1912

The design of a water supply distributing system for the City of St. James, Missouri

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THE DESIGN OF A WATER SUPPLY DISTRIBUTING SYSTEM FOR THE CITY OF ST. JAMES, MISSOURI.

by

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A

THESIS

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1912

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Professor of Civil Engineering.

-: TABLE OF CONTENTS :-

THE DESIGN OF THE DISTRIBUTING SYSTEM.

The design of the distributing system, being governed by the fire requirements, it is proposed to provide three 250-gallon fire streams under a hydrant pressure of 70 pounds per square inch for the business section, from Scioto St. to Bowman St., and from Seymour St. to Meramec St., with a maximum length of hose of six hundred feet; and two fire streams of a minimum total capacity of 425 gallons, each under a hydrant pressure of 72 pounds per square inch for the outlying district; the water to enter the system under a pressure of 100 pounds per square inch.

Allowing a maximum loss of pressure of 28 pounds per square inch at the extremity of the system, the intersection of Meramec and Aida St's, due to friction in the pipe, it is found by the system of eliminating cross lines and substituting equivelent diameters, as shown by accompanying computations and sketches, that 425 gallons per minute are available at that point under a hydrant pressure of 60 pounds per square inch.

The population of St. James, Mo., by the census of 1910, is 1100 but provision is made for a possible increase to 1500 with a rate of consumption of 100 gallons per capita per day. For small cities, where the fire demand is relatively large, the assumption is made that it will increase but little with the increase of population.

In the design of this system it is intended to provide a supply adequate to meet the demands, of the territory covered, for a period of twenty years. The system can easily be extended to take in new territory without increasing the size of the mains here designed.

The system contains 375 feet of eight inch, 4240 feet of six inch, and 11300 feet of four inch cast-iron pipe with the necessary valves and fittings, designed to withstand a pressure of 130 pounds per square inch.

The "Diagram for Calculating Cast-Iron Pipes" given on page 243 of Turneaure and Russell's "Public Water Supplies", edition of 1910, was used in these computations.

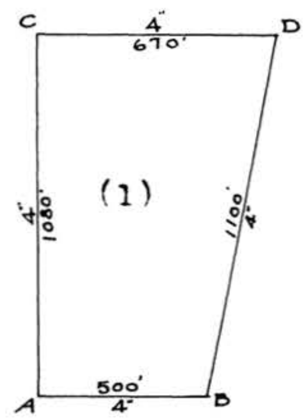
District (1)

Assumed loss of head from A to B, 20'

Discharge thru line A-B, gallons 215

Discharge thru line A-C-D-B, gal. 80

Equivalent diameter of pipe, 500 ft. long, which will discharge 295 gallons with a loss of head of 20', is 4.5 inches.



District (2)

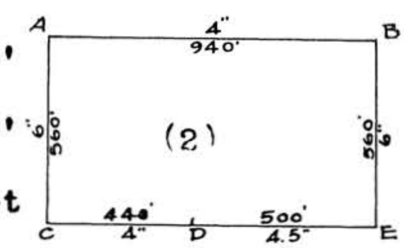
Assumed discharge thru line B-E-C-A, gallons 400

Loss of head B-E plus C-A, feet 19.04'

Loss of head E-D 32.50'

Loss of head D-C 52.80'

Equivalent diameter of pipe, 2060 feet long, which will give a loss of head of 104.3' when discharging 400 gallons, is 4.7 inches.



District (2),continued.

Assumed loss of head from A to B, 20'

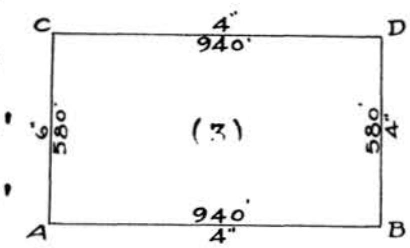
Discharge thru line A-B,gallons 150

Discharge thru line B-E-C-A,gal. 160

Equivalent diameter of pipe, 940 ft. long which will discharge 310 gallons with a loss of head of 20 feet,is 5.2 inches.

District (3)

Assumed discharge thru line A-C-D-B, gallons 300



Loss of head C-D plus D-B, 106.4'

Loss of head A-C 5.8'

Equivalent diameter of pipe,2100 ft. long which will give a loss of head of 112.2 ft. when discharging 300 gallons is 4.3 inches.

Assumed loss of head from A to B, 20'

Discharge thru line A-B,gallons 150

Discharge thru line A-C-D-B,gal. 115

Equivalent diameter of pipe,940 feet long which will discharge 265 gallons with a loss of head of 20 feet, is 5.8 inches.

