DESIGN OF IMPROVEMENTS IN THE WATER SUPPLY SYSTEM OF MICHIGAN STATE COLLEGE

THESIS FOR DEGREE OF B. S.

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DESIGN OF IMPROVEMENTS
IN THE
WATER SUPPLY SYSTEM
OF
MICHIGAN STATE COLLEGE.

A Report

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By

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Candidate for Degree of

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THESIS

In the selection of the subject for this Thesis the writer is indebted to Professor H. G. Woods of the Civil Engineering Department, and to Mr. Lavers and Mr. Miller of the Department of Buildings and Grounds.

Since the problem is one that will in the course of a few months be covered to completion in the field and is of a highly practical nature, the writer is well satisfied in having obtained it for a Thesis.

The writer also wishes to express his appreciation of the suggestions and cooperation which were accorded him by Professor C. L. Allen, Head of the Civil Engineering Department, Professors Miller and Woods also of the Civil Engineering Department, and Mr. Lavers and Mr. Miller of the Department of Buildings and Grounds.

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A DESCRIPTION OF THE PROBLEM.

At the present time the water supply system at Michigan State College is inadequate for the needs of the College. Water comes entirely from wells, a sufficient number having been sunk, but only two have pumps capable of supplying water to the system. One of these pumps is a two-cylinder reciprocating pump which will furnish the amount of water that the College uses for ordinary consumption, while the other is an air lift pump. The reciprocating pump is in good repair and can be classed as a dependable piece of machinery, but the air lift pump, while being itself in poor condition, is dependent for air on a small compressor operated by an engine incapable of running at a high enough rate of speed, which leaves the unit of no real value to the system. The College is dependent on the City of East Lansing for all its water at any time it becomes necessary to shut down the reciprocating pump, and also dependent in the face of any unusual demand such as a fire. The College uses a considerable amount of water (about 290,000 gallons per 24 hours) and has power available to pump this water and operators caring for present machinery who can operate and maintain the system. For reasons of safety and economy the system should be improved.

A short time ago the State Legislature voted an appropriation of $25,000 for improvement of the system. The Department of Buildings and Grounds is planning to improve the system in the summer of 1926. It is the wish of the Department to build what improvements it is possible to make, liberal enough and lasting, to the extent that the College can depend on these improvements to be all that the demands of the College will require them to be for an indefinite period in the future. The problem of this thesis is to furnish a general design which will answer these requirements and which can be built from the funds available.

The steps followed in working out the problem, and as found in this Thesis are as follows:

First, the topography of the ground in the region where all the changes are to be made was taken, as it has an influence on the design.

Second, The type of pumping equipment, amount and kind of storage, and all miscellaneous equipment was decided upon.

Third, The reservoir was designed.

Fourth, The piping and pumping system was designed.

Fifth, The cost was checked.

This last item could be done only approximately, due to the limited time available, and does not appear as a separate part of the Thesis, but it was considered in picking equipment as much as existing information allowed it to be. It is certain that when final figures are available some changes must be made, but if the design falls within reasonable limits and the general layout does not need to be altered, the results hoped for in working this problem will be reached.

TOPOGRAPHY

Before starting work on the mapping of the area of wells and reservoir it was necessary to obtain data on the College triangulation system in order that features of the map, and elevations, might be in accordance with maps of the campus. College triangulation station Number Eleven comes just within the area of the map which made the orientation of the map and reference for levels easy to obtain. College Station Number 6 was sighted from Station 11 for orientation. Data obtained from the Civil Engineering Department was as follows: Azimuth of line 6 to 11 - 318° - 07' - 36.7". Elevation of Station 11 - 848.51 ft. All elevations and directions are based on these two things.

To obtain several accurately known points of reference a closed traverse was run from Station 11 and the azimuth and length of each line recorded. Later a second traverse was attached to the west side of the first. The error of closure of each traverse and of the whole figure as one traverse was computed and as it was found to be so small ($\frac{1}{10,000}$) as to be of no account, and the traverse was not balanced.

Next, a line of levels were run from Station 11, using traverse corners as benches with a few convenient benches at other points.

Most of the features and all contours were run in by transit and stadia. With the instrument over some station and orientated and the telescope level the rod was sighted setting over a desired point. The station, azimuth, stadia distance, object, and in some cases the level rod reading were recorded. Azimuth angles were taken as measured clockwise from the south. Contours were taken at 1 ft. intervals. With height of instrument known a rod reading was computed which would place the foot of the rod on a desired contour. A band was placed around the rod at this reading and the rod moved up and down slope until this band was cut by the horizontal cross-hair. Note headings given above were then entered under. This located a point on the contour and a number of such points at apparent turns, allowed the contour to be traced on the map.

Later levels were run to all well pipes and static water levels determined. They were found to be almost exactly the same. Elevations of pump room floor and of other objects having a bearing on the design were also taken.

The majority of results obtained are included on the topographical map or in some part of this Thesis. Notes taken in the field include all data but are held by the Department of Buildings and Grounds. In the writer's opinion the maps may be depended upon to the extent that any distance may be scaled with an error of not over 5 feet.

PRESENT CONDITION OF THE SUPPLY SYSTEM.

The College is now using, as has always been the case, a ground water source of supply, securing it from coal measure sand-stones. The present wells are five in number but only two are hooked up to supply water to the system. One of these is pumped by a deep well pump and the other by air-lift. At the present rate of consumption the deep-well pump is able to supply the College if no abnormal demands are placed on it.

