FRICTION HEAD LOSSES IN THE MICHIGAN STATE COLLEGE CAMPUS WATER DISTRIBUTION SYSTEM

THESIS FOR THE DEGREE OF B. S.

Clarence Stielstra

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THESIS

Water – Distribution

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SUPPLEMENTARY MATERIAL IN BACK OF BOOK

Friction Head Losses
in the
Michigan State College Campus
Water Distribution System

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By

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THESIS

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PREFACE

The writer wishes to take this opportunity to acknowledge indebtedness to Mr. W. A. Davenport and his staff of engineers of the Buildings and Grounds Department of the College for their willingness in supplying data, and also to Professor F. R. Theroux and Professor C. L. Allen of the Civil Engineering Department for the assistance rendered by them in the writing of this paper.

Friction Head Losses in the Michigan State College Campus Water Distribution System

Michigan State College loscated at East Lansing, Michigan is a Land Grant College with an approximate enrollment of 3,000 students. It was founded in 1857 and was then known as the Michigan Agricultural College, it being the first college of its type to be organized. The first years were years of struggle and reverses due no doubt to the fact that it was a pioneering school in its branch of learning. Its period of prosperity actually began in the later nineties, since which time it has had a remarkable growth. The campus proper is laid out on an extravagant plan and covers many acres of ground. It is bounded by the city of East Lansing on the North and West, by the Red Cedar River on the South, and by Farm Lane on the East. Its landscape is of the gentle rolling type with the greatest difference in elevation of any two points being about thirty-five feet. The college farms and farm buildings lie to the South of the Red Cedar River.

Michigan State College has its own Power House where it pumps all of its water, and generates all of its steam and electricity. The Power House is quite centrally located so that it can easily supply light, water, heat and power to all the college buildings and still it is not located to interfere with or mar the beauty of the campus landscape.

The Campus Water Supply is obtained from five deep wells by means of air lifts. These wells are all located quite close to the storage reservoir, the farthest one being 980

feet away. All of the wells are of 6 inch diameter but varying depths, except well #5 which is a 12 inch well 380 feet deep. Wells 1, 2, 3, and 4 are operated alternately in pairs, that is; two wells are kept flowing continuously. Each well yields approximately 250 g.p.m. during operation. Well #5 is operated continually and has an approximate yield of 350 g.p.m. All of the water flows into a storage reservoir located behind the Power House. The reservoir has a storage capacity of 100,000 gallons. The wells are kept flowing twenty-four hours a day at almost a constant rate, the storage reservoir serving the purpose to supply the peak demands during the day. A deep-well pump will be installed in well #5 at a future date replacing the air lift, so as to increase its efficiency. A by-pass from the well to the main pumps will be installed, so as to make it possible to take water from the wells directly into the mains in case of damage or repairs to the storage reservoir.

*List of Wells

No.	Depth	Size	Flow in g.p.m.
1	350'	6"	250
2	400'	6"	250
3		6"	250
4		6"	250
5	380'	12"	350

*See layout of wells on page #21.

The water for distribution is pumped from the storage reservoir into the mains by electrical and steam driven centrifugal pumps. These pumps are controlled by electric regulators so that the pressure head on them is approximately 55 to 60 pounds per sq. in. This pressure is maintained at all times during ordinary domestic consumption. In case of fire when a large flow under high pressure is demanded the pumps are set to pump at 100 pounds per sq. in.

The distribution system has a large layout so that water can be supplied to all of the college buildings. There are two 8" C.I. mains into which all of the water is pumped. One main runs *east to the Agriculture building where it divides into 8" and 6"** mains supplying water to the east side of the campus and the Dairy Barns south of the river, respectively. The other main leaving the Power House runs west supplying water to the western part of the campus. At the Old Armory across from the Gymnasium this 8" main divides into two 6"*** mains, one of which runs north to the Hospital, Mary Mayo Hall, and thence to the Union Building where it connects with the east side 8" main, to make a complete loop. The other 6" main runs west to the Gymnasium, supplying water to that building, and then reduces to a 4" main and continues on to Demonstration Hall, State Police, Poultry Plant and

*See map in pocket on back cover of this book.

