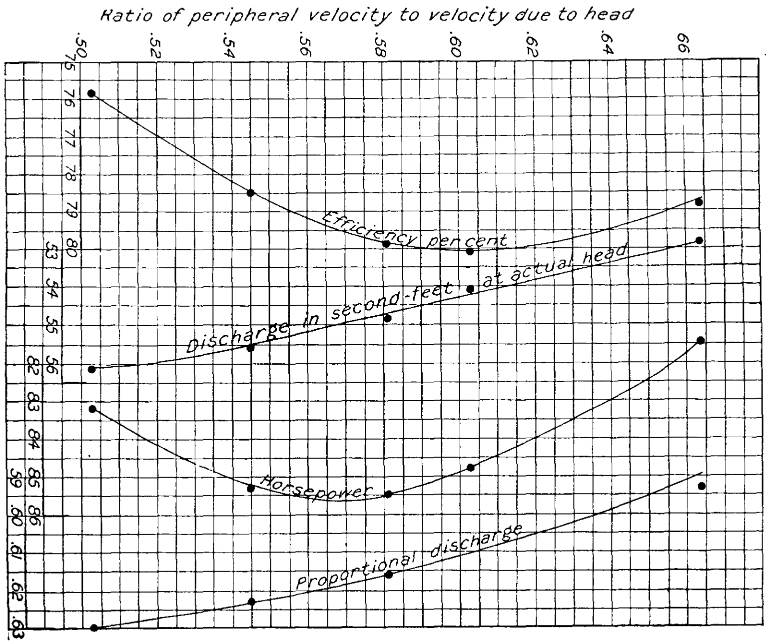


FIG. 18.—Log of test of 36-inch right-hand Hercules, 0.489 gate, test No. 190, October 13, 1883.

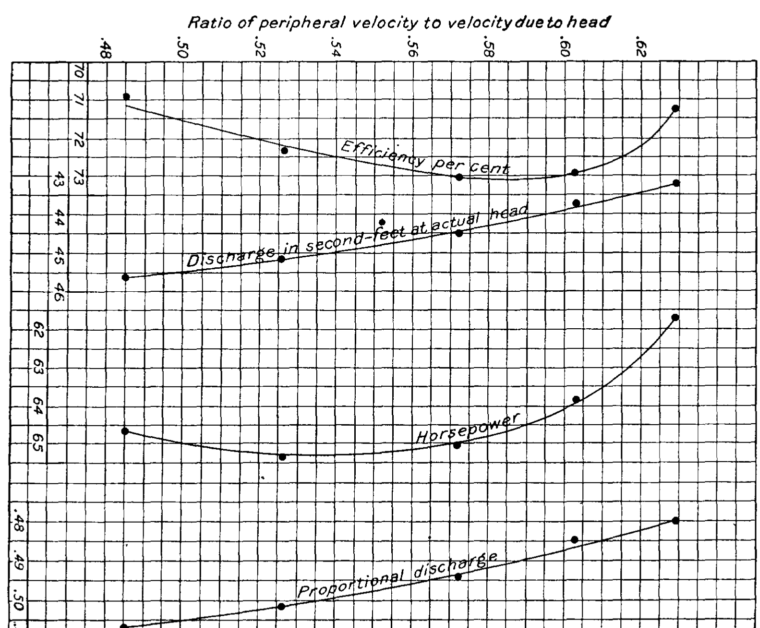


FIG. 19.—Log of test of 36-inch right-hand Hercules, 0.379 gate, test No. 190, October 13, 1883.

the measured discharge and power. This factor, together with the horsepower, is omitted from the series of tests of Smith-McCormick turbines.

In the reduction of the experiments, the ratio of the peripheral speed of the turbine to the spouting velocity due to the head is determined, and the data for each width of the gate opening are plotted, using as an argument the speed ratio described above. A series of curves is thus obtained for each gate opening showing the variation in the discharge, power, speed, and efficiency. A set of these curves for a 36-inch Hercules turbine is shown in figs. 15-19. From these diagrams the maximum efficiency for each width of gate opening and the speed at which it occurs may be easily determined.[a]

In column 3 of the tables of tests (pp. 43–76) is given the proportional part of the full-gate discharge, the unit discharge at full gate being that which occurs at the speed giving maximum efficiency under the head used in the experiments. The head and discharge corresponding to the highest efficiency having been determined from the full-gate test diagram, the proportional discharge is obtained as follows:

Let H_e represent the head at which maximum full-gate efficiency was observed, and H any other head corresponding to a discharge Q at either full or part gate, then $Q'=\frac{\sqrt{H_e}}{\sqrt{H}}Q$ is approximately the discharge which would have resulted with the given gate opening

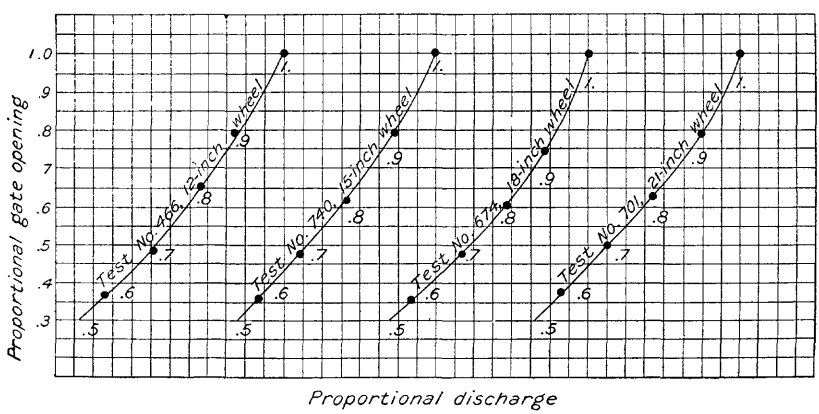


FIG. 20.—Proportional discharge coefficients for 12-, 15-, 18-, and 21-inch McCormick turbines.

under a head H_e and the ratio of the quantity Q′ to the full-gate discharge at maximum efficiency $=\frac{Q'}{Q}$ is called the "proportional discharge" and is given in column 3. This column shows, therefore, the relative discharge at different gate openings all reduced to the head of maximum full-gate efficiency as a standard.

DETAILED HOLYOKE TESTS.

M'CORMICK TURBINES.

The McCormick turbine is notable for its great depth and capacity in proportion to its diameter. Many tests of all sizes have been made for the manufacturers, the S. Morgan Smith Company, York, Pa., and J. & W. Jolly, Holyoke, Mass. In the following tables will be found complete tests of all sizes from 12 to 57 inches diameter.

The mean factors for the group of experiments included in a single gate opening for a wheel of each size have been computed and are given in tabular form on pages 43–59. This data will enable any desired feature of the tests to be readily worked out for the different sizes. On figs. 20–23 are given the coefficients of part-gate discharge in form for ready comparison.

[a] The systematic testing of water wheels in the United States: Trans. Am. Soc. Mech. Eng., vol. 8, pp. 339-420.

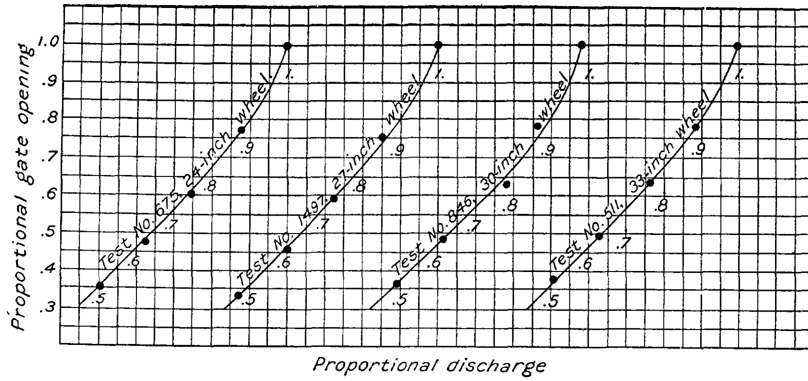


FIG. 21.—Proportional discharge coefficients for 24-, 27-, 30-, and 33-inch McCormick turbines.

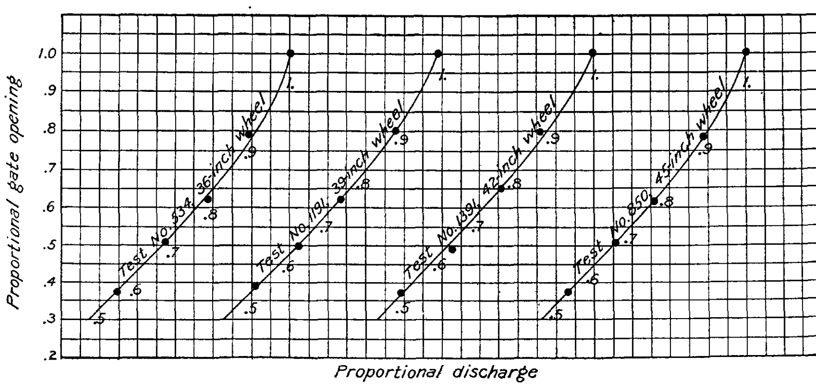


FIG. 22.—Proportional discharge coefficients for 36-, 39-, 42-, and 45-inch McCormick turbines.

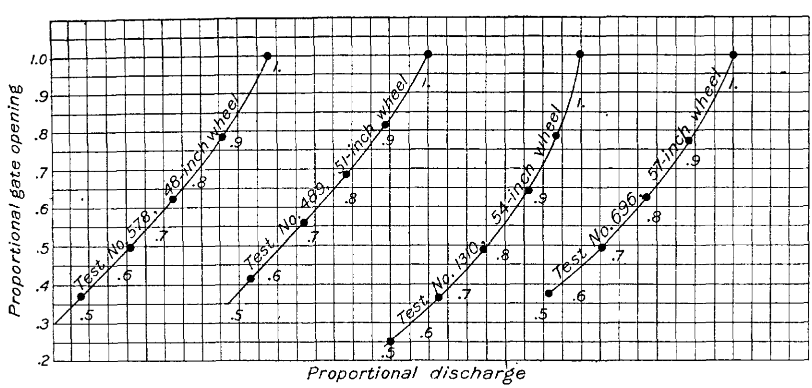


FIG. 23.—Proportional discharge coefficients for 48-, 51-, 54-, and 57-inch McCormick turbines.

Holyoke tests of McCormick turbines.a

12-INCH RIGHT-HAND SMITH-McCORMICK WHEEL.

[Test No. 466, January 17, 1890.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
1	1.000	1.013	17.92	5	Still.	11.35
9	1.000	1.019	17.84	4	375.0	11.39
8	1.000	1.010	17.85	5	395.0	11.29
7	1.000	1.009	17.80	4	406.7	11.27
6	1.000	1.000	18.00	4	424.7	11.23
5	1.000	.995	18.01	4	437.7	11.18
4	1.000	.991	18.02	4	449.0	11.13
3	1.000	.985	18.09	4	464.5	11.09
2	1.000	.979	17.98	6	477.8	10.99
Mean	1.000	1.000	17.945		381.16	
22	.799	.895	17.90	4	361.0	10.02
21	.799	.889	17.87	4	388.5	9.95
20	.799	.882	17.87	3	407.0	9.87
19	.799	.875	17.85	3	421.3	9.79
18	.799	.870	17.86	4	435.7	9.73
17	.799	.864	17.89	5	451.8	9.67
16	.799	.860	17.91	3	476.0	9.63
Mean		.876	17.878		420.1	
29	.651	.801	17.92	4	364.0	8.98
28	.651	.799	17.92	5	401.6	8.95
27	.651	.794	17.93	6	421.0	8.90
26	.651	.788	17.94	4	440.2	8.83
25	.651	.781	17.98	3	460.0	8.77
24	.651	.778	18.05	3	477.3	8.75
23	.651	.770	18.02	3	503.0	8.65
Mean		.787	17.965		438.15	
33	.488	.667	18.06	4	362.0	7.50
32	.488	.662	18.08	3	392.0	7.45
31	.488	.660	18.02	4	415.0	7.42
30	.488	.656	18.04	4	439.5	7.38
34	.488	.651	18.07	4	462.0	7.32
35	.488	.644	18.07	6	479.5	7.25
Mean	.488	.656	18.056		425.0	
15	.369	.541	18.35	3	346.0	6.13
14	.369	.539	18.12	4	366.0	6.07
13	.369	.537	18.12	4	392.2	6.05
12	.369	.531	18.10	4	417.5	5.98
11	.369	.524	18.14	3	440.7	5.91
10	.369	.520	18.23	4	477.0	5.88
Mean	.369	.532	18.176		406.56	

a Made by S. Morgan Smith Company, York, Pa.

Holyoke tests of McCormick turbines—Continued.

15-INCH LEFT-HAND McCORMICK HOLYOKE WHEEL.

[Test No. 740, March 20, 1894.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
1	1.000	0.978	15.34	4	Still.	17.91
8	1.000	1.015	15.55	4	282.2	18.71
7	1.000	1.010	15.57	4	302.2	18.64
6	1.000	1.007	15.59	4	321.7	18.59
5	1.000	1.003	15.61	4	333.5	18.52
4	1.000	1.000	15.63	5	354.0	18.48
3	1.000	.993	15.65	5	372.0	18.37
2	1.000	.992	15.27	5	375.8	18.12
Mean	1.000	.999	15.526	....	377.34	15.526
15	.791	.910	15.80	4	284.7	16.91
14	.791	.904	15.80	3	306.7	16.80
13	.791	.900	15.75	5	326.2	16.69
12	.791	.893	15.75	4	340.0	16.61
11	.791	.891	15.77	5	353.0	16.54
10	.791	.883	15.79	4	372.2	16.40
9	.791	.869	15.81	4	395.7	16.16
Mean	.791	.893	15.781	....	339.78	....
24	.615	.780	16.15	3	270.0	14.66
23	.615	.779	16.13	4	293.2	14.63
22	.615	.775	16.12	5	307.0	14.55
21	.615	.772	16.08	5	323.2	14.47
20	.615	.767	16.09	4	338.2	14.39
19	.615	.760	16.09	4	352.7	14.26
18	.615	.755	16.08	4	365.5	14.16
17	.615	.750	16.08	4	377.7	14.06
16	.615	.745	16.08	4	389.0	13.96
Mean	.615	.765	16.10	....	335.17	....
32	.475	.654	16.26	4	267.5	12.32
31	.475	.651	16.29	3	292.0	12.29
30	.475	.648	16.30	4	310.0	12.24
29	.475	.644	16.35	4	327.5	12.17
28	.475	.639	16.37	4	342.5	12.09
27	.475	.636	16.41	4	358.0	12.04
26	.475	.632	16.43	4	372.7	11.97
25	.475	.627	16.41	4	395.5	11.88
Mean	.475	.641	16.35	....	333.21	....
39	.359	.539	16.37	4	268.2	10.20
38	.359	.539	16.38	4	291.5	10.20
37	.359	.535	16.39	4	313.0	10.12
36	.359	.533	16.40	4	328.5	10.09
35	.359	.527	16.42	4	348.0	9.99
34	.359	.523	16.43	4	365.7	9.92
33	.359	.520	16.44	4	382.2	9.85
Mean	.359	.531	16.40	....	328.16	....

Holyoke tests of McCormick turbines—Continued.

18-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 674, April 18, 1893.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
1	1.000	1.071	17.37	5	Still.	27.57
6	1.000	1.020	17.41	4	235.5	26.28
5	1.000	1.012	17.41	4	248.0	26.07
4	1.000	1.005	17.43	4	258.7	25.92
3	1.000	.999	17.45	4	271.2	25.76
2	1.000	.990	17.48	4	286.0	25.55
7	1.000	.980	17.42	4	299.7	25.27
Mean	1.000	1.011	17.424	....	228.44	....
13	.748	.904	17.44	5	227.8	23.30
12	.748	.899	17.47	5	243.0	23.20
11	.748	.892	17.46	6	259.0	23.01
10	.748	.888	17.50	4	266.0	22.95
9	.748	.883	17.48	4	274.7	22.80
8	.748	.872	17.52	4	292.0	22.55
Mean	.748	.889	17.478	....	260.42	....
19	.604	.797	17.68	4	234.0	20.70
18	.604	.794	17.65	4	245.2	20.60
17	.604	.792	17.63	5	257.2	20.54
16	.604	.789	17.63	5	266.4	20.45
15	.604	.783	17.61	5	272.5	20.30
14	.604	.779	17.56	6	281.6	20.16
Mean	.604	.789	17.626	....	259.48	....
23	.476	.673	17.65	5	215.5	17.47
27	.476	.675	17.73	3	227.7	17.54
22	.476	.672	17.59	10	230.0	17.41
26	.476	.672	17.68	4	243.0	17.45
21	.476	.672	17.50	4	246.5	17.36
25	.476	.668	17.69	4	256.2	17.36
20	.476	.668	17.40	4	256.2	17.21
24	.476	.663	17.69	4	273.5	17.21
Mean	.476	.670	17.616	....	243.57	....
28	.356	.540	17.82	4	195.5	14.08
29	.356	.539	17.79	4	214.2	14.05
30	.356	.538	17.79	4	233.2	14.01
31	.356	.536	17.79	4	250.2	13.96
32	.356	.533	17.87	4	267.0	13.92
33	.356	.531	17.84	4	279.2	13.85
Mean	.356	.536	17.816	....	239.88	....

Holyoke tests of McCormick turbines—Continued.

21-INCH LEFT-HAND McCORMICK HOLYOKE WHEEL.

[Test No. 701, August 17, 1893.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
8	1.000	1.024	15.66	4	205.7	35.40
7	1.000	1.018	15.62	4	214.5	35.15
6	1.000	1.013	15.62	4	224.0	34.95
5	1.000	1.006	15.65	4	234.2	34.76
4	1.000	1.000	15.66	4	244.0	34.55
3	1.000	.993	15.68	4	253.7	34.32
2	1.000	.983	15.71	4	266.7	34.02
1	1.000	.972	15.75	4	280.0	33.69
Mean	1.000	1.001	15.869		240.35	
15	.790	.914	15.79	4	194.2	31.73
14	.790	.911	15.81	4	210.0	31.63
13	.790	.904	15.82	4	222.0	31.39
12	.790	.899	15.83	4	233.2	31.22
11	.790	.893	15.85	4	244.0	31.03
10	.790	.886	15.89	4	255.5	30.85
9	.790	.874	15.90	4	271.5	30.45
Mean	.790	.897	15.841		232.91	
21	.628	.780	15.58	4	190.0	26.88
20	.628	.781	15.60	5	209.4	26.95
19	.628	.776	15.63	5	225.0	26.79
18	.628	.772	15.67	4	237.5	26.67
17	.628	.768	15.71	4	248.0	26.57
16	.628	.763	15.73	5	258.4	26.43
22	.628	.756	15.68	4	265.0	26.15
Mean	.628	.711	15.157		233.33	
29	.499	.652	15.79	4	192.2	22.64
28	.499	.655	15.82	4	211.0	22.75
27	.499	.656	15.77	4	223.0	22.75
26	.499	.654	15.76	4	230.6	22.67
25	.499	.653	15.76	4	239.7	22.64
24	.499	.648	15.81	4	252.2	22.49
23	.499	.642	15.87	4	263.5	22.35
Mean	.499	.651	15.797		230.31	
36	.374	.534	15.69	4	186.2	18.46
35	.374	.535	15.70	4	205.7	18.50
34	.374	.533	15.70	4	217.2	18.44
33	.374	.531	15.74	4	227.0	18.41
32	.374	.529	15.74	3	235.0	18.33
31	.374	.526	15.77	4	245.0	18.25
30	.374	.522	15.82	4	256.2	18.14
Mean	.374	.530	15.737		224.61	

Holyoke tests of McCormick turbines—Continued.

24-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 675, April 19, 1893.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
39	1.000	1.012	16.83	4	178.25	47.88
38	1.000	1.009	16.84	3	186.33	47.74
37	1.000	1.005	16.83	4	195.25	47.55
36	1.000	1.002	16.82	4	203.50	47.41
35	1.000	.999	16.84	4	210.00	47.27
34	1.000	.995	16.86	4	216.50	47.13
33	1.000	.992	16.88	4	222.25	46.99
32	1.000	.984	16.94	4	232.00	46.71
Mean	1.000	.999	16.855	....	228.44	....
31	.771	.894	17.13	4	179.00	42.65
30	.771	.891	17.14	4	189.25	42.55
29	.771	.887	17.25	4	199.75	42.47
28	.771	.882	17.24	4	207.75	42.25
27	.771	.879	17.29	4	215.00	42.16
26	.771	.875	17.30	4	221.50	41.95
25	.771	.869	17.32	4	228.75	41.73
24	.771	.861	17.33	4	240.00	41.34
Mean	.771	.879	17.250	....	210.12	....
23	.604	.765	17.47	4	183.00	36.87
22	.604	.761	17.49	4	191.75	36.68
21	.604	.756	17.49	5	202.00	36.46
20	.604	.750	17.47	4	209.75	36.16
19	.604	.744	17.47	5	218.00	35.86
18	.604	.739	17.43	4	224.75	35.56
17	.604	.726	17.44	4	236.50	34.98
Mean	.604	.749	17.465	....	209.39	....
16	0.471	.643	17.47	4	176.00	30.98
15	.471	.639	17.44	4	186.00	30.77
14	.471	.635	17.47	4	195.00	30.61
13	.471	.630	17.45	4	202.75	30.36
12	.471	.625	17.47	4	211.50	30.12
11	.471	.618	17.48	4	220.25	29.80
10	.471	.611	17.52	4	229.50	29.48
9	.471	.601	17.53	4	240.25	29.03
Mean	.471	.625	17.478	....	207.65	....
8	.358	.519	17.58	4	169.25	23.11
7	.358	.518	17.54	4	179.00	25.01
6	.358	.513	17.54	4	191.25	24.80
5	.358	.507	17.51	4	200.75	24.49
4	.358	.504	17.48	4	209.00	24.28
3	.358	.497	17.42	4	219.50	23.93
2	.358	.491	17.45	4	230.50	23.67
1	.358	.487	17.46	4	238.25	23.47
Mean	.358	.504	17.497	....	204.69	....

Holyoke tests of McCormick turbines—Continued.

27-INCH RIGHT-HAND SMITH-McCORMICK WHEEL, CONICAL CYLINDER.

[Test No. 1497, December 14, 1903.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute	Discharge in second-feet.
1	2	3	4	5	6	7
7	1.000	1.011	17.79	3	168.00	60.32
6	1.000	1.008	17.78	4	178.50	60.13
5	1.000	1.007	17.78	4	186.50	60.07
4	1.000	1.005	17.78	4	194.75	60.00
3	1.000	1.003	17.80	4	203.25	59.87
2	1.000	1.000	17.78	5	213.00	59.66
1	1.000	.992	17.80	4	231.25	59.20
Mean	1.000	1.003	17.787	....	196.46	....
15	.754	.872	17.95	4	163.50	52.30
14	.754	.871	17.96	4	174.00	52.24
13	.754	.865	17.95	4	185.25	51.89
12	.754	.858	17.97	4	190.75	51.45
11	.754	.853	17.98	4	198.50	51.21
10	.754	.848	17.98	4	206.50	50.90
9	.754	.840	17.99	4	216.25	50.40
8	.754	.829	17.99	4	225.50	49.78
Mean	....	.854	17.971	....	195.03	....
22	.591	.740	18.08	4	160.50	44.51
21	.591	.741	18.08	4	173.75	44.58
20	.591	.737	18.10	4	184.00	44.39
19	.591	.730	18.11	4	191.25	43.95
18	.591	.723	18.12	4	199.25	43.58
17	.591	.712	18.16	4	210.00	42.91
16	.591	.700	18.16	4	223.00	42.19
Mean	.591	.726	18.116	....	191.67	....
28	.456	.609	18.22	4	164.00	36.80
27	.456	.610	18.23	4	175.00	36.86
26	.456	.608	18.23	4	183.50	36.74
25	.456	.602	18.25	4	190.25	36.40
24	.456	.596	18.26	4	200.00	36.06
23	.456	.589	18.28	4	211.75	35.65
Mean	....	.602	18.245	....	187.42	....
33	.334	.481	18.39	4	161.25	29.21
32	.334	.480	18.39	4	171.50	29.14
31	.334	.476	18.41	4	180.00	28.90
30	.334	.473	18.40	4	187.25	28.73
29	.334	.470	18.41	4	195.00	28.53
34	.334	.464	18.42	5	210.00	28.18
Mean	.334	.474	18.043	....	184.17	....

Holyoke tests of McCormick turbines—Continued.

30-INCH RIGHT-HAND SMITH-McCORMICK WHEEL.

[Test No. 846, May 10, 1895.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
15	1,000	1.007	16.73	4	146.00	75.06
15	1,000	1.006	16.73	4	156.00	72.99
14	1,000	1.002	16.71	4	168.50	72.71
13	1,000	.993	16.73	5	169.30	72.06
11	1,000	.974	16.74	4	176.50	76.71
10	1,000	.976	16.78	4	188.50	70.28
9	1,000	.959	16.81	4	193.95	69.79
8	1,000	.942	16.89	4	207.75	68.71
Mean	1,000	.981	16.76	....	177.58	....
24	.783	.896	17.11	4	143.30	64.32
23	.783	.881	17.08	4	154.50	64.59
22	.783	.874	17.18	4	161.75	64.32
21	.783	.868	17.19	5	167.00	63.89
20	.783	.863	17.14	4	174.00	63.37
19	.783	.855	17.08	4	185.25	62.71
18	.783	.847	17.03	4	186.25	62.05
17	.783	.830	17.06	3	188.67	60.84
Mean	.783	.864	17.10	....	170.08	....
30	.630	.757	17.34	4	155.50	65.96
29	.630	.757	17.37	4	153.00	56.02
28	.630	.755	17.37	4	168.75	55.32
27	.630	.751	17.33	4	173.86	55.43
26	.630	.744	17.34	4	178.75	54.95
25	.630	.736	17.41	4	187.00	54.24
Mean	.630	.750	17.36	....	169.64	....
38	.489	.622	17.54	4	144.25	46.25
37	.489	.624	17.53	4	151.25	46.37
36	.489	.624	17.53	3	158.67	46.37
35	.489	.623	17.53	4	166.00	46.32
34	.489	.620	17.55	4	171.25	46.12
33	.489	.615	17.54	4	177.50	45.74
32	.489	.608	17.56	4	185.25	45.24
31	.489	.589	17.58	4	198.50	44.56
Mean	.489	.616	17.55	....	169.08	....
7	.369	.495	17.60	4	132.75	36.94
6	.369	.498	17.62	3	142.33	37.12
5	.369	.498	17.61	3	149.33	37.12
4	.369	.498	17.57	3	159.00	37.07
3	.369	.492	17.63	4	172.00	36.72
2	.369	.488	17.60	3	179.33	36.33
1	.369	.481	17.59	4	190.50	35.81
Mean	.369	.493	17.602	....	160.748	....

Holyoke tests of McCormick turbines—Continued.

SPECIAL 33-INCH LEFT-HAND IMPROVED SMITH-McCORMICK WHEEL.

[Test No. 511, January 29–30, 1891.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
46	1.000	0.998	15.37	4	141.50	83.77
45	1.000	.992	15.42	4	149.75	83.33
44	1.000	.982	15.31	3	156.00	82.26
42	1.000	1.003	13.11	3	128.00	77.70
43	1.000	1.000	13.13	3	133.00	77.55
41	1.000	.994	13.17	4	137.75	77.19
40	1.000	1.014	11.27	4	112.75	72.83
39	1.000	1.010	11.30	3	116.75	72.69
38	1.000	1.007	11.32	4	121.00	72.48
37	1.000	1.003	11.36	5	126.00	72.34
36	1.000	.993	11.40	5	132.20	71.78
35	1.000	.982	11.45	3	140.00	71.13
Mean	1.000	.998	12.80	....	132.89	....
34	.783	.900	11.48	4	115.00	65.23
33	.783	.897	11.51	5	120.00	65.09
32	.783	.891	11.55	4	124.00	64.79
31	.783	.885	11.55	4	130.00	64.36
30	.783	.876	11.61	4	136.00	63.84
29	.783	.864	11.66	4	144.25	63.15
Mean	....	.885	11.56	....	128.21	....
27	.634	.784	11.59	4	115.00	57.10
26	.634	.776	11.64	4	121.00	56.69
25	.634	.769	11.67	4	127.75	56.20
24	.634	.756	11.73	4	135.00	55.38
28	.634	.742	11.79	4	142.00	54.34
Mean	.634	.632	13.25	....	135.25	....
22	.493	.646	13.21	4	120.50	50.24
21	.493	.641	13.21	4	127.50	50.03
20	.493	.635	13.23	4	132.50	49.46
19	.493	.629	13.25	3	138.00	48.97
18	.493	.623	13.28	4	143.00	48.60
17	.493	.616	13.33	3	150.00	48.16
Mean	.493	.632	13.252	....	135.26	....
16	.377	.526	12.55	4	105.25	39.88
15	.377	.524	12.54	3	112.00	39.70
14	.377	.519	12.54	4	118.00	39.36
13	.377	.517	12.55	4	122.00	39.19
12	.377	.510	12.57	4	128.00	38.68
11	.377	.506	12.60	4	133.75	38.40
10	.377	.499	12.63	4	139.75	37.94
9	.377	.491	12.68	4	148.25	37.43
8	.377	.484	12.72	3	155.33	36.92
Mean	.377	.508	12.598	....	129.15	....

Holyoke tests of McCormick turbines—Continued.

36-INCH LEFT-HAND McCORMICK HOLYOKE WHEEL.

[Test No. 534, June 13, 1891.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
6	1.000	1.026	16.83	4	119.75	103.93
5	1.000	1.019	16.81	4	125.00	103.30
4	1.000	1.015	16.83	4	131.00	102.94
3	1.000	1.008	16.83	4	137.00	102.25
2	1.000	1.003	16.74	4	142.25	101.42
7	1.000	.995	16.84	5	149.20	100.96
1	1.000	.986	16.81	3	155.67	99.91
Mean	1,000	1.007	16.81	....	137.15	....
14	.789	.919	16.99	4	118.25	93.61
13	.789	.917	16.99	4	125.50	93.40
12	.789	.912	17.00	4	132.50	92.93
11	.789	.907	17.01	4	139.25	92.49
10	.789	.900	17.05	4	145.75	91.80
9	.789	.892	17.07	4	152.50	91.13
8	.789	.885	17.06	4	158.50	90.34
Mean	.789	.894	17.024	....	138.89	....
20	.629	.799	17.28	4	118.50	82.10
19	.629	.797	17.30	4	128.00	81.89
18	.629	.793	17.29	4	134.75	81.46
17	.629	.787	17.30	4	140.75	80.90
16	.629	.781	17.32	4	146.50	80.37
15	.629	.773	17.31	4	152.50	79.49
Mean	.629	.788	17.300	....	135.17	....
27	.502	.681	17.58	4	115.75	70.59
26	.502	.681	17.60	3	124.00	70.59
25	.502	.677	17.59	4	131.75	70.19
24	.502	.675	17.61	4	138.75	69.97
23	.502	.672	17.60	4	141.50	69.67
22	.502	.664	17.61	3	147.00	68.84
21	.502	.656	17.65	5	153.60	68.12
Mean	.502	.672	17.605	....	135.76	....
34	.379	.554	17.82	4	110.75	57.78
33	.379	.553	17.81	5	118.80	57.68
32	.379	.551	17.80	4	126.75	57.48
31	.379	.550	17.83	4	134.75	57.39
30	.379	.545	17.81	4	141.50	57.83
29	.379	.539	17.81	3	148.33	56.26
28	.379	.533	17.82	3	156.67	55.58
Mean	.379	.546	17.814	....	133.94	....

Holyoke tests of McCormick turbines—Continued.

39-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 1191, May 29, 1899.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
8	1.000	1.009	15.79	1	126.00	117.83
7	1.000	1.006	15.79	4	131.75	117.46
6	1.000	1.001	15.82	4	138.00	116.98
5	1.000	.998	15.85	4	143.00	116.73
4	1.000	.990	15.87	4	150.00	115.89
3	1.000	.977	15.91	5	154.60	114.53
2	1.000	.961	15.96	4	160.25	112.80
1	1.000	.945	15.98	4	165.75	110.99
Mean	1.000	.986	15.871	....	148.17	....
43	.796	.903	15.95	4	118.25	105.98
42	.796	.899	15.97	4	123.75	105.51
41	.796	.893	15.97	4	128.25	105.02
40	.796	.888	15.99	4	133.00	104.44
39	.796	.882	15.99	5	136.60	103.62
38	.796	.874	16.03	4	140.50	102.78
37	.796	.864	16.08	4	145.00	101.72
36	.796	.853	16.06	4	149.00	100.45
35	.796	.843	16.11	4	153.25	99.41
Mean	.796	.876	16.018	....	136.51	....
34	.621	.760	16.26	4	123.75	89.97
33	.621	.754	16.29	4	127.25	89.41
32	.621	.748	16.29	5	130.80	88.73
31	.621	.742	16.30	4	134.00	87.94
30	.621	.734	16.34	4	138.25	87.18
29	.621	.728	16.35	4	142.25	86.51
28	.621	.716	16.37	4	147.75	85.09
27	.621	.703	16.40	4	156.25	83.65
Mean	.621	.736	16.575	....	137.54	....
26	.498	.645	16.55	3	115.00	77.10
25	.498	.640	16.55	4	120.25	76.47
24	.498	.636	16.55	5	123.60	75.95
23	.498	.630	16.56	4	127.75	75.31
22	.498	.625	16.59	4	131.75	74.77
21	.498	.619	16.60	4	136.25	74.12
20	.498	.611	16.69	4	143.00	73.30
19	.498	.600	16.71	4	150.25	72.03
18	.498	.588	16.78	4	157.75	70.71
Mean	.498	.621	16.620	....	133.95	....