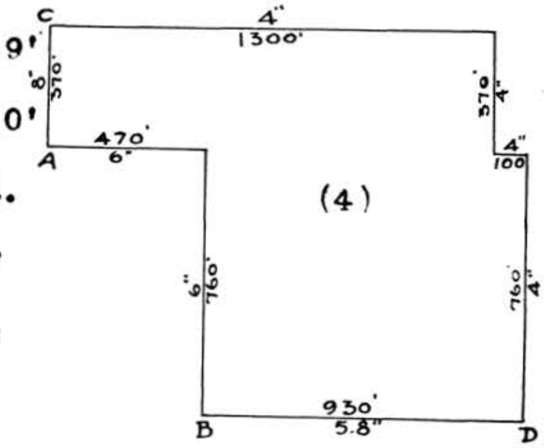
District (4)

Assumed discharge thru line A-C-D-B, gallons 300

Loss of head, C-D 177.1'

Loss of head, A-C .9'

Loss of head, D-B 11.0'



Equivalent diameter of pipe, 3830 ft. long, which will give a loss of head of 189.0 feet when discharging 300 gallons is 4.3 inches.

Assumed loss of head from A to B, 20'

Discharge thru line A-B, gallons 380

Discharge thru line A-C-D-B, gal. 85

Equivalent diameter of pipe, 1230 ft, long, which will discharge 465 gallons with a loss of head of 20 ft. is 6.5 in.

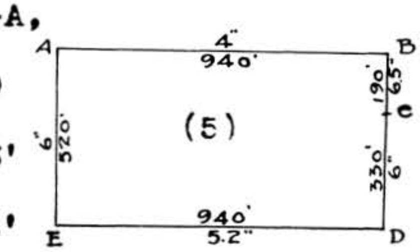
District (5)

Assumed discharge thru line B-C-D-E-A, gallons 400

Loss of head, B-C 2.3'

Loss of head, C-D plus E-A 14.5'

Loss of head, E-D 32.9'



District (5),continued.

Equivalent diameter of pipe,1980 ft. long, which will give a loss of head of 49.7 feet when discharging 400 gallons,is 5.6 inches.

Assumed loss of head from A to B, 20'

Discharge thru line A-B,gallons 150

Discharge thru line B-C-D-E-A,gal.235

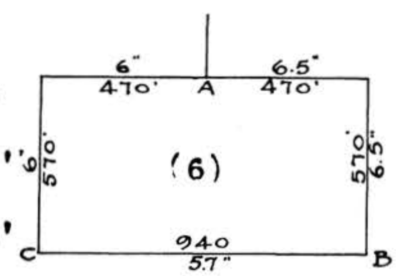
Equivalent diameter of pipe,940 ft. long, which will discharge 385 gallons with a loss of head of 20 ft.,is 5.7 inches.

District (6)

Assumed discharge thru line A-C-B, gallons 400

Loss of head A-C 17.7'

Loss of head C-B 21.6'



Equivalent diameter of pipe,1980 ft. long, which will give a loss of head of 39.3 feet when discharging 400 gallons,is 5.8 inches.

Assumed loss of head from A to B,20'

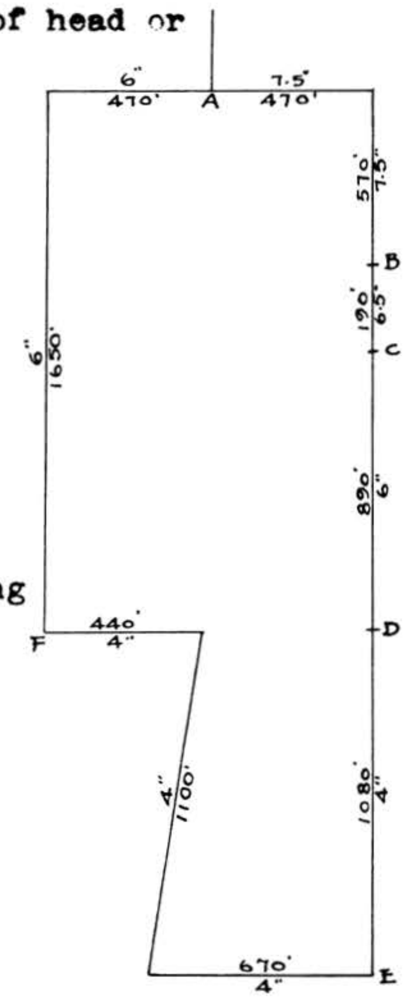
Discharge thru line A-B,gallons 520

Discharge thru line A-C-B,gal's 270

District (6),continued.

