THESIS.

Design for a System of Water Works

FOR THE CITY OF PAXTON, ILLINOIS.

By

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For the Degree of Bachelor of Science in Course in Civil Engineering.

College of Engineering.

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Introduction.

The town of Paxton, county seat of Ford Co., is situated in the eastern part of Illinois at the crossing of the Illinois Central with the Lake Erie & Western Railroad, one hundred three miles south of Chicago and fifty miles east of Bloomington.

The town lies upon the top of a low hill which is the summit of a large glacial terminal moraine, drained upon the north, west, and south by a creek. The larger part of the city drainage flows southward to this creek about two miles away.

The surrounding country consists of well imposed farm land with some timber on it and is increasing in value every year. Nearly all the grain and stock raised in the vicinity is hauled to Paxton or shipped into town from the smaller sur-
rounding corns. It is then shipped over the Illinois Central R.R. to the markets in Chicago. This furnishes business for two large transfer grain elevators. There is also a flourishing flour and feed mill. Also located in the town is a canning factory, employing over 200 hands during the summer months, and a flouring mill, machine shops and a number of smaller factories. Being backed by a prosperous agricultural country, large grain and stock trade and an enterprising class of citizens the town is growing in population, wealth and importance.

The desire for modern improvements and conveniences has kept pace with its growth, and in fact the town has reached that stage of its existence where it wishes to discard the features of a country town and establish those of a small city. This is well illustrated in the erection of a 30,000 high school building, an excellent 25,000 electric
light plant, the paving of the principal business street
with brick at a cost of $2,500 and the construction of
a water tower with a small distribution system costing
over $2,000.

Of these public improvements, the first three
have been constructed within the last two years and
have given general satisfaction. The water works system
was constructed about ten years ago, and I regret to say
has been found to be neither adequate to the demands
upon it nor economical in cost of construction and
maintenance.

This condition of affairs in connection with the
water supply of a city is a serious one. In this inst-
ance, it not only leaves the city without sufficient
fire protection, but it also becomes a drain upon the city
finances, requiring the city to support a public
investment which at no time is contributing its
full amount of good to the general welfare. As a consequence there is at present and will continue to be a general demand among the citizens for an supply of good water for domestic and manufacturing purposes.

The design for a system of water works for Paxton, including places of construction and first cost has been chosen as a subject for this thesis. A division of the subject into two general divisions will be made as follows,

1. The Supply System.
2. The Distribution System.

0. The Supply System.

The amount of water to be supplied will be based upon the demands of the present population and also the future growth, considering that the present population of 5000 will increase to 5000 in the course
Of ten years. In towns of this size it is customary to adopt a water system which furnishes fire protection as well as domestic supply. Therefore in choosing the daily consumption, it will be well to state some of the reasons that form the basis for this assumed quantity.

For domestic purposes people are very free with the water, even so far as to become extravagant. During the summer months a great deal of water is used for sprinkling lawns and streets and since the rain has often built up a water table the city street sprinkler will be in almost constant use during the warmer part of the year. There are stores, public watering tanks and two city wells supplied from the water works. Nearly every business house and manufacturing shop has its own hydrant, and a large number of residents are being supplied.

Taking as previously stated, a population of 6,000, Peyton may be classed as one of the smaller cities of
the state, and the average domestic consumption per day
per capita will be based upon the following quantities.

For ordinary domestic use not
including hose use 15

For stable, carriage washing, etc. 2

For commercial and manufacturing purposes 5

For water tanks and public wells 3

For private hose, sprinkling yards, streets, etc.
during the driest months of the year 8

For waste in service, pipes, mains, fixtures, etc. 2

35 gallons

Making a total of 35 gallons per capita per day as the average
daily amount. It is believed this quantity will answer
very nearly the actual amount used.

In addition to the average daily demand, there
will be several days in the year when, according to Mr. J.T.
Fanning, the average consumption for the day may
exceed the mean daily for the year by 50 per cent. and
the maximum hourly consumption during one of these
days may exceed the mean daily by 100 per cent.
Therefore it is thought best to have a maximum daily
supply equal to 150 per cent. of the average daily for the
year, which will give very nearly 52 gallons per capita
per day.

