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THE HOLLY SYSTEM OF WATER SUPPLY AND FIRE PROTECTION FOR CITIES AND VILLAGES—

Is an invention of Birdsill Holly, of Lockport, N. Y., and was designed not only to supply cities with water for ordinary purposes at any desired elevation, without the use of a reservoir or stand pipe, or any other contrivance for calling into requisition the principle of the hydrostatic equilibrium, but also to furnish the means of extinguishing fires at several points at the same time, if necessary, and all this without the use of any movable engine for that purpose.

This is accomplished by placing a set of Holly pumping machinery within a frost-proof and fire-proof building, located at a convenient point where the supply of water is accessible, and from whence, by a proper system of pipes, the water can be conducted wherever it is needed.

The machinery forces the water directly into the mains, contrivances being provided by which the pressure within the mains may be increased or diminished, or kept uniform at any degree that may be needed.

The pumping machinery must be adequate to the service required, having a reserve of power for extraordinary occasions.

To guard against the contingency of accidents, the machinery is duplicated, and in large works triplicated.

Mr. Holly's first works were established in Lockport for fire protection alone, the machinery consisting of a rotary pump and turbine water wheel, with necessary connections, and a hydrostatic regulator. Three years later he conceived the idea that the same system of pipes could, by adding to the machinery another pump with suitable connections, be made to serve the daily wants of the community, and the feasibility of the combined service was successfully demonstrated and accomplished at Auburn, N. Y., from which time the system has grown in popular favor, until now it is in use in over a hundred cities and villages in the United States, more than seventy of which were furnished with plans and pumping apparatus by the Holly Manufacturing Company.

The Auburn works had triplicate rotary pumps and turbines, and works having similar pumping apparatus were subsequently introduced at Minneapolis, Minn.; Gouverneur, Ogdensburg and Potsdam, N. Y.; Canton, Ohio; and Allegan, Mich.

The rotary pump was also used in connection with high pressure steam engines for water works in Binghamton, Batavia and Syracuse, N. Y.; Peoria and Decatur, Ill.; Kalamazoo, Jackson and Big Rapids, Mich. In these places the matter of fire protection was the first consideration, that of domestic supply and cost of power being secondary.

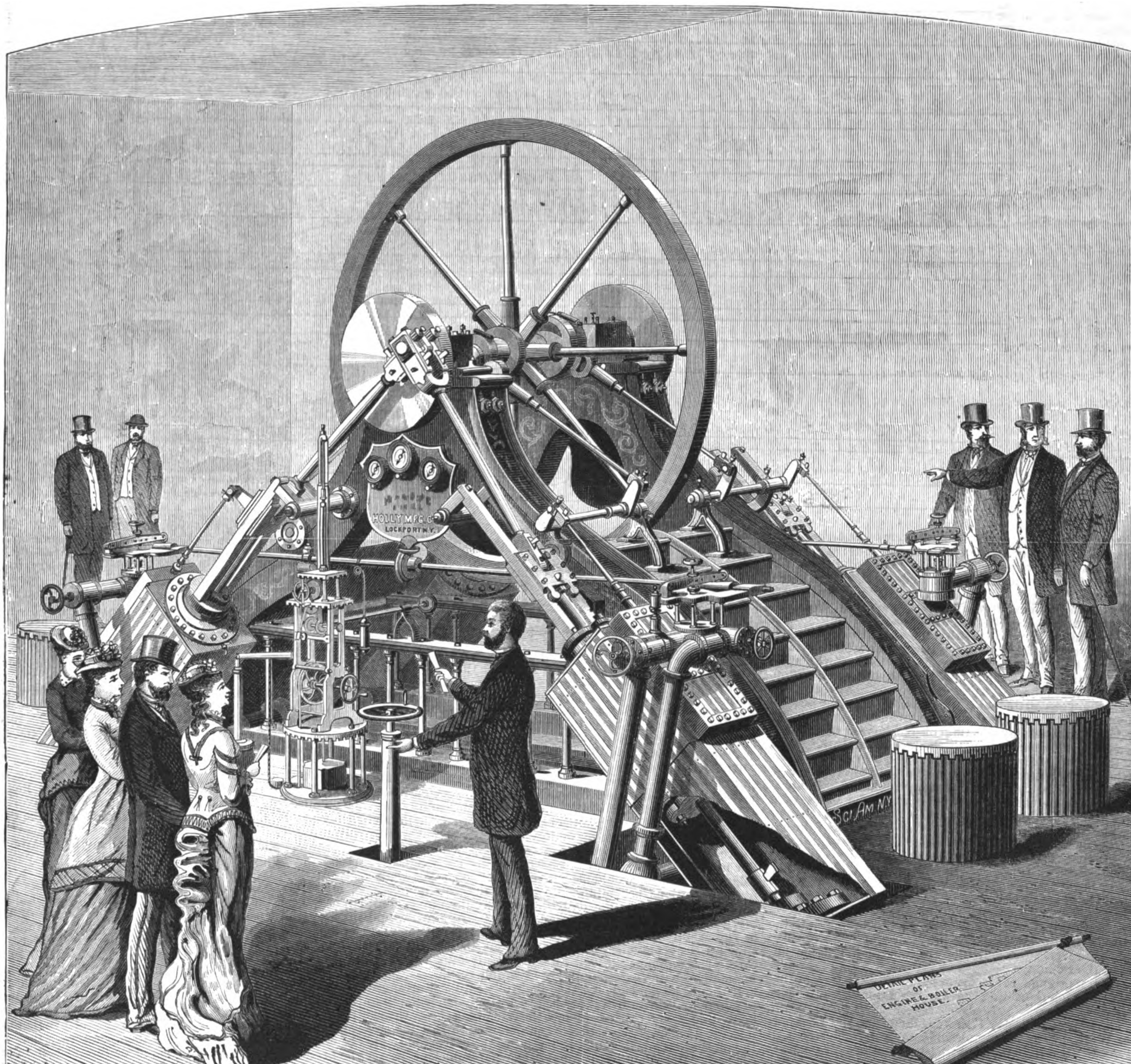
In due time the inventor sought to make such improvements in the mechanism as insured greater economy in the expenses attending daily pumping. The first of these improvements consisted of a series of single acting reciprocating pumps arranged to operate in regular succession, each pump having the lead of that preceding it by one-sixth the length of a stroke, which secured a constant flow of water into the mains. This was called a gang pump, and was designed for domestic supply alone, the rotary pump being in all cases relied upon for the occasional though severer service of fire protection. Some twenty-three water works were supplied with this pump with satisfactory results.