Holyoke tests of McCormick turbines—Continued.

39-INCH LEFT-HAND SMITH-McCORMICK WHEEL—Continued.

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
17	0.390	0.527	16.72	4	116.75	63.25
16	.390	.522	16.73	4	121.50	62.66
15	.390	.516	16.75	4	125.50	62.06
14	.390	.512	16.78	4	129.50	61.66
13	.390	.509	16.77	4	133.00	61.28
12	.390	.506	16.76	4	135.50	60.86
11	.390	.502	16.75	4	139.75	60.38
10	.390	.495	16.77	4	145.00	59.60
9	.390	.489	16.77	5	150.60	58.81
Mean	.390	.509	16.757	....	133.01	....

42-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 1391, March 19, 1902.]

43	1.000	1.002	16.32	4	121.50	148.20
42	1.000	1.002	16.06	5	123.40	147.02
41	1.000	1.002	16.02	4	128.00	146.85
44	1.000	1.000	16.34	4	135.00	147.94
40	1.000	1.001	16.05	4	135.20	146.73
39	1.000	.986	16.19	4	141.00	145.14
38	1.000	.970	16.28	4	146.50	143.27
Mean	1.000	.995	16.180	....	132.94	....
37	.794	.886	16.56	4	110.25	131.89
36	.794	.882	16.59	5	116.80	131.50
35	.794	.876	16.64	4	120.50	130.73
34	.794	.865	16.68	4	125.00	129.34
33	.794	.856	16.71	4	128.75	128.07
32	.794	.845	16.79	5	133.80	126.68
31	.794	.832	16.85	4	138.50	125.02
30	.794	.819	16.93	4	144.00	123.28
Mean	.794	.858	16.718	....	127.20	....
28	.648	.770	16.96	4	103.00	116.11
27	.648	.775	16.94	4	111.00	116.70
29	.648	.771	16.94	5	114.20	116.21
26	.648	.770	16.96	4	118.00	116.11
25	.648	.762	16.97	4	121.50	114.90
24	.648	.754	17.01	4	125.00	113.80
23	.648	.743	17.03	4	129.50	112.22
22	.648	.737	17.04	4	133.75	111.33
21	.648	.725	17.11	4	139.75	109.77
20	.648	.716	17.12	4	145.00	108.46
Mean	.648	.752	17.000	....	124.07	....

Holyoke tests of McCormick turbines—Continued.

42-INCH LEFT-HAND SMITH-McCORMICK WHEEL—Continued.

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
19	0.497	0.642	17.34	2	102.00	97.81
18	.497	.645	17.30	4	108.50	98.15
17	.497	.643	17.29	4	114.25	97.91
16	.497	.639	17.30	4	118.00	97.21
15	.497	.634	17.25	4	121.00	96.31
14	.497	.628	17.25	4	124.50	95.52
13	.497	.625	17.10	5	127.00	94.61
12	.497	.619	17.13	4	132.00	93.80
11	.497	.616	17.19	4	137.00	93.46
10	.497	.608	17.29	4	142.75	92.55
9	.497	.600	17.38	4	149.50	91.56
Mean	.497	.627	17.257	....	125.14	....
8	.375	504	17.67	4	92.62	77.53
7	.375	.505	17.73	4	100.00	77.85
6	.375	.507	17.81	4	108.25	78.28
5	.375	.505	17.80	4	116.50	77.95
4	.375	.500	17.82	5	123.40	77.21
3	.375	.495	17.75	5	129.00	76.27
2	.375	.489	17.74	5	137.00	75.40
1	.375	.484	17.64	4	144.25	74.46
Mean	.375	.498	17.745	....	118.88	....

45-INCH RIGHT-HAND SPECIAL McCORMICK-HOLYOKE WHEEL.

[Test No. 850, June 10, 1895.]

10	1.000	1.031	16.37	4	100.50	112.94
9	1.000	1.025	16.41	4	104.87	112.45
8	1.000	1.019	16.46	4	109.50	111.96
7	1.000	1.013	16.50	5	114.00	111.35
6	1.000	1.007	16.23	4	116.00	109.78
5	1.000	1.000	16.23	4	120.37	109.05
4	1.000	.994	16.23	4	124.50	108.45
3	1.000	.987	16.28	4	129.50	107.85
2	1.000	.978	16.31	5	134.80	106.91
1	1.000	.966	16.37	4	141.50	105.84
Mean	1.000	1.002	16.339	....	119.55	....
18	.783	.913	16.63	4	96.00	100.80
17	.783	.906	16.64	4	101.50	100.09
16	.783	.899	16.67	4	106.75	99.40
15	.783	894	16.68	4	111.50	98.83
14	.783	.888	16.67	4	115.50	98.14
13	.783	.882	16.67	4	120.00	97.46
12	.783	.875	16.65	4	125.50	96.67
11	.783	.866	16.68	4	132.00	95.74
Mean	.783	.890	16.661	....	113.59	....

Holyoke tests of McCormick turbines—Continued.

45-INCH RIGHT-HAND SPECIAL McCORMICK-HOLYOKE WHEEL—Continued.

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency =**1**.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
25	0.612	0.777	17.16	4	97.25	87.17
24	.612	.771	17.17	4	103.00	86.51
23	.612	.765	17.18	4	108.75	85.85
22	.612	.758	17.17	4	113.75	85.08
21	.612	.751	17.14	4	118.75	84.21
20	.612	.746	16.97	4	122.75	83.22
19	.612	.735	17.00	4	129.50	82.02
Mean	.612	.757	17.112	....	113.39	....
33	.503	.676	17.29	4	95.00	76.15
32	.503	.672	17.30	4	101.25	75.62
31	.503	.665	17.31	4	107.00	74.88
30	.503	.658	17.34	4	113.50	74.13
29	.503	.651	17.36	4	118.50	73.40
28	.503	.643	17.38	4	123.75	72.56
27	.503	.633	17.39	5	130.00	71.41
26	.503	.620	17.41	4	137.75	69.99
Mean	.503	.652	17.347	....	115.84	....
41	.373	.548	17.56	4	93.00	62.15
40	.373	.545	17.54	4	98.25	61.76
39	.373	.540	17.59	4	104.50	61.35
38	.373	.535	17.59	4	109.75	60.75
37	.373	.531	17.53	4	115.25	60.18
36	.373	.526	17.54	4	120.00	59.69
35	.373	.520	17.55	4	125.00	59.00
34	.373	.511	17.57	3	131.00	58.03
Mean	.373	.532	17.558	....	112.09	....

48-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 578, April 5, 1892.]

54	1.000	1.017	12.99	5	78.70	157.07
53	1.000	1.008	13.03	4	83.50	155.97
52	1.000	1.000	13.06	4	89.00	154.87
51	1.000	.991	13.13	5	93.70	153.80
50	1.000	.983	12.96	4	95.75	151.65
49	1.000	.973	13.01	5	100.00	150.35
48	1.000	.960	13.09	4	104.00	148.80
47	1.000	.948	13.16	4	108.37	147.35
46	1.000	.935	13.22	4	111.75	145.63
Mean	1.000	.979	13.072	....	96.08	....

Holyoke tests of McCormick turbines—Continued.

48-INCH LEFT-HAND SMITH-McCORMICK WHEEL—Continued.

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
38	0.780	0.895	13.10	4	75.62	138.80
37	.780	.887	13.10	4	80.12	137.55
36	.780	.882	13.09	4	84.62	136.75
35	.780	.875	13.05	5	88.00	135.45
34	.780	.868	13.08	4	91.75	134.55
33	.780	.860	13.16	4	96.50	133.65
32	.780	.849	13.23	4	100.50	132.35
31	.780	.839	13.31	4	105.00	131.16
30	.780	.831	13.10	4	107.25	128.90
29	.780	.820	13.20	3	111.00	127.65
Mean	.780	.860	13.142	....	94.03	....
28	.621	.764	13.90	4	78.25	122.05
27	.621	.758	13.93	4	82.75	121.17
26	.621	.751	13.97	4	87.37	120.31
25	.621	.743	14.00	4	91.75	119.17
24	.621	.737	14.00	4	95.50	118.16
23	.621	.727	14.03	4	99.50	116.70
22	.621	.717	14.08	4	103.50	115.35
21	.621	.707	14.10	4	107.37	113.75
20	.621	.696	14.17	5	110.90	112.28
19	.621	.688	14.19	4	114.25	111.08
Mean	.621	.728	14.039	....	97.11	....
18	.499	.638	14.09	4	82.00	102.55
17	.499	.633	14.10	4	85.50	101.85
16	.499	.626	14.11	4	89.50	100.80
15	.499	.620	14.13	4	93.50	99.85
14	.499	.613	14.15	4	97.62	98.73
13	.499	.605	14.19	4	101.87	97.67
12	.499	.595	14.27	4	106.75	96.28
11	.499	.584	14.35	4	111.37	94.85
10	.499	.575	14.40	5	116.10	93.58
Mean	.499	.609	14.198	....	98.24	....
9	.371	.504	13.68	4	76.00	79.89
8	.371	.498	13.70	4	81.00	79.03
7	.371	.494	13.74	4	85.37	78.40
6	.371	.488	13.78	4	89.87	77.65
5	.371	.484	13.83	4	93.50	77.05
4	.371	.477	13.88	4	99.00	76.08
3	.371	.469	13.93	4	104.62	74.95
2	.371	.461	13.98	4	110.12	73.79
1	.371	.453	14.03	4	115.50	72.75
Mean	.371	.480	13.838	....	94.99	....

Holyoke tests of McCormick turbines—Continued.

51-INCH LEFT-HAND McCORMICK WHEEL.

[Test No. 489, June 28, 1890.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
35	1.000	1.026	11.49	3	68.67	169.60
34	1.000	1.021	11.52	3	72.50	169.05
33	1.000	1.016	11.53	4	76.50	168.35
32	1.000	1.009	11.58	6	80.50	167.50
31	1.000	1.001	11.62	3	84.50	166.50
30	1.000	.989	11.68	4	88.62	164.95
29	1.000	.979	11.74	3	92.17	163.60
Mean	1.000	1.005	10.165	....	80.49	....
8	.818	.915	12.88	3	74.00	160.18
7	.818	.910	12.91	2	78.25	159.50
6	.818	.902	12.96	3	83.17	158.40
5	.818	.895	12.99	4	87.62	157.32
4	.818	.887	13.02	4	92.00	156.10
3	.818	.880	12.84	4	94.00	155.89
2	.818	.870	12.91	3	98.67	152.45
1	.818	.850	13.09	5	105.10	150.05
Mean	.818	.888	12.950	....	89.10	....
28	.685	.808	13.09	4	71.62	142.70
27	.685	.803	13.11	4	77.75	141.78
26	.685	.797	13.09	4	83.00	140.72
25	.685	.790	13.10	4	87.25	139.42
24	.685	.782	13.10	4	92.00	138.01
23	.685	.768	13.18	4	97.25	136.10
22	.685	.753	13.29	3	102.00	133.90
Mean	.685	.785	13.137	....	87.26	....
21	.554	.693	13.25	3	71.00	123.10
20	.554	.688	13.26	4	76.75	122.30
19	.554	.684	13.14	5	82.00	120.92
18	.554	.677	13.17	4	88.00	119.80
17	.554	.666	13.25	4	93.00	118.28
16	.554	.656	13.31	4	97.75	116.69
15	.554	.641	13.44	4	105.50	114.60
Mean	.554	.672	13.260	....	87.71	....
14	.414	.549	13.92	4	71.62	99.90
13	.414	.546	13.91	4	78.75	99.30
12	.414	.542	13.93	4	84.25	98.72
11	.414	.537	13.91	4	89.50	97.70
10	.414	.529	13.95	4	95.50	96.45
9	.414	.521	13.99	4	101.25	95.05
Mean	.414	.537	13.935	....	86.81	....

Holyoke tests of McCormick turbines—Continued.

54-INCH RIGHT-HAND SMITH-McCORMICK WHEEL, PLAIN CYLINDER GATE.[a]

[Test No. 1310, December 10–11, 1900.]

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
26	1.000	1.015	14.00	4	80.87	227.98
25	1.000	1.007	14.27	4	87.75	228.28
24	1.000	1.003	14.51	4	94.50	229.34
23	1.000	.997	14.54	4	98.25	228.28
22	1.000	.994	14.46	4	101.25	226.91
21	1.000	.981	14.54	4	109.87	224.60
Mean	1.000	.999	14.586	....	95.41	....
35	.783	.939	14.66	4	92.25	215.80
34	.783	.936	14.74	4	97.75	215.64
33	.783	.930	14.90	4	102.62	215.48
36	.783	.927	14.58	4	104.87	212.43
Mean	.783	.933	14.720	....	99.37	....
31	.643	.872	15.19	3	86.50	204.04
30	.643	.869	15.21	4	91.37	203.44
29	.643	.865	15.36	4	96.87	203.44
32	.643	.862	15.25	4	98.50	202.10
28	.643	.858	15.42	4	103.50	202.36
27	.643	.850	15.53	3	109.67	201.03
Mean	.643	.862	15.326	....	97.73	....
13	.490	.759	14.09	4	80.50	171.00
12	.490	.755	14.54	4	89.37	172.85
11	.490	.750	14.90	6	96.00	173.84
10	.490	.739	15.22	4	101.25	173 11
9	.490	.729	15.32	4	105.75	171.40
Mean	.490	.746	14.814	....	94.57	....
16	.366	.646	16.12	4	83.75	155.59
5	.366	.642	16.22	3	91.00	155.20
4	.366	.638	16.21	3	96.50	154.10
3	.366	.630	16.22	3	100.12	152.20
2	.366	.621	16.26	4	105.37	150.21
1	.366	.600	16.35	4	116.50	145.80
Mean	.366	.629	16.062	....	97.20	....
19	.250	.517	16.33	4	74.25	125.40
18	.250	.516	16.37	5	79.40	125.40
17	.250	.515	16.29	4	84.50	124.67
20	.250	.512	16.30	4	87.75	124.15
16	.250	.510	16.33	4	91.00	123.79
15	.250	.505	16.02	4	93.50	121.40
14	.250	.502	15.80	4	97.00	119.79
Mean	.250	.500	16.205	....	86.77	....

[a] Tested on conical draft tube manufactured by S. Morgan Smith Company.

Holyoke tests of McCormick turbines—Continued.

57-INCH McCORMICK-HOLYOKE WHEEL.

[Test No. 696, August 7, 1893.

Number of experiment.	Gate opening (proportional part).	Proportional discharges. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.
1	2	3	4	5	6	7
31	1.000	1.020	9.32	5	60.20	200.67
30	1.000	1.015	9.27	4	62.87	199.18
29	1.000	1.006	9.25	4	65.37	197.23
28	1.000	.999	9.20	5	68.00	195.28
27	1.000	.992	9.16	4	70.50	193.48
26	1.000	.987	9.05	4	72.50	191.28
Mean	1.000	1.003	9.208	....	66.57	....
25	.780	.903	9.89	4	62.62	182.98
24	.780	.894	9.98	4	66.75	182.03
23	.780	.885	10.04	4	70.50	180.73
22	.780	.876	10.05	4	73.62	179.45
21	.780	.876	10.04	4	75.25	178.86
20	.780	.866	10.14	4	78.25	177.72
Mean	.780	.883	10.023	....	71.16	....
19	.629	.789	10.83	4	63.25	167.31
18	.629	.784	10.86	4	67.50	166.48
17	.629	.779	10.90	4	71.12	165.67
16	.629	.768	10.98	4	75.62	164.04
15	.629	.757	11.07	4	79.25	162.29
14	.629	.744	11.16	3	82.67	160.09
Mean	.629	.770	10.966	....	73.23	....
13	.493	.669	11.13	4	61.62	143.74
12	.493	.662	11.20	5	65.90	142.82
11	.493	.657	11.22	4	70.37	141.92
10	.493	.649	11.30	4	74.12	140.59
9	.493	.641	11.34	4	77.62	139.03
8	.493	.630	11.42	5	82.00	137.12
Mean	.493	.651	11.268	....	71.80	....
7	.376	.537	11.42	4	61.37	117.01
6	.376	.534	11.45	4	66.25	116.39
5	.376	.527	11.52	4	70.87	115.18
4	.376	.519	11.61	4	75.50	113.93
3	.376	.512	11.67	4	79.87	112.72
2	.376	.503	11.73	4	84.87	111.01
1	.376	.497	11.79	4	88.75	109.94
Mean	.376	.518	11.598	....	75.38	....

HOLYOKE TESTS OF HERCULES TURBINES.

The Hercules turbine has been developed by elaborate experiments from the original design of John B. McCormick. The runners are very carefully finished, and the guide and bucket openings are made to conform with standard gauges, resulting in great uniformity of the output.

Tests of five sizes of Hercules turbines from recent patterns have been furnished by the Worcester (Mass.) shops of the Holyoke Machine Company. The mean head, speed, discharge, power, and efficiency for each group of experiments made with a given size of wheel and proportional gate opening have been computed and are given in the tables.

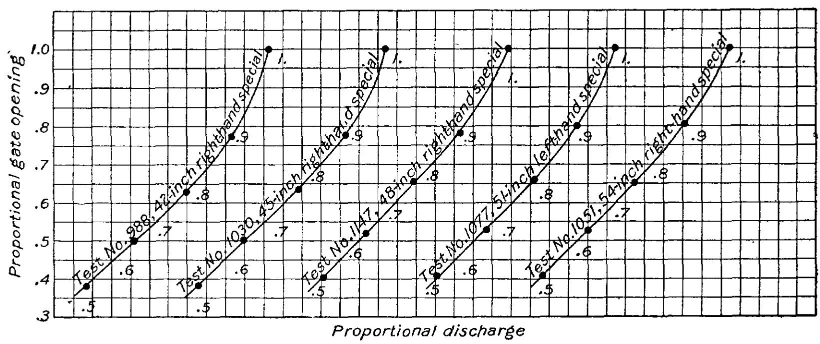


FIG. 24.—Proportional discharge coefficients for Hercules special turbines.

Holyoke tests of Hercules turbines.[a]

42-INCH RIGHT-HAND SPECIAL WHEEL.

[Test No. 988, February 18-19, 1897.]

Number of experiment.	Gate opening (proportional part).	Proportional discharge (discharge at full gate with highest efficiency=1).	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
8	1.000	1.011	15.73	4	113.25	141.39	201.37	79.84
7	1.000	1.006	15.73	4	116.75	140.77	201.85	80.38
6	1.000	1.002	15.73	4	119.75	140.25	201.14	80.39
5	1.000	.998	15.76	5	122.40	139.72	199.57	79.92
4	1.000	.993	15.80	4	125.87	139.20	199.03	79.80
3	1.000	.983	15.83	4	130.87	138.01	197.28	79.62
2	1.000	.975	15.82	4	136.00	136.85	192.46	78.39
1	1.000	.962	15.78	4	142.25	134.78	183.80	76.20
43	1.000	.714	16.54	4	200.50	102.50	....	....
Mean	....	.960	15.857	....	134.182	134.83	197.062	79.317
17	.778	.894	16.18	4	104.37	126.89	186.23	79.98
16	.778	.887	16.20	4	108.75	125.98	187.31	80.94
15	.778	.881	16.25	4	113.00	125.23	187.72	81.34
14	.778	.875	16.30	4	117.50	124.61	187.96	81.60
13	.778	.867	16.35	4	121.37	123.72	186.69	81.38
12	.778	.860	16.28	4	124.75	122.45	183.45	81.14
11	.778	.854	16.30	4	128.62	121.60	180.43	80.27
10	.778	.846	16.34	4	132.62	120.60	177.07	79.23
9	.778	.836	16.34	4	139.25	119.23	171.35	77.56
Mean	....	.866	16.282	....	121.136	123.36	183.13	80.38

[a] Made by Holyoke Machine Company, Holyoke, Mass.

Holyoke tests of Hercules turbines—Continued.

42-INCH RIGHT-HAND SPECIAL WHEEL—Continued.

Number of experiment.	Gate opening (proportion part).	Proportional discharge (discharge at full gate with highest efficiency=1).	Mean head, in feet.	Duration of test, in minutes.	Revolutions per minute.	Discharge, in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
25	0.633	0.765	16.48	4	102.50	109.61	158.29	77.27
24	.633	.760	16.51	5	108.00	109.01	161.47	79.11
23	.633	.756	16.54	4	112.00	108.40	161.94	79.64
22	.633	.750	16.56	4	116.00	107.69	162.01	80.11
21	.633	.747	16.52	4	118.50	107.08	159.67	79.59
20	.633	.742	16.53	4	122.00	106.38	158.38	79.42
19	.633	.733	16.57	4	127.00	105.33	156.28	78.95
18	.633	.723	16.58	4	133.50	103.91	151.96	77.77
Mean		.747	16.536		117.437	107.176	158.75	78.98
34	.501	.627	16.86	5	103.00	90.81	127.38	73.36
33	.501	.625	16.80	4	105.62	90.36	127.37	73.98
32	.501	.620	16.83	4	110.50	89.80	128.50	74.97
31	.501	.616	16.87	4	114.50	89.23	128.22	75.10
30	.501	.610	16.84	4	118.25	88.34	126.60	75.04
29	.501	.605	16.79	4	121.50	87.44	124.09	74.53
28	.501	.599	16.82	4	124.87	86.65	121.39	73.44
27	.501	.591	16.82	4	129.37	85.57	117.80	72.17
26	.501	.583	16.89	4	135.50	84.47	112.55	69.56
Mean		.6084	16.835		118.12	88.074	123.76	73.57
42	.382	.502	17.05	4	98.75	73.12	95.39	67.47
41	.382	.500	17.08	4	104.00	72.91	96.62	68.42
40	.382	.496	17.09	4	108.25	72.27	96.58	68.95
39	.382	.491	17.09	4	111.50	71.65	95.36	68.67
38	.382	.487	17.12	4	114.87	71.03	94.00	68.16
37	.382	.482	17.13	4	119.75	70.43	92.10	67.31
36	.382	.475	17.18	4	126.25	69.39	87.78	64.92
35	.382	.467	17.20	4	133.12	68.26	81.91	61.51
Mean		.4875	17.12		114.56	71.13	92.217	66.926

45-INCH RIGHT-HAND SPECIAL WHEEL

[Test No. 1030, July 19, 1897.]

10	1.000	1.024	15.81	5	96.20	163.23	236.04	80.79
9	1.000	1.016	15.79	4	99.75	161.85	235.94	81.55
8	1.000	1.012	15.78	4	103.67	161.15	236.05	82.00
7	1.000	1.007	15.78	5	108.00	160.35	236.36	82.51
6	1.000	1.001	15.75	5	111.20	159.25	234.30	82.52
5	1.000	.997	15.74	4	115.00	158.54	232.92	82.45
4	1.000	.990	15.78	5	119.60	157.60	231.67	82.29
3	1.000	.982	15.84	5	124.60	156.67	228.66	81.39
2	1.000	.969	15.84	4	130.25	154.48	221.32	79.89
1	1.000	.952	15.98	4	135.25	152.45	211.43	76.66
44	1.000	.712	16.80	5	188.60	116.90		
Mean		.969	15.899		121.10	154.77	230.469	81.205

Holyoke tests of Hercules turbines—Continued.

45-INCH RIGHT-HAND SPECIAL WHEEL—Continued.

Number of experiment.	Gate opening (proportion part).	Proportional discharge (discharge at full gate with highest efficiency=1).	Mean head, in feet.	Duration of test, in minutes.	Revolutions per minute.	Discharge, in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
18	0.779	0.894	16.24	4	97.25	144.31	216.80	81.72
17	.779	.887	16.26	4	101.25	143.35	218.15	82.67
16	.779	.880	16.30	4	105.62	142.43	218.23	83.03
15	.779	.873	16.34	4	110.50	141.41	218.55	83.55
14	.779	.866	16.36	5	114.00	140.38	215.40	82.85
13	.779	.856	16.39	4	117.62	138.81	211.85	82.25
12	.779	.846	16.38	5	122.00	137.25	207.30	81.45
11	.779	.834	16.40	4	128.25	135.42	200.49	79.74
Mean		.867	16.33		112.06	140.42	213.34	82.157
26	.636	.770	16.63	4	96.62	125.86	187.82	79.26
25	.636	.766	16.66	4	100.75	125.23	189.00	80.02
24	.636	.760	16.68	5	105.00	124.36	189.12	80.54
23	.636	.752	16.71	4	109.25	123.21	188.61	80.92
22	.636	.745	16.74	4	112.75	122.21	186.22	80.41
21	.636	.738	16.75	5	117.40	120.98	183.53	80.00
20	.636	.728	16.72	4	122.25	119.23	178.64	79.16
19	.636	.716	16.72	5	127.00	117.39	172.64	77.70
Mean		.7468	16.701		111.37	122.308	184.435	79.75
34	.502	.632	16.89	4	95.87	104.14	149.22	74.94
33	.502	.627	16.92	5	100.60	103.31	150.43	76.02
32	.502	.620	16.97	4	105.12	102.36	150.75	76.66
31	.502	.616	16.98	4	108.75	101.66	149.31	76.40
30	.502	.611	17.01	4	112.00	100.97	147.68	75.95
29	.502	.601	17.07	4	116.50	99.59	144.11	74.88
28	.502	.591	17.14	5	122.60	98.07	139.16	73.13
27	.502	.583	17.15	4	126.75	96.70	133.53	71.12
43	.502	.484	17.49	4	179.00	81.20		
Mean		.596	17.067		118.576	98.66	145.52	74.88
42	.386	.500	17.34	4	96.75	83.47	113.10	69.03
41	.386	.494	17.37	4	101.25	82.49	112.86	69.58
40	.386	.489	17.38	4	105.75	81.72	111.41	69.29
39	.386	.484	17.37	4	109.12	80.88	109.02	68.55
38	.386	.478	17.40	4	114.25	79.91	106.38	67.59
37	.386	.472	17.39	4	118.25	78.83	102.07	65.77
36	.386	.465	17.39	5	123.20	77.65	96.30	62.99
35	.386	.456	17.40	5	129.80	76.15	88.22	58.81
Mean		.4797	17.38		112.296	80.137	104.92	66.45

Holyoke tests of Hercules turbines—Continued.

48-INCH RIGHT-HAND SPECIAL WHEEL.

[Test No. 1147, October 10–11, 1898.]

Number of experiment.	Gate opening (proportional part).	Proportional discharge (discharge at full gate with highest efficiency=1).	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
9	1.000	1.026	15.47	4	89.50	182.27	255.49	79.95
8	1.000	1.018	15.46	4	93.25	180.83	256.69	81.02
7	1.000	1.011	15.52	4	97.00	179.85	257.12	81.28
6	1.000	1.005	15.51	4	100.50	178.69	256.15	81.55
5	1.000	.998	15.53	4	104.25	177.57	255.08	81.62
4	1.000	.986	15.62	4	109.62	175.98	253.32	81.32
3	1.000	.978	15.56	4	113.75	174.16	247.40	80.56
2	1.000	.969	15.57	5	119.00	172.76	242.64	79.60
1	1.000	.957	15.68	4	124.25	171.05	236.46	77.79
Mean		.994	15.55		105.68	177.02	251.15	80.52
17	.784	.888	16.12	5	90.80	161.09	235.13	79.90
16	.784	.885	16.08	4	95.50	160.27	238.86	81.78
15	.784	.878	16.24	4	101.00	159.87	242.32	82.36
14	.784	.872	16.30	4	104.50	158.90	241.49	82.27
13	.784	.863	16.38	5	108.30	157.79	239.23	81.67
12	.784	.853	16.40	4	112.75	156.05	233.73	80.59
11	.784	.841	16.34	4	117.37	153.57	227.35	79.95
10	.784	.832	16.31	4	124.50	151.83	220.01	78.25
Mean		.864	16.275		106.84	157.42	234.76	80.85
24	.651	.768	16.32	4	93.87	140.07	204.16	78.81
23	.651	.763	16.35	4	100.00	139.27	207.30	80.33
22	.651	.756	16.35	4	104.62	137.97	206.21	80.66
21	.651	.747	16.37	4	109.25	136.54	204.20	80.81
20	.651	.740	16.41	4	113.00	135.37	199.69	79.32
19	.651	.730	16.42	4	116.62	133.57	194.20	78.13
18	.651	.717	16.45	4	121.50	131.27	185.81	75.93
Mean		.746	16.38		108.41	136.29	200.22	79.11
31	.521	.635	16.74	4	89.75	117.34	161.65	72.62
30	.521	.632	16.77	4	97.25	116.97	167.23	75.23
29	.521	.626	16.82	4	102.25	115.97	167.49	75.76
28	.521	.618	16.84	4	106.25	114.53	164.65	75.33
27	.521	.610	16.85	4	110.25	113.07	161.11	74.62
26	.521	.602	16.86	4	114.25	111.59	155.31	72.84
25	.521	.595	16.87	4	118.20	110.28	148.62	70.49
Mean		.617	16.82		105.45	114.25	160.86	73.84
39	.402	.520	17.07	4	90.00	96.98	128.46	68.47
38	.402	.516	17.08	4	95.75	96.31	130.16	69.82
37	.402	.511	17.07	4	100.00	95.29	129.14	70.05
36	.402	.505	17.10	4	103.62	94.38	126.77	69.31
35	.402	.502	17.11	4	106.62	93.70	123.19	67.80
34	.402	.496	17.14	4	110.62	92.66	120.30	66.84
33	.402	.489	17.15	4	115.62	91.42	113.95	64.13
32	.402	.482	17.18	4	120.50	90.17	106.47	60.65
Mean		.503	17.11		105.34	93.86	122.305	67.13

Holyoke tests of Hercules turbines—Continued.

51-INCH LEFT-HAND SPECIAL WHEEL.

[Test No. 1077, February 25, 1898.]

Number of experiment.	Gate opening (proportional part).	Proportional discharge (discharge at full gate with highest efficiency=1).	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
46	1.000	1.022	13.86	4	Still.	204.26		
45	1.000	1.016	13.96	4	83.00	203.83	267.40	82.86
44	1.000	1.011	13.94	4	85.50	202.64	267.32	83.44
43	1.000	1.004	14.00	4	88.50	201.58	268.27	83.82
42	1.000	1.000	14.01	4	91.25	200.98	267.93	83.90
41	1.000	.992	14.05	5	93.80	199.65	266.49	83.77
40	1.000	.987	14.04	5	95.60	198.45	262.51	83.08
39	1.000	.978	14.11	4	99.00	197.26	261.75	82.92
38	1.000	.975	14.14	6	102.08	196.83	259.49	82.21
37	1.000	.967	14.20	4	106.12	195.65	257.49	81.72
36	1.000	.959	14.28	5	109.30	194.46	252.58	80.20
35	1.000	.949	14.35	3	113.33	192.85	246.49	78.54
47	1.000	.731	15.62	4	164.50	155.15		
Mean		9.685	14.196		102.665	195.66	261.61	82.405
34	.800	.902	14.50	4	83.37	184.33	250.46	82.63
33	.800	.894	14.54	4	87.37	183.04	252.38	83.62
32	.800	.886	14.61	4	90.62	181.74	251.30	83.45
31	.800	.878	14.64	4	93.87	180.30	249.46	83.33
30	.800	.871	14.65	4	96.87	178.90	246.24	82.84
29	.800	.864	14.63	4	99.87	177.45	242.33	82.31
28	.800	.857	14.64	4	103.25	176.01	238.60	81.65
27	.800	.851	14.68	4	107.50	174.90	233.81	80.30
26	.800	.841	14.75	3	111.33	173.35	227.00	78.28
Mean		.872	14.626		97.116	178.89	243.508	82.40
25	.660	.789	14.97	4	83.00	163.76	221.14	79.54
24	.660	.781	15.02	4	87.25	162.37	223.57	80.83
23	.660	.775	15.05	5	90.70	161.27	223.16	81.07
22	.660	.767	15.12	4	94.50	160.17	222.87	81.15
21	.660	.761	15.16	5	98.10	159.08	221.36	80.94
20	.660	.754	15.17	5	101.40	157.72	218.47	80.52
19	.660	.748	15.19	4	105.00	156.48	215.52	79.95
18	.660	.741	15.22	4	109.12	155.26	211.37	78.87
17	.660	.732	15.26	4	112.75	153.50	203.08	76.44
Mean		.761	15.128		97.98	158.84	217.837	79.92
16	.530	.658	15.61	4	79.75	139.58	183.21	74.15
15	.530	.654	15.64	4	84.50	138.80	186.08	75.58
14	.530	.648	15.67	5	88.90	137.63	187.31	76.58
13	.530	.644	15.69	5	92.80	136.85	186.70	76.67
12	.530	.637	15.72	5	96.80	135.55	184.88	76.50
11	.530	.629	15.75	4	101.00	134.01	181.23	75.71
10	.530	.622	15.79	4	105.50	132.59	177.11	74.59
9	.530	.614	15.84	4	109.00	131.18	170.39	72.31
Mean		.638	15.713		94.53	135.77	182.113	75.26

Holyoke tests of Hercules turbines—Continued.

51-INCH LEFT-HAND SPECIAL WHEEL—Continued.

Number of experiment.	Gate opening (proportional part).	Proportional discharge (discharge at full gate with highest efficiency=1).	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
8	0.410	0.525	16.22	5	79.20	113.53	142.65	68.31
7	.410	.521	16.24	4	83.50	112.66	143.58	69.20
6	.410	.516	16.24	4	87.50	111.66	143.33	69.69
5	.410	.510	16.29	4	92.50	110.45	142.71	69.94
4	.410	.502	16.36	4	97.75	109.00	139.52	68.99
3	.410	.494	16.38	5	103.60	107.33	133.79	67.10
2	.410	.486	16.41	4	109.00	105.68	125.94	64.04
1	.410	.478	16.46	4	114.75	104.03	116.99	60.24
Mean		.504	16.325		95.975	109.29	136.063	67.188
48	.091	.148	17.68	4	102.75	33.36		

54-INCH RIGHT-HAND SPECIAL WHEEL.