For fire protection the amount of water demanded
is governed by the size of the fire likely to occur
in any one place or within a radius of 200 feet
of one place; also by the size and value of the
buildings and their contents. For this town where
the large and valuable buildings are close to each
other it should be possible to concentrate the
total number of fire streams upon one block,
and its mains leading to this neighborhood will be
calculated to furnish this supply.
There is no definite rule for deciding upon the number of fire streams necessary, in a town of given size, to give the most economical fire protection. But in choosing the size and number of streams to be concentrated at one place, I shall bear in mind the statements given by the following authorities.

<table>
<thead>
<tr>
<th>Authority</th>
<th>Population City</th>
<th>Discharge in Gallons</th>
<th>Number of Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. A. U. Talbot.</td>
<td>5000</td>
<td>150-175</td>
<td>4-6</td>
</tr>
<tr>
<td>Mr. Freeman.</td>
<td>&quot;</td>
<td>250</td>
<td>4-8</td>
</tr>
<tr>
<td>J. H. Svedd.</td>
<td>&quot;</td>
<td>200</td>
<td>5</td>
</tr>
<tr>
<td>J. T. Janning.</td>
<td>4000 - 10000</td>
<td>250</td>
<td>7-10</td>
</tr>
</tbody>
</table>

If the discharge is 150 gallons per minute, then six such streams with 2½ inch base with 1 inch smooth nozzle should be sufficient. This will give 900 gallons per minute or 54,000 gals per hour for fire supply. If
This draft occurs at the time of maximum daily consumption for domestic use (which is 10,833 gallons per hour) we will have a total maximum demand per hour for all purposes of 64,833 gallons.

It is seldom in a city of this size that a fire requiring 700 gallons of water per minute will last more than an hour, yet in the design of the tank to contain its supply, provision will be made for a longer duration of maximum draft.
Selection of System.

Two systems of water works are adapted to flat prairie lowas—the direct pressure system and the standpipe or elevated tank system. The first cost of the direct pressure system is often the smaller, but this system is less efficient and allows more chances for the works to become disabled. These two systems offer advantages and disadvantages in different ways and its choice between them depends largely upon local conditions. A summary of their relative value may be made as follows.

The Direct Pressure System.

**Advantages.**

1. Less first cost than the standpipe system.
2. Less continuous heat to pump against and consequently less consumption of fuel.
3. Less continuous strains on valves.
   Disadvantages.
1. The machinery must be duplicated in order that an accident to the pump may not cripple the fire protection.
2. Increased expense for a night engineer over the stand-pipe system.
3. Pumps cannot be run uniformly and hence are less economically worked.
4. The condition of the fire under the boilers may not allow the making of sufficient steam to furnish and maintain fire pressure when an unexpected demand is made.
5. The engineer may neglect his duty or be asleep when the fire alarm is turned in.
6. Defective fire alarm apparatus may cause a failure to give immediate pressure.
7. Accident to pumps may deprive the city of fire protection.
8. In nearly all cases it will require a storage reservoir.

Stand Pipe or Elevated Tank System.

Advantages:
1. One set of pumps will give a fair security.
2. The pumps may be economically worked, since they may be run at its speed and pressure for which they were designed.
3. There is no sudden demand on the boiler for increased steam pressure and supply.
4. Less dependence need be placed on the engineer in time of fire.
5. No fire alarm apparatus is necessary.
6. If tubular wells are used, the large tank may act as a storage reservoir.
7. Less liability of mains bursting in time of fire
8. Certainty of action, with promptness and efficiency when the fire stream is turned on.

disadvantages,

1. Greater first cost of the system.
2. Danger of wreck of the tank by ice, wind, or through defective work.
3. Greater lift of water for the pumps, for ordinary pumping.

From the above statements it may be seen, that although the stand pipe system for the town involves greater first cost than a direct pressure system of equal efficiency, the extra expense is offset by dispersing with a reservoir which would necessarily have to be built in this flat city. One set of high pressure pumps and the service of a night engineer could be done away with if the tanks will hold the supply demanded for domestic and fire purposes.
during the night. I have therefore selected an elevated tank, as preferable for this city and for its water constant eeffective
head, ultimately cheaper than a direct pressure system.

Selection of Size and Kind of
Elevated Tank.

In determining the size of tank, the probable amount of
water which will be used for fire and other purposes must be
considered. The tank should act as a reservoir of several
hours supply, in case the pumps become disabled and
other causes make it necessary to stop pumping for
a short time.