The second important improvement was made in 1871–2, when a direct acting, condensing, steam pumping engine, similar in general construction to the compound engine hereafter described, was erected at the Dunkirk, N. Y., Water Works.

This engine was adapted to both domestic and fire service, and made it possible to dispense with the rotary pumps in some instances.

The third important improvement in the pumping machinery was the addition to the last mentioned engine of appliances for compounding steam. This was first introduced at the Rochester, N. Y., water works in 1873–4, and subsequently at the works in Binghamton, Buffalo, Flushing and Garden City, N. Y.; Titusville, Penn.; Sacramento, Cal.; Bay City and Port Huron, Mich.; Hyde Park, Evanston and Rockford, Ill.; Taunton, Mass.; Burlington and Keokuk, Iowa; Dayton, Columbus and Urbana, Ohio; Indianapolis, Ind.; Kansas City, Mo.; Pueblo, Colorado; and Atlanta, Georgia.

Following is a general description of this *Holly Compound Pumping Engine*, which is the subject of our illustration.



HOLLY'S NEW PUMPING ENGINE AND AUTOMATIC PRESSURE REGULATOR.

The engine consists of four steam cylinders, having four corresponding reciprocating pumps attached by direct connections, and erected on a heavy arched double frame of iron, set at an angle of 90°, one steam cylinder and its pump being placed at each of the four corners. The frame supports at its top a shaft with an overhanging crank on either end, to which the four engines are connected by ordinary connecting rods. The cylinders and pumps are detachable at pleasure, and may be run singly, in pairs, or all together, according to the demands for water supply. The engine is provided with the usual air pump and jet or surface condenser, and by a peculiar arrangement of pipes and valves may be run on either the high, low, or compound steam pressure principle, and may be changed from one to another at any moment, by the engineer. This arrangement is necessary to secure economical daily pumping for domestic supply, which is done by compounding steam, and prompt increase of power for efficient fire protection, which is amply secured by converting the machine into a high pressure engine. When compounding, the steam is taken directly from the boilers into one of the cylinders and exhausted into the remaining three; and when running high pressure, steam is taken directly into all of the cylinders, the latter operation increasing the power of the whole, four to eight times. To supply this increase reserve boilers are provided, and to guard against a failure in the water supply duplicate engines are added when the demands of consumers equal one-half the capacity of the engines first erected.

The Direct Pumping Service, we are informed, requires, to make it efficient and economical, the following highly important features in the pumping apparatus:

1. Ample power to meet the extraordinary demands for water for fire protection. 2. Duplicate engines, pumps and boilers, as a provision against accidents. 3. Economy in daily running expenses. 4. Uniformity of water pressure. 5. Prompt increase of pressure for fire protection.

All these conditions are fulfilled by the engine just described in connection with

THE HOLLY HYDROSTATIC AUTOMATIC REGULATOR,

for controlling the water pressure in the mains and pipes of water works, which next to the engines and pumps is the most important feature of the Holly system of water supply, and is essential to securing the following results:

1. Uniformity of water pressure. 2. Economy in the use of fuel. 3. Relief to the machinery, mains and service pipes from "water hammer," and the strain of unequal pressure. 4. Relief to the engineer from almost constant attention at the throttle valve. 5. Saves the wages of one man.