**This intersection will be referred to as the "A" Intersection.

***Hereafter referred to as "B" Intersection.

Show Horse Barns where it has a dead end. It can be seen from the above discussion andthe map referred to that the layout and location of the mains has been well planned. All buildings are located comparatively close to the main so that they can be connected with short laterals. It would be impracticable to have mains or large laterals running close to each building as is done in the design of a city water distribution system.

Friction losses occuring during the maximum domestic consumption, it has been found, are not large. Even at the most remote point on the distribution system, at the State Police building, to which the friction losses are the greatest, the total head loss due to friction was found to be only about 12.2 ft. or 5.3 lbs. With a difference in elevation of the State Police building and Power House of 5 ft. which equals 2.2 lbs. the pressure delivered at that point is equal to 55 - 5.3 - 2.2 = 47.5 pounds per sq. in. Assuming that the pressure head at the Power House will not drop below 55 lbs. per sq. in. the lowest pressure encountered in the mains would be 45.6 pounds per sq. in. at the Hospital, and this is due to the elevation of the main and not to friction losses.

Maximum flows used in the calculations could not be assumed by any hard and fast rule as is done in city flows. Water used in class buildings is consumed mostly during the hours from 8 A.M. to 5 P.M. and the maximum flow occurs between class hours when the drinking fountains, lavatories and toilets are mostly used. This peak demand was assumed to be 200% of the average 24 hour flow. At the Gymnasium where a large number of showers are in use at the same time between classes, a maximum demand of 500% of the average consumption was assumed. The Dairy Barn and other farm buildings were assumed to have a more constant consumption with a peak demand of 125% of the average. Eventho the assumption of the various maximum flows may not always be near the actual flow the writer considers them close enough so that the approximate friction losses can be found. Certainly the maximum flows could not be considered much larger in most instances when all things are taken into consideration.

Losses occuring during fire flow are naturally much larger than losses during domestic flows due to the increased velocities in the mains. It has been found, as can be seen by the computation on page 14 etc., that ample fire protection is available at all building on the campus proper and at the cattle barns, but that there is no protection provided for the State Police buildings or Poultry Plant. The friction losses occuring in the long line of 4" pipe are so immense for even 175 g.p.m. stream that it would be necessary to pump to a 150 lb. head at the Power House. This is impossible for the present pumping system. The only way feasible to supply a stream with sufficient pressure at the nozzle is to use a pumper truck at the end of the main. This method would give only one sufficiently large stream, because water sufficient ~~xx~~ for two streams at 175 g.p.m. could not be supplied at the end of the main by 100 lbs. pressure at the Power House. Two streams at 175 g.p.m. would cause a loss of 228 lbs. in the mains. With the

proposed 4" main from the Beef Cattle Barns to the Show Horse Barn joining the two dead ends and making a complete loop, the friction losses would be reduced considerably, making ~~two~~ one 185 g.p.m. fire stream~~s~~ possible. The fire protection at other outlying points on the distribution system can be considered as adequate. As can be seen from the computations, two 200 g.p.m. fire streams are available at the Dairy Barns, three 200 g.p.m. streams at the Hospital and four 200 g.p.m. at the Union. All the other campus buildings are closer to the Power House and would have the same amount or greater protection.

In computing the flow and pressure required for fire streams a minimum stream of 175 g.p.m. through a 1" nozzle was used as this is the minimum satisfactory stream for a three or four story building. See Table on page 19 for friction losses in hose, height of stream, etc.

The college fire equipment consists of about 500 ft. of hose and two or three 1" nozzles, mounted on a two-wheel trailer. This is probably inefficient, but the writer does not wish to discuss its efficiency in this paper. Added protection can be obtained by the College from the City of East Lansing, which has one ladder and chemical truck, and one hose and pumper truck.

In the calculations of friction losses occuring by water flowing through pipes the diagram on page 20 was used. By having a known flow and known pipe diameter the head loss occuring in 1000 ft. of pipe can be determined directly from the diagram. A straight edge passing through any two known values will also pass through the desired

unknowns on the other scales. This chart was taken from Babbitt and Doland's textbook on Water Supply Engineering and has been prepared by using Hazen and Williams' formula $V = 1.318CR^{.63}S^{.54}$ with $C = 100$ for old tuberculated, cast iron pipe. All of the mains in the campus distribution system are cast iron and are possibly old and tuberculated.