The deep-well pump is a two-cylinder reciprocating lift pump, which pumps directly into the mains. It is in good repair having just been overhauled and can be classed as a reliable piece of machinery and a good one to retain in the system. The well itself is a 10 inch being the largest well and capable of supplying more water than any well in the system. This well and pump are located back of the Physics Building several hundred feet remote from the other four wells.

The remaining four wells are located in the region of the boiler room. They are all 6 inch cased down to a depth of approximately 80 ft. The oldest of these wells was driven in 1880 and has been pumped, until recently, by a centrifugal deep well pump. This equipment has been junked and nothing remains but the well and well-house. The remaining three wells were sunk in about 1900. Two of them have been hooked up with air lift pumps while the other has never been in use. One of the air lifts can be made to discharge thru a pressure pump to the system but the other discharges to the sewer and has been used only for test purposes.

Pumping equipment from the air-lift to mains consists of a Duplex reciprocating steam pump located in the basement of the power house. Arrangement of this pump between well and mains is to be condemned. A man is required on duty at all times that the pump is used for if it pumps faster than the well supplys it it pumps vacuum, and if slower the pump room is flooded.

Storage and pressure regulation is obtained from an elevated tank 156.5 ft. high having a capacity of 50,000 gallons.

Compressed air is furnished to the air-lift by a Burg 14" x 14" single stage horizontal compressor driven by a single cylinder 12" x 12" vertical steam engine. Due to slow speed and vibration of the engine and poor qualities of the compressor this equipment is practically worthless and makes it impractical to pump water with it.

Two means are provided for supplying fire demand. One is to turn on the City of East Lansing, and the other to pump from a cistern connected to the river. The former is troublesome and costly and the latter is apt to be more injurious than a fire for it pollutes the mains.

Briefly, the only real supply equipment the college now has is the one reciprocating deep well pump and a 50,000 gallon elevated storage and pressure regulating tank. This This means that so long as the reciprocating pump operates continuously and there are no abnormal demands that the College can furnish its own water but in the face of any break down or unusual demands it will be entirely dependent on outside sources.

SELECTION OF TYPE OF RESERVOIR AND ITS DIMENSIONS.

At the start of this problem it was known that some storage must be provided. It is a fact established by good practice that storage must be provided to absorb peak loads, to aid in purifying the water, to allow closing down of the wall pumps for short periods, and to supply abnormal demands without the use of expensive standby equipment which might not be needed for long periods of time. Because all water has to be pumped and there already was an elevated tower for pressure regulation, it was also established that the reservoir must set on the ground, or under ground if possible to keep the water cool and more sanitary. The problem then in selecting a reservoir was to decide on type and size to be used.

Two types of reservoir could be used, steel and reinforced concrete. Points in regard to each used in making the selection are as follows:

Steel Circular Reservoir.

1. Cost approximately $4000 per 200,000 gallon capacity. (According to an estimate from Chicago Bridge & Iron Works).
2. Maintenance cost high.
3. Life comparatively short.
4. Shape of reservoir affords very little settling space.
5. Tank is high and so means a large lift from the wells,

higher pumping costs, and an intermediate pump if air-lift equipment is used.

6. Inflexible. If the tank is cleaned there can be no storage in the meantime.
7. Used but little in similar systems.
8. Affords but slight protection against heat and cold.

<u>Concrete Rectangular Reservoir</u>.

1. Cost approximately $10,000 per 200,000 gallons. (According to a rough estimate received from Christman Company).
2. Maintenance cost low.
3. Life comparatively long.
4. Rectangular shape provides very liberal settling area.
5. Height can be made to set low leaving a low head against the well pumps.
6. A flexible unit allowing one section to be shut down while another is cleaned.
7. Used almost exclusively in good practice.
8. Protects water from extreme temperatures.

A study of these facts showed the concrete tank to be more expensive but otherwise far more desirable. It was decided that a more serviceable and in the end cheaper tank could be built from concrete.

Capacity and Dimensions.

Data effecting required capacity was found to be as follows:

Largest fire demand necessary to design for = 5-250 gal.

Standard fire streams = 250 gal. per minute.

Maximum possible rate of pumping = 850 gal. per minute.

Maximum duration to be expected of any fire = 5 hours.

By assuming a 200,000 gallon storage reservoir designed to never contain less than 100,000 gallons, it was possible to solve for the minimum and maximum duration of fire it would be sufficient for.

$$\text{Maximum duration} = \frac{100,000}{1,250 - 850} = 250 \text{ minutes} = 4 \text{ hours and}$$

10 minutes.

Maximum duration = 2 x 4 hrs. 10 min. = 8 hrs. 20 min.

These figures show a capacity of 200,000 gallon to be satisfactory.

Dimensions.

It was found that two tanks each 10' x 20' x 75' inside built on a common foundation slab offered a flexible arrangement for water circulation, gave room for piping, did not make the resisting head against the well pumps too great, and provided the necessary capacity. Ten feet of depth allows for an extra foot at the top in which to put distributing pipes.

WELL PUMPING EQUIPMENT.

Small consideration was given to any type of pumps other than air-lifts. Other types were considered but as the odds were heavily in favor of air-lifts, only the reasons for picking them will be given.

1. More water can be secured from a well by air-lift pumps than by any other known means, making a valuable fire system.
2. The over-all efficiency is good.
3. The College already has some air-lift equipment on hand.
4. There are no moving parts and hence a minimum of upkeep at the well.
5. The wells can all be operated from the power house simply by turning a valve.
6. Men already engaged in the power plant can operate the system.
7. The unit is flexible allowing a new well to be installed with a minimum of expense and without affecting the rest of the system.
8. All machinery is under cover with operators present whenever it is used.
9. The first cost is not abnormally high.
10. Low installation cost.
11. Air-lifts are becoming a favored type of pump.

