HURRICANE PROTECTION PROJECT

FOX POINT

HURRICANE BARRIER

PROVIDENCE RIVER, PROVIDENCE, RHODE ISLAND

DESIGN MEMORANDUM NO. 10

PUMPING STATION

U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.

JANUARY 1960

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DDRESS REPLY TO:
IVISION ENGINEER

EFER TO FILE NO.

NEDGW 9 May 1960

SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 10, Pumping Station

TO: Chief of Engineers
Dept. of the Army
Washington, D.C.
ATTN: ENGCW-P

Reference is made to letter dated 22 January 1960, subject as above. In accordance with Paragraph 14 of the Design Memorandum there is submitted for review and approval Appendix A, Foundation Pile Design, for the Fox Point Hurricane Barrier Pumping Station.

FOR THE DIVISION ENGINEER:

JOHN WM. LESLIE
Chief, Engineering Division

Incl. (10 cys)
Append. A, Des. Memo No. 10
Pump. Sta. Fox Pt. Barr.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

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22 January 1960

SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 10, Pumping Station

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTENTION: ENGWE

In accordance with EM 1110-2-1150 there is submitted herewith for review and approval Design Memorandum No. 10, Pumping Station, for the Fox Point Hurricane Barrier, Providence, Rhode Island.

FOR THE DIVISION ENGINEER:

JOHN WM. LESLIE
Chief, Engineering Division

Incl (10 cys)
Des Memo No. 10,
Pumping Station -
Fox Point Hurricane Barrier

FOX POINT HURRICANE BARRIER

PROVIDENCE
RHODE ISLAND

DESIGN MEMORANDUM NO. 10

PUMPING STATION

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FOX POINT HURRICANE BARRIER
PROVIDENCE, RHODE ISLAND
DESIGN MEMORANDUM NO. 10
PUMPING STATION

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FOX POINT HURRICANE BARRIER
PROVIDENCE, RHODE ISLAND

DESIGN MEMORANDUM NO. 10
PUMPING STATION

A. PERTINENT DATA

Purpose.	The principal purpose of the pumping station is to pass the flow of the Providence River during gate closure for hurricane tides.
Location of Project.	
State	Rhode Island.
County	Providence.
City	Providence.
River	On the Providence River 900 feet upstream from the confluence of the Seekonk and Providence Rivers.
Drainage Area.	77 square miles.
Pumping Station	
Structure	Reinforced concrete with brick and steel superstructure.
Size	214' x 91'. Bottom Elevation -27.0 m.s.l. Roof Elevation +68.15 m.s.l.
Pumps	5-120" diameter, 150 RPM.
Pumps, capacity, each	1,400 c.f.s. @ 20 ft. head.
Motors	Electric, ea. 4300 HP.

B. INTRODUCTION

1. Purpose of Design Memorandum. - The purpose of this design memorandum is to present for review the basic design criteria and computations and equipment and structure layout for the pumping station for the Fox Point Hurricane Barrier.

2. Location. - As indicated in Design Memorandum No. 5, "General", the location of the pumping station is on the Providence River 900 feet upstream from the confluence of the Seekonk and Providence Rivers. (See Plate 10-1, "General Plan".)

The pumping station was located as near the west bank as possible for the following reasons:

a. For proximity to the power supply from Manchester Street substation.

b. To incorporate the intake cooling water canal gates with the pumping station for economy of construction and for convenience of operation.

3. Description. - The pumping station is located on the westerly side of the river barrier and will contain the five pumps and two gates controlling the operation of the cooling water canal. The superstructure is approximately 214 feet long by 38 feet wide with an electrical equipment lean-to on the bayside measuring 82 feet by 17'-0". The base dimensions are 91 feet by 214 feet. The structure will be divided into four units above the base slab separated by a 1" expansion joint in order to provide for shrinkage and expansion. The base slab will be poured as a continuous slab but with construction joints spaced approximately 33 feet c. to c. Entrance to the station will be from the west abutment to an access floor at elevation 9.5, which is directly over the cooling water canal conduits. Access to the operating floor at elevation 26.0 will be by a concrete stairway in an open well through which equipment can also be hoisted to the operating floor by means of the 40-ton crane. At the east end of the station a concrete platform 11'-0" wide will be constructed at elevation 35.0 for the tainter gate operation and to afford access to the service bridge leading to the river gate section. Access to the platform will be by steel stairs.

4. Function and Operation. - The function and operation of the pumping station is discussed in Design Memorandum No. 2, "Hydrology". The function of the pumping station will be to pump flows from the upstream Providence River and tributaries when the river gates are closed due to damaging storm tides. In addition, it will pump the discharge of cooling water from the Narragansett Electric Co., wave overtopping, and a small quantity of sanitary sewage flow.

Preceding a forecast hurricane tide at Providence the barrier gates will be closed, preferably at low tide. For low or moderate rates of local inflow the pool behind the barrier will be maintained as nearly as practicable at elevation 0.0 m.s.l. by the operation of the pumps. When higher rates of inflow are anticipated, the pool will be pumped down initially to an elevation not lower than -3.0 to obtain additional storage.

The cooling water gates will normally be open. They will be operated during periods of river gate closure to throttle the flow of cooling water and will be closed completely when upstream inflow is in excess of 3,000 c.f.s.

5. Coordination With Local Authorities. - During the planning of the pumping station, consultations were held with officials representing the City of Providence. The pumping station design as finally developed is satisfactory to the City and State.

C. PUMPING REQUIREMENTS

6. General. - Pumping requirements are presented in Design Memorandum No. 2, "Hydrology", and are summarized herein.

7. Pumping Requirements. - The capacity of the pumps is established primarily with reference to peak rate of inflow related to maximum tide levels and probability of coincidence. In addition, a small quantity of normal sewage flow bypassed to the river during a period of gate closure, wave overtopping at high tide stages, and cooling water discharge at moderate river inflows will be pumped when the river gates are closed. When upstream inflow is in excess of 3,000 c.f.s., the cooling water will be obtained from the upstream river pool instead of the bay.

The selected capacity, 7,000 c.f.s. at 20-foot head, is adequate for all floods of record coincident with the maximum design tide, as well as for certain more severe flood assumptions as given in Design Memorandum No. 2.

D. FOUNDATIONS

8. Foundation Conditions. - Foundation conditions and design are discussed in Design Memorandum No. 6, "Embankments and Foundations". In brief, the bedrock at approximate elevation -110 m.s.l. is overlain successfully by glacial till, interbedded silt, gravelly sand and soft organic silt.

9. Treatment. - The organic silt, extending down to approximate elevation -40 m.s.l. will be excavated and replaced with sand fill. Steel bearing piling will be driven to virtual refusal in glacial till or rock. A sheet steel cutoff driven into the interbedded silt layer will be provided.

E. CONCRETE MATERIALS

10. Concrete Materials. - Several nearby commercial sources of aggregates have been tested and found acceptable. On account of the excessive sulfate content of the river water, Type V cement will be used. See Design Memorandum No. 14, "Concrete Aggregates".

F. ARCHITECTURAL DESIGN

11. General. - The Fox Point pumping station superstructure will be of a contemporary design which will harmonize with other large existing structures in the area.

12. Description. - The exterior facing of the building will be of red brick with architectural type windows. A flat type concrete roof slab, overhanging the 13" thick exterior walls, was selected for economy and for conformance with the architectural design. The slab will be overlaid with a lightweight concrete to obtain a slope toward the inside drains. A 14' wide roll-up type door will be provided on the west end of the building to receive equipment and a personnel door will be provided adjacent to the equipment door. A 7-foot x 8-foot door will be provided at the east end for access to the tainter gates.

G. STRUCTURAL DESIGN

13. General. - This section of the design memorandum presents the design criteria, basic data and assumptions used in the structural design of the pumping station. The design procedure showing loading conditions and assumptions for the principal elements of the structure are included herein. Plates showing the pumping station space arrangement, typical sections illustrating steel arrangement and stability diagrams are included in the Appendix. The Appendix also includes the computations showing the design conditions investigated for a typical monolith of the structure. The remaining monoliths of the structure will be designed in a similar manner. Computations for minor elements are not included herein and will in general follow standard procedure as set forth in the Engineering Manuals or standard practice.

14. Scope. - Hurricane wave loading, stability investigations, and the design of the roof, superstructure including steel frames and crane brackets, floor slabs and substructure design are outlined herein. Foundation pile design will be submitted in Design Memorandum 10A.

15. Design Criteria. -

a. General. - All working stresses conform to those specified in the Engineering Manual EM 1110-1-2101, "Working Stresses for Structural Design", dated 6 January 1958. General loading conditions, design assumptions and other design criteria are based on the following applicable parts of the Engineering Manual for Civil Works: Standard Practice for Concrete (Part CXX, October 1953); Structural Design of Pumping Stations (EM 1110-2-3104) dated 9 June 58; and Hydraulic Design, Waves and Wave Pressures, Part CXVI, Chapter 8. Technical Report No. 4, titled "Shore Protection Planning and Design" by the Beach Erosion Board was also used in the analysis of wave forces.

b. Concrete. - The following table lists the concrete and reinforced concrete stresses used in the design of structures. In each case the Civil Works Manual exposure classification A (applicable to structures subject to moderately severe weather exposure) has been used:

Flexure	Lbs. per Sq. In.
Extreme fiber stresses in compression	1,050
Extreme fiber stresses in tension (plain concrete)	60
Shear - (v)	
Beam - no web reinforcement	90
Beams with properly designed web reinforcement	240
Bond - (u) Deformed bars -	
Top bars	210
Exterior surface bars (exposed to sea water)	210
All others	300
Bearing - (fc)	
Load on entire area	750
Load on one-third area or less-maximum permissible	1,125
Modular Ratio - (n)	10

c. Reinforcement. -

(1) Grade and Working Stresses. - All reinforcement in the structures, including temperature and shrinkage reinforcement, is designed for the working stress of new billet steel, intermediate grade, deformed bars, which is 20,000 p.s.i. in flexural tension. The reinforcement will conform to the requirements of Federal Specification QQ-B-71a and to ASTM A-305-50T.

(2) Spacing. - The clear distance between parallel bars will not be less than 1½ times the diameter of round bars except that in no case will the clear distance between parallel bars be less than 1 inch, or 1½ times the maximum size of the coarse aggregate.

(3) Minimum Cover for the Main Reinforcement. -

Item	Minimum Cover (Inches)
Interior slabs	3/4"
Interior girders and beams	1½"
Exposed concrete (water or atmosphere)	4"
Over pile caps	6"

The concrete covering of stirrups, spacer rods and similar reinforcement may be reduced by the diameter of such rods.

(4) Splices. - All splices will be lapped 30 diameters to develop by bond, the total working strength of the bars. Splices in the main reinforcement at points of maximum moment have been avoided in the design.

(5) Temperature and Shrinkage Reinforcement. - Temperature and shrinkage reinforcement will be provided in slabs and walls where the main reinforcement extends in only one direction. Such reinforcement will provide for a ratio of steel area to concrete area (bd) of .002 with a minimum of .0012 in each face up to a maximum of #6 bars at 12" cc.

d. Expansion and Construction Joints. - The base slab of the structure will be poured as a continuous mat 213'-10" long with construction joints at approximately 33' to control shrinkage. The structure above the base slab will be divided into 4 units separated by expansion joints.

e. Structural Steel. - Structural steel was designed for the working stresses of ordinary bridge and building steel (yield point 33,000 p.s.i. minimum), which conforms to the "Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings" issued by the American Institute of Steel Construction. Allowable

design working stresses conform to those given in the Engineering Manual for Civil Works for a basic stress of 20,000 lbs. per sq. in. except for steel H piles where the working stress used was 7500 lbs. per sq. in.

f. Increase in Normal Working Stresses. - Normal allowable working stresses have been increased 33-1/3 percent where earthquake or wind loads govern. Normal working stresses have been used for a hydrostatic loading up to S. W. L. 20.5. Normal working stresses have been increased 33-1/3 percent for dynamic wave loadings above S. W. L. 20.5 where maximum wave in the train or breaking waves are used.

g. Waterstops. - Rubber or polyvinyl waterstops will be used on the exterior edges of expansion joints exposed to the sea water or atmosphere and where it is embedded in concrete. Copper waterstops will be used in the masonry walls and roof slab. Steel plates will be used for interior expansion joints following an appropriate design. Where leakage is considered harmful, rubber or polyvinyl waterstops will be used in both construction and contraction joints.

h. Steel Bearing Piles and Steel Sheet Pile Cut-off. -

(1) Bearing Piles. - Steel H bearing piles will be driven to virtual refusal in glacial till or bedrock beneath the structure to carry the load of the structure. The pile selected is a BP 14 x 117 lbs. and a 1/8 inch allowance all around has been made for loss of metal due to corrosion. Using a design stress of 7500 lbs. per sq. in. which conforms to the requirements of the Boston Building Code, the allowable bearing capacity of the pile that will be used in the design is 90 tons. Design capacity will be increased 25% for construction and hurricane loads. Cathodic protection is being investigated to determine whether the increase in the life of the pile is economically justifiable.

(2) Sheet Pile Cut-off. - At the bayside edge of the structure, steel sheet piling type M 113 is to be used as a seepage cutoff. This piling will extend approximately 5 feet into the interbedded silt layer. No cathodic protection is contemplated.

16. Basic Data and Assumptions . -

a. Controlling Elevations. (m.s.l.) -

Operating floor	26.0
Invert of intake	21.0
Invert of discharge	-15.0
Bottom of structural base slab	-27.0
Raking platform	9.5

a. Controlling Elevations (m.s.l.) (cont'd)

Top of crane rail	57.2
Top of main structural roof slab	68.15
Top of low roof slab	44.00
Max. drawdown elev. (riverside)	-3.0
Min. discharge level (bayside)	+3.0
Assumed mean high tide	+3.0
Assumed mean low tide	-3.0

b. Hurricane Wave Data. -

Design stillwater level (S. W. L.) Elev.	20.5 m.s.l.
Significant wave height	6.5 ft.
Significant wave period	5.5 sec.
Max. wave height in train	10.27 ft.
Depth of water at S. W. L. (bayside)	35.5 ft.

Subsequent to completion of computations, the criteria on wave forces were revised in the following manner:

	Cond. I	Cond. II
Design S. W. L.	20.5	11.4
Significant wave height	5.1	6.5
Significant wave period	4.8	5.5

These revisions were found to have only minor effect on the computations and they have not been revised.

c. Loads. -

(1) Dead Loads. - The following unit weights for materials have been used:

Concrete	150 lbs. per cu. ft.
Steel	490 lbs. per cu. ft.

(2) Live Loads. - The following live loads have been used:

Water (salt)	64.2 lbs. per cu. ft.
Wind (Hurricane conditions)	30 lbs. per sq. ft.
Wind (Normal conditions)	20 lbs. per sq. ft.
Design load on roof slab	30 lbs. per sq. ft.
Design load on operating floor	200 lbs. per sq. ft. (or equipment load)
Design load on platform at El. 35	270 lbs. per sq. ft.
Design load on gate hoist platform	Max. hoist load
Design load on stairways	100 lbs. per sq. ft.

Design load on entrance slab floor	8 wheel trailer axle load = 80,000#
Design load on raking platforms	250 lbs. per sq. ft.
Design load on bayside platforms	250 lbs. per sq. ft.
Crane capacity	40 tons
Max. crane wheel load	63 kips
Crane max. lateral wheel load	2250 lbs.
Equipment	as furnished by manufacturer

d. External Water Pressure. - Hydrostatic water pressure has been assumed acting over the entire area of the base. Sheet piling has been neglected as far as its effect on uplift, except that it has been considered as eliminating clapotis, breaking wave or broken wave uplift pressures for the elements of the waves above stillwater level. The vertical height of water acting on the ocean side has been taken as the weight of the depth of water to the significant wave crest. Lateral pressures from wave loadings are discussed under paragraph j below.

e. Earth Pressure. - Lateral earth pressure against the structure is not a factor.

f. Earthquake Forces. - A review of the earthquake history of New England reveals that shocks with an estimated intensity of VIII or greater on the Rossi-Forel scale have been felt in Canada and New York and also along the Eastern seaboard. The Providence Area felt some of the effects of these shocks with reduced intensity, but otherwise has been free from serious earthquakes. Using the acceleration values which correspond to the Rossi-Forel ratings, as given in Engineering for Dams, Volume II, by Hinds, Creager and Justin, page 280, it is deduced that the area around Providence has never experienced a shock equal to 0.05g. This conclusion is believed to be conservative, especially for reinforced concrete structures which are well adapted to resist earthquake shocks. The value of 0.05g has, therefore, been used in the stability analysis under normal conditions of loading. Earthquake loading has been neglected when considering hurricane loading conditions.

g. Ice Pressure. - In view of historical temperature records of the water of the Providence River, and recognizing the large quantities of hot water discharged into the area by the Narragansett Electric Co., there is no justification for considering ice pressure. Even if ice pressure could be exerted on the structures, the location of the point of application is such that it will have only minor effect on the structures in the river. Ice pressure has, consequently, been disregarded in the design.

h. Wind Pressure. - A wind pressure of 30 pounds per square foot has been used for exposed portions of the structure that can be subject to hurricane winds. A wind pressure of 20 pounds per square foot has been used for construction and normal conditions when investigating stability.

i. Frost Protection. - The base of the pumping station is not subject to frost action and it has been disregarded.

j. Wave Pressures. - The pumping station will be subjected to the following two conditions of wave loading.

(1) The structure will be subjected to and has been analyzed for a 10.27 ft. breaking wave with crest elevation 25.63 because of the projecting platform on the ocean side. Wave forces were computed by the Minikin Method.

(2) The structure has also been analyzed for a 10.27 ft. wave (max. wave in train) which produces a crest height of elevation 33.32 on the structure. Wave forces were computed by the Sainflow Method.

k. Location of Resultant. - Because of the massiveness and width of the structure necessitated by other requirements, the resultant for all conditions of loadings will fall within the middle third of the base.

l. Factor of Safety for Resistance to Sliding. - The unbalanced horizontal forces contributing to sliding will be resisted by batter piles. A factor of safety of at least two will be maintained.

17. Design of Pumping Station. -

a. Roof Slab. -

(1) Main Roof Slab. - The main roof slab will be a 5" reinforced concrete slab with a lightweight concrete fill sloped to provide drainage. The structural concrete slab will be supported on steel purlins spanning in the longitudinal direction of the structure and supported on steel bents spaced approximately 16-6" c. to c. Diagonal rod bracing will be provided in the end bays of each section primarily to stiffen the steel frame work during construction.

(2) The roof slab over the electrical equipment room will be a 6" slab supported on the outside wall and keyed into the main building wall.

b. Steel Bents in the Superstructure. - Steel bents will be provided at approximately 16'-6" maximum spacing, and will provide the wind bracing for the superstructure as well as support the crane beams. The bents were assumed pinned at the base and were analyzed for all possible conditions of dead load, live load and crane loads. A built-up section will be used for the column using a 21" web and 11" flanges for the lower portion and a 13" web with 11" flanges for the upper portion. The horizontal roof member will be a 21" WF 73 lb..beam..

c. Bracing, Girts and Lintels. - Diagonal bracing will be incorporated into the end panels of the sidewalls. It will only be 2 panels in height starting approximately 5 feet below the crane level and extending upward to the roof. No bracing is contemplated for the end walls nor is bracing required for the sidewall of the lean-to. Three levels of girts will be required to stiffen the masonry sidewalls and end walls and where lintels are required to support the masonry above openings they will,in general, be framed into the columns.

d. Operating Room Floor. - The operating floor supporting the pumps has been designed as a 4-foot thick slab taking the full load of the pumps including the 200 kip thrust per pump. This load has been proportioned to cantilever supports on three sides and to the slab spanning the discharge chamber on the fourth side based on their relative stiffness. The concentrated load from the bent leg as well as the masonry wall load has likewise been designed to be carried by the 4-foot thick slab spanning the discharge chamber. A circular boxout will be left in the floor slab to permit accurate installation of the pumps. The pump load will be transferred into the supporting slab by a shear key.

e. Tainter Gate Operating Platform. - The platform at the east end of the station that supports the tainter gate operating controls and serves as a roof over a storage room is a flat slab with a clear span of 10'-4". It will be supported on a 8" reinforced concrete wall and framed into the exterior walls. The design load is 270 lbs. per sq. ft. and the required slab is 8 inches thick. This live load will permit the use of a 5-ton fork lift truck. The steel stairway providing access to the platform will be designed for a 100 lbs. per sq. ft. live load.

f. Gate Stand Platform. - The two gates for the cooling water canal are operated from a platform recessed 4'-0" below the operating floor. Each gate will have a double stem and single gate stand with a maximum thrust on the supporting floor of 25 kips for each stem. In order to carry this load steel framing has been provided to transmit the load to the exterior wall on one side and a concrete beam on the interior side having a span of 13'-0".

g. Access Floor Elevation 9.5. - This floor will be designed for a trailer with 8 wheels on two rear axles, with a total rear wheel load of 80,000 lbs. This loading was chosen because of the 35-ton weight of the maximum piece of equipment which will have to be placed on a trailer in this area. The floor slab has a maximum span of 13'-0" and will be designed continuously with the walls and base slab below.

h. Stability. -

(1) Loading Conditions. - A typical 66-foot monolith of the pumping station has been investigated for the following conditions of loading. Other monoliths will vary slightly but will be loaded in a similar manner.

Case I. - Construction period, cofferdam in place, no hydrostatic loading, no wind loads, dead load of structure and equipment.

Case II. - Hurricane and maximum high water condition from maximum breaking waves on the structure with stillwater level at elevation 20.5 feet. Dead load of structure and equipment, downward thrust of pumps, discharge chamber full of water, intake chamber with water to elevation -3.0, water on bayside deck to elevation 23.75, full hydrostatic loading laterally as determined from the Miniken Method, uplift over base varying from maximum stillwater level to elevation -3.0 at the riverside, wind on the exposed face using 30 lbs. per sq. ft.

Case III. - Hurricane and high water condition with stillwater at elevation 20.5 using a maximum wave with crest of clapotis at elevation 33.32. Tailwater on riverside assumed at elevation +3.0, full hydrostatic pressure on the base varying from stillwater level on the bayside to tailwater level on riverside. Dead load of structure and equipment plus downward thrust of pumps. Water in the pump chambers and on the bayside deck to crest of significant wave (elevation 23.75). Full lateral pressures as determined by the Sainflow Method.

Case IV. - Same as Case III except tailwater elevation changed to elevation -3.0.

Case V. - Normal condition with water on both sides at elevation 0.0 and pumps not in operation. Full dead load of structure and equipment and wind load on the riverside of 20 lbs. per sq. ft. Uplift across the bottom uniform for head to elevation 0.00.

Case Va. - Same as Case V but without wind and with earthquake forces applied from the riverside.

Case Vb. - Same as Case V but without wind and with earthquake forces applied from the bayside.

(2) Critical Conditions. - Stability investigations show that Case II will give the maximum pile loading on the riverside. Case I was found to give the maximum pile loading on the bayside.

i. Design of Substructure (Typical Monolith). - The substructure has been analyzed as a series of longitudinal sections. A uniform distribution of loading across the bottom of the base has been used until such time as type and spacing of piles are determined. If final pile design results in a wide spacing of piles these sections will be reinvestigated using the pile loads as concentrations. Longitudinal walls will be designed as continuous members across the transverse walls. Hurricane loading will be applied where applicable. The following three sections whose computations are included in the Appendix, represent the critical conditions and method applied.

(1) Section at Bayside Edge. - Section was analyzed as a continuous frame for conditions of loading previously set forth in Cases I, III, V and Va. Case Ia loading was also investigated using Case I loading plus a 250 lbs. per sq. ft. live load on the deck. Case I was found to be critical in the design of the base slab. Case Ia was critical for the design of the roof deck, and Case III was critical for the wall design.

(2) Section Through Interior of Station Adjacent to the Pump. - The upper portion of this section was analyzed as a continuous frame with the vertical side walls considered fixed at the massive section between elevations 0.00 and -13.75. The lower portion was analyzed in a similar manner with the walls fixed at this same mass of concrete. Case I and III loadings were applied to the upper section and Case I, II, III, IV and V loadings were applied to the lower section. Case I was found critical in the design of the base slab and I and III were found critical in the design of the upper section walls.

(3) Section at the Riverside End. - This section was analyzed as a continuous frame for Case I, II, V and Vb loadings. Case Ia was also investigated using Case I loading plus a live load on the deck of 250 lbs. per sq. ft. Case II was found to be critical in the design of the base slab and Case Ia was critical for the roof deck while Case Vb gave the critical loading for the wall design.

Both the projecting portions on the bayside and riverside have been investigated for cantilever action about the main structure, resulting from unbalanced vertical load over these projections.

FOX POINT HURRICANE BARRIER
Providence, Rhode Island

Design Memorandum No. 10

APPENDIX A

Foundation Pile Design

Pages A 129 - A 131 inclusive are added to the structural computations.

The following subparagraph m. is added at the end of paragraph 17.

m. Pile Foundations. - Pile loading has been investigated using an Elastic Center Method for Cases I, II and V which are considered the critical conditions. Under Case II loading the maximum pile loading was found to be 233.5 kips occurring at the riverside edge in the piles battered in the upstream direction. Under Case V, the normal condition the maximum pile loading is 178 kips occurring at the bayside edge in the piles battered downstream.

j. End Monoliths. - The end sections of the pumping station will be analyzed for stability and designed in a similar manner as set forth in the typical 66-0" monolith.

k. Trash Racks. - The trash racks on the riverside will be constructed of steel shapes and flat bars spaced 10" c. to c. The design will be based on a 5-foot differential head which is considered conservative.

l. Stop Gates. - A single stop gate will be provided to permit dewatering of the intake chamber in order to permit inspection of the pump impeller. The gate has been designed as spanning the 25-foot width for a head of water to elevation +5.0 m.s.l. The gate will be made up of 4 identical sections 6'-8" high composed of a 9/16" skin plate on ST 15 WF 54# horizontal members framed into 15" WF 54# end post. Rubber or polyvinyl seals will be provided on the sides and bottom. Total weight of the gate will be approximately 7.5 tons. Allowable design stress for steel was held to 24,000 lbs. per sq. in. The same gate could be used to permit dewatering of the discharge chamber.

H. MECHANICAL DESIGN

18. General. - Plates No. 10-11 and No. 10-12 indicate proposed pump curves and Plates No. 10-13 and No. 10-14 show the general arrangement of the pump and miscellaneous mechanical equipment.

19. Pumping Equipment. - The pumping equipment will consist of five (5) vertical propeller pumps driven by vertical electric motors. Each pump will have a capacity of 1400 c.f.s. at pool to pool head of 20 feet. Each pump will be of the vertical flared-tube design discharging into a large rectangular concrete chamber and conduit. Several studies were made of various types of suction chambers and discharge tubes using various numbers of units. The design selected is the most economical arrangement as it eliminates the expensive construction involved in the forming and fabrication of the irregularly curved elliptical surfaces, in both steel and concrete, necessary in the elbow discharge design for pumps of this capacity. Although using six or more units would result in slightly less cost for the equipment due to its smaller size and higher rotative speeds, the added size of station required to house the units would increase the total cost to more than that for the 5-unit station. Using four or less units would result in no savings, and since no standby pumping capacity is being provided, the loss of 25% of the total pumping capacity, if one pump is inoperable, is considered too great.

Since pumping will start when the water level in the Bay is the same or even slightly lower than in the suction pool, the top of the opening of the discharge conduit will be at elevation +10.0 m.s.l. so that the siphon will not be established until the water in the Bay reaches this elevation. This eliminates the possibility of operating at any static head of less than 7 feet, even at maximum suction pool elevation of +3.0 m.s.l. The maximum operating capacity of each pump is, therefore, established by the pump curve at this 7-foot static head. This permits use of smaller diameter, higher RPM, pump and smaller suction chamber than would be required to avoid cavitation at the increased capacity that would result if operated at zero static head, unless some means of throttling the discharge were provided. Any gate for throttling the discharge would add considerably to the initial cost and increase operating and maintenance problems and expense. Preliminary designs by several pump manufacturers indicate that the propeller diameter will be 120 inches, operating at a speed of 150 RPM. However, the design and arrangement of the station permits larger diameter propeller and lower speed pumps, if actual model tests by the successful bidders indicate that such is necessary, without overall size or structural changes to the station.

The top of the vertical flared tube will be at elevation 17.5, m.s.l. Although this is 3 feet below the design tide elevation of 20.5 m.s.l., back flow will occur only through idle pumps and will only require placing an additional pump in operation for the period of two to three hours during which the tide may remain above elevation 17.5 m.s.l. Since tides above 17.5, m.s.l. are expected to be extremely infrequent, the cost of operating an additional pump for the short duration required is not sufficient to justify additional cost of raising top of the discharge tube to 20.5 or providing shut-off gates.

The pump casing, suction head, defuser section, and discharge column will be constructed of steel, coated and provided with cathodic protection. The propeller will be a casting of a non-corrosive nickel-iron alloy. Shaft will be forged steel with monel metal sleeve below elevation +5.0 and through the stuffing box. Propeller nut and pump bearing, if grease lubricated and constructed of metal, will be sealed from the water with packing and monel covers. Cathodic protection and additional corrosion resistant features are covered in SECTION J. Investigations are continuing relative to the bearing construction, including the possible use of a synthetic rubber bearing lubricated by the water being pumped. The thrust bearing will be located on the motor, will be oil-cooled with integral air coolers on each unit.

Plate No. 10-11 indicates typical horsepower, efficiency, and head-capacity curves for the proposed pumps at maximum, minimum, and average suction pool elevations. Plate No. 10-12 indicates typical curves of the cumulative capacity of the units at elevation +3.0, m.s.l., suction pool. Due to the extremely small number of hours of expected operation, there will be no evaluation of efficiency in the purchasing of the units.

20. Traveling Crane. - A 40-ton traveling crane with electric operated bridge, trolley, and hoist will be installed for handling the equipment during construction and for maintenance. The crane capacity is based on handling the heaviest piece of equipment that may have to be replaced during the life of the station.

21. Dewatering Pump. - A vertical, centrifugal type pump will be installed in a dry sump and connected through a header to each suction chamber. The line to each suction chamber will be valved in the dry sump to permit dewatering each suction chamber separately. The valves will be of the butterfly type, rubber lined for protection against salt water corrosion. The valve will be connected to a nickel-iron wall flange and the embedded pipe between the wall flange and the suction chamber will be cement asbestos. A city water connection will be made to the suction side of the pump to permit flushing the salt water out of the pump, leaving it full of fresh water when not in use. The pump will have a capacity of approximately 400 gpm, sufficient to dewater a single chamber in 4 hours. Stop gates for only one suction chamber will be provided which may be used also for dewatering the discharge chamber.

22. Heating and Ventilating. - Suspended type, gas fired unit heaters will be installed to provide heat for the station and to prevent excessive condensation on the walls and the equipment. Heaters will have sufficient capacity to maintain the station at 50° F during the coldest weather. Gas will be supplied from city mains. Ventilation will be provided as required for the transformer rooms and the battery room.

23. Cooling Water Intake Gates. - Two vertical lift sluice gates each ten (10) feet wide by fifteen (15) feet high, with twin stem screw hoist electric motor operated will be provided to control the flow of water from the Bay to the cooling water canal of the Narragansett Electric Co.

The gates will be open the major part of the time and will be operated only when the river gates are closed. Operation will be carried out by throttling the opening to maintain required cooling water flow as nearly as practicable. The gates will be closed completely when upstream inflow is in excess of 3,000 c.f.s.

Since the gates will be submerged for only short periods of time, special protection against corrosion due to salt water is not necessary. The gates are to be welded steel construction, with synthetic rubber seals on the Bay side of the gates. The gates will be provided with eight (8) wheels, four on each side to reduce the friction load on the hoists.

The gate frames and guides which will be submerged in sea water will be made of corrosion-resisting, nickel-iron castings. The wheel rails will also be made of nickel-iron castings machine finished and set into the gate frame castings. The surface of the rails on which the wheels will roll will be heat treated to a Brinell of 225. Seal strips will be monel.

Twin screw hoists, which will be provided for each gate, will consist of two (2) bevel gear screw hoist floor stands coupled to a geared electric motor drive unit mounted on a pedestal midway between the gate stems. The controls will include torque limit switches, handwheel for manual operation, pushbuttons at the motor and a remote control station which will be located to suit operating requirements.

I. ELECTRICAL

24. Power Supply. - Power supply for the pumping plant and accessory structures will be obtained at 11 kv from the Narragansett Electric Co. The source of supply is their Franklin Square substation located approximately 2500 feet from the pumping plant. The substation is fed by nearby Manchester Street generating plant (capacity 150 MVA) and is interconnected by the two 110 kv transmission lines with New England Electric System and Narragansett Electric Co. South Street generating plant (capacity of this interconnection is 120 MVA). The power supply will be extended to the pumping plant underground in concrete encased ducts and will consist of two, independent, 100% rated circuits (See Plate 10-1). Each supply circuit will be fed through a breaker from a separate bus section in the supply substation. The bus sections are thoroughly isolated from each other by masonry partitions.

25. Selection of Utilization Voltage. - A cost comparison was made to determine the most economical voltage for operation of the main pumps (see Appendix C). It was found that 4000 volt motors and equipment will cost the least.

Utilization of the 11 kv supply voltage is more expensive because 11 kv motors alone cost more than the combined cost of 4 kv motors and transformers.

Utilizing a voltage lower than 4 kv will be more expensive because of increased conductor sizes and because of the additional cost of reactors necessary to reduce the available short circuit of 195 MVA to the 150 MVA maximum rating of standard breakers at 2300 volts or below.

26. Selection of Motor Type. - Either synchronous motors or induction motors could be used to drive the main pumps. Synchronous motors were selected because of economic considerations. Appendix C includes a cost comparison which shows that synchronous motors (including excitation system and main power transformers) will cost $49,000 less per motor than squirrel cage motors (including power transformers).

27. Main Power Transformers. - At the pumping plant, each of the supply circuits will feed 11 kv - 4.16 kv main power transformer, rated (with overload capability) to carry the full plant load. Each main power transformer will feed a section of 4 kv metal-clad switchgear. A normally-open bus-tie breaker will be installed between the two bus sections. (See Plate 10-16.)

28. Main Pump Motors. - Each of the main pump motors will be served from a 4 kv bus section through an air circuit breaker and will be started at full voltage. The interrupting duty at the 4 kv switchgear will be 194.8 MVA, and all breakers will be rated for that duty. The excitation for the synchronous motors will be supplied from two common D. C. buses, separated by a normally-open bus-tie breaker and fed by two induction motor - d. c. generator sets. Each motor-generator set will be rated to provide the excitation requirements of the entire plant.

29. Station Service System. - The station service system will be supplied from two 11 kv - 480 volt transformer load centers connected ahead of each of the main power transformers. (This arrangement will allow normal maintenance of the plant with the main power transformers de-energized.) Each station service transformer will be rated to carry the entire station service load. The two 480-volt load center bus sections will be connected through a normally-open bus-tie breaker. The interrupting duty at each load center will be 10,755 amperes. Therefore, 15,000 ampere interrupting capacity moulded case breakers will be used. All station service loads, the river gate structure and the cooling water intake gates will be fed from the service station system.

J. CORROSION PROTECTION

30. Existing Conditions. - The Fox Point Hurricane Protection Project is located on the upper end of Narragansett Bay, a tidal salt water site. The Moshassuck and Woonasquatucket Rivers that flow into the Narragansett Bay have for many years been badly contaminated with sanitary and industrial wastes and due to the river contamination, there is no marine growth in the location of this project. However, the State of Rhode Island is presently engaged in a project to eliminate wastes from these rivers. Whether the rivers will ever be cleaned up to the point that marine growth will again be a problem is conjectural. This eventuality has been recognized and taken into consideration in the design.

31. General Considerations. - In order to avoid the corrosive effects of salt water the project is being designed so that insofar as possible all exposed metal is located above the normal high tide water level. Large metal surfaces which must, of necessity, be underwater, will be protected by impressed current cathodic protection systems and small submerged areas of metals will be fabricated from materials highly resistant to attack by contaminated and salt water.

32. Trash Racks. - The trash racks will be constructed of mild steel, painted with 4 coats of vinyl paint and protected with an impressed current cathodic protection system. Anodes will be Duriron set in recesses in the wall on each side of the trash racks on the pumping station side of the racks. A rectifier will be installed for each trash rack having a capacity of 5 m.a. per square foot of trash rack exposed metal area. Provision will be made so that "OFF" voltage may be read between the anode and cathode. The rectifier output will be adjusted to maintain this "OFF" voltage to a minimum of .2 volts and a maximum of .4 volts. Trash racks will bear against a finished concrete surface with the corner rounded off.

33. Stop Gate Guides. - Stop gate guides will be provided with a Monel angle for the bearing surface to aid in providing a good seal.

34. Pumps. - The fabrication of the pumps presents the most difficult problem of any of the submerged metals and some details have not as yet been fully resolved. For instance, as regards the lower guide bearing which will be submerged all of the time, one pump manufacturer has suggested making the bearing out of neoprene; another has expressed a preference for a Babbitt metal. However, the general parameters of the corrosion resistant features of pumps are well resolved.

The exterior of the pump casing, which will be fabricated of mild steel, will be embedded up to elevation 0.0. Above this point the exterior of the casing will be given a standard four-coat vinyl paint treatment in accord with the usual V-101-V-102 paint system. No cathodic protection will be applied to the exterior of the pump casing because experience has shown that any steel twoo feet or more above the low tide line can be kept in good condition by painting. Workmen can stand on the floor of the concrete discharge chamber and touch up any holidays in the paint.

The interior of the pump casing, guide vanes, impeller, shaft and other metals on the interior of the pumps will be protected with an impressed current cathodic protection system. Flush type anodes utilizing platinum or palladium for the anode material will be fastened to the interior of the pumps'casings and connected to the rectifiers through conduits embedded in the concrete on the exterior of the pumps. Two anodes will be located on opposite sides of the pump below the impeller and below the guide vanes, if possible. Two other anodes will be located above the impeller and above the straightening vanes, if possible. One rectifier will be furnished for each pump designed to have a capacity of 5 m.a. per square foot of protected metal area. Output will be checked monthly and adjusted as necessary using the same method outlined under "Trash Racks" above. All metal on the interior of the pump except for the impeller would be painted with a four-coat vinyl system as outlined above.

Impellers will be cast from a nickel-iron designed to be resistant to salt water corrosion. The impellers will not need a paint coating for protection from salt water corrosion but it is proposed to paint them with a coal-tar enamel primer to reduce the amount of cathodic protection current which will be absorbed by the impeller. It is realized that, during pumping operations, at the parts of the impeller under high velocity attack, some paint will be removed. However, these areas left bare will not appreciably affect the cathodic protection system.

The bearings will either be neoprene or of a metal more noble than steel so no trouble will result from local electrolytic action. The noble metal will be extended sufficiently far out of any recesses to allow the cathodic protection system to suppress any attack on the steel adjacent to the bearing.

Ground straps will be firmly attached to the pump motor when the pump is at rest to furnish a path for the cathodic protection current to leave the shaft without passing through the thrust bearing.

If marine growth ever becomes an environmental problem, the pumps are the only items that could be adversely affected by the growth. Stop gate slots are provided on both sides of the pumps so that each pump chamber may be dewatered and an inspection made of the pump periodically; marine growth can be cleaned off from the interiors of the pumps at these times.

35. Cooling Water Intake Gates. - The gates on the intake of the cooling water canal to the Narragansett Electric Co. will be stored in the open position the majority of the time which is above the high tide level. The gate frame, gate guide extensions, and rails will be fabricated from corrosion-resisting, nickel-iron castings. Gate seals will be Monel.

K. CONSTRUCTION SEQUENCE

36. Construction Sequence. - A continuing contract for construction of the Fox Point Hurricane Barrier will be awarded in the Fall of 1960, subject to the appropriation of construction funds. Construction of the pumping station structure will be a part of this contract. A separate continuing contract will be awarded at the same time for pumping equipment, with early preparation of outlines and dimensions of pumps and hydraulic passages specified.