[Test No. 1051, November 12, 1897.]

42	1.000	1.004	13.98	5	80.40	230.06	305.38	83.72
41	1.000	.997	14.07	4	84.12	228.98	306.94	84.00
40	1.000	.989	14.13	4	87.00	227.80	305.62	83.71
39	1.000	.981	14.22	4	90.50	226.71	305.62	83.58
38	1.000	.974	14.26	4	94.00	225.30	303.39	83.26
37	1.000	.964	14.29	4	98.00	223.16	299.65	82.83
36	1.000	.956	14.34	4	101.50	221.65	293.11	81.31
35	1.000	.944	14.38	4	104.87	219.38	285.03	79.66
Mean		.976	14.21		92.548	225.38	300.59	82.76
34	.800	.881	14.69	4	80.00	206.93	287.01	83.25
33	.800	.875	14.73	5	83.20	205.72	287.19	83.56
32	.800	.868	14.80	5	86.60	204.66	287.16	83.59
31	.800	.859	14.87	4	90.25	202.98	286.38	83.65
30	.800	.852	14.94	4	93.75	201.77	284.75	83.28
29	.800	.844	15.01	4	97.12	200.41	281.78	82.59
28	.800	.836	15.07	4	101.00	198.92	277.94	81.75
27	.800	.829	15.09	4	104.87	197.26	270.78	80.20
26	.800	.820	15.15	5	108.40	195.46	261.48	77.85
Mean		.852	14.82		93.91	201.567	280.496	82.19
25	.650	.749	15.38	5	77.00	179.88	246.95	78.70
24	.650	.745	15.40	5	81.00	179.02	250.42	80.09
23	.650	.739	15.45	5	84.60	177.87	251.78	80.78
22	.650	.734	15.48	5	88.60	176.85	252.85	81.43
21	.650	.728	15.49	5	92.80	175.59	252.22	81.76
20	.650	.722	15.47	5	95.80	173.91	248.01	81.28
19	.650	.714	15.50	4	99.25	172.09	242.10	80.02
18	.650	.705	15.53	5	102.40	170.10	234.48	78.26
17	.650	.696	15.57	4	105.75	168.14	226.34	76.23
Mean		.726	15.47		91.91	174.83	245.02	79.84

Holyoke tests of Hercules turbines—Continued.

54-INCH RIGHT-HAND SPECIAL WHEEL—Continued.

Number of experiment.	Gate opening (proportional part).	Proportional discharge (discharge at full gate with highest efficiency=1).	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
16	0.527	0.622	15.97	4	74.50	152.27	202.49	73.42
15	.527	.618	16.01	4	78.87	151.47	205.79	74.82
14	.527	.612	16.03	4	83.12	150.12	207.28	75.94
13	.527	.606	16.09	4	87.25	148.80	207.50	76.41
12	.527	.597	16.12	4	91.62	146.94	205.44	76.47
11	.527	.591	16.15	4	95.37	145.60	200.89	75.32
10	.527	.584	16.22	4	99.25	143.98	195.57	73.84
9	.527	.578	16.23	4	103.00	142.55	188.96	72.01
Mean		.601	16.10		89.12	147.72	201.74	74.77
8	.410	.499	16.58	4	77.00	124.59	163.24	69.67
7	.410	.494	16.63	4	81.62	123.44	163.61	70.27
6	.410	.489	16.64	4	85.50	122.20	162.67	70.53
5	.410	.483	16.68	4	90.50	120.82	159.88	69.95
4	.410	.478	16.66	4	94.75	119.58	154.51	68.38
3	.410	.472	16.68	5	99.10	118.20	148.14	66.25
2	.410	.467	16.73	4	103.75	117.00	140.99	63.51
1	.410	.460	16.79	5	109.30	115.53	129.97	59.07
Mean		.480	16.67		92.69	120.17	152.88	67.20

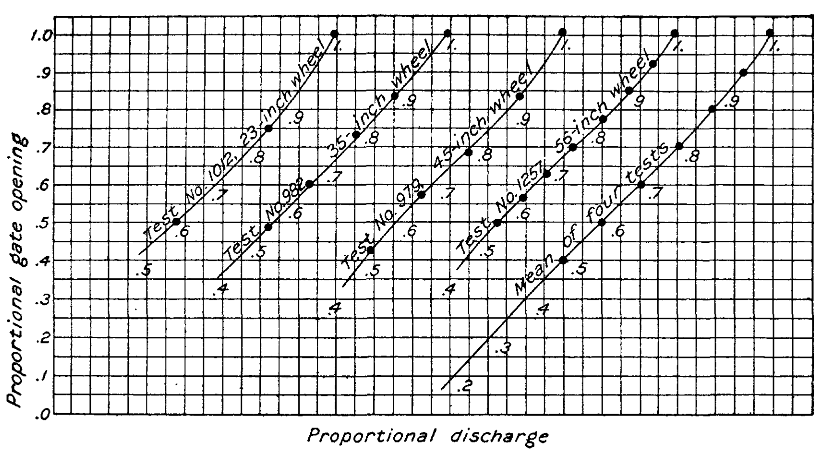


FIG. 25.—Proportional discharge coefficients for Leffel-Samson turbines.

HOLYOKE TESTS OF SAMSON TURBINES.

The Samson turbine is constructed by James Leffel & Co., Springfield, Ohio. It has been developed along lines similar to the earlier Leffel wheels, but with greatly increased depth and capacity. The runner resembles that of the McCormick turbines, except that a division plate provides for a narrow ring of inward discharge buckets near the top. It is operated with pivoted gates, differing in this respect from the Victor, Hercules, McCormick, and most other large-capacity turbines, which are provided with cylinder gates.

Complete Holyoke tests of three sizes of Samson wheels have been furnished by the builders. The means of the factors for each group of experiments in the tests are given in the tables, together with the original data of the tests.

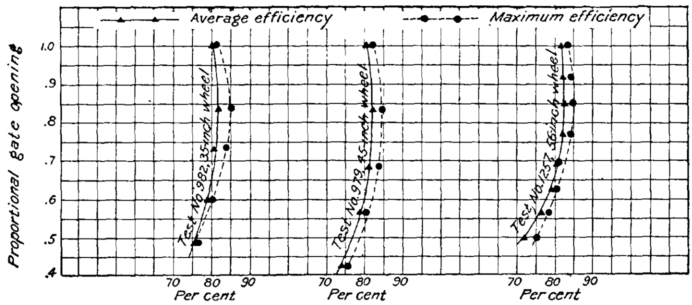


FIG. 26.—Efficiency curves for Leffel-Samson turbines.

Holyoke tests of Samson turbines.

35-INCH RIGHT-HAND WHEEL.

[Test No. 982, February 1, 1897.]

Number of tests.	Gate opening (proportional part).	Proportional discharge. (Discharge of full gate at highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
7	1.000	0.989	15.23	4	171.00	100.85	138.90	79.74
3	1.000	.994	15.20	5	179.60	101.31	140.36	80.37
4	1.000	.996	15.18	4	186.50	101.43	141.16	80.84
2	1.000	.998	15.29	4	194.25	102.02	143.44	81.08
5	1.000	1.002	15.25	4	201.75	102.25	142.77	80.74
1	1.000	.999	15.34	4	209.00	102.25	141.47	79.53
6	1.000	.997	15.29	3	214.67	101.90	138.71	78.50
Mean	....	.996	15.25	....	193.82	101.72	140.97	80.11
16	.834	.865	16.62	4	171.25	92.15	144.37	83.12
15	.834	.869	16.59	4	181.25	92.49	147.23	84.60
14	.834	.866	16.56	4	187.75	92.15	146.73	84.78
13	.834	.864	16.48	4	195.00	91.69	144.00	84.03
12	.834	.858	16.24	3	197.33	90.36	137.22	82.45
11	.834	.855	15.79	4	196.50	88.79	129.38	81.37
10	.834	.845	15.74	4	200.50	87.65	124.61	79.65
9	.834	.838	15.69	4	203.75	86.77	120.37	77.96
8	.834	.826	15.63	4	206.25	85.36	116.77	77.17
Mean	....	.854	16.15	....	193.28	89.72	134.52	81.68

Holyoke tests of Samson turbines—Continued.

35-INCH RIGHT-HAND WHEEL—Continued.

Number of tests.	Gate opening (proportional part).	Proportional discharge. (Discharge of full gate at highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency
1	2	3	4	5	6	7	8	9
25	0.733	0.770	17.32	4	163.25	83.70	133.61	81.27
24	.733	.771	17.34	4	170.75	83.95	136.60	82.74
23	.733	.772	17.33	4	178.50	83.95	138.40	83.88
22	.733	.769	17.32	4	183.75	83.62	136.82	83.30
21	.733	.762	17.31	4	187.00	82.84	133.49	82.08
20	.733	.753	17.32	4	192.25	81.87	130.13	80.92
19	.733	.735	17.38	4	200.75	80.40	126.00	79.87
18	.733	.729	17.38	4	214.00	79.38	121.15	77.43
17	.733	.717	17.36	4	227.75	78.12	112.12	72.90
Mean		.753	17.34		190.88	81.94	129.81	80.48
32	.601	.644	17.53	4	160.00	70.45	111.26	79.44
31	.601	.642	17.55	4	167.00	70.34	112.01	80.01
30	.601	.636	17.54	4	170.50	69.63	110.17	79.54
29	.601	.629	17.54	5	176.40	68.82	109.64	80.09
28	.601	.627	17.55	4	182.75	68.60	109.08	79.89
27	.601	.623	17.56	4	188.25	68.28	107.73	79.23
26	.601	.616	17.58	4	198.75	67.46	103.96	77.29
Mean		.631	17.55		177 06	69.08	109.12	79.35
37	.488	.527	17.66	4	155.75	57.88	87.22	75.24
36	.488	.526	17.66	4	162.25	57.79	87.86	75.91
35	.488	.525	17.68	4	168.50	57.69	88.14	76.19
34	.488	.523	17.69	4	174.00	57.51	87.80	76.10
33	.488	.518	17.72	4	180.75	57.03	86.76	75.70
38	.488	.513	17.67	4	194.00	56.38	83.57	73.96
Mean		.522	17.68		172.54	57.36	86.89	75.51

45-INCH RIGHT-HAND WHEEL.

[Test No. 979, January 25-26, 1897.]

8	1.000	0.992	14.94	5	127.60	171.24	233.49	80.48
7	1.000	1.000	14.88	5	133.40	172.12	236.84	81.54
6	1.000	.998	14.92	4	138.12	172.12	238.65	81.94
5	1.000	.999	15.00	4	144.00	172.69	240.97	82.03
4	1.000	1.001	15.02	4	148.75	173.23	240.82	81.61
3	1.000	1.002	15.03	3	153.33	173.38	239.89	81.18
2	1.000	.998	15.04	4	157.75	172.81	236.08	80.09
1	1.000	.986	15.11	3	169.33	171.11	218.85	74.64
Mean		.997	14.99		146.54	172.337	235.698	80.437

Holyoke tests of Samson turbines—Continued.

45-INCH RIGHT-HAND WHEEL—Continued.

Number of tests.	Gate opening (proportional part).	Proportional discharge. (Discharge of full gate at highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
18	0.832	0.887	14.99	4	112.50	153.24	208.16	79.90
17	.832	.892	15.02	4	119.75	154.34	215.05	81.80
16	832	.896	15.04	4	126.12	155.04	219.62	83.05
15	.832	.897	15.03	4	132.25	155.27	223.11	84.30
14	.832	.896	15.04	4	138.12	155.03	223.61	84.55
13	.832	.893	15.06	4	143.00	154.74	221.79	83.92
12	.832	.888	15.09	4	148.12	153.93	219.65	83.38
11	.832	.881	15.16	4	151.25	153.12	214.01	81.29
10	.832	.874	15.21	4	155.00	152.15	208.77	79.55
9	.832	.847	15.32	4	160.50	148.02	196.52	76.42
Mean	....	.885	15.10	....	138.66	153.48	215.029	81.82
27	.684	.766	15.19	3	112.67	133.24	183.94	80.14
26	.684	.769	15.12	3	121.33	133.52	189.83	82.91
25	.684	768	15.11	4	127.67	133.24	191.06	83.68
24	.684	.762	15.14	4	131.50	132.34	187.85	82.67
23	.684	.756	15.20	4	135.50	131.58	185.27	81.68
22	.684	.745	15.28	4	139.00	130.06	182.49	80.97
21	.684	.734	15.33	4	141.75	128.02	178.39	80.15
20	.684	.728	15.39	4	147.00	127.52	176.99	79.52
19	.684	.719	15.43	4	156.00	125.99	169.79	77.01
Mean	....	.749	15.24	....	134.71	130.61	182.84	80.97
57	.568	.641	15.85	5	125.80	113.89	162.59	79.42
58	.568	.633	15.88	4	131.50	112.65	162.80	80.25
59	.568	.630	15.85	4	135.75	112.04	160.68	79.78
60	.568	.629	15.83	4	139.75	111.68	157.81	78.71
61	.568	.622	15.84	4	143.25	110.45	152.99	77.11
62	.568	.613	15.85	4	148.25	109.02	146.23	74.62
Mean	....	.628	15.85	....	137.38	111.62	157.18	78.315
46	.424	.500	16.50	4	112.50	90.70	123.97	73.05
45	.424	.499	16.53	4	121.25	90.59	127.84	75.28
47	.424	.499	16.49	4	124.00	90.37	127.79	75.61
44	.424	.497	16.55	4	127.00	90.24	127.86	75.49
49	.424	.497	16.47	4	126.87	90.04	127.73	75.95
43	.424	.494	16.55	4	131.75	89.69	125.47	74.53
48	.424	.487	16.50	4	135.50	88.24	121.67	73.69
42	.424	.479	16.58	4	151.25	87.01	113.18	69.18
Mean	....	.495	16.52	....	128.76	89.61	124.43	74.097

Holyoke tests of Samson turbines—Continued.

56-INCH RIGHT-HAND WHEEL.

[Test No. 1257, June 20, 1900.]

Number of tests.	Gate opening (proportional part).	Proportional discharge. (Discharge of full gate at highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
19	1.000	0.995	13.27	3	99.67	245.41	303.28	82.29
18	1.000	.996	13.27	4	104.00	245.75	307.27	83.26
17	1.000	1.001	13.27	4	108.62	246.86	309.85	83.58
16	1.000	.999	13.30	4	111.75	246.69	307.40	82.79
15	1.000	.992	13.33	4	113.50	245.26	302.19	81.68
14	1.000	.980	13.50	4	117.00	243.81	294.03	78.94
Mean		.994	13.32		109.09	245.63	304.00	82.09
25	.919	.945	13.52	4	99.37	235.43	301.69	83.75
24	.919	.947	13.50	4	104.25	235.56	304.47	84.60
23	.919	.943	13.52	4	107.75	234.80	301.52	83.93
22	.919	.936	13.56	4	110.12	233.37	295.43	82.50
21	.919	.928	13.63	4	112.37	231.98	288.50	80.63
20	.919	916	13.71	4	115.12	229.82	281.48	78.94
Mean		.936	13.57		108.16	233.49	295.51	82.39
32	.846	.885	13.80	4	96.62	222.77	293.34	84.32
31	.846	.888	13.79	4	101.00	223.37	296.35	85.01
30	.846	.882	13.80	4	103.12	221.99	292.06	84.24
29	.846	.876	13.82	4	105.00	220.47	286.69	83.14
28	.846	.868	13.91	5	107.80	219.26	283.35	82.10
27	.846	.855	14.09	4	110.87	217.31	278.62	80.41
26	.846	.843	14.11	4	113.50	214.58	269.81	78.75
Mean		.871	13.90		105.41	219.96	285.74	82.567
54	.771	.824	14.15	4	97.50	210.02	282.77	84.08
53	.771	.819	14.18	4	100.37	208.95	280.18	83.56
52	.771	.812	14.21	4	102.12	207.29	274.66	82.40
51	.771	.802	14.24	4	104.00	205.01	269.13	81.46
50	.771	.794	14.27	4	106.25	203.03	264.12	80.56
49	.771	.786	14.33	3	109.67	201.51	260.71	79.78
Mean		.806	14.23		103.31	205.96	271.92	81.97
48	.696	.736	14.63	4	97.50	190.73	254.95	80.74
47	.696	.727	14.69	4	100.37	188.70	254.28	81.06
46	.696	.725	14.70	4	103.75	188.28	253.68	80.99
45	.696	.717	14.76	4	106.87	186.67	250.42	80.31
44	.696	.715	14.81	4	110.50	186.38	247.67	79.29
Mean		.724	14.72		103.798	188.15	252.20	80.478
43	.626	.663	15.11	4	98.25	174.50	238.90	80.06
42	.626	.660	15.12	4	102.00	173.83	239.01	80.36
41	.626	.655	15.16	4	105.00	172.83	236.77	79.85
40	.626	.651	15.13	4	107.37	171.55	231.17	78.70
39	.626	.647	15.17	4	110.75	170.70	225.66	77.01
Mean		.655	15.14		104.67	172.68	234.30	79.196

Holyoke tests of Samson turbines—Continued.

56-INCH RIGHT-HAND WHEEL—Continued.

Number of tests.	Gate opening (proportional part).	Proportional discharge. (Discharge of full gate at highest efficiency=1.)	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
38	0.564	0.603	15.45	4	95.50	160.63	219.89	78.29
37	.564	.600	15.44	4	98.62	159.54	218.36	78.33
36	.564	.598	15.46	4	102.25	159.11	217.37	78.09
35	.564	.592	15.49	4	105.75	157.75	214.04	77.40
34	.564	.587	15.51	4	109.87	156.65	208.95	75.99
33	.564	.581	15.56	4	114.00	155.30	201.31	73.62
Mean	....	.594	15.48	....	104.33	158.16	213.32	76.95
6	.497	.537	15.91	4	101.25	145.14	195.99	75.00
5	.497	.532	15.95	4	105.12	143.93	192.77	74.20
4	.497	.527	16.00	5	109.20	142.87	189.13	73.11
3	.497	.522	16.04	4	113.37	141.70	184.80	71.85
2	.497	.520	16.04	4	117.50	140.91	179.56	70.20
1	.497	.517	16.07	4	125.75	140.27	170.82	66.96
Mean	....	.526	16.00	....	112.03	142.47	185.51	71.88

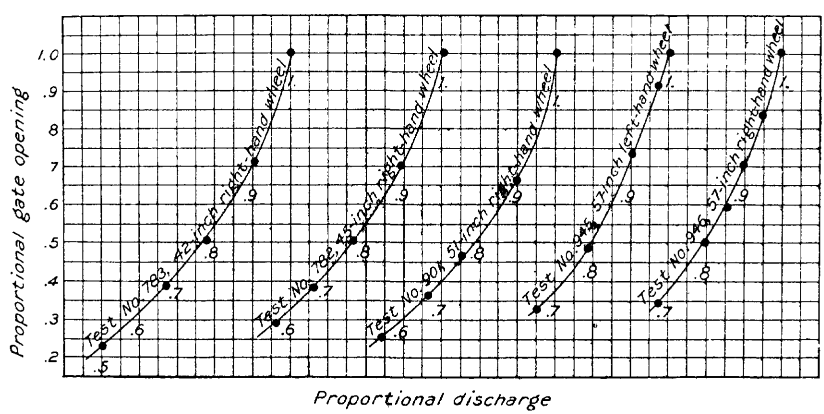


FIG. 27.—Proportional discharge coefficients for New American turbines.

HOLYOKE TESTS OF NEW AMERICAN AND SWAIN TURBINES.

The New American turbine has a modern large-capacity runner mounted in a pivoted-gate case. The runner resembles that of the Swain type of turbine, and bulges downward and outward less than those of the McCormick type of turbine.

Complete tests of three sizes of New American turbines have been published by the builders, the Dayton Globe Works, of Dayton, Ohio, and are presented in the following tables. The means of the various factors for each experimental gate opening and for each size of wheel have been computed and are included in the tables.

A recent test of a Swain turbine is appended.

Holyoke tests of New American turbines.

42-INCH RIGHT-HAND WHEEL.

[Test No. 783, July 14, 1894.]

Number.	Gate opening (proportional part).	Proportional discharge. (Discharge at full gate with highest efficiency=1.)	Mean head in feet.	Duration of tests in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
33	1.000	1.014	16.39	4	116.25	136.40	200.24	79.17
32	1.000	1.008	16.37	4	120.50	135.60	200.99	80.03
31	1.000	1.004	16.36	4	124.00	134.97	200.08	80.09
30	1.000	.999	16.33	4	128.00	134.18	199.56	80.50
29	1.000	.994	16.33	4	132.25	133.54	198.08	80.29
28	1.000	.988	16.28	3	136.00	132.52	194.44	79.66
Mean		1.001	16.34		126.16	134.54	198.86	77.96
27	.710	.916	16.43	4	112.25	123.38	184.18	80.31
26	.710	.912	16.46	4	117.50	122.99	186.39	81.38
25	.710	.907	16.47	4	122.25	122.36	187.27	82.13
24	.710	.900	16.51	4	128.25	121.60	187.73	82.65
23	.710	.893	16.56	5	134.80	120.85	188.14	83.09
22	.710	.877	16.55	4	144.00	118.57	181.37	81.69
Mean		.903	16.50		126.51	121.63	185.85	81.87
21	.504	.798	16.87	3	110.00	108.99	164.76	79.20
20	.504	.795	16.74	3	113.33	108.15	164.34	80.24
19	.504	.793	16.53	5	117.00	107.18	163.29	81.47
18	.504	.785	16.56	4	124.00	106.25	164.62	82.70
17	.504	.774	16.59	3	129.33	104.85	162.89	82.77
16	.504	.764	16.67	4	133.75	103.67	159.35	81.50
15	.504	.736	16.77	4	141.75	100.20	149.58	78.68
Mean		.778	16.68		124.17	105.61	161.26	80.94
14	.389	.700	17.10	4	106.00	96.17	140.73	75.64
13	.389	.697	17.04	3	113.33	95.58	144.28	78.30
12	.389	.685	17.11	4	120.25	94.22	144.91	79.45
11	.389	.674	17.13	4	125.25	92.76	142.40	79.21
10	.389	.660	17.15	4	130.00	90.85	138.96	78.83
9	.389	.646	17.20	4	136.00	89.10	134.26	77.43
8	.389	.633	17.25	4	144.50	87.44	127.89	74.94
Mean		.671	17.14		125.05	92.30	139.06	77.69
7	.230	.530	17.42	4	102.62	73.51	100.61	69.44
6	.230	.527	17.44	4	108.50	73.10	101.20	70.16
5	.230	.520	17.48	4	113.25	72.27	100.23	70.13
4	.230	.509	17.48	4	121.00	70.80	98.85	70.60
3	.230	.501	17.48	4	128.75	69.66	96.42	69.99
2	.230	.494	17.51	5	136.20	68.73	92.73	68.10
Mean		.514	17.47		118.39	71.34	98.34	69.74

Holyoke tests of New American turbines—Continued.

45-INCH RIGHT-HAND WHEEL.

[Test No. 782, July 9, 1894.]

Number.	Gate opening (proportional part).	Proportional discharge. (Discharge at full gate with highest efficiency=1).	Mean head in feet.	Duration of tests in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
37	1.000	1.022	15.98	4	103.50	144.87	205.05	78.26
36	1.000	1.015	16.01	4	107.50	143.95	205.66	78.84
35	1.000	1.009	16.02	3	112.00	143.17	206.64	79.60
34	1.000	1.003	16.04	4	115.37	142.36	205.79	79.63
33	1.000	.997	16.06	3	119.17	141.58	205.27	79.76
32	1.000	.990	16.09	4	123.00	140.77	203.49	79.38
31	1.000	.983	16.13	4	127.75	140.02	200.04	78.26
Mean	....	1.003	16.05	....	115.47	142.39	204.56	79.10
30	.699	.921	16.30	4	101.25	131.77	195.08	80.25
29	.699	.914	16.38	4	105.75	131.12	197.27	81.15
28	.699	.905	16.40	4	110.25	129.93	198.16	82.17
27	.699	.899	16.41	4	113.87	129.11	197.69	82.44
26	.699	.893	16.42	3	117.33	128.35	196.51	82.38
25	.699	.885	16.42	4	122.00	127.18	195.19	82.58
24	.699	.874	16.45	4	127.50	125.67	190.97	81.62
23	.699	.856	16.53	3	134.00	123.42	182.46	79.02
Mean	....	.893	16.41	....	116.49	128.32	194.17	81.45
22	.505	.800	16.68	4	102.00	115.77	175.69	80.39
21	.505	.796	16.71	3	106.00	115.29	176.81	81.09
20	.505	.787	16.74	4	110.75	114.17	177.19	81.92
19	.505	.775	16.78	3	117.33	112.60	175.74	82.18
18	.505	.762	16.81	4	122.50	110.81	170.97	81.10
17	.505	.746	16.85	5	127.40	108.50	164.80	79.64
16	.505	.725	16.86	4	133.50	105.56	154.51	76.71
Mean	....	.770	16.78	....	117.07	111.81	170.82	80.43
15	.382	.687	16.97	4	101.25	100.29	149.58	77.66
14	.382	.681	17.00	4	107.00	99.50	150.79	78.77
13	.382	.671	17.03	3	111.83	98.12	149.99	79.31
12	.382	.661	17.07	4	116.00	96.83	147.68	78.94
11	.382	.651	17.11	4	119.75	95.48	144.30	78.05
10	.382	.635	17.19	4	127.50	93.32	138.89	76.50
Mean	....	.664	17.09	....	113.89	97.26	146.87	78.21
8	.293	.584	16.84	4	99.25	84.91	120.28	74.32
7	.293	.579	16.83	3	103.33	84.27	120.30	74.94
6	.293	.572	16.86	3	108.00	83.28	119.85	75.42
5	.293	.563	16.88	3	118.67	82.07	118.40	75.52
4	.293	.553	16.90	3	119.67	80.54	114.06	74.04
3	.293	.541	16.94	4	127.00	78.93	108.08	71.42
Mean	....	.565	16.87	....	112.65	82.33	116.83	74.28

Holyoke tests of New American turbines—Continued.

51-INCH RIGHT-HAND WHEEL.

[Test No. 901, March 11-12, 1896.]

Number.	Gate opening (proportional part).	Proportional discharge. (Discharge at full gate with highest efficiency=1).	Mean head in feet.	Duration of tests in minutes.	Revolutions per minute.	Discharge in second-feet.	Horsepower developed.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
42	1.000	1.021	14.83	5	84.20	195.90	255.10	77.42
41	1.000	1.016	14.88	4	88.50	195.30	259.09	78.61
40	1.000	1.010	14.88	5	91.70	194.24	259.09	79.04
43	1.000	1.007	14.87	4	93.50	193.52	259.08	79.38
39	1.000	1.005	14.94	4	95.62	193.65	260.40	79.36
44	1.000	1.003	14.86	5	96.80	192.78	258.34	79.51
38	1.000	.999	15.03	6	100.00	192.94	262.11	79.70
37	1.000	.991	15.13	4	103.25	192.08	260.09	78.91
45	1.000	.988	14.94	4	104.87	190.34	253.46	78.59
Mean		1.004	14.93		95.38	193.42	258.53	78.95
36	.659	.916	15.39	4	85.50	179.12	251.47	80.43
35	.659	.911	15.40	4	89.12	178.10	253.01	81.34
34	.659	.905	15.43	5	92.80	177.11	253.98	81.95
33	.659	.898	15.46	4	96.75	175.98	254.91	82.61
32	.659	.891	15.49	4	100.25	174.85	252.53	82.21
31	.659	.882	15.50	4	104.50	173.16	249.01	81.80
Mean		.9005	15.44		94.82	176.39	252.48	81.72
30	.465	.806	15.88	4	79.75	160.00	223.15	77.44
29	.465	.802	15.95	4	85.33	159.70	230.05	79.63
28	.465	.794	16.09	5	90.60	158.74	235.01	81.13
27	.465	.788	16.04	5	93.40	157.23	232.73	81.37
26	.465	.781	15.96	4	96.25	155.60	230.01	81.66
25	.465	.774	15.97	5	99.10	154.26	226.70	81.14
24	.465	.763	16.05	5	102.60	152.36	222.13	80.09
23	.465	.751	16.12	5	106.20	150.36	216.91	78.91
22	.465	.730	16.42	3	112.00	147.43	209.69	76.38
Mean		.754	16.05		96.14	155.08	225.15	79.75
21	.362	.700	16.43	4	80.25	141.35	196.69	74.67
20	.362	.696	16.44	4	86.50	140.59	203.17	77.51
19	.362	.689	16.44	4	90.00	139.25	202.20	77.88
18	.362	.681	16.50	4	93.75	137.97	201.05	77.87
17	.362	.673	16.56	4	97.25	136.40	198.63	77.54
16	.362	.662	16.59	4	100.25	134.33	194.52	76.96
15	.362	.651	16.67	4	103.25	132.40	189.80	75.82
14	.362	.643	16.70	4	106.50	130.89	184.90	74.58
13	.362	.633	16.74	4	111.25	128.98	179.51	73.30
12	.362	.620	16.79	4	117.50	126.70	167.99	69.63
Mean		.665	16.59		98.65	134.88	191.85	75.58
11	.251	.559	17.03	4	82.50	115.02	155.58	70.03
10	.251	.556	17.00	4	85.50	114.31	155.42	70.52
9	.251	.551	17.02	4	88.50	113.20	154.85	70.87
8	.251	.544	17.06	4	92.00	111.98	154.71	71.40
7	.251	.537	17.10	4	96.25	110.76	153.99	71.69
6	.251	.531	17.10	4	100.00	109.44	149.78	70.53
5	.251	.529	17.10	4	101.50	109.08	148.57	70.27
Mean		.544	17.06		92.32	111.97	153.27	70.74

Holyoke tests of Swain turbines.[a]

36-INCH RIGHT-HAND WHEEL.

[Test No. 977, January 20–21, 1897.]

Number.	Gate opening (decimal part).	Discharge (decimal part).	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge in second-feet.	Developed horsepower.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
64	1.000	1.004	15.16	3	130.33	76.49	111.57	84.84
63	1.000	.995	15.25	4	135.00	75.98	111.47	84.83
62	1.000	.984	15.40	3	140.33	75.52	111.61	84.62
61	1.000	.973	15.42	3	144.00	74.74	110.16	84.28
60	1.000	.966	15.43	4	146.50	74.19	108.51	83.58
59	1.000	.954	15.48	4	150.75	73.45	107.08	83.04
58	1.000	.945	15.47	4	154.00	72.73	104.72	82.07
57	1.000	.934	15.44	3	158.00	71.76	101.68	80.92
56	1.000	.922	15.33	4	161.37	70.58	97.97	79.84
Mean		.964	15.38		146.70	73.94	107.20	83.11
55	.875	.932	15.16	3	132.00	70.95	102.58	84.10
54	.875	.925	15.15	4	135.75	70.42	102.20	84.47
53	.875	.916	15.28	4	140.75	70.01	102.54	84.52
52	.875	.907	15.41	4	147.00	69.61	102.63	84.37
51	.875	.896	15.50	4	153.50	68.99	101.58	83.75
50	.875	.877	15.60	3	162.33	67.75	98.55	82.22
Mean		.909	15.35		145.22	69.62	101.68	83.91
49	.750	.866	15.66	4	130.00	67.03	100.24	84.20
48	.750	.857	15.74	4	136.00	66.52	100.73	84.83
47	.750	.849	15.76	4	141.00	65.96	100.16	84.96
46	.750	.844	15.70	2	146.00	65.41	99.28	85.24
45	.750	.838	15.54	4	149.75	64.64	97.28	85.39
44	.750	.829	15.62	3	157.33	64.09	96.47	84.97
43	.750	.826	15.16	4	156.75	62.88	91.36	84.51
42	.750	.814	15.20	4	162.75	62.06	88.93	83.13
Mean		.840	15.55		147.45	64.82	96.81	84.65
41	.625	.783	15.30	4	127.50	59.90	85.92	82.67
40	.625	.775	15.38	4	134.75	59.45	86.72	83.63
39	.625	.767	15.43	4	142.12	58.95	87.15	84.48
38	.625	.758	15.47	4	149.50	58.30	86.23	84.30
37	.625	.749	15.51	4	154.50	57.70	84.42	83.18
36	.625	.733	15.58	4	162.75	56.62	81.02	80.99
35	.625	.715	15.65	4	169.50	55.32	76.15	77.56
Mean		.754	15.50		148.66	58.03	83.95	82.40
34	.500	.683	15.74	5	123.20	52.98	74.80	79.09
33	.500	.676	15.78	4	131.25	52.54	75.70	80.51
32	.500	.668	15.83	4	137.50	51.98	75.13	80.51
31	.500	.660	15.85	4	144.00	51.42	74.31	80.40
30	.500	.652	15.91	4	150.25	50.87	72.98	79.51
29	.500	.644	15.95	4	157.50	50.31	71.72	78.81
28	.500	.635	15.96	3	163.33	49.62	69.41	77.29
Mean		.660	15.86		143.86	51.39	73.44	79.44

[a] Made by Swain Turbine and Manufacturing Company, Lowell, Mass.

Holyoke tests of Swain turbines—Continued.

36-INCH RIGHT-HAND WHEEL—Continued.

