THE HOLLY SYSTEM

OF

WATER SUPPLY

AND

FIRE PROTECTION.

MANUFACTURED BY

THE HOLLY MANUFACTURING COMPANY,

LOCKPORT, NEW YORK.

NEW YORK OFFICE,

No. 157 BROADWAY.

P. O. Box 1372.

CITIES AND TOWNS USING THE HOLLY SYSTEM OF WATERWORKS.

	POPULATION.
CALIFORNIA.	
Sacramento	21,420
COLORADO.	
Denver	35,630
Pueblo	7,821
Golden	2,731
DAKOTA.	
Fargo	2,700
DELAWARE.	
Dover	3,000
GEORGIA.	
Atlanta	34,398
ILLINOIS.	
Decatur	9,450
Evanston	4,870
Town of Lake	10,000
Litchfield	4.307
Peoria	29,315
Rock Island	11,660
Rockford	13.136
INDIANA.	
Columbus	6,000
Connersville	3,226
*Fort Wayne	26,880
Evansville	29.280
Indianapolis	75,074
Do Insane Asylum.	
Laporte	6,189
IOWA.	
Atlantic	2,916
Burlington	19,450
Des Moines	22,408
Iowa City	8,865
Keokuk	12,117
Oskaloosa	4,800
KANSAS.	
Abilene	2,047
Emporia	5,760
Salina	3,111
Topeka	15,451
KENTUCKY.	
Covington	29.720
*Newport	20,433
Owensborough	10,000
MAINE.	
Bangor	16,857
*Rockland	7,600
MARYLAND.	
Cumberland	10,666
MASSACHUSETTS.	
Milford	9,310
Taunton	21,213
MICHIGAN.	
Allegan	
Alpena	4,758
Bay City	20,693
Big Rapids	3,500
East Saginaw	19,016
Jackson	16,105
Kalamazoo	11,937
Marquette	6,510
Manistee	7,075
Plainwell	1,402
Port Huron	9,992
Saginaw City	10,525
MINNESOTA.	
Minneapolis	46,887
MISSOURI.	
Sedalia	1,100
Kansas City	55,813

* *Reservoir Works.*

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CONSTRUCTION

OF

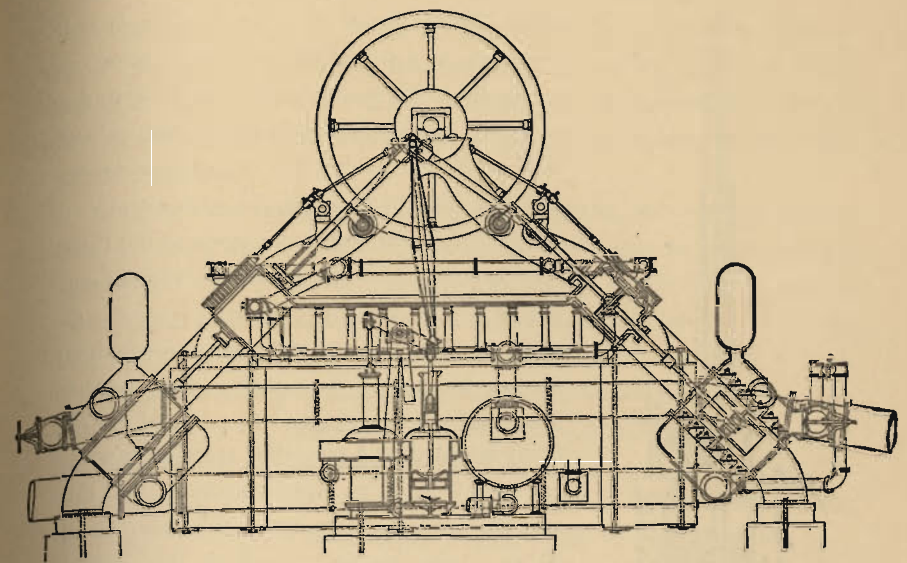
THE HOLLY QUADRUPLEX

PUMPING ENGINE,

AND

AUTOMATIC PRESSURE REGULATOR.

The Holly Quadruplex Pumping Engine is represented in perspective in the frontispiece and in sectional elevation in Fig. 1. It has four steam cylinders inclined at an angle of forty-five degrees, and four pumps, one of which is in a direct line with each cylinder. The steam cylinders and their pumps are arranged in pairs on opposite sides of a heavy iron frame, the two cylinders of each pair being connected to a common crank-pin, and the crank for one pair of cylinders being set 135 degrees in advance of that on the opposite side. The engines are of the reciprocating piston form, with guides and connecting rods. A connecting rod attached to the back crank-pin actuates an air-pump beam, giving motion to two single-acting air pumps and two boiler feed pumps, one of which draws water from the hot well, and the other from the steam jackets which surround the sides of all the steam cylinders. The steam from the jackets passes through a feed water heater, so that the temperature of the feed can be raised to any desired point by increasing the amount of steam supplied to the jackets.



The connection of the pumps with the steam cylinders and the steam piston rods with the pumps, is by means of keys, so that any engine or pump can readily be thrown out of action.

The steam piston is packed by cast-iron rings set out by springs, the set screw of which projects beyond the face of the piston, and there are bonnets in the lower cylinder heads, so that the piston rings can be adjusted without opening the cylinder.