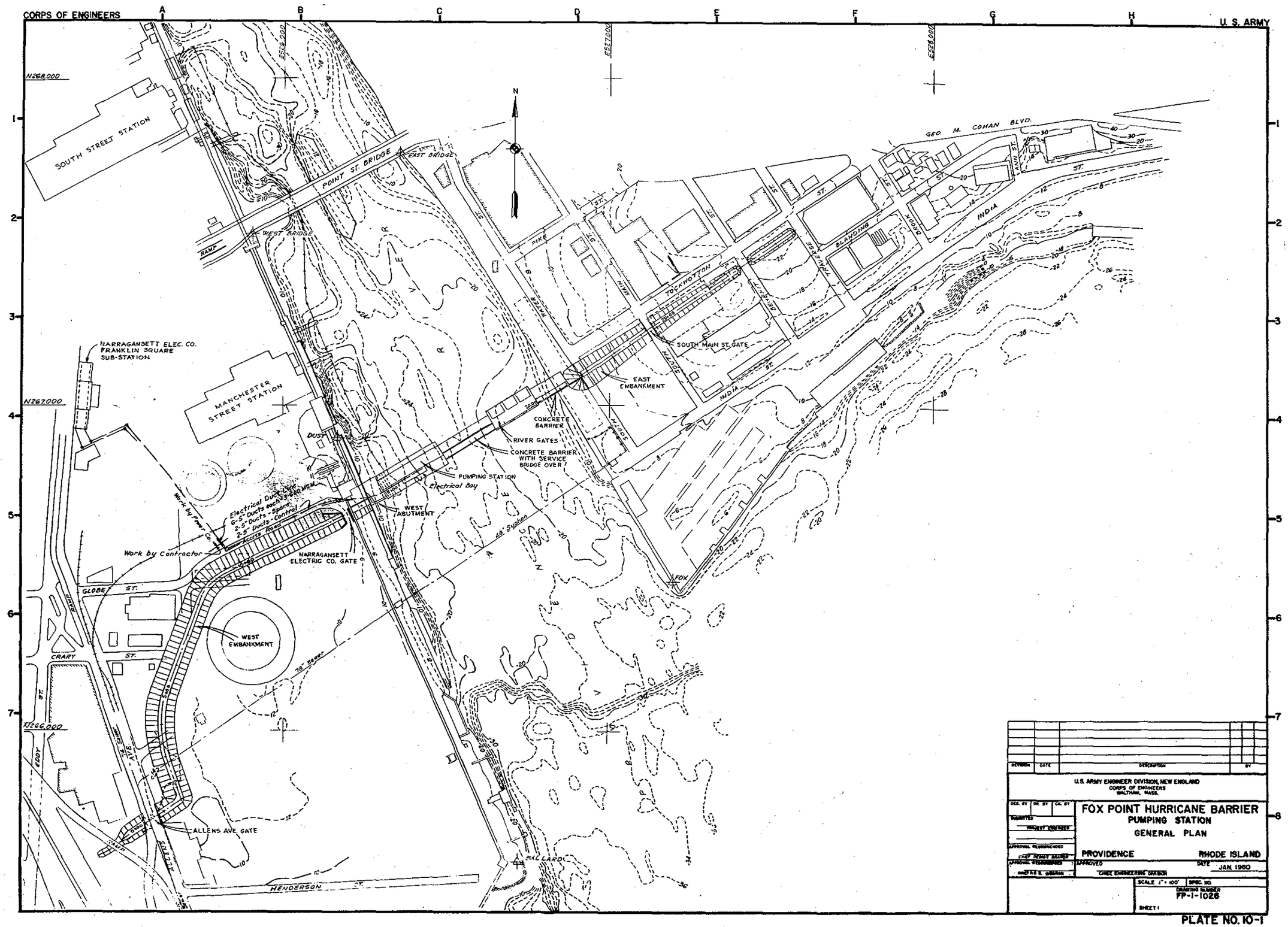
The cooling water canal will be constructed initially, with a temporary sheet pile wall through the Barrier construction area adjacent to and west of the pumping station.

After the foundation work has been completed, including driving of bearing and cutoff piling, and the area dewatered, the pumping station substructure will be constructed.

At completion of this stage the cofferdam may be removed and the pumps installed at any time behind the stop logs. The cooling water flow will be diverted through the cooling water passage of the pumping station.

The superstructure will be subsequently constructed and installation of equipment completed.

Construction is scheduled to be completed in three construction seasons.



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED
PROJECT ENGINEER

APPROVAL RECOMMENDED
CHIEF DESIGN BRANCH

APPROVAL RECOMMENDED
CHIEF R & D BRANCH

FOX POINT HURRICANE BARRIER
PUMPING STATION
GENERAL PLAN

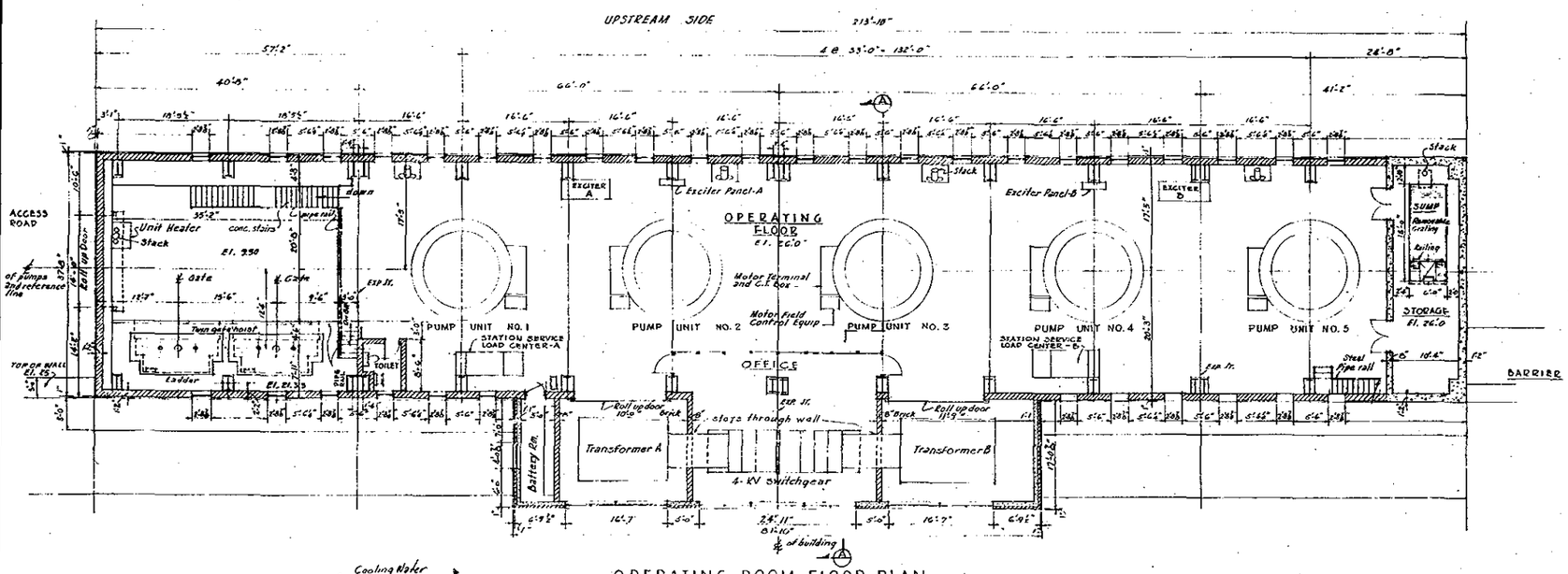
PROVIDENCE — RHODE ISLAND

APPROVED — DATE JAN. 1960
CHIEF, ENGINEERING DIVISION

SCALE 1" = 100' | SPEC. NO.
DRAWING NUMBER FP-1-1026
SHEET 1

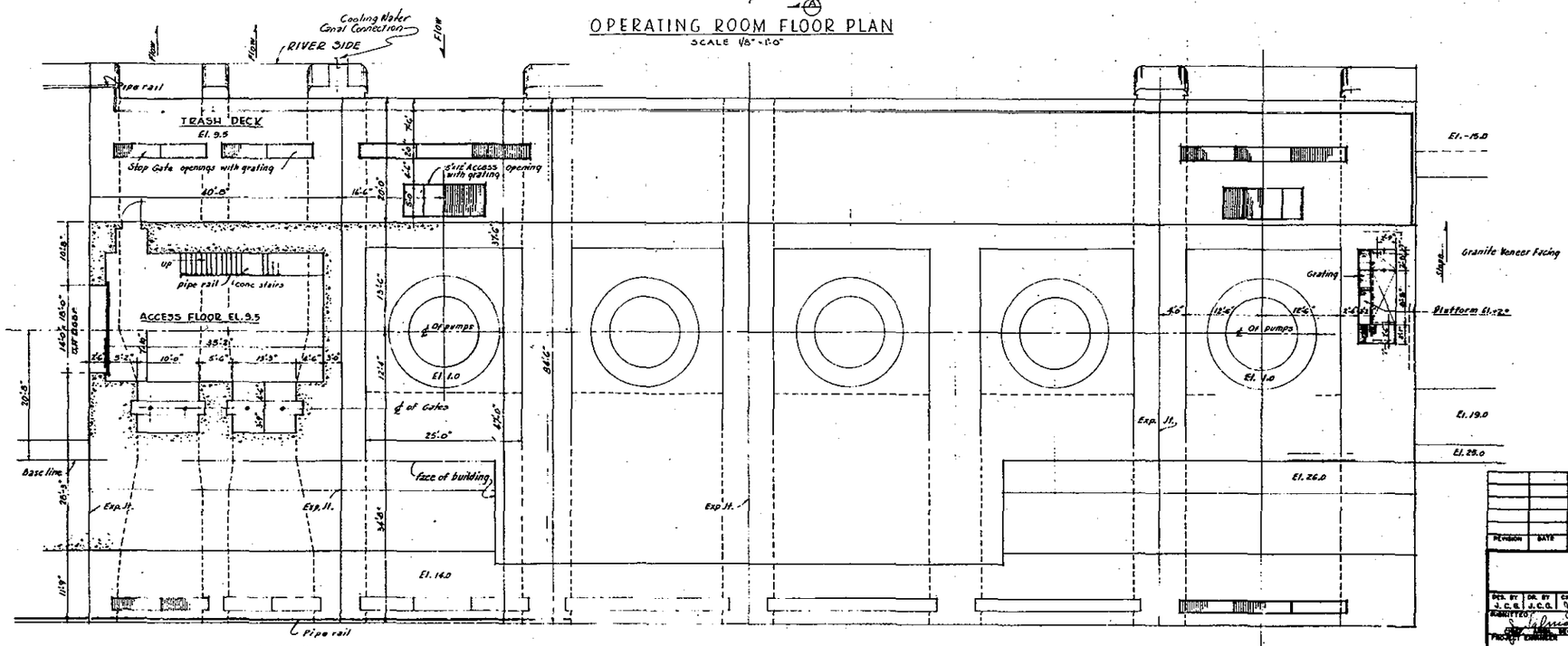
PLATE NO. 10-1

CORPS OF ENGINEERS U. S. ARMY



OPERATING ROOM FLOOR PLAN

SCALE 1/8" = 1'-0"



BAY SIDE

ACCESS FLOOR PLAN

SCALE 1/8" = 1'-0"

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U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
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WALTHAM, MASS.

DES. BY J.C.G. | DR. BY J.C.G. | CK. BY

SUBMITTED: CHIEF, ENG. SECTION

PROJECT ENGINEER

APPROVAL RECOMMENDED

CHIEF, DESIGN BRANCH

APPROVAL RECOMMENDED

CHIEF, P. & R. BRANCH

APPROVED

CHIEF, ENGINEERING DIVISION

FOX POINT HURRICANE BARRIER

PUMPING STATION

ARCHITECTURAL

FLOOR PLANS

PROVIDENCE RHODE ISLAND

DATE JAN. 1960

SCALE AS SHOWN | SPEC. NO.

DRAWING NUMBER FP-1-1027

SHEET 2

PLATE NO.10-2

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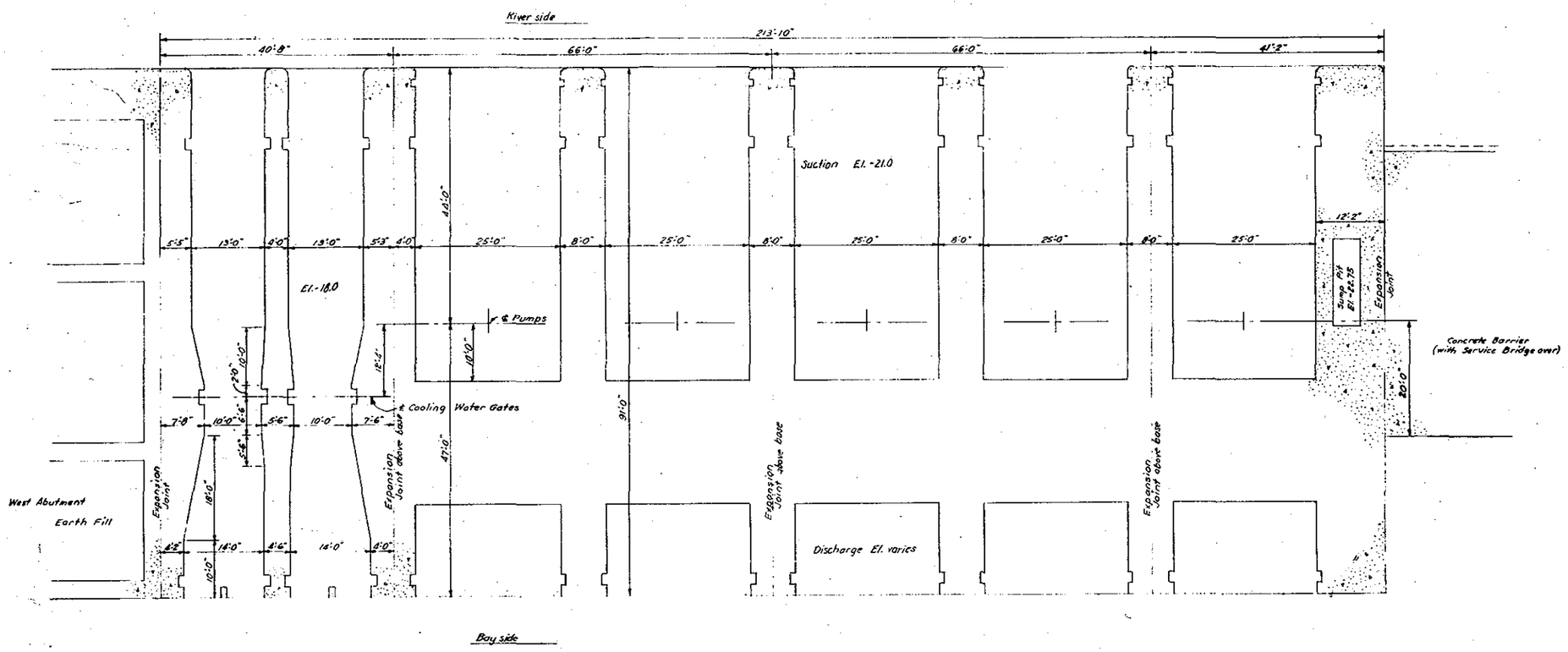

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PROJECT ENGINEER

CHIEF, DESIGN BRANCH

CHIEF, R & D BRANCH

FOX POINT HURRICANE BARRIER
PUMPING STATION
CONCRETE
PLAN AT EL.-18.0

PROVIDENCE RHODE ISLAND

APPROVED

CHIEF, ENGINEERING DIVISION

DATE JAN. 1960

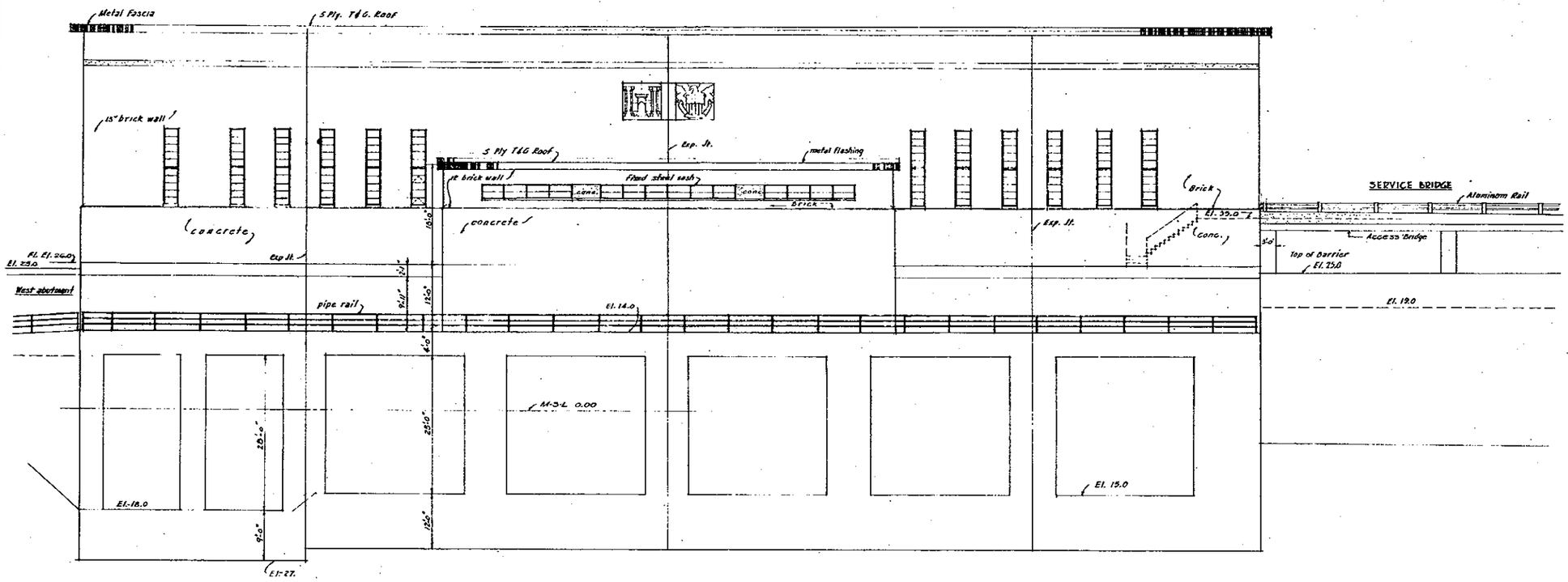
SCALE: 1/8"=1'-0" SPEC. NO.

DRAWING NUMBER
FP-1-1028

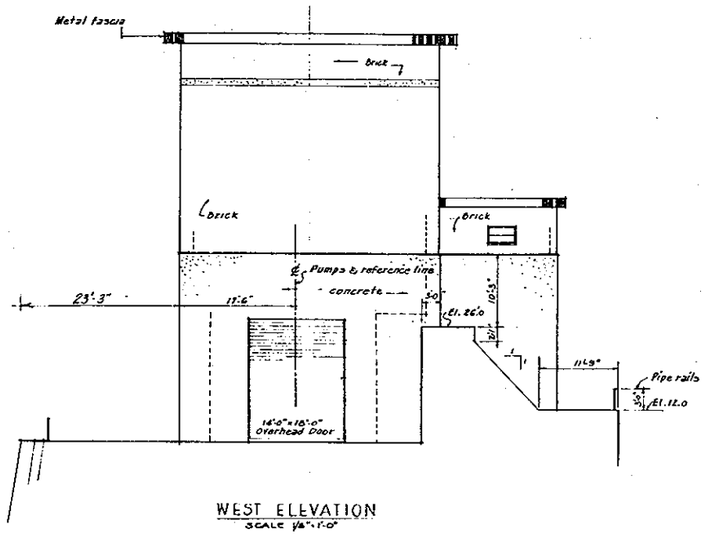
SHEET 5

PLATE NO. 10-3

CORPS OF ENGINEERS U. S. ARMY



SOUTH ELEVATION
SCALE 1/8" = 1'-0"



WEST ELEVATION
SCALE 1/8" = 1'-0"

REVISION	DATE	DESCRIPTION	BY

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WALTHAM, MASS.

DES. BY J.C.B. | DR. BY J.C.B. | CK. BY

SUBMITTED: CHIEF, DESIGN SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED: CHIEF, F. & M. BRANCH

FOX POINT HURRICANE BARRIER
PUMPING STATION
ARCHITECTURAL
SOUTH & WEST ELEVATIONS

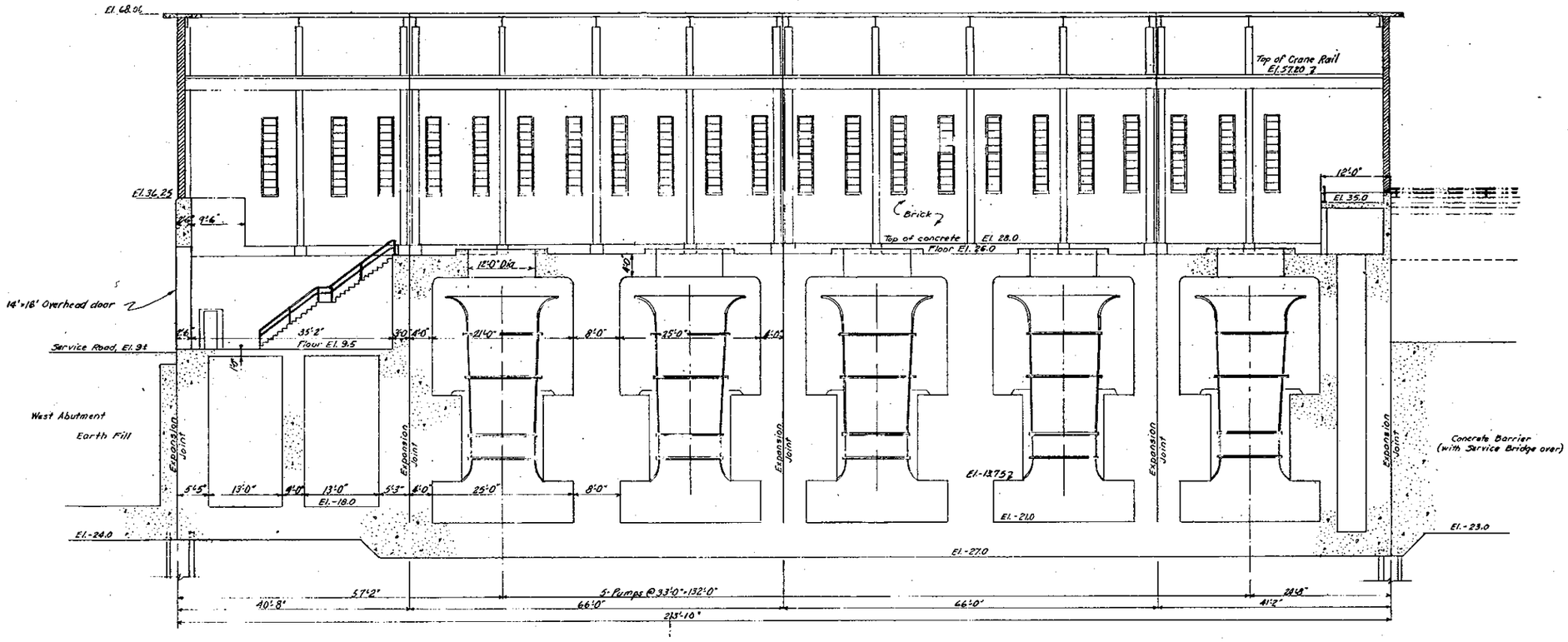
PROVIDENCE RHODE ISLAND

APPROVED: CHIEF, ENGINEERING DIVISION
DATE JAN. 1960

SCALE AS SHOWN | SPEC. NO.
DRAWING NUMBER FP-1-1029
SHEET 4

PLATE NO. 10-4

CORPS OF ENGINEERS U. S. ARMY



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CHIEF, F&R BRANCH

FOX POINT HURRICANE BARRIER

PUMPING STATION

LONGITUDINAL SECTION ON ℄ PUMPS

PROVIDENCE RHODE ISLAND

APPROVED
CHIEF, ENGINEERING DIVISION

DATE JAN. 1960

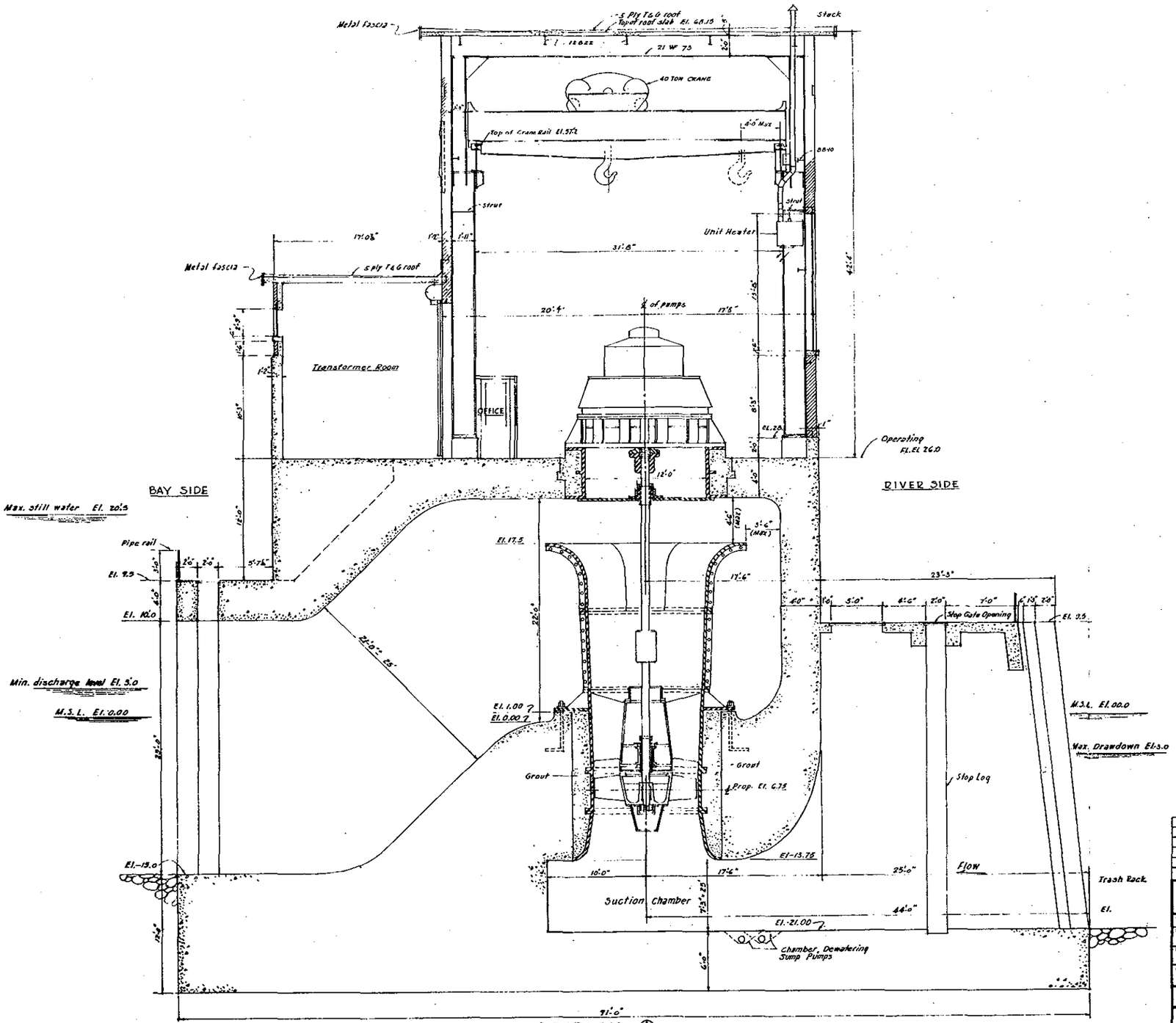
SCALE: 1/8" = 1'-0" | SPEC. NO.

DRAWING NUMBER
FP-1-1030

SHEET 5

PLATE NO. 10-5

CORPS OF ENGINEERS U. S. ARMY



SECTION Ⓐ
SCALE 1/4" = 1'-0"

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U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
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WALTHAM, MASS.

DES. BY J.C.G. DR. BY J.C.G. CK. BY

SUBMITTED

PROJECT ENGINEER

APPROVAL RECOMMENDED

APPROVAL RECOMMENDED

APPROVED

FOX POINT HURRICANE BARRIER
PUMPING STATION
ARCHITECTURAL
SECTION

PROVIDENCE RHODE ISLAND

DATE NOV. 1960

SCALE

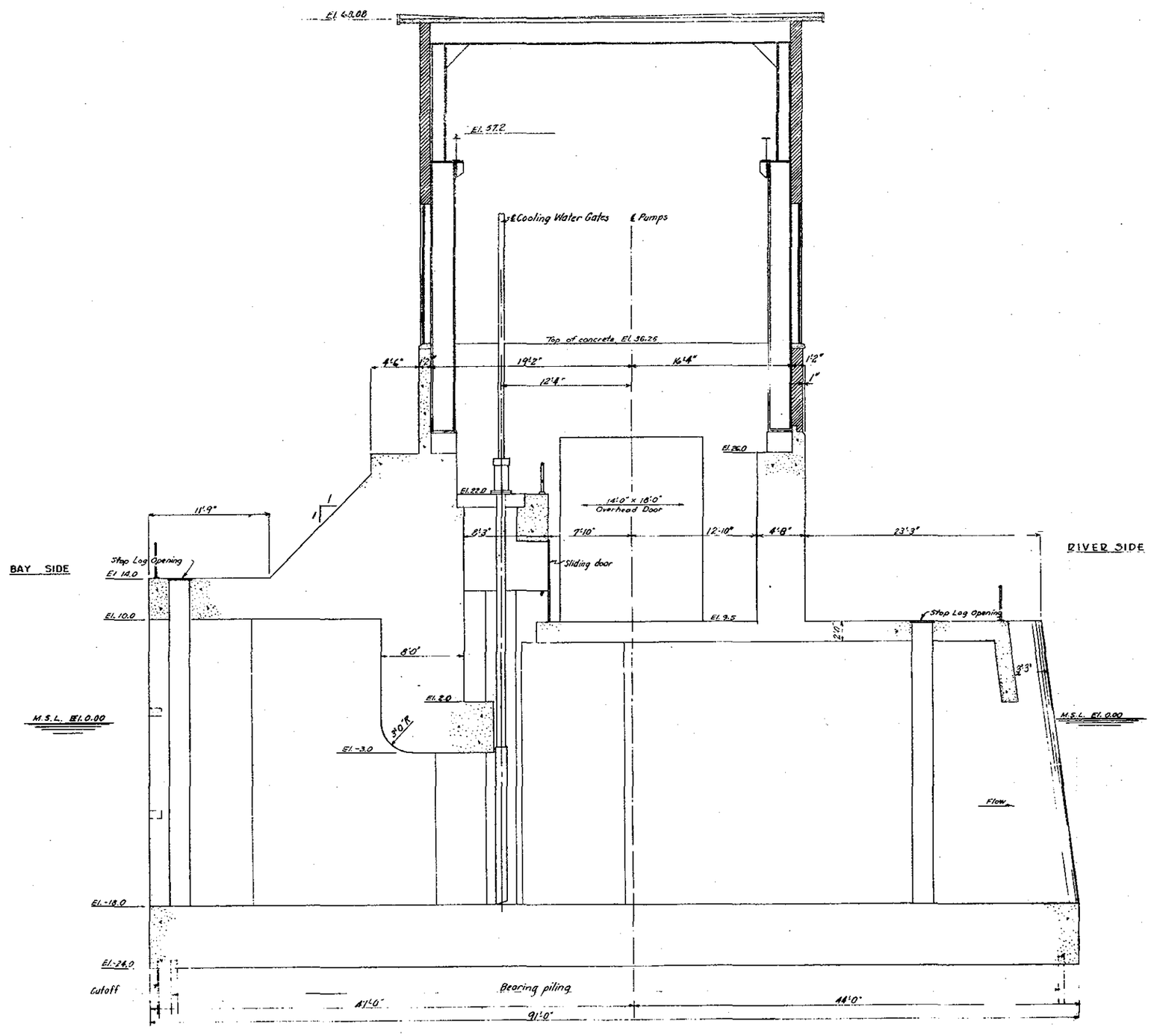
SPEC. NO. ENG-18-016-

DRAWING NUMBER
FP-1-1026

SHEET 6

PLATE NO. 10-6

CORPS OF ENGINEERS U. S. ARMY



NOTE:
For section on ℄ pumps, see Plate No. 10-14.

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CHIEF, PLAN BRANCH

APPROVAL RECOMMENDED

CHIEF, P&S BRANCH

FOX POINT HURRICANE BARRIER
PUMPING STATION
CONCRETE
SECTION THRU ACCESS BAY

PROVIDENCE RHODE ISLAND

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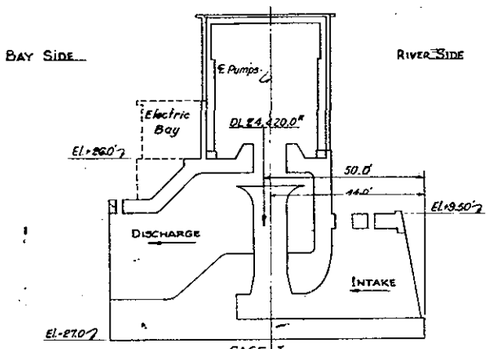
DATE JAN. 1960

SCALE 1/4" = 1'-0" | SPEC. NO.

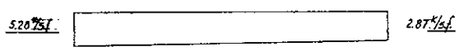
DRAWING NUMBER
FP-1-1032

SHEET 7

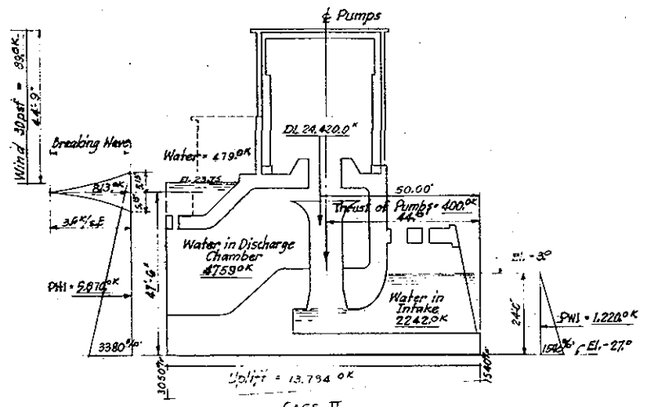
PLATE NO. 10-7



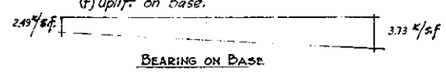
CASE I
CONSTRUCTION PERIOD - IN THE DRY
(a) Dead Load of Structure and Equipment
(b) No lateral loads



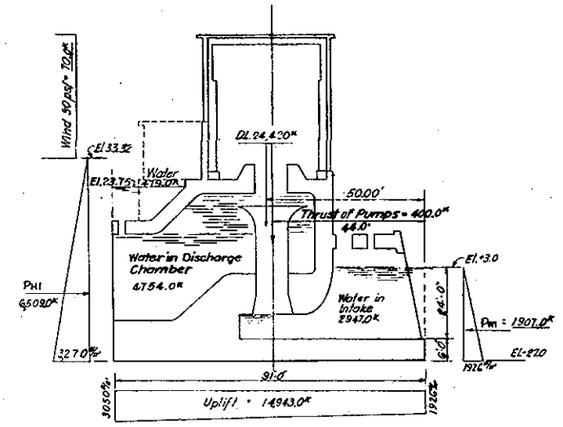
BEARING ON BASE



CASE II
HURRICANE AND HIGH WATER
(a) Dead Load of Structure and Equipment.
(b) Downward Thrust of Operating Pumps
(c) Water on Deck (Bay Side), in Intake and Discharge Chambers.
(d) Hydrostatic Lateral Loading with Breaking Wave.
(e) Wind on Exposed Bay Side
(f) Uplift on Base.



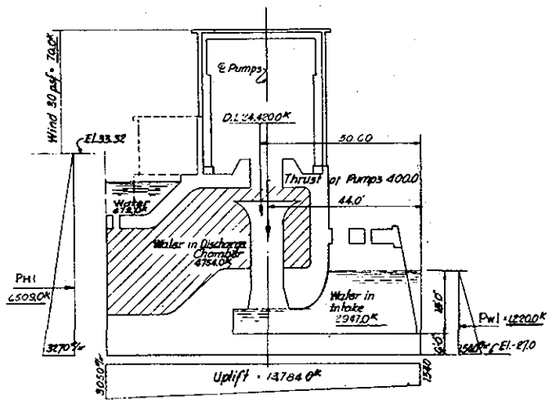
BEARING ON BASE



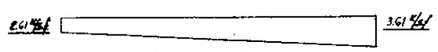
CASE III
HURRICANE AND HIGH WATER
(a) Dead Load of Structure and Equipment
(b) Water on Deck (Bay side) and in Intake and Discharge Chambers
(c) Hydrostatic Lateral Loading with Clapotis at El. 33.3?
(d) Wind on exposed Bay side
(e) Uplift on Base
(f) Downward Thrust of Operating Pumps

BEARING ON BASE

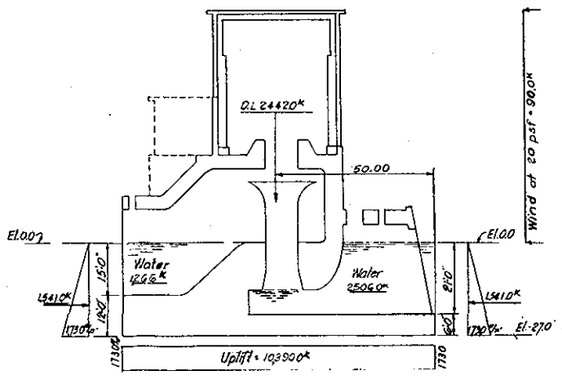
NOTES:
Stability analysis of Pump Station based on monolith 66'-0" long between expansion joints, with two pumps in a monolith.



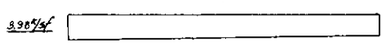
CASE IV
HURRICANE AND HIGH WATER
Same as Case III except tailwater at El. -3.0



BEARING ON BASE

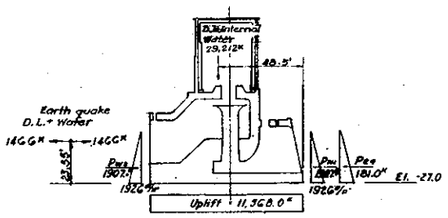


CASE V
NORMAL CONDITION
(a) Dead Load of Structure and Equipment
(b) Water at El. 0.0 on Bay and Land sides
(c) Water at El. 0.0 in Intake and Discharge Chambers
(d) Wind on exposed River side at 20 psf
(e) Uplift on Base

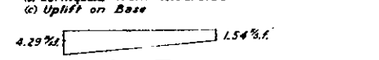


BEARING ON BASE

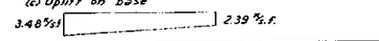
NOTE: All elevations refer to mean sea level.



CASE V a
NORMAL CONDITION - WATER AT El. +3.0 ON BOTH SIDES
(a) Dead Load of Structure and Equipment
(b) Earthquake from Riverside
(c) Uplift on Base



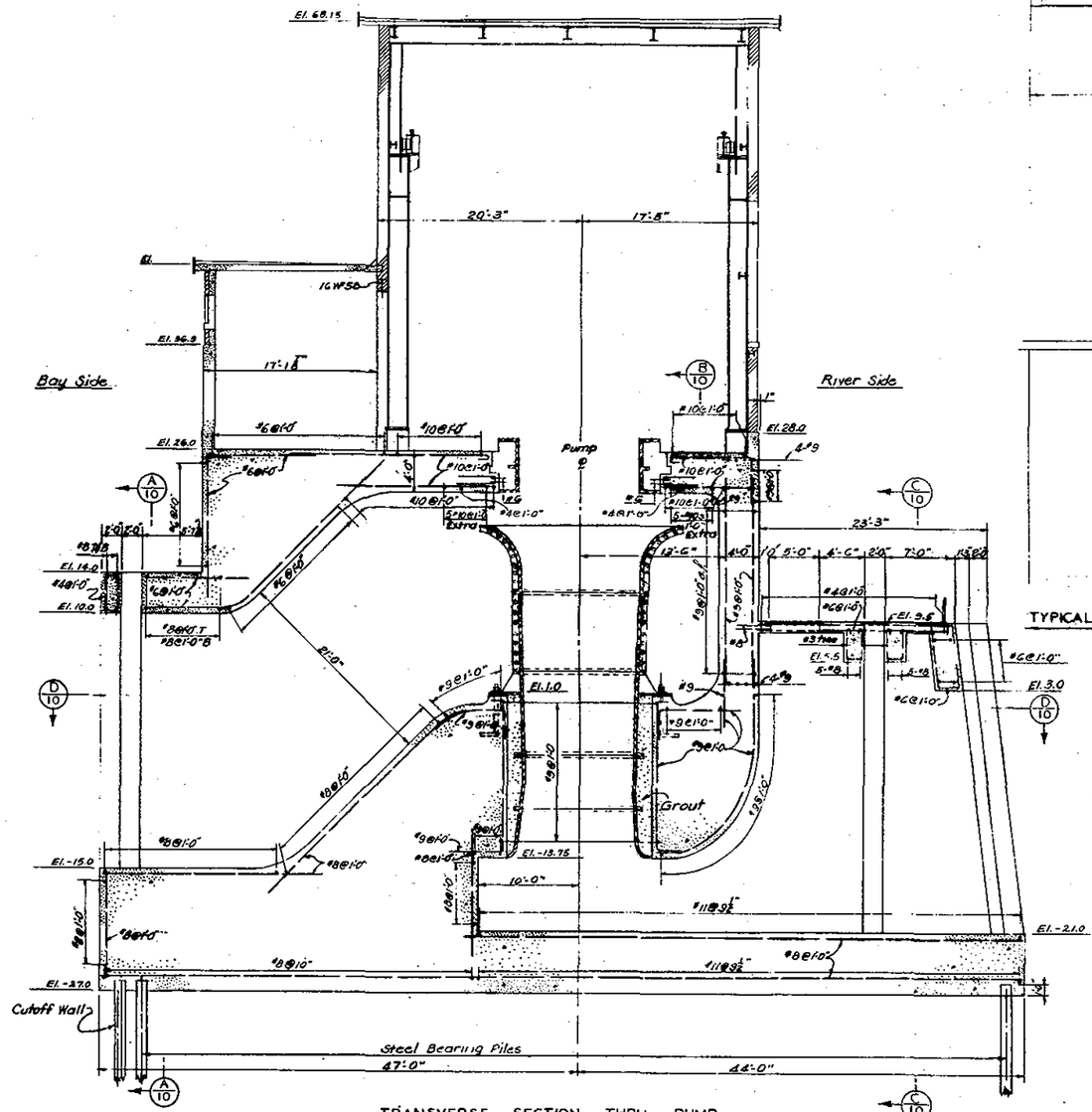
CASE V b
NORMAL CONDITION - WATER AT El. +3.0 ON BOTH SIDES
(a) Dead Load of Structure and Equipment
(b) Earthquake from Bayside
(c) Uplift on Base



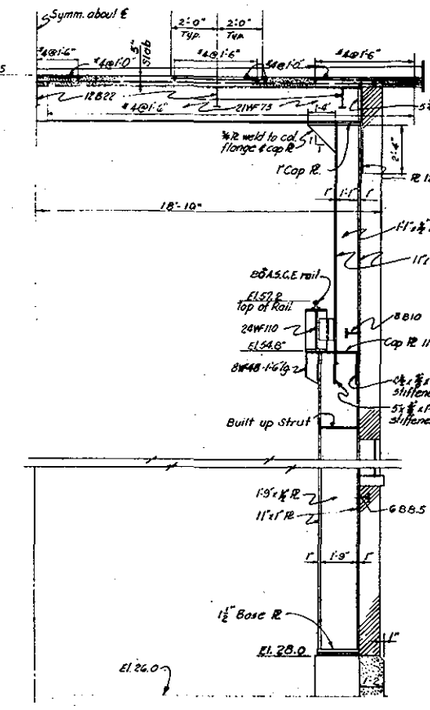
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

FOX POINT HURRICANE BARRIER
PUMPING STATION
STRUCTURAL
STABILITY ANALYSIS
PROVIDENCE RHODE ISLAND
DATE JAN. 1960
FP-1-1033

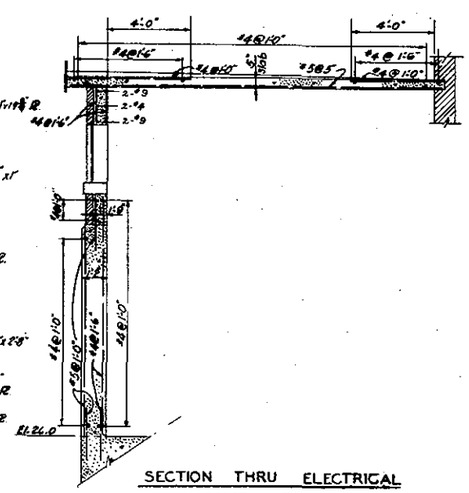
CORPS OF ENGINEERS U. S. ARMY



TRANSVERSE SECTION THRU PUMP
SCALE 3/16"=1'-0"



TYPICAL STEEL BENT & ROOF SLAB
SCALE 3/8"=1'-0"



SECTION THRU ELECTRICAL EQUIPMENT BAY
SCALE 3/8"=1'-0"

NOTES
1. Elevations refer to M.S.L. datum.
2. Outlines of intake and discharge passages are preliminary. They will be determined definitely by manufacturer's model test after the contract for manufacture of pumps is awarded.
3. Construction joints are not shown.