The Regulator is provided with a piston, placed within an upright cylinder, and having a rod extending upward which is connected to a cross bar, having heavy weights, which by means of suitable contrivances bear down upon the piston with a force that increases as the piston rises. A small pipe connects the water mains with the cylinder below the piston, and any change in the water pressure (which would be increased or diminished by opening or closing service cocks) at once communicates motion to the piston, and the force below the piston is always met by an equal resisting force from the increasing weight. By means of simple appliances, the changes in the position of the piston are utilized to operate on the steam valves of the engine (or the gates of a water-wheel, if works are run by water power), and change the point at which steam is cut off in the cylinders of the engine, thereby increasing or decreasing the power of the engines, the speed of the pumps, and the quantity of water supplied. Thus it will be seen that if the piston moves either higher or lower in the cylinder than the point at which it may have been set to maintain the desired pressure, it will automatically bring the speed of the engine to the rate required to supply the demands for water, and permit the pressure to vary only within the limits needed—two or three pounds—to reverse the action of the cut-off moving mechanism of the regulator.

We here reproduce cards made by an Edson's "recording gauge," showing the action that the regulator has on water pressure.

The diagram dated May 17th was taken from the Lockport Water Works, with the regulator detached from 7:30 A.M. until noon. It will be noticed that the extremes of pressure with the regulator attached are within a range of five pounds, while without the regulator the variation is 35 pounds. The diagram marked "Sandusky Water-Works" was published by parties opposed to direct pumping to show the alleged imperfections of the Holly system. The Sandusky works are on the stand pipe plan, with duplex pumping machinery. This card was taken with the stand pipe disconnected, and the water pumped direct to the city. The only means that could be used to regulate the pressure was the engine throttle valve operated by the attendant. The similarity between this card and the irregular portion of that dated May 17th shows that the system of direct pumping needs some contrivance that will by automatic action maintain a nearly uniform pressure. The differences shown by the diagrams demonstrate the usefulness of the Holly regulating devices.

The maintaining of uniform pressure is of further utility, as it operates to lessen the consumption of coal, by preventing an undue increase of labor on the pumps, such as would result from attempting to carry a fluctuating pressure sufficient to supply the highest portions of a city at all hours. To illustrate, suppose that it is required to force the water to an elevation of 100 feet to supply the most elevated buildings, and that the extremes of pressure from a non-regulated pump have, as the diagrams show, a range of 76 feet head (or 35 pounds). It is plain that if the pressure be allowed to go below 100 feet the highest buildings will not be supplied, and that to maintain the supply the fluctuations of pressure must range wholly above that point. Under these circumstances the actual pressure would be by average 36 feet (36 per cent.) greater under the non-regulated direct pumping than under the Holly plan, which would require a corresponding increase in fuel and strength of machinery, and cause greater strain and wear upon all parts of the works.

It has been a problem of considerable difficulty to design an engine which would meet all the requirements of the direct supply system, and at the same time produce economical results as regards coal consumption. Mr. Holly during his long experience with this system has noted all its defects, and by ingenious contrivances and peculiar methods of construction has remedied them, so that the Holly Company is now prepared to guarantee results in coal consumption, while pumping direct, that will exceed any that can be produced by a duplex pumping engine while pumping into a stand pipe or reservoir, or better results when pumping into reservoir or stand pipe, than with a duplex pumping direct.

Referring again to the Holly compound engine, it is desired to call special attention to the facility with which the pumps may be connected or disconnected to meet the extremes of domestic and fire service. As before stated, the latter requires a supply four to eight times greater than the former, and when the demand for an increase is made the response must be prompt and sure. This can only be insured by providing machinery of sufficient capacity to meet the larger demand. A single engine is objectionable, because the slow rate at which it must be run for the domestic supply makes it impossible to secure economical results in the consumption of fuel, it being a well-known fact that any engine will give the best results when operating at its full capacity and a steady rate of speed. The desired results may be best secured by using several pumps of smaller size, but they should all be connected so as to insure their working in harmony, else the flow of water will not be uniform.

The Holly engine is practically a combination of four engines in one, but so arranged that either or all of them may be used at pleasure, and connected or disconnected in one to three minutes without interrupting the water supply.

This arrangement of pumps has, as intimated, an important bearing upon the matter of duty, especially in new works, where the domestic supply for a few years will be small. For instance, an engine of 2,000,000 gallons daily capacity, using four pumps, would be run at the rate of, say, twenty-four revolutions per minute to pump the full quantity. During the first year the daily demand would not exceed, say, 500,000 gallons, to supply which the four pumps would be run at only six revolutions per minute—a rate much too slow for the economical use of steam, but by disconnecting three of the pumps the full rate of twenty-four would be maintained with correspondingly favorable results.