The location selected for the tank is upon the city
lot near the corner of Market and Center Streets as
shown on the map of the city. This lot is centrally
located with reference to the whole city and is about
600 ft. from the center of the business portion. Upon this
lot the supply wells will be located and the pumps may be placed near the tower in a pump house or as shown in the plan of plate 1.

The height of the tank is determined by the required maximum height of fire stream, by its length and size of mains leading to its point of application. The highest and most valuable building in the town is the Masonic Temple, a four story brick building at the corner of Market and State Streets. It is about 60 feet high and 1000 ft. from the water tower. In case of fire this building would require the maximum number of fire streams here to fore mentioned.

To throw water upon the top of this building will require a stream 50 ft. high. Six such streams of 150 gallons per minute each will discharge 900 gallons per minute. I find by trial computation that about half this quantity will flow through the side and branch mains and reach two
joins through the 6 inch pipe at the north end of the street, while the other half flows through the 1000 ft of 6 inch pipe leading from the water cover to this joint, as shown on the plan of distribution system heretofore described. The friction head will be 25 pounds or 1.61 ft. of head, and the velocity is 2.87 ft. per second. From Emmert's fire stream tables it may be seen that with a 4 inch smooth nozzle connected to 200 ft. of rubber hose a stream 51 ft. high may be obtained with a hydrant pressure of 43 lbs. per sq. in., equal to a head of 100 ft.

This requires approximately 105 feet of head. This is the least height of water which will give the desired fire stream, and the tank above this height should have the required capacity. Instead of building the lower to a height of

* In the computations for friction head, size, weights, etc. of pipes, the tables found in the Addyson Pipe Co. Catalogue were used.
105 feet, I believe it a more economical plan to shorten the lower and lengthen the tank.

For a tank 20 ft. diameter by 60 ft. in height the cost of metal in place per foot of height is less than the cost of the masonry required to replace it. Besides a saving in cost there will be 25 ft. of tank below the 105 ft. mark, which will give capacity for storage of an extra supply that could be used for domestic purposes. The tank capacity is 141,000 gallons. This will supply 13 hours domestic supply, and will supply six fire streams of 600 gallons per minute each, one hour and twenty minutes before lowering to the 105 foot mark. This would leave below this elevation a six hour and twenty minute domestic supply.

For a tower to support the tank, I have chosen a circular brick tower 80 feet high. While the masonry is much more expensive than the metal which could replace it, I prefer to have it this height for the following reasons.
A good grade of brick is manufactured in Boston and I believe it better to patronize home industries when possible. Further, I do not wish to increase the capacity of the tank beyond that already chosen. The ratio of the height of the tank to that of the tower is as 3 to 4 and this will give a better architectural appearance than a less ratio and will not give to the whole structure the appearance of being too heavy.

**Details of Tank**

The tank will be 20 ft x 60 ft and will consist of a good grade of wrought iron plates of such width and length as to complete when built a vertical height 15 feet each, using five such plates to the circumference. To the cylindrical body will be attached a conical bottom with an upper diameter sufficient to fit tightly within the body diameter by means of a flanged end as shown.
in the detailed drawings on plate V. The bottom will be 
built as a frustum of a cone having a depth of 73 feet 
and a lower diameter of 5 ft.

The wrought iron used will have a tensile strength of 
48,000 lbs per sq. in. and a working tensile strength of 
12,000 lbs per sq. in. has been used, thus giving a factor 
of safety of nearly four. Efficiency of single riveted joints 
have been taken as 50 per cent, and efficiency of double 
riveted joints at 65 per cent. The lap of these plates, size and 
pitch of rivets used are given in the following table.

Table II a 2.

Dimensions for Rivet Work.