After careful consideration and calculation it can be truthfully stated that the Michigan State College Campus Water Distribution System is well planned and efficient for the destribution of domestic water demands. It also gives adequate fire protection for all of its buildings except the following group which are located on the 4" main: Show Horse Barn, State Police, Poultry Houses, Cavalry Barn and Demonstration Hall. With the installation of the proposed 4" main connecting the dead ends between the Beef Cattle Barns and Show Horse Barn this inefficiency will be remedied.considerably.

DATA

Monthly Consumption in Thousands of Gallons in 1931

Bldg.	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	April	March	Feb.	Average
Agriculture Bldg.	*2769.00			*71.30	409.10	426.00	466.50	391.50	350.50	380.60	342.20	395.20
Anatomy	71.30	77.60	118.00	92.80	100.50	100.80	86.00	111.20	88.20	71.00		91.74
Beef Cattle Barn	9.70	7.54	6.55	6.39	9.75	9.78	8.58	8.23	9.58	10.01	19.32	9.58
Sheep Barn	1.23	1.40	1.29	2.34	2.09	2.87	2.54	7.69	5.45	5.85	4.84	3.42
Exp. Sheep & Cattle Barn	4.84	2.90	0.56	2.25		0.61	0.45	3.48	2.95	2.11	4.41	2.45
Meat Lab. Barn	12.00	18.30	7.80	3.90	14.90	15.40	19.30	17.00	10.80	12.40	21.30	13.92
Show Horse Barn	9.76	*24.83		12.56	19.72	17.40	24.10	14.94	14.62	10.71	10.49	17.68
Exp. Dairy Barn	11.80	12.40	13.50	16.00	20.10	26.10	19.10	14.90	18.40	10.80	7.20	14.93
Dairy Barn	490.70	446.80	143.90	144.00	304.20	237.00	237.20	388.60	428.20	373.30	254.70	313.51
Botany Greenhouse	23.19	33.29	29.78	20.08	12.64	17.84	*163.60	*9.65		*75.10		22.80
Chemistry	518.05	500.27	462.28	241.06	288.13	405.45	525.88	542.84	465.69	158.07	179.56	389.75
Dairy Bldg.	1318.50	1306.20	866.70	*81.70	*123.78	*65.56	1873.81	785.75	624.20	742.65	816.21	1041.63
Demonstration Hall	468.00	298.10	299.70	304.20	275.20	233.80	200.40	207.50		*71.10	*82.20	285.86
Gymnasium	1291.00	1457.70	1501.50	664.60	575.70	1351.00	1459.00	1551.60	1184.60	1691.30	1647.60	1306.87
Home Economics	141.30	141.80	141.80	67.20	78.60	120.90	232.50	154.90	142.20	136.70	130.00	135.26
Hospital	263.01	249.55	257.56	233.38	50.68	238.17	119.16	81.79	84.36	82.51		166.02
Horticulture	*39.46	*32.59	*920.08	318.42	320.09	*1660.77	334.05	215.02	*1001.82	203.24		278.16
Library	107.20	130.80	210.61	150.42	137.11	251.48	198.36	130.61	105.77	136.74	*11.44	155.91
Olds Hall	176.30	163.90	269.10	99.80	98.40	112.00	120.00	129.90	112.20	147.40		142.90
Poultry Plant	19.20	22.00	20.60	30.30	51.80	45.20	14.10				*8.60	29.03
Poultry Laying House	3.30	3.30	3.50	*11.20	4.50	4.80	2.20	3.90	3.90	1.80	1.70	4.01
Poultry Exp. House	1.30	1.40	6.20	10.00	8.50	18.50	5.00	4.10	1.20	9.30		6.55
Physics Bldg. South Meter	96.45	86.65	79.48	62.43	65.10	89.77	109.14	100.27	40.30	95.96	100.54	84.19
Physis Bldg. North Meter	30.80	28.80	32.40	29.10	25.40	23.20	29.20	26.40	20.60			27.32

DATA (CONT.)

Bldg.	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	April	March	Feb.	Average
State Police	330.01	358.02	355.27	326.64	624.85	794.03	340.63	242.56	285.67		*2.23	406.40
Union Bldg.	533.10	1078.20	954.29	648.23	76.85	780.76	693.25	828.39	668.46	784.55	431.25	679.76
Weather Bureau	12.58	12.03	11.04	20.90	46.55	12.00	12.44		6.61	6.61		15.64
Wells Hall	88.10	91.60	115.70		44.50	120.10	141.00	131.40	98.30	102.50	94.60	102.78
Women's Bldg.	187.80	227.00	232.60		93.20	41.30	440.40	485.40	391.10	477 .80	457.40	303.40
Mary Mayo Hall	564.30	714.50	936.50	278.70								623.50

* Not figured in average.