The pumps are of the piston variety, double-acting, the pump barrel being secured in a chamber containing the valves by a rib which forms a partition between valves on the opposite ends. The pump valves are flat discs of rubber, secured to iron discs having stems working in guides. These iron discs are of sufficient weight to bring the valves to their seats promptly, and no springs are used. The valves seat on metal gratings. The steam and exhaust pipe of the several steam cylinders are so arranged that steam from the boilers can be admitted directly into all the cylinders, and exhausted into the condenser, or live steam can be admitted to but one cylinder, and exhausted into the other three, then passing the condenser, forming a compound engine at pleasure. To

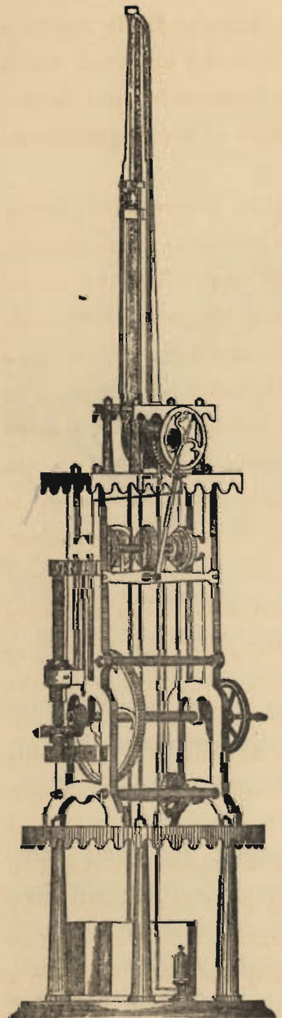


Fig. 2.

change from direct to compound, it is only necessary to manipulate three stop valves, one connecting the steam pipe of three cylinders with the boilers, one connecting the exhaust pipe of the fourth cylinder with the condenser, and the third connecting the exhaust pipe of one cylinder with the steam pipes of the three.

The valve gear of each steam cylinder consists of a slide valve moved by an eccentric in the usual manner, and admitting steam throughout the whole stroke. A double puppet valve in the steam chest regulates the point of cut-off, being actuated by a revolving spiral cam which can be moved in an axial direction, and thus vary the period of admissions from zero to full stroke. The manner in which this cam is moved so as to regulate the speed and power exerted, is an important peculiarity of the Holly Pumping Engine.

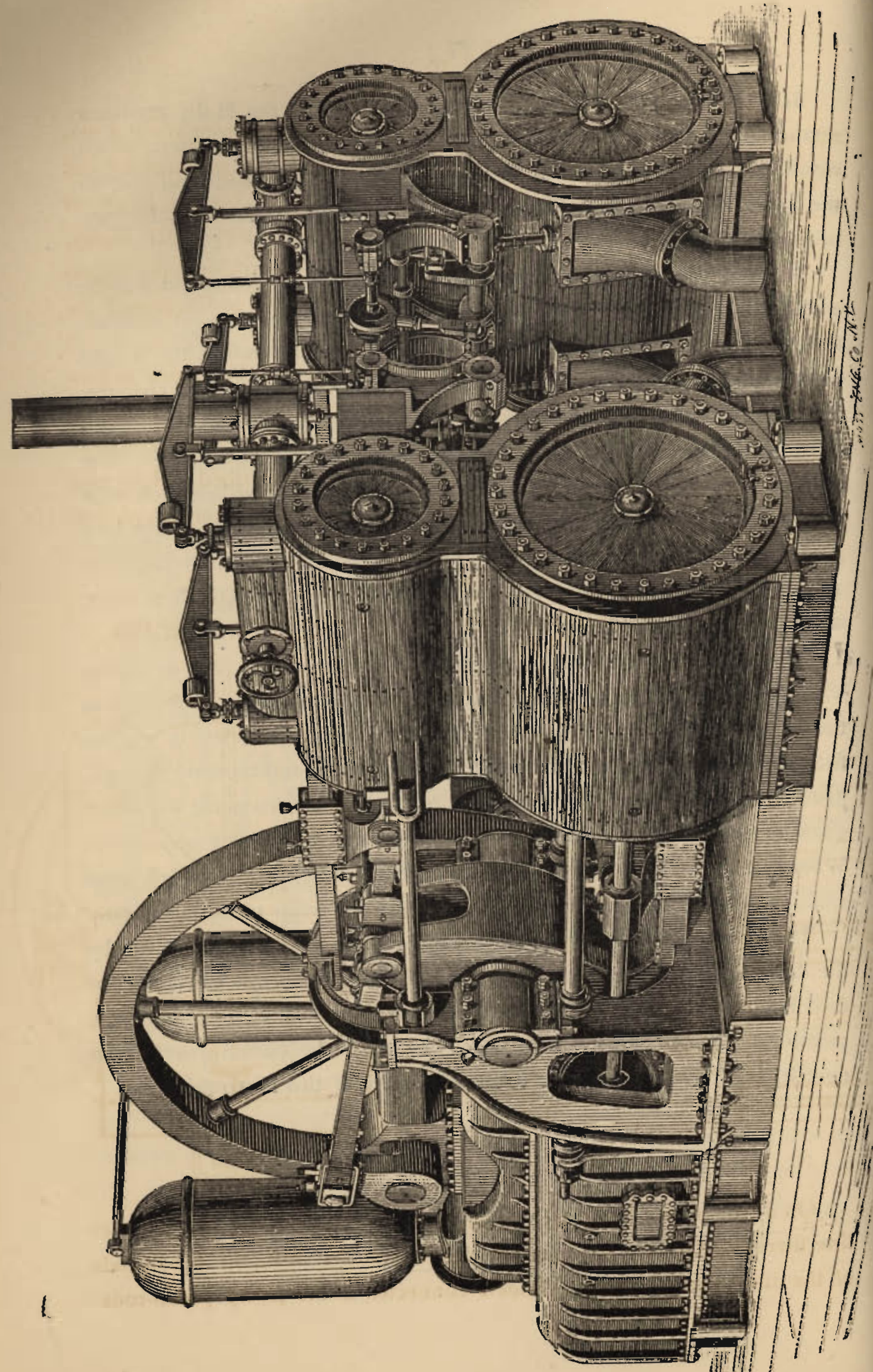
The adjustment is effected by means of a regulator connected with the water main in such a manner that any change in water pressure is immediately corrected by an adjustment of the cut-off, resulting in a practically uniform water pressure, under the most varying conditions of supply. If the water pressure tends to fall, owing to an unusual draft upon the main, the cut-off is immediately lengthened, and the engines exert a sufficient power to maintain the original pressure; if the consumption is suddenly lessened, so that there is a tendency for the water pressure to increase, the cut-off is at once shortened, diminishing the power of engine sufficiently to maintain the original pressure under the reduced supply, and if all consumption of water suddenly ceases the engine will immediately stop. The regulator is represented in Fig. 2.