SCALE 3/16" = 1'-0"

SCALE 3/8" = 1'-0"

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY E.P.R. | DR. BY W.C.L. | CK. BY G.F.K.

SUBMITTED
CHIEF, STRUCT. SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED
CHIEF, E.&D.R. BRANCH

FOX POINT HURRICANE BARRIER
PUMPING STATION
STRUCTURAL
REINFORCEMENT DETAILS NO. 1
PROVIDENCE RHODE ISLAND

APPROVED
CHIEF, ENGINEERING DIVISION

DATE JAN. 1960

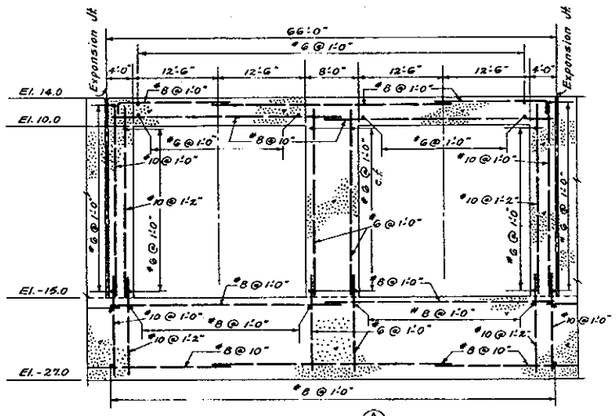
SCALE | SPEC. NO. ENG.-10-010-

DRAWING NUMBER
FP-1-1034

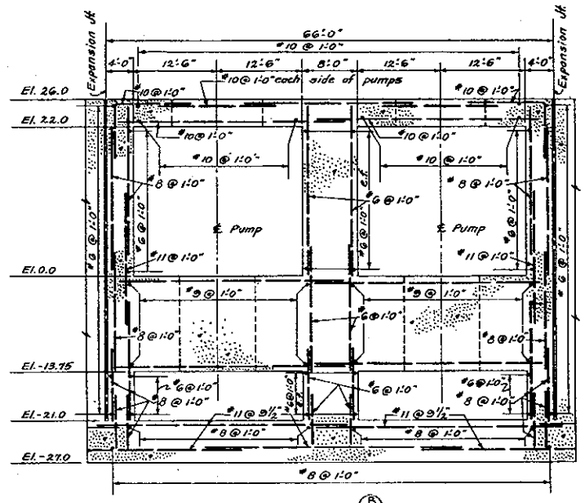
SHEET 9

PLATE NO. 10-9

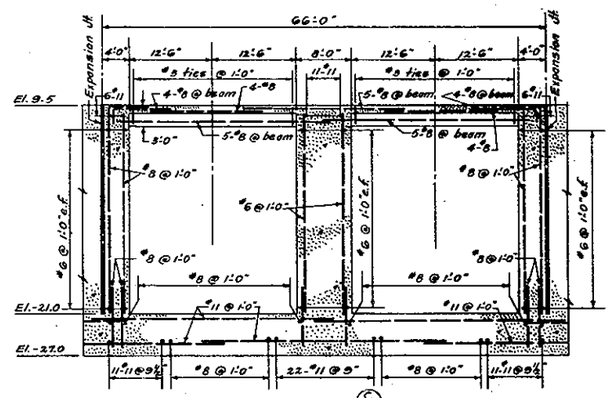
CORPS OF ENGINEERS — U. S. ARMY



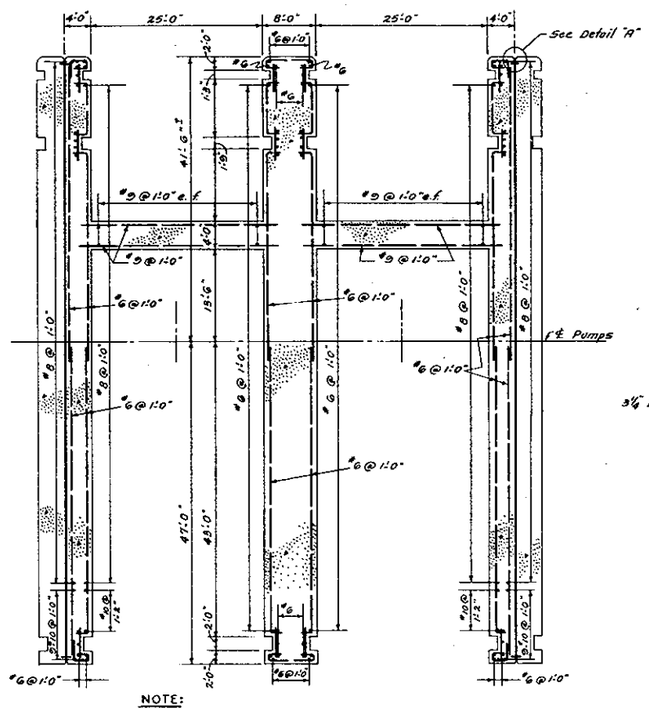
SECTION A
SCALE 1/8" = 1'-0"



SECTION B
SCALE 1/8" = 1'-0"

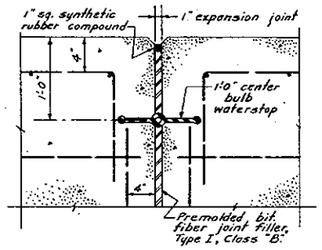


SECTION C
SCALE 1/8" = 1'-0"

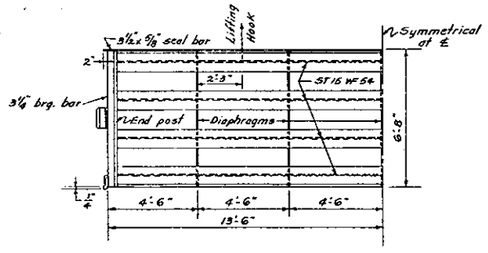


NOTE:
Pump casing not shown

SECTION D
SCALE 1/8" = 1'-0"

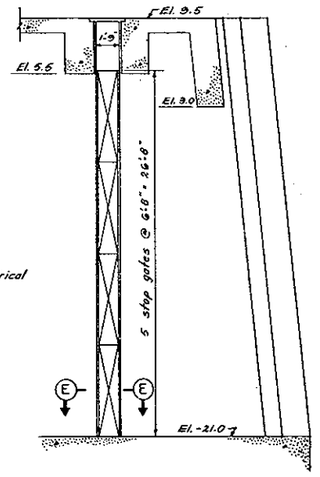


DETAIL "A"
SCALE 1 1/2" = 1'-0"

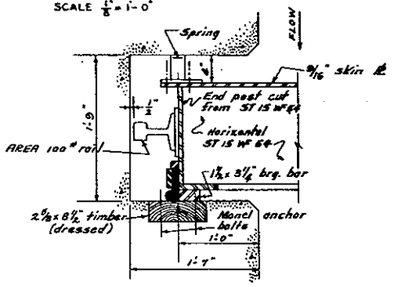


EL. OF STOP-GATE
SCALE 3/8" = 1'-0"

NOTE:
Complete seal assembly not shown.
To be of mechanical compression type.



SECTION THRU STOP-GATE
SCALE 1/4" = 1'-0"



SECTION E-E
SCALE 1 1/2" = 1'-0"

NOTE:
Elevations refer to Mean Sea Level

SCALE 3/8" = 1'-0"
SCALE 1/4" = 1'-0"
SCALE 3/8" = 1'-0"
SCALE 1 1/2" = 1'-0"

REVISION	DATE	DESCRIPTION	BY

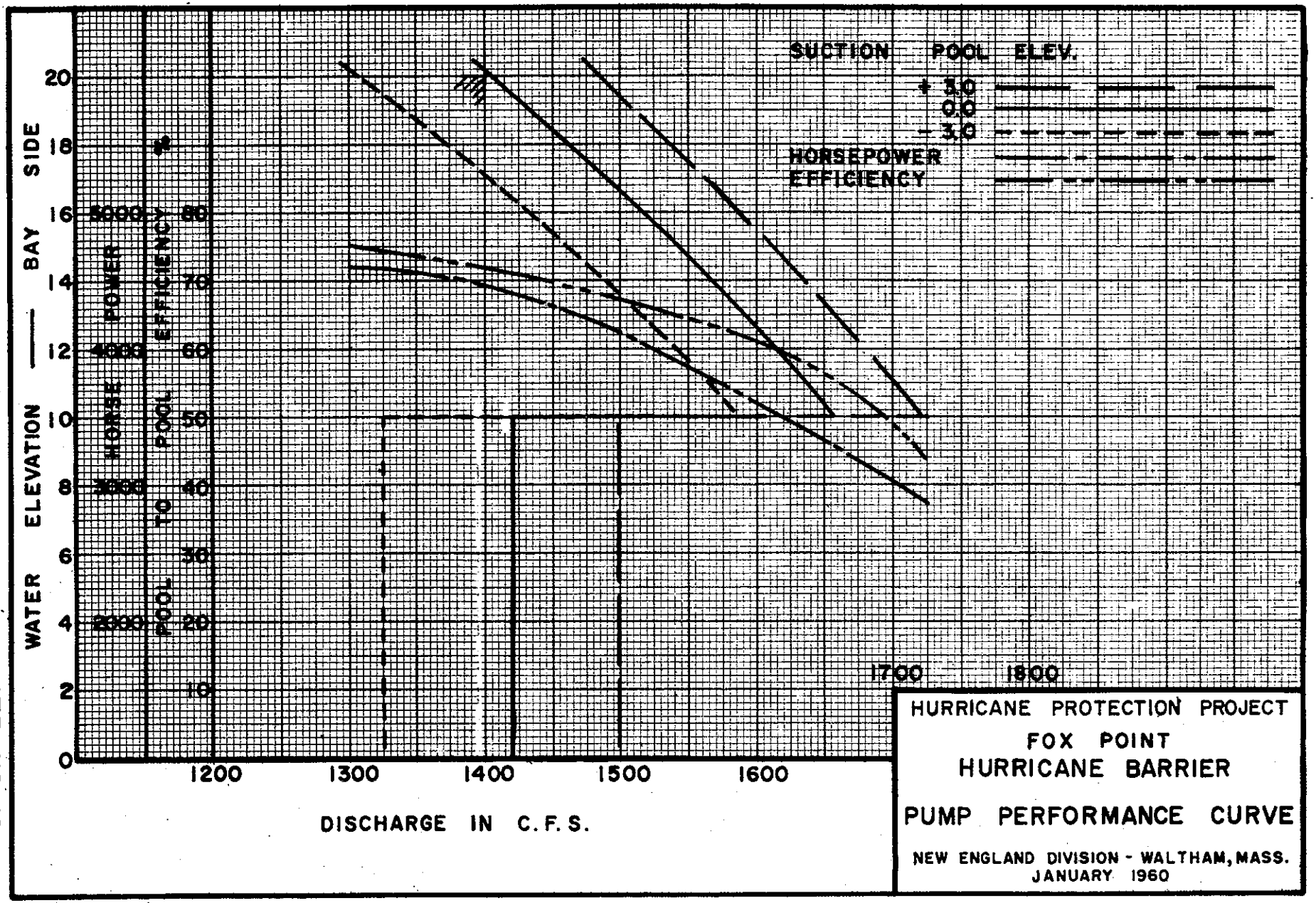
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY Eckert · CK. BY G.A.G. · CK. BY R.P.W.
SUBMITTED: Robert P. Wheeler, CHIEF, STRUCT. SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED
CHIEF, U.S.A. DIVISION

FOX POINT HURRICANE BARRIER
PUMPING STATION
STRUCTURAL
REINFORCEMENT DETAILS NO. 2

PROVIDENCE — RHODE ISLAND
DATE JAN. 1960
APPROVED
SCALE
SPEC. NO. DACW-10-060-
DRAWING NUMBER FP-1-1036
SHEET 10

PLATE NO. 10-10



HURRICANE PROTECTION PROJECT

FOX POINT
HURRICANE BARRIER

PUMP PERFORMANCE CURVE

NEW ENGLAND DIVISION - WALTHAM, MASS.
JANUARY 1960

PLATE NO. 10-11

PLATE NO. 10-11

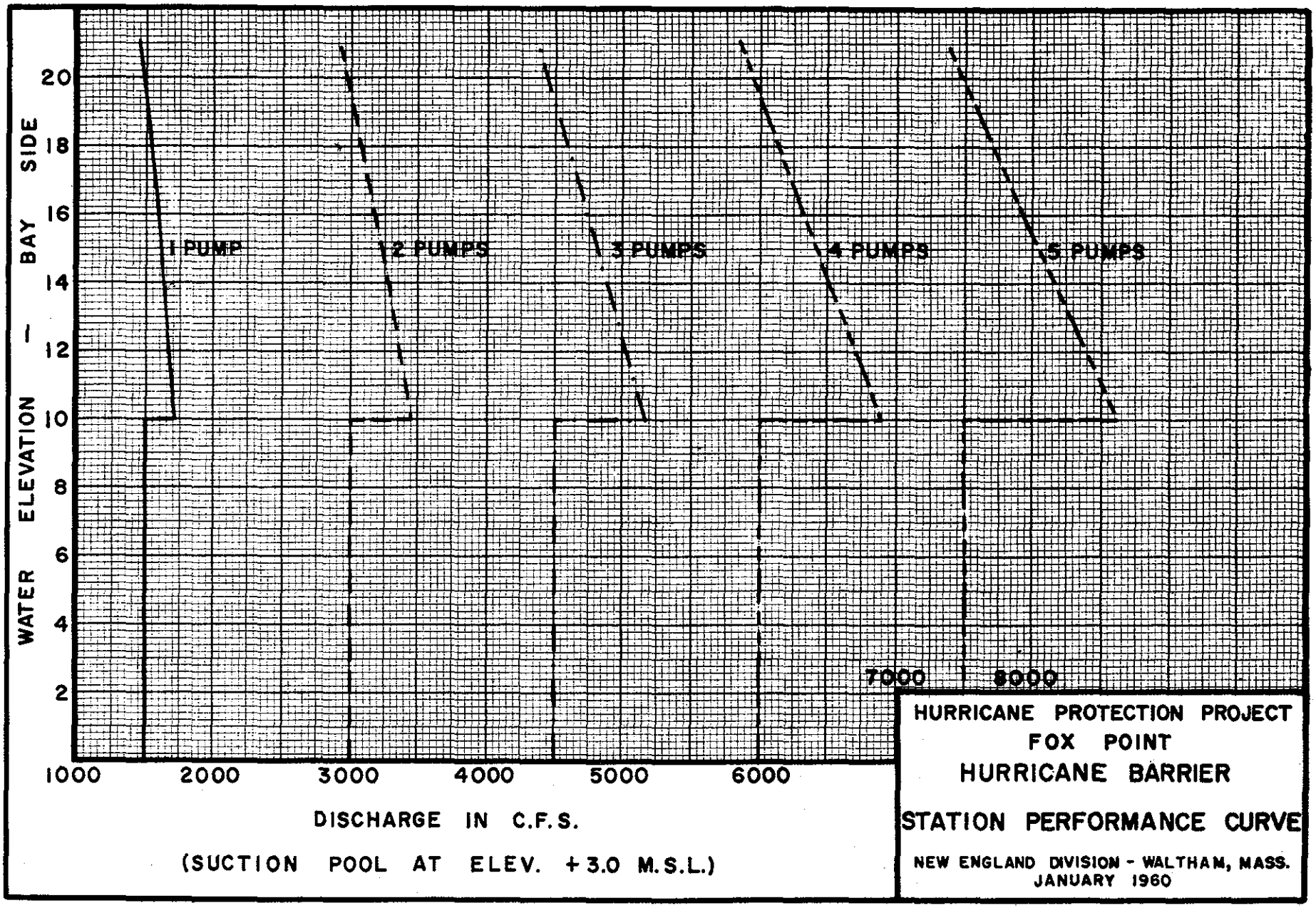
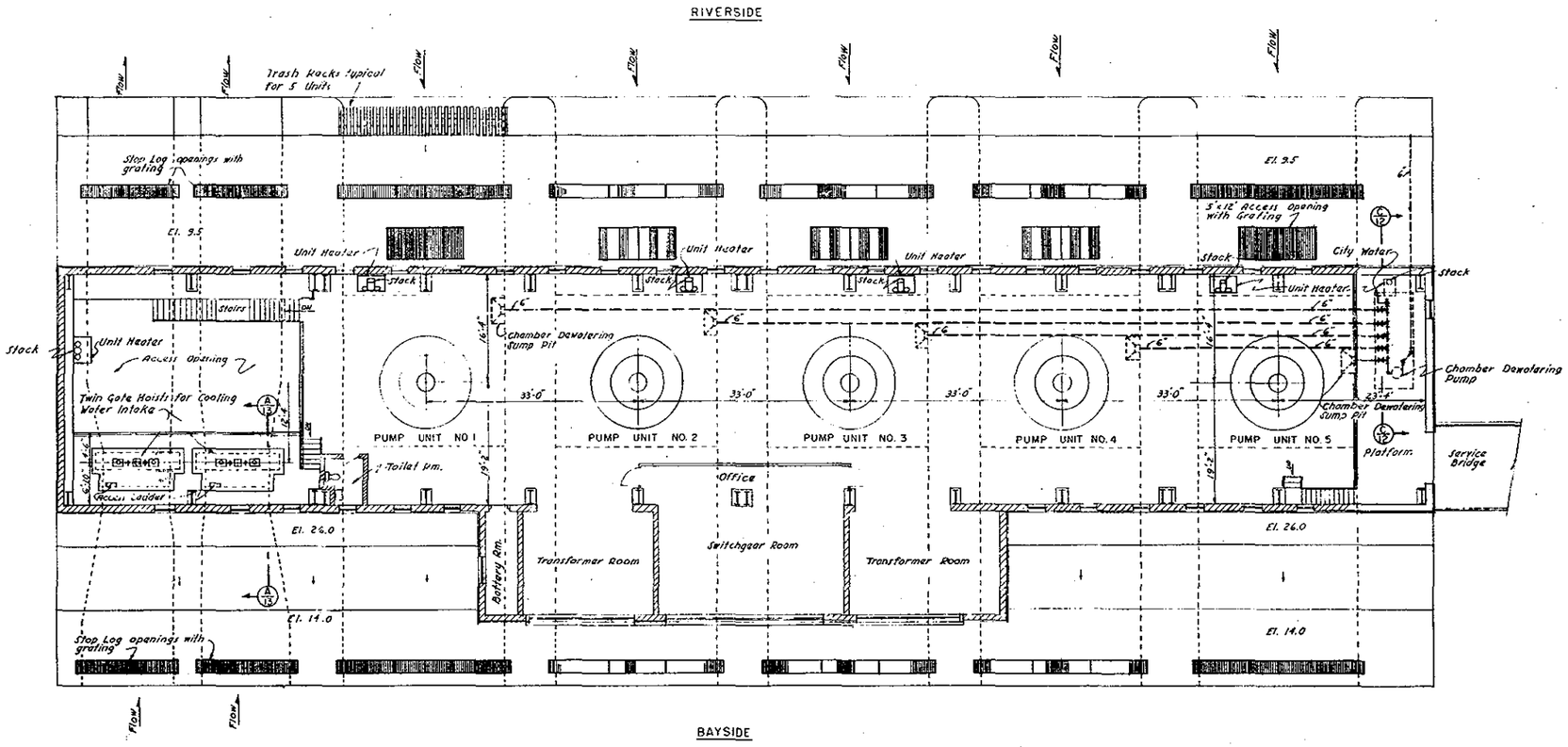


PLATE NO. 10-12

CORPS OF ENGINEERS U. S. ARMY



PLAN - OPERATING FLOOR

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY J.W.F. | DR. BY J.P.V. | CK. BY

SUBMITTED
CHIEF, MECH. SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED
CHIEF, P. & S. BRANCH

FOX POINT HURRICANE BARRIER
PUMPING STATION
MECHANICAL
FLOOR PLAN

PROVIDENCE RHODE ISLAND

APPROVED
CHIEF, ENGINEERING DIVISION
DATE JAN. 1960

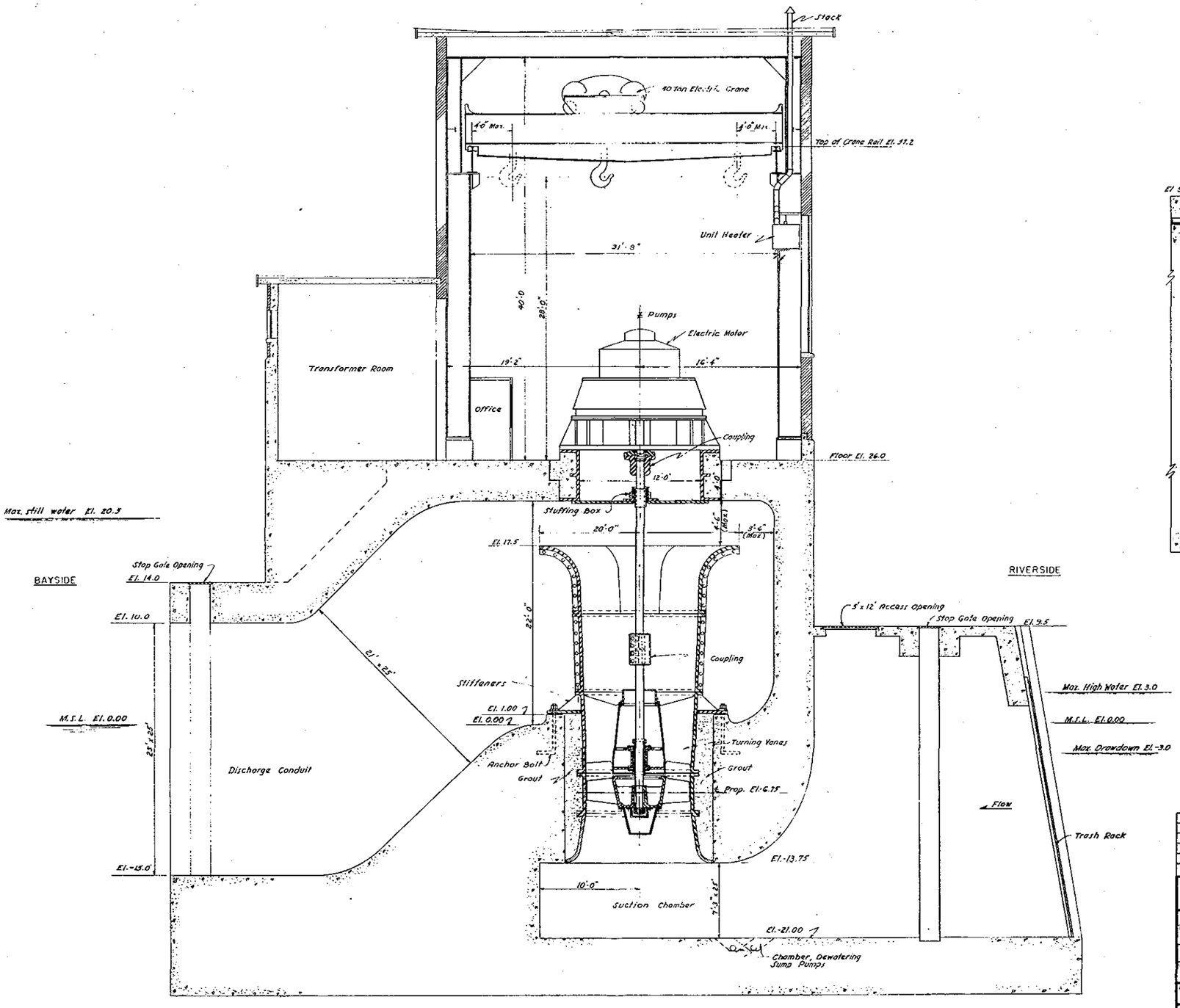
SCALE: 1/8" = 1'-0" | SPEC. NO. ENG.-10-016-

DRAWING NUMBER
FP-1-1036

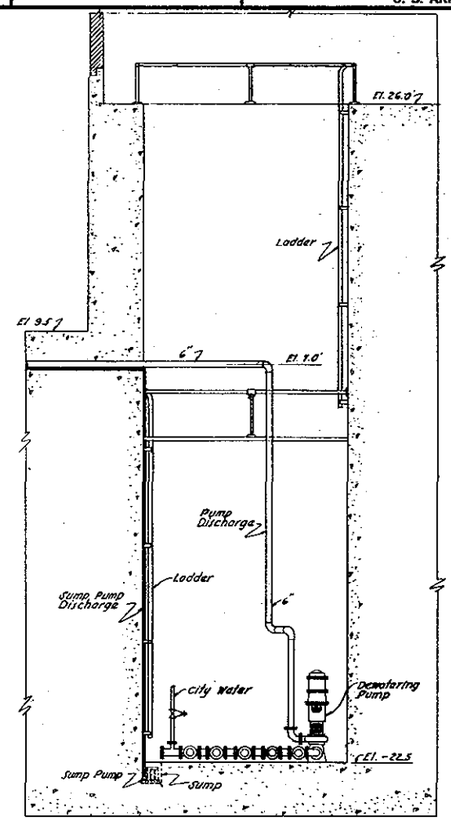
SHEET 11

PLATE NO. 10-13

CORPS OF ENGINEERS U. S. ARMY



TYPICAL SECTION THRU PUMP HOUSE AT PUMPS



SECTION

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY J.W.F. | DR. BY J.P.V. | CK. BY

SUBMITTED
CHIEF, MECH. SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED
CHIEF, P. & R. BRANCH

FOX POINT HURRICANE BARRIER
PUMPING STATION
MECHANICAL SECTIONS

PROVIDENCE RHODE ISLAND

APPROVED DATE JAN 1960

CHIEF, ENGINEERING DIVISION

SCALE: 1/4" = 1'-0" SPEC. NO. ENG-19-016-

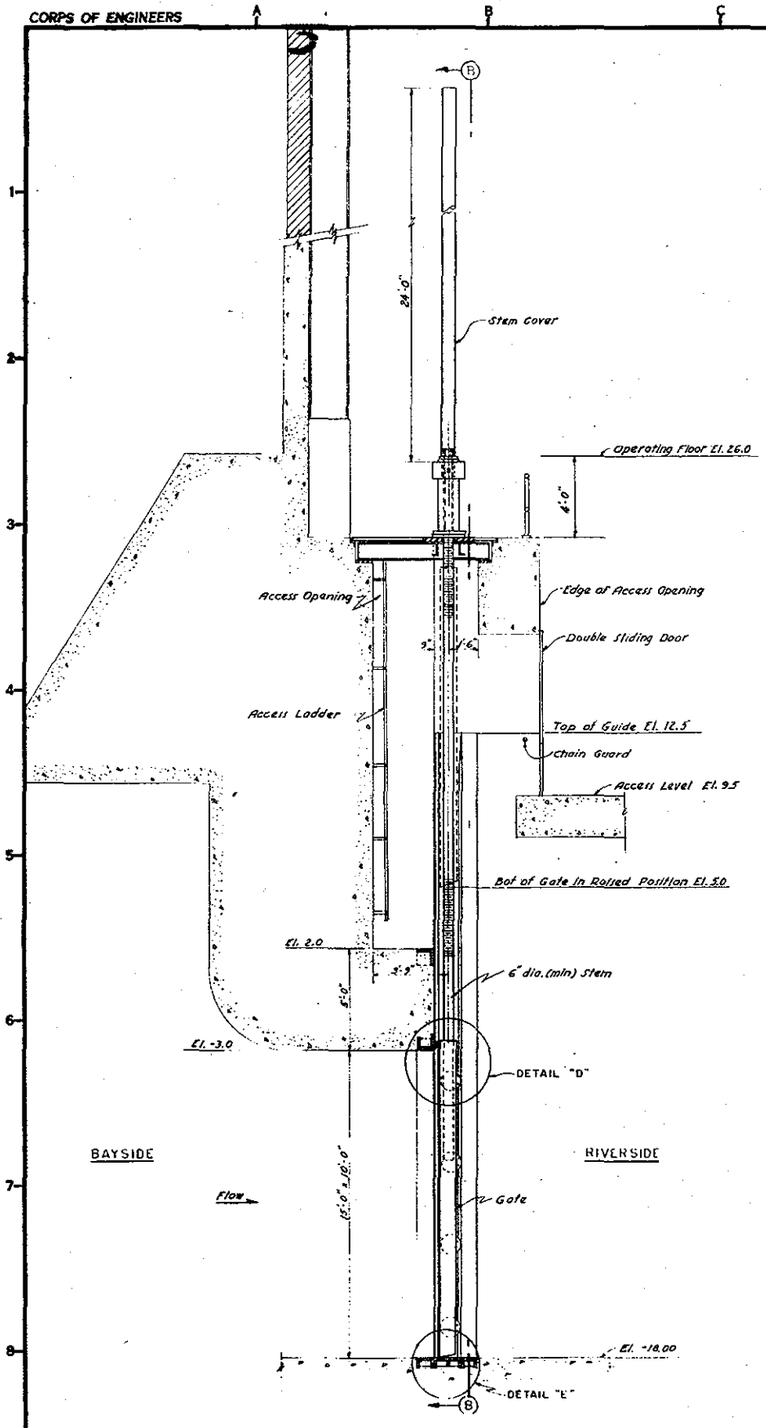
DRAWING NUMBER
FP-1-1037

SHEET 12

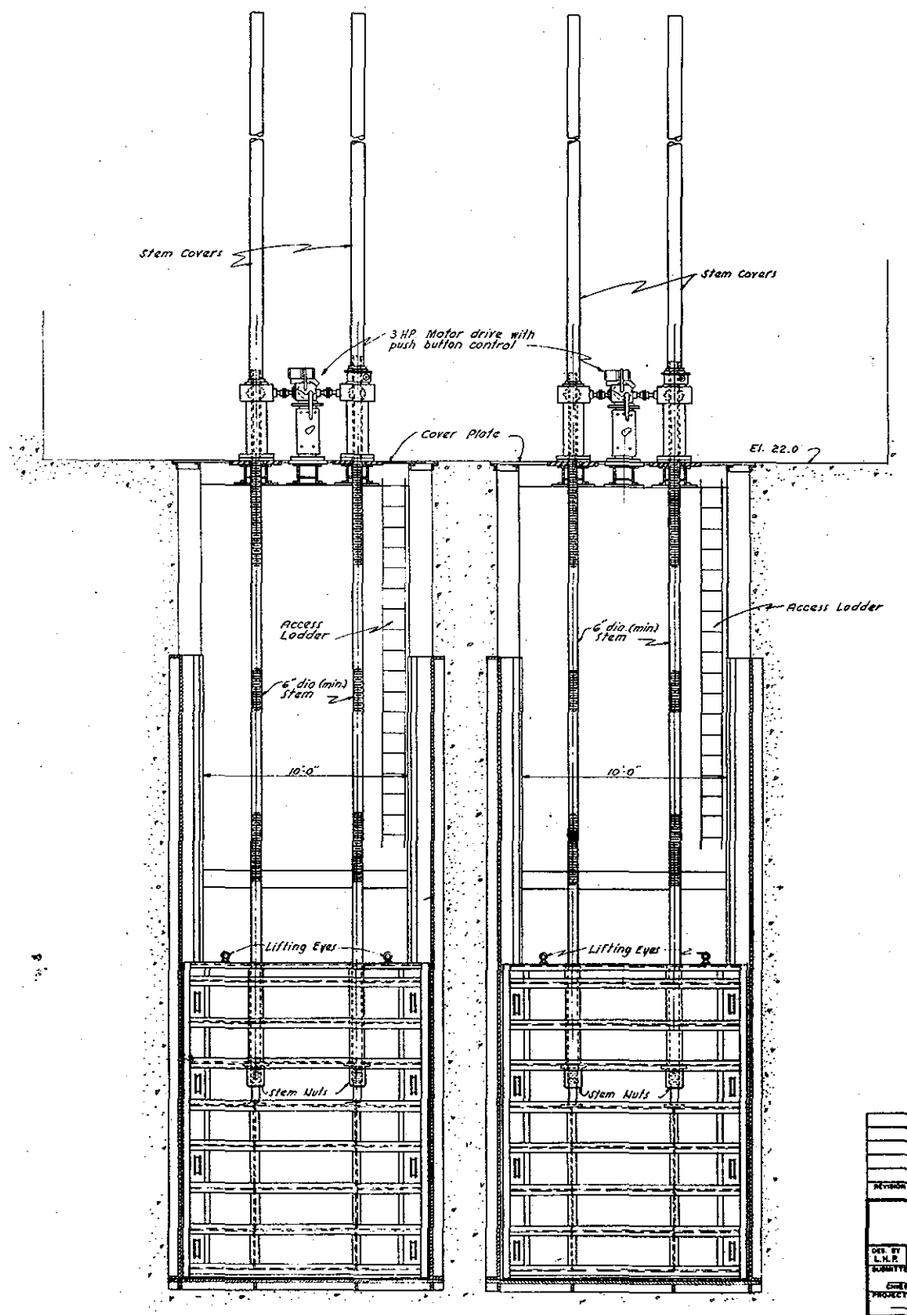
PLATE NO. 10-14

CORPS OF ENGINEERS

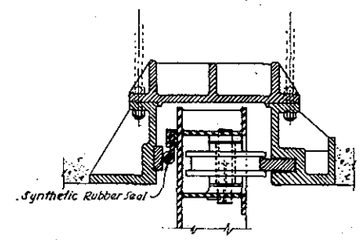
U. S. ARMY



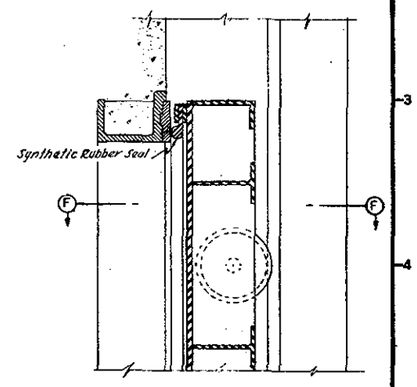
SECTION A/B



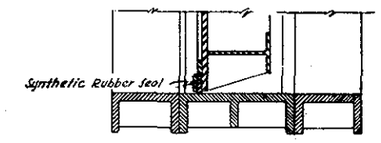
SECTION B-B



SECTION F-F



DETAIL "D"



DETAIL "E"

DETAILS OF GATES

SCALE 1 1/2" = 1'-0"

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY L.H.P. | DR. BY J.P.W. | CK. BY

SUBMITTED
CHIEF, MECH. SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED
CHIEF, J. & R. BRANCH

FOX POINT HURRICANE BARRIER
PUMPING STATION
MECHANICAL
COOLING WATER INTAKE GATES

PROVIDENCE RHODE ISLAND

APPROVED
CHIEF, ENGINEERING DIVISION

DATE JAN. 1960

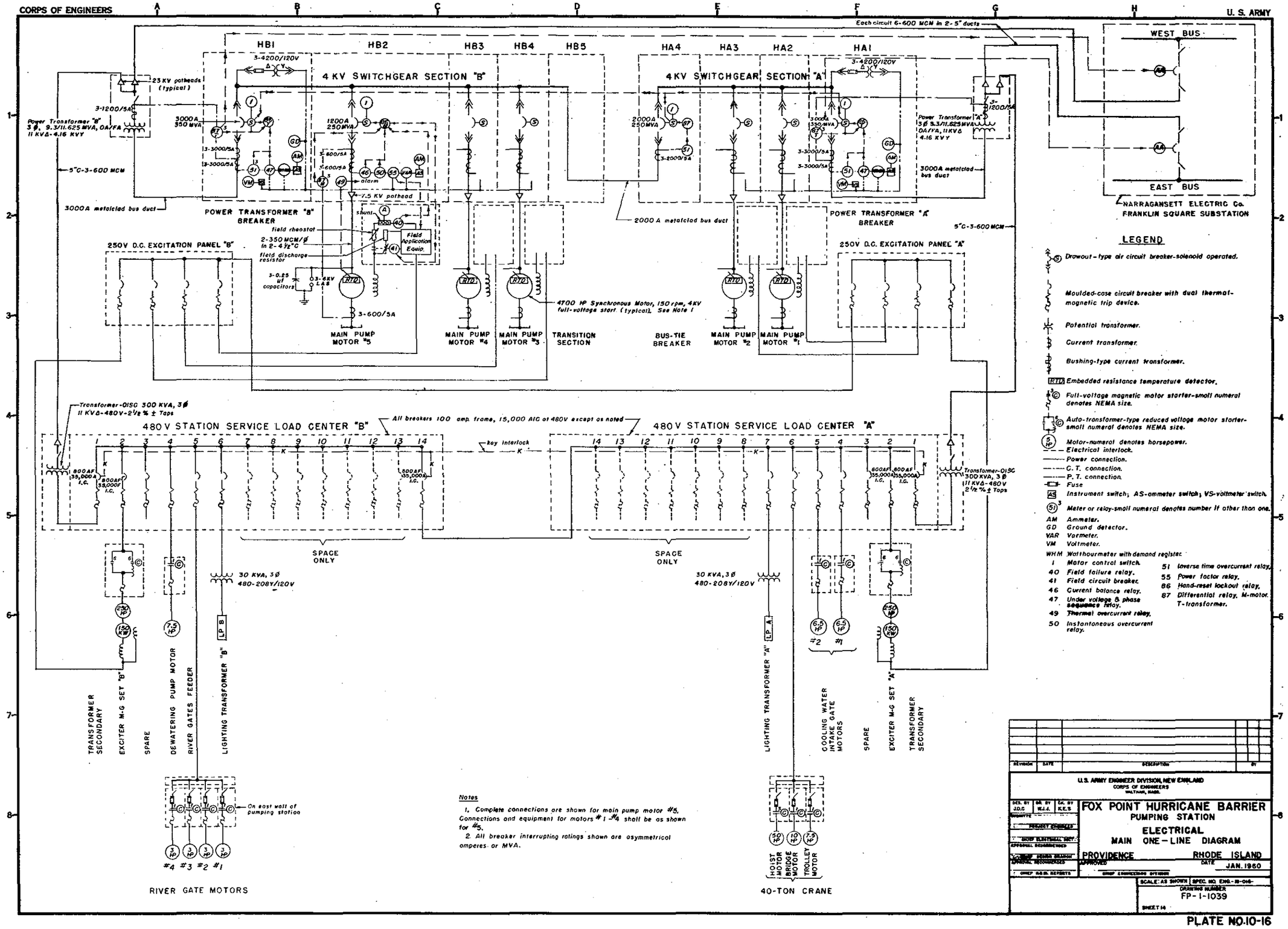
SCALE: 3/8" = 1'-0" | SPEC. NO. ENG.-18-016-

DRAWING NUMBER FP-I-1038

SHEET 15

PLATE NO. 10-15

CORPS OF ENGINEERS — U. S. ARMY



Notes

1. Complete connections are shown for main pump motor #5. Connections and equipment for motors #1-#4 shall be as shown for #5.
2. All breaker interrupting ratings shown are asymmetrical amperes or MVA.

PLATE NO.10-16

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Wave Forces on Pumping Station
COMPUTED BY CMT & BFW CHECKED BY Cmt DATE 12/29/59

1. The Pumping Station is subjected to two types of wave forces from the following applied criteria :-
   a Still Water Level @ El. + 20.5
   b. Significant Wave Height = 6.5 ft.
   c. Period = 5.5 sec.