COMPUTATIONS

Consumption of Respective Buildings

Bldg.	Monthly Avg. in 1000 gal.	G. P. M.	Max. Flow in % of Avg.	Max. Flow in G.P.M.
Agriculture Bldg.	395.20	9.15	200	18.30
Anatomy	91.74	2.12	200	4.24
Beef Cattle Barn	9.58	.22	125	0.28
Sheep Barn	3.42	.08	125	0.10
Exp. Sheep & Cattle Barn	2.45	.06	125	0.08
Meat Lab Barn	13.92	.32	200	0.64
Show Horse Barn	17.68	.41	125	0.51
Exp. Dairy Barn	14.93	.35	125	0.44
Dairy Barn	313.51	7.25	150	11.00
Botany Greenhouse	22.80	.53	200	1.06
Chemistry	389.75	9.04	200	18.08
Dairy Bldg.	1041.63	24.10	200	48.20
Demonstration Hall	285.86	6.62	300	19.86
Gymnasium	1306.87	30.25	500	151.25
Home Economics	135.26	3.13	200	6.26
Hospital	166.02	3.85	150	5.80
Horticulture Bldg.	278.16	6.44	200	12.88
Library	155.91	3.61	200	7.22
Olds Hall	142.90	3.31	200	6.62
Poultry Plant	29.03	0.67	150	1.00
Poultry Laying House	4.01	0.09	150	.13
Poultry Exp. House	6.55	0.15	200	.30
Physics Bldg. South Meter	84.19	1.95	200	3.90
Physics Bldg. North Meter	27.32	0.63	200	1.26

COMPUTATIONS (CONT.)

Bldg.	Monthly Avg. in 1000 gal.	G. P. M.	Max. Flow in % of Avg.	Max. Flow in G.P.M.
State Police	406.40	9.40	300	28.20
Union Bldg.	679.76	15.75	200	31.50
Weather Bureau	15.64	0.36	150	0.54
Wells Hall	102.78	2.38	200	4.76
Woman's Bldg.	303.40	7.03	200	14.06
Mary Mayo Hall	623.50	14.43	200	28.86

Friction Losses During Maximum Consumption

Flow in Mains in g.p.m.

Assume flow in East Main from Power House to be:

Assume total flow to Dairy Barns	25.00	
Dairy Bldg.	50.00	
Anatomy	5.00	
Chemistry	20.00	
Agriculture Bldg.	18.25	
Horticulture	13.00	
Woman's Bldg.	14.00	
Home Economics	6.25	
Union Bldg.	31.50	
Mary Mayo Hall	28.80	
Hospital	5.80	
	219.60	Use 220

Assume flow in West Main from Power House to be:

Library	7.25	
Wells Hall	4.75	
Physics Bldg. (north & south)	5.15	
Gymnasium	150.00	
Demonstration Hall	20.00	
State Police and Poultry	30.00	
	216.15	Use 215

COMPUTATIONS (CONT.)

Losses

"A" Intersection to Dairy Bldg.

Flow = 75 Pipe 250'-6"
Loss = .24 x .9 = 0.25'

Dairy Bldg. to Dairy Barns

Flow = 25 Pipe 2200'-6"
Loss = 2.2 x .15 = 0.33'

"B" to Gymnasium

Flow = 200 Pipe 310'-6"
Loss = .31 x 6.5 = 2.00'

Gymnasium to Demonstration Hall

Flow = 200 - 150 = 50 Pipe 1300'-4"
Loss = 1.3 x 3.75 = 4.9'

Demonstration Hall to State Police

Flow = 50 - 20 = 30 Pipe 2070'-4"
Loss = 2.07 x 1.5 = 3.1'

COMPUTATIONS (CONT.)

Losses

Power House to Library

Flow = 215 Pipe 400'-8"

Loss = 1.6 x .4 = 0.60'

Library to Wells Hall

Flow = 215-5 = 210 Pipe 200'-8"

Loss = 1.6 x .2 = 0.30'

Wells Hall to Physics Bldg.