12. The City of Lansing has used all types of well pumps and now is using air-lifts.

Boosters.

The use of air-lift pumps brought up the questions of getting water to the reservoir since air must be separated from water before it gets far from the well, or trouble will arise in the form of a partial separation and back pressure. Two common methods of doing this were considered.

First, air separators setting high enough to cause gravity flow to the reservoir.

Second, Boosters set underground and maintaining a pressure to force water into the reservoir. Quotations showed that the boosters would cost about $100 more per well than air-separators but this being a small item in comparison with total cost and there being many points in favor of boosters, the decision was made to use them.

The reasons for doing this are as follows:

1. Everything is under ground which eliminates freezing troubles and unsightly piping.
2. The efficiency compares favorably with other methods.
3. Pipes to reservoir can be made smaller.
4. The pressure in the booster can be varried to suit the particular requirements of any well.
5. Details of the piping system are simplified.

MISCELLANEOUS EQUIPMENT.

For convenience of the operators and the betterment of the system two additional pieces of apparatus are suggested. One is a 2 inch pipe leading from the reservoir into the powerhouse and connected with a static head recorder. This will give at a glance the amount of water in the reservoir. The other is a recording venturi-meter to be set on the discharge line from pressure pumps.

DESIGN OF RESERVOIR.

The plan of the réservoir had been settled as two tanks on a common base (separated by a partition wall) each, 10 ft. deep x 20 feet wide x 75 ft. long, depth of water to be 9 ft.

Hool and Johnson's concrete design formulaes and constants have been used throughout with conservative values of f_c and f_s to insure against cracking. Formulaes and nomenclature are to be found in either Hool and Johnson's Volume I, or in their Concrete Engineers' Handbook, and for that reason will not be given here. All design is for a section 1 ft. in width.

Walls.

1:2:4 mix.

$f_s = 12,000$

$f_c = 500$

$n = 12$

Force producing overturning $= \frac{9 \times 62.4 \times 9}{2} = 2527$ lbs.

Moment at base of wall = 2527 x 9/3 = 7581 ft. lbs.

$d = \sqrt{\frac{M}{K}} = \sqrt{\frac{7581}{74}} = 10.2$

Say d = $10\frac{1}{2}$ inches – D = 13"

Steel ratio p = .0069.

$A_s = pbd = .0069 \times 12 \times 10\frac{1}{2} = 0.87$ sq. in.

Use 3/4" round rods spaced 6 inches on centers A_s = 0.88

Shear V = 2527

$$v = \frac{V}{bjd} \quad \frac{2527}{12 \times 10.5 \times .889} = 22.6 \text{ lbs per sq. in.}$$

This is safe as 40 is allowable.

$$u = \frac{V}{\Sigma\, o\, jd} = \frac{2527}{2.356 \times 2 \times 0.889 \times 10.8} = 57.5.$$

This is safe as 80 is allowable.

$$\text{Moment 3 ft. up} = \frac{6 \times 62.4 \times 6}{2} \times \frac{6}{3} = 2240.$$

Ratio of steel required here to that at bottom =

$$\frac{2240}{7581} = 0.30$$

$$\text{Moment 6 ft. up} = \frac{3 \times 62.4 \times 3}{2} \times 1 = 280.$$

Ratio of steel required here to that at bottom =

$$\frac{250}{7581} = 0.037$$

Carry two thirds of rods up 3 ft., one third up 6 ft., and one sixth to top. Although computations show that this much steel is not needed it is not advisable to do away with more because of danger of shrinkage cracks.

$$\text{Necessary length of imbedment} = L = \frac{fi}{4u} = \frac{12,000 \times 3/4}{4 \times 80} = 28"$$

To be on the safe side run the wall steel a distance of 3 ft. into and along the base slab.

Roof

Designed as flat slab.

Span = 21 ft.

f_s = 16,000

f_c = 650

N = 15

Assume 2t. per ft. = 150#

Live load per ft. = 50#

W = 200#

$M = 1/8\ Wl^2 = 1/8 \times 200 \times 21 \times 21 = 11,500$ ft. lbs.

$d = \sqrt{\dfrac{11,500}{107.4}} = 10.7$

Say d = 11 inches, D = 13". Taper to any desired thickness at edge.

Taking concrete at 150 lbs. per cubic ft. the assumed and actual weights check very closely.

p = .0077

As = .0077 x 12 c 11 = 1.02

Use 3/4" round rods spaced 5 inches on centers As = 1.06 sq. in. per ft.

$V = 5/8\ Wl = 5/8 \times 200 \times 21 = 2688$

$v = \dfrac{V}{bjd} = \dfrac{2688}{12 \times .874 \times 11} = 23.4$ Satisfactory.

$u = \dfrac{V}{\Sigma o\, jd} = \dfrac{2688}{2.356 \times 12/5 \times 0.874 \times 11} = 49.4$ Satisfactory as a bond stress of 80 is allowable.

Base Slab.

Several widths of base slab were considered before the one given was chosen. It was picked because it gave the least variation in stresses and hence the most uniform required depth. For shear and moments sample computations only will be given.

Conditions for Maximum Stresses.

Three conditions were taken as being the ones which would bring out macimum stresses.

First, Live lead on roof with one tank full.