It is evident from the foregoing description that the Holly regulator acts in an essentially different manner from the ordinary governor, which would increase the cut-off as the water pressure augmented, and shorten the cut-off as the same diminished. The details of the regulator are briefly as follows:

A small water cylinder, containing a solid piston, is connected directly with the main, and a weight is attached to the piston so as to counter-balance the water pressure. This is effected by suspending the weight from a strap which passes over a cam that rotates as the pressure changes, thus altering the lever arm of the counter-balance, and keeping it in equilibrium with the water pressure, however much the latter may vary. The cut-off cams of the steam cylinders are moved axially, either to shorten or lengthen the cut-off when the regulator throws a friction clutch into gear, which it does whenever the water pressure varies from a given amount. A weighted lever would maintain this friction clutch in gear, were it not for the action of the regulator.

The shaft on which the counter-balance cam rotates has an index wheel, and the index can be set at any desired water pressure. So long as the water pressure varies from the figure at which the index is set, the friction clutch is kept in gear by the weighted lever, and the cut off is adjusted until the required pressure is reached. At this point the index engages with the weighted lever, and throws the friction clutch out of gear. Whenever the water pressure varies, the friction clutch is thrown into gear again, changing the cut-off so as to maintain the water pressure constant.

It will be seen that the cut-off is regulated by positive gear driven by the engine, and the only work required of the regulator is to connect or disconnect this gear. Should the pressure rise very suddenly, however, a piston in a safety cylinder raises a lever to which the cut-off gear is connected, and throws the cut-off to zero instantly, if this is requisite.



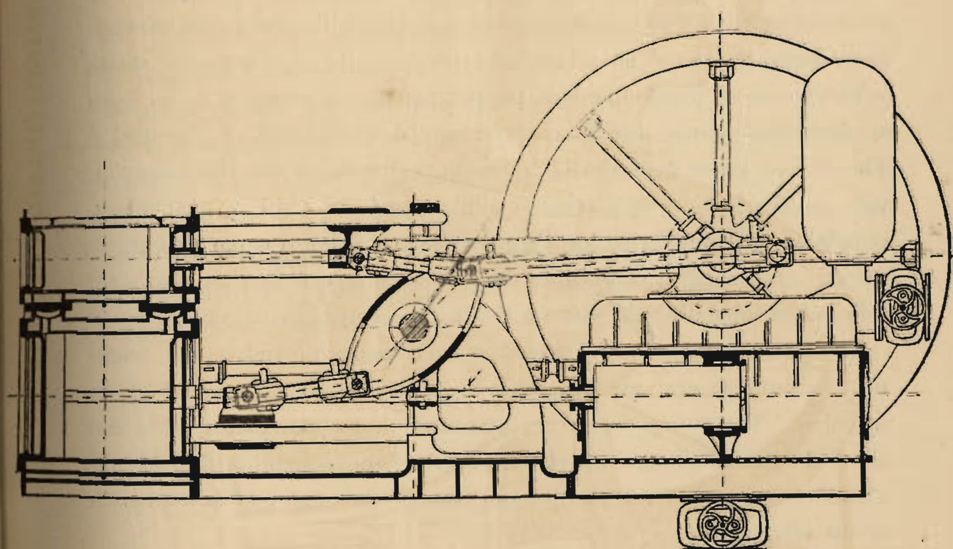
GASKILL HORIZONTAL COMPOUND PUMPING ENGINE.

Following the Quadruplex Engine, the Company has brought out a new Horizontal Compound Condensing Engine, designed and patented by, and constructed under the superintendence of Mr. Harvey F. Gaskill, Engineer and Superintendent of the Company's works, and successor to Mr. Holly, who, on account of engaging in other enterprises, relinquished the superintendence of the mechanical details of this business, and accepted the position of Consulting Engineer.

It was the purpose of the Company in bringing out this engine to provide one less costly than the quadruplex, and better adapted for pumping larger quantities of water; also to stand in the first rank as to economy. This engine, when built as a non-compound, as described below, also provides for the want of a cheaper class of pumping machinery adapted to the use of small towns and cities of limited means.

Following is a description of the

GASKILL HORIZONTAL COMPOUND PUMPING ENGINE.



On a pair of iron bed plates are mounted the two pumps, and in direct line therewith the two low-pressure steam cylinders, with the piston-rods of the low-pressure steam cylinders connected to the pump piston-rods.