Equivalent diameter of pipe,1040 ft. long, which will discharge 795 gallons with a loss of head of 20 feet,is 7.5 inches.

Determination of the discharge available,for fire purposes, at the extremity of the system,the intersection of Meramec and Aide St's,and the loss of head or pressure between the pumps and that point.



Assumed a discharge thru line A-B---E,

gallons	300
Loss of head A-B	3.64'
Loss of head B-C	1.33'
Loss of head C-D	9.34'
Loss of head D-E	75.60'

Equivalent diameter of pipe,3200 ft. long which will give a loss of head of 89.9 feet when discharging 300 gallons is 4.8 inches.

Assumed a discharge thru line A-F-E,

gallons	300
Loss of head A-F	22.26'
Loss of head F-E	154.70'

Equivalent diameter of pipe,4330 feet long,which will give a loss of head of 177.0 feet when discharging 300 gallons, is 4.5 inches.

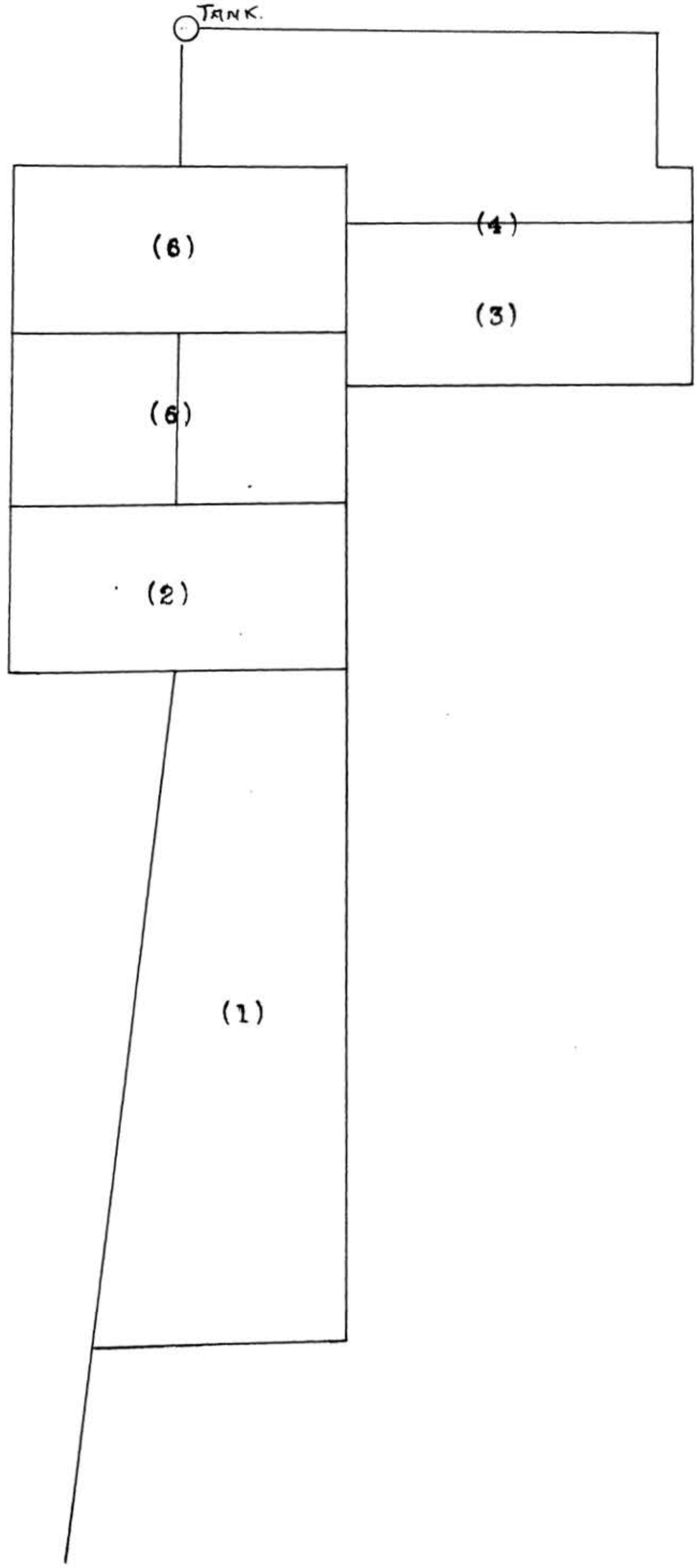
Assuming a loss of head of 65 ft. from A to E,

Discharge thru line A-B---E,gallons	250
Discharge thru line A-F-E, gallons	175

A loss of head of 65 ft. is equivalent to a loss of pressure of 28 pounds per square inch. With a pressure,at the pumps,of 100 pounds per square inch the minimum hydrant pressure in the outlying district will be 72 pounds per square inch. This pressure will give one 250 gallon stream thru a maximum length of hose of 200 ft.,and one 175 gallon stream thru a maximum length of hose of 450 ft. The above is the maximum necessary length of hose.