Second, Live lead on roof with both tanks full.

Third, Live load on roof with both tanks empty.

Materials and Stresses.

These values are conservative to insure against cracking.

Mix 1:2:4

fc = 500

fs = 12,000

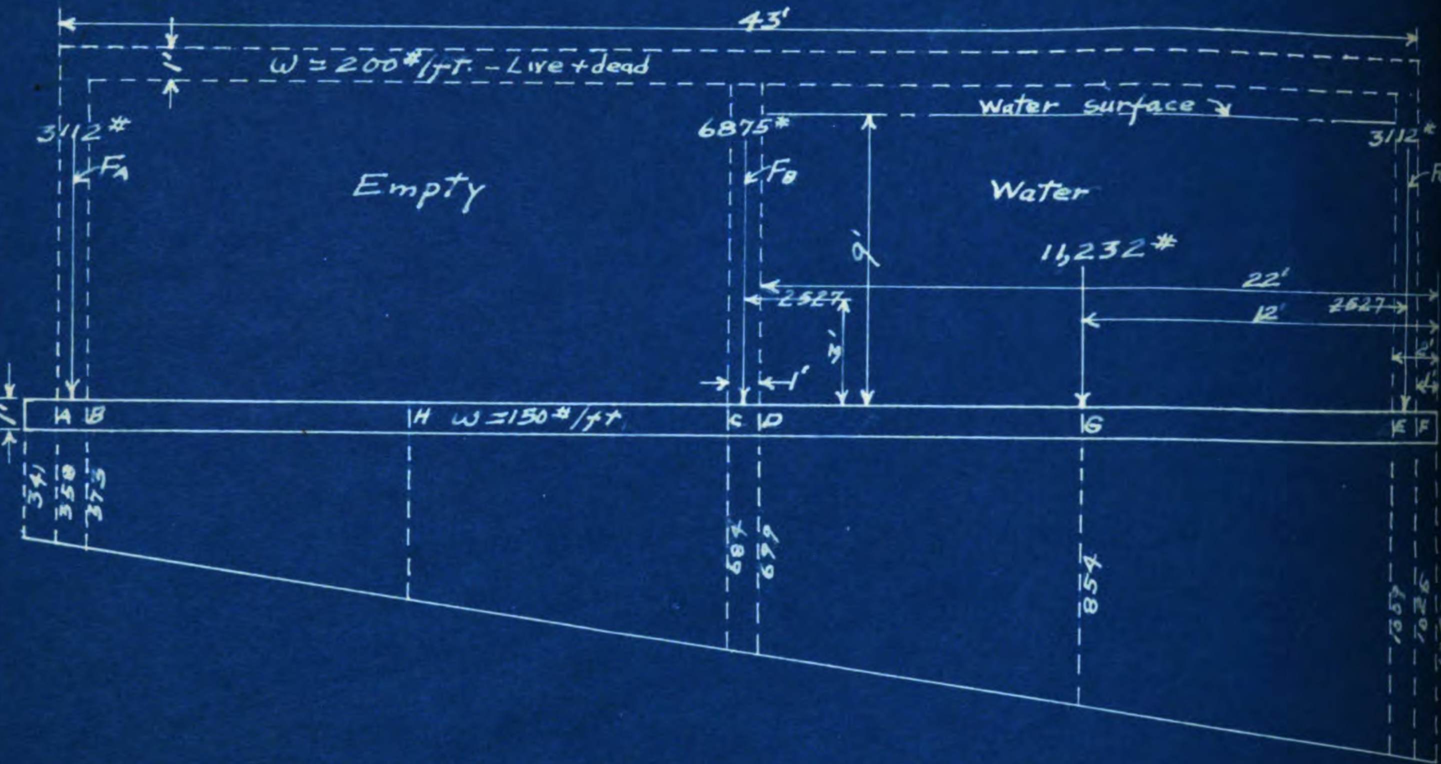
n = 12

Earth Pressures.

The reservoir was designed as setting on top of the ground although it is expected to eventually partly bury it. This is on the safe side and provides for stresses before burying.

Diagram 1

Forces Acting On Base Slab
One Tank Full And One Empty



Computation Of Above Forces

Roof reactions considering roof as a 1ft slab continous over 3 supports

Outer reactions $= \frac{3}{8} w l = \frac{3}{8} \times 200 \times 21.5 = 1612$# each - 2 of them = 3,224#

Inner reaction $= \frac{10}{8} w l = \frac{10}{8} \times 300 \times 21.5$ - - - - - - - - - - - - - - = 5,375

Wt. of walls = 10 × 150# = 1500# each - 3 walls - - - - - - - - - - - = 4,500

Wt. of foundation = 45 × 150 - = 6,750

Total wt. of concrete - = 19,849#

F_A & F_C = 1612 + 1500 = 3,112#
F_B - - - = 5375 + 1500 = 6,875#

Wt. of water = 62.4 × 20 × 9 = 11,232#

Taking moments about left end of foundation

Dist. to pt. app of res $= \frac{19{,}849 \times 22\frac{1}{2} + 11{,}232 \times 33}{19{,}849 + 11{,}232} = 26.294'$

Excentricity = 26.294 − 22.5 = 3.794'

Unit soil pressure (Max & Min) $= \frac{P}{A}\left(1 \pm \frac{6e}{A}\right) = \frac{31{,}081}{45}\left(1 \pm \frac{6 \times 3.79}{45}\right) = 1{,}040$ & 341#/sq ft

Increase per. ft $= \frac{1040 - 341}{45} = 15.5$#/ft. from which unit stresses/ft at the various sections are as shown.