It should be remembered that the Holly engine is arranged to compound steam by taking it direct from the boiler into one cylinder, and exhausting into the remaining three, thence into the condenser, and that when operated in this manner the most economical results in pumping the daily supply are secured. But when so operated it has not sufficient power to meet all the requirements of fire service, so provision is made for increasing the power by converting it into a condensing or low pressure engine, live steam being then taken into all of the cylinders at partial or full length of stroke, as may be necessary. In case the air pumps or any part of the condensing apparatus become disarranged, they may be disconnected and the engines run on the high pressure principle. Thus it will be seen that the economic results due to a compound engine, and the greater power due to the condensing and high pressure engines, are both secured in this latest improvement of Mr. Holly.

An attempt to accomplish equal results in economic daily running and effective fire protection with a large compound engine of sufficient power to perform the latter service would fail in securing the former, for the reason before given, that an engine must be constantly used at its full capacity to secure the best results.

The chief merits and advantages of the Holly System are that it—

1. Secures by variable pressure a more reliable supply of water for all purposes. 2. Less cost of construction. 3. Less cost for maintenance. 4. Less cost for daily supply by the use of Holly's Improved Pumping Machinery. 5. Affords the best fire protection in the world. 6. Largely reduces insurance risks and premiums. 7. Dispenses with fire engines in whole or in part. 8. Reduces fire department expenses.

A great mass of undisputed evidence could be presented in verification of these claims, but it is deemed unnecessary, because the Holly system has become generally known throughout the country, and its successful operation in seventy cities and villages has long since established the fact that it is no longer an experiment, but one of the greatest inventions of the age.

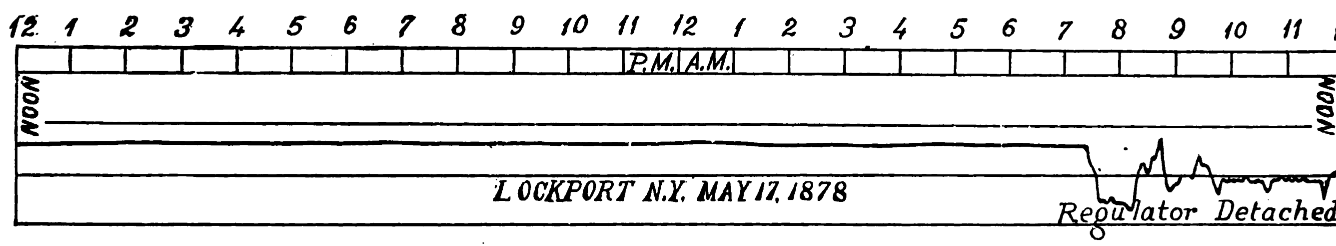
The idea has been industriously circulated that the Holly plan is only suitable for small places, and on a small scale, when, in fact, it is susceptible of enlargement to meet fully the wants of the largest city on the face of the globe. This enlargement may be accomplished either by increasing the size of machinery, or by multiplying sets of machinery, or both of these modes combined, and with corresponding enlargement and extension of street mains. It also provides for supplying water at higher elevations and longer distances than can be done with works on any other plan.

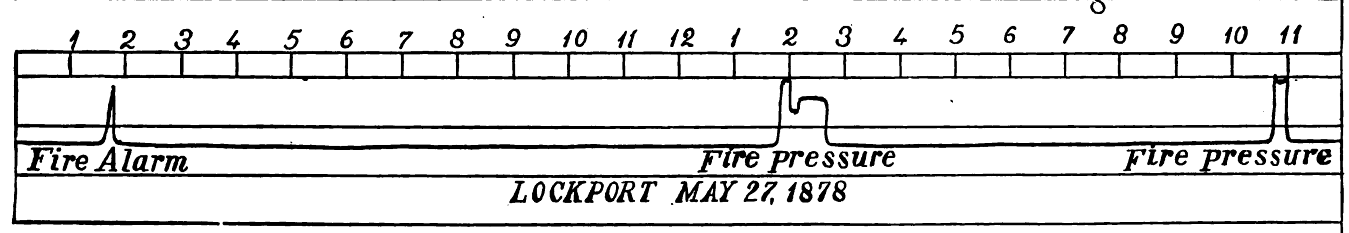
The Holly system, like all other important inventions, has met with vigorous opposition. Some came from persons having honest differences of opinion as to its practicability, much from men who opposed without fully investigating its merits, and more from parties whose pecuniary interests were more or less affected by the success of the new plan.