<table>
<thead>
<tr>
<th>Thickness of Plate in inches</th>
<th>Diameter of Rivets in inches</th>
<th>Single Riveted.</th>
<th>Double Riveted.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>pitch</td>
<td>cap</td>
</tr>
<tr>
<td>3/16&quot;</td>
<td>3/8&quot;</td>
<td>1/4&quot;</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>1/2&quot;</td>
<td>1 1/2</td>
<td>1 1/2</td>
</tr>
<tr>
<td>5/16&quot;</td>
<td>3/4&quot;</td>
<td>1 3/4</td>
<td>2</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>3/4&quot;</td>
<td>1 3/4</td>
<td>2</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>3/4&quot;</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
The formulas for determining the thickness of plates to withstand static pressure and bending by wind forces are those given by Prof. Talbot and are, for thickness of plates for steel pipes: 

\[ t = \frac{2.64D}{S} \]

where \( t \) = head in feet; \( D \) = diameter in feet; and \( s \) = the working strength of the metal times the efficiency of vertical joint. The minimum thickness of plates recommended is \( \frac{1}{4} \) inch and this has been used to a depth requiring a greater thickness. By the above formula, \( 48 \) ft. The formula for thickness against bending of shell, due to wind pressure of \( 40 \) lbs. per sq. ft. on half the projection of the semi-circumference is 

\[ t = \frac{0.644h^2}{D^2S} \]

This is not applicable as it gives a much less value for thickness than the formula for static pressure.

The concrete bottom has a uniform thickness of \( \frac{3}{4} \) inch and has a 6 inch lap on the main body of the tank and double horizontal riveting. The arrangement and size of details, etc., are shown on plates IV and V.
Estimates of Weight:

Weight of cylindrical part of the tank. ———— 21.26 tons

" " conical bottom. ———— 2.925 "

Adding 20 percent for loss of joints, rivets, etc. 24.185 "

Ladder, roof, anchor plates & bolts, etc, etc. ———— 4.82 "

Total weight of tank complete ———— 29.00 tons

Weight of water in the tank ———— 621.00 "

Total weight of tank and water ———— 640.00 tons.

Details of Tower:

For detailed drawings of the tower see plates I and VI.

The height of the tower above the stone masonry foundation is 18 feet. Upon this are placed two courses of coping stones, each one foot thick and in the position as shown in the drawing on plate V, making the total height of tower 30 feet.

The inside face of the wall is vertical. The outside
face has a batter of 4 inch to its foot. The top of the wall is 22 inches thick and 28 ft. diameter from center to center. The wall is 42 inches thick at its foot. The top of the wall has an area of 114.24 square feet and upon this area the weight of the tank and water 650 tons is distributed, giving 5.68 tons pressure per square foot. This is a safe pressure for brick masonry.

Anchor Rode.

The tank is secured to the tones by means of eight anchor rode. To determine this size and length it is necessary to determine whether the weight moment of the empty tank is larger or smaller than the wind moment when it is considered as turning over about the edge of the bottom, or about the line 27'' shown in the sketch.

The weight moment of the empty shell is \( W \times \frac{1}{2} d \).

When \( W = \text{weight} = 29,000 \) tons, and \( d = \text{diameter} = 28 \) ft.

Then \( 350,000 \times 10 \times 48 = 380,000 \) ft. lbs. which is the moment.
exit of the empty tank about the edge of the bottom, or the floor of support.

The wind pressure is taken at 40 lbs. per sq. ft. on an area equal to half the vertical projection of the semi-circumference. This gives a wind moment of \( \frac{1240 \times 40^2 \times 31}{2} \)

\[ = 728,800 \text{ ft. lbs.} \] The lever arm of this force is half the height of the tank from the place of support.

The difference of these two moments is 728,800 - 380,000 = 148,800 ft. lbs. excess for wind moment. This force must be overcome by the anchor rods, and for this purpose I shall take eight rods uniformly distributed around the circumference of the base as shown in the drawing on plate V.

The formula given by Mr. Talbot for computing the tension upon any one of eight anchor rods is \( W = 27 T d \).

When \( W = \text{excess of wind moment over weight moment} \), \( T = \text{tension in pounds on one rod} \), \( d = \text{diameter of tank in feet} \). Then
148800 = 2T \times 20, \quad T = 3720 \text{ lbs tension on one rod.}

A 1 inch round wrought iron rod may be safely used, giving a yield strain of 4740 lbs per sq. inch of metal. The anchor plates will be cast iron circular plates, 12 inches in diameter and 1 inch thick.

Since there may be tension in the anchor rods when the tank is empty, this would necessarily produce a tension in the masonry above the anchor plates unless the weight of the masonry is greater than the stress in the rod. We no tension will be allowed in the masonry. This will be overcome by placing the anchor plates such a depth that the weight of masonry is greater than the tension on the rod.