Between the pumps and steam cylinders are placed beam supports, which are firmly bolted to the bed plates, and also rigidly stayed by wrought-iron struts to the pumps and steam cylinders. These beam supports carry the beam shafts and beams, the lower end of the latter being connected to the cross-heads of the low-pressure cylinders by means of links.

On the top of the pumps are placed the main shaft bearings, which support the shaft, fly-wheel, and cranks, the latter being keyed to the shaft at right angles to each other. On top of the low-pressure steam cylinders are mounted the two high-pressure steam cylinders, with their centres in the same horizontal plane as the centre of the main crank shafts. The cross-heads of the high-pressure steam cylinders are connected by means of links to the upper ends of the beams, and the beams are in turn connected by means of connecting rods to the crank-pins. From the high-pressure steam cylinders heavy cast-iron girders extend to the pillow-blocks. On the inner end of each of the beam centers an arm is keyed, from which the air pumps are driven. The valves of the steam cylinders are operated by means of eccentrics on a shaft, which is driven from the main shaft through small bevel gears. The admission valves to the high-pressure steam cylinders are of the double-beat poppet pattern, so arranged as to open at the proper time and to close at any desired point of the stroke. The exhaust valves from the high-pressure cylinder are also the admission valves to the low-pressure steam cylinders, and are ordinary slide valves, remaining open somewhat less than the time required to make a complete stroke. The exhaust valves from the low-pressure cylinders are also plain slide valves, operating the same as the high-pressure exhaust valves.

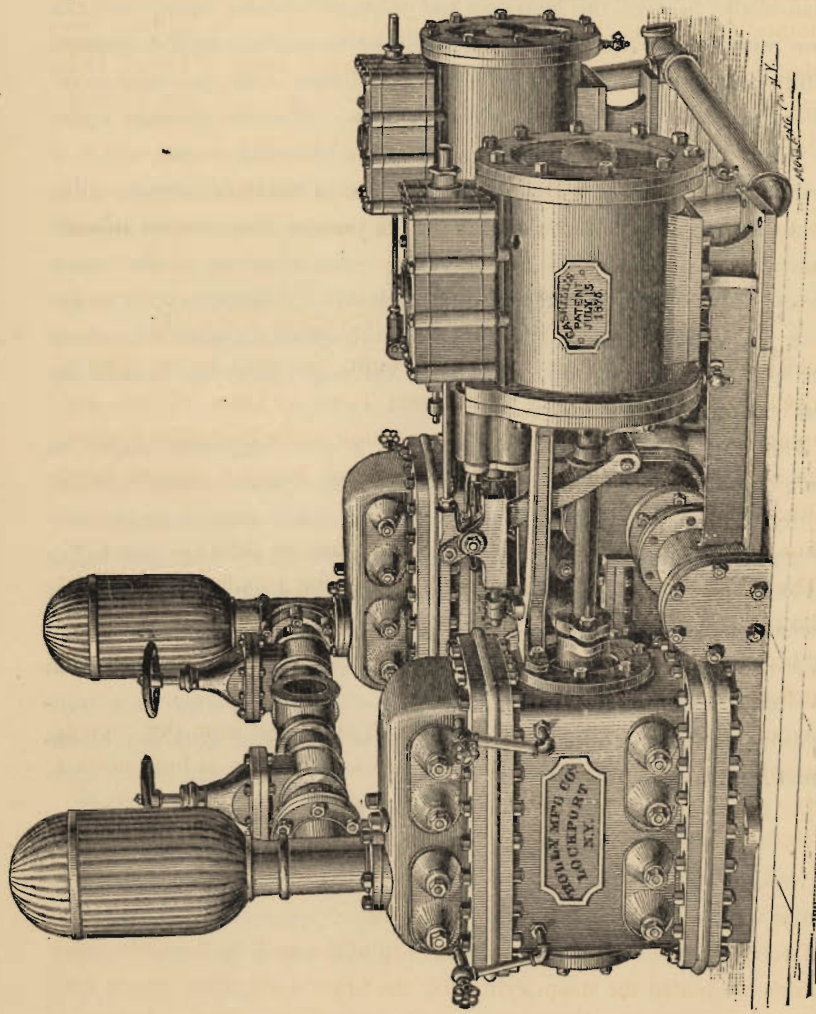
The pump plungers are arranged to work through glands in the center of the pumps, and are accessible from the covers at the end of the machine. The pump valves are placed on horizontal plates below and above the line of plunger travel. The glands above-mentioned divide the valves of one end of the pump from those of the other end at the center of the valve plates.

The operation of the machine is as follows :

Steam is admitted through the automatic cut-off valves into the high pressure steam cylinders, urging the pistons forward under full boiler

pressure until the point of cut-off is reached. The valve then closes and the remaining portion of the stroke is accomplished by the elastic force of the steam. When the piston has nearly reached the end of its travel, the exhaust valve between the high and low pressure cylinder opens and the steam remaining in the high pressure cylinder rushes into the low-pressure cylinder and against its piston, which at that time is at the end of its travel and at the opposite of the high pressure piston. The low pressure cylinder piston is then in turn urged forward by the incoming steam, which is expanded to four times the volume it occupied in the high pressure cylinder at the time of its release therefrom. The release from the low pressure cylinders is accomplished by means of the exhaust valves in the return strokes. This operation is repeated on each side and at each end at proper times. The close connection between the two cylinders reduces the clearance spaces to a minimum, which with thorough jacketing insures the most economical use of steam.