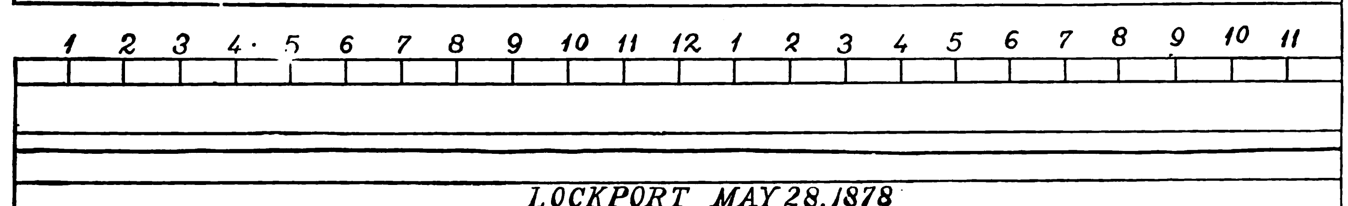
The crowning proof of the merits of Holly's Water Works is found in the fact that in several instances parties are striving to imitate the plan which Mr. Holly has devised, perfected and secured to himself and associates in the Holly Manufacturing Company by numerous letters patent. It is alleged that this may be done without incurring legal liabilities for patent infringement, because Holly's plan is not new, but was in use in London some three hundred years ago and in other places at later dates. In order to test the validity of Mr. Holly's claims, the first two cases of infringement were promptly taken up and carried into the courts; one was against the city of Rahway, N. J., and the other the city of Union City, Ind. It was decided to make the latter the test case, and a vigorous contest extending over a term of more than seven years ensued. It was finally decided in June last, by Judge Drummond, in favor of the Holly patent, as will be seen by extracts from the decision given below.

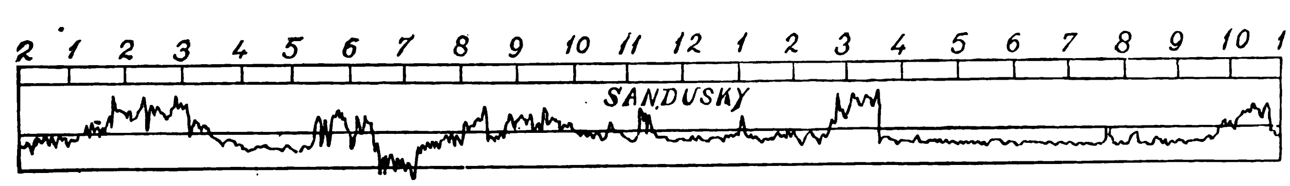
In order that the question at issue may be clearly understood the following quotations from the letters patent are given:

Mr. Holly says in the specifications: "I do not pretend to have been the first to conceive the idea of furnishing water in limited quantities for ordinary use by means of forcing pumps; nor do I deny that stationary pumps have been employed instead of movable ones in throwing water for the extinguishment of fires; but my invention consists in effecting these two objects by one single apparatus, and then developing that apparatus into an effective system for the attainment of these ends. This is accomplished by pumping the water directly into the mains of the water works, having made provision by which the degree of pressure therein may be entirely under the control of the operator, so that it may be preserved uniform or increased or diminished in any degree at his pleasure. By this means the apparatus which with one degree of pressure may be serving as a means of supplying water to a whole city for ordinary use may, by simply increasing that pressure, become at the same time a









most effective fire engine, which through hydrants previously and properly located may be made to operate in various portions of the city at the same time, and (owing to the great incompressibility of water) this change can be effected almost instantaneously throughout. This is the subject matter of my invention."

This first claim, upon which the suit was founded, reads as follows:

"1. The above described method of supplying a city with water—that is to say, by pumping directly into the mains when the apparatus for that purpose is supplied with contrivances by which the pressure within those mains may be preserved in a great degree uniform, sufficiently so for practical purposes, *or increased or diminished at pleasure*, substantially as and for the purpose above shown."

The following extracts from the decision of the Court embrace the points of general interest:

"That the letters patent No. 5,132, reissue, on the first claim of which the present suit is founded, are good and valid in law; that the method of supplying a city with water, as described in said first claim, is the invention of said Holly, and that the said claim is not anticipated by any of the prior patents and uses pleaded in this case; that the defendant has infringed said letters patent, and an injunction is therefore ordered to restrain the defendant from making, using, or vending any system of water works whereby the water is pumped directly into the water mains, the apparatus for that purpose being supplied with contrivances like or substantially like those shown and described in said reissued letters patent, by which the pressure within the mains may be preserved in a great degree uniform, sufficiently so for practical purposes, *or whereby it may be increased or diminished at pleasure*, or from in any manner infringing upon or violating any right or privilege granted or secured to the complainant by the said reissued letters patent."

After the success of the Holly Water Works had become assured, various parties, some of whom were unwilling to fully acknowledge its advantages, and others who desired to evade the Holly patents, devised and suggested several modifications and compromises between it and the older systems of water supply, all of which were designed "to enable the operator to increase or diminish the water pressure at pleasure." These devices may be classed under the following heads:

1. The use of gates for shutting off the reservoir or stand pipe, and an auxiliary main through which the water might be pumped direct in case of fire or other emergency.

2. The erection on the top of a stand pipe of a tank, of sufficient size to contain a few hours' supply of water, by way of avoiding constant pumping, and having gates and direct main, as above, for fire supply.

3. The construction of an exceedingly large stand pipe or iron reservoir for domestic supply, with a small internal stand pipe of greater height for fire pressure; also with gates and direct main, as above.