To find the length of the rod let

\[ T = \text{tension on one rod in pounds}, \]
\[ d = \text{distance necessary to anchor plate}, \]
\[ w = \text{weight of brick masonry per cubic foot}. \]
\[ a = \text{area of the section of masonry; } \text{ton } \text{in sq. ft.} \]
\[ \text{load} = \text{total weight of masonry; } \text{ton} \]
\[ \frac{a}{\text{water}} = \text{ton} \]

Substituting the values we have
\[ \frac{5 \times 3220}{125 \times 114.24} = 2.76 \text{ feet} \]

This is upon the supposition that the weight of the masonry above the anchor plates is equally divided among the eight sides. In order to allow for shocks or other strain the rod will be made 6 ft. in length and the anchor plates placed beneath a row of lower coping stones as shown on plate V.

The pressure per square foot on the brickwork at the base of the tower when the tank is full is \( \frac{A}{W} \). When \( A \) = area in sq. ft. \( W \) = surface pressed; and \( W \) = total weight of tank, towers, and water.

\[ \begin{align*}
\text{Weight of water is} & \quad \text{---} \quad 621.00 \text{ tons} \\
\text{tank} & \quad \text{---} \quad 28.00 \text{ tons} \\
\text{lower} & \quad \text{---} \quad 819.53 \text{ tons} \\
\text{Total weight is} & \quad 1469.53 \text{ tons}
\end{align*} \]
The area at the base is 243.5 sq. ft., giving 5.87 lbs per sq. ft. upon the brick masonry at the foot of the tower, which is safe. The weight of the stone foundation is 287.4 tons and this plus the total weight of bank, tower, water is 1736.9 tons. The area of the lower ring of the stone foundation is 713.84 sq ft. This gives a pressure of 1.9 lbs per sq. ft. upon the earth under the foundation. This earth is a compact yellow clay under which is a bed of hard pan. According to Prof. Baker "Masonry Construction", p. 194, table 23, soil of this character will safely stand a pressure ranging from 2.5 to 7 lbs per sq. ft.

**Estimate of Costs**

The prices herein given are the estimated costs of finished materials in the structure when completed. The price of plate iron is taken as that given by the market price of today.

- Cost of Plate Iron ———— 1¾ cts per pound.
- " " Shop Work ———— 3¼ " " "
Cost of field work — — — — — — — 14 cts per pound.
Freight and Engineering — — — — 3½ " " " "
Total — — — 4½ " " " "

At these prices the cost of the tank in place would be:
Bought iron: 58,000 @ 4½ cts per lb. — — $2,640.00

Painting: 433 sq. yds. @ 15 " " sq. yd. — — — 65.00
Total — — — 2475.00

Brick Masonry: 486 cu. yds. @ 850 per cu. yd. — — 413.00
Stone: 2281 " @ $10 " " " " " " — — 2281.00
Adding for windows, doors, stairway, etc., — — — 413.00
Total Cost Complete is — — $9,500.00

(2). The Distribution System.

In the design of this system no mains will be placed along blocks at the limits of the city, where at present there may be only three or four houses to the block.
but the distribution will be as nearly equal as possible along these streets already settled and those being rap-

idly built up. The construction of the distribution system shown by the plan of plate II is well warranted by the fact that the residents along the streets on which brick mains are shown are willing to pay their share of expense provided they are furnished with reasonable fire protection and a liberal quantity of good water.

The size of mains for a city is determined by the probable greatest demand for water and by the pressure at which it is to be delivered. This greatest discharge occurs when there is a demand for a fire supply at the time of maximum daily consumption along that street leading most directly to the fire. Upon some of the older streets where residence property is compact and valuable and more water is need for the various domestic purposes, a larger pipe will be laid than upon those streets which have
been lately and nearly built up. Bearing this in mind, the sizes of pipes as shown in the plan herein contained are thought to be best suited to the several streets in which they are located.

The three sizes of pipe used are 4 in., 6 in., and 8 in. Of the total amount of pipe laid, 56,207 ft. or 10.65 miles:

- 49.4% is 4 in.
- 45.6% is 6 in.
- 5% is 8 in.

Some authorities recommend nothing less than a 6 in. pipe be put in, unless for isolated and small buildings and also that each hydrant shall have a 6 in. feed pipe to the main, but in this city a four inch main along some streets is found to be sufficient and more economical.