The fire hydrants are to be placed at the block corners,as shown on plat. Those in resident districts to be one stream hydrants and those in the business section to be two stream hydrants.

The plan of the distributing system is shown on the plat.


TANK.
(6)
(4)
(3)
(6)
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(1)

SOURCE OF SUPPLY.

Brook Spring.

The situation of Brook Spring, as determined by stadia measurements, is 12000 feet East of and at an elevation 300 feet below the sight of the proposed reservoir. Measurements with a Cippoletti weir show a flow of 230 gallons per minute.

The excessive cost of piping and pumping renders Brook Spring unworthy of consideration as a source of supply.

Deep Wells.

As an abundant supply for private uses and for the St. James Ice and Power Plant is obtained from wells 150 to 200 feet deep, it is assumed that a supply sufficient to meet the demands of the City can be had at a depth of from 500 to 600 feet. In the City of Rolla an abundant supply has been found at the last named depth.

MERAMEC SPRINGS AS A SOURCE OF POWER.

An investigation of Meramec Springs as a source of power was made August 16,1911.

The flow was determined by taking readings with the Price Current Meter at five-feet intervals along three different cross-sections of the Spring Branch where eddy currents caused by riffle were a minimum. The least of these readings shows a flow of 84 cubic feet per second.

At a point 500 feet distant from the foot of the present dam,a head of ten feet can be obtained by making the present dam water tight. With a power plant afficiency of 75% this would develop approximately 70 horse power, with an additional 7 horse power for each one foot increase in the height of the dam.

The winter preceeding ,and the season of 1911 being exceedingly dry it is probable that the above flow of 84 cubic feet per second is about a minimum.

The Price Current Meter was reted by rowing a boat at constant speed and measuring the distance covered in ten revolutions of the wheel by triangulation.

DESIGN OF REINFORCED CONCRETE TANK.

Dimensions:

Diameter	20 ft.
Depth	21 ft.
Columns	36 ft.
Capacity	56000 gal.

Unit stresses:

Steel	15000 lbs/sq.in.
Concrete columns	650 "
Concrete floor	710 "

Floors and beams were designed by the straight line formulae of Turneaure and Maurer.

The stresses in the columns, due to the wind, were based upon an assumed maximum pressure of 40 pounds per square foot on the vertical projection of the tank.

Tank Walls.

Depth	T = pr r = 10	Area req.	Bars. No.	Size	Spacing c. to c.	No. rods 34' ea.	Feet	Lbs/ft.	Total. pounds
23.5	14687	.9792	6	5/8"	3"	26	884	1.328	1174
22.5	14062	.9375							
21.5	13437	.8958							
20.5	12812	.8542	7	5/8"	5"				
19.5	12187	.8125							
18.5	11562	.7708							
17.5	10937	.7292	7	9/16"	5"	14	476	1.076	512
16.5	10312	.6875							
15.5	9687	.6458							
14.5	9062	.6042	8	1/2"	4 3/4"				
13.5	8437	.5625							
12.5	7812	.5208				32	1088	.85	925
11.5	7187	.4792	8	1/2"	6"				
10.5	6562	.4375							
9.5	5937	.3958							
8.5	5312	.3542							
7.5	4687	.3125	7	7/16"	6 1/2"	14	476	.65	309
6.5	4062	.2708							

DESIGN OF FLOOR SLAB.

Moment at center of 12" strip along the line A-B on plan = $wl^2/10$ = (1500)(4)(4)(12)/10 = 28800 inch pounds.

$A_s = M/f_s(.87)(d)$ = 28800/15000(.87)(4.5) = .487 sq. in's of steel. Assumed d = 4.5" Floor 6" thick.

Percentage of steel = p = .487/(4.5)(12) = .9%.

Stress in concrete = f_c = $28800/(.17)(12)(4.5)^2$ = 710 pounds per square inch.

Use 1/2" square bars, spaced 6" c-c and expanded metal as shown on plan.

DESIGN OF RADIAL FLOOR BEAM.

Maximum moment by graphics, as shown on plan = 1,071,000 inch-pounds.

Area of steel = $A_s = M/f_s(d-1/3t)$. t = 6".

Assumed d = 16". Then A = 4.5 square inches.