4. A stand pipe with partially closed top, having a valve by which it could be closed entirely to prevent overflowing when pumping direct for fire pressure, and which, when closed, would serve as a huge air chamber.

5. A large iron air chamber, called by the inventor an "accumulator," filled with compressed air, which was to be turned on to the water mains so as to quickly increase the pressure sufficiently to throw five streams directly from the hydrants. In this case the water was to be pumped direct for all purposes.

Following is the record of the Holly Compound Pumping Engine, as regards duty, or pounds of water raised one foot by the engine, with a consumption of one hundred pounds of coal under the boilers:

Place.	*Date of test.*	*Duty in foot pounds.*	*Authority.*
Rochester, N. Y.	July 9, 1874	63,309,107	J. E. Booth & F. H. Clement.
Evanston, Ill	Mar. 24, 1875	54,960,024	J. R Fitch & L. E. Cooley.
Atlanta, Ga	Sept 28, 1875	60,408,800	R. T. Scowden.
Binghamton, N.Y.	Mar. 6, 1876	81,514,000	John Evans.
Indianapolis, Ind.	April 6, 1876	76,257,848	W. Bellis & W. G. Hamilton.
Taunton, Mass.	Dec. 26, 1876	49,045,944*	Geo. H. Bishop.
Taunton, Mass.	Dec. 28, 1876	75,117,514	Carlos Holly.
Hyde Park, Ill	April —, 1878	65,258,700	E. S. Chesbrough & J.D.Cook.
Burlington, Iowa	May 30, 1878	71,514,000	T. N. Boutelle.
Keokuk, Iowa	July 18, 1878	62,334,429	W. C. Stripe.

In all the tests no allowance was made for cinders or ashes, excepting at Burlington, where, on account of inferior quality of coal, twenty per cent. of the refuse was deducted.

The average cost of pumping one million gallons of water one foot high with Holly engines during the past year was, according to official reports: In Binghamton, N. Y., 7 1/10 cents; Rock Island, Ill., 8 1/10 cents, and Atlanta, Ga., 9 1/10 cents. This includes repairs and all other expenses pertaining to the pumping departments.

As a system of fire protection there can be no doubt this is the best. It makes every hydrant a powerful fire engine, which can be used to put out fires more successfully than by the movable engines which must be used in connection with gravitation works. Under the Holly system there are increased barriers against large conflagrations, and protection against large and fearful losses. We are informed that underwriters recognize the introduction of this improved method of fire suppression as a reason for reduction in insurance rates.

An astonishing fire stream display was given at the trial for acceptance of the Holly Works, in Rochester, N. Y., in February, 1874, which may appear almost incredulous, but the statements here made are vouched for by no less than nine civil engineers and surveyors, who were stationed at different points to measure the height of the streams. We summarize the result of the test as reported as follows:

1st. Thirty streams from 1-inch nozzles through single lines of hose attached to the hydrants were thrown to the height of 135 feet. 2d. One 2-inch stream supplied by three leads of hose attached to a discharge pipe, having triplicate couplings, was thrown 230 feet high. 3d. One 3-inch stream from a special attachment to one of the principal water mains was forced 285 feet high. 4th. One 4-inch stream was forced 297 feet high and 465 feet horizontally. 5th. One 5-inch stream was thrown 250 feet perpendicularly.

For further information address the Holly Manufacturing Company, Lockport, N. Y.

TERRIFIC cloud bursts are common in the Black Hills, where one recently inundated a large tract of farming country, sweeping away ox teams and drowning one man. They have also done much damage to the track of the Union Pacific Railroad.

* The first test at Taunton was made with the engine pumping only one third its rated capacity.

ROCK-BORING MACHINERY.

AN admirable sketch of the history and characteristics of rock-boring machinery is given in an interesting pamphlet by Mr. Richard Schram,* whose own invention for a rock drill was referred to in the *Mining Journal* a few weeks since. He remarked that during recent years the success attending the introduction of rock-boring machines for accomplishing various engineering works had induced many to decide upon substituting machine work for hand labor in drilling for the purpose of blasting in mining and excavating operations. Some difficulties have been encountered in selecting a machine precisely suited for the particular work in hand, and thus a certain prejudice against the use of these machines in general has not unnaturally been created.

Referring to the causes which have led to rock-boring machines not having proved wholly successful, Mr. Schram is of opinion that it will be found upon inquiry that it is because their practical working has not been properly understood. Experience teaches us, he remarks, that in the employment of rock-boring machines it is as essential that the whole system of operations be sound and well planned as that the machines themselves be effective and simple, so as not to require much or frequent repairing. Upon the first introduction of rock-boring machines old experienced miners were employed, and it was quite natural that they should endeavor to give the holes such directions, and proceed generally as nearly as possible in the same manner, as they had been accustomed to do in hand boring.