Flow 210-5 = 205 Pipe 420'-8"

Loss 1.55 x .42 = 0.60'

Physics Bldg. to "B" Intersection

Flow 205-5 = 200 Pipe 620'-8"

Loss 1.5 x .62 = 0.90'

Total Loss to "B" = 0.90 + 0.60 + 0.30 + 0.60 = 2.40 ft.

Power House to "A" Intersection

Flow 220 Pipe 350'-8"

Loss 1.75 x .35 = 0.62'

"A" Intersection to Agriculture Bldg.

Flow 220-100 = 120 Pipe 185'-8"

Loss .6 x .18 = 0.12'

Agriculture to Botany

Flow 120-20 = 100 Pipe 250'-8"

Loss .25 x .45 = 0.12'

Botany to Woman's Bldg.

Flow 100-15 = 85 Pipe 770'-8"

Loss .77 x .33 = 0.26'

Woman's Bldg. to Union Bldg.

Flow 85-20 = 65 Pipe 865'-8"

Loss .865 x .2 = 0.18'

Union to Mary Mayo Hall

Flow 65-20 = 35 Pipe 760'-6"

Loss .76 x .25 = 0.20

Mary Mayo Hall to Hospital

Flow 35-30 = 5 Pipe 340'-6"

Loss negligible

Total Loss from Power House to Hospital

.20 + .18 + .26 + .12 + .12 + .62 = 1.50 ft.

Difference in pressure between Hospital and "B" Intersection

2.40 - 1.50 = 0.90 ft. or 0.40 lbs. per sq. in.

Friction Losses During Fire Consumption

Fire Demand at Union Bldg.

Assume 4 fire streams at 185 g.m.p. each = (approx.) 750

Trial #1

Assume 600 g.p.m. from Power House to "A" and 500 g.p.m. from "A" to Union; 450 g.p.m. from Power House to "B" and 250 g.p.m. from "B" to Union.

Loss - P.H.* to "A"	.350 x 11	= 3.8'
" - "A" to Union	2.07 x 7.8	= 16.2'
		20.0'

Loss - P.H. to "B"	1.63 x 6.5	= 10.5'
" - "B" to Union	2.12 x 9.2	= 19.5'
		30.0'

Trial #2

Assume 650 g.p.m. from P.H. to "A", 550 g.p.m. from "A" to Union; 400 g.p.m. from P.H. to "B", 200 g.p.m. from "B" to Union.

Loss - P.H. to "A"	.350 x 13.0	= 4.5
" - "A" to Union	2.07 x 9.4	= 19.5
		24.0'

Loss - P.H. to "B"	1.63 x 5.3	= 8.6
" - "B" to Union	2.12 x 6.3	= 13.4
		22.0'

Trial #3

Assume 640 g.p.m. from P.H. to "A" and 540 g.p.m. from "A" to Union; 410 g.p.m. from P.H. to "B", 210 g.p.m. from "B" to Union

Loss - P.H. to "A"	.350 x 12.5	= 4.4
" - "A" to Union	2.07 x 9.0	= 18.6
		23.0'

Loss - P.H. to "B"	1.63 x 5.4	= 8.8
" - "B" to Union	2.12 x 6.9	= 14.6
		23.4

Loss approximately 23.1 ft. or 10 lbs.

*Power House

COMPUTATIONS (CONT.)

Difference in elevation of Power House and Union 10' or 4.33#
400' of 2½" hose. Loss = 4.00 x 10 = 40#
Total Loss to base of nozzle = 40 + 10 + 4.33 = 54.33#
100 - 54 = 46# pressure at nozzle which will give a flow of between 185 and 200 g.p.m. per nozzle.

Fire Demand at Hospital.

Assume 3 fire streams at 200 g.p.m. each = 600

Trial #1

Assume 400 g.p.m. from P.H. to "A" and 300 g.p.m. from "A" to Hospital; 500 g.p.m. from P.H. to "B", 300 g.p.m. from "B" to Hospital.

Loss	- P.H. to "A"	.35 x 5.3	=	1.9
"	- "A" to Hosp.	(2.07x3.25) + (1.1x13)	=	21.00
				22.9

Loss	- P.H. to "B"	1.63 x 7.8	=	12.7
"	- "B" to Hosp.	1.02 x 13	=	13.3
				26.0

Trial #2

Assume 410 g.p.m. from P.H. to "A" and 310 g.p.m. from "A" to Hospital; 490 g.p.m. from P.H. to "B", 290 g.p.m. from "B" to Hospital.