Number.	Gate opening (decimal part).	Discharge (decimal part).	Mean head in feet.	Duration of test in minutes.	Revolutions per minute.	Discharge, in second-feet.	Developed horsepower.	Percentage of efficiency.
1	2	3	4	5	6	7	8	9
26	0.375	0.557	15.21	4	120.37	42.50	54.08	73.77
25	.375	.552	15.19	4	127.50	42.06	54.19	74.78
24	.375	.545	15.21	4	133.50	41.58	53.49	74.58
23	.375	.538	15.21	4	139.00	41.06	52.32	73.87
22	.375	.531	15.22	3	145.67	40.53	51.30	73.32
21	.375	.524	15.21	3	152.33	40.01	49.94	72.36
20	.375	.514	15.30	4	160.25	39.36	48.65	71.23
27	.375	.504	15.30	5	167.20	38.57	45.68	68.25
Mean	....	.533	15.23	....	143.23	40.71	51.21	72.77
19	.250	.420	15.53	4	113.50	32.40	36.52	64.00
18	.250	.416	15.54	4	120.25	32.11	36.50	64.50
17	.250	.412	15.57	4	126.50	31.83	36.10	64.22
16	.250	.407	15.61	4	133.25	31.46	35.60	63.91
15	.250	.401	15.60	4	139.50	31.00	34.72	63.31
14	.250	.396	15.61	4	146.25	30.59	33.74	62.31
13	.250	.386	15.66	4	155.75	29.91	32.15	60.52
12	.250	.378	15.70	4	163.50	29.26	29.78	57.16
11	.250	.367	15.74	4	171.75	28.45	26.07	51.33
10	.250	.356	15.79	4	179.50	27.64	21.80	44.04
Mean	....	.394	15.64	....	144.98	30.46	32.30	59.53
9	.125	.257	16.03	4	111.50	20.06	16.92	46.41
8	.125	.254	16.01	4	119.00	19.89	16.62	46.01
7	.125	.252	16.07	4	126.75	19.76	16.16	44.88
6	.125	.249	16.17	4	134.12	19.62	15.47	43.00
5	.125	.247	16.23	4	141.00	19.45	14.55	40.65
4	.125	.245	16.18	4	146.25	19.24	13.32	37.73
3	.125	.242	16.22	4	152.25	19.07	12.02	34.26
2	.125	.239	16.11	4	159.50	18.73	9.68	28.30
Mean	....	.248	16.13	....	123.80	19.48	14.34	40.16
1	.067	.161	16.49	4	153.25	12.80	....	....

THE USE OF THE TURBINE AS A WATER METER.

In conjunction with the stream-gaging operations of the United States Geological Survey in New York and the New England States the method of utilizing existing dams as weirs and of determining the flow through turbines by using them as meters has been found convenient in many instances.

It not infrequently happens that nearly the entire fall of a stream is taken up at existing dams, leaving no opportunity for gaging by floats or current meter in open section without encountering backwater. In rapid, precipitous streams the current may be so rough as to render open section measurements unfeasible without great expense for preparation.

The use of the turbine as a water meter, as well as a water motor, has been most elaborately carried out at Holyoke, where about 150 turbines are used in 50 mills. They have all been accurately calibrated in the testing flume, and the amount of water used and to be paid for by the different companies is ascertained from daily observations of the head and speed-gate opening.

A similar method of stream measurement has been in use at Mechanicsville, N. Y., on the Hudson River, beginning in 1888, under the direction of R. P. Bloss. In 1891-92 stream gagings at dams and mills were extensively carried out in New Jersey by C. C. Vermeule, and in 1898 a number of such gaging stations were established in New York by George W. Rafter. At the present time many gaging stations at dams and mills are maintained in the Great Lakes and New England districts by the United States Geological Survey. It is found that continuous gaging records can often be maintained summer and winter in this way where other methods would not be feasible owing to obstruction of the streams by ice.

In some cases the identical turbines used in the mills have been tested at Holyoke, but in the majority of cases dependence must be placed upon tests of wheels from the same patterns. Where these are not available tests of wheels of the same make but of different sizes may be used to determine the proper discharge coefficients, or, in the absence of all tests, the manufacturer's rating tables may be used as a guide in calibrating the turbines. (For discussion of such tables, see p. 87.)

In connection with the use of the turbine as a water meter various questions arise relative to the accuracy attainable under different conditions.

RELIABILITY OF HOLYOKE TESTS AS TO TURBINE DISCHARGE.

Tests made by the writer indicate very close agreement between tested and actual discharge. This is confirmed by other unpublished tests which have been examined.

In general it may be said that whereas local conditions may cause considerable departure from the test in regard to power and speed, the discharge will remain fairly constant unless the turbine is in so cramped a position as to partially shut off free access of the water supply to the wheel. The above statements also apply to the agreement between manufacturer's rating tables and wheels in actual use, in cases where the rating tables have been deduced from authentic tests.

The following figures for flow measured by a turbine and by a current meter at gaging stations were obtained without special precautions, conditions being the same as for the regular gaging record. They may be taken as representing what may ordinarily be expected, the fact being borne in mind that a part of the difference between the turbine and current meter measurements may be attributed to errors of the meter measurements.

Comparison of discharge measurements made by means of turbine and current meter.

Middleville, N. Y., March 28, 1901, head 8.25 feet.

Turbine measurement:	
66-inch Leffel, full gate	105
21-inch Camden, full gate	14.4
36-inch Camden, 0.75 gate	36
Waste weir	6.4
Total	161.8
Current-meter measurement in headrace	160.0

Middleville, N. Y., September 10, 1900, head 10 feet.

Turbine measurement:	
66-inch Leffel, full gate	115.0
21-inch Camden, full gate	16.0
Total	131.0
Current-meter measurement	132.3

Schoharie Falls, N. Y., April 5, 1901, head 35.61 feet.

Turbine measurement:	
Pair Leffel-Samson 40-inch horizontal turbines, average gate, 0.449	210
Current-meter measurement[a] in headrace	216

[a] A slight loss by leakage occurred between point of measurement and the power house, probably about 2 second-feet.

Little Falls, N. Y., Paper Company's mill, head 12.25 feet.

Turbine measurement:	
60-inch Camden, approximately 0.75 gate	129
42-inch Camden, 0.75 gate	55
36-inch Camden, 0.75 gate	44
Reddy turbines, 0.75 gate	60
Total	288
Current-meter measurement in headrace	302

Mechanicsville, N. Y., October 20, 1900.

Turbine measurement	1,977
Current-meter measurement[a]	1,871

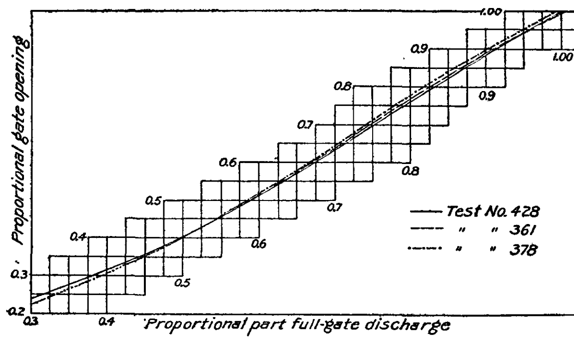


FIG. 28.—Part-gate discharge coefficients for three 24-inch Hercules turbines, showing close agreement of duplicate wheels from the same patterns.

VARIATION IN DISCHARGE FOR DIFFERENT WHEELS OF SAME PATTERN.

For the best modern wheels having guide and bucket openings made to conform with standard gages, wheels from the same patterns will be found to agree closely as to discharge. This is illustrated by fig. 28, showing part-gate coefficient for three 24-inch Hercules turbines.

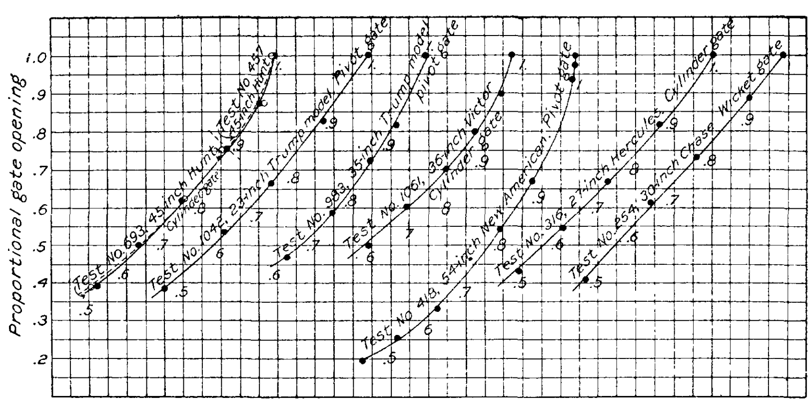


FIG. 29.—Types of part-gate discharge coefficient curves.

[a] Probably too small; slackwater. Very unsatisfactory meter measurement. The flow through individual turbines in this mill has been checked by the engineer and found to agree within 2 or 3 per cent with maker's tables.

VARIATION IN DISCHARGE FOR DIFFERENT WHEELS OF THE SAME TYPE.

Each type of runner and speed gate has its own characteristic part-gate discharge coefficient curve. Fig. 29 shows a series of such curves for various types of wheels with cylinder, pivot, and other forms of gate. As a rule, the part-gate coefficient curve is slightly concave upward. The discharge for one-half gate usually exceeds one-half of that of the full gate, while the discharge from three-fourths to full gate is often nearly proportional to the gate opening.

The various sizes of patterns of the principal builders resemble one another very closely. It will be found (see pp. 94–125) that the power, speed, and discharge of the various sizes are very nearly mathematical functions of the diameter.

The characteristic part-gate coefficient curve for any type of wheel is usually persistent for all sizes, within narrow limits of variation. Figs. 20 to 23 (on pp. 41–42) show part-gate discharge coefficient curves for various sized McCormick turbines from 12 to 57 inches diameter. With the exception of the 54-inch wheel, the curves for the different diameters resemble one another closely.

Taking the coefficients for various gate openings from the diagram, we obtain the following table:

Part-gate discharge coefficients for McCormick turbines.

Diameter of wheel.	Full gate.	Three-fourths gate.	One-half gate.	Diameter of wheel.	Full gate.	Three-fourths gate.	One-half gate.
Inches.				*Inches.*			
12	1.000	0.855	0.660	39	0.988	0.845	0.628
15	1.000	.868	.666	42	.993	.830	.628
18	1.012	.888	.695	45	1.005	.868	.655
21	1.005	.866	.655	48	.980	.838	.610
24	.998	.864	.655	51	1.006	.840	.625
27	1.006	.855	.645	57	1.005	.864	.652
30	.970	.850	.642				
33	.998	.860	.638	Average....	.998	.8574	.6484
36	1.006	.870	.672				

It will be seen that the departure from the average does not exceed 5 per cent for either the one-half or three-fourths gate coefficients for any of the sizes litted. This variation is due, at least in part, to the fact that the different wheels were not all tested over the same range of loads and speeds. The coefficients given are the averages for the loads and speeds included in the test at a given gate opening. These cover the range of variation likely to occur in ordinary practice.

Part-gate discharge coefficients for Hercules, Leffel-Samson, and New American turbines.

HERCULES.

Diameter of wheel.	Full gate.	Three-fourths gate.	One-half gate.
Inches.			
42	0.960	0.847	0.612
45	.969	.842	.598
51	.994	.834	.598
	.9685	.834	.600
54	.976	.815	.574

Part-gate discharge coefficients for Hercules, Leffel-Samson, and New American turbines—Con.

LEFFEL-SAMSON.

Diameter of wheel.	Full gate.	Three-fourths gate.	One-half gate.
Inches.			
23	0.995	0.82	0.58
35	.995	.78	.535
45	.995	.81	.56
56	.995	.785	.535
Average...	.995	.799	.552

NEW AMERICAN.

42	1.001	0.924	0.768
45	1.003	.920	.768
51	1.004	.940	.790
57	1.003	.914	.796
57	.998	.922	.795

VARIATION OF TURBINE DISCHARGE WITH SPEED.

Holyoke tests show that a turbine gives maximum efficiency for each gate opening under some certain speed. Considering the peripheral speed as a percentage of the spouting velocity due to the head, the following ratios are found for maximum efficiency for the Hercules turbine, results of tests of which are shown in figs. 15 to 19.

Peripheral speed for maximum efficiency, various gate openings.—Hercules turbines.

Gate opening.	Ratio of peripheral velocity to velocity due to head.
Full.	0.675
0.806	.652
.647	.642
.489	.603
.379	.585

It will be seen that the speed of maximum efficiency decreases slowly with decreased gate opening. A turbine should be geared to drive the machinery to which is connected at a proper speed when the turbine is running at its speed of maximum efficiency for the gate opening at which it is commonly operated. If a turbine is running above or below its normal speed for a given head and gate opening its discharge will vary from that given in the maker's tables. In using the turbine as a water meter it is important that the normal speed at which the wheel runs under load should be known. The amount of variation in discharge resulting from varying the load and speed, the head remaining constant, is shown in figs. 30, 31, 32, which give speed-discharge curves for three sizes of Smith-McCormick turbines. A similar analysis of the effect of variation in load and speed can be made for other sizes and types of turbines from the data furnished by Holyoke tests, given on pages 43–76.

For the ordinary range of speed variation the discharge at a given gate opening usually decreases as the load decreases or as the speed increases. An overloaded turbine will, as a rule, use more water than one running at its normal load under the same head and gate opening. Turbines may be so constructed that the quantity of water discharged attains a maximum for each head and gate opening when running under a certain load. For loads either less or greater the discharge and power will decrease.

The amount of variation in discharge corresponding to a given range of variation in speed is usually a maximum at full gate, decreasing as the gate opening is decreased. The amount of variation in full-gate discharge resulting from such variations in speed as will usually be allowable in practice is ordinarily small. This is illustrated by the following table.

Variation in full-gate discharge with varying speed, Smith-McCormick turbines.

Wheel.	Range in speed.	Corresponding variations in discharge.
	Revolutions per minute.	*Per cent.*
24-inch	178 to 231	2.8
42-inch	123 to 146	3.3
54-inch	81 to 110	3.4

For the turbines considered in the above table a variation of 25 per cent in the speed at full gate will cause a variation but little exceeding 3 per cent in the discharge. If a turbine runs normally at its tabled speed, and variations in excess or deficiency are equally likely to occur, their effect on discharge may commonly be neglected in using the turbine as a water meter.

Turbines controlled by automatic governors often afford favorable opportunities for recording the discharge. Care should always be taken to eliminate slip of the turbine gate mechanism and to have the governor gate indicator so set that its indications correspond with the actual proportional opening of the turbine gates. A scale attached directly to the turbine gate cylinder or gate stem and graduated by trial may often be used. It should indicate zero when waste motion in the mechanism has just been taken up and full gate at such a point that any further opening does not increase the area of the inlet ports.

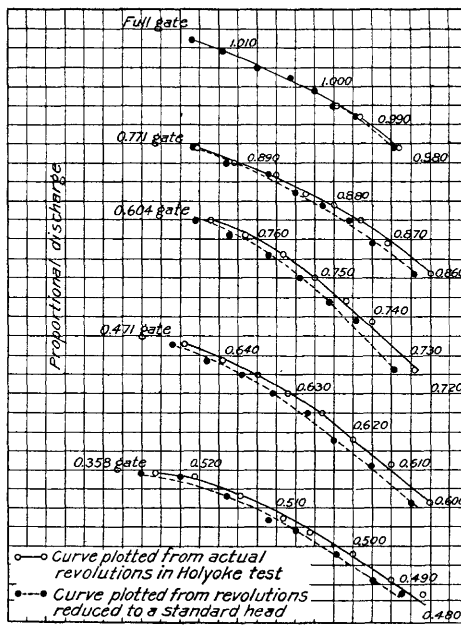


FIG. 30.—Variation of turbine discharge with speed, 24-inch McCormick turbine.

VARIATION OF TURBINE COEFFICIENTS WITH VARIATION IN HEAD.

The discharge coefficients for heads corresponding with those used in making tests at the Holyoke flume are known with considerable accuracy.

In the use of the turbine as a water meter, where the wheels are installed under heads either greater or less than those used at the Holyoke flume, the question arises as to the applicability of the discharge coefficients. Data of tests by James Emerson (p. 30) indicate that the coefficients of discharge through turbine buckets and guides, considered as orifices, are very nearly constant for ordinary heads.

It will be reasonably supposed, however, in accordance with the well-known variation of coefficient for standard orifices, that as the head is increased the coefficient of discharge for turbines would slightly decrease. Data to determine whether this is true or not are almost entirely wanting. It may be said, however, from inference by comparison with experiments on orifices under varying heads, that the coefficient of discharge probably differs slightly for turbines under high heads from that for similar wheels under lower heads, the rate of variation decreasing as the head increases.

The rating tables of manufacturers are deduced by making the discharge directly proportional to the square root of the head. This will be correct only in case the coefficient of discharge through the turbine orifices remains constant.

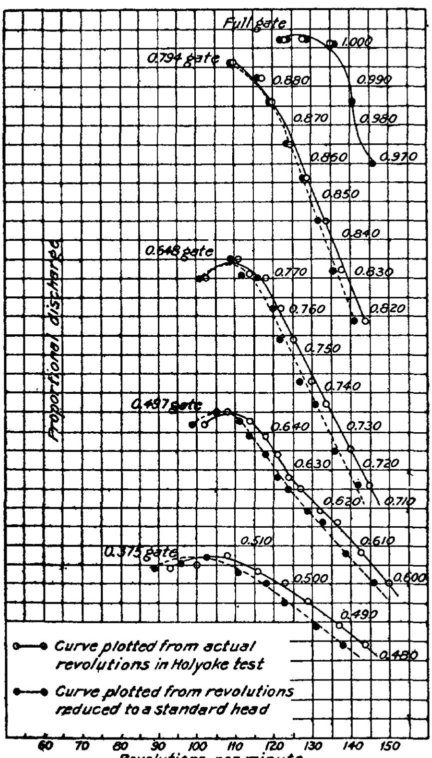


FIG. 31.—Variation of turbine discharge with speed, 42-inch McCormick turbine.

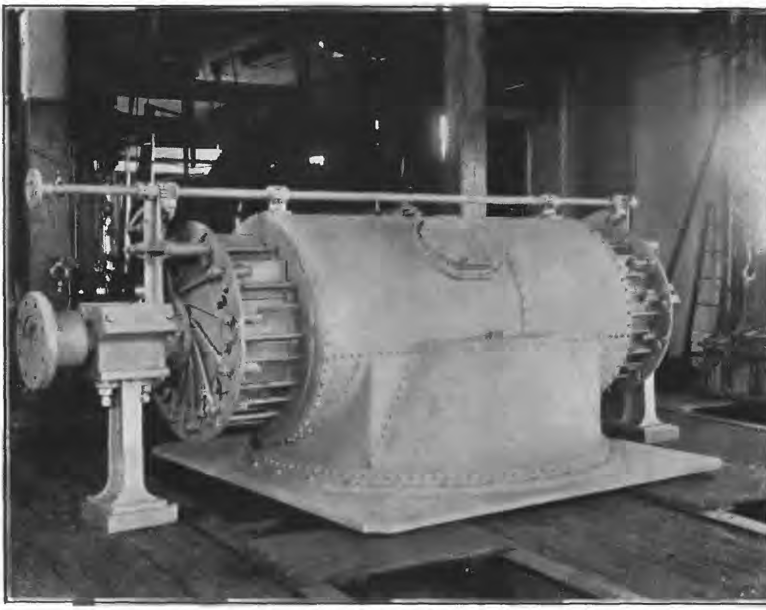
Stock patterns of the turbines are seldom applied under heads exceeding 60 feet. The available records of tests of special high-head turbines in situ do not afford any means of determining what the discharge coefficient for the same turbines would be if they were operated under such heads as are commonly experienced with stock patterns of wheels.

METHODS OF TURBINE SETTING AND ARRANGEMENT.

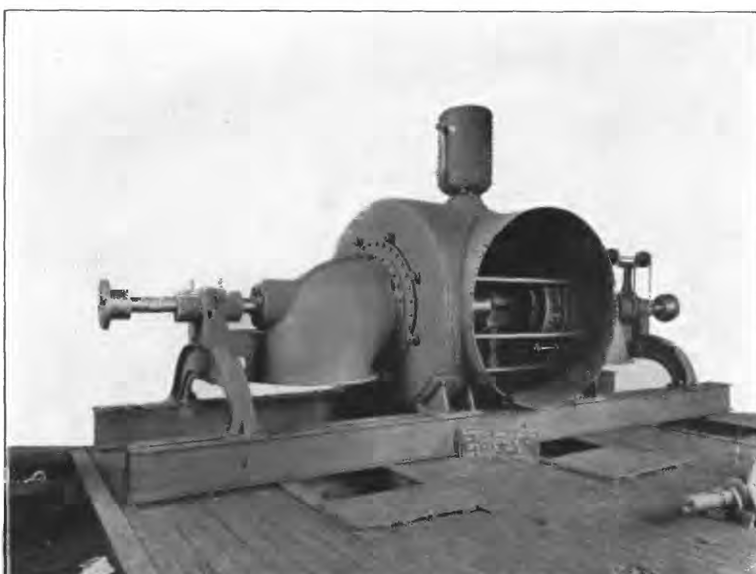
The rouet volante, scroll central-discharge, Fourneyron, and early Francis turbines were erected on vertical shafts in wooden or iron penstocks set alongside the flume to which they were con nected by a short trunk or chute.

The tub wheel and the Jonval turbine were capable of being set over a hole in the bottom of an open flume. The greatly decreased cost of this mode of erection led to its general use in the latter half of the last century, and most turbines of the American type are designed with special reference to this mode of erection, several wheels often being set in the same flume. The serious disadvantage of this method is the impossibility of inspecting or repairing any wheel without stopping all and drawing off the water. For most purposes, except burrstone mills, power is required on horizontal shafts, and gears must be introduced if vertical turbines are used.

The step or thrust bearings of vertical turbines support the weight of the incumbent millwork and machinery. The weight and thrust of a vertical turbine is now often supported by a water-balanced step bearing, which relieves the mechanism of undue friction and wear. Where two wheels discharging in opposite directions are placed on a horizontal shaft the end thrust is neutralized (Pl. II). By inverting a vertical turbine and causing the water to flow upward through the buckets, the vertical component of pressure can be utilized for the same purpose, as it is in the Fourneyron turbines of the Niagara Falls Power Company's installation (fig. 3).



A. PAIR OF TURBINES WITH PIVOT GATES MOUNTED ON HORIZONTAL SHAFT AND DISCHARGING INTO A COMMON DRAFT TUBE.



B. PAIR OF TURBINES ON HORIZONTAL SHAFT.

Water is received from cylindrical steel penstock and discharged in opposite directions into quarter-turn draft tubes.

Credit for the erection of the first pair of turbines on a horizontal shaft is claimed by E. Geyelin,[a] by whom the Jonval turbine was introduced into America about 1850. The draft tube was a feature of the Jonval turbine, and its use made the horizontal turbine possible, since without it a considerable portion of the head of horizontal wheels must be lost, as the wheels have to stand above tail-water.

Vertical turbines in open flumes must be set singly, one on a shaft. With the double horizontal arrangement power equal to that of a very large vertical turbine can be obtained together with a much greater speed.

Tests of turbines on horizontal shafts were made by James Emerson in 1879. A pair of 35-inch Gates-Curtis wheels with a rectangular wooden draft tube were used, and an average full-gate efficiency of 71.07 per cent was obtained, as compared with 82.52 per cent for one of the same runners tested vertically.

The result of this test and the belief that a horizontal wheel shaft would wear its bearings unequally and rub at the bottom and leak at the top of its case—a belief held by James Emerson—undoubtedly did much to delay the introduction of horizontal wheels. Their advantages are facility of access and facility of direct connection to generators, centrifugal pumps, and other machines, together with the ability to obtain large power on a single high-speed shaft, four or even six runners often being mounted tandem for this purpose.

Too much emphasis can not be laid upon the importance of allowing ample room all around the gate inlets where turbines are set in quarter-turn, globe, or cylindrical casings. The Holyoke Water Power Company gives the general rule: allow velocity in turbine casing not to exceed 3 feet per second and in draft tube not to exceed 4 or 5 feet per second.

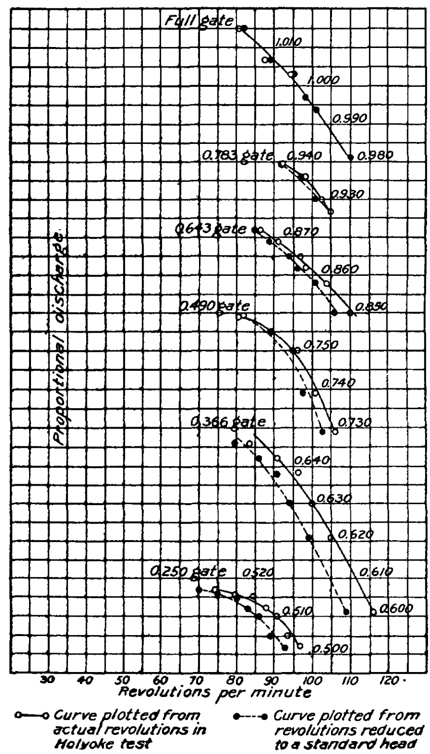


FIG. 32.—Variation of turbine discharge with speed, 54-inch McCormick turbine.

The more common methods of turbine setting in power plants are as follows:

1. Wheels may be arranged vertically in open flumes and connected by bevel gear harness. This method is well adapted for use under low heads. Several wheels can be controlled by one governor. Wheels can be arranged in units of three or four, which can be cut off successively by means of clutches beginning with the unit most remote from the driving end, thus allowing for variation of head and load. The governor may be attached to but one unit, additional units being controlled by hand and generally operated full gate, thus giving maximum efficiency for the system. Wheels are set in cast-iron penstocks or globe cases, or in cylindrical riveted steel penstocks in a number of ways. Single wheels are often placed in quarter-turn cases, with vertical or horizontal shafts. Double horizontal wheels may receive water from separate penstocks and discharge through a common draft tube, or may receive through a common penstock and have separate draft tubes; or they

[a] First pair of horizontal turbines ever built, working on a common axis: Proc. Eng. Club, Philadelphia, vol. 12, 1895, pp. 213–217.

may have both feeder and draft tubes in common. The principal features of each method are included in the following classification.

2. Wheels may be arranged in pairs on a horizontal shaft, with a common draft tube. Each pair may be in a penstock compartment by itself, with drop planks at the entry, so that the water can be drawn from any pair without disturbing the others. This is an excellent and economical arrangement for moderate heads, say 12 to 40 feet, and one which gives large area and free access of water to wheel chutes from all sides. Two pairs in tandem, with quill shaft, can be used, enabling them to be operated singly or as a unit.

3. Horizontal pairs of runners may be set in a cylindrical steel penstock, having a common central-draft tube. This method is adapted to cases where a line of driving shaft can be placed parallel to a circular steel flume leading from the dam, or where several units are to be driven from a common bulkhead, in which case the wheels for each unit are in a short

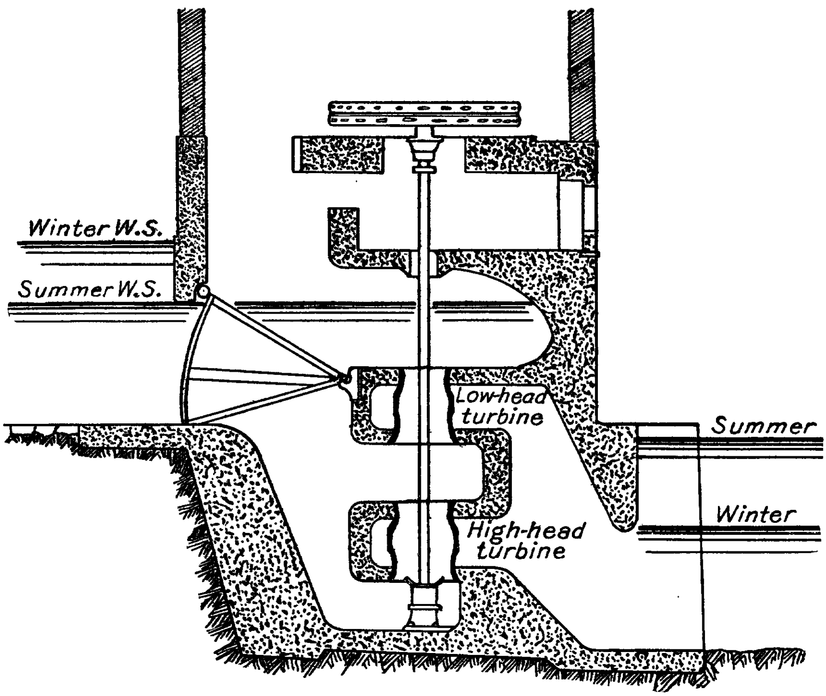


FIG. 33.—Cross section of power house, at Chevrés, near Geneva, Switzerland.

trunk leading from the foot of the bulkhead. A gate valve near the bulkhead will enable each unit to be separately cut off. Two wheel units, each containing either two, four, or even six pairs of runners, can be used in conjunction with a quill shaft, if desired.

4. Horizontal pairs of runners may be set in a cylindrical steel penstock, fed from the center and discharging outward into separate quarter-turn draft tubes. This arrangement possesses features similar to the preceding, but enables the driving shaft to be placed at right angles to the feeder trunk and also gives the water somewhat more freedom of access to wheel inlet ports. A feeder trunk is sometimes placed parallel to the power house, and short lateral feeders connect it with the penstocks, arranged as above. Short bends in the feeder line are, however, undesirable. This arrangement generally leaves a dead end at the foot of the penstock, in which ice may accumulate. A large blow-off valve should always be provided at the foot of a steel penstock.

TURBINE PLANTS FOR VARYING HEAD.

If the guide chutes of a turbine are designed with an area somewhat in excess of that required by theory at full gate, a wheel of very great capacity may be obtained, which will give its maximum efficiency at three-fourths or seven-eighths gate. (See figs. 14–19). Turbines for electrical service must nearly always have some reserve power and are seldom operated at full gate. With a fairly steady load, a moderate range of variation in the head may be taken care of with such wheels and uniform speed maintained by increasing the gate opening as the head decreases. Where there are large variations in the head, covering considerable periods of time, other expedients must be resorted to. The effect of a given range of variation in head increases rapidly as the head decreases. For example, the decrease in speed resulting from 1 foot decrease in head is as follows:

Effect of varying heads on turbine speed.

Original head.	Decreased head.	Resulting speed (per cent of original).
Feet.	*Feet.*	
4	3	86.60
10	9	94.87
50	49	99.00
100	99	99.50

In order to obtain uniform speed and power when operating under high head with small flow part of the time, and under a small head with large flow part of the time, two sets of turbines may be installed, one of large diameter, but with small openings, to operate under high head, the other of small effective diameter, but greater depth and capacity, for lower heads. Such an arrangement, in use at Chevrés, near Geneva, Switzerland, is illustrated in fig. 33. The upper wheel is used in winter with a head of 28 feet and a stream discharge of 4,250 cubic feet per second, and the lower wheel is used in summer with a head of 15 feet and a stream discharge of 31,800 cubic feet per second.

CONDITIONS GOVERNING ECONOMY IN SIZE AND NUMBER OF TURBINES USED.

The cost of a turbine, including foundation and erection, is about proportional to its diameter. Small turbines are sometimes selected for use under low heads because of their greater speed, which enables them to be directly connected to machines. The writer observed in one case 26 small old register-gate turbines in one flume, doing only as much work as perhaps one-third their number of large modern wheels would have done, including loss through gearing and jack shaft.

Turbines in use on Black River, New York, in 1898.

Diameter of wheel in inches.	Number.	Diameter of wheel in inches.	Number.
18 to 27½	16	50 to 54	44
30 to 34	84	55 to 57	17
35 to 39	111	60 to 61	30
40 to 44	46	66 to 72	5
45 to 48	27		
		Total....	380

In a canvass of water power on Black River, New York, in 1898, it was found that of a total of 380 turbines 50 per cent were from 30 to 40 inches diameter. In many places, notably at pulp mills, it was clearly evident that the use of larger turbines would have been more economical. The heads were those most commonly occurring everywhere—10 to 20 feet. It was also found that 25 per cent of the wheels in use were operated at very uneconomical widths of gate opening, varying from one-fourth to three-fourths.

Turbines of medium sizes, of which the greater number are manufactured, are likely to be the most reliable and to give the best service. Manufacturers scales of prices are also so adjusted that turbines of medium sizes, 36 to 48 inches diameter, cost less per horsepower than do sizes either larger or smaller.

The peripheral speed of maximum full-gate efficiency is, for turbines of a given design, nearly a constant fraction of the spouting velocity due to the head. This is illustrated by the following tests of various sized Hercules turbines:

Peripheral speed of Hercules turbines at full gate.

Diameter in inches.	Date of test.	Test number.	Head (in feet) at maximum efficiency.	$\sqrt{2gH}$= vel. due to head.	Speed in revolutions per minute.	Peripheral speed in feet per second.	Ratio: Col. 7. / Col. 5.
1	2	3	4	5	6	7	8
42..........	February 18-19, 1897...	988	15.73	31.809	119.75	21.946	0.68994
45..........	July 19, 1897...........	1030	15.75	31.829	111.20	21.804	.68598
48..........	October 10-11, 1898....	1147	15.53	31.606	104.25	21.838	.69080
51..........	February 25, 1898.....	1077	14.01	30.020	91.25	20.306	.67642
54..........	November 12, 1897.....	1051	14.07	30.084	84.12	19.820	.65882

The discharge, and hence also the power of a turbine, is nearly proportional to the square of its diameter. The extent to which this is true in practice depends upon the similarity of form of different sized turbines of the same make. The members of certain series of patterns made by some builders are perfectly homologous, one particular size having been developed by experiments and others being made larger or smaller in strict proportion. For other types each size is a law unto itself, though, of course, there is a general resemblance between the different sizes. How nearly proportional to the square of the diameter is the discharge may be judged from the following table, in which the capacity of various sized Hercules and Smith No. 2 Success turbines are compared. The factor vent÷(Diam.^{2}) should be constant if the discharge is proportional to the square of the diameter. If the efficiency is constant, the power at a given head is proportional to the discharge.