The thickness of shell of these pipes is determined, (1) by the static pressure, (2) allowance for water run, & necessary thickness to insure safety in handling and shipping.
Assuming that the probable or possible water rent will not produce an additional effect greater than that due to a static pressure of 100 lbs per sq. in. and adding a small percent for insurance of safety against damage in handling, the formula used for determining the thickness of cast iron pipe is the one given by J.T. Fanning in his "Water Supply Engineering." It is

\[ t = \frac{(b+100)d}{0.45} + 0.333 \left(1 - \frac{d}{b}\right) \]

where

- \( t \) = required thickness in inches
- \( b = \) .434 \( b = \) .434 \* 140 = 60.76 lbs per sq. in.
- \( d = \) internal diameter of pipe in inches
- \( S = \) tensile strength per sq. in. for good cast iron = 18000 lbs

The following table will give the thickness as found by the formula, also other dimensions for the various sized pipes.

<table>
<thead>
<tr>
<th>INTERNAL DIAM. IN INCHES</th>
<th>CLASS B, 100% 230' HEAD</th>
<th>LENGTH OVER ALL</th>
<th>DEPTH OF HUB</th>
<th>WEIGHT PER FT. IN LBS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>( \frac{7}{16} )</td>
<td>12' 3&quot;</td>
<td>3&quot;</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>( \frac{17}{32} )</td>
<td>12' 3&quot;</td>
<td>3&quot;</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>( \frac{17}{32} )</td>
<td>12' 3&quot;</td>
<td>3&quot;</td>
<td>47</td>
</tr>
</tbody>
</table>
All specials and pipes will have the sizes, weights, etc., adopted by the Addyton Pipe Co., and have been taken from their catalogue. The formula they use for determining the thickness of their pipes is the same as the one above. The fire hydrant will be used, and the make selected for this design is that of the Chapman Valve Co. It has a gate valve closing against the pressure which prevents water hammer and has a drip which is always open when the valve is closed thus preventing freezing.

**Prices for Estimating Casts.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Iron Pipe per ton f.o.b.</td>
<td>$21.00</td>
</tr>
<tr>
<td>Hydrants (on the ground)</td>
<td>$28.00</td>
</tr>
<tr>
<td>Valve Boxes</td>
<td>$4.00</td>
</tr>
<tr>
<td>4&quot; Valves</td>
<td>$8.00</td>
</tr>
<tr>
<td>6&quot;</td>
<td>$12.00</td>
</tr>
<tr>
<td>8&quot;</td>
<td>$18.00</td>
</tr>
<tr>
<td>Specials per pound</td>
<td>$0.025</td>
</tr>
</tbody>
</table>
### Bill of Materials with Costs

#### Table No. 4

<table>
<thead>
<tr>
<th>Size in Inches</th>
<th>Number of Feet</th>
<th>Weight per Ft. in Lbs.</th>
<th>Weight in Tons</th>
<th>Total Weight in Tons</th>
<th>Cost</th>
<th>Total Cost of Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>27,810</td>
<td>22</td>
<td>305.91</td>
<td>305.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>25,689</td>
<td>33</td>
<td>423.87</td>
<td>423.87</td>
<td>@ 24 $/per ton</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>2768</td>
<td>47</td>
<td>65.05</td>
<td>65.05</td>
<td>6.0/b. cost</td>
<td>16,691.43</td>
</tr>
</tbody>
</table>

The total length of pipe is 56,267 ft or 10.65 miles. In this length is included all branch pipes of various sizes from the mains to the hydrants. The weights per foot include the hub and spigot joint, its pipe to lay 12 feet per length.

#### Table No. 5

Estimates of Cost in Detail of Laying Cast Iron Pipe

<table>
<thead>
<tr>
<th>Diameter in Inches</th>
<th>Cost per Lineal Ft of Laying Pipe, etc.,</th>
<th>No. of Ft. of Pipe.</th>
<th>Cost of Laying the Same</th>
<th>Total Cost of Laying Pipe.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Excavation</td>
<td>Labor</td>
<td>Lead</td>
<td>Total</td>
</tr>
<tr>
<td>4</td>
<td>EASY</td>
<td>0.0976</td>
<td>0.0224</td>
<td>0.12</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>0.1234</td>
<td>0.0320</td>
<td>0.155</td>
</tr>
<tr>
<td>8</td>
<td>HARD</td>
<td>0.2230</td>
<td>0.0431</td>
<td>0.266</td>
</tr>
</tbody>
</table>
The quantities given in the above table are taken from Weston's tables for "Estimating the Cost of Laying Cast Iron Water Pipe." They include excavating and back filling for the same. The column headed "labor" includes all work related to the laying of the pipe and special, and setting valves and hydrants, such as excavating and back filling, laying and calking pipe etc; also casting pipes, special, and hydrants etc; and cleaning up the street after the work has been completed, and all other expenses generally incurred in ordinary water pipe laying which is not mentioned elsewhere in detail.