If, however, we glance at the progress of any other branch of industry, we shall find that a more systematic method of working has invariably been the consequence of the introduction of machinery, and that to the improved organization and regularity thus accruing must be attributed no inconsiderable part of the great and manifold advantages of all machine work over hand labor. Rock boring by machinery forms no exception to the industries obeying this general law of progress, and upon its introduction rational systematic methods of working must be adopted. At the present time there is scarcely any branch of industry in which machinery does not play an important part. In some branches the mechanical appliances are so perfect that it would be impossible now to dispense with them; in others, on the contrary, the machines may be said to be in their infancy. To this last category rock boring has hitherto belonged.

The idea of using machinery in rock drilling was, Mr. Schram tells us, entertained long ago. In 1844 Burton, an Englishman, suggested the idea of employing compressed air to work a hammer striking upon a drill, but no practical support was given to the suggestion; and it was in the year 1854 that Bartlett, also an Englishman, and in 1855 that Schumann, of Freiberg, first appeared before the public with practical experiments. From these dates down to the present time improvements and developments in rock-boring machinery have succeeded one another with great rapidity. Mr. Schram ranges the existing rock-boring machines into five classes—the ram system, embracing the Schwarzkopff and Warsop drills; the lever system, embracing Schumann's, Burleigh's, Sach's, McKean's, Warrington's, Ingersoll's, Dunn's, Roanhead, Cranston, Barrow, and many other machines; the duplex system, embracing the machines of Sommeiller and Ferroux; the rotary system, embracing the diamond drill, Brandt's, etc.; and the direct acting system, including Darlington's, Schram's, and Reynolds', without slide, and Osterkamp's, Schram's, Cederblom's, and others with slides.

Discussing the merits of the several systems, Mr. Schram remarks that the ram system as applied to rock-boring machines must prove impracticable, and must be so apparent to every one who has seen a worn-out hammer and hand drill that it is unnecessary to give it any consideration. The lever system has, he says, long kept its place, and several machines constructed upon this system have done very good service, but he considers the disadvantages of the system are the great wear and tear to which the machines must be exposed, and the unpreventable loss of power, results which he regards as inseparable from a mode in which levers or tappets are actuated by the piston.

The duplex system has, Mr. Schram states, only been employed in places where compressed air has been cheap and plentiful, as in the Mont Cenis and St. Gothard Tunnels, but in either of these places machines of a later invention would have been found to work both better and more economically. By employing a separate engine to work the slide, the piston which carries the cutting tool runs perfectly free, and as these pistons are made of a large diameter and have a long stroke, the machines are consequently very powerful. But in proportion to their great consumption of compressed air (first in the subsidiary engine and again in the main cylinder) they prove very expensive in working. Moreover, in consequence of the great length of the machines, the holes must all be bored in a nearly horizontal position, thereby necessitating the use of a greater amount of explosive for blasting than would otherwise be necessary. The rotary system, as carried out for blasting operations, has likewise met with very limited approval.

It is true that Lisbeth's rotary hand drill, as improved by Macdermott, works admirably in coal and soft slate, and no doubt the employment of these machines in coal mines is already extensive, and is rapidly spreading, but they are by no means adapted for the harder varieties of rock. Mr. Schram admits that for prospecting purposes the diamond drill is no doubt extremely valuable. One of the advantages held out in favor of rotary rock drills is that they are incessantly working into the stone, a condition evidently incompatible with any percussive action; but, on the other hand, the force of each blow of a percussion machine is very much greater than the force which in a rotary machine is constantly exerted. Moreover, the constant resistance to which the tool of a rotary drill is subjected necessitates a greater motive power, and, after all, the actual work done is less than that of a percussion machine.

An interesting trial of a rotary rock-boring machine invented by Brandt was made in 1877 in the Sonnenwendstein Tunnel, on Ebensee, in Austria. On the shore of the lake Ebensee an engine house was built, in which was erected a steam engine with two steam cylinders, each 24 centimeters in diameter. Water under a very high pressure (stated to be 70 atmospheres) was carried in strong wrought-iron tubes into the tunnel, where it worked the rock-boring machines. These consisted of two auxiliary cylinders, acting upon a crank shaft laid at right angles across the drill, and a worm cut in the middle of this shaft caused the drill to rotate. The central part of the machine formed a cylinder, in which was fitted a plunger piston attached to a joint, by means of which the machine was connected with a very strong stretcher or standard. Water being admitted to this cylinder, and exerting its force against the plunger, pressed the whole machine forward toward the rock, and thus maintained an enormous pressure on the cutting tool as it rotated. In the extreme end of the drill, which was hollow, there was a steel crown furnished with teeth, which, through the rotary motion and the great force with which the apparatus was pressed against the rock, cut the stone in a similar manner to the diamond drill. Water was employed to clear out the debris from the holes.