This engine is also built to operate as a non-compound engine, in which case the upper or high pressure steam cylinders and connections are omitted, and the lower steam cylinders are provided with automatic cut-off valves. Steam is admitted to these cylinders direct from the boiler and exhausted into the condenser. This mode of construction is adapted to small places, and to cities and villages where the cheapness of fuel renders the first cost of the machine a matter more to be considered than the annual saving of fuel. Although even when constructed as a non-compound engine, a duty of 50,000,000 foot pounds of work can be obtained from 100 pounds of coal.



HIGH PRESSURE DUPLEX PUMPING ENGINE.

Another type of pumping engine is the

HIGH PRESSURE DUPLEX PUMPING ENGINE.

Which is without the crank and fly wheel, and is especially designed for domestic pumping, but will do excellent service as an ordinary fire pump. Engines of this type are in use at the water works in Dover, Delaware; Kenton, Ohio; Iowa City and Atlantic, Iowa; Abilene, Kansas; and the Binghamton, N. Y., Asylum for Chronic Insane.

OTHER TYPES OF PUMPING ENGINES

Have been constructed by the company from time to time to meet special cases. The principal of these is a

VERTICAL COMPOUND CONDENSING ENGINE,

Of which four sets or pairs have been built, one each for the cities of Evansville, Indiana; Memphis, Tennessee; Town of Lake, Illinois, and Newport, Kentucky. Following is a description of the Evansville Engine, which will answer for all, the Town of Lake and Newport engines being modifications.

For report on duty tests of one of these engines see page 44.

The engines are mounted in an iron well casing 16.5 feet diameter at the bottom, 17.5 feet diameter at the top, and 52 feet deep; constructed of .5 inch boiler plate, with rings of 4x4 inch angle iron, set three feet apart from top to bottom of well.

Around the iron well casing, for a depth of 16 feet from the coping, an annular wall 25 inches thick, of brick work in cement, is built upon a shelf or rim of plate iron attached to the iron well casing, by brackets.

The steam end of the engines is mounted upon a heavy frame work of cast iron, arranged to effect a general distribution of the load around the annular wall, and the shell of the well casing.

Two heavy cast iron beams span the top of the well, to the under sides of which are bolted the steam cylinders; the upper sides of the beams having planed seats for the reception of the feet of the inclined columns of the gallows frame.

The steam cylinders are each provided with two admission and two exhaust valves, of the double seat poppet variety. The steam and exhaust valve chambers are arranged one immediately over the other in the same casting.

The steam valves are worked by a liberating gear which can be adjusted by hand to vary the cut-off, and when connected with the pressure regulators, furnished with the engines, automatically adjusts the point of cut-off to the load and steam pressure. The exhaust valves have a fixed rise and fall.

The valves of each steam cylinder are operated by a gang of four cams revolving on a shaft mounted in standard bearings on the bed plates, and driven through an angular shaft, and miter wheels from the fly wheel shaft overhead.

The piston rods pass through both heads of the steam cylinders; through the upper heads to cross-heads, traveling on square wrought-iron guide bars, and through the lower heads to the pumps at the bottom of the well casing. The piston rods are uniform in diameter from end to end, and are guided for every four feet between the steam and water cylinders.

The receivers are placed below and between the two cylinders of each engine.

The steam pipes, steam cylinders, and receivers are all heavily lagged with a plastic covering.

The low-pressure cylinders are fitted with the "Bulkley" injector condenser. This form of condenser was adopted to avoid the use of an air pump, which would be liable to clog in the valves with the debris drawn through the suction pipe from the river.

The pumps—two to each engine—are of the double-acting piston variety, with receiving and discharge valves at each end.

The pump cylinders are nominally 18 inches diameter, and the water pistons have the same motion as the corresponding steam pistons. The pump valves are rubber discs set in iron shells, which rise and fall on central guide stems.

Air vessels upon the discharge side are provided for each pump, and an air vessel common to all pumps, is connected with the suction pipe.

The engines are compactly arranged. Strength and utility have been carefully considered in the design of all parts.

Following are the principal dimensions of engines and boilers:

Diameter of high pressure steam cylinder	24.	inches.
" " low " "	41	"
" " pump pistons	18.	"
Stroke of steam and water piston	36.	"
Diameter of fly wheel	12.33	feet.
" " " shaft	10.00	inches.
Length " " "	7.375	feet.
" " " " cen' to cen' journals	4.271	"
Weight of fly wheel ... pounds,	13000.	
" " engine complete ... tons	125.	

A description of the other special engines is omitted here, because it would not be of general interest, but will be cheerfully given to would-be purchasers on application. They are designated as follows:

Holly's Quadruplex Pump, driven by a Horizontal Engine having a single cylinder through cog gearing: several sizes, from 1,000,000 to 5,000,000 gallons of water daily capacity.

Holly's Horizontal Compound Engine, used as reserve power in connection with pumps usually driven by water power. Capacity, 150 to 200 Horse Power.

Holly's Quadruplex Pump, with turbines and engine for either steam or water power, or both; several sizes, from 1,000,000 to 10,000,000 gallons of water, daily capacity.