Relations between diameter and discharge and power of turbines of various sizes.

Diameter.	Square of diameter.	Hercules (cylinder gate).		Smith No. 2 Success (pivot gate).	
		Vent.	Vent / Diameter.^{2}	Vent.	Vent / Diameter.^{2}
Inches.		*Sq. in.*		*Sq. in.*	
9	81	24.80	0.305	....	....
12	144	42.89	.298	....	....
15	225	69.19	.307	41	0.182
18	324	96.56	.298	59	.182
21	441	136	.308	81	.183
24	576	168	.292	102	.177
30	900	265	.297	168	.188
36	1,296	379	.293	235	.181
42	1,764	555	.315	361	.205
48	2,304	687	.298	471	.204
54	2,496	897	.308	580	.199
60	3,600	1,074	.297	730	.203

It will be seen that for the Hercules and No. 2 Success the discharge as rated by the manufacturer is nearly proportional to the square of the diameter. Assuming the power to be proportional to the square of the diameter, the diameter D of a single turbine equal in power to two smaller wheels, each of diameter d, is:

$$D=\sqrt{2\,d^2}=1.41\ d.$$

If two equal wheels of diameter d are to replace a single wheel of diameter D, then

$$d=\frac{D}{\sqrt{2}}=\frac{1}{2}\sqrt{2}\times D=0.705\,D.$$

If m wheels each of diameter D are to replace n wheels of diameter d, then

$$mD^2=nd^2$$

and

$$D=d\sqrt{\frac{n}{m}}$$

$$d=D\sqrt{\frac{m}{n}}$$

If a single wheel of diameter D is to replace two wheels of unequal diameters d_1 and d_2, then

$$D=\sqrt{d_1^2+d_2^2}$$

Similarly, if m wheels of diameter D are to replace any series of wheels in which there are A wheels of diameter d_a, B wheels of diameter d_b, C wheels of diameter d_c, etc., then

$$mD^2=A\ d_a^2+B\ d_b^2+C\ d_c^2+\text{etc.}$$

or

$$D=\sqrt{\frac{1}{m}(A\ d_a^2+B\ d_b^2+C\ d_c^2+\text{etc.})}$$

Considerations like the above will be found convenient in selecting the best diameters and arrangements of turbines and in remodeling old plants.

MANUFACTURER'S TABLES OF POWER, SPEED, AND DISCHARGE.

GENERAL DISCUSSION.

Nearly all American turbine builders publish rating tables in their catalogues, showing the discharge in cubic feet per minute, speed in revolutions per minute, and horsepower for each size pattern under heads varying from 3 or 4 feet to 40 feet or more.

Inasmuch as these rating tables furnish in many cases the only means of ascertaining the quantities of water provided by riparian rights, or the amounts of power used by mills, the question of their reliability is of some importance.

Examples of each size of a number of the leading types of turbines have been tested in the Holyoke flume. For such turbines the rating tables have usually been prepared directly from the tests. In some cases the average of the full-gate power of a number of tests has been used; in other cases the power corresponding to maximum efficiency from a single test has been used as a basis for calculation.

Let M, R, and Q denote, respectively, the horsepower, revolutions per minute, and discharge in cubic feet per minute of a turbine, as expressed in the manufacturer's tables, for any head H in feet. The subscripts 1 and 16 added signify the power, speed, and discharge for the particular heads 1 and 16 feet, respectively.

Let P, N, and F denote coefficients of power, speed, and discharge, which represent, respectively, the horsepower, revolutions per minute, and discharge in cubic feet per second under a head of 1 foot.

The speed of a turbine or the number of revolutions per minute and the discharge are proportional to the square root of the head. The horsepower varies with the product of the head and discharge, and is consequently proportional to the three-halves power of the head.

If we have given the values of M, R, and Q from the manufacturer's tables for any head H we can calculate these quantities for any other head h by the following formulas:

$$\left.\begin{aligned} M_H : M_h &: : H^{\frac{3}{2}} : h^{\frac{3}{2}} \\ R_H : R_h &: : H^{\frac{1}{2}} : h^{\frac{1}{2}} \\ Q_H : Q_h &: : H^{\frac{1}{2}} : h^{\frac{1}{2}} \end{aligned}\right\} \qquad (1)$$

If H and h are taken at 16 feet and 1 foot, respectively, we may derive formulas from which the coefficients P, N, and F can be conveniently calculated as follows:

$$\left.\begin{aligned} P &= \frac{M_{16}}{H^{\frac{3}{2}}} = \frac{M_{16}}{64} = 0.01562\ M_{16} \\ N &= \frac{R_{16}}{H^{\frac{1}{2}}} = \frac{R_{16}}{4} = 0.25\ R_{16} \\ F &= \frac{Q_{16}}{60H^{\frac{1}{2}}} = \frac{Q_{16}}{240} = 0.00417\ Q_{16} \end{aligned}\right\} \qquad (2)$$

P, N, and F, when derived for a given wheel, enable the power, speed, and dicharge to be calculated without the aid of the manufacturer's tables, and for any head H, integral or fractional, by means of the following formulas:

$$\left.\begin{aligned} M &= M_1 \left(\frac{H^{\frac{3}{2}}}{H_1}\right) = PH^{\frac{3}{2}} \\ R &= R_1 \sqrt{\frac{H}{H_1}} = N\sqrt{H} \\ Q &= Q_1 \sqrt{\frac{H}{H_1}} = 60\ F\sqrt{H} \end{aligned}\right\} \qquad (3)$$

Since at a head of 1 foot, and M_1, R_1, and Q_1 equal P, N, and 60 F, respectively, $H_1^{\frac{3}{2}}$ and $\sqrt{H_1}$ each equals 1.

The accompanying tables give the values of P and N and F for turbines of various styles and sizes, and tables are appended giving three-halves powers and square roots, by the use of which the quantities can be calculated for any head and turbine with facility.

Besides presenting the individual constants of turbines in very compact form, as compared with manufacturer's rating tables, these coefficients afford a means for comparison of the capacity of different turbines.

The following examples illustrate the use of the tables:

On page 122 we find for a 36-inch Hercules turbine—

Power coefficient, 1.91 = P
Discharge coefficient, 21.1 = F
Speed coefficient, 32.2 = N

To find the power, discharge, and speed for any head, multiply P by the three-halves power of the head to get the horsepower, and mutiply F and N by the square root of the head to get the discharge in cubic feet per second and the revolutions per minute, respectively, or as formulas:

Horsepower $= PH^{\frac{3}{2}}$
Cubic feet per second $= FH^{\frac{1}{2}}$
Revolutions per minute $= NH^{\frac{1}{2}}$

To determine these factors for a head of, say, 7.5 feet, find in the tables of three-halves powers, and square roots, pages 90–94:

$$7.5^{\frac{3}{2}} = 20.54$$
$$\sqrt{7.5} = 2.74$$

Multiplying, we get for a 36-inch Hercules turbine under 7.5 feet head—

Horsepower $=20.54\times 1.91=39.2$.

Cubic feet per second $=21.1 \times 2.74=57.8$.

Revolutions per minute$=32.2 \times 2.74=88.2$.

If the discharge in cubic feet per minute is desired, multiply the cubic feet per second by 60 and we get, cubic feet per minute=3,468.

Tests of different turbines from the same pattern have been found to agree closely if the conditions were similar. The manufacturers' rating tables can as a rule be relied upon within a small percentage, where they are obtained from complete test records as above described.

There are other turbines on the market for which tests of only one or two sizes of patterns have been made. In such cases, the rating tables for sizes other than those tested have been computed, usually on the following basis:

1. The efficiency and coefficients of gate and bucket discharge for the sizes tested have been assumed to apply to the other sizes also.

2. The discharge for additional sizes has been computed in proportion to the measured area of the vent or discharge orifices.

Having these data, together with the efficiency, the tables of discharge and horsepower can be prepared. The peripheral speed corresponding to maximum efficiency determined from tests of one size of turbine may be assumed to apply to the other sizes also. From this datum the revolutions per minute can be computed, the number of revolutions required to give a constant peripheral speed being inversely proportional to the diameter of the turbine.

Other turbines are on the market for which there appear to be no authentic tests of any sizes. Some of these wheels are close copies of known types, the rating tables for which have been adopted or slightly modified as seemed necessary.

In point of discharge, the writer's observation has been that the rating tables are usually fairly accurate. In the matter of efficiency there are undoubtedly much larger discrepancies.

The discharge of turbines is nearly always expressed in the manufacturers' tables in cubic feet per minute. The vent in square inches is also used by millwrights and manufacturers, although to a decreasing extent. Engineers prefer to express the discharge of turbines in cubic feet per second (second-feet) to conform with general practice in stream gaging and in power calculations. The vent of the turbines, as usually expressed, is the area of an orifice which would, under any given head, theoretically discharge the same quantity of water that is vented or passed through a turbine under that same head when the wheel is so loaded as to be running at maximum efficiency.

If V=vent in square inches

Q=discharge in cubic feet per minute under a head H

F=discharge in cubic feet per second under a head of 1 foot,

then

$$Q=\frac{60V}{144}\sqrt{2gH}=3.344V\sqrt{H}$$

and

$$V=\frac{144}{60}\frac{Q}{\sqrt{2gH}}=0.3\frac{Q}{\sqrt{H}}$$

also

$$V=17.94F \text{ and } F=0.0557V.$$

Manufacturers formerly gave the vent of their wheels in conjunction with the rating tables, and water privileges are often deeded in the terms of the right to use a certain number of "square inches" of water from a stream or power canal. As commonly interpreted, this implies no definite coefficient of contraction, the owner being entitled to use as much water as can flow naturally through an orifice of a given area, under the existing head. The limiting value of the coefficient of discharge is unity.

In the use of scroll wheels, fed by short flumes leading out of the raceways, and having a contracted rectangular throat, the ventage agrees more or less closely with the area of the throat.

The vent of a turbine should not be confused with the area of the outlet orifice of the buckets. The actual discharge through a turbine is commonly from 40 to 60 per cent of the theoretical discharge of an orifice whose area equals the combined cross-sectional areas of the outlet ports measured in the narrowest section.

Table of square roots for calculating discharge and speed of turbines.

Head in feet.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.0000	0.3162	0.4472	0.5477	0.6324	0.7071	0.7745	0.8366	0.8944	0.9486
1	1.0000	1.0488	1.0954	1.1401	1.1832	1.2247	1.2649	1.3088	1.3416	1.3784
2	1.4142	1.4491	1.4832	1.5165	1.5491	1.5811	1.6124	1.6431	1.6733	1.7291
3	1.7320	1.7606	1.7888	1.8165	1.8439	1.8708	1.8973	1.9235	1.9493	1.9748
4	2.0000	2.0248	2.0493	2.0736	2.0976	2.1213	2.1447	2.1679	2.1908	2.2135
5	2.2360	2.2583	2.2803	2.3021	2.3237	2.3452	2.3664	2.3874	2.4083	2.4289
6	2.4494	2.4698	2.4899	2.5099	2.5298	2.5495	2.5690	2.5884	2.6076	2.6267
7	2.6457	2.6645	2.6832	2.7018	2.7202	2.7386	2.7568	2.7748	2.7928	2.8106
8	2.8284	2.8460	2.8635	2.8809	2.8982	2.9154	2.9325	2.9495	2.9664	2.9832
9	3.0000	3.0166	3.0331	3.0495	3.0659	3.0822	3.0983	3.1144	3.1304	3.1464
10	3.1622	3.1780	3.1937	3.2093	3.2249	3.2403	3.2557	3.2710	3.2863	3.3015
11	3.3166	3.3316	3.3466	3.3615	3.3763	3.3911	3.4058	3.4205	3.4351	3.4496
12	3.4641	3.4785	3.4928	3.5071	3.5213	3.5355	3.5496	3.5637	3.5777	3.5916
13	3.6055	3.6193	3.6331	3.6469	3.6606	3.6742	3.6878	3.7013	3.7148	3.7282
14	3.7416	3.7549	3.7682	3.7815	3.7947	3.8078	3.8209	3.8340	3.8470	3.8600
15	3.8729	3.8858	3.8987	3.9115	3.9242	3.9370	3.9496	3.9623	3.9749	3.9874
16	4.0000	4.0124	4.0249	4.0373	4.0496	4.0620	4.0743	4.0865	4.0987	4.1109
17	4.1231	4.1352	4.1472	4.1593	4.1713	4.1833	4.1952	4.2071	4.2190	4.2308
18	4.2426	4.2544	4.2661	4.2778	4.2895	4.3011	4.3127	4.3243	4.3358	4.3474
19	4.3588	4.3703	4.3817	4.3931	4.4045	4.4158	4.4271	4.4384	4.4971	4.4609
20	4.4721	4.4833	4.4944	4.5055	4.5166	4.5276	4.5387	4.5497	4.5607	4.5716
21	4.5825	4.5934	4.6043	4.6151	4.6260	4.6368	4.6475	4.6583	4.6690	4.6797
22	4.6904	4.7010	4.7116	4.7222	4.7328	4.7434	4.7539	4.7644	4.7749	4.7853
23	4.7958	4.8062	4.8166	4.8270	4.8373	4.8476	4.8579	4.8682	4.8785	4.8887
24	4.8989	4.9091	4.9193	4.9295	4.9396	4.9497	4.9598	4.9699	4.9799	4.9899
25	5.0000	5.0099	5.0199	5.0299	5.0398	5.0497	5.0596	5.0695	5.0793	5.0892
26	5.0990	5.1088	5.1185	5.1283	5.1380	5.1478	5.1575	5.1672	5.1768	5.1865
27	5.1961	5.2057	5.2153	5.2249	5.2345	5.2440	5.2535	5.2630	5.2725	5.2820
28	5.2915	5.3009	5.3103	5.3197	5.3291	5.3385	5.3478	5.3572	5.3665	5.3758
29	5.3851	5.3944	5.4037	5.4129	5.4221	5.4313	5.4405	5.4977	5.4589	5.4680
30	5.4772	5.4863	5.4954	5.5045	5.5136	5.5226	5.5317	5.5407	5.5497	5.5587
31	5.5677	5.5767	5.5856	5.5946	5.6035	5.6124	5.6213	5.6302	5.6391	5.6480
32	5.6568	5.6656	5.6745	5.6833	5.6920	5.7008	5.7096	5.7183	5.7271	5.7358
33	5.7445	5.7532	5.7619	5.7706	5.7792	5.7879	5.7965	5.8051	5.8137	5.8223
34	5.8309	5.8395	5.8480	5.8566	5.8651	5.8736	5.8821	5.8906	5.8991	5.9076
35	5.9160	5.9245	5.9329	5.9413	5.9497	5.9581	5.9665	5.9749	5.9833	5.9916
36	6.0000	6.0083	6.0166	6.0249	6.0332	6.0415	6.0497	6.0580	6.0663	6.0745
37	6.0827	6.0909	6.0991	6.1073	6.1155	6.1237	6.1318	6.1400	6.1481	6.1562
38	6.1644	6.1725	6.1806	6.1886	6.1967	6.2048	6.2128	6.2209	6.2289	6.2369
39	6.2449	6.2529	6.2609	6.2689	6.2769	6.2849	6.2928	6.3007	6.3087	6.3166
40	6.3245	6.3324	6.3403	6.3482	6.3560	6.3639	6.3718	6.3796	6.3874	6.3953

Table of square roots for calculating discharge and speed of turbines—Continued.

Head in feet.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
41	6.4031	6.4109	6.4187	6.4265	6.4342	6.4420	6.4498	6.4575	6.4652	6.4730
42	6.4807	6.4884	6.4961	6.5038	6.5115	6.5192	6.5268	6.5345	6.5421	6.5498
43	6.5574	6.5650	6.5726	6.5802	6.5878	6.5954	6.6030	6.6105	6.6181	6.6257
44	6.6332	6.6407	6.6483	6.6558	6.6633	6.6708	6.6783	6.6858	6.6932	6.7007
45	6.7082	6.7156	6.7230	6.7305	6.7379	6.7453	6.7527	6.7601	6.7675	6.7749
46	6.7823	6.7896	6.7970	6.8044	6.8117	6.8190	6.8264	6.8337	6.8410	6.8483
47	6.8556	6.8629	6.8702	6.8774	6.8847	6.8920	6.8992	6.9065	6.9137	6.9209
48	6.9282	6.9354	6.9426	6.9498	6.9570	6.9641	6.9713	6.9785	6.9856	6.9928
49	7.0000	7.0071	7.0142	7.0213	7.0285	7.0356	7.0427	7.0498	7.0569	7.0639
50	7.0710	7.0781	7.0851	7.0922	7.0992	7.1063	7.1133	7.1203	7.1274	7.1344
51	7.1414	7.1484	7.1554	7.1624	7.1693	7.1763	7.1833	7.1902	7.1972	7.2041
52	7.2111	7.2180	7.2249	7.2318	7.2387	7.2456	7.2525	7.2594	7.2663	7.2732
53	7.2801	7.2869	7.2938	7.3006	7.3075	7.3143	7.3212	7.3280	7.3348	7.3416
54	7.3484	7.3552	7.3620	7.3688	7.3756	7.3824	7.3891	7.3959	7.4027	7.4094
55	7.4161	7.4229	7.4296	7.4363	7.4431	7.4498	7.4565	7.4632	7.4699	7.4766
56	7.4833	7.4899	7.4966	7.5033	7.5099	7.5166	7.5232	7.5299	7.5365	7.5432
57	7.5498	7.5564	7.5630	7.5696	7.5762	7.5828	7.5894	7.5960	7.6026	7.6092
58	7.6157	7.6223	7.6288	7.6354	7.6419	7.6485	7.6550	7.6615	7.6681	7.6746
59	7.6811	7.6876	7.6941	7.7006	7.7071	7.7136	7.7201	7.7265	7.7330	7.7395
60	7.7459	7.7524	7.7588	7.7653	7.7717	7.7781	7.7846	7.7910	7.7974	7.8038
61	7.8102	7.8166	7.8230	7.8294	7.8358	7.8421	7.8485	7.8549	7.8612	7.8676
62	7.8740	7.8803	7.8866	7.8930	7.8993	7.9056	7.9120	7.9183	7.9246	7.9309
63	7.9372	7.9435	7.9498	7.9561	7.9624	7.9686	7.9749	7.9812	7.9874	7.9937
64	8.0000	8.0062	8.0124	8.0187	8.0249	8.0311	8.0374	8.0436	8.0498	8.0560
65	8.0622	8.0684	8.0746	8.0808	8.0870	8.0932	8.0993	8.1055	8.1117	8.1178
66	8.1240	8.1301	8.1363	8.1424	8.1486	8.1547	8.1608	8.1670	8.1731	8.1792
67	8.1853	8.1914	8.1975	8.2036	8.2097	8.2158	8.2192	8.2280	8.2340	8.2401
68	8.2462	8.2522	8.2583	8.2643	8.2704	8.2764	8.2825	8.2885	8.2945	8.3006
69	8.3066	8.3126	8.3186	8.3246	8.3306	8.3366	8.3426	8.3486	8.3546	8.3606
70	8.3666	8.3725	8.3785	8.3845	8.3904	8.3964	8.4023	8.4083	8.4142	8.4202
71	8.4261	8.4320	8.4380	8.4439	8.4498	8.4557	8.4616	8.4675	8.4734	8.4793
72	8.4852	8.4911	8.4970	8.5029	8.5088	8.5146	8.5205	8.5264	8.5322	8.5381
73	8.5440	8.5498	8.5556	8.5615	8.5673	8.5732	8.5790	8.5848	8.5906	8.5965
74	8.6023	8.6081	8.6139	8.6197	8.6255	8.6313	8.6371	8.6429	8.6486	8.6544
75	8.6602	8.6662	8.6717	8.6775	8.6833	8.6890	8.6948	8.7005	8.7063	8.7120
76	8.7177	8.7235	8.7292	8.7349	8.7407	8.7464	8.7521	8.7578	8.7635	8.7692
77	8.7749	8.7806	8.7863	8.7920	8.7977	8.8034	8.8090	8.8147	8.8204	8.8260
78	8.8317	8.8374	8.8430	8.8487	8.8543	8.8600	8.8656	8.8713	8.8769	8.8825
79	8.8881	8.8938	8.8994	8.9050	8.9106	8.9162	8.9218	8.9274	8.9330	8.9386
80	8.9442	8.9498	8.9554	8.9610	8.9666	8.9721	8.9777	8.9833	8.9888	8.9944
81	9.0000	9.0055	9.0111	9.0166	9.0221	9.0277	9.0332	9.0388	9.0443	9.0498
82	9.0553	9.0609	9.0664	9.0719	9.0774	9.0829	9.0884	9.0939	9.0994	9.1049
83	9.1104	9.1159	9.1214	9.1268	9.1323	9.1378	9.1433	9.1487	9.1542	9.1596
84	9.1651	9.1706	9.1760	9.1815	9.1869	9.1923	9.1978	9.2032	9.2086	9.2141
85	9.2195	9.2249	9.2303	9.2357	9.2412	9.2466	9.2520	9.2574	9.2628	9.2682
86	9.2736	9.2790	9.2843	9.2897	9.2951	9.3005	9.3059	9.3112	9.3166	9.3220
87	9.3273	9.3327	9.3380	9.3434	9.3487	9.3541	9.3594	9.3648	9.3701	9.3754
88	9.3808	9.3861	9.3914	9.3968	9.4021	9.4074	9.4127	9.4180	9.4233	9.4286
89	9.4339	9.4392	9.4445	9.4498	9.4551	9.4604	9.4657	9.4710	9.4762	9.4815
90	9.4868	9.4921	9.4973	9.5026	9.5078	9.5131	9.5184	9.5236	9.5289	9.5341

Table of square roots for calculating discharge and speed of turbines—Continued.

Head in feet.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
91	9.5393	9.5446	9.5498	9.5551	9.5603	9.5655	9.5707	9.5760	9.5812	9.5864
92	9.5916	9.5968	9.6020	9.6072	9.6124	9.6176	9.6228	9.6280	9.6332	9.6384
93	9.6436	9.6488	9.6540	9.6591	9.6643	9.6695	9.6747	9.6798	9.6850	9.6902
94	9.6953	9.7005	9.7056	9.7108	9.7159	9.7211	9.7262	9.7313	9.7365	9.7416
95	9.7467	9.7519	9.7570	9.7621	9.7672	9.7724	9.7775	9.7826	9.7877	9.7928
96	9.7979	9.8030	9.8081	9.8132	9.8183	9.8234	9.8285	9.8336	9.8386	9.8437
97	9.8488	9.8539	9.8590	9.8640	9.8691	9.8742	9.8792	9.8843	9.8893	9.8944
98	9.8994	9.9045	9.9095	9.9146	9.9196	9.9247	9.9297	9.9347	9.9398	9.9448
99	9.9498	9.9548	9.9599	9.9649	9.9699	9.9749	9.9799	9.9849	9.9899	9.9949
100	....	....	....	....	....	....	....	....	....	....

Table of $H^{\frac{3}{2}}$ for calculating horsepower of turbines.[a]

Head in feet.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.0000	0.0316	0.0894	0.1643	0.2530	0.3536	0.4648	0.5857	0,7155	0.8538
1	1.0000	1.1537	1.3145	1.4822	1.6565	1.8371	2.0238	2.2165	2.4150	2.6190
2	2.8284	3.0432	3.2631	3.4881	3.7181	3.9529	4.1924	4.4366	4.6853	4.9385
3	5.1962	5.4581	5.7243	5.9947	6.2693	6.5479	6.8305	7.1171	7.4076	7.7019
4	8.0000	8.3019	8.6074	8.9167	9.2295	9.5459	9.8659	10.1894	10.5163	10.8466
5	11.1803	11.5174	11.8578	12.2015	12.5485	12.8986	13.2520	13.6086	13.9682	14.3311
6	14.6969	15.0659	15.4379	15.8129	16.1909	16.5718	16.9557	17.3425	17.7322	18.1248
7	18.5203	18.9185	19.3196	19.7235	20.1302	20.5396	20.9518	21.3666	21.7842	22.2045
8	22.6274	23.0530	23.4812	23.9121	24.3455	24.7815	25.2202	25.6613	26.1050	26.5523
9	27.0000	27.4512	27.9050	28.3612	28.8199	29.2810	29.7445	30.2105	30.6789	31.1496
10	31.6228	32.0983	32.5762	33.0564	33.5390	34.0239	34.5111	35.0006	35.4924	35.9865
11	36.4829	36.9815	37.4824	37.9855	38.4908	38.9984	39.5082	40.0202	40.5343	41.0507
12	41.5692	42.0910	42.6128	43.1388	43.6648	44.1952	44.7256	45.2600	45.7944	46.3332
13	46.8720	47.4148	47.9576	48.5048	49.0520	49.6032	50.1544	50.7096	51.2648	51.8240
14	52.3832	52.9464	53.5096	54.0768	54.6440	55.2152	55.7864	56.3616	56.9368	57.5156
15	58.0944	58.6776	59.2608	59.8472	60.4336	61.0244	61.6152	62.2096	62.8040	63.4020
16	64.0000	64.6020	65.2040	65.8096	66.4152	67.0244	67.6336	68.2464	68.8592	69.4760
17	70.0928	70.7132	71.3336	71.9572	75.5808	73.2084	73.8360	74.4672	75.0984	75.7328
18	76.3672	77.0056	77.6440	78.2856	78.9272	79.5724	80.2176	80.8664	81.5152	82.1672
19	82.8192	83.4748	84.1304	84.7892	85.4480	86.1104	86.7728	87.4384	88.1040	88.7732
20	89.4424	90.1152	90.7880	91.4636	92.1392	92.8184	93.4976	94.1800	94.8624	95.5484
21	96.2344	96.9232	97.6120	98.3044	98.9968	99.6924	100.3880	101.0868	101.7856	102.4872
22	103.1883	103.8940	104.6008	105.3076	106.0160	106.7276	107.4392	108.1540	108.8688	109.5864
23	110.3040	111.0248	111.7456	112.4700	113.1944	113.9216	114.6488	115.3788	116.1088	116.8420
24	117.5752	118.3128	119.0496	119.7876	120.5272	121.2696	122.0120	122.7576	123.5032	124.2516
25	125.0000	125.7516	126.5032	127.2576	128.0120	128.7706	129.5292	130.2876	131.0480	131.8112
26	132.5744	133.3408	134.1072	134.8764	135.6456	136.4180	137.1904	137.9652	138.7400	139.5180
27	140.2960	141.0768	141.8576	142.6416	143.4256	144.2120	144.9984	145.7880	146.5776	147.3700
28	148.1624	148.9572	149.7520	150.5500	151.3480	152.1488	152.9496	153.7532	154.5568	155.3632
29	156.1696	156.9788	157.7880	158.6000	159.4120	160.2268	161.0416	161.8588	162.6760	163.4964
30	164.3168	165.1396	165.9624	166.7884	167.6144	168.4428	169.2712	170.1020	170.9328	171.7668

[a] Original.

Table of $H^{\frac{3}{2}}$ for calculating horsepower of turbines—Continued.[a]

Head in feet.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
31........	172.6008	173.4372	174.2736	175.1128	175.9520	176.7940	177.6360	178.4804	179.3248	180.1720
32........	181.0192	181.8692	182.7192	183.5716	184.4240	185.2792	186.1344	186.9920	187.8496	188.7100
33........	189.5704	190.4336	191.2968	192.1624	193.0280	193.8960	194.7640	195.6348	196.5056	197.3788
34........	198.2520	199.1460	200.0400	200.9008	201.7616	202.6424	203.5232	204.4068	205.2904	206.1764
35........	207.0624	207.9512	208.8400	209.7312	210.6224	211.5204	212.4184	213.3104	214.2024	215.1012
36........	216.0000	216.9012	217.8024	218.7060	219.6096	220.5760	221.4224	222.3312	223.2400	224.1512
37........	225.0624	225.9760	226.8896	227.8056	228.7216	299.6404	230.5592	231.4800	232.4008	233.3244
38........	234.2480	235.1736	236.0992	237.0276	237.9560	238.8868	239.8176	240.7508	241.6840	242.6196
39........	243.5552	244.4932	245.4312	246.3712	247.3112	248.2540	249.1968	250.1420	251.0872	252.0348
40........	252.9824	253.9320	254.8816	255.8340	256.7864	257.7412	258.6960	259.6528	260.6096	261.5688
41........	262.5280	263.4896	264.4512	265.4152	266.3792	267.3456	268.3120	269.2804	270.2488	271.2200
42........	272.1912	273.1644	274.1376	275.1132	276.0888	277.0672	278.0456	279.6252	280.0048	280.9872
43........	281.9696	282.9544	283.9392	284.9264	285.9136	286.9028	287.8920	288.8836	289.8752	290.8692
44........	291.8632	292.8597	293.8552	294.8536	295.8520	296.8528	297.8536	298.8564	299.8592	300.8640
45........	301.8688	302.8764	303.8840	304.8936	305.9032	306.9148	307.9264	308.9404	309.9544	310.9708
46........	311.9872	313.0056	314.0240	315.0448	316.0656	317.0877	318.1112	319.0556	320.0000	321.1080
47........	322.2160	323.2452	324.2744	325.3060	326.3376	327.3716	328.4056	329.4416	330.4776	331.5156
48........	332.5536	333.5927	334.6333	335.4753	336.7188	337.7588	338.8051	339.8529	340.8972	341.9479
49........	343.0000	344.0486	345.0986	346.1500	347.2079	348.2622	349.3179	350.3750	351.4336	352.4886
50........	353.5500	354.6128	355.6720	356.7376	357.7996	358.8681	359.9329	360.9992	362.0719	363.1409
51........	364.2114	365.2832	366.3564	367.4311	368.5020	369.5794	370.6582	371.7333	372.8149	373.8927
52........	374.9772	376.0578	377.1397	378.2331	379.3078	380.3940	381.4815	382.5703	383.6606	384.7522
53........	385.8453	386.9343	388.0301	389.1219	390.2205	391.3150	392.4163	393.5136	394.6122	395.7122
54........	396.8136	397.9163	399.0204	400.1258	401.2326	402.3408	403.4448	404.5557	405.6679	406.7759
55........	407.8855	409.0017	410.1139	411.2273	412.3477	413.4639	414.5814	415.7002	416.8204	417.9419
56........	419.0648	420.1833	421.3089	422.4257	423.5583	424.6879	425.8131	426.9453	428.0732	429.2080
57........	430.3386	431.4704	432.6036	433.7380	434.8738	436.0110	437.1494	438.2892	439.4302	440.5726
58........	441.7106	442.8556	443.9961	445.1438	446.2869	447.4372	448.5830	449.7300	450.8842	452.0359
59........	454.0849	455.3271	455.4907	456.6455	457.8017	458.9592	460.1179	461.2720	462.4334	463.5960
60........	464.7540	465.9192	467.0797	468.2475	469.4106	470.5750	471.7467	472.9137	474.0819	475.2514
61........	476.4222	477.3942	478.7676	479.9422	481.1181	482.2891	483.4676	484.6473	485.8222	487.0044
62........	488.1880	489.3666	490.5465	491.7339	492.9163	494.1000	495.2912	496.4774	497.6648	498.8536
63........	500.0436	501.2348	502.4273	503.6211	504.8161	506.0061	507.2036	508.4024	509.5961	510.7974
64........	512.0000	513.1974	514.3960	515.6024	516.8035	518.0059	519.2160	520.4209	521.6270	522.8344
65........	524.0430	525.2528	526.4639	527.6762	528.8898	530.1046	531.3120	532.5313	533.7498	534.9630
66........	536.1840	537.2996	538.6230	539.8411	541.0670	542.2875	543.5092	544.7389	545.9630	547.1884
67........	548.4151	549.6429	550.8720	552.1022	553.3337	554.5665	555.6179	557.0356	558.2652	559.5027
68........	560.7416	561.9748	563.2160	564.4516	565.6953	566.9334	568.1795	569.4199	570.6616	571.9113
69........	573.1554	574.4006	575.6473	576.8947	578.1436	579.3937	580.6449	581.8974	583.1510	584.4059
70........	585.6620	586.9122	588.1707	589.4303	590.6841	591.9462	593.2023	594.4668	595.7253	596.9921
71........	598.2531	599.5152	600.7856	602.0500	603.3157	604.5825	605.8505	607.1197	608.3901	609.6616
72........	610.9344	612.2083	613.4340	614.7596	616.0371	617.3085	618.5883	619.8692	621.0841	622.4274
73........	623.7120	624.9903	626.2699	627.5579	628.8398	630.1302	631.4144	632.6997	633.9862	635.2813
74........	636.5702	637.8602	639.1513	640.4437	641.7372	643.0318	644.3276	645.6246	646.9152	648.2145
75........	649.5150	650.8166	652.1118	653.4157	654.7208	656.0195	657.3268	658.6278	659.9375	661.2408
76........	662.5452	663.8583	665.1650	666.4728	667.7894	669.0996	670.4108	671.7131	673.0368	674.3514
77........	675.6673	676.9842	677.2043	679.6216	680.9419	682.2635	683.5784	684.9021	686.2271	687.5454
78........	688.8726	690.2009	691.5226	692.8532	694.1771	695.5100	696.8361	698.1713	699.4997	700.8292
79........	702.1599	703.4995	704.8324	706.1665	707.5016	708.8379	710.1752	711.5137	712.8534	714.1941
80........	715.5360	716.8789	718.2230	719.5683	720.9146	722.2540	723.6026	724.9523	726.2950	727.6496

Table of $H^{\frac{3}{2}}$ for calculating horsepower of turbines—Continued.