Horizontal force of water $= \frac{62.4 \times 9 \times 9}{2} = 2527$#

Pt. of app. is 9/3 = 3' up.

Dimensions.

The walls were considered as 1 ft. thick to simplify computations although they are 13 inches at the base and 10 at the top.

Weight of Concrete.

Concrete was taken at 150# per cu. ft. and the base slab considered to be uniformly 1 ft. thick for design purposes. This proved to be reasonably near to correct.

Positive and Negative Moments.

A positive moment was taken as one which puts compression in the top fibers and a negative moment as one which puts compression in the bottom fibers.

From Diagram 1.

Moments.

$M_F = 1025 \times 1 \times \frac{1}{2} \times 15 \times 1 \times \frac{1}{2} \times 2/3 - 150 \times \frac{1}{2} = +443.$

$M_E = 1009 \times 2 \times 1 + 31 \times 2 \times \frac{1}{2} \times 1.33 - 7581 - 3112 \times \frac{1}{2} -$
$150 \times 2 \times 1 = -7378.$

M_D (By forces to right).

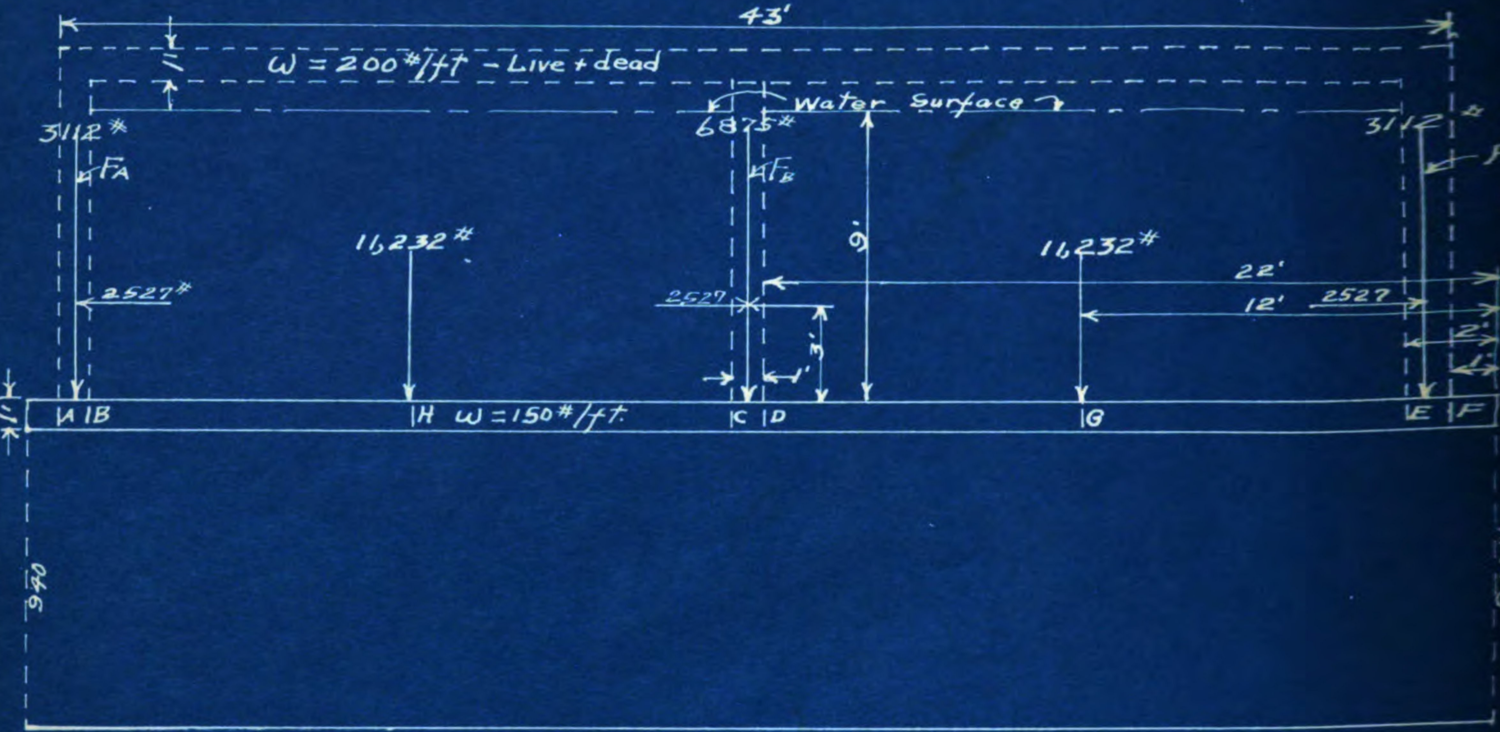
$= 699 \times 22 \times 11 + 341 \times 22 \times \frac{1}{2} \times 14.67 - 132{,}320 - 7581 -$
$3112 \times 20.5 - 150 \times 22 \times 11 = +4188.$

(By forces to left).

$= 341 \times 23 \times 11.5 + 358 \times 23 \times \frac{1}{2} \times 7.67 - 3112 \times 21.5 -$
$6875 \times \frac{1}{2} - 7581 - 150 \times 23 \times 11.5 + 4170.$

$M_C = 10{,}082.$

Forces Acting On Base Slab
Both Tanks Full



Computation Of Above Forces

F_A, F_B, and F_C are as shown on diagram 1
All forces due to water are as shown on diagram 1 with exception that both tanks are full.