The hard digging necessary through Market Street for the 5 in. pipe is allowed on account of the brick pavement having to be removed and dig-ging through about 12 in. of compacted gravel, upon part of the street.

<table>
<thead>
<tr>
<th></th>
<th>Hydrants (on the ground)</th>
<th>20.00 per piece</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td>$220.00</td>
</tr>
<tr>
<td>12</td>
<td>4 inch valves</td>
<td>8.00</td>
</tr>
<tr>
<td>4</td>
<td>6 &quot;</td>
<td>12.00</td>
</tr>
<tr>
<td>3</td>
<td>8 &quot;</td>
<td>18.00</td>
</tr>
<tr>
<td>19</td>
<td>Valve boxes</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Total = $2632.00
<table>
<thead>
<tr>
<th>Number of Pieces</th>
<th>Kind</th>
<th>Dimensions in Inches</th>
<th>Weight per Piece in LBS</th>
<th>Total Weight in Pounds</th>
<th>Cost at 2½ cts. per LB</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Ts tee</td>
<td>4x4x4</td>
<td>100</td>
<td>1200</td>
<td>$30.00</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>4x4x6</td>
<td>110</td>
<td>660</td>
<td>16.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>4x6x6</td>
<td>130</td>
<td>260</td>
<td>6.50</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>6x6x6</td>
<td>150</td>
<td>150</td>
<td>3.75</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>8x8x4</td>
<td>222</td>
<td>222</td>
<td>5.50</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>8x8x6</td>
<td>262</td>
<td>252</td>
<td>6.30</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>+ w 6x6x6</td>
<td>8x8x6x6</td>
<td>263</td>
<td>520</td>
<td>13.25</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>6x6x6x8</td>
<td>225</td>
<td>450</td>
<td>11.25</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>6x6x4x4</td>
<td>160</td>
<td>150</td>
<td>11.25</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>8x8x6x4</td>
<td>230</td>
<td>230</td>
<td>6.25</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>4x4x4x6</td>
<td>160</td>
<td>160</td>
<td>4.00</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>L elbow</td>
<td>4x4 (90°)</td>
<td>48</td>
<td>480</td>
<td>12.00</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>6x4</td>
<td>100</td>
<td>300</td>
<td>7.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0 reduce</td>
<td>6x4</td>
<td>95</td>
<td>190</td>
<td>4.75</td>
<td></td>
</tr>
</tbody>
</table>

Total Cost of Pipe Specials: $138.85
Table No. 8:

Summary of Costs of Distribution System.

<table>
<thead>
<tr>
<th>Cost of Materials in Table No. 4</th>
<th>5</th>
<th>16,691.43</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>8,054.20</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>25,320.00</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>138.85</td>
</tr>
</tbody>
</table>

Total Estimated Cost of Distribution System Complete = 27,416.58
Source of Supply.

In securing a supply of water, quality, quantity of water and adequacy in obtaining it are the controlling elements in the choice of methods. Wells of various sizes previously bored in this city have shown that at a depth of 152 ft there is a water-bearing stratum of coarse gravel which has given a reliable supply of good water. As the water users will be upon the city lot it is thought best to have the engine house, well and pumps on the same lot and arranged as may be seen on Plate III.

There will be four 8-inch wells about 150 feet deep, with an estimated daily capacity of 100,000 gallons each. This quantity may be reasonably expected from wells of this size when they are pumped throughout the 24 hours at a uniform rate. Tests of many similar wells in this part of the state have given twice this quantity. The four wells will be placed, relatively to each other in a rectangular position 38 feet each way and over them will be a large boiler and pump house 40 x 45 ft. square as
shown on plate III.