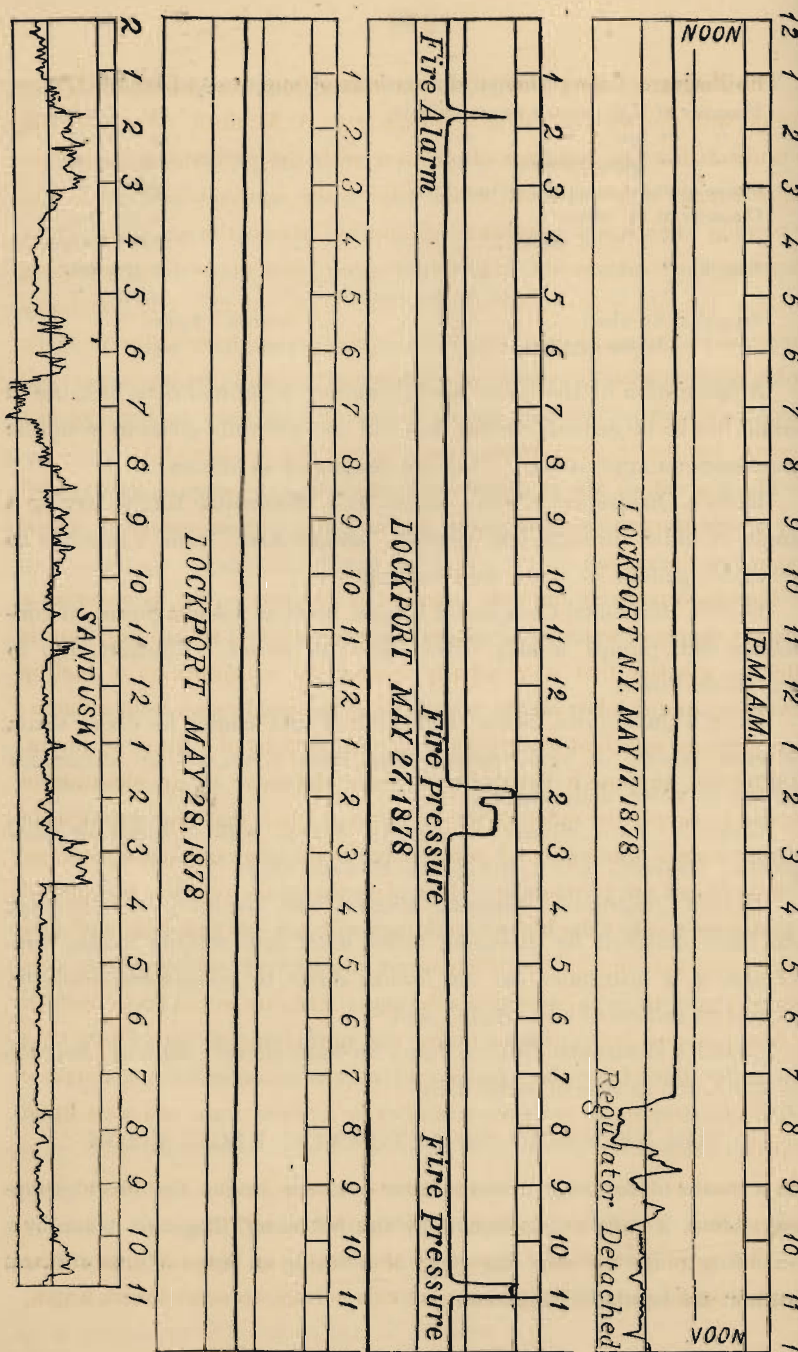
Gaskill's Two-Cylinder Horizontal Pump, with turbines for water power. Capacity, 5,000,000 gallons of water daily.

Holly's Quadruplex Pumping Engine, with low lift pump attached, the latter designed for pumping turbid water into settling basins, from whence it is distributed by the former direct to consumers; capacity, 5,000,000 gallons of water daily; and,

Gaskill's Horizontal Duplex Pump for water power; capacity, 800,000 to 5,000,000 gallons of water daily.

THE NECESSITY OF AUTOMATIC REGULATION

As a means of securing uniform water pressure under the direct pumping system, is fully demonstrated by the following diagrams taken by a recording gauge to show the effect of working an engine both with and without the regulator attachment:



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" is from the Sandusky, Ohio Water Works, and was first published by an opponent to direct pumping to show the alleged imperfections of the Holly plan. 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 diagram of May 27 shows the effect of fire pressure, and that of May 28 an uninterrupted domestic pressure with the automatic regulator attached to the engine.

The importance of uniform pressure is obvious so far as insuring a constant supply of water in all places is concerned, but special attention is called to the fact that it materially lessens the consumption of fuel by preventing undue labor on the pumps, such as would result from a fluctuating pressure sufficient to supply the highest portions of a city at all hours. To illustrate, suppose 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 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, and would require a corresponding increase in fuel and strength of machinery, and cause greater strain and wear upon all parts of the works.

In proof of this, the following statement is submitted, from the Sandusky, Ohio, *Tri-weekly Register*, of November 6, 1877 :

"The most remarkable feature of the Sandusky Water Works is the immense stand pipe. For some time after service to water-takers began, the stand pipe was not completed, and water was pumped directly into the mains. A comparison of four weeks preceding with four following the use of the stand pipe may now be interesting to engineers. For the four weeks immediately preceding the use of the stand pipe the number of gallons of water raised 100 feet with 100 pounds of coal was 41,899. Duty of engine, or pounds of water raised one foot with 100 pounds of coal was 34,301,953.

For the first four weeks of stand pipe service 51,035 gallons 100 feet with 100 pounds of coal. Duty of engine, 42,537,670, showing a remarkable gain.

Also, the following letter from Rock Island, Illinois.

OFFICE OF SUP'T OF WATER WORKS,
ROCK ISLAND, ILLS., May 2d, 1877.