Loss	- P.H. to "A"	.35 x 5.5	=	1.95
"	- "A" to Hosp.	(2.07x3.5) + (1.1x14)	=	22.75
				24.70

Loss	- P.H. to "B"	1.63 x 7.6	=	12.4
"	- "B" to Hosp.	1.02 x 12.5	=	12.6
				25.0

Loss approximately 24.9 x .433 = 10.85 lbs.

Difference in elevation of Power House and Hospital 15' or 6.5#
300' of 2½" fire hose. Loss = 3.00 x 12 = 36#
Total Loss to base of nozzle = 10.85 + 6.5 + 36 = 53.3#
100 - 53.3 = 46.7# pressure at noxxle which will give a flow of approximately 200 g.p.m. per nozzle.

COMPUTATIONS (CONT.)

Fire Demand at Dairy Barns

Assume 2 fire streams at 200 g.p.m. each = 400

550 g.p.m. from P.H. to "A"; 450 from "A" to Dairy Bldg.; 400 g.p.m. from Dairy Bldg. to Dairy Barns.

Loss - P. H. to "A"	.35 x 9.5	= 3.4'
" - "A" to Dairy Bldg.	.25 x 28	= 7.0'
" - Dairy Bldg. to Dairy Barn	2 x 22	= 44.0'
		54.4' or 24 lbs.

Difference in elevation of Power House and Dairy Barn 10' or 4.33#
250 ft. of $2\frac{1}{2}$" fire hose. Loss - 2.5 x 12 - 30#
Total Loss to base of nozzle = 24 + 30 = 54#
100 - 54 = 46# pressure at nozzle which will give a flow of approximately 200 g.p.m. per nozzle.

Fire Demand at State Police

Assume 2 fire streams at 175 g.p.m. each = 350

Trial #1

Assume 400 g.p.m. from P.H. to "B"; and 300 g.p.m. from P.H. to "A", 200 g.p.m. from "A" to Union and 100 g.p.m. from Union to "B".

Loss - P.H. to "B"	1.63 x 5.3	= 8.6'
Loss - P.H. to "A"	.350 x 3.2	= 1.12'
" - "A" to Union	2.07 x 1.5	= 3.1'
" - Union to "B"	2.12 x 1.75	= 3.73'
		7.95'
	(approx.)	8.3
Loss - "B" to Gymnasium	.31 x 38	= 12'
Loss - Gym. to State Police	3.37 x 150	= 505'
Total Loss in Main		= 525.3' or 228 lbs.

Difference in elevation of Power House and State Police 5' or 2.2#
300' of $2\frac{1}{2}$" fire hose. Loss = 3.00 x 10 = 30#
Total loss to base of nozzle = 30 + 2.2 + 228 = 260#
A 175 g.p.m. fire stream requires about 35# at the nozzle or 35 + 260 = 295 # at the Power House.

COMPUTATION (CONT.)

Trial #2

Assume 1 fire stream at 175 g.p.m.

Loss from Gymnasium to State Police	3.37 x 47	=	158' or 69.3#
" " "B" to Gym.	.31 x 15	=	4.7' or 2#
" - 400' of $2\frac{1}{2}$" fire hose	4 x 10	=	40#
" " P.H. to "B" (approx.)		=	7' or 3#
			114.3#

Pressure at base of nozzle = 35#
Total Pressure required at P.H. = 114.3 + 35 = 149.3#

Trial #3

Fire flow at State Police with proposed 4"C.I. pipe connecting the dead ends at the Show Horse Barn and Beef Cattle Barns:

Assume 1 fire stream at 185 g.p.m.

Assume flows: P.H. to "A" 285 g.p.m.; "A" to Dairy Bldg. 160 g.p.m.; Dairy Bldg. to Dairy Barns 110 g.p.m.; Dairy Barns to State Police 85 g.p.m. P.H. to "B" 250 g.p.m.; "B" to Gym. 250 g.p.m.; Gym to State Police 100 g.p.m.