2. The two types of wave forces affecting the Pumping Station are non-breaking waves or a clapotis condition and breaking waves.

3. A clapotis condition exists on the bayside of the Pumping Station where the face is vertical and exhibits no projections. Forces for this condition are determined by the Saintflou method.

4. A breaking wave condition occurs on the bayside of the Pumping Station where the face exhibits a projecting lip. Forces for this condition are determined by the Minikin method.

5. Computations and pressure diagrams for the two types of wave forces on the Pumping Station are presented on the following pages.

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Wave Forces on Pumping Station
COMPUTED BY BPW CHECKED BY Cmt DATE 12/29/59

The Clapotis Condition

H_s	Significant Wave Height	=	6.5' ✓
H_m	Max. Wave Height in Train = 1.58 H_s	=	10.3' ✓
T	Period	=	5.5 sec. ✓
	S.W.L.	=	El. + 20.5' ✓
d	Depth of Water @ S.W.L. Bayside	=	35.5'
L_o	Deep Water Wave Length = 5.12 T^2	=	155'

$d/L_o = \frac{35.5}{155} = .2290$

$d/L = .2498$ For above value of d/L_o (From Table D-1, BEB T.R. No. 4)

L Length of Wave = $\frac{35.5}{.2498}$ = 142'

h_o Mean Level (Orbit Center of Clapotis) = $\frac{\pi H_m^2}{L} \coth \frac{2\pi d}{L}$

$= \frac{\pi \overline{10.3}^2}{142} \times \frac{1}{.9170} =$ 2.56'

$P_1 = \frac{wH}{\cosh \frac{2\pi d}{L}} = \frac{64.2 \times 10.3}{2.506} =$ 264 PSF

$wd = 64.2 \times 35.5 =$ 2280 PSF

$wd_1 = 64.2 \times 12.0 =$ 770 PSF

$P_2 = wd + P_1 - wd_1 = 2280 + 264 - 770 =$ 1774 PSF

$wd_2 = 64.2 \times 47.5 =$ 3050 PSF

$wd_3 = 64.2 \times 24.0 =$ 1540 PSF

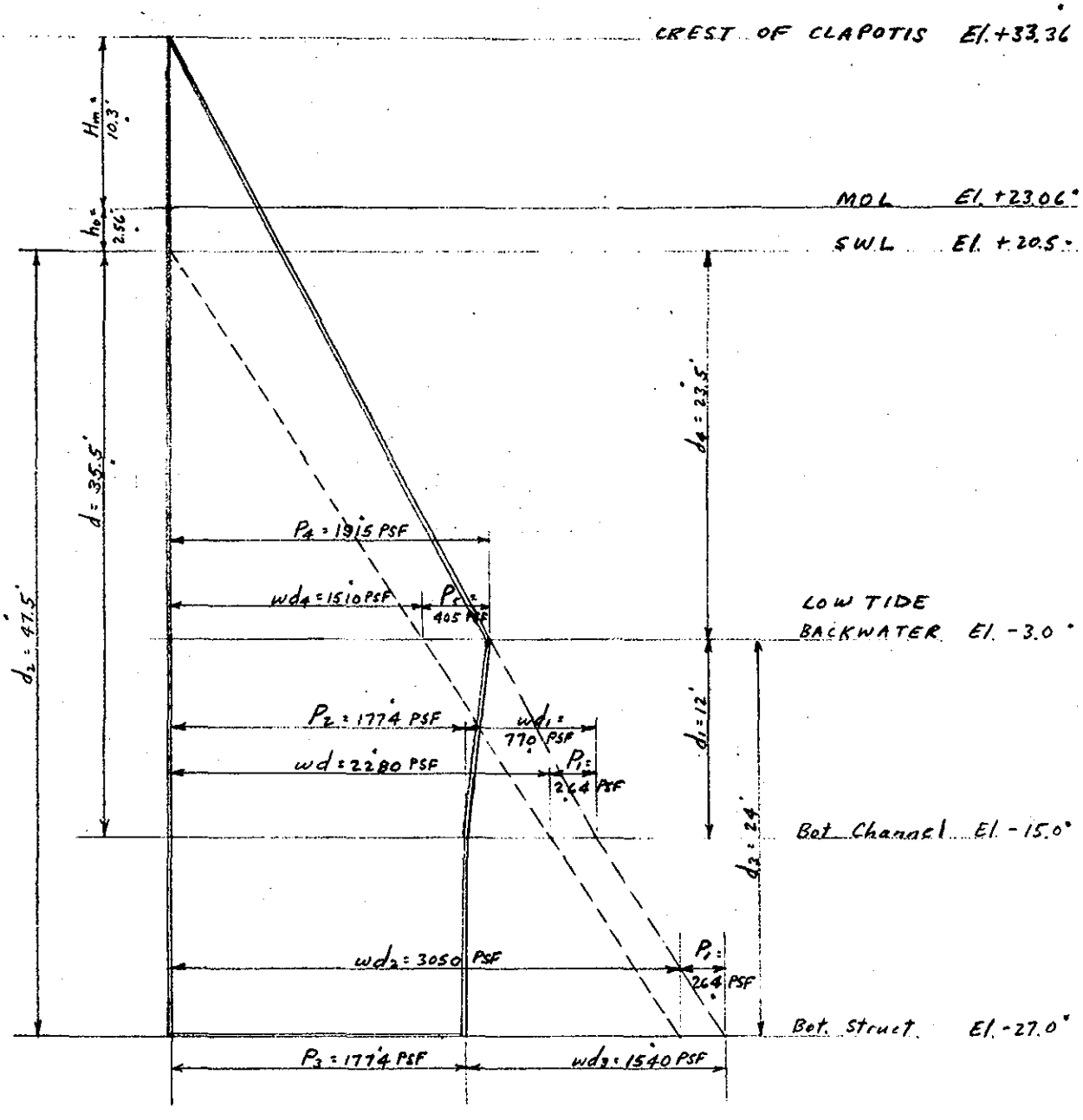
$P_3 = wd_2 + P_1 - wd_3 = 3050 + 264 - 1540 =$ 1774 PSF

$wd_4 = 64.2 \times 23.5 =$ 1510 PSF

$P_4 = (wd + P_1)\left(\frac{d_4 + h_o + H_m}{d + h_o + H_m}\right) = 2544\left(\frac{36.36}{48.36}\right) =$ 1915 PSF

$P_5 = P_4 - wd_4 = 1915 - 1510 =$ 405 PSF

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Wave Forces on Pumping Station
COMPUTED BY BHW CHECKED BY Cmt DATE 12/29/59



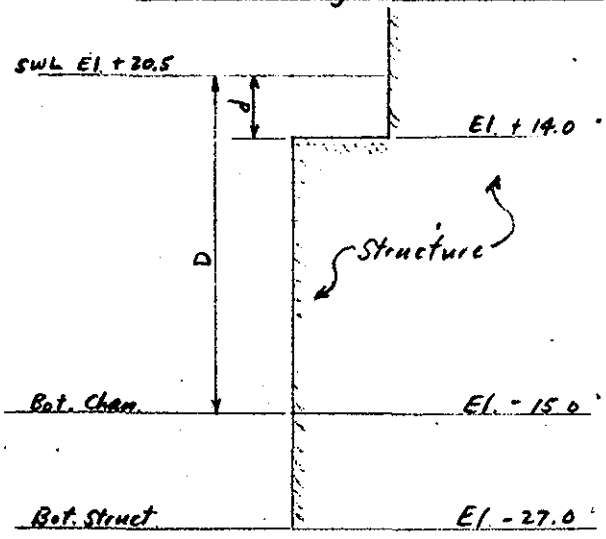
PRESSURE DIAGRAM - CLAPOTIS

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Wave Forces on Pumping Station
COMPUTED BY BPW CHECKED BY Cmt DATE 12/30/59

The Breaking Wave Condition



H_s	Significant Wave Ht.	6.5'
H_b	Ht. of Wave Breaking on Struct.	10.3'
d	Depth of Water at Struct.	6.5'
D	Deeper Water Depth	35.5'
L_D	" " Wave Length	142'
T	Period	5.5 sec.
	S.W.L.	El. +20.5

Dynamic Pressure Concentrated at S.W.L. = P_m

$$P_m = \frac{101 H_b w}{L_D} \times \frac{d}{D}(D+d)$$

$$= \frac{101 \times 10.3 \times 64.2}{142} \times \frac{6.5}{35.5} \times 42.0 = 3620 \text{ PSF}$$

Hydrostatic Pressure at S.W.L. = P_s

$$P_s = \frac{w H_b}{2} = \frac{64.2 \times 10.3}{2} = 331 \text{ PSF}$$

$$P_{d_{BS}} = w\left(d_{BS} + H_b/2\right) = 64.2\,(47.5 + 5.15) = 3380 \text{ PSF}$$

$$P_{BW} = w d_{BW} = 64.2 \times 24.0 = 1540 \text{ PSF}$$

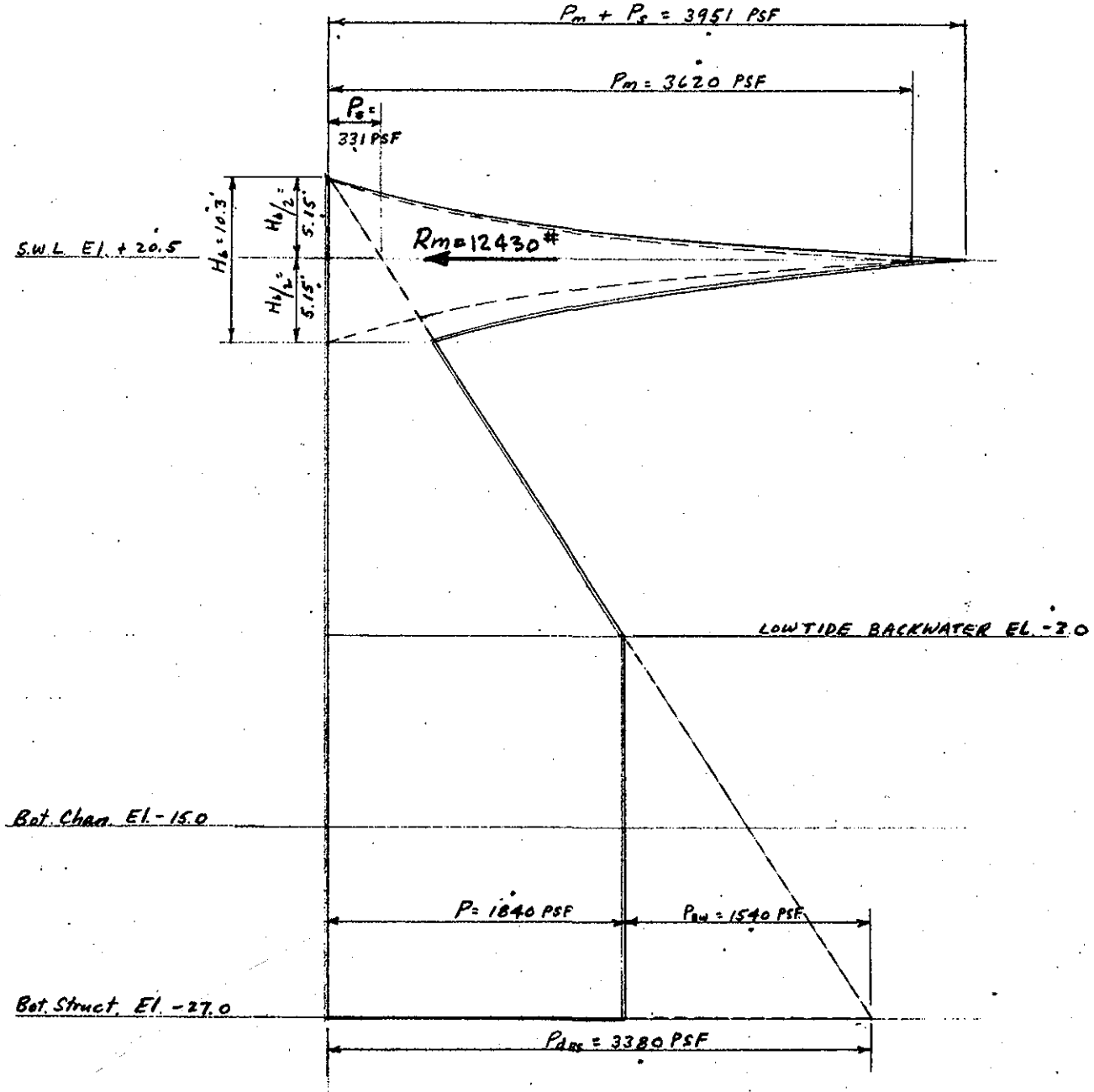
$$P = P_{d_{BS}} - P_{BW} = 3380 - 1540 = 1840 \text{ PSF}$$

$$R_m = \frac{P_m \times H_b}{3} = \frac{3620\,(10.3)}{3} = 12430^{\#}$$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Wave Forces on Pumping Station
COMPUTED BY BPM CHECKED BY Cmt DATE 12/30/59



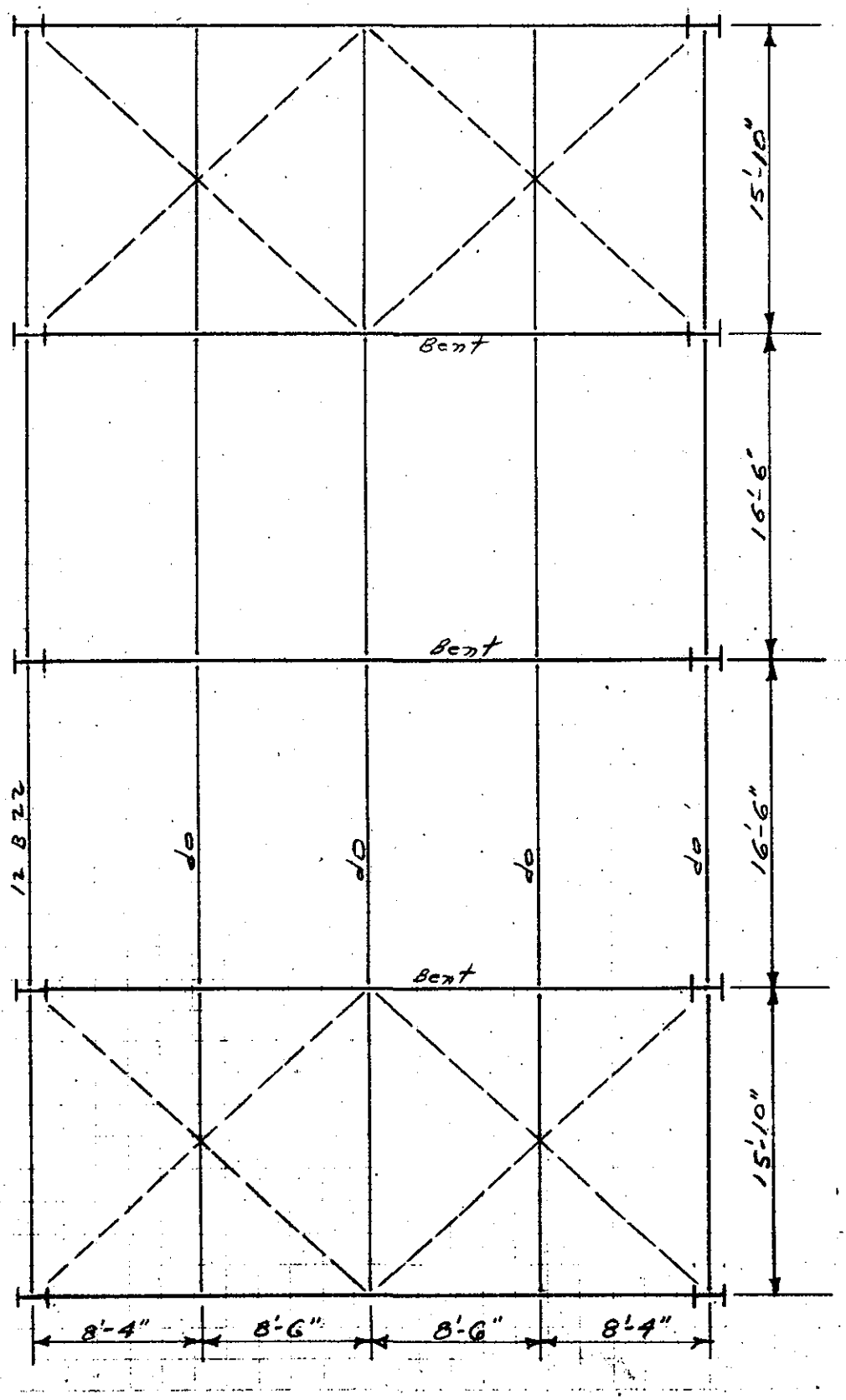
PRESSURE DIAGRAM - BREAKING WAVE

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

PAGE A 6

SUBJECT FOX POINT PUMPING STATION
COMPUTATION ROOF - TYPICAL 66'-0" MONOLITH
COMPUTED BY R.N.W. CHECKED BY GFH DATE 30 SEPT 59



SUBJECT FOX POINT PUMPING STATION
COMPUTATION ROOF - TYPICAL 66'-0" MONOLITH
COMPUTED BY R.N.W. CHECKED BY GFH DATE 30 SEPT. 59

SLAB

span = 8'-6"

Loading:

L.L. —	30
Rfg —	6
(6" avg. cinder conc.) Fill —	30
Slab —	64
	130 psf

$M = \frac{130(8.5)^2}{10} = 939$ FT-#

$t = 5''$
$d = 4''$
$d = 3.5''$ over purlins

$\frac{M}{bd^2} = \frac{939}{(3.5)^2} = 77$

$A_s = \frac{12(.939)}{20(.885)3.5} = 0.18\ IN^2$

shrinkage $A_s = .002(5)(12) = 0.12\ IN^2$

5" slab
#4@12" bottom
#4@12" top over supports
#4@18" normal to main reinf.

PURLINS

Span = 16'-6"
Spacing = 8'-6"

$w = 8.5(130) + 25 = 1130$ #/FT.

$R_L = R_R = \frac{16.5(1130)}{2} = 9323$#

$M = \frac{1.13(16.5)^2}{8} = 38.46$ K-FT.

req. $S = \frac{12(38.46)}{20} = 23.1\ IN^3$

12 B 22 ←
10 WF 25

$\Delta = \frac{5(2)(9323)(198)^3}{384(30)10^6(133.2)} = 0.472''$

$\frac{0.472}{198} = \frac{1}{420}$

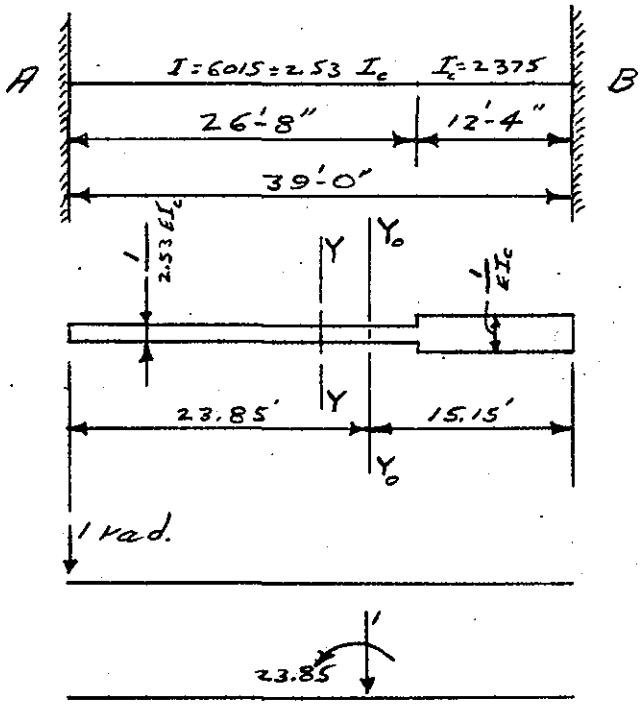
FRAME

assume upper column — Flange 2-PL 14"x1" } $I = .625(16.5)^3\frac{1}{12} + 2(14)(8.75)^2$
Web PL-16½ x 5/8 } $I = 2375\ IN^4$

assume lower column — Flange 2-PL 14"x1" } $I = .625(26)^3\frac{1}{12} + 14(1)(13.5)^2 2$
Web PL-26 x 5/8" } $I = 6015\ IN^4$

SUBJECT: FOX POINT PUMPING STATION
COMPUTATION: SUPERSTRUCTURE FRAME
COMPUTED BY: R.N.W. CHECKED BY: GFH DATE: 29 SEPT. 59

Column Factors



Loads on Top

Letting $EI_c = 1$

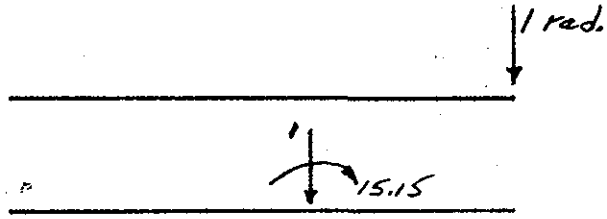
$$\bar{x} = \frac{(26.67)(.39484)(-6.16667) + 12.33(13.333)}{12.33 + (.39484)(26.67)}$$

$\bar{x} = +4.35.$

$A = 12.33 + (.39484)(26.67) = 22.86239$

$I_{Y_oY_o} = (.39484)(26.67)^3 \frac{1}{12} + (1)(12.33)^3 \frac{1}{12} + 26.67(.39484)(10.52)^2 + 12.33(8.98)^2$

$I_{Y_oY_o} = 2940.1.$



Loads on top

Factors at A:

$$M_A = \frac{P}{A} + \frac{Mc}{I}$$

$$= EI_c\left(\frac{1}{22.86239}\right) + \frac{EI_c(23.85)^2}{2940.1}$$

$$= \frac{EI_c}{L}\left(\frac{39}{22.86239}\right) + \frac{EI_c}{L}\frac{(23.85)^2 39}{2940.1}$$

$$M_A = \frac{9.25119\,EI_c}{L}.$$

$$M_B = \frac{P}{A} - \frac{Mc}{I}$$

$$M_B = \frac{EI_c}{L}\left[\frac{39}{22.86239} - \frac{(23.85)(15.15)39}{2940.1}\right]$$

$$M_B = \frac{-3.08710\,EI_c}{L}.$$

$$K_{AB} = \frac{9.25119\,EI_c}{L}. \leftarrow$$

$$C_{AB} = \frac{3.08710}{9.25119} = 0.334. \leftarrow$$

Factors at B:

$$M_B = \frac{P}{A} + \frac{Mc}{I}$$

$$= \frac{EI_c}{L}\left[\frac{39}{22.86239} + \frac{(15.15)^2 39}{2940.1}\right]$$

$$M_B = \frac{4.75043\,EI_c}{L}.$$

$$M_A = \frac{P}{A} - \frac{Mc}{I}$$

$$= \frac{EI_c}{L}\left[\frac{39}{22.86239} - \frac{(23.85)(15.15)39}{2940.1}\right]$$

$$M_A = \frac{-3.08710\,EI_c}{L}.$$

$$K_{BA} = \frac{4.75043\,EI_c}{L}. \leftarrow$$

$$C_{BA} = \frac{-3.08710}{4.75043} = 0.650 \leftarrow$$

SUBJECT FOX POINT PUMPING STATION

COMPUTATION SUPERSTRUCTURE FRAME

COMPUTED BY R.N.W. CHECKED BY GFH DATE 29 SEPT. 57

Frame factors cont'd

absolute $K_{AB} = \frac{9.25119\,EI}{L} = \frac{9.25119\,(6015)}{468} = 118.90.$

absolute $K_{BA} = \frac{4.75043\,EI}{L} = \frac{4.75043\,(2375)}{468} = 24.11.$

absolute $K_{BC} = \frac{4\,EI}{L} = \frac{4\,(2987)}{404} = 29.57.$

absolute $K_{CB} = \quad = 29.57.$

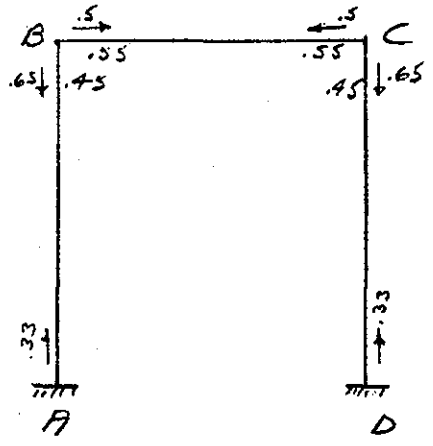
absolute $K_{CD} = \quad = 24.11.$

absolute $K_{DC} = \quad = 118.90.$

distribution factors for joints B & C

$\frac{K_{BA}}{\Sigma K} = \frac{24.11}{53.68} = .45.$

$\frac{K_{BC}}{\Sigma K} = \frac{29.57}{53.68} = .55.$

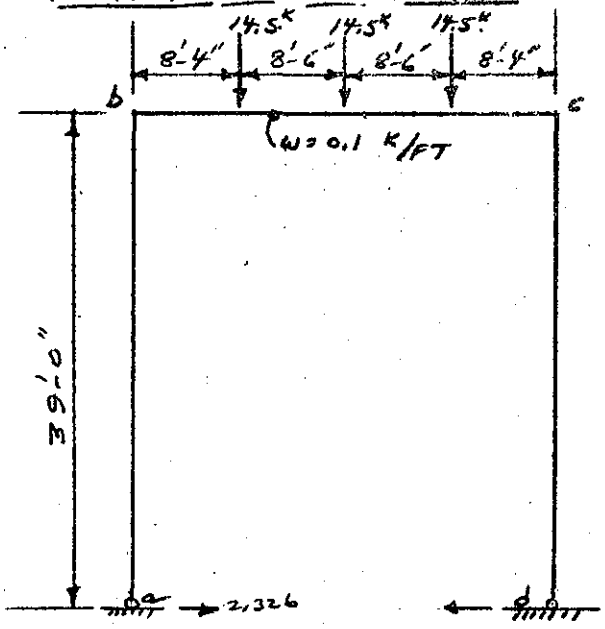


SUBJECT: FOX POINT PUMP STATION

COMPUTATION: SUPERSTRUCTURE FRAME

COMPUTED BY: T.N.W. CHECKED BY: GEH DATE: 1 OCT. 59

Vertical DL on frame -

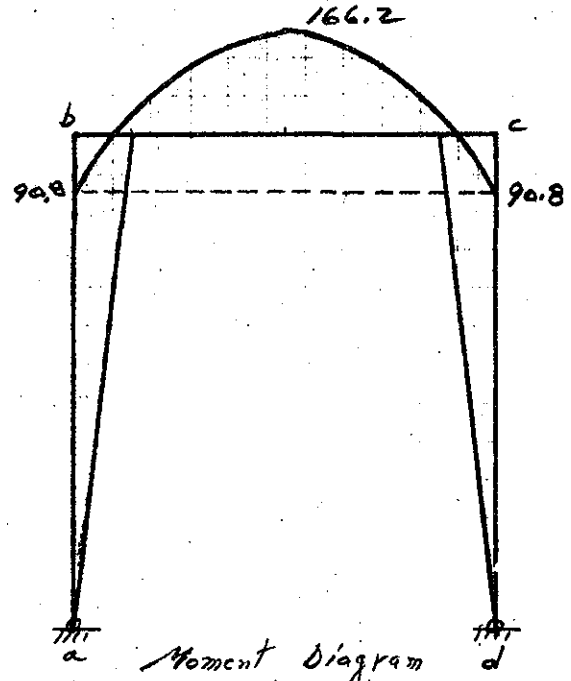


hinged at base

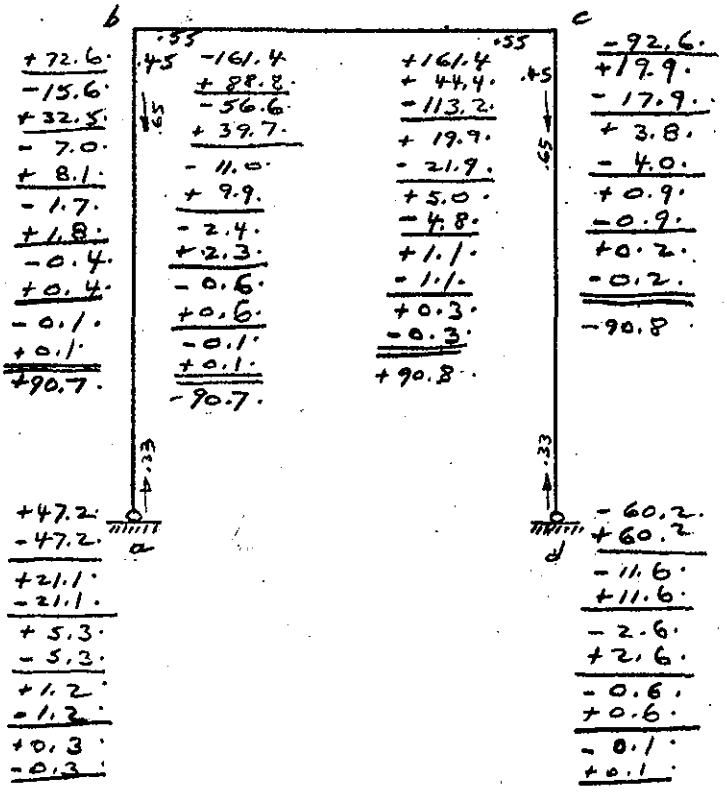
$$M_{Fbc} = 0.1(33.67)^2\frac{1}{12} + \frac{14.5(8.33)(25.34)^2}{(33.67)^2} + \frac{14.5(33.67)}{8} + \frac{14.5(25.34)(8.33)^2}{(33.67)^2}$$

$$M_{Fbc} = M_{Fcb} = 161.39 \text{ k-FT.}$$

$$V = \frac{1}{2}(3)(14.5) + \frac{1}{2}(.1)(33.67)$$
$$= 23.4^k$$

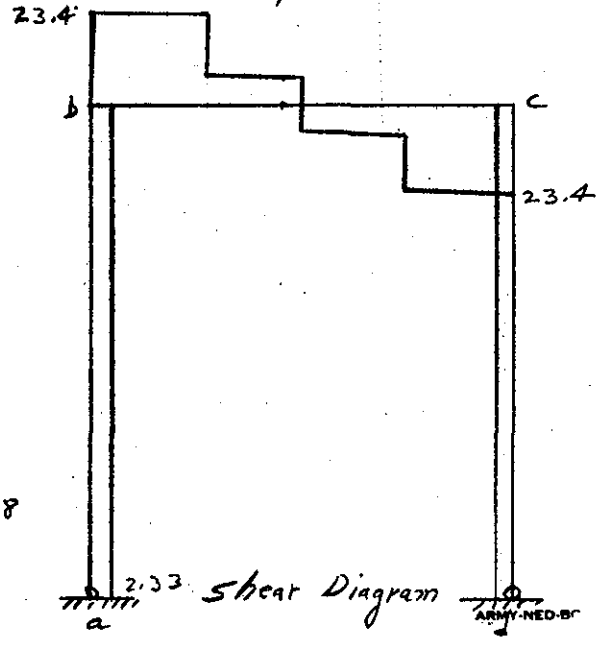


Moment Diagram
Comp. Side



$$\text{pos. } M = \frac{.1(33.67)^2}{8} + 14.5\left(\frac{33.67}{4} + 8.33\right) - 90.8$$
$$= 166.21.$$

$$H_a = -\frac{(90.7)}{39} = 2.326^k$$

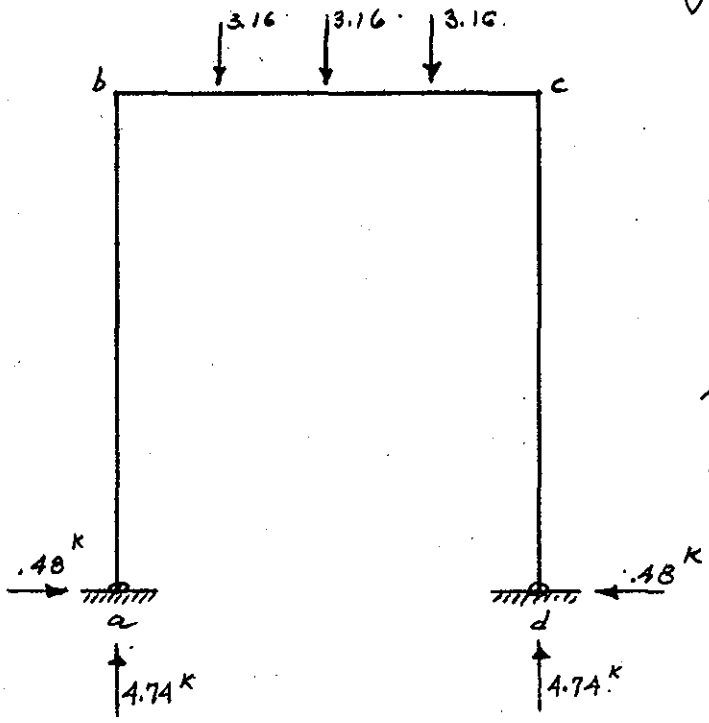


Shear Diagram

SUBJECT Fox Point Pumping Station
COMPUTATION Superstructure Frame
COMPUTED BY R.N.W. CHECKED BY GFH DATE 1 Oct. 59

Vertical L.L. on Frame - hinged base

Purlin load = 8.5(30)/165
= 3.16 k



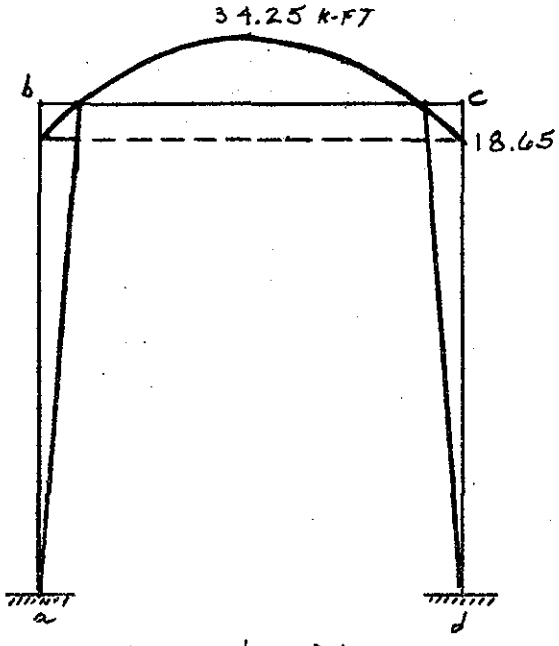
$$M_{fbc} = \frac{3.16(33.6)}{8} + \frac{3.16(8.33)(25.34)}{33.67}$$

$$M_{fbc} = 33.15 \text{ K-FT}$$

$$V = \frac{3(3.16)}{2} = 4.74^{k}$$

$$M_{bc} = \frac{-90.75(33.15)}{161.39} = -18.65 \text{ K-FT}$$

$$M_{ba} = +18.65$$



Moment Diagram
Comp. Side

$$H_a = -\frac{(18.65)}{39} = -0.478^{k}$$

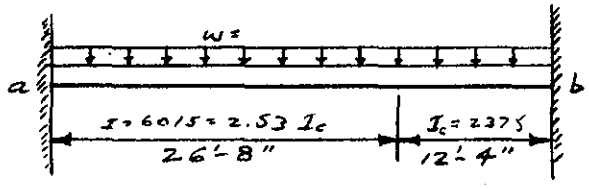
$$\text{pos } M = \frac{3.16(33.67)}{4} + 3.16(8.33) - 18.65 = 34.25 \text{ K-FT}$$

SUBJECT FOX POINT PUMPING STATION

COMPUTATION SUPERSTRUCTURE FRAME

COMPUTED BY R.N.W. CHECKED BY GFH DATE 5 OCT 57

Wind on left leg – 30 psf

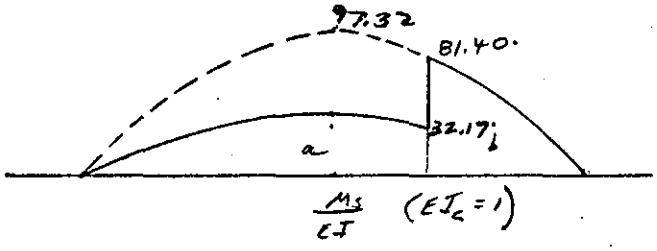


$I_{y_0y_0} = 2940.1$ (page 3)
$A = 22.86239$
$x_1 = 23.85'$
$x_2 = 15.15'$

$W = 16.5(30)(40.33) = 20.0$

simple $M = \frac{16.5(30)(40.33)(37)12}{8}$

$M = 11678.6$ K·IN
$= 97.32$ K-FT



Area of $b = \int_0^{12.33} (9.6525x - .2475x^2)\,dx = 579.35289 = P_2$

Moment of area b about a vertical axis through b

$= \int_0^{12.33} (9.6525x - .2475x^2)\,x\,dx = 4604.49477$

Distance between centroid of area b and right support

$= \frac{4604.49477}{579.35289} = 7.95'$

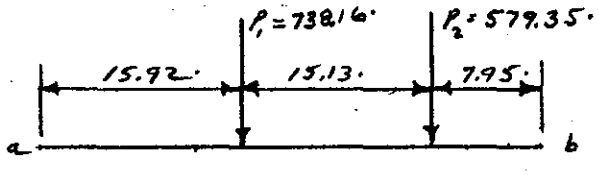
Area of $a = \frac{1}{2.53}\int_0^{26.67} (9.6525x - .2475x^2)\,dx = 738.16403 = P_1$

Moment of area a about a vertical axis through a

$= \frac{1}{2.53}\int_0^{26.67} (9.6525x - .2475x^2)\,x\,dx = 11748.78647$

Distance between centroid of area a and left support

$= \frac{11748.78647}{738.16403} = 15.92'$



Loads on top of analogous column

SUBJECT FOX POINT PUMPING STATION

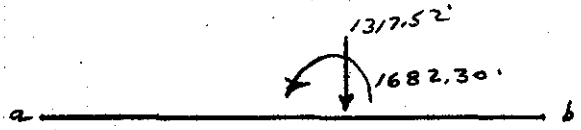
COMPUTATION SUPERSTRUCTURE FRAME

COMPUTED BY R.N.W. CHECKED BY GEH DATE 5 OCT. 59

Total load on column $= P_1 + P_2 = 1317.52$

Total Moment of loads about centroid

$$M = 738.16(7.93) - (579.35)(7.20) = 1682.30$$



Loads on top of analogous column

M_s at $a = 0$

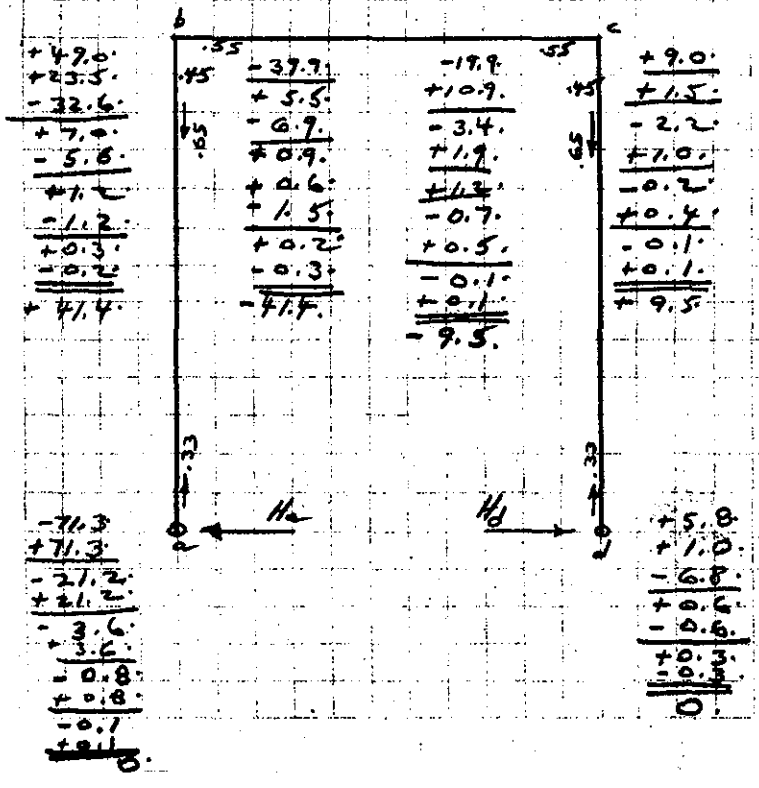
M_i at $a = \frac{P}{A} + \frac{Mc}{I} = \frac{1317.52}{22.86} + \frac{1682.30(23.85)}{2940.1} = 71.27$

$M_{fab} = M_s$ at $a - M_i$ at $a = -71.27$ K-FT.

M_s at $b = 0$

M_i at $b = \frac{P}{A} - \frac{Mc}{I} = \frac{1317.52}{22.86} - \frac{1682.30(15.15)}{2940.1} = 48.96$

$M_{fba} = M_s$ at $b + M_i$ at $b = +48.96$ K-FT.