C. G. HILDRETH, ESQ.,

Dr. Sir,—Your favor of April 30th is here, and in reply would say that our fuel book shows that from Dec. 28th, 1876, to Jan'y 28th. 1877, the New Worthington Engine did all the pumping. Average number of gallons pumped per 24 hours, 910,396, and average cost of fuel per day, 24 hours, $6.86. The Holly Engines were started again on the night of Jan'y 28th, *after having received their first repairs since they were put in here in May, 1872*, and up to Feb. 28th, the record shows that they furnished an average of 920,430 gallons per day (24 hours) at a cost of $3.63 per day (24 hours) for fuel. During this time is included 6 hours fire duty under a pressure of 120 pounds. The Worthington had 2 hours fire duty, same pressure.

Very respectfully,

FRED. A. CRAMER,
Sup't. and Chief Eng'r.

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 so many 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 can be successfully operated only on a small scale, when, in fact, it is susceptible of enlargement to meet fully the wants of the largest city. 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 several parties are striving to imitate the plan which Mr. Holly 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, two cases of infringement were promptly taken up and carried into the courts; one was against the city of Union City, Ind., and the other against the Vergennes Machine Company, of Vergennes, Vermont. After long and vigorous contests both cases were decided in favor of the Holly patents, as will be seen from the following extracts from the decisions. The first was by Judge Drummond, in June, 1878, and the second by Judge Wheeler, in May, 1880.

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 suits were founded, reads as follows :

"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 these 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 decisions of the Courts embrace the points of general interest. In the Union City case Judge Drummond decided—

"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."

In the Vergennes case Judge Wheeler decided.—

1st. That the letters patent granted Birdsill Holly, of Lockport, New York, March 2d, 1869, reissued August 2d, 1870, and again reissued November 5th, 1872, which said last reissue was numbered 5,132, on the first claim of which this suit is in part founded ; and the letters patent No. 94,747, granted the said Birdsill Holly on the 14th day of September, 1869, on which said suit is also founded, are good and valid in law, and that the title to the same is in said Holly.

2d. That the defendants, each and all of them, by the manufacture and setting up of pumping mechanism, known as the "Flanders System," have infringed upon and violated the rights of the complainant under the first claim of the reissued patent, by the use of the devices specified in Flanders' patent for improvement in pumps, No. 154,468, and the claims of letters patent, No. 94,747, aforesaid, by the use of the dash-pot applied to the safety-valve lever.

It is therefore ordered, adjudged and decreed, and this Court, by virtue of the power therein vested, doth order, adjudge and decree:

1st. That the complainant do recover of the said defendants, and each of them, the profits, gains and advantages that have arisen or accrued to said defendants, and each of them, from the said wrongful manufacture, as well as the damages that have resulted to complainant therefrom.

2d. That an account of the said profits and gains, and of the said damages be taken and stated, and reported to this Court.

Third. That an injunction issue out of and under the seal of this Court against the said defendants, and each of them, commanding them, and each of them, to desist from any further infringement of the said first claim of the said reissue No. 5,132, and of the claims of Letters Patent No. 94,-747 in any manner, either by manufacture, sale or use.

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 fie streams directly from the hydrants. In this case the water was to be pumped direct for all purposes.

THE DUTY AND GENERAL EFFICIENCY OF HOLLY PUMPING ENGINES.

The efficiency of a pumping engine is estimated by its "duty." By this term is meant the useful work exerted by the engine pumps, expressed by the term "foot-pounds" of work done for each 100 lbs. of coal consumed. A "foot-pound" is an expression indicating a weight of one pound lifted a height of one foot. In the case of a pump, the weight is the water. Hence, when a pumping engine is said to have a duty of, for example, seventy million, the meaning is that the machine is competent to raise that number of pounds of water one foot high, through the expenditure of 100 pounds of fuel under the boiler. We are thus given a convenient type and form ; for it is evident that, all else being equal, that engine is the most economical which does the most work with the smallest expenditure of fuel.

The question of duty, therefore, is one of great importance in an economical sense, and committees charged with the selection of water-works are generally called upon to give it their careful consideration. The point often arises as to whether it is better, with regard to two engines, both presumably capable of doing the required work, to pay a higher price for the one guaranteed to give the higher duty. Frequently the yearly saving in outlay for fuel amounts to considerably more than the interest at six per cent. of the difference in cost, so that there may be higher economy in buying the relatively more expensive machine.

In comparing the duty reached by the Holly pumping engines with that attained by the engines of other makers, the circumstances under which the machines work must be borne in mind. It is hardly necessary to point out that where an engine is working steadily and uniformly against an invariable pressure, and delivering water into a reservoir, the conditions are far more favorable toward its giving a high duty than when it is running against the constantly varying pressure in the supply mains. Despite this obvious disadvantage, the Holly engines have given extraordinary high duties.