Total wt. on soil = 19,849 + 2 × 11,232 = 42,312# (with no excentricity)

Unit soil pressure = $\frac{42,312\#}{45}$ = 940# per sq. ft.

$M_B = -1155$

$M_A = +98$

$M_G = -8721$

$M_H = 14{,}436$

Shears.

$V_F = -1033 + 150 = +883$

$V_E = 5112 + 150 \times 2 - 1025 \times 2 = +2387$

$V_D = -\frac{1759}{2} \times 22 + 150 \times 22 + 11{,}232 + 5112 = -1475$

$V_C = 4863$

$V_B = -2698$

$V_A = +200$

$V_G = -856$

$V_H = +302$

From Diagram 2.

Moments.

$M_F = 940 \times 1 \times \frac{1}{2} - 150 \times \frac{1}{2} = +395$

$M_E = 940 \times 2 \times 1 - 7581 - 5112 \times \frac{1}{2} - 150 \times 2 \times 1 = -7557$

M_D (By forces to right).

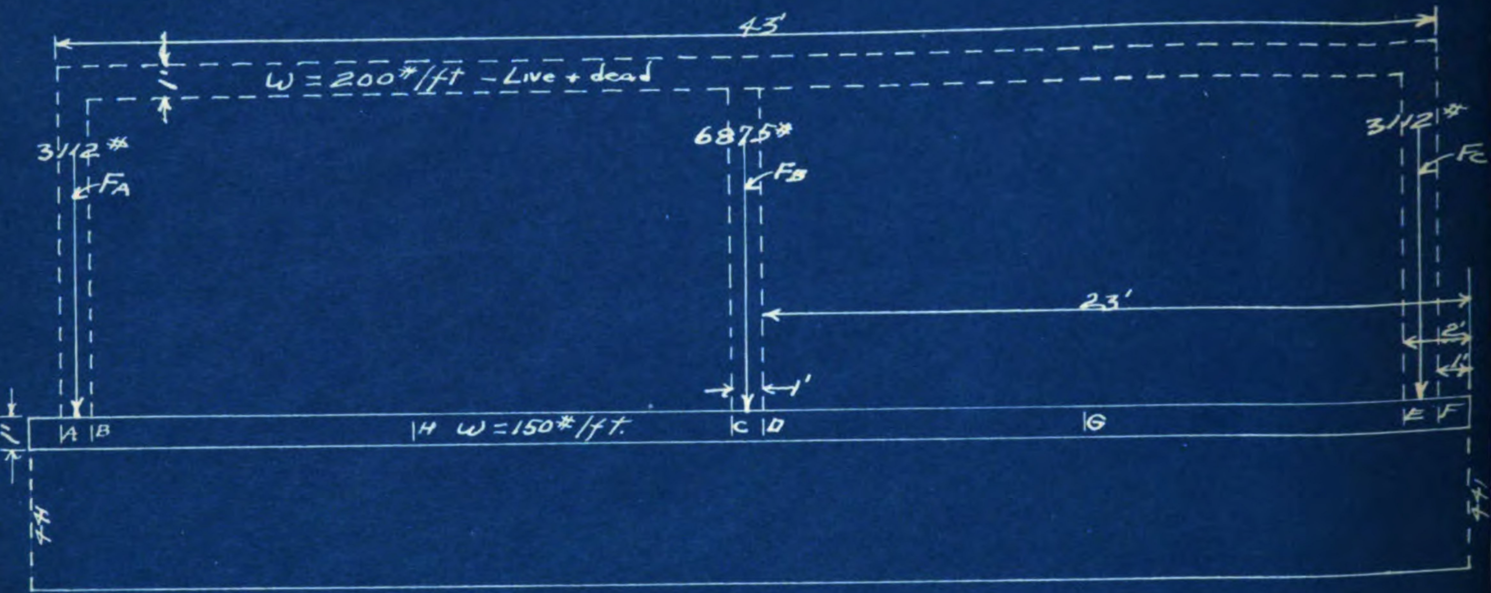
$= 940 \times 22 \times 11 - 11{,}232 \times 10 - 7581 - 5112 \times 20.5 - 150 \times 11 = +7483$

(By forces to left)

$= 940 \times 23 \times 11.5 - 6875 \times \frac{1}{2} - 7581 - 5112 \times 21.5 - 150 \times 23 \times 11.5 - 11{,}252 \times 11 = +7476.$

$M_G = -11{,}457$

Forces Acting On Base Slab
Both Tanks Empty



Computation Of Above Forces

F_A, F_B, and F_C are as shown on diagram. Forces of water are lacking and there is no eccentricity.

Unit soil pressure = $\frac{19,849}{45}$ = 441 lbs. per sq. ft.

$V_F = -940 + 150 = -790$

$V_E = -940 \times 2 + 3112 + 380 = +1532$

$V_D = 940 \times 22 + 11,232 + 3112 + 150 \times 22 = -3,056$

$V_G = -772$

From Diagram 3.

Moments.

$M_F = 145$

$M_E = -974$

$M_D = -11,724$

Shears.

$V_F = -291$

$V_E = +2530$

$V_D = -3290$

$V_G = -380$

Maximum moments and shears at each section - moments in ft. lbs. and shears in lbs.

Section at which stress occurs.

		A	B	G	C
Moments	+	443			10,082
	-		7557	14,436	
Shears	+	883	2530	302	4,863
	-	790	2698	836	3,056

Moments at other sections correspond to the above.