Distributed moments without side sway

$H_a = 9.782 - \frac{(49.4)}{39} = 8.921$

$H_d = -\frac{(9.5)}{39} = -0.244$

Unbalanced Force,

$F_1 = \frac{16.5(30)(40.33)}{(1000)} - 8.921 + 0.244$

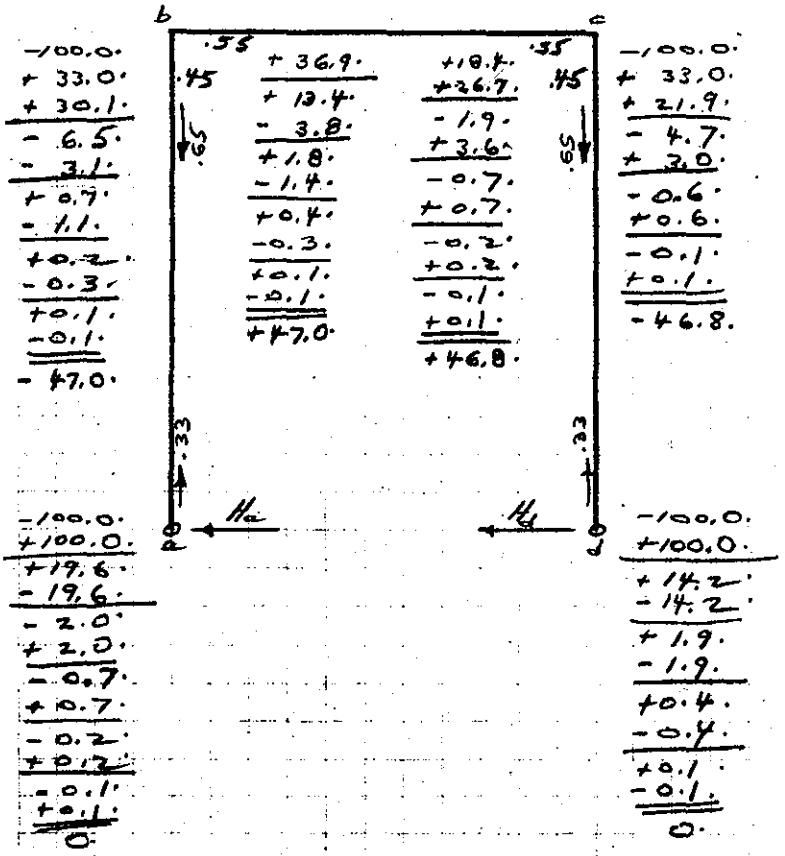
$F_1 = 11.288^K \rightarrow$

SUBJECT FOX POINT PUMPING STATION

COMPUTATION SUPERSTRUCTURE FRAME

COMPUTED BY R.N.W. CHECKED BY GFH DATE 6 OCT. 59

Distribute arbitrary moments of 100.0 k-FT on unloaded frame



$$H_a + H_d = -\frac{(-47.0-46.8)}{39}$$

unbalance $= F_2 = +2.40512$

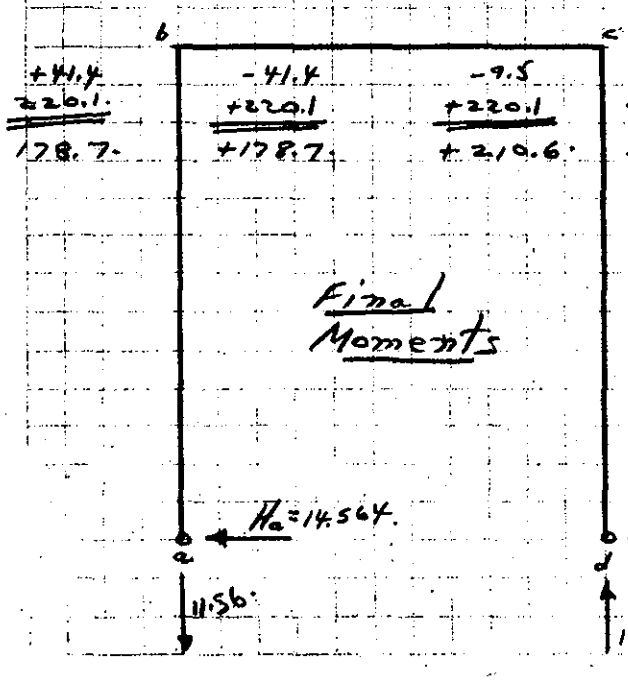
$$\text{Factor} = f = \frac{F_1}{F_2} = \frac{11.288}{2.405}$$

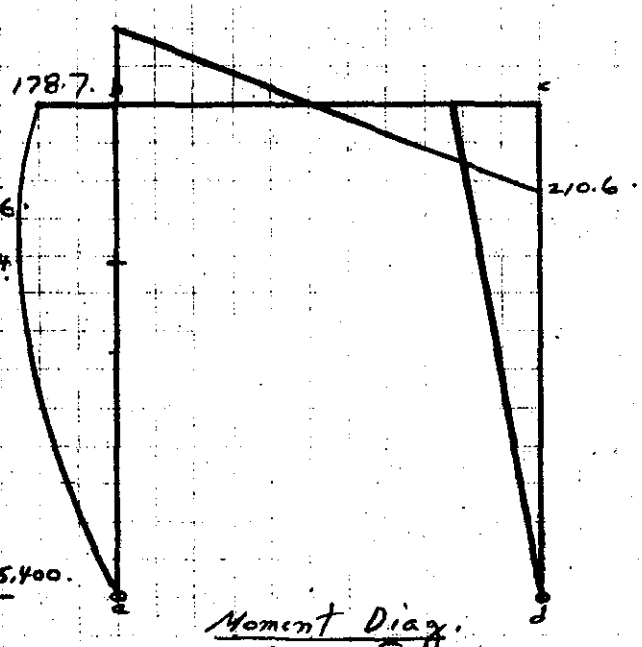
$$f = 4.693$$

Add moments found in first distribution (page 8) to moments at left multiplied by f. – Final moments shown below.

$$H_a = 9.982 - \frac{(-178.7)}{39} = +14.564$$

$$H_d = -\frac{(-210.6)}{39} = +5.400$$

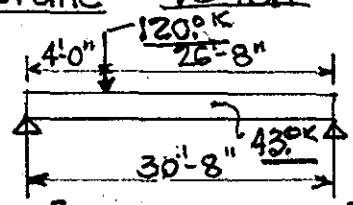




Moment Diag. Comp. Side

SUBJECT Fox Point Pump Station
COMPUTATION Crane and Crane Girder
COMPUTED BY E.P.R. CHECKED BY R.N.W. DATE 18 Sept. 1959

Crane 40 Ton

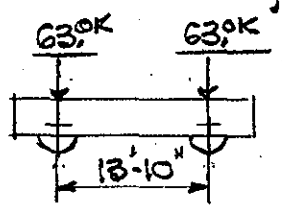


21.5	21.5
104.5	15.5
126.0	37.0

Max. carriage truck load

Load 80.0 K
Trolley, Hoist & Hook } 40.0
120.0 K

Carriage = 43.0 K



Crane Girder Span = 16'-6" Max. wheel load = 63.0 K
Impact 18% = 11.3
74.3 K

Assume girder weight
= 140
Rail = 25
165 #/l.f.

Vert. M = 165* × 16.5²/8 = 5.65
= 74.3 × 16.5/4 = 306.5
311.15
Say 312.0 K'

Lateral Load (10% of trolley + crane capacity) 3/4
Distributed equally between crane wheel at each end of carrige.

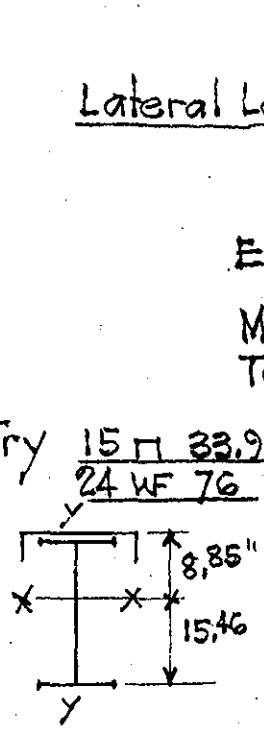
Each wheel = [(0.1 × 40.0 + 80.0)] 3/4 × 1/4 = 2.25 K

M in girder = 2.25 × 16.5/4 = 9.28 K'
Taken by top flg. of girder + ⊓

Try 15 ⊓ 33.9
24 WF 76

c.g. ⊓	9.9 × 0.79 =	7.8	
I	22.4 × 12.4 =	278.0	
	32.3	285.8	

285.8/32.3 = 8.85"



$I_x = 8.2 + (9.9 \times \overline{8.06}^2) = 8.2 + 644.0 = 652$
$2096.4 + (22.4 \times \overline{3.55}^2) = 2096.4 + 284.0 = 2380$
3032 in^4

$I_y = 312.6 + (0.68 \times \overline{8.99}^2/12) = 354 \text{ in}^4$

f (vert. lds) bottom flg. = 12 × 312 000 × 15.46 / 3032 = 19100 psi tension

Top flg. f (vert.) = 12 × 312 000 × 8.85 / 3032 = 11,000 psi compression
" " f (lateral) = 12 × 9280 × 7.5 / 354 = 2360 psi comp.

SUBJECT Fox Point Pumping Station

COMPUTATION

COMPUTED BY F.N.W. CHECKED BY GFH DATE 16 NOV. 59

Crane Girder - cont'd

$M_x = 312$ K-FT.

$M_y = 9.28\,(2)$ — Ref: Gaylord & Gaylord, Design of Steel Structures, p. 171.

Try 24 WF 110 without ⊔

$S_x = 274.4$ $\qquad \frac{Ld}{bt} = \frac{198(24.16)}{12.042(.855)} = 465. < 600$

$S_y = 38.0$

$f_x = \frac{312\,000(12)}{274.4} = 13644.$

$f_y = \frac{9280(2)(12)}{38.0} = 5861.$

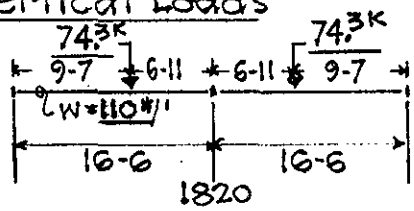
$f_x + f_y = 19505$ psi $< 20,000$

$\Delta = \frac{PL^3}{48EI} = \frac{74.3(198)^3 \times 10^3}{48(30)10^6(3315)} = 0.12''$ $\qquad$ allow. $\Delta = \frac{L}{1000} = 0.198.$ O.K.

SUBJECT Fox Point Pump Station
COMPUTATION Superstructure Frame
COMPUTED BY E.P.R. CHECKED BY R.N.W. DATE 18 Sept. 1959

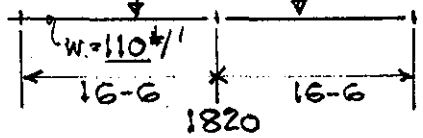
Crane Loads on Frame

Vertical Loads



1820
43135
43135
89090#

Heavy end

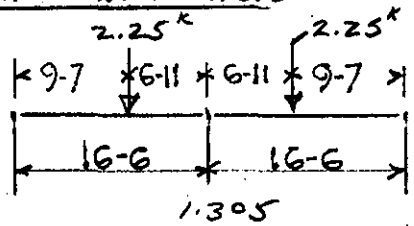


Whl. Ld = 18.5
Impact = 3.3
21.8K

1820
12700
12700
27220#

Light end

Lateral Loads



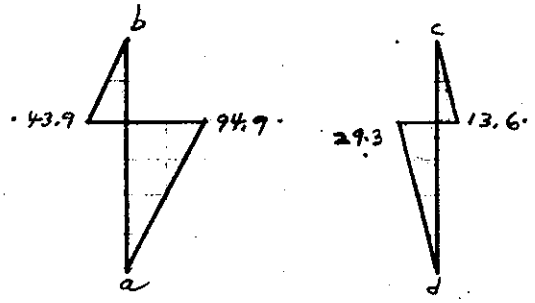
1.305
1.305
2.61 Both sides

SUBJECT: FOX POINT PUMPING STATION
COMPUTATION: SUPERSTRUCTURE FRAME
COMPUTED BY: R.N.W. CHECKED BY: GFH DATE: 9 OCT. 59

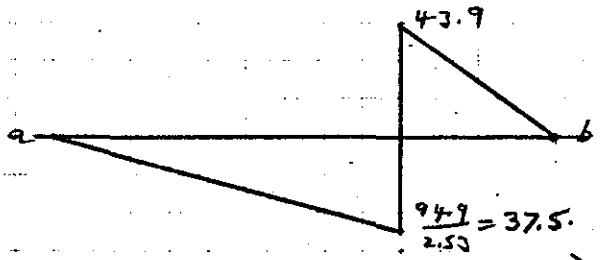
Vertical Crane Loads - See p. 11

Bracket $M = 1.576(88.09) = 138.8$ K-FT (column a b)

Bracket $M = 1.576(27.22) = 42.9$ K-FT (column cd)



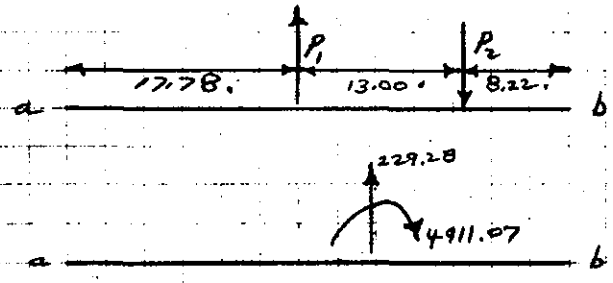
Member a-b



$\frac{MS}{EI}$ Diag. $(EI_c = 1)$.

$P_1 = 37.5(26.67)\frac{1}{2} = 500.00$

$P_2 = 43.9(12.33)\frac{1}{2} = 270.71659$



Total load on analogous column $= -P_1 + P_2 = -229.28341$

Total Moment about centroid
$M = 500(6.07) + 270.72(6.93)$
$M = 4911.06596$

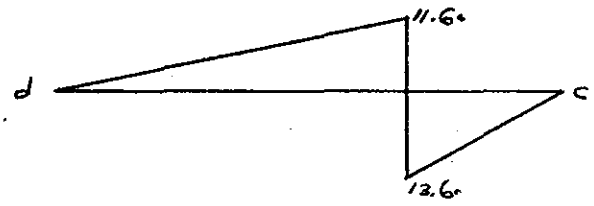
$$M_{Fab} = \frac{-229.28}{22.86} - \frac{4911.07(23.85)}{2940.1} = -49.87$$

$$M_{Fba} = -\frac{229.28}{22.86} + \frac{4911.07(15.15)}{2940.1} = +15.28$$

SUBJECT FOX POINT PUMPING STATION
COMPUTATION SUPERSTRUCTURE FRAME
COMPUTED BY R.N.W. CHECKED BY GEH DATE 9 OCT. 59

Vertical Crane Loads – cont'd.

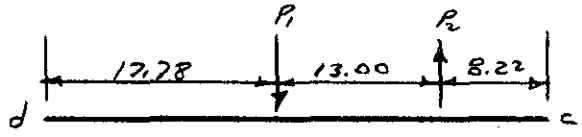
Member ed



$\frac{M_s}{EI}$ Diag $(EI_c = 1)$

$P_1 = 26.67(11.6)\frac{1}{2} = 154.40002$

$P_2 = 13.6(12.33)\frac{1}{2} = 83.86664$

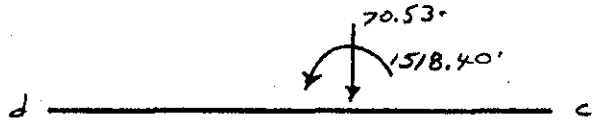


Total Load = 70.53338

Total Moment about centroid,

$M = 154.40(6.07) + 83.87(6.93)$

$= 1518.40393$



Loads on analogous column

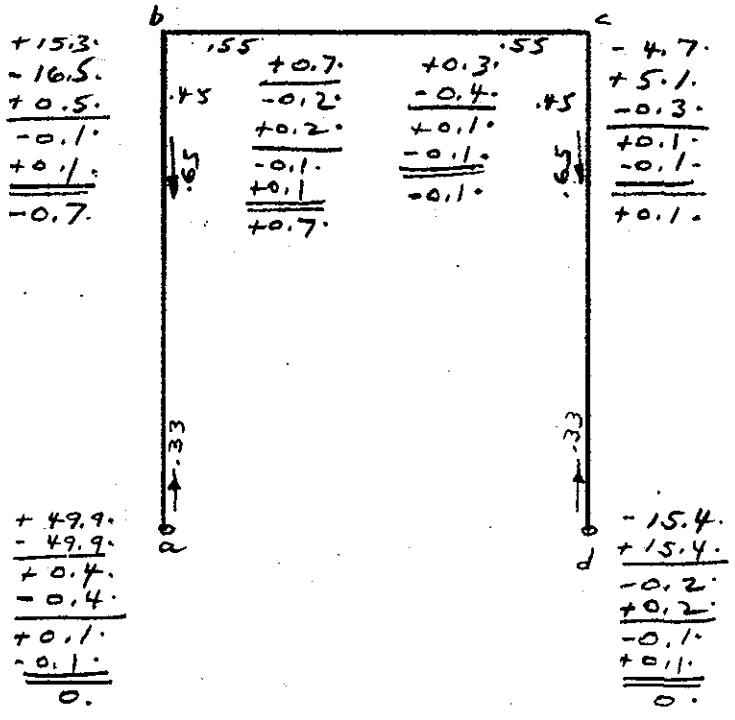
$$M_{Fdc} = \frac{70.53}{22.86} + \frac{1518.40(23.85)}{2940.1} = 15.40 \text{ K-FT}$$

$$M_{Fcd} = \frac{70.53}{22.86} - \frac{1518.40(15.15)}{2940.1} = -4.74 \text{ K-FT}$$

SUBJECT FOX POINT PUMPING STATION
COMPUTATION SUPERSTRUCTURE FRAME
COMPUTED BY R.N.W. CHECKED BY GEH DATE 14 OCT. 59

Vertical Crane Loads - cont'd

Distribute Fixed End Moments without side sway



Simple beam $H_a = \frac{138.8}{39} = 3.56 \rightarrow$

Simple beam $H_d = \frac{42.9}{39} = 1.10 \leftarrow$

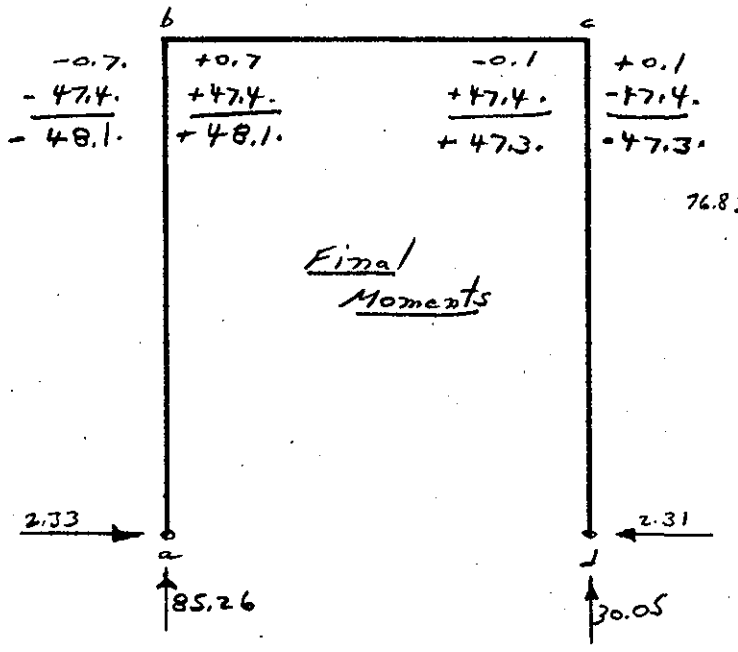
$H_a = 3.56 - \frac{.7}{39} = 3.54. \rightarrow$

$H_d = 1.10 - \frac{0.1}{39} = 1.10. \leftarrow$

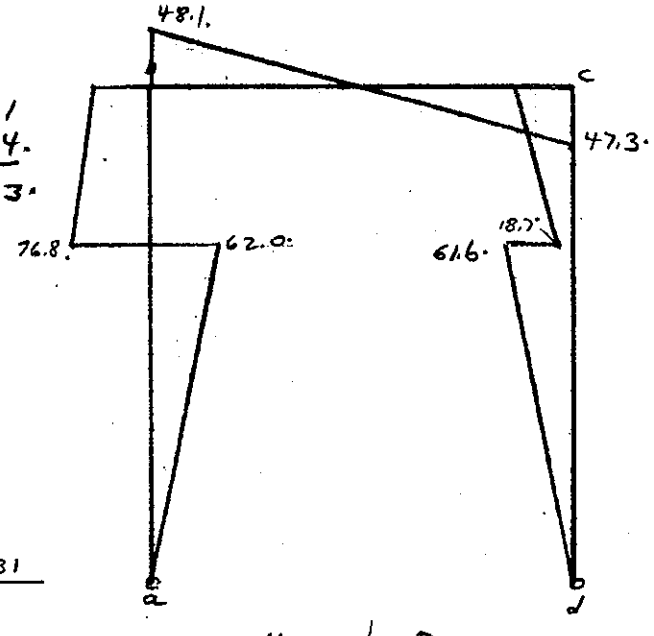
Unbalanced force = 2.44 →

Factor = $f = \frac{2.44}{2.405} = 1.01.$

(Sidesway distribution found on p. 9.)



Final Moments



Moment Diag Comp. Side

$H_a = 3.56 - \frac{48.1}{39} = 2.33.$

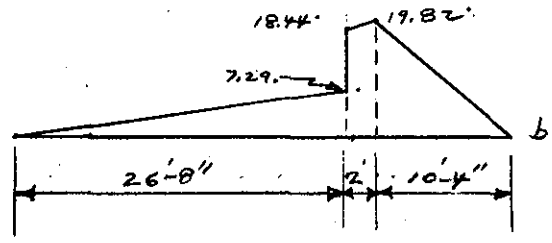
$H_d = 1.10 + \frac{47.3}{39} = 2.31.$

SUBJECT FOX POINT PUMPING STATION

COMPUTATION SUPERSTRUCTURE FRAME

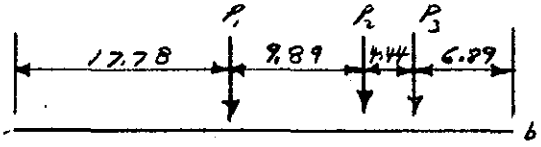
COMPUTED BY R.N.W. CHECKED BY GFH DATE 15 OCT. 59

Lateral Crane Loads



$P = 2.61^{K}$ simple $M = \frac{2.61(10.33)(28.67)}{39}$

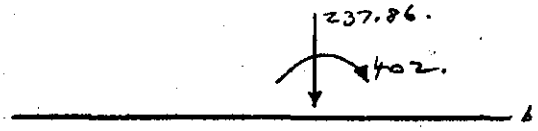
$= 19.82$ K-FT.



$P_1 = 26.67(7.29)\frac{1}{2} = 97.20001.$

$P_2 = \left(\frac{18.44+19.82}{2}\right) 2.00 = 38.26.$

$P_3 = 10.33(19.82)\frac{1}{2} = 102.40330.$



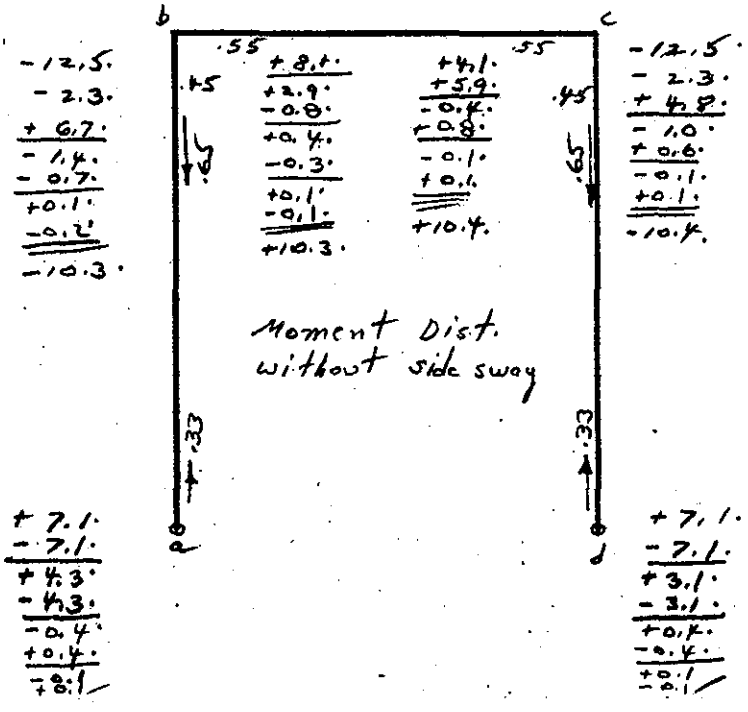
Total Load = 237.86331.

Total Moment about centroid,

$M = 38.26(3.82) + 102.40(8.26) - 97.2(6.07) = 402.00039.$

$M_{fab} = \frac{237.86}{22.86} - \frac{(402)(23.85)}{2940.1} = 7.14.$ K-FT

$M_{fba} = \frac{237.86}{22.86} + \frac{402(15.15)}{2940.1} = 12.48.$ K-FT



Simple beam $H_a = \frac{10.33(2.61)}{39}$

$= 0.69. \rightarrow$

$H_d = 0.69. \rightarrow$

$H_a = 0.69 - \frac{10.3}{39} = 0.427. \rightarrow$

$H_d = 0.69 - \frac{10.4}{39} = 0.425. \rightarrow$

Unbalanced $F = 2(2.61) - .852.$

$F = 4.368. \leftarrow$

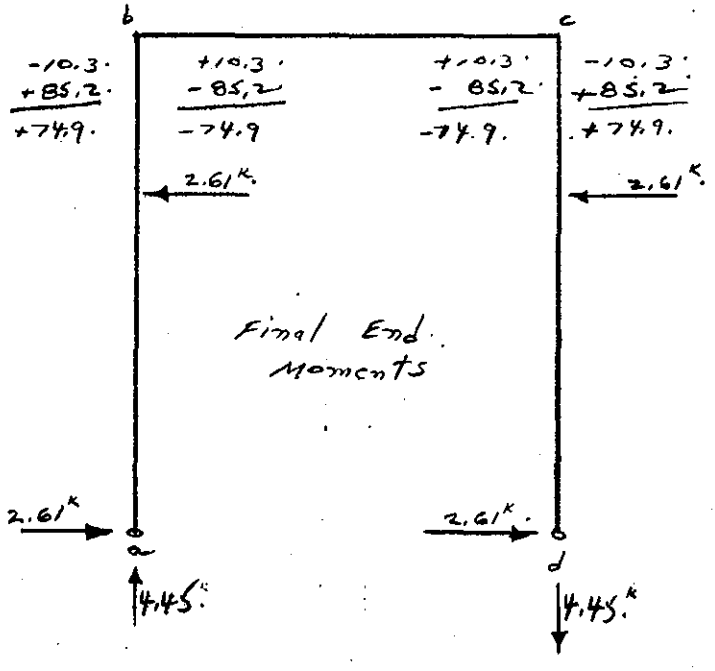
Factor $= f = \frac{4.368}{2.405} = -1.816.$

SUBJECT FOX POINT PUMPING STATION

COMPUTATION SUPERSTRUCTURE FRAME

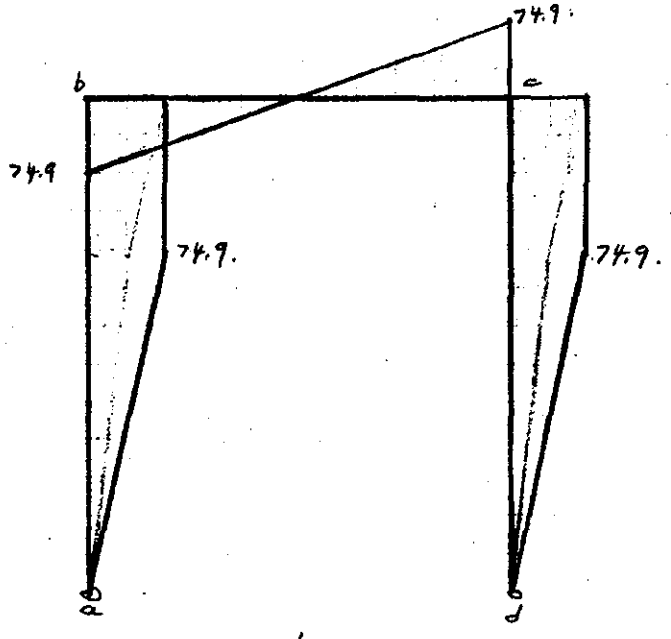
COMPUTED BY R.N.W. CHECKED BY GEH DATE 15 OCT. 59

Lateral Crane Loads – cont'd.



$$H_a = 0.69 + \frac{74.9}{39} = 2.61$$

$$V = 2\frac{(2.61)(28.67)}{33.67} = 4.45^k$$



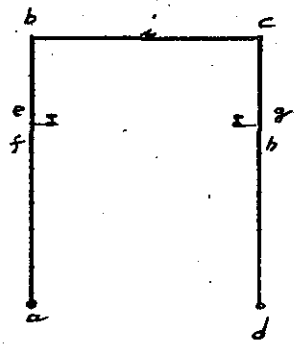
Moment Diag.
Comp. Side

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT: FOX POINT PUMPING STATION
COMPUTATION: SUPERSTRUCTURE FRAME
COMPUTED BY: P.N.W. CHECKED BY: GFH DATE: 20 OCT. 59

Design Moments



Point on Frame → / Loading ↓	At Crane Girder f	a	Col. & Gird. b	Girder ℄ i	Col. & Gird. c	At Crane Girder g	h
D.L.	+62.1	+62.1	+90.8	−166.2	+90.8	+62.1	+62.1
L.L.	+12.7	+12.7	+18.6	−34.2	+18.6	+12.7	+12.7
Wind-left	−212.4	−212.4	−178.7	+15.9	+210.6	+144.0	+144.0
Vert. Crane-left	+62.0	−76.8	−48.1	−0.4	+47.3	+18.7	+61.6
Vert. Crane-right	+61.6	+18.7	+47.3	−0.4	−48.1	−76.8	+62.0
Lat. Crane ←	+74.9	+74.9	+74.9	0	−74.9	−74.9	−74.9
Lat. Crane →	−74.9	−74.9	−74.9	0	+74.9	+74.9	+74.9
D.L. + L.L.	+74.8	+74.8	+109.4	−200.4	+109.4	+74.8	+74.8
D.L. + ½ L.L. + W.L.	−143.9	−143.9	−78.6	−167.4	+320.0	+212.5	+212.5
D.L. + W.L.	−150.3	−150.3	−87.9	−150.3	+301.40	+206.1	+206.1
D.L. + C.L. (left) + Lat ←	+199.0	+60.2	+117.6	−166.6	+63.2	+5.9	+48.8
D.L. + C.L. ← + L.L.	+136.8	−2.0	+61.3	−200.8	+156.7	+93.5	+136.4
D.L. + W.L. → + C.L. ← + LBT ←	−13.4	−152.2	−61.1	−150.7	+273.8	+149.9	+192.8
D.L. + W.L. → + C.L. + LBT →	−163.6	−206.5	−115.5	−150.7	+328.2	+204.2	+343.0
D.L. + L.L. + C.L. ← + LBT ←	+211.7	+72.9	+136.2	−200.8	+81.8	+18.6	+61.5

SUBJECT: FOX POINT PUMPING STATION

COMPUTATION: SUPERSTRUCTURE FRAME

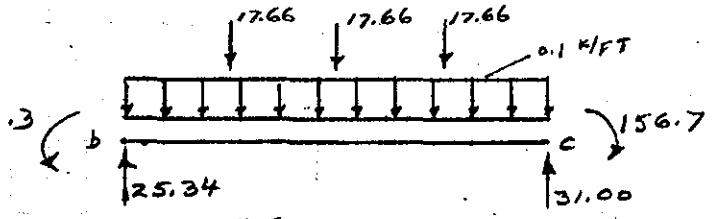
COMPUTED BY: R.N.W. CHECKED BY: GFH DATE: 20 OCT. 59

Design of Girder

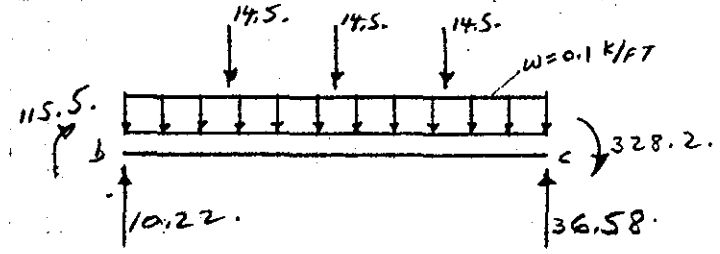
Span = 33'-8"

$f_s = 20{,}000$ psi

$-M = 136.2$ K-FT (D.L.+L.L.+C.L.+LAT)
$+M = 212.3$ K-FT (D.L.+C.L.+L.L.)
$-M = 328.2$ K-FT (D.L.+C.L.+LAT+W.L.)



$S_{req} = \frac{12(156.7)}{20} = 94 \text{ IN}^3$



$S_{req} = \frac{12(328.2)}{26.6} = 148 \text{ IN}^3$

21 WF 73

S = 150.7

shear: $v = \frac{36580}{21(.455)} = 3828.$ psi

Design of column

a) Upper Section

P = 31.00 (No wind)
= 36.58 (wind)

Moment at bottom flange of girder:

M (DL) = - 88.7.
(LL) = - 18.3
(CL) = - 45.2.
- 152.2

M = (DL) = - 88.7.
(WL) = - 205.8.
(CL) = + 50.2. P=36.98
(LAT) = + 74.9
319.2

Try Web – 13" x ½"
Flange – 11" x 1"

A = 22 + 6.5 = 28.5.

$I_x = \frac{.5(13)^3}{12} + 11(7)^2 2 = 1170 \text{ IN}^4$

$S = \frac{1170}{7.5} = 156 \text{ IN}^3$

$I_y = (11)^3 2\left(\frac{1}{12}\right) = 222 \text{ IN}^4$

$r = \sqrt{\frac{222}{28.5}} = 2.79.$

$\frac{l}{r} = \frac{148}{2.79} = 53.$

$F_a = 15638(1.33) = 20851.$ psi

$f_a = \frac{36580.}{28.5} = 1284$ psi

$f_b = \frac{319.2(12)}{156} = 24554.$ psi

$\frac{f_a}{F_a} + \frac{f_b}{F_b} = .06 + .92 = 0.98.$ O.K.

SUBJECT FOX POINT PUMPING STATION
COMPUTATION SUPERSTRUCTURE FRAME
COMPUTED BY T.N.W. CHECKED BY GFH DATE 21 OCT. 59

Design of column

b) Lower Section

max. M (wind) = 343.0 K-FT D.L. + W.L. + CL + LAT
$P = 23.43 + 11.58 + 85.26 + 4.45 = 124.72^k$

max. M (without Wind) = 216.0 K-FT D.L. + L.L. + CL + LAT
$P = 23.43 + 4.78 + 85.26 + 4.45 = 117.92^k$

Try Web – 21" x ½"
Flange – 2 PL – 11" x 1" $A = 22 + 10.5 = 32.5 \text{ IN}^2$

$I_x = \frac{.5(21)^3}{12} + 11(11)^2 2 = 3048 \text{ IN}^4$

$S = \frac{3048}{11.5} = 265 \text{ IN}^3$

$I_y = \frac{(11)^3 2}{12} + \frac{21(.5)^3}{12} = 222 \text{ IN}^4$

$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{222}{32.5}} = 2.61 \text{ IN.}$

$\frac{l}{r} = \frac{26.67(12)}{2.61} = 123.$ $F_A = 9662.$ 12883. (with wind)

$\frac{ld}{bt} = \frac{26.67(12)(23)}{1(11)} = 669$ $F_B = 17937.$ 23916. (with wind)

with wind:

$f_a = \frac{124720}{32.5} = 3838 \text{ psi}$

$f_b = \frac{343(12)}{265} = 15532 \text{ psi}$

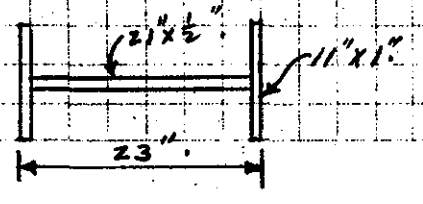
$\frac{f_a}{F_a} + \frac{f_b}{F_b} = .30 + .65 = 0.95.$ O.K

without wind:

$f_a = \frac{117920}{32.5} = 3628 \text{ psi}$

$f_b = \frac{216(12)}{265} = 9781 \text{ psi}$

$0.38 + 0.55 = 0.93.$ O.K

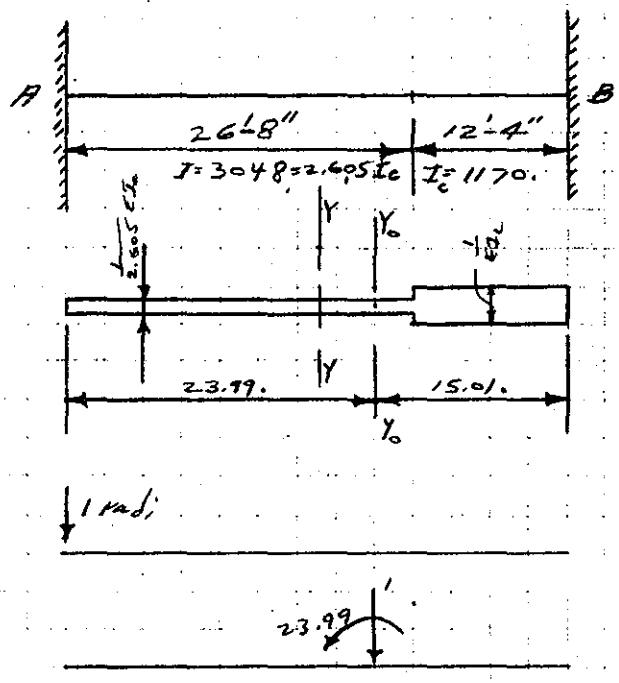


SUBJECT FOX POINT PUMPING STATION

COMPUTATION SUPERSTRUCTURE FRAME

COMPUTED BY R.K.W. CHECKED BY GEH DATE 22 OCT. 59

check column Factors



Loads on top

Letting $EI_c = 1$

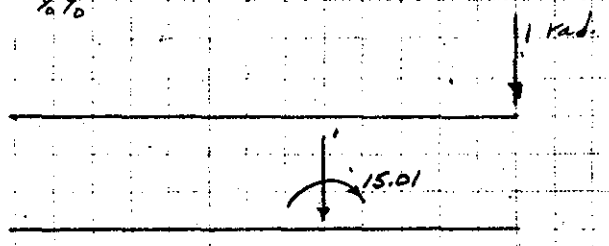
$$\bar{x} = \frac{26.67(.38385)(-6.16667) + 12.33(13.33333)}{12.33 + 26.67(.38385)}$$

$$\bar{x} = +4.48938.$$

$$A = 12.33 + .38385(26.67) = 22.56933.$$

$$I_{Y_oY_o} = .38385(26.67)^3\tfrac{1}{12} + (1)(12.33)^3\tfrac{1}{12} + 26.67(.38385)(10.66)^2 + 12.33(8.84)^2$$

$$I_{Y_oY_o} = 2889.9.$$



Loads on top

Factors at A:

$$M_A = \frac{P}{A} + \frac{Mc}{I}$$

$$= EI_c\left(\frac{1}{22.56933}\right) + \frac{EI_c(23.99)^2}{2889.9}$$

$$= \frac{EI_c}{L}\left(\frac{39}{22.56933}\right) + \frac{EI_c}{L}\frac{(23.99)^2 39}{2889.9}$$

$$M_A = \frac{9.4948\,EI_c}{L} = K_{AB} \leftarrow$$

$$M_B = \frac{P}{A} - \frac{Mc}{I}$$

$$M_B = \frac{EI_c}{L}\left[\frac{39}{22.56933} - \frac{23.99(15.01)(39)}{2889.9}\right]$$

$$M_B = -\frac{3.13151\,EI_c}{L}.$$

$$C_{AB} = \frac{3.13151}{9.4948} = 0.330 \leftarrow$$

Factors at B:

$$M_B = \frac{P}{A} + \frac{Mc}{I}$$

$$= \frac{EI_c}{L}\left[\frac{39}{22.56933} + \frac{(15.01)^2 39}{2889.9}\right]$$

$$M_B = \frac{4.76848\,EI_c}{L} = K_{BA} \leftarrow$$

$$M_A = \frac{P}{A} - \frac{Mc}{I}$$

$$= \frac{EI_c}{L}\left[\frac{39}{22.56933} - \frac{15.01(23.99)39}{2889.9}\right]$$

$$M_A = -\frac{3.13151\,EI_c}{L}.$$

$$C_{BA} = \frac{3.13151}{4.76848} = 0.657. \leftarrow$$

SUBJECT Fox Point Pumping Station
COMPUTATION Superstructure Frame
COMPUTED BY R.N.W. CHECKED BY GFH DATE 22 Oct. 59