Head in feet.	0.0.	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
81........	729.0000	730.3460	731.7613	733.0495	734.3989	735.7575	737.1091	738.4699	739.8237	741.1876
82........	742.5346	743.8998	745.2580	746.6173	747.9776	749.3392	750.7018	752.0655	753.4303	754.7962
83........	756.1632	757.5312	758.9004	760.2624	761.6338	763.0063	764.3798	765.7461	767.1219	768.4904
84........	769.8684	771.2474	772.6192	774.0004	775.3743	776.7493	778.1338	779.5110	780.8892	782.2770
85........	783.6575	785.0389	786.4215	787.8052	789.1984	790.5843	791.9712	793.3591	794.7482	796.1383
86........	797.5296	798.9219	800.3066	801.7011	803.0966	804.4932	805.8909	807.2810	808.6808	810.0833
87........	811.4751	812.8781	814.2736	815.6788	817.0763	818.4837	819.8834	821.2929	822.6947	824.1064
88........	825.5704	826.9154	828.3214	829.7374	831.1456	832.5549	833.9652	835.3766	836.7890	838.2025
89........	839.6171	841.0327	842.4494	843.8671	845.2859	846.7058	848.1267	849.5487	850.9627	852.3868
90........	853.8120	855.2382	856.6564	858.0847	859.5051	860.9355	862.3670	863.7905	865.2241	866.6496
91........	868.0763	869.5130	870.9417	872.3806	873.8114	875.2432	876.6761	878.1192	879.5541	880.9901
92........	882.4272	883.8652	885.3044	886.7445	888.1857	889.6280	891.0712	892.5156	893.9609	895.4073
93........	896.8548	898.3032	899.7528	901.1946	902.6456	904.0982	905.5519	906.9972	908.4530	909.9097
94........	911.3582	912.8170	914.2675	915.7284	917.1809	918.6439	920.0985	921.5541	923.0202	924.4778
95........	925.9365	927.4056	928.8664	930.3281	931.7908	933.2642	934.7290	936.1948	937.6616	939.1295
96........	940.5984	942.0683	943.5392	945.0111	946.4841	947.9581	949.4331	950.9091	952.3764	953.8545
97........	955.3336	956.8136	958.2948	959.7672	961.2503	962.7345	964.2099	965.6961	967.1735	968.6617
98........	970.1412	971.6314	973.1129	974.6051	976.0886	977.5829	979.0684	980.5548	982.0522	983.5407
99........	985.0302	986.5206	988.0220	989.5145	991.0080	992.5025	993.9980	995.4945	996.9920	998.4905
100.......	1,000.0000	....	....	....	....	....	....	....	....	....

Rating table for Fourneyron turbines.

McELWAIN'S FOURNEYRON.[a]

Diameter of runner in inches.	Manufacturer's rating for a head of 16 feet.			Coefficients.		
	Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (= P).	Discharge (= F).	Speed (= N).
24.......	13.05	480	220.5	0.203	2.000	55.10
30.......	20.39	750	172.9	.318	3.125	43.20
36.......	29.37	1,080	143.9	.458	4.500	35.90
42.......	39.97	1,470	121.0	.624	6.125	30.20
48.......	52.22	1,920	106.0	.815	8.000	26.50
54.......	65.46	2,430	92.8	1.022	10.125	23.20
60.......	81.60	3,000	83.5	1.275	12.500	20.80
66.......	98.73	3,630	74.9	1.540	15.125	18.70
72.......	117.50	4,320	68.6	1.833	18.000	17.10
84.......	159.93	5,880	58.1	2.495	24.500	14.50
96.......	208.89	7,680	50.3	3.259	32.000	12.50
108......	264.38	9,720	44.3	4.124	40.500	11.07
120......	326.40	12,000	39.6	5.092	50.000	9.90

[a] Formerly made by H. S. McElwain & Co., Amsterdam, N. Y. Mounted in a quarter-turn iron case similar to the Boyden Fourneyron, with cylinder gate inside of guide ring.

Rating tables for scroll central-discharge turbines.

JOHN TYLER IMPROVED.[a]

[1869 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (= P).	Discharge (= F).	Speed (= N).		
9......	2	2.42	101	493	0.038	0.421	123.2	5	....
12......	2	4.24	177	363	.066	.738	90.7	10	....
14......	3	4.84	202	343	.076	.842	85.7	16	....
18......	9	10.90	456	246	.170	1.901	61.5	36	....
24......	5	20.30	849	181	.317	3.54	45.2	67	....
30......	2	30.30	1,267	144	.473	5.296	36.0	100	....
36......	2	45.45	1,900	121	.709	7.923	30.2	150	....
42......	2	60.60	2,534	104	.945	10.55	26.0	200	....
48......	2	78.78	3,293	90	1.229	13.719	22.5	260	....
60......	2	121.20	5,068	72	1.891	21.141	18.0	400	....
72......	2	151.50	6,333	60	2.363	26.396	15.0	500	....

REYNOLDS IMPROVED.[b]

Diameter of runner in inches.	Listed style or number.	Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (= P).	Discharge (= F).	Speed (= N).	Vent in square inches.	Weight in pounds.
12......	A.	....	48	....	....	0.200	....	....	200
12......	B.	....	80	....	....	.333	....	....	200
12......	1	....	144	....	....	.600	....	....	200
12......	2	....	180	....	....	.751	....	....	200
15......	1	....	216	....	....	.901	....	....	350
15......	2	....	276	....	....	1.151	....	....	350
18......	1	....	328	....	....	1.367	....	....	650
18......	2	....	408	....	....	1.701	....	....	650
18......	3	....	496	....	....	2.067	....	....	650
24......	1	....	652	....	....	2.718	....	....	1,200
24......	2	....	732	....	....	3.052	....	....	1,200
24......	3	....	876	....	....	3.653	....	....	1,200
30......	1	....	1,008	....	....	4.205	....	....	1,800
30......	2	....	1,208	....	....	5.033	....	....	1,800
30......	3	....	1,356	....	....	5.654	....	....	1,800
36......	1	....	1,320	....	....	5.504	....	....	2,700
36......	2	....	1,552	....	....	6.467	....	....	2,700
36......	3	....	1,980	....	....	8.257	....	....	2,700
42......	2	....	2,056	....	....	8.574	....	....	3,600
42......	3	....	2,288	....	....	9.541	....	....	3,600
48......	2	....	2,932	....	....	12.226	....	....	4,800
48......	3	....	3,296	....	....	13.744	....	....	4,800
48......	4	....	3,664	....	....	15.279	....	....	4,800
54......	2	....	3,960	....	....	16.513	....	....	6,000
54......	3	....	4,396	....	....	18.321	....	....	6,000
60......	2	....	4,580	....	....	19.099	....	....	8,600
60......	3	....	5,500	....	....	22.935	....	....	8,600

[a] Made by the Sullivan Machine Company, Claremont, N. H., usually with sliding gate in the throat, but also with a cylinder gate surrounding the runner within the scroll case. Has inward flow and discharges downward.

[b] Made by Kingsford Foundry and Machine Works, Oswego, N. Y. This turbine has an iron runner mounted in a boiler-iron scroll case, and a pivoted butterfly gate in the throat. The discharge is both upward and downward at the center, and the buckets protrude slightly from case.

Rating tables for scroll central-discharge turbines—Continued.

CARLEY HELICAL WHEEL.[a]

[1889 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
15......	....	6.80	280	326	0.106	1.168	81.50	21	....
18......	....	9.72	401	272	.152	1.672	68.0	30	....
21......	....	13.59	500	232	.212	2.085	58.0	42	....
24......	....	19.44	802	202	.303	3.344	50.5	60	....
28......	....	25.92	1,069	173	.404	4.458	43.2	80	....
36......	....	45.68	1,885	136	.713	7.860	34.0	141	....
50......	....	89.83	3,733	97	1.401	15.567	24.2	280	....

PERFECTION STANDARD.[b]

[1894 list.]

6......	....	1.32	49	806	0.021	0.204	201.5	3.5	100
8......	....	2.43	91	630	.038	.379	157.5	6.5	140
10......	....	3.70	157	480	.058	.655	120.0	9.0	200
12......	....	5.39	204	405	.084	.851	101.2	16.0	300
14......	....	7.83	284	350	.122	1.184	87.5	21.0	400
16......	....	9.89	348	315	.154	1.451	78.8	30.0	550
18......	....	11.94	482	276	.186	2.010	69.0	36.0	700
21......	....	16.82	624	245	.262	2.602	61.2	45.0	1,000
24......	....	20.99	785	206	.327	3.273	51.5	64.0	1,100
27......	....	26.68	1,062	186	.416	4.428	46.5	80.0	1,700
30......	....	32.92	1,310	167	.514	5.463	41.8	100.0	2,000
36......	....	47.47	1,886	140	.740	7.965	35.0	142.0	2,900
42......	....	67.90	2,715	120	1.059	11.322	30.0	203.0	4,500
48......	....	87.90	3,476	104	1.371	14.495	26.0	263.0	6,000
54......	....	110.80	4,426	93	1.728	18.456	23.2	....	....

DOUBLE PERFECTION WHEEL.[b]

[1894 list.]

6......	....	1.32	49	806	0.021	0.204	201.5	7.0	175
8......	....	2.43	91	630	.038	.379	157.5	13.0	285
10......	....	3.70	157	480	.058	.655	120.0	18.0	475
12......	....	5.39	204	405	.084	.851	101.2	32.0	650
14......	....	7.83	284	350	.122	1.184	87.5	42.0	950
16......	....	9.89	348	315	.154	1.451	78.8	60.0	1,040
18......	....	11.94	482	276	.186	2.010	69.0	72.0	1,500
21......	....	16.82	624	245	.262	2.602	61.2	190.0	2,000
24......	....	20.99	785	206	.327	3.273	51.5	128.0	2,180
27......	....	26.68	1,062	186	.416	4.428	46.5	160.0	2,770
30......	....	32.92	1,310	167	.514	5.463	41.7	200.0	3,290
36......	....	47.47	1,886	140	.741	7.865	35.0	284.0	....
42......	....	67.90	2,715	120	1.059	11.322	30.0	406.0	....
48......	....	87.90	3,476	104	1.373	14.495	26.0	....	....
54......	....	110.80	4,426	93	1.728	18.456	23.2	....	....

[a] Made by Alexander, Bradley & Dunning, Syracuse, N. Y. Has an iron runner set in an iron scroll case, discharging both upward and downward, and a pivoted butterfly gate in throat of case. There are no guides. Similar wheels are known by the names "Mahler" and "Cushing."

[b] Made by Craig Ridgway & Son, Coatesville, Pa. This has an inward flow and downward discharge. The buckets are curved in line of radius and slightly curved in line of axis at bottom. The Double Perfection turbine has a division plate and discharges both upward and downward. It has a sliding gate in the throat of scroll case.

Rating tables for scroll central-discharge turbines—Continued.

JONES LITTLE GIANT.[a]

[1890 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
6		2.2	91	642	0.034	0.379	160.5	6.8	
8		3.3	136	483	.051	.567	120.7	10.0	270
10½		6.6	272	376	.103	1.134	94.0	20.0	390
12		9.9	409	321	.154	1.706	80.2	30.0	525
14		14.8	614	276	.231	2.560	69.0	45.0	760
16		18.2	750	242	.284	3.128	60.5	56.0	950
18		26.4	1,090	214	.412	4.545	53.5	81.0	1,525
21		34.6	1,431	184	.540	5.967	46.0	107.0	1,950
24		44.6	1,840	161	.696	7.673	40.2	138.0	2,500
33		79.2	3,270	121	1.236	13.636	30.2	245.0	4,800
45		118.5	4,810	92	1.849	20.058	23.0		

JONES LITTLE GIANT.[a]

[1900 list.]

8	Double	3.23	134	507	0.050	0.559	126.8	10	
10	do	6.48	267	381	.101	1.113	95.2	20	
12	do	9.70	401	337	.151	1.672	84.2	30	
14	do	13.61	562	288	.212	2.344	74.0	42	
16	do	18.15	749	250	.283	3.123	62.5	56	
18	do	25.94	1,070	224	.405	4.462	56.0	80	
21	do	34.60	1,431	190	.540	5.967	47.5	107	
24	do	45.30	1,872	169	.707	7.806	42.2	140	
33	do	97.24	4,011	121	1.517	16.726	30.2	300	
44	Single	118.50	4,810	92	1.849	20.058	23.0	360	

[a] Made by Munson Brothers, Utica, N.Y. This wheel, as described in the trade list of 1890 is mounted in a scroll case with sliding gate in throat. The buckets are double curved and protrude from center of case. The runner has a division plate and discharges both at top and bottom of case. There are no guides. Wheels from similar patterns are made by J. C. Wilson & Co., Picton, Ontario. In 1895 Munson Brothers' patterns were destroyed by fire. The sizes and capacities of the new patterns, as shown by the later list, differ somewhat from the earlier ones, largely owing to their lower rating in efficiency. A peculiarity of the runner is a groove and swell forming a corrugation in the center of each bucket intended to guide the water through the wheel. Later wheels are also mounted in register-gate cases.

Rating tables for Jonval turbines.

McELWAIN JONVAL.[a]

[1871 list.]

Diameter of runner in inches	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
12	....	4.71	171	479	0.073	0.713	119.8	....	....
14	....	5.79	214	406	.090	.892	101.5	....	....
16	....	9.05	335	323	.141	1.397	80.7	....	....
18	....	12.69	471	300	.198	1.964	75.0	....	....
20	....	16.20	601	280	.253	2.501	70.0	....	....
25	....	21.74	807	230	.338	3.365	57.5	....	....
28	....	28.98	1,076	216	.452	4.464	54.0	....	....
30	....	38.04	1,413	202	.593	5.892	50.5	....	....
38	....	50.00	1,856	160	.780	7.740	40.0	160	....
44	....	65.21	2,420	144	1.017	10.091	36.0	220	....
48	....	79.71	2,959	116	1.240	12.339	29.0	292	....
50	....	94.20	3,497	106	1.470	14.582	26.5	....	....
55	....	115.94	4,304	101	1.809	17.948	25.2	....	....
60	....	144.94	5,381	86	2.261	22.438	21.5	....	....
72	....	217.41	8,061	73	3.392	33.614	18.2	....	....

BLOOMINGDALE, OR WAIT'S CHAMPION.[b]

Diameter of runner in inches	Listed style or number.	Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).	Vent in square inches.	Weight in pounds.
10	....	3.4	122	688	0.053	0.509	172.0	9	....
13	....	4.6	160	508	072	.667	127.0	12	....
17	....	7.6	280	372	.118	1.168	93.0	21	....
21	....	12.0	474	325	.187	1.976	81.2	35	....
24	....	18.0	678	276	.281	2.827	69.0	50	....
27	....	25.0	940	253	.390	3.920	63.2	70	....
30	....	34.0	1,220	242	.530	5.087	60.5	90	....
36	....	45.0	1,611	190	.702	6.718	47.5	120	....
40	....	56.0	2,034	172	.874	8.482	43.0	150	....
44	....	64.0	2,406	155	.998	10.033	38.7	180	....
48	....	72.0	2.710	133	1.123	11.301	33.2	200	....
54	....	93.0	3,531	122	1.451	14.724	30.5	260	....
60	....	107.0	4,068	102	1.670	16.964	25.5	300	....
72	....	181.0	6,783	86	2.824	28.285	21.5	500	....

[a] Made by H. S. McElwain & Co., Amsterdam, N. Y. Has outside register gate, similar to that of the Bodine Jonval.

[b] Made by Mc arthy & Doremus Manufacturing Company, Sandy Hill, N. Y. Has cast-iron Jonval runner and guide ring. Not usually provided with a gate, but erected in an iron or wooden penstock having a gate in the throat. Wheels from similar patterns were made by the Sandy Hill (N. Y.) Iron and Brass Works and by Ryther & Pringle, Carthage, N. Y.

Rating tables for Jonval turbines—Continued.

DIX IMPROVED JONVAL.[a]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
12		4.13	160	491	0.064	0.669	122.7	12.0	
18		10.33	401	327	.161	1.676	81.7	30.5	
20		13.77	535	294	.215	2.223	73.5	40.0	
24		19.28	749	270	.301	3.121	67.5	56.0	
30		30.99	1,203	216	.484	5.012	54.0	90.0	
36		46.49	1,805	164	.726	7.521	41.0	135.0	
40		55.09	2,139	147	.861	8.912	36.7	160.0	
48		77.48	3,008	123	1.210	12.533	30.7	225.0	
54		96.41	3,744	109	1.504	15.600	27.2	280.0	
60		120.51	4,679	108	1.880	19.496	27.0	350.0	
72		172.17	6,685	90	2.686	27.854	22.5	500.0	

OSGOOD IMPROVED JONVAL.[b]

[1883 list.]

12		4.54	160	540	0.071	0.669	135.0	12.0	
18		11.36	401	359	.177	1.676	89.8	30.5	
20		15.14	535	323	.236	2.223	80.8	40.0	
24		21.20	749	297	.331	3.121	74.2	56.0	
30		34.08	1,203	237	.531	5.012	59.2	90.0	
36		51.18	1,805	180	.798	7.521	45.0	135.0	
40		60.59	2,139	161	.945	8.912	40.2	160.0	
48		85.22	3,008	135	1.329	12.533	33.8	225.0	
54		106.05	3,744	119	1.654	15.600	29.8	280.0	
60		132.56	4,679	118	2.068	19.496	29.5	350.0	
72		189.38	6,685	99	2.954	27.854	24.8	500.0	

BODINE JONVAL.[c]

12		4.71	171	479	0.073	0.713	119.7	13	190
14		5.79	214	406	.090	.892	101.5	13	260
16		9.05	335	323	.141	1.397	80.7	25	370
18		12.69	471	300	.198	1.964	75.0	35	490
20		16.20	601	280	.253	2.506	70.0	45	650
25		21.74	807	230	.339	3.365	57.5	60	980
27		28.98	1,076	216	.452	4.487	54.0	80	1,150
30		38.04	1,413	202	.593	5.892	50.5	105	1,350
35		50.00	1,856	160	.780	7.740	40.0	138	1,680
40		65.21	2,420	144	1.017	10.091	36.0	180	2,075
45		79.71	2,959	116	1.243	12.339	29.0	220	2,420
50		94.20	3,497	106	1.470	14.582	26.5	260	3,000
55		115.94	4,304	101	1.808	17.948	25.2	320	3,500
60		144.94	5,381	86	2.261	22.439	21.5	400	4,000
72		217.41	8,061	73	3.392	33.614	18.2	630	5,100

[a] Made by J. L. & S. B. Dix, Glens Falls, N. Y. This wheel has a cast-iron runner and guide ring. It has no case or gate, and is set in a penstock having a gate in the throat of the leading flume.

[b] Made by John Osgood, Fort Edward, N. Y. A cast-iron runner with guide ring is mounted in a wrought-iron penstock having a gate in the throat similar to that of the Chase Jonval.

[c] Made by Genesee Valley Manufacturing Company, successors to Bodine Manufacturing Company, Mount Morris, N. Y. Has a register gate over the guide chute entrance. The guides are thickened at the top, where they have a width equal to the breadth of the chute openings.

Rating tables for Jonval turbines—Continued.

CHASE IMPROVED JONVAL.[a]

[1897 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
12	Regular	5.47	240.6	576	0.085	1.003	144.0	18	....
15	do	7.90	347.4	462	.123	1.449	115.5	26	....
18	do	13.09	574.8	356	.204	2.397	89.0	43	....
21	do	16.40	721.8	308	.256	3.010	77.0	44	....
24	do	28.25	1,243.2	287	.441	5.184	71.7	93	....
27	do	35.55	1,564.2	254	.555	6.523	63.5	117	....
30	do	42.53	1,871.4	241	.663	7.804	60.2	140	....
36	do	56.21	2,472.6	197	.877	10.311	49.2	185	....
42	do	88.10	3,876.6	177	1.374	16.165	44.2	290	....
48	do	114.83	5,052.6	151	1.791	21.069	37.7	378	....
54	do	127.59	5,614.0	143	1.990	23.395	35.7	420	....
66	do	196.85	8,661.6	124	3.071	36.119	31.0	648	....
78	do	243.03	1,069.3	110	3.791	44.591	27.5	800	....
12	Special	8.64	379.0	658	.135	1.58	164.5	28	....
15	do	15.80	694.0	528	.246	2.894	132.0	52	....
18	do	24.23	1,069.0	411	.378	4.458	102.7	80	....
21	do	31.16	1,369.0	367	.486	5.709	91.7	102	....
24	do	42.37	1,864.0	328	.661	7.773	82.0	140	....
27	do	53.33	2,346.0	290	.832	9.783	72.5	175	....
30	do	60.59	2,673.0	276	.945	11.146	69.0	200	....
36	do	82.06	3,609.0	233	1.280	15.050	58.2	270	....
42	do	126.86	5,581.0	201	1.979	23.273	50.2	417	....
48	do	151.45	6,683.0	186	2.363	27.868	46.5	500	....
54	do	178.80	7,891.0	173	2.778	32.905	43.2	590	....
66	do	303.00	13,366.0	142	4.727	55.736	35.5	1,000	....
78	do	436.32	19,248.0	128	6.806	80.264	32.0	1,440	....

[a] Made by Chase Turbine Manufacturing Company, Orange, Mass. This is a parallel downward-flow turbine having a runner like that of the Jonval wheel, but with vanes curved both axially and radially. The runner is mounted in a wrought-iron penstock with a wicket gate in the throat.

Rating tables for register-gate turbines.

GATES CURTIS.[a]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet. Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Coefficients. Power (=P).	Discharge (=F).	Speed (=N).	Vent in square inches.	Weight in pounds.
20......	Regular..	9.33	597	....	0.295	3.146	....	57.2	....
20......	Register..	7.35	486	....	.232	2.561	....	46.0	....
25......	Regular..	14.54	923	....	.459	4.864	....	88.0	....
25......	Register..	11.30	748	....	.357	3.942	....	71.0	....
30......	Regular..	21.58	1,376	....	.682	7.252	....	130.8	....
30......	Register..	16.20	1,072	....	.512	5.649	....	101.0	....
35......	Regular..	32.16	2,051	....	1.016	10.809	....	193.7	....
35......	Register..	22.04	1,458	....	.696	7.684	....	138.0	....
40......	Regular..	41.60	2,653	....	1.315	13.981	....	250.8	....
40......	Register..	29.00	1,920	....	.916	10.118	....	182.0	....
48......	Regular..	62.07	3,960	....	1.961	20.869	....	374.4	....
48......	Register..	40.69	2,693	....	1.286	14.193	....	255.0	....
56......	Regular..	88.83	5,666	....	2.807	29.860	....	535.0	....

ECLIPSE DOUBLE.[b]

[1883 list.]

8......	....	2.22	94	616	0.035	0.392	154.0	7.0	....
10......	....	3.20	132	488	.050	.550	122.0	9.9	....
12½......	....	5.51	227	395	.086	.946	98.5	17.0	....
15......	....	7.20	297	327	.112	1.238	81.8	22.3	....
17½......	....	10.37	428	280	1.62	1.784	70.0	31.8	500
20......	....	17.52	721	244	.273	3.006	61.0	53.6	675
25......	....	24.46	1,010	197	.382	4.212	49.3	75.6	1,150
30......	....	33.55	1,384	164	.523	5.771	41.0	103.6	1,800
35......	....	52.46	2,160	140	.818	9.007	35.0	161.8	2,400
40......	....	67.36	2,778	122	1.051	11.584	30.5	208.0	3,300
48......	....	98.12	4,048	103	1.531	16.880	25.8	303.0	5,000
54......	....	128.16	5,293	91	2.000	22.072	22.8	396.0	6,725
60......	....	168.41	6,947	82	2.627	28.969	20.5	519.8	8,225
66......	....	214.10	8,818	74	3.340	36.771	18.5	660.0	10,000
72......	....	254.89	10,517	68	3.976	43.773	17.0	787.5	10,825

HELMER'S PATENT ROME.[c]

12......	....	7.00	300.0	426	0.109	1.250	106.5	22	....
15......	....	10.50	450.0	355	.161	1.875	88.7	33	....
18......	....	14.00	600.0	284	.218	2.500	71.0	45	....
21......	....	21.44	900.0	248	.335	3.750	62.0	67	....
24......	....	28.88	1,200.0	213	.451	5.000	53.2	90	....
30......	....	46.54	1,920.0	170	.726	8.000	42.5	144	....
36......	....	64.00	2,640.0	142	1.000	11.000	35.5	198	....
42......	....	84.02	3,466.2	122	1.310	14.442	30.5	260	....
48......	....	108.56	4,479.6	106	1.694	18.665	26.5	336	....

[a] Made by Gates Curtis, Ogdensburg, N.Y. A turbine of small capacity, commonly with an inside register gate. The water enters in an inward and downward direction and is discharged downward. The wheel closely resembles the Jonval type. According to the list the "regular" pattern of each size is built with cylinder gate.

[b] Made by Stillwell & Bierce Manufacturing Company, Dayton, Ohio. An inside register-gate turbine. The gate ring is of about the same thickness as the fixed outside guide ring. One-half of each guide is in the inner ring. The ends slide past each other in such manner as to give a continually contracting jet without sharp angles. The runner has central division plate. The buckets are curved slightly downward, but do not bulge outward.

[c] Made by S. Adams & Son, Rome, N.Y. A turbine of small capacity with inside register gate. Buckets curve radially, but discharge inward and downward.

Rating tables for register-gate turbines—Continued.

CASE NATIONAL IMPROVED.[a]

[1898 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
5	....	1.16	48	980	0.018	0.200	245.0	3.6	45
10	....	2.77	112	550	.043	.467	137.0	8.4	250
10	....	4.16	168	550	.065	.700	137.0	12.6	280
15	....	7.14	288	362	.111	1.201	90.5	21.6	530
15	....	9.54	385	362	.149	1.605	90.5	28.8	550
15	....	11.92	481	362	.186	2.006	90.5	36.0	600
20	....	12.72	513	266	.198	2.139	66.5	38.4	860
20	....	15.89	641	266	.248	2.673	66.5	48.0	880
20	....	19.09	770	266	.298	3.211	66.5	57.6	900
25	....	23.26	938	208	.363	3.911	52.0	70.2	1,500
25	....	31.02	1,251	208	.484	5.217	52.0	93.6	1,600
30	....	31.57	1,273	174	.492	5.308	43.5	96.0	2,000
30	....	36.60	1,476	174	.571	6.155	43.5	110.4	2,150
30	....	43.35	1,708	174	.675	7.122	43.5	127.8	2,200
40	....	56.69	2,286	132	.884	9.533	33.0	171.0	3,500
40	....	69.61	2,807	132	1.086	11.705	33.0	210.0	3,700
40	....	83.55	3,369	132	1.303	14.049	33.0	252.0	3,900
50	....	124.32	5,013	106	1.932	20.904	26.5	375.0	7,000
50	....	143.22	5,775	106	2.234	24.082	26.5	432.0	7,200
60	....	167.10	6,738	90	2.607	28.097	22.5	504.0	12,000
60	....	200.53	8,086	90	3.128	33.719	22.5	604.8	13,000

WETMORE.[b]

12	....	5.49	213	457	0.085	0.888	114.2	16	....
15	....	8.34	333	366	.130	1.388	91.5	25	....
18	....	11.70	467	305	.182	1.947	76.2	35	....
21	....	17.41	695	260	.272	2.898	65.0	52	....
24	....	24.47	976	228	.382	4.070	57.0	73	....
27	....	30.16	1,203	201	.471	5.016	50.2	90	....
30	....	37.70	1,497	182	.589	6.242	45.5	112	....
36	....	54.29	2,167	153	.848	9.036	38.2	162	....
42	....	81.44	3,251	130	1.272	13.566	32.5	243	....
48	....	112.20	4,479	114	1.753	18.677	28.5	334	....
54	....	137.09	5,472	101	2.142	22.818	25.2	409	....
60	....	191.38	7,639	91	2.990	31.855	22.7	571	....

[a] Made by the Case Wheel and Mill Company, Bristol, Conn. This wheel has buckets of medium depth, moderately curved both in line of radius and parallel to axis, but not protruding below lower outside band of runner, which can be lifted from case vertically. Runner resembles that of the Swain turbine; has inside register gate. One-half of each quadrant of wheel is entirely closed, the other half contains four guides. The register gate fits against the closed portion of guide ring when wheel is open, leaving four openings opposite the guide chutes which are completely shut off one after another as register ring is moved over them.

[b] Made by Sullivan Machine Company, Claremont, N. H. This turbine has outside register gate. The buckets are large and the guide chutes few in number. The buckets are curved axially and radially, but do not protrude beyond the lower rim band of runner.

Rating tables for register-gate turbines—Continued.

FLENNIKEN.[a]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
8		2.76	115	760	0.043	0.480	190.0	8	130
10		3.80	157	608	.059	.655	152.0	11	210
12		5.58	234	506	.087	.976	126.5	16	333
14		6.61	270	435	.103	1.126	108.8	19	380
16		8.74	367	380	.136	1.530	95.0	25	460
18		12.34	500	338	.192	2.085	84.5	35	600
21		15.34	669	304	.239	2.790	76.0	47	800
22½		19.35	794	270	.302	3.311	67.5	55	940
25		25.85	1,058	243	.403	4.412	60.8	73	1,110
30		34.34	1,406	203	.536	5.863	50.8	96	1,500
35		45.30	1,909	173	.707	7.960	43.2	130	2,200
40		65.15	2,678	152	1.016	11.167	38.0	182	2,900
45		83.67	3,526	135	1.305	14.703	33.8	240	3,750
50		118.99	4,948	122	1.856	20.633	30.5	336	5,000
55		139.90	5,878	114	2.182	24.511	28.5	400	6,100
60		184.73	7,554	102	2.882	31.500	25.5	514	7,300
72		243.85	9,961	85	3.804	41.537	21.2	702	11,000

HUMPHREY STANDARD IXL.[b]

[1898 list.]

12		4.6	150	400	0.072	0.626	100.0		
15		7.1	236	320	.1110	.984	80.0		
18		10.2	340	267	.160	1.418	66.7		
21		14.0	464	229	.218	1.935	57.2		
24		18.3	604	200	.285	2.519	50.0		
27		23.1	765	178	.360	3.190	44.5		
30		28.5	945	160	.445	3.941	40.0		
33		34.5	1,144	145	.538	4.770	36.2		
36		41.1	1,360	133	.641	5.671	33.2		
42		56.0	1,852	115	.874	7.723	28.7		
48		73.1	2,420	100	1.142	10.091	25.0		
54		92.5	3,064	89	1.443	12.777	22.2		
60		114.2	3,780	80	1.782	15.763	20.0		
68		146.3	4,838	71	2.282	20.158	17.7		
78		195.0	6,450	62	3.042	26.897	15.5		
88		243.8	8,064	52	3.803	33.627	13.0		
100		318.7	10,550	48	4.972	43.994	12.0		

[a] Made by Dubuque Turbine and Roller Mill Company, Dubuque, Iowa. An inside register-gate turbine of moderate capacity.
[b] See footnote (*a*) on following page.

Rating tables for register-gate turbines—Continued.

HUMPHREY STANDARD XLCR.[a]

[1898 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
6	....	2.3	75	800	0.036	0.313	200.0	....	....
8	....	4.0	134	600	.062	.559	150.0	....	....
10	....	6.3	210	480	.098	.876	120.0	....	....
12	....	9.1	302	400	.142	1.259	100.0	....	....
15	....	14.3	473	320	.223	1.972	80.0	....	....
18	....	20.5	680	267	.320	2.836	66.8	....	....
21	....	28.0	926	229	.437	3.861	57.2	....	....
24	....	36.5	1,210	200	.569	5.046	50.0	....	....
27	....	46.2	1,532	178	.721	6.388	44.5	....	....
30	....	57.1	1,890	160	.891	7.881	40.0	....	....
33	....	69.0	2,288	145	1.076	9.541	36.2	....	....
36	....	82.2	2,720	133	1.282	10.134	33.2	....	....
42	....	112.0	3,704	115	1.747	15.446	28.8	....	....
48	....	146.2	4,840	100	2.281	20.183	25.0	....	....
54	....	185.0	6,064	89	2.886	25.287	22.2	....	....
60	....	228.4	7,560	80	3.563	31.525	20.0	....	....
68	....	292.6	9,676	71	4.565	40.349	17.8	....	....

BURNHAM'S NEW IMPROVED STANDARD.[b]

[1900 list.]

9	....	4.41	178	540	0.068	0.742	135.0	13.3	160
10½	....	6.03	244	463	.094	1.017	115.8	18.3	185
12	....	7.89	318	405	.123	1.326	101.2	23.7	290
13½	....	9.97	402	360	.156	1.676	90.0	30.0	370
15	....	12.30	497	324	.192	2.072	81.0	37.3	450
16½	....	14.88	600	295	.231	2.502	73.8	44.8	580
18	....	17.70	714	270	.276	2.977	67.5	53.4	640
21	....	24.11	972	232	.376	4.053	58.0	72.7	956
24	....	31.47	1,259	203	.491	5.292	50.8	94.0	1,260
27	....	39.87	1,608	180	.622	6.705	45.0	120.3	1,600
30	....	49.22	1,984	162	.768	8.273	40.5	14[illegible].5	2,000
36	....	70.90	2,859	135	1.106	11.922	33.8	213.7	2,850
42	....	101.5	4,087	116	1.583	17.043	29.0	[illegible]5.7	4,080
48	....	131.1	5,289	101	2.045	22.055	25.2	395.4	6,000
54	....	165.4	6,670	90	2.580	27.814	22.5	498.9	6,900
60	....	203.4	8,203	82	3.173	34.206	20.5	613.5	8,900

[a] Made by Humphrey Machine Company, Keene, N. H. The IXL is a flume wheel. The XLCR is similar, but is mounted in pairs on horizontal shaft with central draft tube. A register ring of the ordinary type lies between the guide ring and runner. About this the guide ring revolves, giving in effect a register gate. The upper and lower rims of the guide ring are boldly curved, and the guide vanes are few and give long curved chutes. Manufacturers' power table is based on the theoretical power of the water, and the quantities are to be multiplied by an efficiency factor to get net power.