Loss - P.H. to "A"	.350 x 2.8	=	.97'
" - "A" to Dairy Bldg.	.250 x 4.2	=	1.0'
" - Dairy Bldg. to DairyBarn	2.18 x 2.2	=	4.8'
" - D Barns to State Police	4.60 x 9.9	=	45.5'
			52.2'

Loss - P.H. to "B"	1.63 x 2.5	=	4.1'
" - "B" to Gym.	.31 x 9.5	=	3.1'
" - Gym. to State Police	3.37 x13.0	=	44.0'
			51.2'

(approx. 51.5' or 22.3#)

Difference in elevation of Power House to State Police 5'or 2.2#
350' of $2\frac{1}{2}$" fire hose. Loss 3.5 x 10 = 35#
Total loss to base of nozzle = 35 + 2.2 + 22.3 = 59.5#
100 - 60 = 40# pressure at nozzle which will give a flow of approximately 185 g.p.n. per nozzle.

COMPUTED DATA

Pressures Available during Maximum Flow

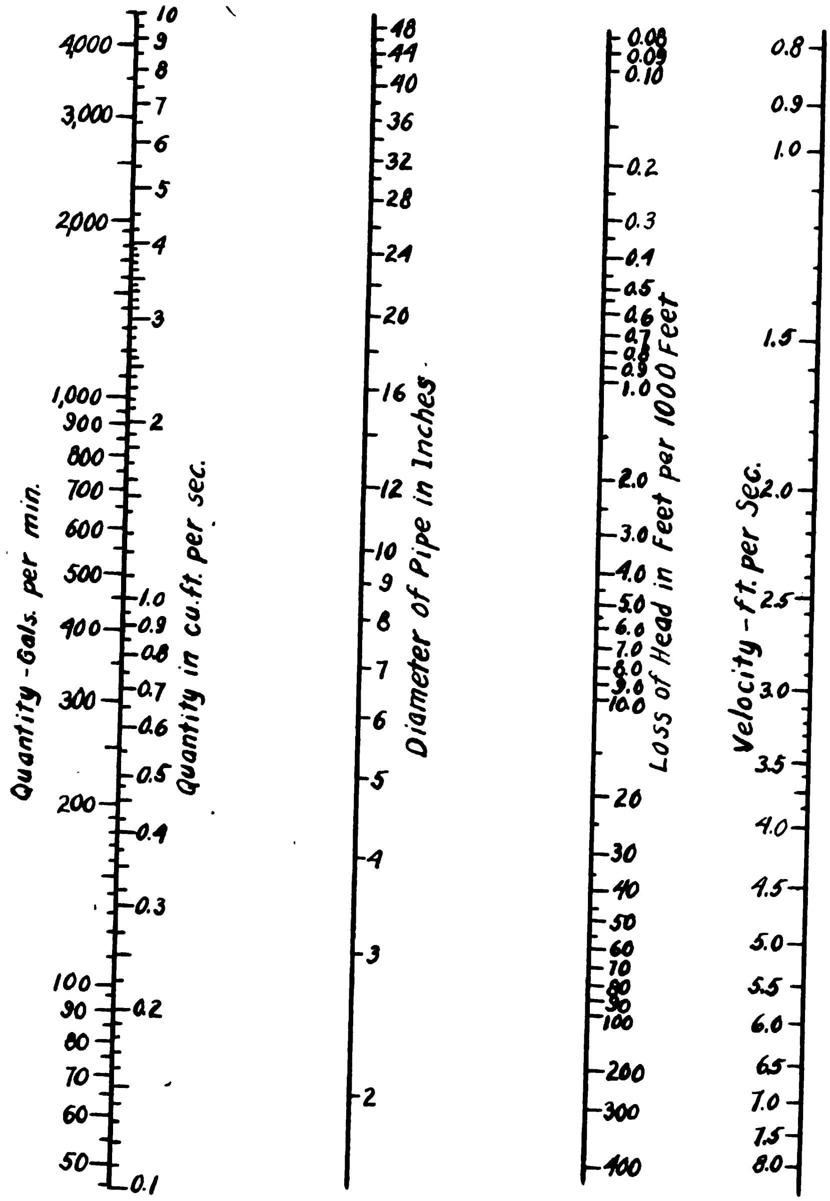
Bldg.	Elev.	Friction Losses in Feet	Pressure Feet	Pressure #/sq. In.
Power House	845	0	127.0	55
Agriculture Bldg.	850	0.74	121.3	52.5
Dairy Barns	855	1.20	115.8	50.2
Botany	850	0.86	121.1	52.5
Chemistry	845	1.00	126.0	54.7
Dairy Bldg.	845	1.00	126.0	54.7
Demonstration Hall	835	9.00	128.0	55.5
Gymnasium	840	4.10	127.9	55.5
Home Economics	850	1.15	120.8	52.4
Hospital	865	1.75	105.2	45.6
Library	850	0.60	121.4	52.7
Olds Hall	845	0.50	126.5	54.8
Poultry Houses	850	12.20	109.8	47.6
Physics Bldg.	845	1.50	125.5	54.5
State Police	850	12.20	109.8	47.6
Union Bldg.	855	1.30	115.7	50.2
Wells Hall	850	0.90	121.1	52.2
Woman's Bldg.	845	1.12	125.8	54.5
Mary Mayo Hall	850	1.50	120.5	52.3