In the center of this room and against the side joining the rooms will be placed the boilers and their masonry beds as shown in plate III. Each pump will force the water through a 6 inch pipe which will connect with a 6 inch main feed pipe leading into the rooms and up to the tank. See plat VII.

The total estimated capacity of the four wells is 400,000 gals. per day. The total quantity of water necessary for the city is 260,000 gals. which must be pumped during the two hours that the pumps will be operated. This gives 6500 gallons per pump per hour or a rate of 624,000 gals. per 24 hours. This exceeds the estimated daily rate of the wells but as the pumping will only be for ten hours I believe the wells can safely give this increased rate for that period.

**Selection of Pumps.**

To pump this quantity four vertical Cook pumps are selected having the following dimensions and capacity.
Diameter of Steam Piston 10 inches
\[ \text{...offers lower water piston 7\frac{1}{2} inches.} \]
Length of Stroke — 36 inches

With twenty strokes per minute the pump has a capacity of 8,250 gallons per hour which is 27 percent above that necessary and leaves an allowance for slip and other defects. The greatest lift for these pumps is 150 feet, from bottom to surface, on the upstroke and this gives a resistance upon the 7\frac{1}{2} inch plunger of 3971.32 pounds. On the down stroke they will force its water into the tank a height of 140 ft., but as this is less than 150 feet from the bottom of the well, its pressure will be computed with reference to the greatest lift.

A margin of 35 percent, for friction in the pipes, well, and the extra resistance due to weight of well water etc., will be allowed between the resistances of the water piston and the power of the steam piston. This will give 4011.25 pounds resistance. A ten inch steam piston with a
pressure of 70 lbs per sq. in. gives 5497.8 lbs pressure, which is sufficient to over come all resistances in the pumping.

**Selection of Boilers.**

The four pumps with 10 inch cylinders, 36 inch stroke and 20 strokes per minute will use 17671 cu. ft. of steam per hour. One pound of steam at 70 lbs absolute pressure has a volume of 6.07 cu. ft. Then \( \frac{17671}{6.07} = 2636 \) lbs of steam are used by the four pumps in one hour.

Allowing 20 lbs of steam, at 70 lbs pressure, per horse power per hour as the unit of rating for the boiler, a boiler of 87.8 H.P. capacity will be required.

In selecting the boilers I believe it is best to have two of them of 45 horse power each, since if one becomes disabled the other may be used day and night until the repairs are completed. The boilers should be a make that will admit of easy cleaning and repair by the ordinary machinist. I have chosen the circular horizontal boiler sold
by Fairbanks, Morse & Co. of Chicago, having the following dimensions.

**Table No. 9**

**Dimensions of Boilers.**

<table>
<thead>
<tr>
<th>Boiler with 4 inch tubes,</th>
<th>Shell</th>
<th>Number of tubes</th>
<th>Heating surface in sq. ft.</th>
<th>Horse power.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter in inches.</td>
<td>Length in feet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>18</td>
<td>22</td>
<td>547</td>
<td>45.6</td>
</tr>
</tbody>
</table>

The plans for setting these boilers in their masonry beds may be seen on plate VIII.

Estimated cost of supply system.

The price given per foot for the wells is for a completed well ready for connection with the pumps. See Table 10, p. 41.
Table II.

Estimated Cost of Supply System.

Four 8" wells 135 feet deep @ $200 per foot = $1240.00
Four vertical Cook pumps in place and ready
for operation @ $302.00 per pump = 1211.50
Two horizontal boilers in place = 1430.50
110 feet of 6" flanged cast iron flanged pipe in place = 27.50
Total Cost of Supply System = $4108.00

Table III.

Summary of Costs of Whole System.

Tank and Tower = $9500.00
Distribution System = 27416.50
Supply System = 4108.50
Cost of Complete System = $41024.00
GROUND PLAN

OF

PUMP HOUSE AND TOWER.

Scale 1 in. = 20 ft.

PLATE III.

PIPE TO CITY 8"
DETAILS
OF
TANK.
Details of Anchorage, Manhole and Feed-Pipe Connections
PLANS
OF
FOUNDATION
AND
STAIRWAY.

PLATE VI.
ELEVATION
OF
FEED PIPE PEDESTAL

PLAN
OF
PUMP CONNECTION
WITH FEED MAIN.

FLOOR

LEVEL

BRICK PIER.
PLANS
FOR
MASONRY BOILER BEDS.

PLATE VIII.