[b] Made by Burnham Brothers, York, Pa. This is an inside register-gate turbine. The buckets are not deep, and the vanes curve axially at bottom. The stated weights are for wheels with worm gate gearing.

Rating tables for register-gate turbines—Continued.

BALANCED GATE.[a]

[1895 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
6	....	1.86	76	790	0.029	0.317	197.5	....	....
8	....	3.36	138	604	.052	.575	151.0	....	....
10	....	5.28	217	486	.082	.905	121.5	....	180
12	....	7.66	312	406	.119	1.301	101.5	....	260
14	....	10.38	426	348	.162	1.776	87.0	....	360
16	....	13.60	558	306	.212	2.327	76.5	....	530
18	....	17.27	708	274	.269	2.952	68.5	....	690
21	....	23.58	967	236	.368	4.032	59.0	....	840
24	....	31.85	1,267	206	.497	5.283	51.5	....	1,170
27	....	39.28	1,606	184	.613	6.697	46.0	....	1,540
30	....	48.78	1,988	166	.761	8.290	41.5	....	1,710
33	....	58.87	2,410	150	.918	10.050	37.5	....	2,400
36	....	70.74	2,874	138	1.104	11.984	34.5	....	3,100
42	....	96.74	3,930	120	1.509	16.388	30.0	....	4,000
48	....	127.1	5,164	105	1.983	21.534	26.2	....	5,700
54	....	161.8	6,574	94	2.524	27.414	23.5	....	6,800
60	....	200.6	8,150	85	3.129	33.986	21.25	....	8,500
66	....	243.8	9,908	77	3.803	41.316	19.2	....	10,500
72	....	291.4	11,804	72	4.546	49.223	18.0	....	13,000

ALCOTT'S HIGH DUTY.[b]

[1898 list.]

10	Standard.	4.1	160	484	0.064	0.667	121.0	12	165
10	Special....	9.95	397	484	.155	1.655	121.0	30	275
12	Standard.	5.7	223	403	.089	.930	100.7	17	225
12	Special....	13.00	540	403	.203	2.252	100.7	41	400
13	Standard.	7.2	281	378	.112	1.172	94.5	21	275
13	Special....	16.45	681	378	.257	2.840	94.5	51	475
15	Standard.	8.1	334	337	.126	1.393	84.2	25	325
15	Special....	20.29	845	337	.317	3.524	84.2	63	550
18	Standard.	12.2	508	276	.190	2.118	69.0	38	500
18	Special....	29.25	1,217	276	.456	5.075	69.0	91	850
21	Standard.	18.9	762	234	.295	3.178	58.5	57	750
21	Special....	39.80	1,656	234	.621	6.906	58.5	124	1,250
24	Standard.	24.8	968	209	.387	4.036	52.2	73	950
24	Special....	52.00	2,164	209	.811	9.024	52.2	162	1,600
27	Standard.	29.3	1,140	188	.457	4.754	47.0	89	1,200
27	Special....	65.80	2,724	188	1.026	11.359	47.0	204	2,050
30	Standard.	43.9	1,818	166	.685	7.581	41.5	137	1,800
30	Special....	81.17	3,381	166	1.266	14.099	41.5	253	3,050
30	Medium..	62.0	2,406	166	.967	10.033	41.5	180	....
36	Standard.	63.2	2,616	139	.986	10.909	34.7	195	2,600

[a] Made by the Christiana Machine Company, Christiana, Pa. Has inside register gates. The buckets are nearly straight, curving slightly at the bottom.

[b] Made by T. C. Alcott & Son, Mount Holly, N. J., in regular and special styles. The regular style has a cylindrical runner similar to that of the Swain. The special style has bulging buckets extending the discharge area outside of nominal diameter, as in McCormick and Victor. Inside register gate.

Rating tables for register-gate turbines—Continued.

ALCOTT'S HIGH DUTY—Continued.

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
36......	Special....	117.00	4,868	139	1.825	20.300	34.7	365	4,400
42......	Standard.	79.3	3,182	118	1.237	13.269	29.5	238	3,700
42......	Special....	159.20	6,624	118	2.484	27.622	29.5	495	6,300
48......	Standard.	117.5	4,742	103	1.833	19.774	25.7	354	5,000
48......	Special....	208.00	8,656	103	3.24	36.096	25.7	648	7,500
54......	....	174.5	6,958	92	2.722	29.015	23.0	531	5,800
60......	....	208.5	8,622	83	3.253	35.954	20.7	645	7,860
66......	....	278.2	11,450	76	4.340	47.746	19.0	869	9,300

LESNER'S IMPROVED.[a]

[1898 list.]

5 [b]	....	0.64	26.3	994	0.010	0.109	248.5	1.97	....
8 [b]	....	1.44	58.7	621	.022	.244	155.2	7.33	....
8......	....	2.36	97.8	621	.037	.407	155.2	4.40	....
8......	....	....	....	....	....	....	....	7.33	....
11......	....	4.29	177.6	452	.067	.740	113.0	13.27	....
11......	....	5.72	236.4	452	.089	.985	113.0	17.70	....
14......	....	7.60	314.4	355	.119	1.312	88.7	23.60	....
16½.....	....	7.44	307.8	302	.116	1.282	75.5	23.05	....
16½.....	....	9.52	393.6	302	.148	1.640	75.5	29.50	....
18......	....	9.74	403.2	276	.152	1.680	69.0	30.16	....
18......	....	12.19	504.0	276	.190	2.100	69.0	37.70	....
18......	....	14.63	604.8	276	.228	2.520	69.0	45.24	....
22......	....	16.55	684.0	226	.258	2.850	56.5	51.15	....
22......	....	22.07	912.0	226	.344	3.800	56.5	68.20	....
22......	....	27.58	1,140.0	226	.430	4.750	56.5	85.25	....
28......	....	31.50	1,302.0	178	.491	5.425	44.5	97.37	....
28......	....	38.50	1,591.2	178	.606	6.630	44.5	119.00	....
33......	....	40.83	1,687.2	151	.637	7.030	37.7	125.90	....
33......	....	49.00	2,024.4	151	.764	8.435	37.7	149.08	....
36......	....	54.61	2,256.6	138	.852	9.402	34.5	168.79	....
36......	....	63.71	2,632.8	138	.994	10.970	34.5	196.92	....
44......	....	73.51	3,037.8	113	1.147	12.658	28.2	227.22	....
44......	....	83.31	3,442.8	113	1.300	14.345	28.2	257.18	....
56......	....	97.30	4,023.0	89	1.518	16.762	22.2	300.88	....
56......	....	116.80	4,827.0	89	1.811	20.112	22.2	361.05	....
56......	....	142.75	5,899.8	89	2.227	24.582	22.2	441.44	....

[a] Made by Fultonville Foundry Company, successors to William B. Wemple's Sons, Fultonville, N. Y. This is an inside register-gate turbine, with buckets curving axially at bottom but not protruding below lower rim band of runner, which can be lifted out of the case vertically. This turbine has been extensively used to operate boat winches at locks on the Erie Canal.

[b] Brass runner for large heads.

Rating tables for register-gate turbines—Continued.

RISDON CYLINDER- AND REGISTER GATE-TURBINES.[a]

[1896 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
12......	X.	1.72	66.8	404	0.027	0.278	101.0	5.0	....
12......	XX.......	2.75	107.0	404	.043	.446	101.0	8.0	....
12......	XXX.....	3.39	140.0	404	.053	.584	101.0	10.5	....
12......	Standard.	4.80	187.0	404	.075	.780	101.0	14.0	....
12......	T. C......	6.2	240.0	404	.097	1.001	101.0	18.0	....
12......	D. C......	7.20	281.0	404	.112	1.172	101.0	21.0	....
16......	Standard.	7.20	281.0	314	.112	1.172	78.5	21.0	....
16......	T. C......	12.4	481.0	314	.193	2.006	78.5	36.0	....
16......	D. C......	14.40	562.0	314	.225	2.344	78.5	42.0	....
20......	Standard.	12.4	481.0	264	.193	2.006	66.0	36.0	....
20......	T. C......	18.6	722.0	264	.290	3.011	66.0	54.0	....
20......	D. C......	24.8	962.0	264	.387	4.012	66.0	72.0	....
25......	Standard.	18.6	722.0	218	.290	3.011	54.5	54.0	....
25......	T. C......	31.0	1,203.0	218	.484	5.016	54.5	90.0	....
25......	D. C......	43.0	1,669.0	218	.671	6.960	54.5	125.0	....
30......	Standard.	31.0	1,203.0	188	.484	5.016	47.0	90.0	....
30......	T. C......	43.0	1,669.0	188	.671	6.960	47.0	125.0	....
30......	D. C......	68.0	2,646.0	188	1.061	11.034	47.0	200.0	....
36......	Standard.	43.0	1,669.0	157	.671	6.960	39.2	125.0	....
36......	T. C......	58.4	2,272.0	157	.911	9.474	39.2	170.0	....
36......	D. C......	96.2	3,743.0	157	1.500	15.608	39.2	280.0	....
40......	Standard.	58.4	2,272.0	142	.911	9.474	35.5	170.0	....
40......	T. C......	75.6	2,941.0	142	1.179	12.264	35.5	220.0	....
40......	D. C......	116.8	4,544.0	142	1.825	18.948	35.5	340.0	....
43......	Standard.	75.6	2,941.0	132	1.179	12.264	33.0	220.0	....
43......	T. C......	96.2	3,743.0	132	1.501	15.608	33.0	280.0	....
43......	D. C......	151.2	5,882.0	132	2.359	24.528	33.0	440.0	....
50......	Standard.	96.2	3,743.0	113	1.501	15.608	28.2	280.0	....
50......	T. C......	146.0	5,681.0	113	2.278	23.690	28.2	425.0	....
50......	D. C......	192.4	7,486.0	113	3.001	31.217	28.2	560.0	....
54......	Standard.	120.3	4,671.0	105	1.877	19.478	26.2	350.0	....
54......	T. C......	178.7	6,943.0	105	2.788	28.952	26.2	520.0	....
54......	D. C......	240.6	9,342.0	105	3.753	38.956	26.2	700.0	....
60......	Standard.	146.0	5,681.0	94	2.278	23.690	23.5	425.0	....
60......	T. C......	197.4	7,686.0	94	3.079	32.051	23.5	575.0	....
60......	D. C......	292.0	11,362.0	94	4.556	47.380	23.5	850.0	....
66......	Standard.	178.7	6,943.0	86	2.788	28.952	21.5	520.0	....
66......	T. C......	248.9	9,691.0	86	3.883	40.411	21.5	725.0	....
66......	D. C......	357.4	13,886.0	86	5.575	57.905	21.5	1,040.0	....
72......	Standard.	223.4	8,688.0	78	3.485	36.229	19.5	650.0	....
72......	T. C......	292.0	11,362.0	78	4.555	47.380	19.5	850.0	....
72......	D. C......	446.8	7,376.0	78	6.970	30.758	19.5	1,300.0	....

[a] Made by T. H. Risdon & Co., Mount Holly, N. J. The runner is similar to that of the Swain. The depth varies for each size according to capacity. Built both with register and with inside cylinder gate. The guide ring has no upper flange, and water is admitted from above as well as around the circumference.

Rating tables for pivot-gate turbines.

CROCKER (NEW TYPE).[a]

[1901 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
15	....	23.04	970	326	0.359	4.045	81.5	72	950
20	....	41.6	1,710	258	.649	7.131	64.5	129	1,650
25	....	64.5	2,665	196	1.006	11,113	49.0	200	2,550
30	....	94.0	3,250	164	1.466	13.552	41.0	288	4,360
35	....	124.4	5,160	142	1.941	21.517	35.5	384	6,480
40	....	167.3	6,940	127	2.610	28.940	31.7	512	8,850
43	....	189.9	7,876	119	2.962	32.843	29.7	554	11,850
45	....	205.0	8,500	114	3.198	35.[illegible]5	28.5	640	....
50	....	263.0	10,400	102	4.103	43.368	25.5	800	....
55	....	311.0	12,830	95	4.852	53.501	23.7	960	....
60	....	366.0	15,260	85	5.710	63.634	21.2	1,120	....

CROCKER (OLD TYPE).[a]

[1896 list.]

15	....	14.4	601	326	0.225	2.506	81.5	45	....
20	....	25.9	1,070	258	.404	4.462	64.5	80	....
25	....	40.5	1,670	196	.632	6.964	49.0	125	....
30	....	58.4	2,406	164	.911	10.033	41.0	180	....
35	....	77.8	3,210	142	1.214	13.386	35.5	240	....
40	....	104.8	4,345	127	1.635	18.119	31.7	320	....
45	....	128.0	5,292	114	1.997	22.168	28.5	400	....
50	....	162.4	6,700	102	2.533	27.939	25.5	500	....
55	....	194.4	8,040	95	3.033	33.527	23.7	600	....
60	....	228.8	9,435	85	3.569	39.344	21.2	700	....

CAMDEN HORIZONTAL.[b]

12	....	10.3	401	489	0.161	1.672	122.2	30	....
18	....	26.3	1,043	327	.413	4.349	81.8	78	....
21	....	28.7	1,149	280	.448	4.791	70.0	86	....
24	....	45.9	1,805	245	.716	7.527	61.2	135	....
27	....	61.3	2,418	218	.956	10.083	54.5	181	....
30	....	73.4	2,886	195	1.145	12.035	48.8	216	....
33	....	83.4	3,286	177	1.301	13.702	44.2	246	....
36	....	102.5	4,007	163	1.599	16.709	40.8	300	....

[a] Made by E. D. Jones & Sons Company, Pittsfield, Mass. This turbine has a small number of large gates pivoted near the circumference of the wheel. A short outrigger from each gate is connected to the turbine axis by a linkage, by means of which the gates are opened and closed. The later type of Crocker turbine has double curved buckets with ladle-shaped outlets protruding below and outside of the inlet ring.

[b] See footnote on following page.

Rating tables for pivot-gate turbines—Continued.

CAMDEN VERTICAL.[a]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
12...	....	12.14	481	478	0.189	2.006	119.5	6	....
18...	....	27.17	1,082	277	.424	4.512	69.2	8	....
21...	....	30.71	1,202	265	.479	5.012	66.2	11	....
24...	....	48.93	1,924	236	.763	8.023	59.0	13	....
27...	....	58.74	2,378	202	.916	9.916	50.5	13	....
30...	....	74.74	2,925	183	1.166	12.197	45.7	15	....
33...	....	88.10	3,447	168	1.374	14.374	42.0	16	....
36...	....	102.40	4,007	156	1.597	16.709	39.0	16	....
42...	....	132.87	5,196	134	2.073	21.667	33.5	18	....
48...	....	196.14	7,694	116	3.060	32.084	29.0	19	....
54...	....	211.79	8,282	102	3.304	34.536	25.5	19	....
60...	....	307.50	12,022	95	4.797	50.132	23.7	21	....

CAMDEN STEEL DOUBLE.[a]

13...	....	3.43	133	631	0.054	0.555	157.7	....	....
12...	....	6.27	240	478	.098	1.001	119.5	....	....
5¾...	....	9.04	347	360	.141	1.447	90.0	....	....
20...	....	16.76	642	275	.261	2.667	68.7	....	....
23½...	....	30.01	1,149	236	.469	4.791	59.0	....	....
30...	....	64.68	2,471	183	1.009	10.304	45.7	....	....
36...	....	94.40	3,606	156	1.473	15.037	39.0	....	....
42...	....	114.70	4,382	134	1.789	18.273	33.5	....	....
48...	....	157.37	6,011	116	2.455	25.066	29.0	....	....
54...	....	239.26	9,150	102	3.735	38.156	25.5	....	....
60...	....	302.04	11,544	95	4.712	48.138	23.7	....	....

UNITED STATES.[a]

[1903 list.]

15...	....	27.9	1,154	375	0.435	4.812	93.8	85	....
18...	....	41.2	1,706	314	.643	7.114	78.5	126	....
21...	....	56.3	2,330	269	.878	9.716	67.2	174	....
24...	....	72.1	2,981	234	1.125	12.431	58.5	220	....
27...	....	93.2	3,855	209	1.454	16.175	52.2	286	....
30...	....	119.3	4,933	188	1.861	20.571	47.0	368	....
33...	....	144.1	5,960	171	2.248	24.853	42.8	445	....
36...	....	171.6	7,100	156	2.677	29.607	39.0	524	....
39...	....	201.2	8,322	144	3.139	34.703	36.0	621	....
42...	....	229.6	9,496	134	3.582	39.598	33.5	710	....
45...	....	263.3	10,888	124	4.007	45.403	31.0	812	....
48...	....	295.3	12,215	116	4.607	50.937	29.0	904	....

[a] Made by Camden Water Wheel Works, Camden, N. Y. The Camden turbine is built with either pivot or register gates. The bucket ring is deep and narrow. The vanes are slightly ladle-shaped at bottom and broaden below lower rim band of runner. The Camden Horizontal turbine has two similar runners mounted on a horizontal shaft with central draft tube. The rating table is for a single runner. In the Camden Steel Double turbine the runner comprises a central dome having an upper ring of central-discharge buckets, the lower ring consisting of inward- and downward-flow buckets. The inlet ports to the latter are about one-half the depth of the frame. The buckets are curved axially and the outlet is at the bottom. The inner edge of the buckets is attached to the central drum. The United States turbine is a later type, having deep, bulging buckets and either cylinder or pivot gates.

Rating tables for pivot-gate turbines—Continued.

COLE DOMINION.[a]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (= P).	Discharge (= F).	Speed (= N).		
12...	....	8.11	....	459	0.126	....	114.7	25	....
15...	....	12.90	....	367	.201	....	91.7	40	....
18...	....	17.80	....	306	.278	....	76.5	55	....
21...	....	24.30	....	265	.379	....	66.2	75	....
24...	....	35 60	....	229	.556	....	57.5	110	....
27...	....	42.00	....	204	.655	....	51.0	130	....
30...	....	50.10	....	183	.782	....	45.7	155	....
36...	....	68.00	....	153	1.061	....	38.2	210	....
42...	....	102.00	....	131	1.591	....	32.7	315	....
48...	....	137.00	....	114	2.137	....	28.5	425	....
54...	....	174.00	....	102	2.714	....	25.5	540	....
60...	....	217.00	....	91	3.385	....	22.7	660	....
66...	....	271.00	....	83	4.321	....	20.7	815	....
72...	....	357.00	....	76	5.476	....	19.0	965	....

BRADWAY.[b]

[1903 list.]

12...	Standard...	5.20	212	441	0.081	0.884	110.2	....	....
15...	3-in. bucket.	9.40	365	344	.147	1.522	86.0	....	....
15...	5-in. bucket.	15.65	497	344	.244	2.072	86.0	....	....
18...	Standard...	22.79	895	276	.356	3.732	69.0	....	....
20...	.....do......	25.31	900	250	.395	3.753	56.2	....	....
24...	.....do......	30.38	1,120	208	.474	4.467	52.0	....	....
27...	.....do......	42.60	1,580	186	.665	6.588	46.5	....	....
30...	.....do......	50.29	1,930	166	.785	8.048	41.5	....	....
36...	12-in. bucket	69.89	2,600	135	1.090	10.842	33.8	....	....
36...	Standard...	89.09	3,000	135	1.390	12.510	33.8	....	....
36...	Special......	104.75	3,790	138	1.634	15.804	34.5	....	....
42...	Standard...	118.20	4,650	124	1.844	19.390	31.0	....	....
48...	.....do......	167.00	6,122	104	2.605	25.528	26.0	....	....
48...	Special......	200.00	7,632	104	3.120	31.826	26.0	....	....

[a]Made by Vulcan Iron Works, Oswego, N. Y. A shallow wheel having inward discharge buckets, which curve, but do not bulge. The inner end of each of the pivoted guides is attached to the crown ring; the outward ring is actuated by linkages reaching from an outside gate ring to the ends of outriggers attached to the guides.

[b]Made by C. P. Bradway Machine Works, West Stafford, Conn. The runner is similar to that of the Swain. The gates are pivoted near the outer ends and open two, four, or six guide chutes at a time in successive sections, the remainder being closed.

Rating tables for pivot-gate turbines—Continued.

BARTLEY WATER-TIGHT.[a]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
14....	Standard...	4.10	170	343	0.064	0.709	85.8	....	....
14....	Special......	10.00	414	343	.156	1.726	85.8	....	....
16....	Standard...	6.30	259	300	.098	1.080	75.2	....	....
16....	Special......	15.00	596	300	.234	2.485	75.2	....	....
19....	Standard...	10.00	414	253	.156	1.726	63.2	....	....
19....	Special......	20.00	805	253	.312	3.357	63.2	....	....
22....	Standard...	15.00	596	218	.234	2.485	54.5	....	....
22....	Special......	27. e0	1,125	218	.421	4.691	54.5	....	....
25....	Standard...	20.00	805	192	.312	3.357	48.0	....	....
25....	Special......	36.00	1,492	192	.562	6.222	48.0	....	....
29....	Standard...	27.00	1,125	166	.421	4.691	41.5	....	....
29....	Special	49.00	2,018	166	.764	8.415	41.5	....	....
33....	Standard...	36.00	1,492	145	.562	6.222	36.2	....	....
33....	Special......	60.00	2,746	145	.936	11.450	36.2	....	....
38....	Standard...	49.00	2,018	126	.764	8.415	31.5	....	....
g8....	Special......	91.00	3,731	126	1.420	15.558	31.5	....	....
44....	Standard...	67.00	2,746	109	1.045	11.450	27.2	....	....
44....	Special......	91.00	3,731	109	1.420	15.558	27.2	....	....
51....	Standard...	91.00	3,731	94	1.420	15.558	23.5	....	....
51....	Special......	118.09	4,860	94	1.841	20.266	23.5	....	....
58....	Standard...	158.00	6,510	83	2.465	27.147	20.8	....	....
66....	......do......	192.00	8,680	73	3.000	36.196	18.2	....	....
18....	1900 pattern.	30.20	1,310	300	0.471	5.463	75.0	....	....
21....	....	42.25	1,836	255	.658	7.664	63.8	....	....
24....	....	53.00	2,280	212	.827	9.508	53.0	....	....
30....	....	82.40	2,924	170	1.285	12.193	42.5	....	....
36....	....	118.00	5,140	140	1.841	21.434	35.0	....	....
42....	....	169.00	7,352	128	2.636	30.658	32.0	....	....
48....	No. 1........	212.00	9,500	106	3.307	39.615	26.5	....	....
48....	No. 2........	140.00	6,300	106	2.184	26.271	26.5	....	....

CANADA.[b]

[1895 list.]

12....	....	5.88	232	432	0.092	0.967	108.0	17	....
16....	....	10.60	419	324	.165	1.747	81.0	31	....
20....	....	16.32	646	259	.255	2.694	64.7	47	....
24....	....	24.10	954	216	.376	3.978	54.0	71	....
30....	....	36.14	1,431	173	.564	5.967	43.2	108	....
36....	....	53.02	2,099	144	.827	8.753	36.0	159	....
42....	....	73.60	2,914	123	1.148	12.151	30.7	218	....
50....	....	103.83	4,111	104	1.620	17.143	26.0	304	....
50....	....	103.83	4,111	104	1.620	17.143	26.0	304	....
60....	....	170.53	6,752	87	2.660	28.156	21.7	494	....

[a] Made by William Bartley & Sons, Bartley, N. J. The runner resembles that of the Swain. The flow is inward and downward. The buckets do not protrude below lower rim band of runner. The runner can be lifted vertically from case. The gates consist of semicircular columns, which are pivoted in a recess in the guide chutes and which turn half round, cutting off the guide opening.

[b] Made by Reading Foundry Company, Reading, Pa. This turbine has inward and downward flow. The buckets are curved, but are not bulging. The gates are few in nmuber, are pivoted near their inner ends, and are actuated by a gate ring surmounting the dome of the turbine.

Rating tables for pivot-gate turbines—Continued.

ELMER WATER WHEEL.[a]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
10		6.02	240	548	0.094	1.001	137.0		
12.5		9.37	374	438	.146	1.560	109.5		
15		14.06	560	366	.219	2.335	91.5		
17.5		19.07	760	319	.297	3.169	79.7		
20		25.11	1,001	273	.392	4.174	68.2		
22.5		31.46	1,254	244	.491	5.229	61.0		
25		37.48	1,506	209	.585	6.280	52.2		
30		56.24	2,204	182	.877	9.191	45.5		
35		76.28	3,040	159	1.190	12.677	39.7		
40		100.44	4,004	137	1.567	16.697	34.2		
45		125.84	4,916	122	1.963	20.500	30.5		
50		149.92	6,024	109	2.339	25.120	27.2		
55		193.01	7,712	98	3.011	32.159	24.5		
60		224.26	8,960	92	3.498	37.363	23.0		
65		262.19	10,413	86	4.090	43.422	21.5		

EUREKA IMPROVED.[b]

Diameter of runner in inches.	Listed style or number.	Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).	Vent in square inches.	Weight in pounds.
6								5	
9		4.82	182	507.0	0.075	0.759	126.8	14	
12		6.79	281	472.0	.106	1.172	118.0	21	353
15		10.62	440	384.0	.166	1.835	96.0	33	581
18		13.20	546	319.0	.206	2.277	79.8	41	775
21		18.34	759	214.0	.286	3.165	53.5	57	1,070
24		26.41	1,092	240.0	.412	4.554	60.0	82	1,770
27		31.18	1,289	213.0	.486	5.375	53.2	97	2,220
30		42.18	1,744	192.0	.658	7.272	48.0	131	2,400
36		55.01	2,276	159.0	.858	9.491	39.7	170	3,430
40		66.00	2,730	144.0	1.030	11.384	36.0	204	4,022
48		79.59	3,292	120.0	1.242	13.728	30.0	246	6,000
54		107.10	4,430	106.0	1.671	18.473	26.5	334	8,600
60		140.66	5,818	96.0	2.194	24.261	24.0	437	9,000
66		183.39	7,585	87.0	2.816	31.629	21.7	567	12,220
72		214.02	8,852	76.0	3.342	36.913	19.0	662	15,500
84		324.00	13,370	65.6	5.054	55.753	16.4	1,000	18,000

[a] Made by Valley Iron Works Manufacturing Company Appleton, Wis. A pivot-gate turbine, with outer ends of gates pivoted in frame, and inner ends moved by a gate ring. The buckets are curved along line of radius and have ladle-shaped outlets, not protruding much below lower band of runner. The wheel is of medium depth.

[b] Made by Allentown Foundry and Machine Works, Allentown, Pa. This turbine has an inside ring, similar to a register gate, to which the inner ends of the guides are pivoted. The outer ends slide on ways in the fixed outside guide ring. A very deep wheel.

Rating tables for pivot-gate turbines—Continued.

SMITH IMPROVED SUCCESS.[a]

[1896 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
10....	No. 2.......	5.3	220	515	0.083	0.917	128.0	16.5	....
10....	No. 1.......	3.5	147	515	.055	.613	128.0	11.0	....
11½...	No. 2.......	7.5	311	448	.117	1.297	112.0	23.3	....
11½...	No. 1.......	4.9	207	448	.076	.863	112.0	15.5	....
13....	No. 2.......	9.6	401	397	.150	1.672	99.0	30.0	....
13....	No. 1.......	6.4	267	397	.998	1.113	99.0	20.0	....
15....	No. 2.......	13.2	548	344	.206	2.285	86.0	41.0	....
15....	No. 1.......	8.8	367	344	.137	1.530	86.0	27.5	....
18....	No. 2.......	19.0	788	286	.296	3.286	71.5	59.0	....
18....	No. 1.......	12.5	528	286	.195	2.202	71.5	39.5	....
21....	No. 2.......	26.1	1,082	245	.407	4.512	61.2	81.0	....
21....	No. 1.......	17.3	721	245	.270	3.006	61.2	54.0	....
24....	No. 2.......	32.8	1,363	215	.512	5.684	53.7	102.0	....
24....	No. 1.......	21.9	909	215	.342	3.790	53.7	68.0	....
27....	No. 2.......	43.6	1,814	191	.680	7.564	47.7	135.0	....
27....	No. 1.......	29.0	1,203	191	.452	5.016	47.7	90.0	....
30....	No. 2.......	54.2	2,246	172	2.846	9.366	43.0	168.0	....
30....	No. 1.......	36.1	1,497	172	.563	6.242	43.0	112.0	....
33....	No. 2.......	65.2	2,700	157	1.017	11.259	39.2	202.0	....
33....	No. 1.......	43.6	1,804	157	.680	7.523	39.2	135.0	....
36....	No. 2.......	75.9	3,141	142	1.184	13.098	35.5	235.0	....
36....	No. 1.......	50.7	2,099	142	.791	8.753	35.5	157.0	....
39....	No. 2.......	96.3	3,984	132	1.502	16.613	33.0	298.0	....
39....	No. 1.......	64.6	2,674	132	1.008	11.150	33.0	200.0	....
42....	No. 2.......	116.6	4,826	123	1.819	20.124	30.7	361.0	....
42....	No. 1.......	77.8	3,222	123	1.214	13.436	30.7	241.0	....
48....	No. 2.......	150.4	6,297	106	2.346	26.258	26.5	471.0	....
48....	No. 1.......	100.8	4,198	106	1.572	17.506	26.5	314.0	....
54....	No. 2.......	187.2	7,761	95	2.920	32.363	23.7	580.0	....
54....	No. 1.......	124.8	5,174	95	1.947	21.576	23.7	387.0	....
60....	No. 2.......	235.2	9,766	86	3.670	40.724	21.5	730.0	....
60....	No. 1.......	156.8	6,511	86	2.446	27.151	21.5	487.0	....
66....	No. 2.......	292.8	12,153	78	4.568	50.678	19.5	909.0	....
66....	No. 1.......	195.2	8,102	78	3.045	33.785	19.5	606.0	....
72....	No. 2.......	345.6	14,319	72	5.391	59.710	18.0	1,071.0	....
72....	No. 1.......	230.4	9,546	72	3.594	39.807	18.0	714.0	....

[a] Made by S. Morgan Smith Company, York, Pa. The Improved Success was built with two depths of bucket for each diameter, thus giving two capacities both with same speed. These were termed No. 1 and No. 2 respectively. The New Success is a later type of wheel. The Smith Success turbines have guides pivoted near their inner ends to the turbine case. The gates are opened and closed by pins on a sliding ring near the outer circumference of the case. The buckets are double curved, but do not project below lower ring of runner, which is of same diameter at bottom and top and may be lifted out of wheel case vertically.

Rating table for pivot-gate turbines—Continued.

SMITH NEW SUCCESS.[a]

[1896 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
9		8.5	354	584	0.132	1.476	146.0		
12		14.9	615	437	.232	2.564	109.2		
15		23.7	982	350	.369	4.095	87.5		
18		34.7	1,437	282	.541	5.992	70.5		
21		49.1	2,033	269	.766	8.478	67.2		
24		64.8	2,684	222	1.011	11.192	55.5		
27		82.1	3,399	207	1.281	14,174	51.7		
30		99.0	4,096	183	1.544	17.080	45.7		
33		121.5	5,025	159	1.895	20.954	39.7		
36		139.0	5,752	156	2.168	23.986	39.0		
39		163.5	6,762	134	2.556	28.198	33.5		
42		200.7	8,304	132	3.131	34.628	33.0		
45		213.7	8,842	119	3.324	36.871	29.7		
48		241.1	9,975	114	3.761	41.596	28.5		
51		274.6	11,357	108	4.284	47.359	27.0		
54		323.3	13,372	100	5.043	55.761	25.0		
57		362.7	15,022	97	5.658	62.642	24.2		
60		470.1	19,447	90	7.334	81.094	22.5		
66		568.9	23,530	82	8.875	98.008	20.5		
72		716.0	29,614	74	11.170	123.490	18.5		
84		975.1	40,323	64	15.210	168.147	16.0		

AMERICAN.[b]

13		5.30	219	378	0.083	0.913	94.5		
16½		8.00	332	296	.125	1.384	74.0		
20		12.28	508	244	.192	2.118	61.0		
25		19.67	813	195	.307	3.390	48.8		
30		28.43	1,176	163	.443	4.904	40.8		
36		46.48	1,924	136	.725	8.023	34.0		
42		61.44	2,540	117	.958	10.592	29.5		
48		79.10	3,271	102	1.234	13.640	25.5		
54		119.13	4,927	91	1.856	20.546	22.8		
60		155.89	6,448	82	2.434	26.888	20.5		
66		195.44	8,083	74	3.042	33.706	18.5		
75		245.87	10,170	65	3.838	42.409	16.3		
84		328.08	13,569	58	5.117	56.583	14.5		

[a] See footnote on preceding page.
[b] Made by the Dayton Globe Iron Works Company, Dayton, Ohio. The American and New American turbines have runners of progressively increasing depth and capacity. The earlier types resemble the Swain; the later types resemble the McCormick. The gates comprise a fixed guide, forming the front wall of the chute, and a pivoted guide, forming the back wall. By swinging the latter, by means of a linkage device, the inlet is decreased or increased in size.

Rating table for pivot-gate turbines—Continued.