Losses in Head in Fire Hose and

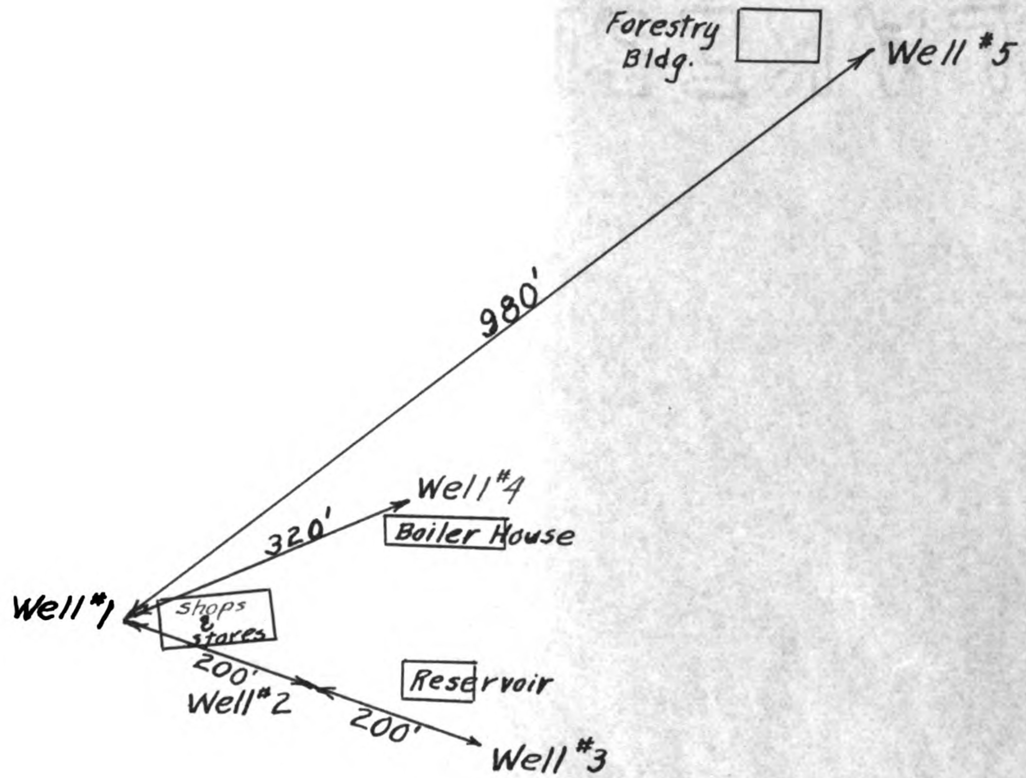
Discharge from 1 in. smooth nozzle.

Pressure at base of nozzle, pounds per square inch	Discharge, gallons per minute	Loss of head per 100 feet in rubber-lined hose, pounds per square inch	Vertical height of jet for good fire stream, feet	Horizontal distance of jet for good fire stream, ft.	Distance of extreme drops at level of nozzle, feet
20	132	5	35	37	77
30	161	7	51	47	109
40	186	10	64	55	133
50	208	12	73	61	152
60	228	15	79	67	167
70	246	17	85	72	179
100	295	25	96	83	205

These figures are from John R. Freeman, Trans. Am. Soc. Civ. Eng., Vol. 21, p. 303, 1889, and are for $2\frac{1}{2}$-in. rubber-lined hose.



Conditions of flow in old cast-iron Pipe
Hazen and Williams Formula C = 100



Layout of Wells

Pocket has: 1 Map