Use five 1" square bars as shown on plan.

DESIGN OF CROSS FLOOR BEAM.

Approximate length, 7'. Width of flange, 48", to carry a uniform load of 1500 pounds per square foot for the full width. t = 6". b = 48". d = 14.5".

$M = wl^2/10 = (1500)(7)(7)(12)/10 = 88200$ inch-lbs.

Area of steel = $A_s = M/f_s(d-1/3t)$ = .5 square inches.

Use two 3/4 inch square rods as shown.

DETERMINATION OF STRESS IN COLUMN DUE TO WIND.

In the determination of the stress in the column due to wind loads a pressure of 40 pounds per square inch on the vertical projection of the tank alone was taken instead of a pressure of 30 pounds per square inch on the vertical projection of both the tank and the columns.

The stress on the outside post A = My/I. I = moment of inertia with respect to the neutral axis as shown on accompanying sketch. y = the normal from the neutral axis to the center of the post. M = bending moment at foot of column due to the wind load on tank, considering the structure as a cantilever beam.

M = (20)(24)(40)(48)(12) = 11,050,000 inch pounds.

I of column "A"= $(area)(r)^2$. a = (10)(10) plus 15(4.76) = 171.4 sq.in. a = area of transformed section when n = E/E = 15. r = (14)(12) = 168 inches.

I = 171.4(168)(168) = 4,840,000.

I of columns "B" plus "C" = $2ar^2$ = (2)(171.4)(84)(84) = 2,420,000. r = 84 inches.

I of whole section = 2(I) of "A" plus "B" plus "C" = (2)(4,840,000)plus (2)(2,420,000) = 14,520,000.

Stress in concrete per square inch = f = 128.lbs.

Total wind stress on one column = 171.4(128) = 21,900 pounds.

Total compressive stress at foot of column due to the dead load of the tank when empty and the column = 30700 pounds. As the maximum tensile stress due to the wind load is less than the compressive stress due to the dead load of the tank when empty the column can never be subjected to tension.

The maximum compressive stress at the foot of the column = wind load(128 lbs),tank walls and 2/3 of floor (125lbs),column and braces(57 lbs),and water(320 lbs) = 630 pounds per square inch on the transformed section.

-: ESTIMATE OF COST. :-

PIPE SYSTEM.

This estimate is based upon pipe of sufficient thickness to withstand a pressure of 130 pounds per square inch, equivalent to a head of 300 feet.

Diameter.	Thickness.	Weight per Ft.	Feet	Total Weight.
4"	.45"	21.7#	11300	245000.
6"	.51	35.5#	4240	151000.
8"	.56	52.0#	375	19500.

Total weight, 415500#.

Lead	for	1000-4"	joints	@ 5.5#	per	joint	=	5500#.
"	"	375-6"	"	@ 8.0#	"	"	=	3000#.
"	"	35-8"	"	@11.5#	"	"	=	400#.
					Total			8900#.

Hemp required, approximately 400 pounds.

208 tons of C.I. pipe @ $27.50 F.O.B. St. James,	$5750.00
9000 pounds lead @ 4.5¢ per pound	400.00
400 pounds of hemp @ 2.5¢ per pound	10.00
Laying 16000 ft. pipe and backfilling @ 17.5¢	2800.00
19 hydrants @ $25.00, setting same, $3.50 ea.	540.00

Brought forward,	$9500.00
Two 8" valves @ $14.00, setting same $3.50 ea.	35.00
Three 6" valves @ $11.00, setting same $2.50 ea.	40.00
Seven 4" valves @ $8.00, setting same $2.00 ea.	70.00
Ten valve boxes, in place	30.00
4.6 tons fittings @ $50.00, F.O.B. St. James,	230.00
One automatic valve, in place	45.00
Total	$10000.00

TANK.

Cement	per cu. yd.	$2.00
Sand and rock	" " "	1.25
Lumber etc. (forms)	" " "	1.25
Placing forms	" " "	1.50
Placing concrete	" " "	4.00
	Total	$10.00

163 cu. yds. concrete		@	$10.00	$1630.00
18.5 " " "	(pedestals)	@	$7.00	130.00
4000 pounds steel	(tank walls)	@	2.25¢	90.00
11000 " "	(columns)	@	4.00¢	440.00
225 " "	(cen. column)	@	2.40¢	6.00

Brought forward,			$2296.00
765 pounds steel (floor)		@ 2.25¢	17.00
1200 " " (floor beams)		@ 2.25¢	27.00
200 " expanded metal		@ 2.50¢	5.00
Screen top, ladder and waterproofing			155.00
	Total		$2500.00