The drill made 30 revolutions per minute, and, boring holes of 7·5 centimeters diameter, it progressed at the rate of 3 centimeters per minute. The rock was dolomite. As great difficulty was experienced in commencing the holes, they were bored double their required depth—that is to say, double the depth at which the explosive proved to be effective, and before being charged and fired were filled up for half their depth with sand. After the first charges were fired the sand was removed from the remainder of the holes, which were then charged and fired again. The heavy expenses of working proved too great for the general adoption of this machine in other places.

As belonging to the direct acting system without slides, Mr. Schram has mentioned the Darlington, Reynolds, and Schram machines. Simple as this system is, it is, he says, nevertheless unpractical, because the piston being propelled by expansion, the pressure is consequently least when it ought to be greatest—*i. e.*, at the end of each stroke. Another defect is that pressure is exerted on the lower side of the piston during the forward stroke, thereby counteracting the force of each blow to a most injurious degree. The Darlington machine especially requires twice the quantity of compressed air necessary for most other machines of the same size, notwithstanding which the effect in boring horizontal holes is over 100 per cent. less than in the case of machines of more modern construction. He describes one of his own machines of this class, but remarks that this system, simple as it is, is by no means practicable, as, though the machine will run at an extraordinary high speed, the boring results, as compared with the direct acting machines with slide, are not satisfactory.

In the class of direct acting machines with slides are those by Osterkamp, Dœring, Schram, Cederblom, and others; and he here describes his own arrangement, which has certainly much to recommend it. The only moving parts of the machine are the main piston, the slide piston and slide, and the rotating movement with its piston. It is an important feature in this machine that the slide rod is made in the form of a double spindle valve; by this method of construction it remains in position without any recoil until the piston has made the greater part of its stroke. As in some varieties of rock it happens that the drill often sticks fast, there is a reversing rod to suddenly reverse the slide, and thus pull the drill out of the hole. With careless workmen it would frequently happen that the piston would strike against the lower cylinder cover, therefore there is an air cushion at the lower end of the cylinder. In addition to this there are an iron ring and an India-rubber washer (exchanged for one of wrought iron when steam is used), with the object of moderating the violence of the shock such blows, inadvertently permitted, would cause. In order that the hole drilled be perfectly round, it is necessary that the cutting tool should partially rotate at each backward stroke so that its cutting edge shall every time strike the rock in a fresh place, but in order not to lose any power it must always make its forward stroke without rotating. For this purpose a twisted bar is employed, connected with a grooved disk, and a brake acted upon by a small piston. Communicating from the slide box with the cylinder is a small port, by means of which the compressed air exerts a constant pressure upon the upper end of the small piston. When the main piston makes its backward stroke the back end of the cylinder is in communication with the outlet, and consequently there is no pressure on the lower end of the small piston.

The constant pressure on the upper end of this piston, therefore, now presses it upon the brake which presses upon the disk, preventing it from turning, and thus the main piston is forced to partially rotate round the twisted bar secured to the disk. But when the main piston makes its forward stroke, and steam or compressed air fills the back end of the cylinder, the motive fluid enters through small ports and presses on the lower end of the small piston, thus counterbalancing the constant pressure on the upper end. There being now no pressure on the brake the disk is free to rotate, and the main piston makes its forward stroke without rotating, partially turning the disk as it proceeds by means of the twisted bar.

This machine is sometimes made with an automatic feed motion actuated directly by means of a piston, instead of, as in other rock-boring machines, through levers, but the inventor nevertheless recommends in all cases a manual feed, as, notwithstanding all the assertions to the contrary of eager rock-boring machine dealers, practical miners know that in some faulty rock the drill will and must occasionally stick fast. When this happens it takes much longer time to clear the cutting tool, if an automatic feed is in use, than in simply giving the handle of a manual feed a turn or two, which is all that is necessary to loosen the drill and permit of the boring being proceeded with. Moreover the workmen are never so attentive to their work when they have nothing to do but to look on as they are when they have the machine constantly under hand. Thus, apart from the increased complication and greater wear and tear to which even the best automatic feed motion renders any machine liable, such a feed has always been found objectionable in actual practice.

Through the perfectly free action of the main piston, and because the motive fluid is admitted to the whole surface of its upper end, each blow is extremely powerful; moreover this free action, combined with that of the slide piston, allows the machine to be run at a very high speed, and enables it to be worked with a very low pressure. Its principal feature, however, is its remarkably small consumption of compressed air, as an air compressor which would only be able to drive one machine constructed on the lever system will easily drive two of Schram's, the diameter of cylinder being the same in both cases. There being no parts exposed to blows, and the principal parts being directly actuated by the motive fluid, this machine is less liable to wear and tear than those of other systems. It should also be observed that the working parts are all inside the cylinders, so that rough-handed miners, unaccustomed to use more fragile instruments than sledge hammers and picks, may be safely intrusted with the handling of these rock drills.

Reverting for one moment to the slide action, it may be mentioned that this machine was at first constructed with a cylindrical slide, but considering the leakage of motive fluid

* "The Application of Machine Power in Rock Drilling." By Richard Schram. London: G. Hill, Westminster Bridge-road.