Frame Factors cont'd

absolute $K_{BA} = \frac{4.76848 E I_c}{L} = \frac{4.76848(1170)}{468} = 11.92 E$

absolute $K_{BC} = \frac{4EI}{L} = \frac{4(16003)}{404} = 15.86 E$

absolute $K_{CB} = \quad = 15.86 E$

absolute $K_{CD} = \quad = 11.72 E$

distribution factors for joints B & C

$\frac{K_{BA}}{\Sigma K} = \frac{11.92}{27.78} = 0.43$

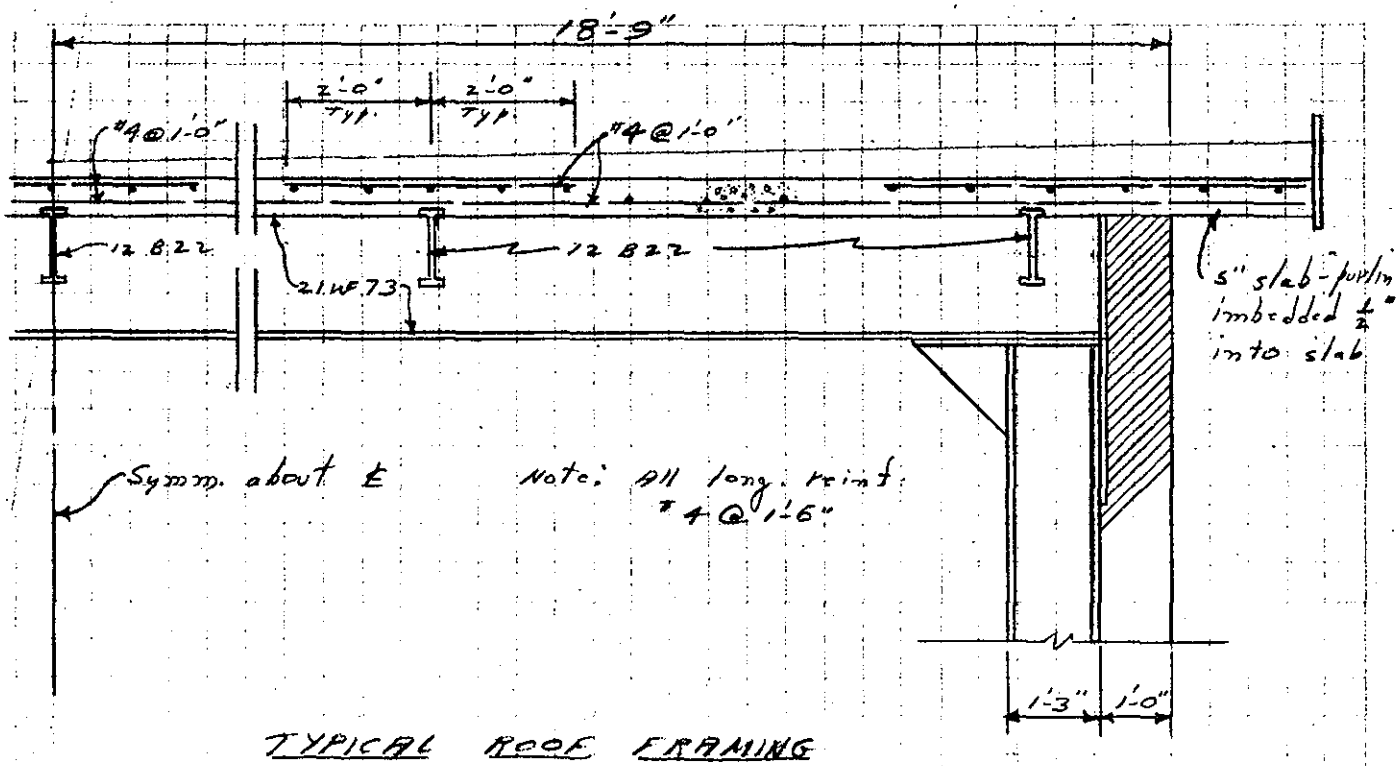
$\frac{K_{BC}}{\Sigma K} = \frac{15.86}{27.78} = 0.57$

} close enough to original factors

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT FOX POINT PUMPING STATION
COMPUTATION SUPERSTRUCTURE FRAME
COMPUTED BY P.N.W. CHECKED BY DATE 11 JAN. 60



TYPICAL ROOF FRAMING AND SLAB

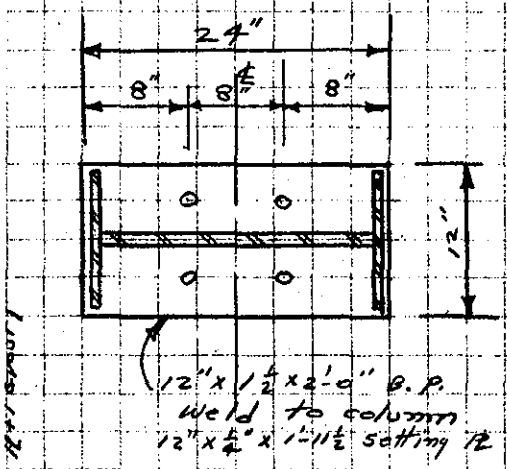
SUBJECT FOX POINT PUMPING STATION
COMPUTATION SUPERSTRUCTURE FRAME
COMPUTED BY R.N.W. CHECKED BY GFH DATE 3 NOV. 59

Column Base Plate max $P = 120^k$

H (DL) = 2.33
(LL) = 0.64
(CL) = 2.32
(LAT) = 2.61
7.90 = H (w/o wind)

H (DL) = 2.33
(WL) = 14.56
12.23

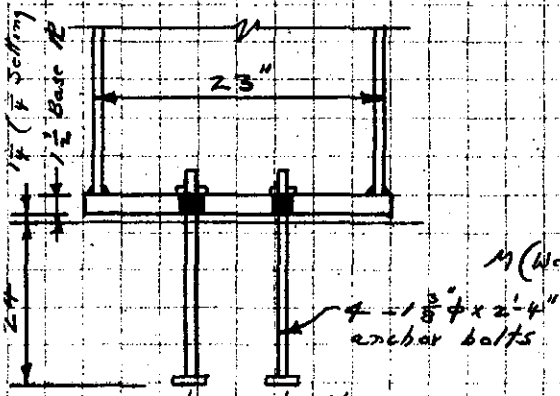
H (DL) 2.33
(WL) 5.40
(CL) 2.32
LAT 2.61
12.66



Area of PL = $\frac{120,000}{625}$ = 192 IN^2

Base Plate size governed by size of column
= 12 x 24 = 288 IN^2

$p = \frac{120000}{288} = 417$ psi



$m = \frac{24 - .95(23)}{2} = 1.08$

$n = \frac{12 - .8(11)}{2} = 1.60$

cant. M = 1.6(417)(.8) = 534 in-lb

M(web to edge) = 417(5.75)(2.875) = 6894 in-lb

$\frac{bt^2}{6} = \frac{6.894}{20.0}$ t = 1.44" say 1½"

12" x 1½" x 2'-0"

4 anchor bolts

$H = \frac{12.66}{4} = 3.165$ each

M = 3165 (2.0) = 6330 in-lb

req. $S = \frac{6330}{26600} = 0.238 IN^3$

$R = \sqrt[3]{\frac{.238}{.785}} = (.303)^{\frac{1}{3}} = .67$

D = 2(.67) = 1.34"

Say 1⅜"

H (w/o wind) = $\frac{7.9}{4}$ = 1.975^k each

M = 1975 (2.0) = 3950 in-lb

$f = \frac{3950}{.255} = 15490$ psi ok.

Anchor bolt brg. against concrete

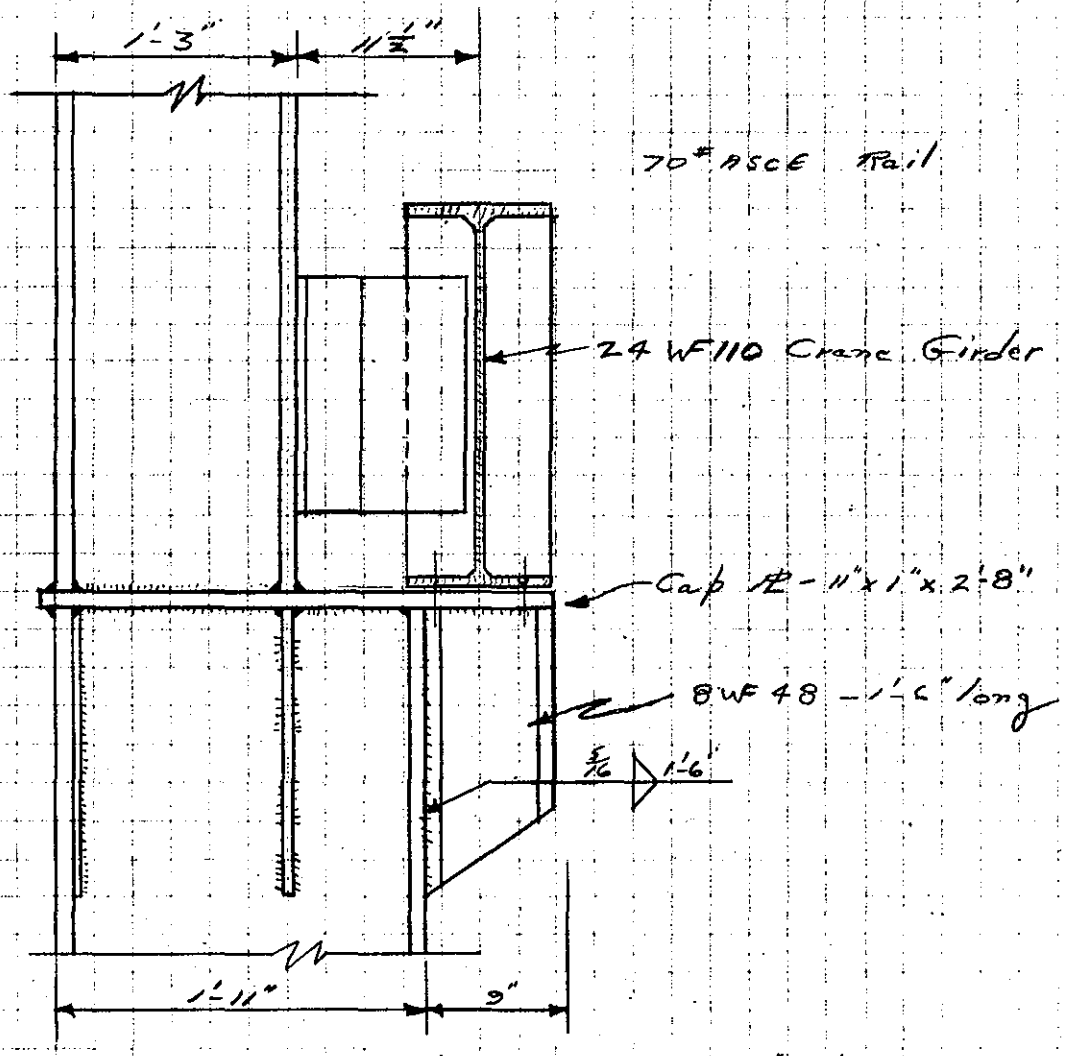
$= \frac{2110\ (2)}{24(1.375)} = 128$ psi max.

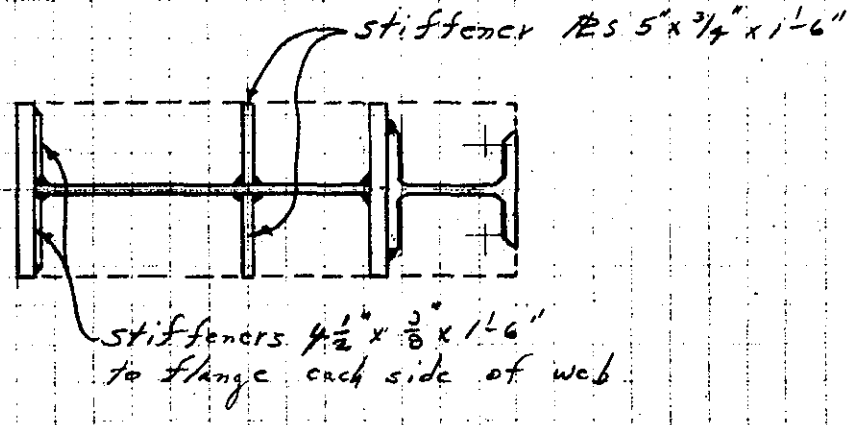
SUBJECT FOX POINT PUMPING STATION

COMPUTATION SUPERSTRUCTURE FRAME

COMPUTED BY R.N.W. CHECKED BY GFH DATE 3 NOV. 59

Stepped Column at Crane Girder





Scale: 1" = 1'-0"

SUBJECT: FOX POINT PUMPING STATION
COMPUTATION: SUPERSTRUCTURE FRAME
COMPUTED BY: R.N.W. CHECKED BY: GFH DATE: 6 NOV. 57

Roof Girder - Column Connection

Max. - M = 328.2 K-FT.

H (top & bot. flange of girder) = $\frac{328.2(12)}{21.24}$ = 185.4 K

7/8" rivets or byten bolts S.S. = 9.02 (1.33) = 12.0 K
No. req. = $\frac{185.4}{12}$ = 15.5

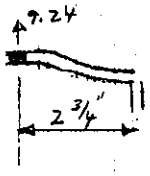
1" " S.S. = 11.78 (1.33) = 15.71 K
No. req. = $\frac{185.4}{15.71}$ = 11.8

Plate at bottom flange of girder
$A = \frac{185.4}{26.6}$ = 6.97 in²
$t = \frac{6.97}{10 - 2(1.0)}$ = 0.87 use 1" PL

Connection to outer face of column & end of girder
$V = \frac{12(328.2)}{15}$ = 262.56 K
using 1" byten bolts no. req. = $\frac{262.56}{15.71}$ = 16.71
PL 12½" $t = \frac{262.56}{26.6(12.5 - 2.25)}$ = 0.96 12½" x 1" PL
Fillet weld plate to column flange
½" Δ = $\frac{262.56}{4.8}$ = 55 lin. in
⅜ Δ = $\frac{262.56}{3.6}$ = 73 lin. in.

Max. + M = 115.5

Conn. bott. flange of girder $V = \frac{12(115.5)}{15}$ = 92.4 K
with 7/8" bolts, tension each of 10 bolts = $\frac{92400}{10(.551)}$ = 16,750 psi



M = 9.24 (2.75) ½ = 12.705 in-K use 18 - 1" bolts
$t = \sqrt{\frac{12705\ (6)}{26600\ (3)}}$ = 0.978 use t = 1"

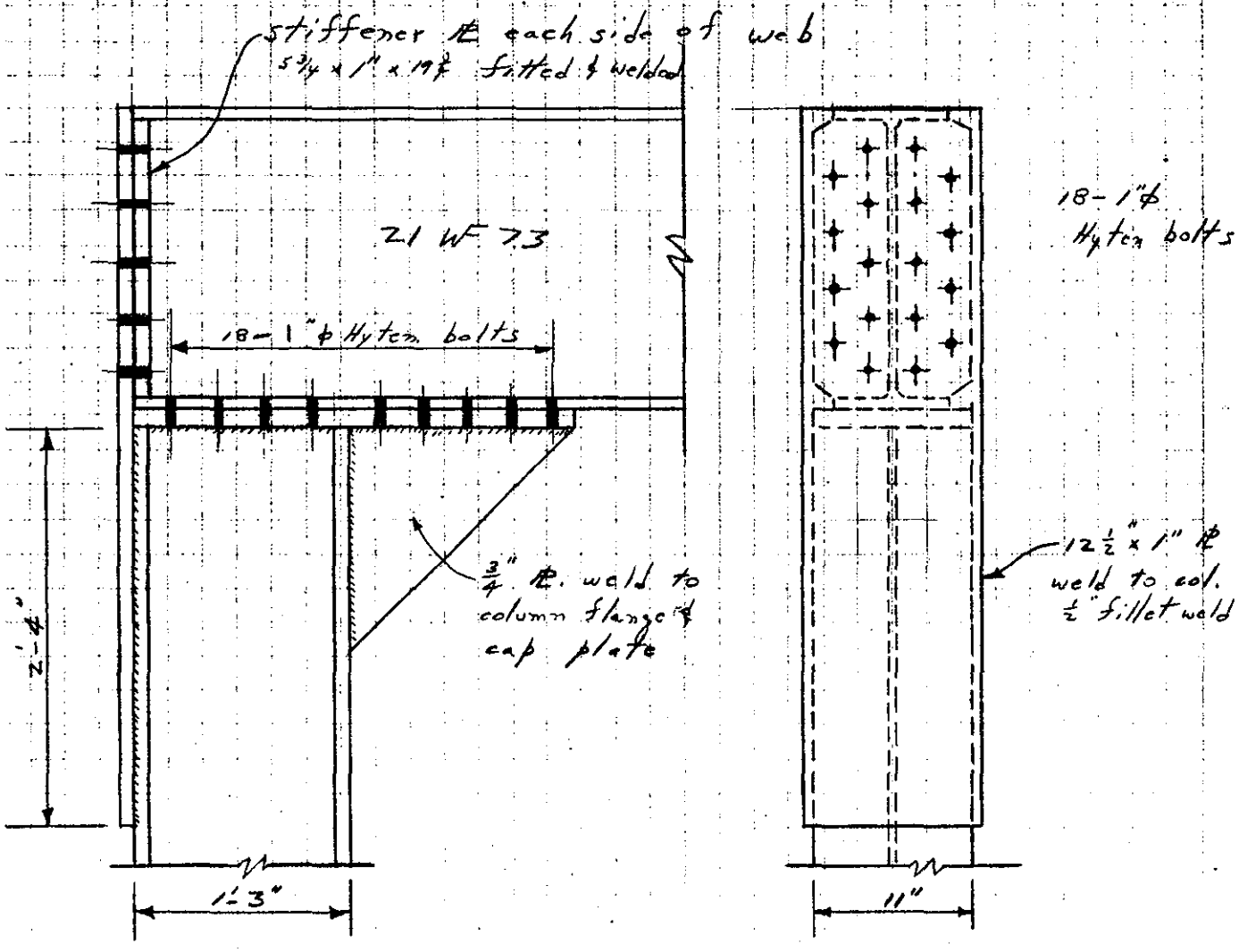
Web f = $\frac{92400}{15(.75)}$ = 8213 psi ¾" PL

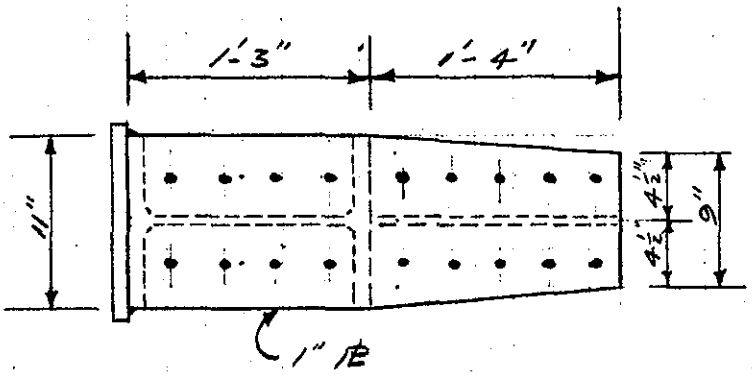
ED FORM 223
7 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pumping Station
COMPUTATION Superstructure Frame
COMPUTED BY R.N.W. CHECKED BY GFH DATE 9 Nov. 59

Column - Roof Girder Connection





Column Cap Plate

Scale: 1" = 1'-0"

SUBJECT FOX POINT PUMPING STATION

COMPUTATION SUPERSTRUCTURE — TYPICAL 66'-0" MONOLITH

COMPUTED BY R.N.W. CHECKED BY GFH DATE 24 NOV. 59

Struts & diag. bracing - See sketch, next page

assume each end bent acts as a frame, each bent acted on by 1/2 longitudinal force = 7.43^k

$H_{5-8} = 7.43^k$ comp.

$$\frac{15.83}{19.57} S_{5-7} + \frac{15.83}{16.6} S_{5-9} = 7.43$$

$$\frac{11.5}{19.57} S_{5-7} = \frac{5.0}{16.6} S_{5-9}$$

$S_{5-9} = 5.43^k$ Tension

$S_{5-7} = 2.78^k$ Tension

$H_{6-7} = \frac{15.83}{19.57}(2.78) = 2.25^k$ comp.

$H_{4-9} = \frac{15.83}{16.6}(5.43) = 5.18^k$ comp.

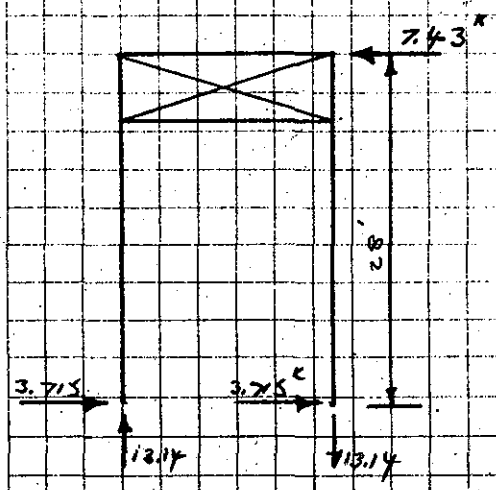
Diagonals $P = 5.43$

$$\text{min. } r = \frac{12(19.57)}{300} = 0.78$$

2 ∟ 2½ × 2 × 5/16 ←

$$f = \frac{5430}{2.62} = 2073 \text{ psi}$$

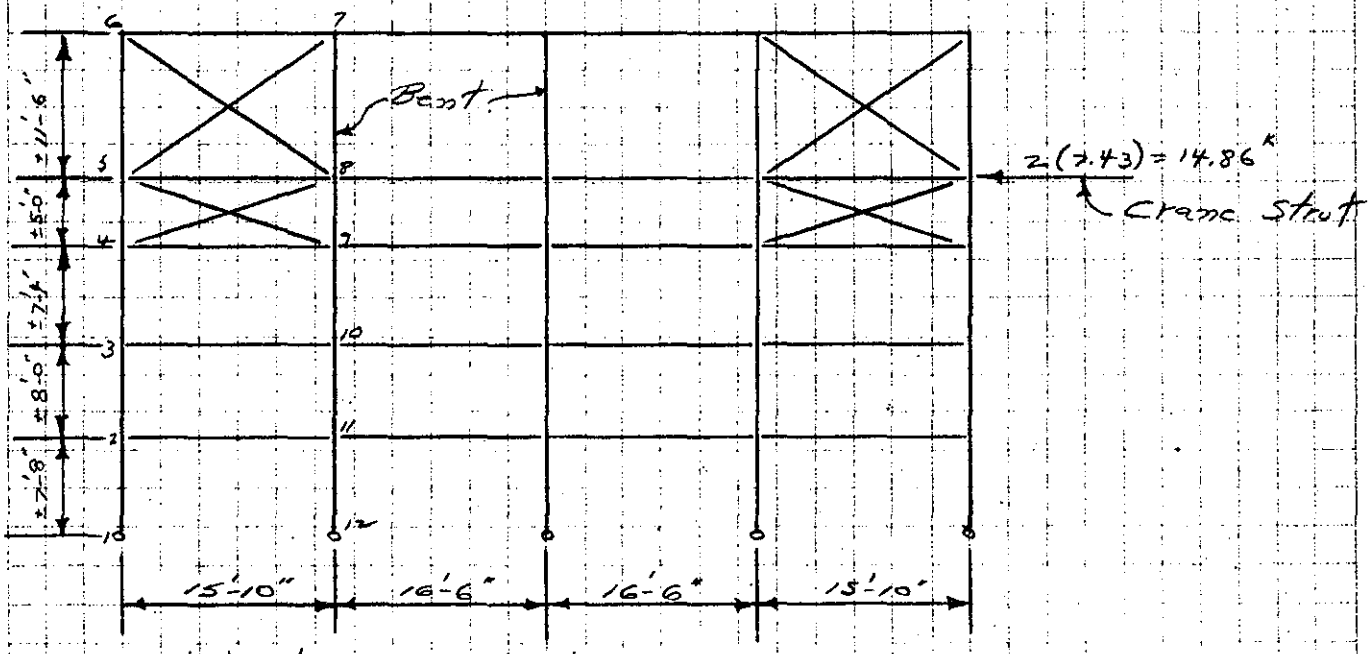
End Bent as frame



Col. 1-3 $M = 3.715(23) = 85.5$ k-ft.

SUBJECT FOX POINT PUMPING STATION
COMPUTATION SUPERSTRUCTURE- TYPICAL 66'-0" MONOLITH
COMPUTED BY R.N.W. CHECKED BY GFH DATE 18 DEC. 59

Struts & Diagonal Bracing



Longitudinal Crane Loads:

max. vertical wheel load = 74.3^k
max. longitudinal " " = 10% (74.3) = 7.43^k

Design of strut #1 - Eave Beam

Span = 16'-6" $w_x = 130(8) + 40 = 1080$ #/FT.

$P = 2250.$

$M_x = 1.08(16.5)^2 \frac{1}{8} = 36.75$ K-FT.

Try 12 B 22

$f_b = \frac{36.75(12000)}{25.3} = 17400$ psi. < 20000 OK

$f_a = \frac{2250}{6.47} = 348$ psi.

Strut #2 $P = 7.43^k$ assume strut anchored to brick wall to provide lateral stability

Span = 16'-6".

$w_x = 30(8.25) = 247.5$ #/FT.
$w_y = 12$ #/FT.

SUBJECT FOX POINT PUMPING STATION
COMPUTATION SUPERSTRUCTURE – TYPICAL 66'-0" MONOLITH
COMPUTED BY R.N.W. CHECKED BY GEH DATE 18 DEC. 59

Strut #2 – Cont'd

$M_x = 247.3(16.5)^2 \frac{1}{8} = 8422.7$ FT-LB.

$M_y = 12(16.5)^2 \frac{1}{8} = 408.4$ FT-LB.

Try 8 B 10.

$f_b = \frac{12(8422.7)}{7.79} + \frac{12(408.4)}{1.01} = 12975 + 4852 = 17827$ psi

$f_a = \frac{7430}{2.95} = 2519.$

$F_b = 26600$ psi.
$F_A = 17000(1.33) = 22667.$

$\frac{f_a}{F_a} + \frac{f_b}{F_b} = 0.78 < 1.0.$

Strut #4 $w_x = 30(7.67) = 230$ #/FT.
$w_y = 10$ #/FT.

$M_x = 230(16.5)^2 \frac{1}{8} = 7827$ FT-LB.

$M_y = 10(16.5)^2 \frac{1}{8} = 340$ FT-LB.

Try 8 B 10.

$f_b = \frac{12(7827)}{7.79} + \frac{12(340)}{1.01} = 16097$ psi o.k.

Strut #5

$w_x = 30(7.83) = 235$ #/FT.

$M = 235(16.5)^2 \frac{1}{8} = 7997.$

req. $S = \frac{12(7997)}{26666} = 3.6$ IN^3.

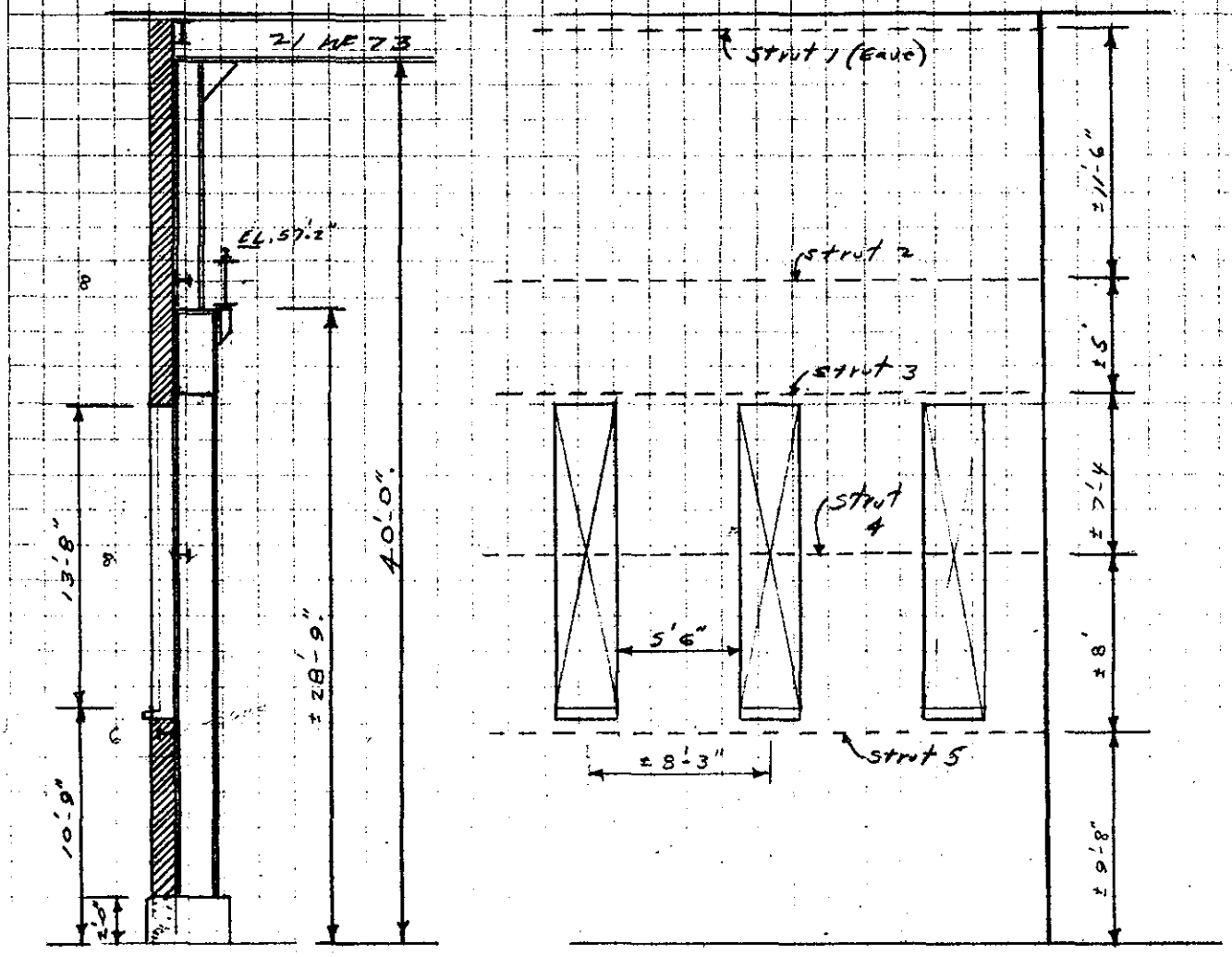
4 WF 10
6 B 8.5.

SUBJECT: FOX POINT PUMPING STATION

COMPUTATION: SUPERSTRUCTURE – TYPICAL 66'-0" MONOLITH

COMPUTED BY: R.N.W. CHECKED BY: GFH DATE: 18 NOV. 59

Brick Masonry Exterior Wall – & supporting members



Masonry wall between struts 1 & 2 – height = 11'

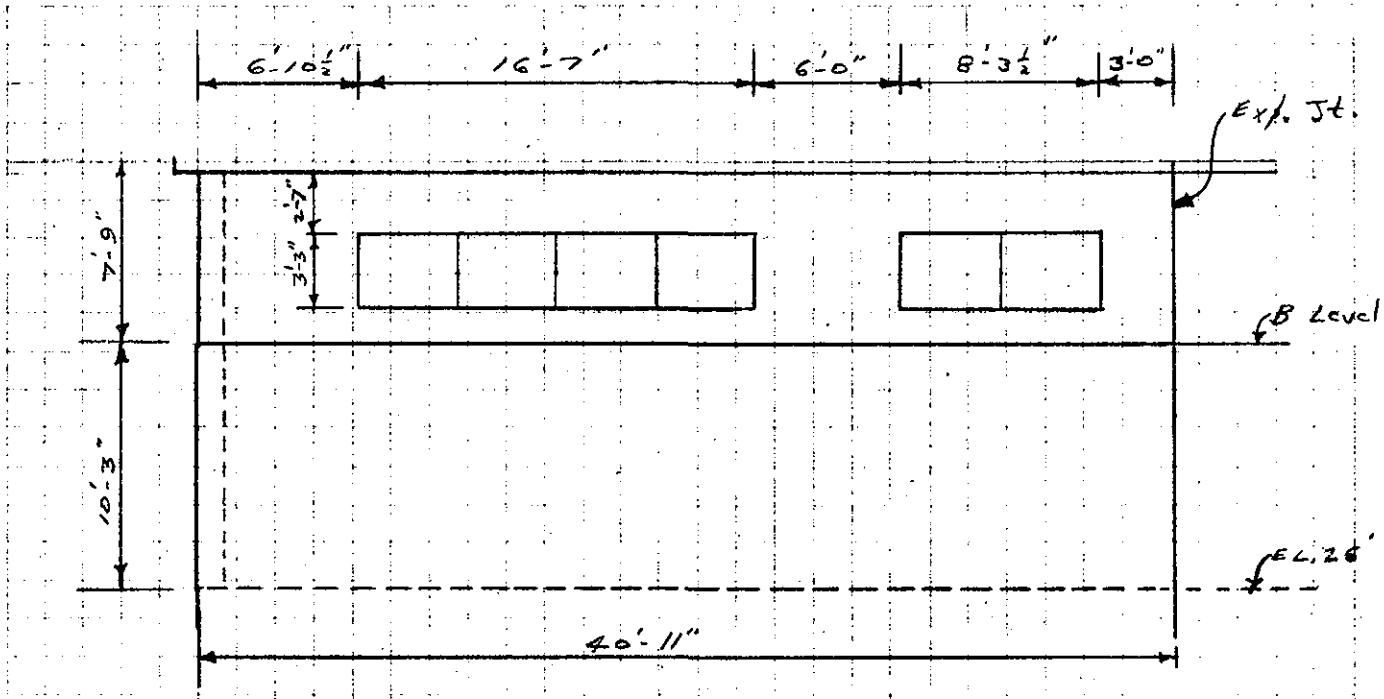
Mid height $p = 1.0(5.5)120 = 660^{\#}$

$$M = \frac{30(11)^2}{8} = 453.75 \text{ FT-LB}$$

$$p = \frac{660}{(12)^2} \pm \frac{453.75(12)6}{12(12)^2} = 4.6 \pm 18.9$$

max. tension = 14.3 psi
allowable " = 10 x 1.33 = 13.33
close enough

SUBJECT FOX POINT PUMPING STATION
COMPUTATION TRANSFORMER LEAN-TO
COMPUTED BY R.N.W. CHECKED BY GEH DATE 10 DEC. 59



SOUTH ELEVATION

Wall assuming wall acts as cantilever from base,

$w = 30$ psf $\qquad t = 14''$

$l = 17.5'$ $\qquad d = 11.25$

$$M = 30(17.5)^2 \tfrac{1}{2} = 4594 \text{ FT-LB}$$

$$A_s = \frac{12(4.594)}{20(.866)(11.25)} = 0.28 \text{ IN}^2/\text{FT} \qquad \#5 \text{ @ } 12''.$$

$$V = 30(17.5) \qquad v = \frac{30(17.5)}{12(.866)(11.25)} = 4.5 \text{ psi.}$$

Wall above B Level — 8" Reinf. conc. + 4" brick facing
Wall below B Level — 14" " "

wall above windows carries wind to panels and serves as lintel

roof load = 133 psf (p.)

as lintel, $w = 133(10.0) + \frac{8(31)}{144}(150) + \frac{4(31)}{144}(120) = 1692$ #/FT

$$M = \frac{1.692(16.58)^2}{10} = 46.512 \text{ K-FT} \qquad t = 31, \; d = 28$$

$$A_s = \frac{46.512(12)}{20(.866)(28)} = 1.15 \text{ IN}^2 \qquad 2\text{-}\#7 \text{ Top}, \; 2\text{-}\#5 \text{ bottom}$$

SUBJECT FOX POINT PUMPING STATION
COMPUTATION TRANSFORMER LEAN-TO
COMPUTED BY R.N.W. CHECKED BY GFH DATE 11 DEC. 59

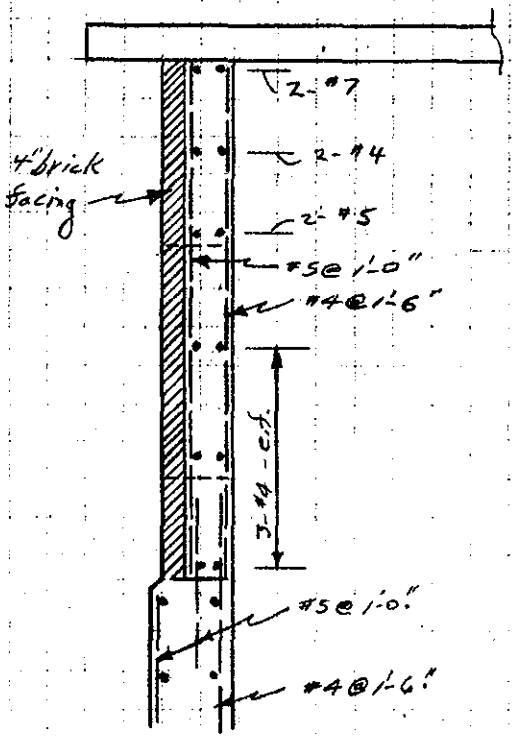
Wall panel between windows

width = 6'-0"
height = 7'-3" (from 8 level)

Loading: uniform $w = 30(6) = 180$ #/FT
concentrated load from lintels $= (4.2)(30)(8.29 + 4.15) = 1567$ #

$M = 180(7.25)^2 \frac{1}{2} + 1567(5.96) = 14070$ FT-LB

$A_s = \frac{12(14.07)}{20(.864)(7.0)} = 1.39$ IN^2 #5 @ 12" outside face.



min. wall reinf.
8" wall - vert. $12(8)(.0015) = .144$ IN^2
horiz. $12(8)(.0025) = .24$ IN^2
14" wall - vert. $12(14)(.0015) = .25$ IN^2
horiz. $12(14)(.0025) = .42$ IN^2

Upper Wall Section Between Windows - Scale $\frac{3}{8}$" = 1'-0"

Slab span = 16'-0" clear

Loading: LL = 30
Fill = 22
Slab = 69
Roofing = 6
127 psf.

$M = 127(12)^2 \frac{1}{8} = 4590$ FT-LB.

req. $d = \sqrt{\frac{12(4590)}{12(236)}} = 4.4$. use $t = 5.5$"
$d = 4.5$.