Moment 5 ft. from partition wall for forces on diagram 1.

$= 341 \times 17 \times 8\frac{1}{2} + 265 \times 17 \times \frac{1}{2} \times 5.67 - 150 \times 17 \times 8\frac{1}{2} - 3112 \times 15.5 = -7,890.$

Moment 2 ft. from partition wall.

$= 341 \times 20 \times 10 + 312 \times 20 \times \frac{1}{2} \times 6.67 - 3112 \times 18.5 - 150 \times 20 \times 10 = +1,400$

The above computations show that the moment is 0 A distance of $2\frac{1}{2}$ ft. from the partition wall and that the rods should be carried about 1.5 ft. each way beyond this point to meet any unforseen conditions.

Depth of Slab.

Section B.

$$d = \frac{7557}{74} = 10.6 \qquad \text{Say } 11''$$

Section G.

$$d = \frac{14,436}{74} = 13.95 \qquad \text{Say } 14''.$$

Section C.

$$d = \frac{10,082}{74} = 11.6 \qquad \text{Say } 12''.$$

For advantages of uniformity the 14 inch depth with a total depth of $16\frac{1}{2}''$ will be used throughout.

Steel

At Partition Wall.

Try 3/4" round rods spaced 6" on centers As = 0.88

$$p = \frac{As}{bd} \quad \frac{.88}{12 \times 14} = .00525$$

Table 3 of handbook shows for p = .00525, k = 0.295 and

$j = 0.901$

$K = p\ fs\ j = .00525 \times 12{,}000 \times .901 = 56.8$

$M = kbd^2$ in lbs. $= kd^2$ ft. lbs. $= 56.8 \times 14 \times 14 = 11{,}100$ ft.lbs.=

$M_c = \frac{1}{2}$ fc $jkbd^2$ inch lbs. $= \frac{1}{2}$ fc kd^2 ft. lbs.

$= \frac{1}{2} \times 500 \times 0.901 \times 0.295 \times 14 \times 14 = 13{,}100$ ft. lbs.

$M_s = p\ fs\ jd^2$ ft. lbs. $= .00525 \times 12{,}000 \times 0.901 \times 14 \times 14 =$

11,120 ft. lbs.

These results all show the resisting moment to be slightly higher than the actual moment and hence the arrangement of steel is satisfactory. Make these rods extend 4 ft. each side of the center or 8 ft. long.

At Center of Tank.

$A_s = .0069 \times 14 \times 12 = 1.16$

Use 3/4 inch round rods spaced 4 inches on centers. As = 1.32 Run these rods within 1 ft. of the partition wall and to the outside of the foundation.

At Section A.

The moment at A is so small that an arbitrary amount of steel can be used, say ½ inch rods spaced 18 inches on centers.

Investigation for shear at worst section.

$$v = \frac{4,863}{12 \times .889 \times 14} = 32.6 \text{ lbs. per sq. inch.} - \text{Satisfactory}$$

Investigation for bond at worst section.

$$u = \frac{4,863}{2,356 \times 3 \times 0.889 \times 14} = 55 \text{ lbs. per sq. in.}$$

Satisfactory.

PIPING.

The piping was simplified when information was received from two different sources that boosters would work. According to the Sullivan Machinery Company's Bulletin 71-H, the proper size booster to handle a discharge of 150 gallons per minute, is 30 inches in diameter and has an outlet pipe 5" in diameter. A suction line already in the ground, for the purpose of pumping raw river water for fire use shortened piping design still more. This line is so large that it can be used without question. It seemed advisable to use check valves on the boosters and run all wells into a common line increasing the size of line as another well was added.

Area of 5 inch pipe	=	19.635 sq. in.
" " 8 " "	=	50.265 sq. in.
" "10 " "	=	78.54 sq. in.

To avoid using several sizes of pipe it seemed desirable to use 5 inch pipe to the point where the second well joined and 8 inch from there to the reservoir where the fourth well joined. Inside the reservoir 10 inch. This gives a greater increase in area in every case than the addition of flow from a well calls for.

WELL PUMPS.

The only design needed for well pumps is the elevation of footpieces. Since static water levels were found to be practically the same in all wells the operating levels were reasonably assumed to be the same. Height of point of discharge was taken as a theoretical point whose elevation is elevation of discharge pipe at reservoie plus fractional loss in booster and pipe line. These losses could not be computed by hydraulics because of the problem in the booster but from data received from the Sullivan Machinery Company it seemed safe to take it as 6 ft. Necessary operating submergence was taken at 55%.

Elevation of discharge pipe at reservoir	= 846.00
Head loss	= 5.00
Elevation of discharge point (Theoretical)	= 851.00
Elevation of static water level	= 810.00 ft.
Drawdown	= 100.00
Operating elevation	= 710.00 ft.

851 - 710 = 141 ft. = total lift = 40% of required length of pipe.