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 :

Date.	Place.	Capacity of engine, Gallons per day.	Duty.	Authority.
1874	Rochester, N. Y.	3,000,000	63,309,100	J. Nelson Tubbs.
1875	Atlanta, Ga.	2,000,000	60,403,800	R. T. Scowden.
1875	Evanston, Ill	2,000,000	54,980,000	J. R. Fitch & E. L. Cooley.
1876	Indianapolis, Ind.	6,000,000	76,257,800	W. Bellis & W. G. Hamilton.
1876	Binghamton, N. Y.	2,000,000	81,514,000	John Evans.
1876	Taunton, Mass.	2,000,000	75,514,000	C. Holly.
1878	Hyde Park, Ill.	2,000,000	65,258,000	E. S. Cheesbrough & J. D. Cook
1878	Burlington, Iowa	3,000,000	71,514,000	T. N. Boutelle.
1878	Keokuk, Iowa.	1,500,000	62,334,000	W. C. Stripe.
1879	Buffalo, N. Y.	6,000,000	86,176,300	R. H. Buell.
1880	Troy, N. Y.	6,000,000	80,094,000	D. M. Greene.
1881	Evansville, Ind.	4,000,000	88,688,800	J. W. Hill.
1881	Fort Wayne, Ind.	3,000,000	86,999,900	J. D. Cook.
1882	Atlanta, Ga,	4,000,000	77,912,000	W. G. Richards.
1882*	Memphis, Tenn.	4,000,000	97,409,600	J. W. Hill.
1882*	" "	4,000,000	99,672,800	J. W. Hill.
1882	Saratoga Sp's, N. Y.	4,000,000	112,899,980	D. M. Greene & J. W. Hill.

*Engines Nos. 1 and 2.

The average cost of pumping one million gallons of water one foot high with Holly engines has been, according to official reports: In Binghamton, N. Y., as low as 5½ cents; Rock Island, Ill., $8\frac{7}{10}$ cents, and Atlanta, Ga., $9\frac{3}{10}$ 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. 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 each 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.

DUTY TESTS OF HOLLY ENGINES.

FROM OFFICIAL REPORTS.

The following are condensed reports of the more important trials, and are given by way of showing that the high duties obtained were the results of fair and exhaustive tests, by disinterested experts:

ROCHESTER, NEW YORK.

J. NELSON TUBBS, ESQ., *Chief Engineer Rochester Water Works:*

Dear Sir,—In accordance with your request, the undersigned were present at the duty tests of the engines of the Holly system in this city, on the 9th day of July, 1874.

Below will be found the results of our observations in tabular form:

The machinery in question consists of four inclined steam cylinders of sixteen (16) inches in diameter and twenty-seven (27) inches stroke, connected direct to four pumps, ten (10) inches by twenty-four (24) inches, located below the floor of the engine room. The steam cylinders were connected in pairs to opposite ends of the same crank shaft, and the steam pipes are so arranged that the exhaust from one cylinder may be admitted into the other three cylinders on the compound system, while from the latter communication is had with the condenser and air pump.

The fuel was 100 pounds of hemlock kindlings and the balance Briar Hill (bituminous) coal.

The data for the calculations given were obtained as follows: Steam was raised to seventy pounds, the fires were hauled and the kindlings immediately put in, followed by the coal, which was carefully weighed by one of our number. When steam was raised to ninety pounds, the engines were started. At the close of the trial, the steam pressure was allowed to run down to seventy pounds, the fire hauled, and the engine stopped, the number of revolutions being shown by a reliable counter. The ashes and cinders remaining were then carefully sifted and the cinders deducted from the total amount of coal used. Hemlock wood was estimated at two-fifths the value of coal.

The engines pumped the usual city supply during the test at sixty pounds pressure, the surplus water flowing back into the suction channels through safety valves.

Every facility for observation was cheerfully granted us by the engineers of the Holly Company who were present, and we are satisfied that all the conditions necessary to a test of this kind were faithfully complied with.

The machinery worked well during the trial, and gave the attendants no trouble further than the usual lubrication. The extremes of water pressure were fifty-eight and one-half pounds and sixty-one pounds; of steam pressure, ninety-three pounds and ninety-five pounds.

TABLE OF RESULTS.

Average pressure of steam during run, 92.3 pounds.
Average pressure of water in mains, 59.75 pounds.
Height due to that pressure, 137.425 feet.
Height from suction surface to gauges, 15.5 feet.
Total height to which water was raised, 152.925 feet.
Diameter of pumps (4), 9.63-64 inches.
Length of stroke, 26.15-16 inches.
Gallons per revolution (4 pumps), 71.27.
Total revolutions during run, 11,506.
Gallons raised during run, 820,032.62.
Gallons raised in twenty-four hours, same rate, 2,989.483.
Revolutions per minute, average, 29.1.

Coal consumed during run, 1,650 pounds.
Actual duty per one hundred pounds of coal, 63,309,107 foot-pounds.
Duration of test, 6 hours and 35 minutes.

(Signed) J. E. BOOTH,
FRANK H. CLEMENT,
Committee.

CHIEF ENGINEER'S OFFICE,
ROCHESTER WATER WORKS, *August* 6th, 1874.

This is to certify, that J. E. Booth and Frank H. Clement, were requested by me to be present and direct a duty test of the Steam Engine connected with the Rochester Water Works, the said Engine having been erected by the Holly Manufacturing Company; that the above named gentlemen did make such test and examination; that I know them to be excellent Mechanical Engineers, and I believe them entirely competent to conduct said test, and that full reliance may be placed upon the statements made by them in their foregoing report.

J. NELSON TUBBS,
Chief Engineer Rochester Water Works.

EVANSTON, ILLINOIS.

To the President and Members of the Board of Trustees of the Village of Evanston:

Agreeably to your instructions, we have made a duty test of your engines at the Water Works, and have the honor to submit the following report:

The test began on Monday, March 22, 1875, at 12:30 P.M., and continued until Tuesday, the 23d, at 6:08 A.M., or seventeen hours, thirty-eight minutes.

[This test was conducted in substantially the same manner as the Rochester test, just described.]

A few diagrams were taken from the upper end of one pump. They show remakrably square, clear cut corners, and a slight gradual descent on the upper side. The ends of the diagrams were straight; the lower