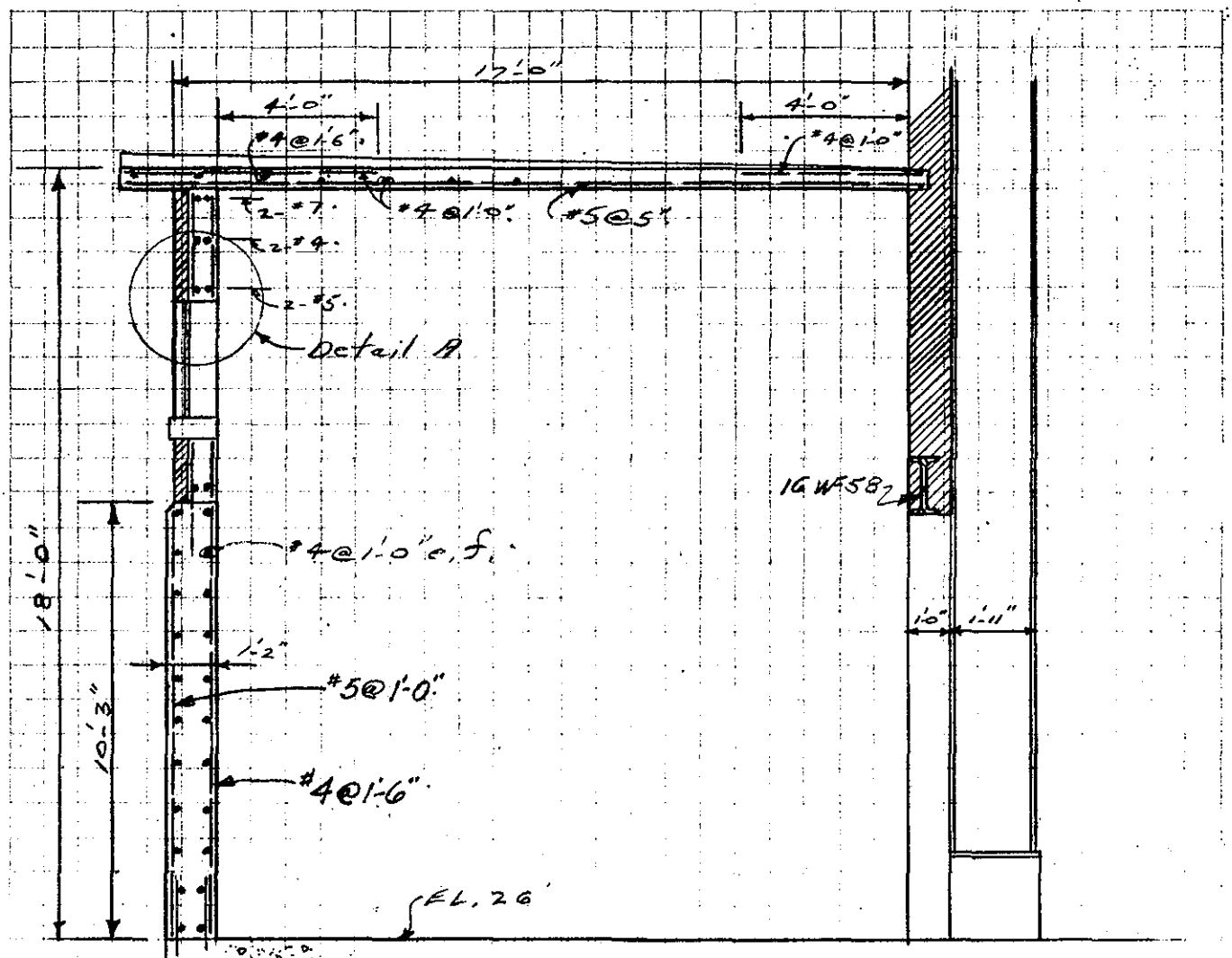
$A_s = \frac{12(4.59)}{20(.864)(4.5)} = .705$. #5 @ 5" ←
#6 @ 7

Longitudinal reinf. = #4 @ 18"

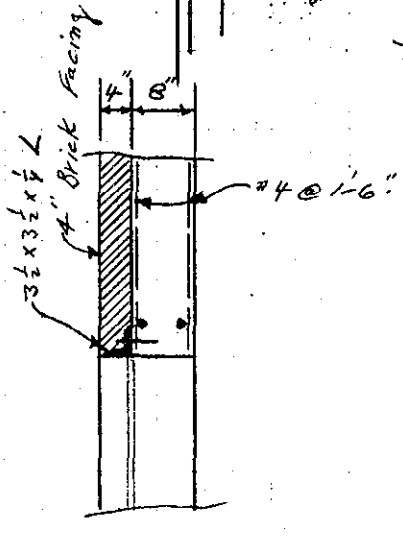
NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT FOX POINT PUMPING STATION
COMPUTATION TRANSFORMER LEAN-TO
COMPUTED BY R.N.W. CHECKED BY GEH DATE 11 DEC. 59



SECTION THROUGH LEAN-TO
Scale: 1/4" = 1'-0"



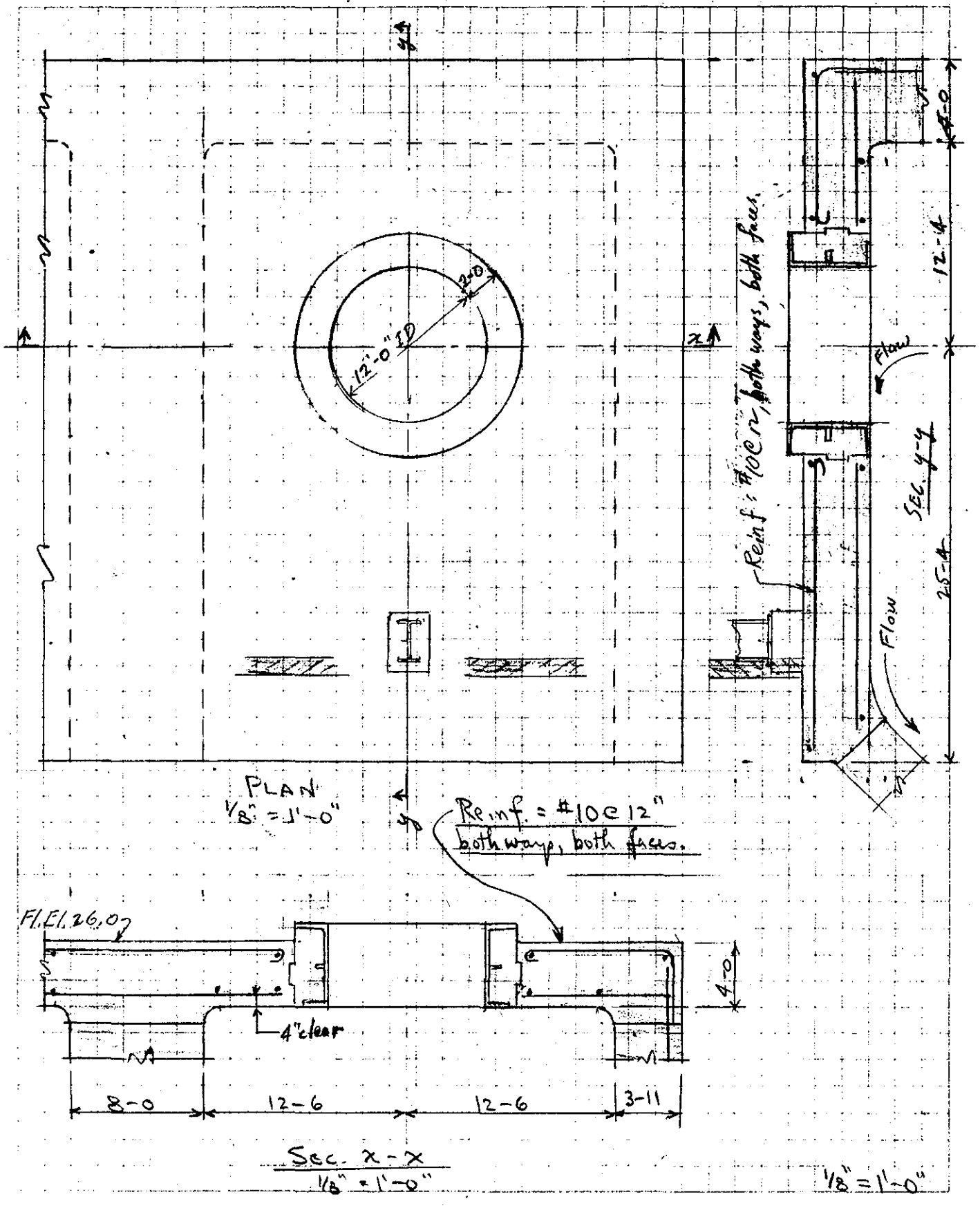
DETAIL A

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

PAGE A 40

SUBJECT FOX PT. PUMP. STA.
COMPUTATION TYPICAL PUMP-BAY FLOOR SLAB AT EL. 26.0
COMPUTED BY C.C.C. CHECKED BY RAK. DATE

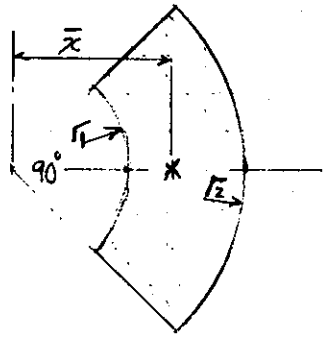


SUBJECT Fox Pt. Pump Sta.

COMPUTATION Typical Pump-Bay Floor Slab at El. 26.0

COMPUTED BY C.C.C. CHECKED BY RAN. DATE

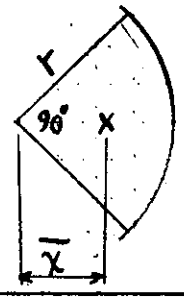
Center of Gravity of 1/4 Motor-Ring Support



Center of gravity of quadrant:

$\bar{x} = 0.6002\, r$

Merriman-Wiggin, Amer. Civ. Engrs. Hdbk., 5th Ed., p. 103.



$$\bar{x} = \frac{(.6002 r_2)(\frac{1}{4}\pi r_2^2) - (.6002 r_1)(\frac{1}{4}\pi r_1^2)}{(\frac{1}{4}\pi r_2^2) - (\frac{1}{4}\pi r_1^2)} = \frac{.6002(r_2^3 - r_1^3)}{r_2^2 - r_1^2}$$

For $r_2 = 9.75'$, $r_1 = 4.75'$:

$$\bar{x} = \frac{.6002(\overline{9.75}^3 - \overline{4.75}^3)}{\overline{9.75}^2 - \overline{4.75}^2} = \frac{.6002(926.859 - 107.172)}{95.0625 - 22.5625}$$

$$= \frac{.6002 \times 819.687}{72.5000} = 6.786'$$

SUBJECT: FOX PT. PUMP STA. - TYPICAL PUMP-BAY FLOOR SLAB AT EL. 26.0

COMPUTATION: DISTRIBUTION OF RING LOAD "W" FROM MOTOR, PUMP & THRUST, TO SLAB

COMPUTED BY: C.C.C. CHECKED BY: RGK DATE:

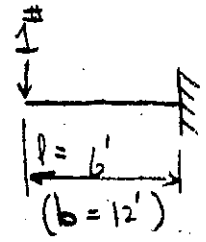
See memo, Mr. Garafalo / VW, dated 6 Oct '59 :

Motor = 173.^{K}
Pump = 85.^{K}
Thrust = 200.^{K}
W = 458.^{K}

Assume that ring load "W" is supported at points "a", "b", "c" and "d" (see next page) by cantilever beams A, B and D and by fixed-end beam C. Assume that percentage of load to each beam is unknown.

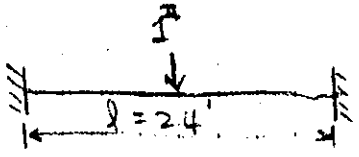
Assume that, when loaded, points a, b, c and d lie in some slant plane "E", and that the load can be considered as supported by four springs of different stiffnesses.

Beam A : deflection of point "a" under 1# load =



$$\frac{l^3}{3EI} = \frac{(12\times 6)^3}{3E\,\frac{(12\times 12)\,d^3}{12}}$$ Same for beams B and D.

Beam C : deflection of point "c" under 1# load =



$$\frac{l^3}{192EI} = \frac{(12\times 24)^3}{192E\,\frac{(12\times 6)\,d^3}{12}}$$

Relative deflection of Beam "C" to Beam "A" under same load =

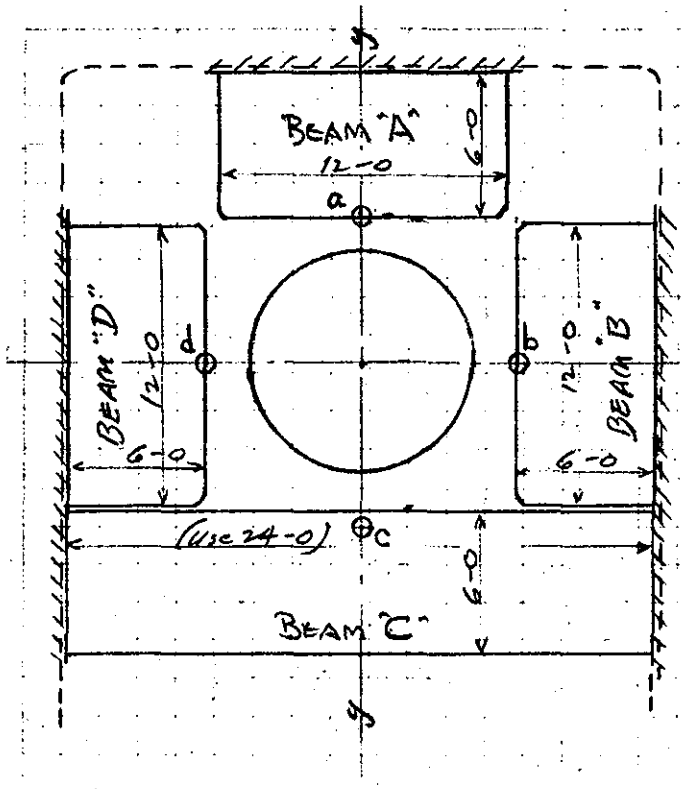
$$\frac{\dfrac{(12\times 24)^3}{192\,\dfrac{12\times 6}{12}}}{\dfrac{(12\times 6)^3}{3\,\dfrac{12\times 12}{12}}} = 2.$$

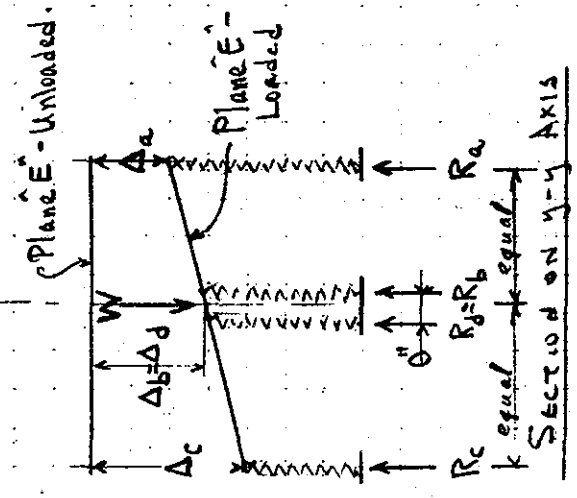
I.e., Beam C is half as stiff as Beam A, B or D.

SUBJECT Fox Pt. Pump. Sta. - Typical Pump-Bay Floor Slab at El. 26.0

COMPUTATION Distribution of Ring Load "W" from Motor, Pump & Thrust (Continued)

COMPUTED BY C.C.C. CHECKED BY RAK DATE





Since $\Sigma M_{y-y} = 0$, $R_b = R_d$.

Let C_a = defl. const. for Beam A, in #/inch defl.

Then $R_a = C_a \Delta_a$, and $R_c = C_c \Delta_c$.

Since $\Sigma M_{x-x} = 0$, $R_c = R_a$, or $C_c \Delta_c = C_a \Delta_a$:

But $C_a = 2C_c$ (See preceding sheet), $\therefore \Delta_c = 2\Delta_a$.

Then from geometry, $\Delta_b = \Delta_d = 1.5\Delta_a$.

Also, $C_a = C_b = C_d$.

Substituting:

$$R_a = C_a\Delta_a = 1.0\,C_a\Delta_a = 1.0/5.0 = 0.2\,W \quad \text{(Use } 0.25\,W\text{)}$$

$$R_b = C_b\Delta_b = 1.5\,C_a\Delta_a = 1.5/5.0 = 0.3\,W$$

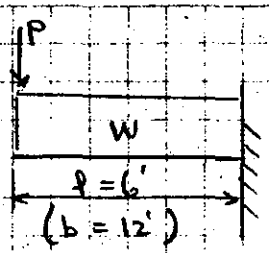
$$R_c = C_c\Delta_c = {}^{*}1.0\,C_a\Delta_a = 1.0/5.0 = 0.2\,W \quad \text{(Use } 0.25\,W\text{)}$$

$$\frac{R_d}{W} = \frac{C_d\Delta_d}{} = \frac{1.5\,C_a\Delta_a}{5.0\,C_a\Delta_a} = 1.5/5.0 = \frac{0.3\,W}{1.0\,W}$$

(* $= \frac{1}{2} C_a \times 2\Delta_a$)

SUBJECT Fox Pt. Pump. Sta.
COMPUTATION Typical Pump-Bay Floor Slab at El. 26.0
COMPUTED BY C.C.C. CHECKED BY RAK. DATE

Beams "B" & "D"



$P = .3 \times 458 = 137.4^k$

$L.L. = 6 \times 12 \times .200 = 14.4^k$

$D.L. = 6 \times 12 \times 4 \times .15 = 43.2$

$W = 57.6^k$

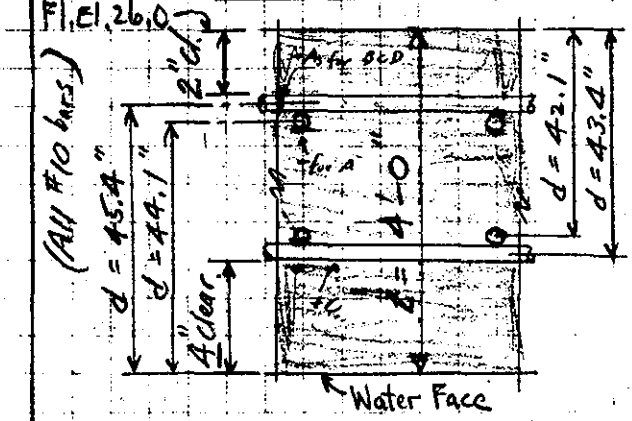
$-M = Pl + \frac{Wl}{2} = 137.4 \times 6 + \frac{57.6 \times 6}{2}$

$= 824.4 + 172.8 = 997.2^{k'}$

$(\div 12 = 83.0^{k'}/_1)$

$Reqd\text{-}A_s = \frac{M}{ad} = \frac{997.2}{1.475 \times 45.4} = 14.9^{\square''} \div 12' = \underline{1.24\ \square''/_1}$

Arrangement of Reinf.

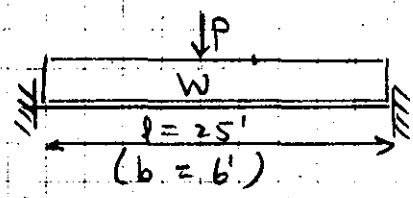


Section on x-x axis
(See preceding page)

(f_c, v and u are more critical for slab at crane column. See next sheet.)

Beam "A": Use same top cantilever steel as for Beams B & D.

Beam "C"



$P = .25 \times 458^k = 114.5^k$

$L.L. = 6 \times 25 \times .200 = 30.^k$

$D.L. = 6 \times 25 \times 4 \times .150 = 90.$

$W = 120.^k$

$-M = \frac{Pl}{8} + \frac{Wl}{12} = \frac{114.5 \times 25}{8} + \frac{120 \times 25}{12} = 357.8 + 250 = 607.8^{k'} (\div 6 = 101.3^{k'}/_1)$

$+M = \frac{Pl}{8} + \frac{Wl}{24} = 357.8 + 125 = 482.8^{k'} (\div 6 = 80.5^{k'}/_1)$

$Reqd\text{-}A_s = \frac{M}{ad} = \frac{607.8}{1.475 \times 45.4} \div 6' = \underline{1.52\ \square''/_1}$

$Reqd\text{+}A_s = \frac{482.8}{1.475 \times 43.4} \div 6 = \underline{1.26\ \square''/_1}$

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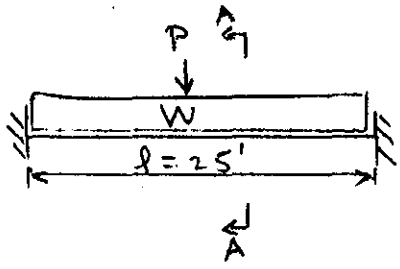
NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

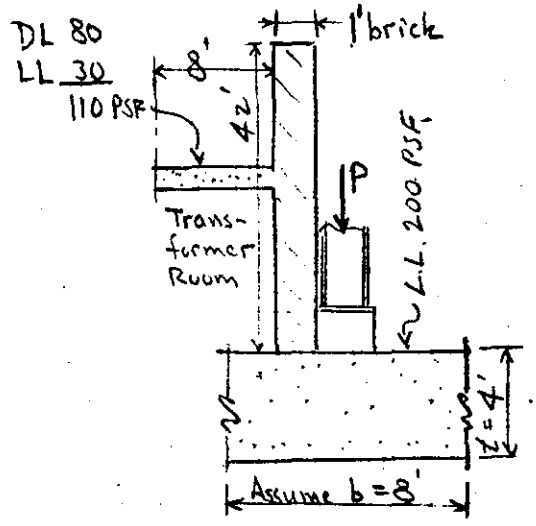
PAGE A 4/5

SUBJECT Fox Pt. Pump. Sta.
COMPUTATION Typical Pump-Bay Floor Slab at El. 26.0
COMPUTED BY C.C.C. CHECKED BY RAK. DATE

Slab at Crane Column

Crane col. = for preliminary figure take
P = 122.^{k} (127.^{k} with wind)
(R. Wheeler, 10/20/59)





Sec. A-A

Slab D.L. : 8 x 25 x 4 x .150 = 120.^{k}
Slab L.L. : 8 x 25 x .200 = 40.
Wall D.L. : 25 x 42 x .120 = 126.
Transformer Room
½ roof load : 8 x 25 x .110 = 22.
W = 308.^{k}

$$-M = \frac{Pl}{8} + \frac{Wl}{12} = \frac{122 \times 25}{8} + \frac{308 \times 25}{12} = 381. + 642. = 1023.^{k'}$$

$$+M = \frac{Pl}{8} + \frac{Wl}{24} = 381. + 321. = 702.^{k'}$$

$$\text{Req'd } d = \sqrt{\frac{M}{Kb}} = \sqrt{\frac{1{,}023{,}000 \times 12}{160 \times 12 \times 8}} = 28.3'' \quad (\text{O.K. } d = 45.4''. \therefore f_c < 1050)$$

$$\text{Req'd } -A_s = \frac{M}{ad} = \frac{1023.}{1.475 \times 45.4} \div 8' = 1.91 \square''/'$$

$$\text{Req'd } +A_s = \frac{702.}{1.475 \times 43.4} \div 8' = 1.38 \square''/'$$

$$V = \frac{P}{2} + \frac{W}{2} = 61.^k + 154^k = 215.^k$$

$$v = \frac{V}{bjd} = \frac{215{,}000}{(8 \times 12)\, .885 \times 45.4} = 56.0 \text{ psi.} \quad (\text{O.K} < 90)$$

$$u = \frac{V}{\Sigma_0 jd} = \frac{215{,}000}{(8 \times 6.0)\, .885 \times 45.4} = 112. \text{ psi.} \quad (\text{O.K.} < 210.)$$

Assume #10 @ 8"

Use #10 @ 12 both ways, both faces. (1.27 □"/')

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NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT: Fox Pt. Pump. Sta.
COMPUTATION: Typical Pump-Bay Floor Slab at El. 26.0
COMPUTED BY: C.C.C. CHECKED BY: DATE:

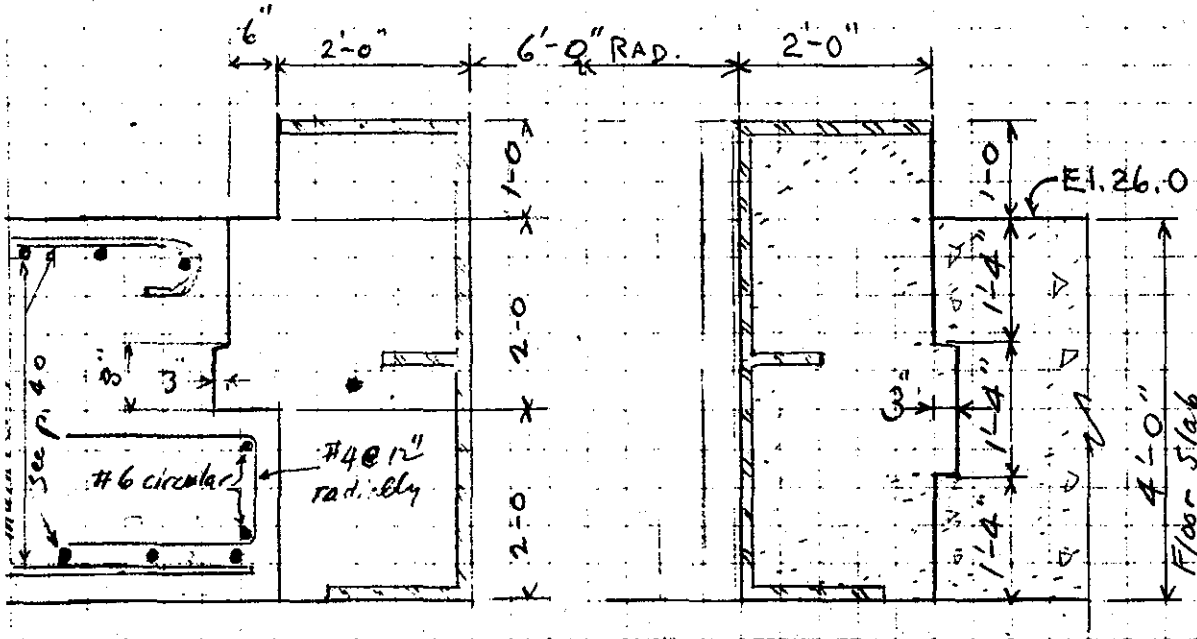
KEYWAY IN SLAB FOR MOTOR

Perimeter of key = $2\pi \times \cancel{6.83}\ 8.00 = 43.0'$

Vertical load = $\frac{468}{43.0} = 10.9^{k}$/lin. ft. of key

Required key depth for bearing = $\frac{10{,}900}{750 \times 12} = 1.21''$ Use 3".

Required 1/3 height of key = $\frac{10{,}900}{90 \times 12} = 10.1''$ Have 16".



1/2" = 1'-0"

ALTERNATE

Use

NED FORM 223
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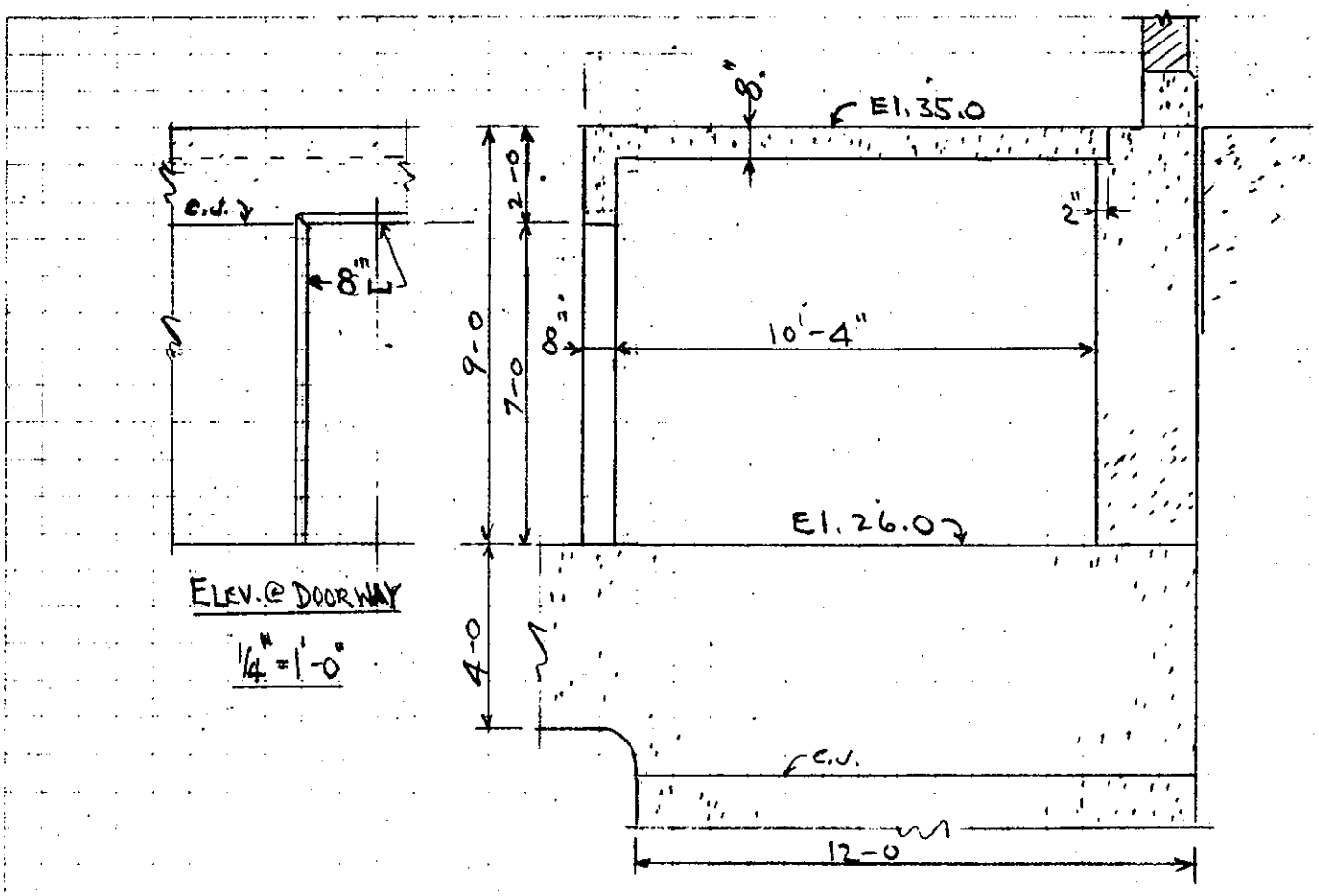
NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT: FOX PT. PUMP. STA.
COMPUTATION: PLATFORM AT EL. 35.0
COMPUTED BY: C.C.C. CHECKED BY: R.A.K DATE: 12-28-59



Area approx. 35' × 10'-4"

Loading = 1 fork-lift truck, 6.5^K on front axle, 3.5^K on rear axle.

Design for mom. per AASHO '57, pp. 24-5, Art. 1.3.2 (c), (f).

No check for u and v required (Art. 1.3.2(f)).

Degree of end-restraint not known, so design as simple span, then add negative steel for frame fixed at base of wall and at right support.

$S = 8''/2 + (10'-4'') + 2''/2 = 10'-9''$.

SUBJECT Fox Pt. Pump. Sta.
COMPUTATION Platform at El. 35.0
COMPUTED BY C.C.C. CHECKED BY R.A.K. DATE 12-28-59

Case A: Main reinf. ⊥ traffic:

$R_1 = \frac{10.75-x}{10.75}5.0 + \frac{7.75-x}{10.75}5.0 = 8.60 - .930x$

$M_x = R_1 x = (8.60 - .930x)x = 8.60x - .930x^2$

For max. M_x, $\frac{dM}{dx} = 0 = 8.60 - 1.860x$. $x = 4.62'$

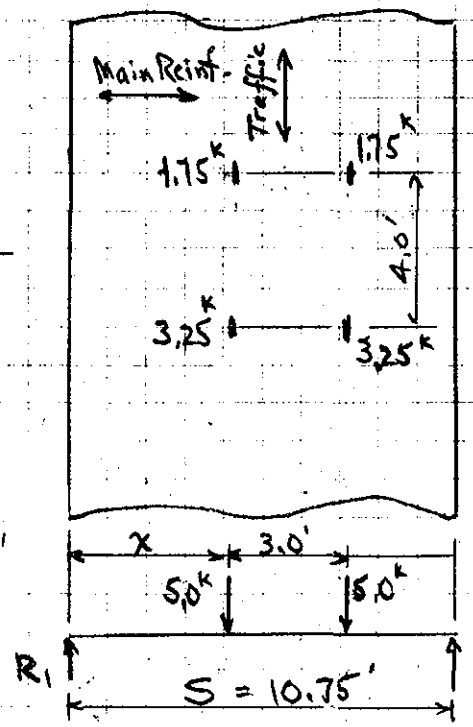
$M = 8.60 \times 4.62 - .930(4.62)^2 = 19.88^{k'}$

$E = .4S + 3.75 = 8.05'$

$M/1 = \frac{19.88}{8.05} = 2.47^{k'}/1$

D.L. M @ x < $\frac{wl^2}{8} < \frac{.100(10.75)^2}{8} < 1.44^{k'}/1$

Design $M_{LL+DL} = 3.91^{k'}/1$



Case B: reinf. ∥ traffic:

$R_1 = \frac{10.75-x}{10.75}6.5 + \frac{6.25-x}{10.75}3.5 = 8.70 - .930x$

$M_x = R_1 x = 8.70x - .930x^2$

For max. M_x, $\frac{dM}{dx} = 0 = 8.70 - 1.86x$. $x = 4.68'$

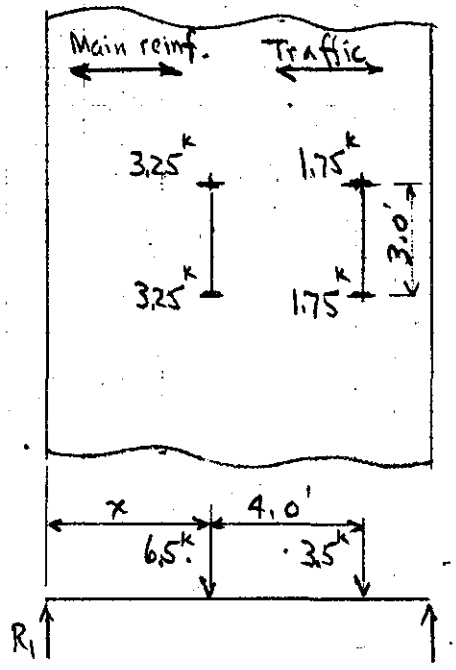
Max. $M = 8.70 \times 4.68 - .930(4.68)^2 = 20.4^{k'}$

$E = .175S + 3.2 = 5.08'$

$M/1 = \frac{20.4}{5.08} = 4.02^{k'}/1$

$M_{DL} < 1.44$

$5.46^{k'}/1$



Case B governs. Use $5.46^{k'}/1$ width of slab.

SUBJECT Fox Pt. Pump. Sta.
COMPUTATION Platform at El. 35.0
COMPUTED BY C.C.C. CHECKED BY R.A.K. DATE 12-28-59

Req'd. d for $f_c = 1050$: $\sqrt{\frac{546}{.160}} = 5.84''$ Use 8" slab.

For 3/4" cover and 3/4" ϕ bars, $d = 8 - \frac{3}{4} - \frac{3}{8} = 6.875''$

Req'd. + $A_s = \frac{M^{k'}}{a\,d} = \frac{5.46}{1.475 \times 6.875} = .54$ □"/' Use #6@10" (= .53 □"/')

Allowable unif. L.L. for this slab:

$$M^{''\#} = \frac{wP^2 \times 12}{8} = f_s A_s j d$$

$$w = \frac{20{,}000 \times .53 \times .885 \times 6.875 \times 8}{(10.75)^2 \times 12} = 372.\ \#/\square'$$

$$-\text{D.L.} \quad -100.$$

$$272.\ \#/\square'$$

Use Allow. unif. L.L. = 272. psf.

Distribution Reinforcement (Art. 1.3.2 (e))

$$\% = \frac{100}{\sqrt{S}} = \frac{100}{\sqrt{10.75}} = 30.4\ \%\ (\text{Max. } 50\%)$$

$.304 \times .52 = .158$ □"/' Use #4@15" (= .16 □"/')

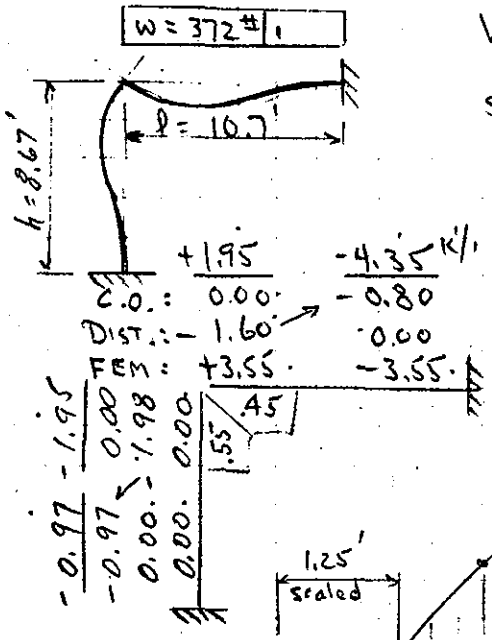
Shrinkage & Temp. Reinf. (ACI Par. 707)

Min. = .001 bt each way, each face

$= .001 \times 12 \times 8 = .096$ □"/' Use #4@18 (= 0.13 □"/')

SUBJECT: Fox Pt. Pump Sta.
COMPUTATION: Platform at El. 35.0
COMPUTED BY: C.C.C. CHECKED BY: R.A.K. DATE: 12-28-59

-As for frame fixed at right of slab and base of wall

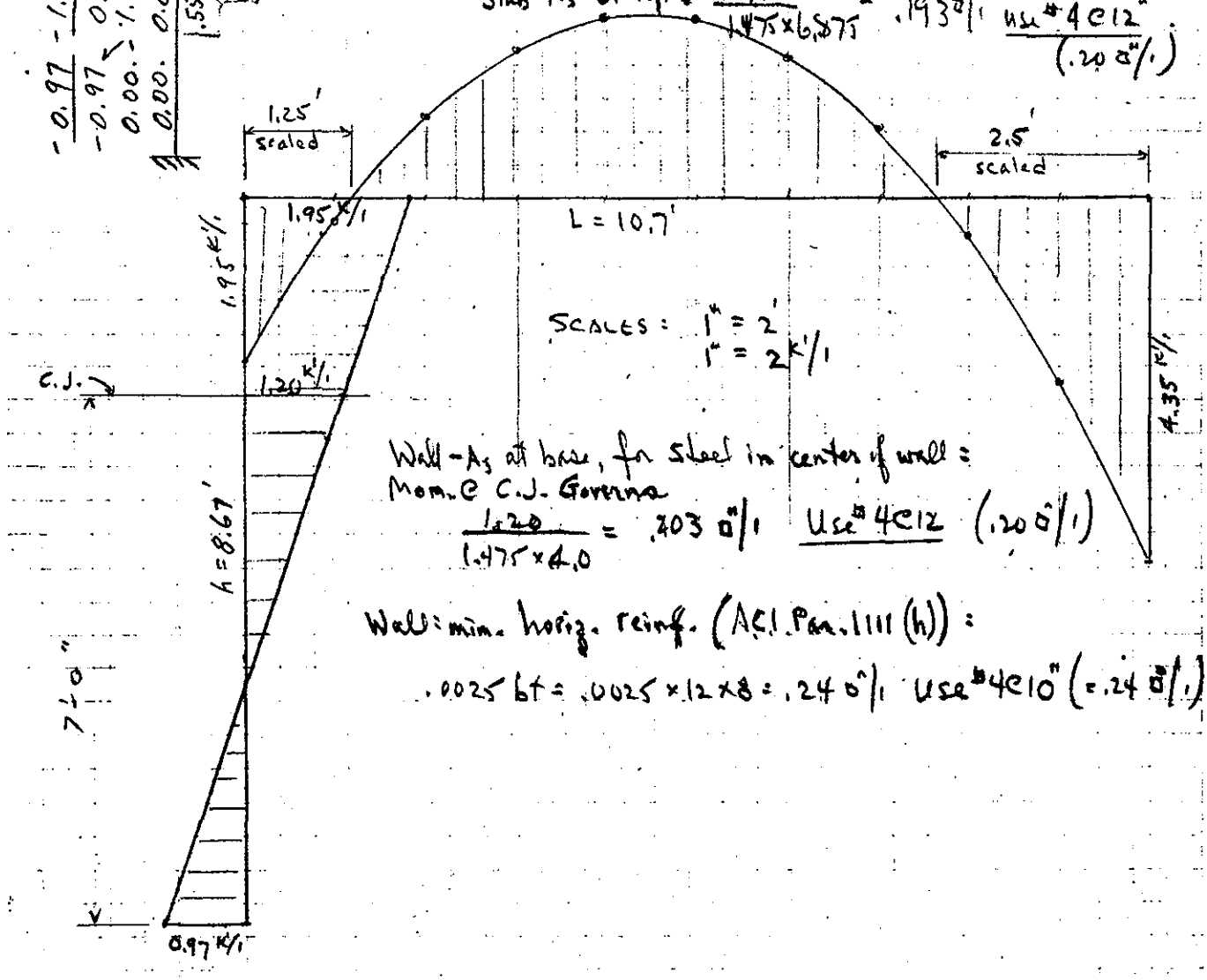


Wall: I/L ∝ 100/8.67 ∝ 11.50 ∝ 0.55 } Distrib. Factors
Slab: I/L ∝ 100/10.7 ∝ 9.35 / 20.85 ∝ 0.45 / 1.00

Slab FEM = $\frac{wL^2}{12} = \frac{.372(10.7)^2}{12} = 3.55$ K'/1

Slab-As at rt. = $\frac{4.35}{1.475 \times 6.875} = .430$ □"/1 Use #6@12" (As = .44 □"/1)

Slab-As at left = $\frac{1.95}{1.475 \times 6.875} = .193$ □"/1 Use #4@12" (.20 □"/1)



SCALES: 1" = 2'
1" = 2 K'/1

Wall-As at base, for steel in center of wall:
Mom. @ C.J. Governs
$\frac{1.20}{1.475 \times 4.0} = .203$ □"/1 Use #4@12 (.20 □"/1)

Wall: min. horiz. reinf. (ACI Par. 1111 (h)):
.0025 bt = .0025 × 12 × 8 = .24 □"/1 Use #4@10" (= .24 □"/1)

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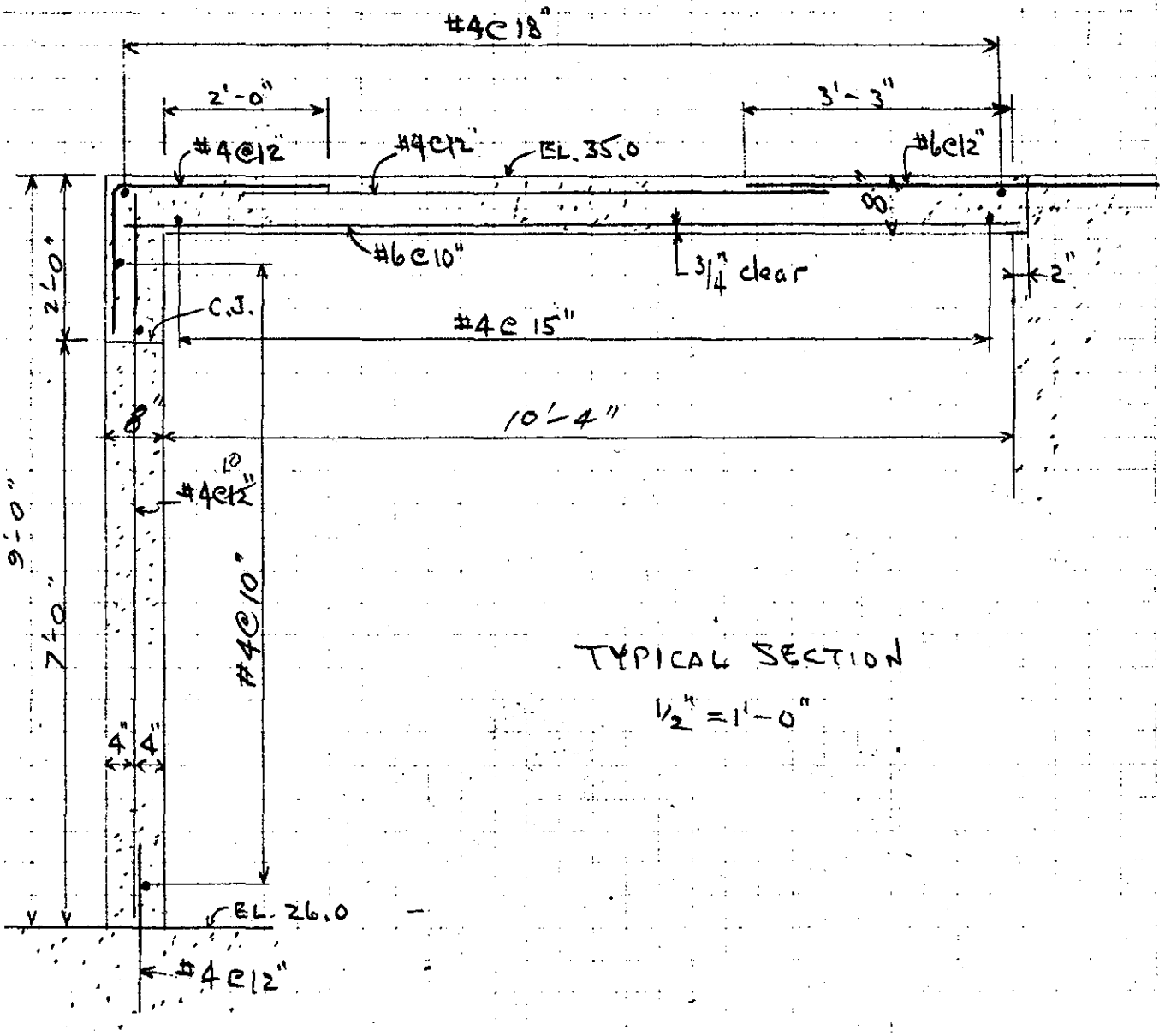
NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Pt. Pump-Sta.
COMPUTATION Platform at El. 35.0
COMPUTED BY C.C.C. CHECKED BY R.A.K. DATE 12-28-59