Length of pipe (Theoretical) = $\frac{141}{45}$ = 312'

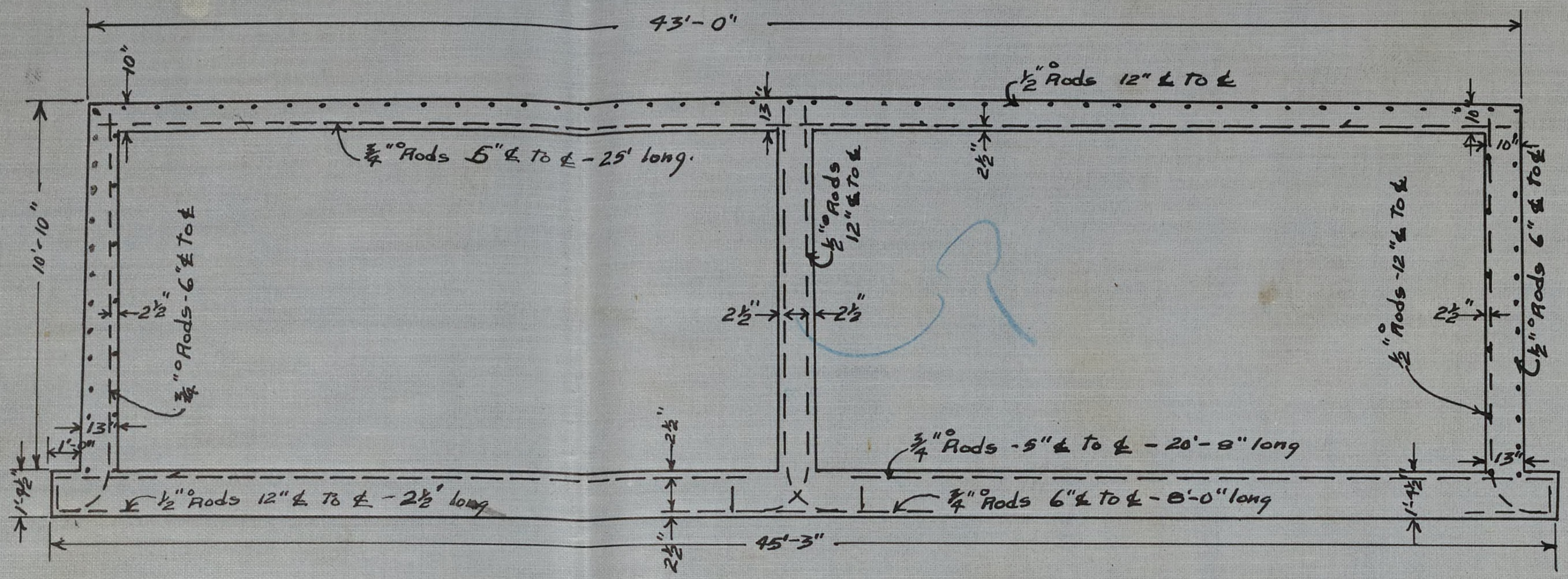
851 - 312 = 539 = required elevation of foot piece.

The greatest bottom elevation recorded for any well is 537 and as there is much silt in the bottom of the wells it appears that this elevation of foot pieces will be satisfactory for after the wells have been pumped a few hours the silt will clean out and give ample clearance.

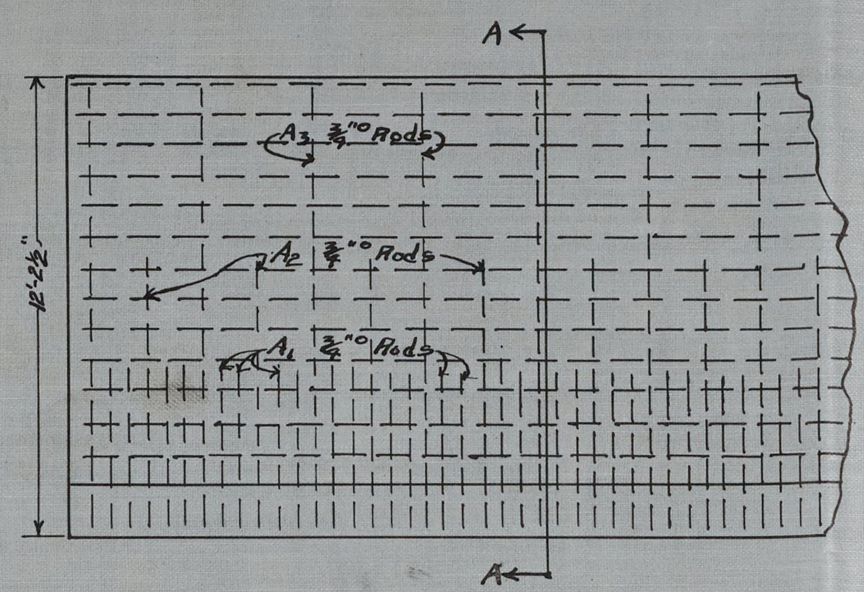
[redacted]

Jun 8 '43 [redacted]

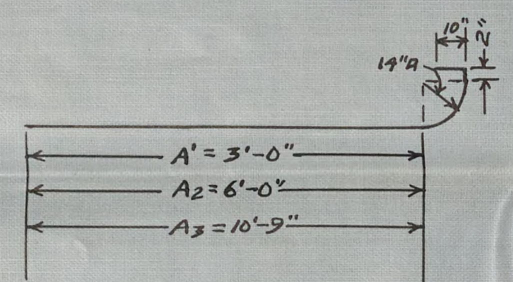
CROSS-SECTION AA



SIDE ELEVATION



WALL STEEL



Concrete - 1:2:4 mix - 3.7 cu. yds. per 10 ft. of vertical wall
Cement - Peerless super

MICHIGAN STATE COLLEGE			
EAST LANSING MICHIGAN			
BUILDING AND GROUNDS			
TITLE ARRANGAMENT OF STEEL			
	DATE	REVISIONS	DATE
Drawn by ~ W. C. Gunn	10/6/26		
Traced by ~ W. C. Gunn			
O. K.			
Scale:		File:	