NEW AMERICAN[a]

[1892 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
6		3.2	134	818	0.05	0.559	204.5	10	
8		5.5	227	614	.086	.946	153.5	17	
10		8.1	334	490	.126	1.393	122.5	25	
13		11.1	508	378	.173	2.118	94.5	38	
16		22.7	908	306	.354	3.786	76.5	67	
19		29.4	1,216	258	.459	5.071	64.5	91	
22		35.8	1,482	222	.558	6.180	55.5	111	
25		39.0	1,616	195	.608	6.739	48.7	121	
30		63.2	2,616	163	.986	10.909	40.7	195	
36		81.5	3,369	136	1.271	14.049	34.0	252	
42		122.7	5,074	117	1.914	21.158	29.2	300	
48		141.8	5,864	102	2.212	24.453	25.5	439	
54		208.5	8,622	91	3.256	35.954	22.7	645	
60		271.1	11,216	82	4.230	46.771	20.5	839	
66		347.5	14,378	74	5.421	59.956	18.5	1,076	
22	Special	40.0	1,657	222	.624	6.910	55.5	124	
25	do	58.2	2,406	206	.908	10.033	51.2	180	
36	do	105.6	4,382	136	1.647	18.273	34.0	328	
45	do	169.0	6,989	114	2.634	29.144	28.5	523	
54	do	238.2	9,841	99	3.716	41.037	24.75	737	

NEW AMERICAN.[a]

[1895 list.]

13		17.2	711	397	0.269	2.965	99.2		
16		28.8	1,153	321	.449	4.808	80.2		
19		41.1	1,702	271	.641	7.097	67.7		
22		53.7	2,227	234	.838	9.286	58.5		
25		58.2	2,406	206	.908	10.033	51.5		
27½		87.3	3,609	186	1.362	15.050	46.5		
30		99.5	4,120	171	1.552	17.180	42.7		
33		126.7	5,260	156	1.976	21.934	39.0		
36		144.9	5,994	143	2.260	24.995	35.7		
39		173.0	7,156	131	2.699	29.840	32.7		
42		207.4	8,582	123	3.235	35.787	30.7		
45		207.5	8,683	114	3.237	36.208	28.5		
48		234.0	9,679	107	3.650	40.361	26.7		
51		285.8	11,809	102	4.458	49.244	25.5		
54		329.9	13,630	97	5.146	56.837	24.2		
57		357.0	14,771	91	5.569	61.595	22.7		
60		399.6	16,535	86	6.234	68.951	21.5		

[a] See footnote (*b*) on preceding page.

Rating tables for pivot-gate turbines—Continued.

NEW AMERICAN.[a]

[1901 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet. Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Coefficients. Power (=P).	Discharge (=F).	Speed (=N).	Vent in square inches.	Weight in pounds.
10		11.3	467	490	0.176	1.947	122.5		750
13		17.2	711	397	.268	2.965	99.2		1,000
16		28.8	1,153	321	.449	4.808	80.2		1,550
19		41.1	1,702	271	.641	7.097	67.7		1,800
22		53.7	2,227	234	.838	9.286	58.5		2,600
25		67.5	2,790	206	1.053	11.634	51.5		3,200
27½		87.3	3,609	186	1.362	15.050	46.5		4,000
30		105.4	4,367	171	1.644	18.210	42.7		4,800
33		126.7	5,260	156	1.976	21.934	39.0		6,000
36		159.5	6,593	143	2.488	27.493	35.7		7,500
39		173.0	7,156	131	2.699	29.840	32.7		8,500
42		193.6	8,007	123	3.020	33.389	30.7		9,300
45		232.4	9,725	114	3.625	40.553	28.5		10,000
48		267.4	11,061	107	4.171	46.124	26.7		11,500
51		285.8	11,809	102	4.458	49.244	25.5		14,600
54		336.5	13,902	95	5.249	57.971	23.7		17,500
57		367.7	15,214	91	5.736	63.442	22.7		20,000
60		427.5	17,692	88	6.669	73.776	22.0		22,500
72		610.6	25,254	75	9.525	105.309	18.7		
6	(b)	3.2	134	818	.050	.559	204.5		
8	(b)	5.5	227	614	.086	.946	153.5		
36	(b)	62.0	2,566	143	.967	10.700	35.7		
45	(b)	116.4	4,812	114	1.816	20.066	28.5		

POOLE & HUNT LEFFEL TURBINE.[c]

Diameter of runner in inches.	Listed style or number.	Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).	Vent in square inches.	Weight in pounds.
7⅝	1	1.79	67	723	0.028	0.279	180.7		
7⅝		2.42	90	723	.038	.375	180.7		
10 or 8¾	1	3.05	114	551	.048	.475	137.7		
10		4.13	154	551	.064	.642	137.7		
13¼	1	5.38	201	416	.084	.838	104.0		
13¼		7.18	267	416	.112	1.113	104.0		
15¼		9.33	34[illegible]	362	.145	1.451	90.5		
17½		12.20	455	315	.190	1.897	78.7		
20		16.15	602	276	.252	2.510	69.0		
23		21.54	802	240	.336	3.344	60.0		
26½		28.00	1,043	208	.437	4.349	52.0		
30½		37.33	1,390	181	.582	5.796	45.2		
35		49.17	1,831	158	.767	7.635	39.5		
40		64.61	2,406	138	1.008	10.033	34.5		
44		75.30	2,209	126	1.175	9.212	31.5		
48		93.32	3,475	115	1.456	14.491	28.7		
52		121.32	4,518	110	1.893	18.840	27.5		
56		158.28	5,853	99	2.469	24.407	24.7		
61		186.64	6,950	90	2.912	28.982	22.5		
66		236.00	8,661	81	3.682	36.116	20.2		

[a] See footnote (b) on page 114.
[b] Reduced discharge.
[c] Made by Poole & Hunt, Baltimore, Md. See footnote (a) on page 118.

Rating tables for pivot-gate turbines—Continued.

TRUMP MODEL TURBINE.[a]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet. Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Coefficients. Power (=P).	Discharge (=F).	Speed (=N).	Vent in square inches.	Weight in pounds.
14	...	23.90	989	385	0.373	4.124	96.2	...	...
17	...	41.8	1,724	317	.652	7.189	79.2	...	...
20	...	58.3	2,406	269	.909	10.033	67.2	...	...
23	...	77.4	3,195	234	1.207	13.323	58.5	...	...
26	...	100.0	4,131	204	1.560	17.226	51.0	...	...
30	...	131.0	5,428	177	2.044	22.635	44.2	...	...
35	...	179.5	7,407	154	2.800	30.887	38.5	...	...
40	...	232.8	9,606	134	3.632	40.057	33.5	...	...
44	...	282.3	11,645	121	4.404	48.560	30.2	...	...
48	...	335.7	13,851	112	5.237	57.759	28	...	...
52	...	394.0	16,257	103	6.146	67.792	25.7	...	...
56	...	457.3	18,865	96	7.134	78.667	24	...	...
61	...	544.2	22,401	88	8.489	93.412	22	...	...
66	...	635.2	26,205	82	9.909	109.275	20.5	...	...

LEFFEL (OLD TYPE.)[b]

[1892 list.]

10	Standard	4.13	163	551	0.064	0.680	137.8	...	...
11½	do	5.38	213	479	.084	.888	119.8	...	...
13¼	do	7.25	286	416	.113	1.193	104	...	...
15¼	do	9.38	370	362	.146	1.543	90.5	...	...
17½	do	12.25	484	315	.191	2.018	78.8	...	...
20	do	16	632	276	.249	2.635	69	...	...
23	do	21.50	849	240	.335	3.540	60	...	...
26½	do	28	1,106	208	.437	4.612	52	...	...
30½	do	37.38	1,476	181	.583	6.155	45.3	...	...
35	do	49	1,935	158	.764	8.069	39.5	...	...
40	do	64.50	2,547	138	1.006	10.621	34.5	...	...
44	do	75	2,962	126	1.170	13.186	31.5	...	...
48	do	93	3,670	113	1.451	15.304	28.3	...	...
56	do	158	6,241	99	2.465	26.025	24.8	...	...
61	do	187	7,386	90	2.917	30.800	22.5	...	...
66	do	224	8,848	82	3.494	36.896	20.5	...	...
74	do	273	10,783	74	4.259	44.965	18.5	...	...
20	Special	23.25	916	276	.363	3.820	69	...	...
23	do	31.13	1,229	240	.486	5.125	60	...	...
26½	do	40.50	1,600	208	.632	6.672	52	...	...
30½	do	54.25	2,143	181	.850	8 936	45.3	...	...
35	do	71	2,804	158	1.108	11.693	39.5	...	...
40	do	93	3,672	138	1.451	15.312	34.5	...	...
44	do	109	4,305	126	1.700	17.952	31 5	...	...
50	do	144	5,688	113	2.246	23.719	28.3	...	...
56	do	183	7,228	99	2.855	30.141	24.8	...	...
61	do	217	8,571	90	3.385	35.741	22.5	...	...
66	do	255	10,072	82	3.971	42.000	20.5	...	...
74	do	306	12,087	74	4.774	50.403	18.5	...	...

[a] Made by the Trump Manufacturing Company, Springfield, Ohio. This wheel has pivot gates similar to the Leffel turbines. The inlet portion of the runner is a frustum of a cone, so that the water has an inward and downward direction as it enters the wheel.

[b] See footnote (*a*) on following page.

Rating tables for pivot-gate turbines—Continued.

LEFFEL (NEW TYPE).[a]

[1900 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
10....	Standard...	3.70	53	535	0.058	0.220	133.8	....	....
11½...	.....do......	4.9	201	463	.076	.838	115.8	....	....
13¼...	.....do......	6.5	267	404	.101	1.113	101.0	....	....
15¼...	.....do......	8.4	348	351	.131	1.451	87.8	....	....
17½...	.....do......	11.00	455	306	.172	1.897	76.5	....	....
20....	.....do......	14.9	602	268	.232	2.510	67	....	....
23....	.....do......	19.4	802	233	.303	3.344	58.2	....	....
26½...	.....do......	25.25	1,043	202	.393	4.339	50.5	....	....
30½...	.....do......	33.61	1,390	176	.524	5.796	44	....	....
35....	.....do......	44.3	1,831	153	.691	7.635	38.2	....	....
40....	.....do......	58.2	2,406	134	.908	10.033	33.5	....	....
44....	.....do......	67.75	2,800	122	1.058	11.676	30.5	....	....
48....	.....do......	84.1	3,475	110	1.312	14.490	27.5	....	....
56....	.....do......	142	5,858	96	2.215	24.428	24	....	....
61....	.....do......	168	6,950	87	2.621	28.982	21.8	....	....
66....	.....do......	202	8,340	80	3.151	34.778	20	....	....
74....	.....do......	247	10,222	72	3.853	42.623	18	....	....
20....	Special.....	21.13	870	268	.329	3.628	67	....	....
23....	.....do......	28.25	1,168	233	.440	4.871	58.2	....	....
26½...	.....do......	36.8	1,520	202	.574	6.338	50.5	....	....
30½...	.....do......	49.3	2,036	176	.769	8.490	44	....	....
35....	.....do......	64.4	2,664	153	1.005	11.089	38.2	....	....
40....	.....do......	84.4	3,488	134	1.317	14.545	33.5	....	....
41....	.....do......	98.9	4,090	122	1.543	17.055	30.5	....	....
50....	.....do......	131	5,404	110	2.044	22.535	27.5	....	....
56....	.....do......	166	6,867	96	2.590	28.635	24	....	....
61[b]...	.....do......	81.7	6,004	66	3.023	33.355	22	....	....
66....	.....do......	98	7,205	56	3.626	39.913	18.7	....	....
74....	.....do......	118	8,672	54	4.366	48.108	18	....	....

[a] Made by James Leffel & Co., Springfield, Ohio. The Leffel double turbine has two independent sets of buckets, one an inward and downward, the other a central discharge. Both receive water from the same set of guides but discharge it independently. The power table given for the Poole & Hunt Leffel (p. 116) is nearly identical with those issued by the Leffel Company in 1879, and for the corresponding sizes is the same as for the Trump Leffel (p. 117). The table for the Leffel of 1892 differs slightly from the preceding but agrees substantially with that in the 1897 list in which are rated new sizes of wheels having greater capacity. The Samson follows with further increase of capacity.

[b] At 9-foot head.

Rating tables for pivot-gate turbines—Continued.

LEFFEL IMPROVED SAMSON.[a]

[1897 and 1900 lists.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
20....	....	51.7	2,111	325	0.806	8.803	81.3	....	....
23....	....	68.3	2,792	283	1.065	11.643	70.8	....	....
26....	....	87.3	3,569	250	1.362	14.883	62.5	....	....
30....	....	116	4,751	217	1.810	19.812	54.3	....	....
35....	....	158	6,440	186	2.465	26.855	46.5	....	....
40....	....	207	8,446	163	3.229	35.220	40.8	....	....
45....	....	262	10,689	145	4.087	44.573	36.3	....	....
50....	....	324	13,196	130	5.054	55.027	32.5	....	....
56....	....	405	16,554	116	6.318	69.030	29.0	....	....
62....	....	497	20,292	105	7.753	84.618	26.3	....	....
68....	....	597	24,409	96	9.313	101.786	24.0	....	....
74....	....	708	28,906	88	11.045	120.538	22.0	....	....
17 E.	....	14.3	581	373	.223	2.423	93.2	....	....
17 D.	....	18.6	758	373	.290	3.161	93.2	....	....
17 C.	....	24.5	998	373	.382	4.162	93.2	....	....
17 B.	....	30.2	1,232	372	.471	5.137	93.0	....	....
17 A.	....	39.5	1.610	372	.616	6.714	93.0	....	....

Rating tables for cylinder-gate turbines.

ROCHESTER.[b]

[1873 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (= P).	Discharge (= F).	Speed (= N).		
16....	Standard...	6.44	267	319	0.100	1.113	79.8	20	450
20....	.....do......	10.68	440	271	.166	1.835	67.8	33	950
20....	Special......	12.94	535	....	.202	2.231	....	40	....
25....	Standard...	16.17	667	199	.252	2.781	49.8	50	1,650
25....	Special......	19.40	802	....	.303	3.344	....	60	....
30....	Standard...	24.25	1,003	162	.378	4.182	40.5	75	2,100
30....	Special......	30.72	1,270	....	.479	5.296	....	95	....
36....	Standard...	40.45	1,669	152	.631	6.960	38.0	125	2,700
36....	Special......	48.51	2,003	....	.757	8.353	....	150	....
42....	Standard...	64.68	2,670	126	1.010	11.134	31.5	200	3,600
48....	.....do......	80.90	3,339	99	1.262	13.924	24.8	250	4,200
54....	.....do......	103.60	4,275	89	1.616	17.827	22.2	320	5,100
60....	.....do......	113.20	4,671	84	1.766	19.478	21.0	350	6,200
66....	.....do......	145.60	6,007	81	2.271	25.049	20.2	450	7,400
72....	.....do......	186.10	7,677	79	2.903	32.013	19.8	575	8,500

[a] See footnote (a) on page 118.

[b] Formerly made by Rochester Turbine Manufacturing Company, Rochester, N. Y. The buckets were of small depth.

Rating tables for cylinder-gate turbines—Continued.

SWAIN.[a]

[1897 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
12...	....	10.840	439.8	441	0.169	0.031	110.2	....	....
18...	....	24.390	989.4	294	.380	.069	73.5	....	....
21¼...	....	35.570	1,444.2	249	.555	.100	62.2	....	....
24...	....	43.370	1,761.0	220	.676	.122	55.0	....	....
27¼...	....	58.275	2,365.9	194	.909	.164	48.5	....	....
30...	....	72.110	2,927.6	176	1.125	.203	44.0	....	....
36...	....	103.720	4,210.9	147	1.618	.293	36.8	....	....
42...	....	141.260	5,734.9	126	2.204	.398	31.5	....	....
48...	....	184.720	7,499.4	110	2.882	.521	27.5	....	....
54...	....	237.070	9,625.2	98	3.698	.485	24.5	....	....
60...	....	293.380	11,910.6	88	4.577	.828	22.0	....	....
66...	....	357.580	14,517.6	80	5.578	1.009	20.0	....	....
72...	....	433.650	17,605.8	74	6.765	1.224	18.5	....	....
80...	....	530.450	21,535.8	66	8.275	1.497	16.5	....	....

DOLAN'S LITTLE GIANT.[b]

[1893 list.]

6...	....	4.11	160	882	0.064	0.667	220.5	12.3	278
8...	....	7.39	288	750	.115	1.201	187.5	23.0	375
10...	....	11.36	442	518	.177	1.843	129.5	33.6	485
12...	....	17.37	655	414	.271	2.731	103.5	49.0	650
14½...	....	24.11	909	345	.376	3.790	86.5	68.0	875
17½...	....	29.78	1,123	283	.464	4.683	70.7	84.0	1,250
20...	....	41.84	1,578	247	.653	6.580	61.7	118.0	1,450
23...	....	54.94	2,072	214	.857	8.640	53.5	155.0	1,650
27...	....	83.71	3,155	186	1.306	13.156	46.5	236.0	2,200
31...	....	95.72	3,610	160	1.493	15.054	40.0	270.0	2,500
36...	....	130.21	4,920	141	2.031	20.516	35.2	368.0	3,600
40...	....	157.25	6,150	130	2.453	25.646	32.5	460.0	5,000
44...	....	190.84	7,219	113	2.977	30.103	28.2	540.0	5,700
40...	....	239.27	9,024	104	3.733	37.630	26.0	675.0	8,400
58...	....	262.37	9,893	92	4.093	41.254	23.0	740.0	9,500
64...	....	310.17	11,698	82	4.839	48.781	20.5	875.0	13,000
66...	....	371.69	14,018	75	5.798	58.455	18.7	1,056.0	15,000
72...	....	443.12	16,712	70	6.913	69.689	17.5	1,250.0	17,000
80...	....	528.21	19,921	61	8.240	83.070	15.2	1,490.0	20,000

[a] Made by Swain Turbine and Manufacturing Company, Lowell, Mass. This was one of the earliest turbines of the American type. The original design followed the Francis center-vent wheel, but the buckets were curved both axially and radially and extended downward from inlet ring. Outside cylinder gate.

[b] Made by Wm. Dolan & Co., Logansport, Ind. Outside cylinder-gate turbine and deep bulging buckets.

Rating tables for cylinder-gate turbines—Continued

DOLAN'S IMPROVED LITTLE GIANT.[a]

[1898 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
6	....	4.13	162	816	0.064	0.676	204.0	12	215
8	....	7.70	289	618	.120	1.205	154.5	22	305
10	....	12.18	464	490	.190	1.935	122.5	35	410
12	....	19.54	723	397	.305	3.015	99.2	54	615
15	....	25.24	957	345	.394	3.991	86.2	72	895
18	....	30.91	1,168	282	.482	4.871	70.5	87	1,250
20	....	43.69	1,653	246	.682	6.893	61.5	124	1,540
23	....	59.92	2,259	214	.935	9.420	53.5	169	2,170
27	....	80.16	3,029	187	1.250	12.631	46.8	225	3,150
31	....	100.45	3,925	160	1.567	16.367	40.0	293	3,600
36	....	130.11	5,097	141	2.030	21.254	35.2	380	5,500
40	....	161.07	6,297	122	2.513	26.258	30.5	470	7,100
44	....	197.79	7,730	112	3.085	32.234	28.0	584	8,000
48	....	241.50	9,538	104	3.767	39.773	26.0	714	9,200
54	....	295.58	11,555	92	4.611	48.184	23.0	866	12,400
60	....	364.55	14,751	80	5.687	61.512	20.0	1,104	17,000
66	....	435.33	17,616	77	6.791	73.459	19.2	1,322	23,000
18	Special	37.09	1,403	279	0.579	5.850	69.7	....	....
21	do	51.59	1,952	243	.805	8.140	60.7	....	....
24	do	69.46	2,618	211	1.084	10.917	52.7	....	....
28	do	91.82	3,469	184	1.433	14.466	46.0	....	....
32	do	115.48	4,514	158	1.801	18.823	39.5	....	....
38	do	146.45	5,739	138	2.285	23.932	34.5	....	....
42	do	179.96	7,033	119	2.807	29.328	29.7	....	....
46	do	222.09	8,672	110	3.465	36.162	27.5	....	....
50	do	264.70	10,454	102	4.129	43.593	25.5	....	....
56	do	345.23	13,495	91	5.386	56.274	22.7	....	....
62	do	399.96	16,183	78	6.239	67.483	19.5	....	....
68	do	513.21	20,766	75	8.006	86.594	18.7	....	....

[a] Made by Wm. Dolan & Co., Logansport, Ind. Outside cylinder-gate turbine and deep bulging buckets.

Rating tables for cylinder-gate turbines—Continued.

HUNT STANDARD, NEW PATTERN.[a]

[1897 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horse-power.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
9...	....	6.33	254	516	0.099	1.059	129.0	19	....
12...	No. 2.......	9.41	374	402	.147	1.560	100.5	28	....
12...	No. 1.......	12.66	508	402	.197	2.118	100.5	38	....
15...	....	18.99	762	337	.296	3.178	82.2	57	....
18...	....	29.52	1,189	276	.460	4.958	69.0	89	....
21...	....	41.25	1,656	242	.644	6.906	60.5	124	....
24...	....	52.99	2,124	209	.827	8.857	52.2	159	....
27...	....	66.15	2,672	188	1.032	11.142	47.0	200	....
30...	....	79.32	3,180	166	1.237	13.261	41.5	238	....
33...	....	97.15	3,891	153	1.516	16.225	38.2	292	....
36...	....	114.99	4,609	139	1.794	19.220	34.7	345	....
39...	....	134.54	5,397	129	2.099	22.505	32.2	404	....
42...	....	154.08	6,176	118	2.404	25.754	29.5	462	....
45...	....	166.84	6,760	111	2.603	28.189	27.7	506	....
48...	....	178.68	7,348	103	2.787	30.641	25.7	550	....
51...	....	210.74	8,617	98	3.288	35.933	24.5	645	....
54...	....	246.66	9,886	92	3.848	41.224	23.0	740	....
60...	....	310.66	12,452	83	4.846	51.925	20.7	932	....
66...	....	344.99	13,828	76	5.382	57.663	19.0	1,035	....
72...	....	383.32	15,364	69	5.980	64.068	17.2	1,150	....

HERCULES.[b]

9...	....	8.04	333	517	0.125	1.389	129.2	24.8	....
12...	....	13.84	573	388	.216	2.389	97.0	42.9	....
15...	....	22.35	925	310	.349	3.857	77.5	69.2	....
18...	....	31.19	1,291	259	.486	5.383	64.7	96.6	....
21...	....	43.92	1,818	222	.685	7.581	55.5	136.0	....
24...	....	54.24	2,245	194	.846	9.362	48.5	168.0	....
27...	....	72.33	2,994	172	1.130	12.485	43.0	224.0	....
30...	....	85.57	3,542	155	1.334	14.770	38.7	265.0	....
33...	....	108.19	4,478	141	1.688	18.673	35.2	335.0	....
36...	....	122.39	5,066	129	1.909	21.125	32.2	379.0	....
39...	....	150.49	6,229	120	2.348	25.975	30.0	466.0	....
42...	....	179.22	7,418	111	2.796	30.930	27.7	555.0	....
45...	....	201.18	8,327	103	3.184	34.724	25.7	623.0	....
48...	....	221.86	9,183	97	3.461	38.293	24.2	687.0	....
51...	....	250.59	10,372	91	3.909	43.251	22.7	776.0	....
54...	....	289.68	11,990	86	4.519	49.660	21.5	897.0	....
57...	....	312.92	12,952	82	4.882	54.010	20.5	969.0	....
60...	....	346.84	14,356	78	5.411	59.864	19.5	1,074.0	....

[a] Made by Rodney Hunt Machine Company, Orange, Mass. This wheel has deep bucket inlets and double-curved bulging buckets. An inside cylinder gate is used with a garniture to conform with the vena contracta.

[b] Made by Holyoke Machine Company, Holyoke, Mass. A turbine of American type, with deep, double-curved, bulging buckets and inside cylinder gate. The runner formerly had rows of rib plates forming partial division plates to guide the water through the wheel.

Rating tables for cylinder-gate turbines—Continued.

McCORMICK.[a]

[1894 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet.			Coefficients.			Vent in square inches.	Weight in pounds.
		Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Power (=P).	Discharge (=F).	Speed (=N).		
9		8.8	365	531	0.137	1.522	132.7		
12		15.4	635	398	.240	2.648	99.5		
15		24.5	1,013	319	.382	4.224	79.7		
18		35.8	1,482	257	.558	6.180	64.2		
21		50.7	2,096	245	.791	8.740	61.2		
24		66.9	2,768	202	1.044	11.542	50.5		
27		84.7	3,505	189	1.321	14.616	47.2		
30		102.1	4,223	167	1.593	17.610	41.7		
33		124.9	5,166	145	1.948	21.542	36.2		
36		143.4	5,931	142	2.237	24.732	35.5		
39		168.6	6,972	124	2.630	29.073	31.0		
42		207.0	8,561	120	3.229	35.699	30.0		
45		220.4	9,116	109	3.438	38.014	27.2		
48		248.6	10,284	98	3.878	42.884	24.5		
51		283.1	11,709	99	4.416	48.826	24.7		
54		333.3	13,786	91	5.199	57.488	22.7		
57		374.0	15,467	89	5.834	64.497	22.2		
60		470.1	19,447	82	7.334	81.094	20.5		
66		568.9	23,530	75	8.875	98.120	18.7		
72		716.0	29,614	74	11.170	123.490	18.5		

McCORMICK'S NEW ENGLAND.[b]

9		8.3	346	584	0.129	1.443	146.0		
12		14.4	595	477	.225	1.600	119.2		
15		23.2	962	382	.362	4.012	95.5		
18		32.3	1,342	308	.504	4,596	77.0		
21		45.5	1,890	294	.710	7.881	73.5		
24		56.3	2,334	242	.878	9.733	60.5		
27		75.2	3,113	226	1.173	12.981	56.5		
30		89.0	3,683	200	1.388	15.358	50.0		
33		112.4	4,657	174	1.753	19.420	43.5		
36		127.2	5,268	170	1.984	21.968	42.5		
39		156.0	6,468	148	2.434	26.972	37.0		
42		186.3	7,714	144	2.906	32.176	36.0		
45		209.2	8,660	131	3.264	36.112	32.8		
48		230.7	9,550	117	3.699	39.824	29.2		
51		260.6	10,786	118	4.065	44.878	29.5		
54		301.2	12,469	109	4.699	45.453	27.2		
57		325.4	13,470	106	5.076	56.170	26.5		
60		360.7	14,930	98	5.627	62.278	24.5		

[a] Made by S. Morgan Smith Company, York. Pa. A turbine of the American type, with deep ladle-shaped bucket outlets protruding below and outside of the guide ring and inside cylinder gate. The tables given are from the catalogue of the S. Morgan Smith Company. Nearly identical rating tables for McCormick turbines are furnished by J. & W. Jolly, Holyoke, Mass.: Rodney Hunt Machine Company, Orange, Mass., and Dubuque Turbine and Roller Mill Company, Dubuque, Iowa. The wheels of these three manufacturers are known, respectively, as the Smith-McCormick, the Hunt-McCormick, and the McCormick-Holyoke turbines.

[b] Made by Hanover Foundry and Machine Company, Hanover, Pa.

Rating tables for cylinder-gate turbines—Continued.

TAYLOR SLEEVE GATE.[a]

[1902 list.]

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet. Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Coefficients. Power (=P).	Discharge (=F).	Speed (=N).	Vent in square inches.	Weight in pounds.
15....	A..........	5.76	223	293	0.090	0.930	73.2	....	....
15....	B..........	8.04	333	293	.125	1.389	73.2	....	....
15....	C..........	13.84	573	293	.216	2.389	73.2	....	....
15....	D..........	22.35	925	293	.349	3.857	73.2	....	....
15....	E..........	31.33	1,295	293	.489	5.400	73.2	....	....
15....	Standard...	45.14	1,866	293	.704	7.781	73.2	....	....
18....	.....do......	64.51	2,667	250	1.006	11.121	62.5	....	....
21....	.....do......	88.27	3,649	216	1.377	15.216	54.0	....	....
24....	.....do......	113.75	4,704	185	1.775	19.616	46.2	....	....
27....	.....do......	144.21	5,963	166	2.250	24.866	41.5	....	....
30....	.....do......	182.07	7,530	149	2.840	31.400	37.2	....	....
33....	.....do......	216.69	8,985	135	3.380	37.467	34.7	....	....
36....	.....do......	254.31	10,518	125	3.967	43.860	31.2	....	....
39....	.....do......	302.32	12,502	116	4.716	52.133	29.0	....	....
42....	.....do......	352.80	14,586	107	5.504	60.824	26.7	....	....
45....	.....do......	401.30	16,596	100	6.260	69.205	25.0	....	....
48....	.....do......	460.27	19,037	93	7.180	79.384	23.2	....	....
51....	.....do......	533.13	21,678	86	8.317	90.397	21.5	....	....
54....	.....do......	565.88	23,402	82	8.828	97.586	20.5	....	....
57....	.....do......	652.11	26,971	78	10.173	112.469	19.5	....	....
60....	.....do......	728.19	30,118	73	11.360	125.592	18.2	....	....
64....	.....do......	816.24	33,759	68	12.733	140.775	17.0	....	....
68....	.....do......	936.09	38,710	62	14.603	161.421	15.5	....	....

VICTOR TURBINE.[b]

[1897, 1900, and 1903 lists.]

12....	Cylinder gate.	12.29	678	406	0.192	2.827	101.5	60	....
15....	.....do......	29.56	1,222	376	.461	5.096	94.0	90	....
18....	.....do......	42.59	1,761	314	.664	7.343	78.5	130	....
21....	.....do......	57.97	2,397	269	.904	9.995	67.2	179	....
24....	.....do......	75.71	3,131	235	1.181	13.056	58.7	231	....
27....	.....do......	95.83	3,963	209	1.495	16.526	52.2	294	....
30....	.....do......	118.31	4,893	188	1.846	20.404	47.0	365	....
33....	.....do......	143.15	5,920	171	2.233	24.686	42.7	442	....
36....	.....do......	170.36	7,046	156	2.658	29.382	39.0	520	....
39....	.....do......	199.94	8,269	144	3.119	34.482	36.0	617	....
42....	.....do......	231.88	9,590	134	3.617	39.990	33.5	717	....
45....	.....do......	266.19	11,009	125	4.152	45.908	31.2	821	....
48....	.....do......	302.87	12,526	116	4.725	52.233	29.0	927	....

[a] Made by John Williams Taylor, Atlanta, Ga. A turbine of recent design, having outside cylinder gate and very deep bucket inlet. The buckets bulge downward but do not extend outside of circumference of inlet ring. The guide chutes and buckets are divided into three compartments by partition plates.

[b] Made by Stillwell-Bierce and Smith-Vaile Company, Dayton, Ohio. The Victor turbine resembles the McCormick pattern. It has very deep bucket inlets, bulging ladle-shaped discharge, and inside cylinder gate. Small-size Victor turbines for high heads are built with register gate. The high-pressure turbine is a recent design (1903), and is tabled for heads of 70 to 675 feet.

Rating tables for cylinder-gate turbines—Continued.

VICTOR TURBINE—Continued.

Diameter of runner in inches.	Listed style or number.	Manufacturer's rating for a head of 16 feet. Horsepower.	Discharge in cubic feet per minute.	Revolutions per minute.	Coefficients. Power (=P).	Discharge (=F).	Speed (=N).	Vent in square inches.	Weight in pounds.
51....	Cylinder gate......	341.91	14,141	107	5.334	58.968	26.7	1,055	....
54....	.....do......	383.32	15,854	102	5.980	66.111	25.5	1,154	....
57....	.....do......	427.09	17,664	97	6.663	73.659	24.2	1,318	....
60....	.....do......	473.24	19,573	92	7.382	81.619	23.0	1,463	....
..	Register gate......	4.05	160	814	.063	.667	203.5	....	....
8....	.....do......	5.76	223	616	.099	.930	154.0	....	....
10....	.....do.....	10.07	397	488	.157	1.665	122.0	....	....
12....	.....do......	15.19	579	395	.237	2.414	98.8	....	....

VICTOR HIGH PRESSURE.[a b]

[1903 list.]

14....	....	37	247	656	0.037	0.412	65.6	....	....
16....	....	50	332	574	.050	.553	57.4	....	....
18....	....	66	442	510	.066	.733	51.0	....	....
20....	....	82	542	459	.082	.903	45.9	....	....
22....	....	106	707	417	.106	1.178	41.7	....	....
24....	....	128	850	383	.128	1.417	38.3	....	....
26....	....	151	1,001	353	.151	1.668	35.3	....	....
28....	....	173	1,147	328	.173	1.912	32.8	....	....
30....	....	191	1,265	306	.191	2.108	30.6	....	....
33....	....	228	1,512	278	.228	2.520	27.8	....	....
36....	....	272	1,805	255	.272	3.008	25.5	....	....
39....	....	303	2,005	235	.303	3.342	23.5	....	....
42....	....	343	2,277	219	.343	3.795	21.9	....	....
45....	....	387	2,563	204	.387	4.272	20.4	....	....
48....	....	426	2,820	191	.426	4.700	19.1	....	....
51....	....	462	3,063	180	.462	5.105	18.0	....	....
54....	....	504	3,340	170	.504	5.567	17.0	....	....
57....	....	544	3,605	161	.544	6.008	16.0	....	....
60....	....	590	3,907	153	.590	6.512	15.3	....	....
63....	....	619	4,100	146	.619	6.833	14.6	....	....
66....	....	680	4,505	139	.680	7.508	13.9	....	....
69....	....	742	4,910	133	.742	8.183	13.3	....	....
72....	....	799	5,290	127	.799	8.817	12.7	....	....

[a] Made by Stillwell-Bierce and Smith-Vaile Company, Dayton, Ohio. The Victor turbine resembles the McCormick pattern. It has very deep bucket inlets, bulging ladle-shaped discharge, and inside cylinder gate. Small-size Victor turbines for high heads are built with register gate. The high pressure turbine is a recent design (1903), and is tabled for heads of 70 to 675 feet.

[b] Table gives maker's rating for head of 100 feet.

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INDEX.

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