TYPICAL SECTION
1/2" = 1'-0"

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NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

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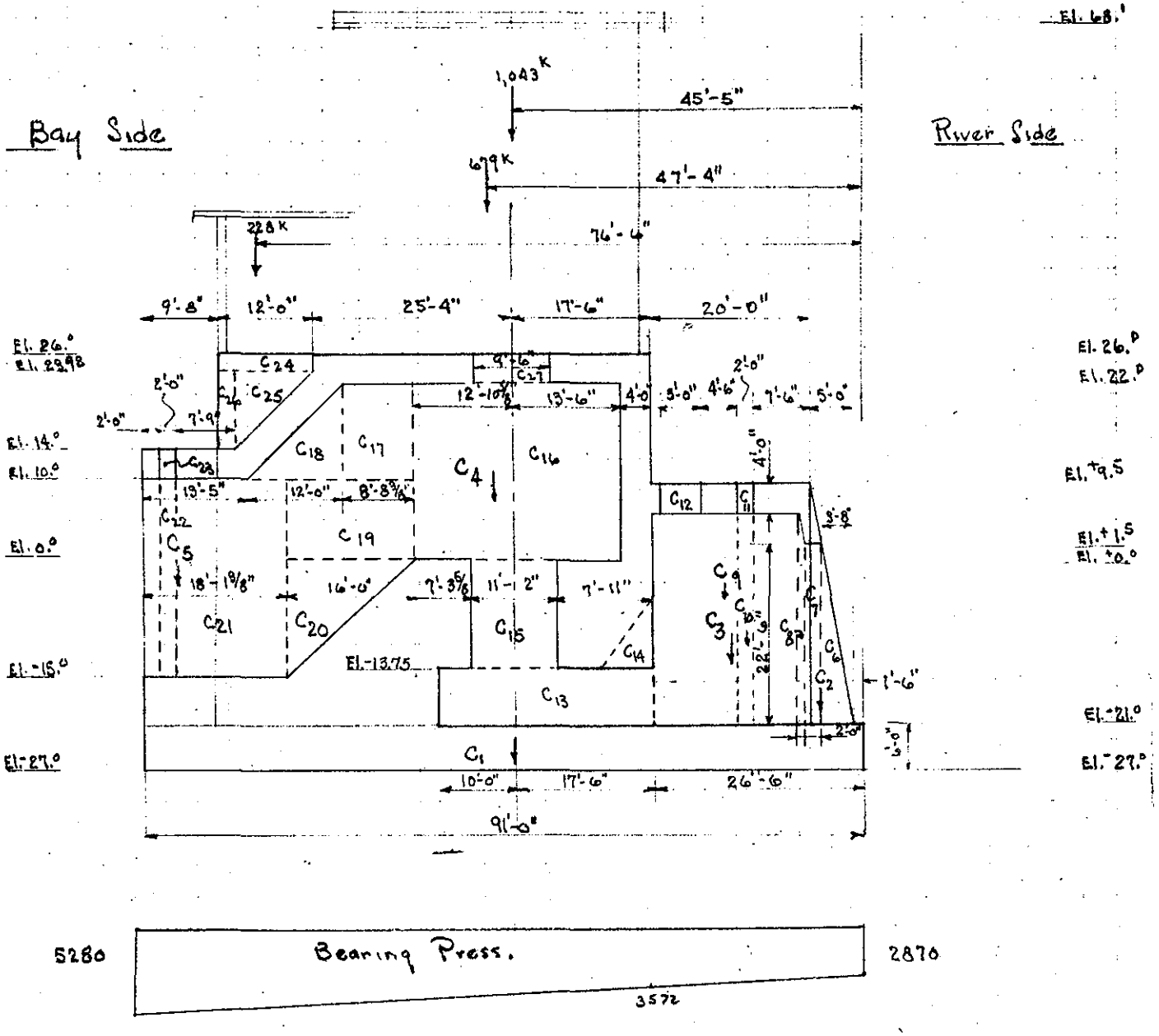
SUBJECT Fox Point Pump Station - Providence R. I.
COMPUTATION Stability Analysis
COMPUTED BY R.A.K. CHECKED BY Hew DATE Dec. 9 1959

Case I Construction period, cofferdam in place, no hydrostatic loading, no wind loads, dead load of structure and equipment



NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT: Fox Point Pump Station – Providence R.I.
COMPUTATION: Stability Analysis of 66'-0" long monoliths
COMPUTED BY: RAK. CHECKED BY: H.E.W. DATE: Dec 9 1959

Case I (cont.) Dead load of Superstructure

Description	Forces Acting Factors	↓	Arm	Moment
5" Concrete Roof Slab	41.0' x 66.0' x 62.5#	169,000#		
4" Light wt. Conc. Slab	41.0' x 66.0' x 30.0#	81,300#		
Tar & Gravel	41.0 x 66.0 x 6.0#	15,840#		
Steel Purlins	3 x 22# x 16.5 x 5	5,445#		
	2 x 31# x 16.5 x 5	5,115#		
Girders	5 x 35.5 x 73#	12,960#		
Bracing		1,200#		
Columns	110.5# x 26.8' x 10	29,600#		
	97.0# x 10.9' x 10	10,650#		
Brkts.		700#		
Misc. Plates		9,000#		
Wall members	66.0 (125# + 10# + 12#) x 2	19,430#		
Wall bracing		1500#		
Crane Matl's.				
Crane Girder	66.0 x 110.0# x 2	14,520#		
Crane rail	66.0 x 70.0# x 2	9,250#		
Cams.		7000#		
Masonry	39.75 x 120# x 66.0 x 2	630,000#		
Conc. Base	3.2 x 2.0 x 150# x 66.0 x 2	126,800#		
Minus windows	13.67 x 2.75 x 11 x 120	− 49620		
" doors	14.67 x 16 x 2 x 120	− 56,330		
	total	1,043,330#	45.42	47,388'K

C.G. from land edge of mat = 45'-5"

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27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pumping Station Prov. R.I
COMPUTATION Stability Analysis 66'-0" Monolith
COMPUTED BY H.E.W CHECKED BY R.A.K. DATE Dec. 9 59

Case I (cont.)

Transformer Lean-to

Description	Factors	↓	Arm	Moment
5½" Conc. roof slab	18 x 41.92 x 69	52,060	72.92	3,796,550
4" Lightweight fill	18 x 41.92 x 30	22 640	75.92	1,718,590
Roofing	18 x 41.92 x 6	4530	72.92	330,140
Conc. wall	10.25 x 40.92 x 1.17 x 150	73 610	80.50	5,925,600
" "	7.25 .67 x 40.92 x 150	29 ~~670~~ 815	80.25	2,~~380~~ 392,680 ~~780~~
" "	10.25 x 16 x 1.17 x 150	28780	71.92	2,070,000
" "	7.25 x .67 x 16 x 150	11 ~~600~~ 58	71.92	8 ~~34~~ 8,443 ~~270~~
Brick wall	7.25 x .33 x 40.92 x 120	11 ~~870~~ 748	80.75	9 ~~58~~ 48,662 ~~,240~~
" "	7.25 x .33 x 16 x 120	4 ~~640~~ 594	71.92	33 ~~3,710~~ 0,372
Block partitions	16 x 17.5 x .51	14280	71.92	~~1,027020~~ 10,270
Minus window openings	29 x 2.75 x 140	− 11 ~~170~~ 65	80.42	− 897890
		~~242 510~~ 228,413		~~18,477000~~ 17,463,417

$$\frac{\Sigma M}{\Sigma V} = \frac{\cancel{18,477,000}\ 17,463,417}{\cancel{242\,510}\ 228,413} = 76.\cancel{14}\ 46'$$

Equipment

Description	Factors	↓	Arm	Moment
Pump + Casing	2 x 85	170.0^k	44.0	7480
Motor	2 x 173	346.0	44.0	15224
Transformers	55.0	55.0	72.17	3970
Switchgear	25.0	25.0	72.17	1804
Crane	83.0	83.0	44.0	3652
		679.0		32,130^k

$$\frac{\Sigma M}{\Sigma V} = \frac{32130}{679} = 47.32'$$

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27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT: Fox Point Pump Station
COMPUTATION: Stability Analysis
COMPUTED BY: H.E.W. CHECKED BY: R.A.K DATE:

Case I (cont.)
Substructure

Description	Factors	Area	Arm	Mom. of Area
C_1 Base Mat.	9 1/x 6 x 66	36040	45.5	1,639,640
C_2 Riverside projection	5x .5x 30.5x 66	5030	4.83	24,290
C_3 " "	20x 30.5x 66	40 264	16.50	664,290
C_4 Main body	55 x 47.0 x 66	170 610	54.0	9,212,940
C_5 Ocean side projection	35.5 x 9.5 x 66	19120	86.25	1,649,400
		271,060		13,190,560
		273,751		13,439,346
	Minus Areas.			
C_6 Riverside projection	22.5x 4x 2.5 x 2 x.5	2250	4.17	9,380
C_7 " "	22.5x 2 x 25 x 2	2250	7.30	16,880
C_8 " "	26.5x .75x 25 x 2	100	9.00	900
C_9 " "	26.5x 18.8x 25 x 2	24 510	17.00	425,740
C_{10} " Stop log slot	2x 26.5x 1.5 x 4	320	15.00	4770
C_{11} Stop log opening in slab	2x 4x 28.0 x 2	450	15.00	6720
C_{12} Riverside access opening	5x15x 4 x 2	600	23.00	13 800
C_{13} Area beneath pump	27.5x 7.25x25x 2	9970	40.25	401240
C_{14} Riverside curved area	6.5x 9x .5x 25x 2	1460	29.00	42410
C_{15} Pump area	πx 11 3/4 x 13.75 x 2	2610	44.0	114990
C_{16} " discharge chamber	26.5x 22x 25x 2	29150	43.75	1,275,310
C_{17} " " "	8.5x 12 x 25x 2	5100	61.25	312370
C_{18} " " "	12x12x .5x25x 2	3600	69.50	250200
C_{19} " " "	15.5x 10x 25x 2	7750	64.75	501,810
C_{20} " " "	15.5x 15x .5x 25x 2	5810	67.33	391360
C_{21} " " "	18.5x 25x 25x 2	23130	81.75	1,890,470
C_{22} Stop log opening	2x1.5x 29 x 4	350	88.0	30620
C_{23} " " "	2x 4x 25x 2	400	88.0	35200
C_{24} Area under Equip Rm.	12x 2.08 x 25.08	650	75.25	48980
C_{25}	9.92 x 9.92 x 25.08 x 1/2	2570	85.00	218,950
C_{26}	2.08 x 9.92 x 25.08	540	80.20	43,160
C_{27} Pump opening in floor	πx 9.5 3/4 x 4 x 2	570	43.83	24850
	123,940	74000	5,946,020	6,086,720
		147,060		7,103,840
		149,800		7,493,330

$$\frac{\Sigma M}{\Sigma V} = \frac{7,103840}{147060} = 48.31 \quad 50.02$$

Total Weight & Mom. of Substructure

149,800	22,470	50.02	1,123,950
147,060 x .150	22,060 K	48.31	1,065,920

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NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT: Fox Point Pumping Station
COMPUTATION: Stability Analysis
COMPUTED BY: HEW CHECKED BY: R.A.K. DATE:

Case I Construction period, cofferdam in place, no hydrostatic loading, no wind loads, dead load of structure and equipment.

Description	Factors	↓+	→+	Arm	↻+ Moment
Superstructure		1.043			47.388
Transformer Rm		~~242~~ 28			~~18,477~~ 17,463
Equipment		679			32,130
Substructure		~~22.060~~ 22,470			1,065,720 1,123,950
		~~24,024~~ 24,420			~~1,163,715~~ 1,220,931

$$\frac{\Sigma M}{\Sigma V} = \frac{\cancel{1,163,715}\ 1,220,931}{\cancel{24.024}\ 24,420} = \cancel{48.44'}\ 50.00'$$

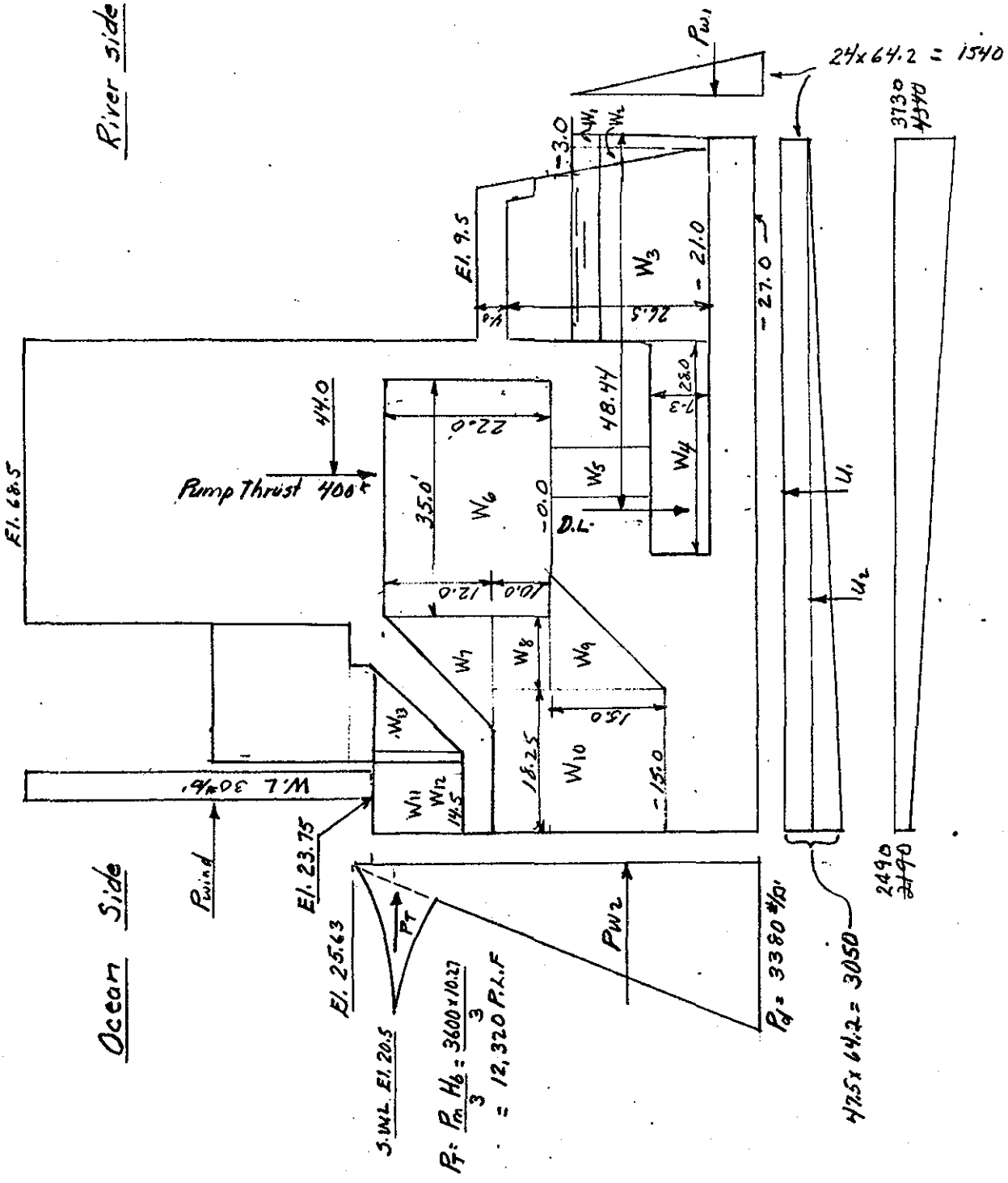
$$e = \frac{91.0}{2} - \frac{\cancel{48.44}\ 50.0}{} = \cancel{-2.94'}\ -4.50' \text{ to bay side}$$

$$\text{Bearing Pressure} = \frac{\cancel{24024}\ 24420}{91 \times 66}\left(1 \pm \frac{6 \times \cancel{2.94}\ 4.50}{91}\right)$$

$$= \cancel{4996}\ 5280\ \#/\square' \text{ at Bayside}$$
$$\cancel{3224}\ 2870\ \#/\square' \text{ at Riverside}$$

SUBJECT Fox Point Pumping Station
COMPUTATION Stability Analysis.
COMPUTED BY Whittemore CHECKED BY R.A.K DATE 11 Dec. 59

Case II Hurricane and maximum high water condition fro breaking waves. S.W.L. 20.5, all dead loads, max pump thru water on Riverside to El. -3.0 (max. drawdown); uplift varyi over full base from S.W.L to -3.0. Wind on exposed side



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NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pumping Station
COMPUTATION Stability Analysis
COMPUTED BY Whittemore CHECKED BY R.A.K. DATE 11 Dec. 59

Case II cont.

	Description	Vertical ↓	Vertical ↑	Horizontal →	Horizontal ←	Arm	Moment ↷	Moment ↶
	Dead Loads	24420				50.00		1,220,931
	Pump thrust	400				44.00		17,600
W_1	1.5x18x16x64.2	28				.75		21
W_2	3.5x18x16x.5x64.2	32				2.67		86
W_3	26.5x.18x25x2x64.2	1531				13.50		20671
W_4	28.0x7.25x25x2x64.2	651				40.00		26040
W_5	2xπx11¾x13.75x64.2	168				44.00		7392
W_6	35.0x~~36~~ 22.0x50x64.2	2478 3403				48.00		163,344
W_7	12x12x.5x50x64.2	231				69.50		16062
W_8	7x10x50x64.2	225				69.00		15504
W_9	15x15x.5x50x64.2	361				67.50		24376
W_{10}	18.25x25x50x64.2	1465				81.88		119918
W_{11}	9.67x9.25x40.92x64.2	235				86.16		20245
W_{12}	11.75x9.25x25.08x64.2	175				85.12		14895
W_{13}	9.25²/2 x64.2x25.08	69				76.17		5260
U_1	1540x91x66		9249			45.50	420840	
U_2	1510x91x66x.5		4535			60.67	275110	
P_{w1}	1540x24x.5x66				1220	8.00		9760
P_{w2}	3380x52.63x66x.5			5870		17.54	102966	
P_T	12320x66			813		47.5	38617	
P_{wind}	30x44.75x66			89		~~69~~ 73.13	5948 6479	
		32,463	13,784				844,014	1,637,403
		~~33394~~	~~13807~~	6772	1220		~~832,511~~	~~1,624,891~~
		19587		5552			792,280	
		18,679					793,389	

$$\Sigma \frac{M}{V} = \frac{\cancel{792,280}\ 793,389}{19587} = \cancel{40.45}\ 42.47$$

$$e = 45.50 - \cancel{40.45}\ 2.67 = \cancel{5.04'}\ 3.03'$$

$$Bear = \frac{\cancel{19587}\ 18,679}{66 \times 91}\left(1 \pm \frac{6 \times \cancel{5.04}\ 3.03}{91}\right)$$

$= \cancel{4340}\ 3730$ at River side

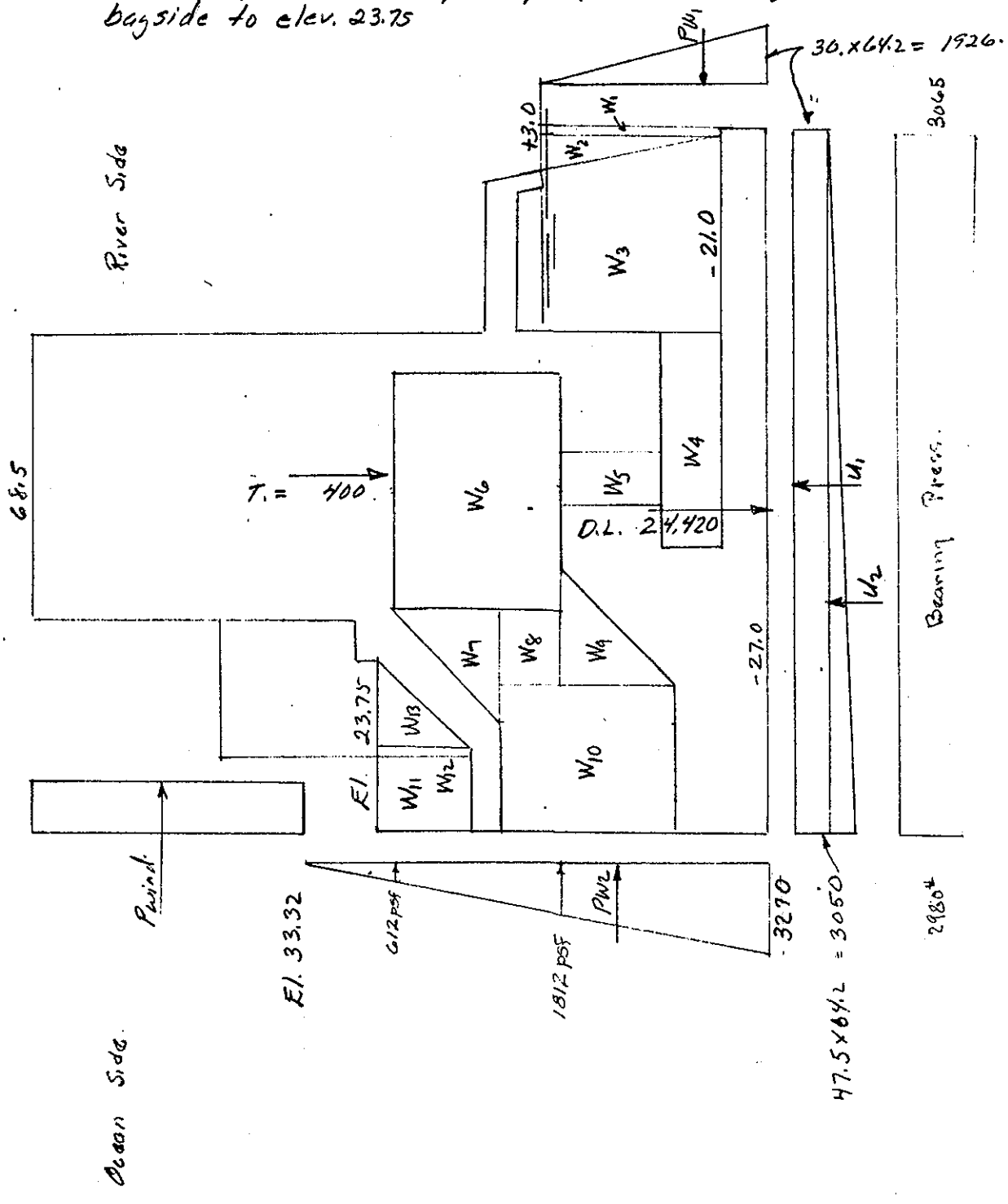
$= \cancel{2190}\ 2490$ at Ocean side

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT: Fox Point Pumping Station
COMPUTATION: Stability Analysis
COMPUTED BY: H.E.W. CHECKED BY: R.A.K. DATE: Dec. 11, 59

Case III Loading. - Hurricane and high water condition with stillwater at elev. 20.5 using a maximum wave with clapotis at elev. 33.32. Riverside tailwater at elev. +3.0, full hydrostatic pressure on the base varying from S.W.L. to tailwater, Dead loads plus pump thrust. Weight of water on bayside to elev. 23.75



NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pumping Station
COMPUTATION Stability Analysis
COMPUTED BY Whittemore CHECKED BY R.A.K. DATE Dec. 14. 59

Case III cont.

	Description	Vertical ↓	Vertical ↑	Horizontal →	Horizontal ←	Arm	Moment ↻	Moment ↺
	Dead Loads	24420				50.00		1,220,931
	Pump Thrust	400				44.00		17600
W_1	1.5x24x16x64.2	37				.75		28
W_2	4.0x24x16x.5x64.2	49				2.83		140
W_3	26.5x24x50x64.2	2,242 204				13.50		27,54 2,756
	$W_4 - W_{13}$ (Same as Case II)	6052	11,568				526,324	368,334
U_1	1926x66x91		11,631			45.50	529,216	
U_2	1124x66x91.x.5		3375			60.67	204,784	
P_{W1}	1926x20x.5x66				1907	10.00		19070
P_{W2}	3270x60.32x.5x66			6509		20.11	130,900	
P_{Wind}	35.18x30x66			70		77.91	5430	
		33,333	4,94				837,438	1,653,670
		31,162	15006	6579	1907		870,330	1,628,859
		16,156		4672			758,529	
		18,057					816,226	

$$\frac{\Sigma M}{\Sigma V} = \frac{758529}{16156} = \cancel{46.95}$$

816,226 / 18,057 = 45.20

$$e = 45.50 - \cancel{46.95} = 1.45$$

45.20 − 0.30 = 0.90

$$\text{Bearing } P = \frac{16,156}{66 \times 91}\left(1 \pm \frac{6 \times \cancel{1.45}}{91}\right)$$

18,057 / 66x91 = 1.10

P = 2960 #/□" of Bayside
P = 2420 #/□" of Riverside Bayside

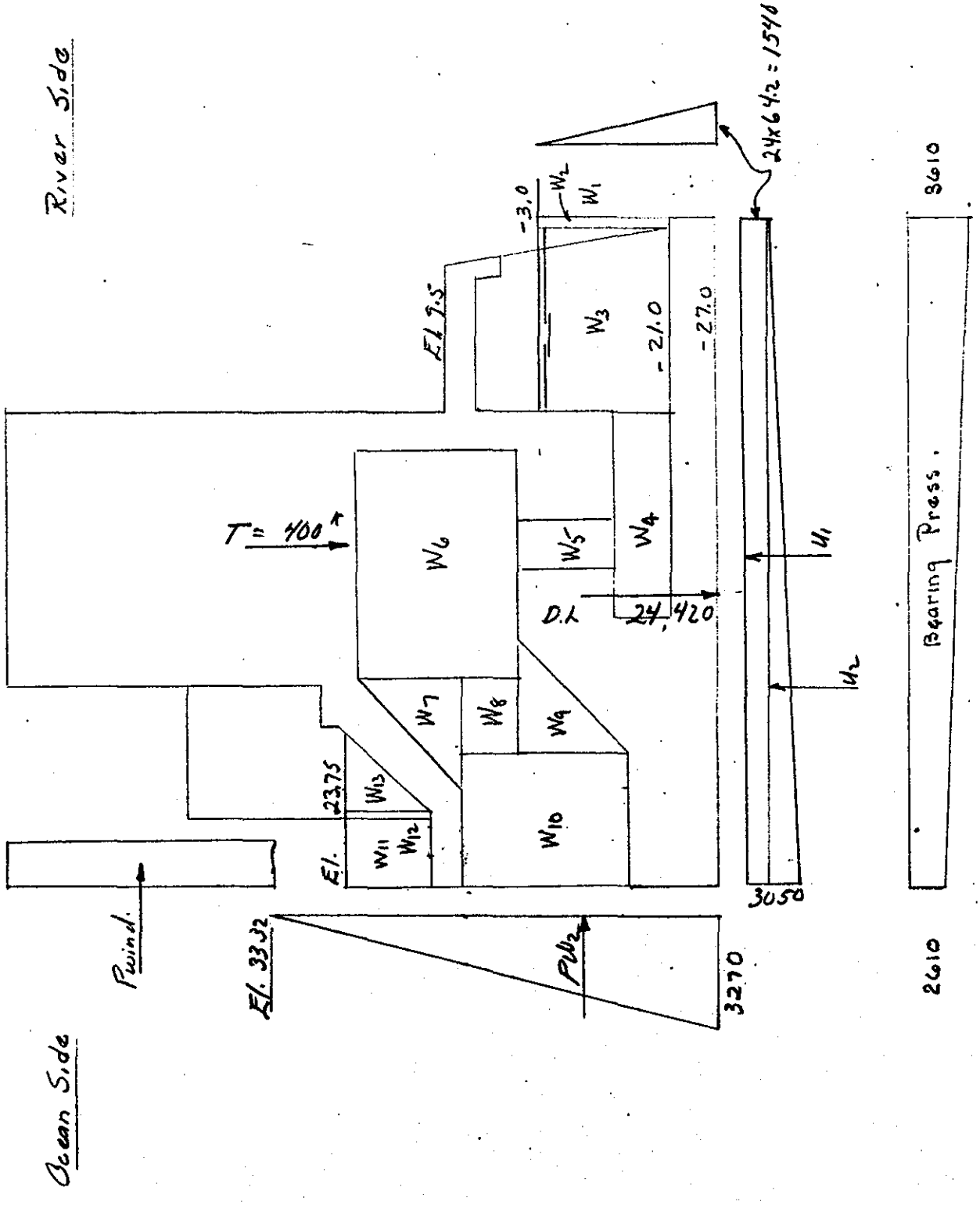
3060 #
2180 #

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pump Station
COMPUTATION Stability Case IV
COMPUTED BY H. E. W. CHECKED BY R. A. K. DATE Dec. 14, 59

Case IV Same as Case III except tailwater elev. taken as -3.0



SUBJECT Fox Point Pumping Station
COMPUTATION Stability Analysis
COMPUTED BY H.E.W CHECKED BY R.A.K. DATE Dec. 14.59

Case IV cont.

	Description	Vertical ↓	Vertical ↑	Horizontal →	Horizontal ←	Arm	Moments ↻	Moments ↺
	Dead Load	24420				50.00		1,220,931
	Pump Thrust	400				44.00		17,600
W_1	1.5×18×16 × 64.2	28				.75		21
W_2	3.5×18×16 × .5×64.2	32				2.67		86
W_3	26.5×18×25×2×64.2	1531				13.50		20,671
W_4	to W_{13} same as Case II	6052						368,334
U_1	1540×66×91		9249			45.5	420,840	
U_2	1510×66×91×.5		4535			60.67	275 110	
P_{W1}	1540×24×.5×66				1220	8.00		9760
P_{W2}	3270×60.32×.5×66			6509		20.11	130,900	
P_{wind}	35.18×30×66			70		77.91	5430	
		32,463	13784	6579	1220		832280	1,637,403
		18679		5359			805123	

$$\frac{\Sigma M}{\Sigma V} = \frac{805,123}{18679} = 43.10$$

$$e = 45.50 - 43.10 = 2.40'$$

$$\text{Bear } P = \frac{18,679}{91 \times 66}\left(1 \pm \frac{6 \times 2.40}{91}\right) \quad 1.16 \quad .84$$

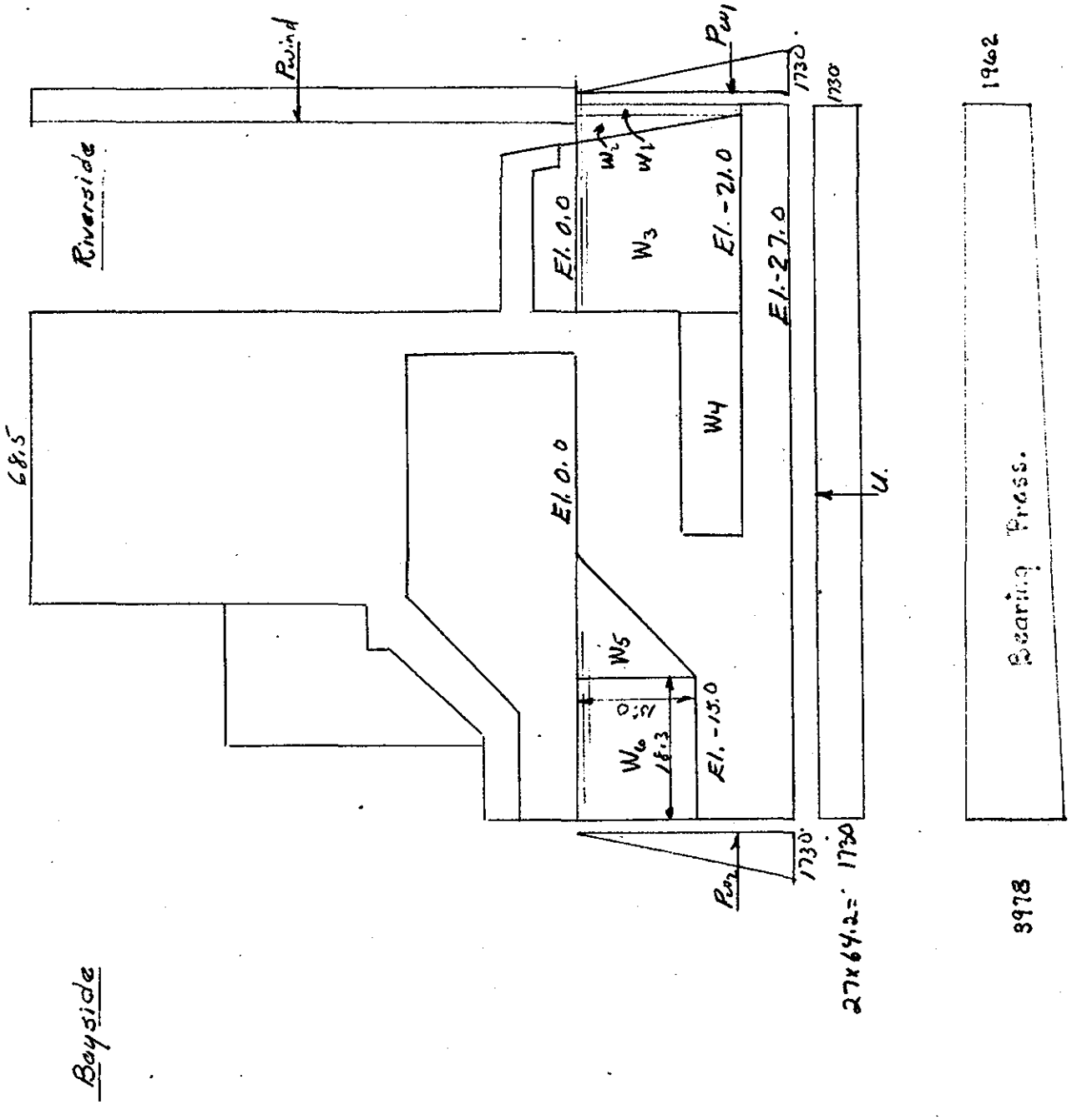
P at Bayside = 2610
P at Riverside = 3610

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pumping Station
COMPUTATION Stability
COMPUTED BY H. E. W CHECKED BY R. A. K. DATE Dec. 14, 55

Case V Normal condition with water on both sides to elev. 0.0 and pumps not in operation. Full dead load and wind load on the exposed river side of 20 #/p'. Up lift uniform across the bottom.



NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pumping Station
COMPUTATION Stability
COMPUTED BY H. E. W. CHECKED BY R. A. K. DATE Dec. 14.

Case V

	Description	Vertical ↓	Vertical ↑	Horizontal →	Horizontal ←	Arm	Moment ↷	Moment ↶
	Dead Loads	24,420.				50.00		1,220,931.
W_1	21x1.5x16x64.2	32				.75		24.
W_2	3.5x21.x.5x16x64.2	37				2.67		100.
W_3	26.5x21x50x64.2	1,784 ~~179~~				13.25		23,669 2,367
W_4	28.0x7.25x50x64.2	651				40.0		26,040 65
W_5	15x~~15~~ 16x.5x50x64.2	361				67.50		26,001 24,376
W_6	18.3x15x50x64.2	881				81.85		72,122
P_{w_1}	1730x27x.5x66				1541.	9.0	13,873	
P_{w_2}	1730x27x.5x66			1541.		9.0		13,873
U_1	1730x66x91		10,390			45.5	472,762	
Wind	68.5x20x66				90	61.25		5538
		28,192						1,388,323
		~~26,561~~	10,390.	1541	1541		486,635	1,365,371
		16,171					878,736	
		17,802					901,688	

$$\frac{\Sigma M}{\Sigma V} = \frac{\overset{901,688}{\cancel{878,736}}}{\underset{17,802}{\cancel{16,171}}} = \overset{50.65}{\cancel{54.34}}$$

$e = \cancel{8.84}$ 5.15

$$\text{Bear } P = \frac{\overset{17,802}{\cancel{16,171}}}{66 \times 91}\left(1 \pm \frac{\overset{1.58}{6 \times \cancel{8.84}\ 5.15}}{91}\right) = 2.9\left(\begin{matrix}1.33956\\ .66044\end{matrix}\right)$$

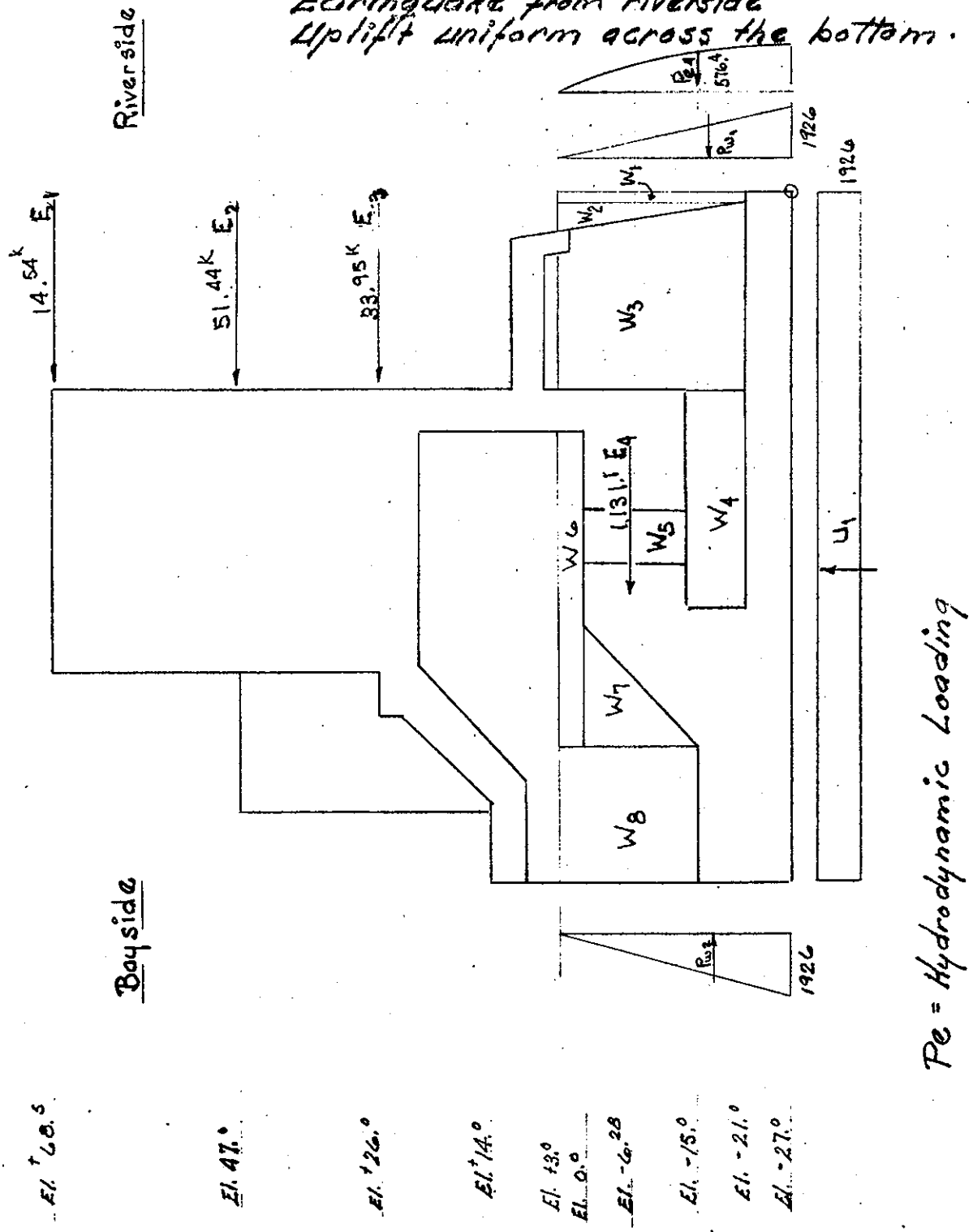
$P = \overset{3978}{\cancel{4250}}$ at Bayside .42

$P = \overset{1962}{\cancel{1130}}$ at Riverside

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Stability Analysis
COMPUTED BY R.A.K. CHECKED BY GFH DATE

Case V a

Normal condition with water at elevation +3.0' on both sides. and pumps not in operation.
Full dead load
Earthquake from riverside
Uplift uniform across the bottom.



Pe = Hydrodynamic Loading

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Stability Analysis
COMPUTED BY R.A.K. CHECKED BY GFH DATE

Earthquake Force 5% of gravity load.

Case Vo (Cont.)

Description	Forces Acting Factors	↓	Arm	Moment
E_1 Conc. Roof		266.14K		
Steel Purlins		10.56K		
Girders		12.96K		
Bracing		1.2K		
		290.86K × 0.05 =		14.54K
E_2 Balance of Superstructure	1,043.33K - 14.54K	= 1,028.79K × 0.05 =		51.44K
E_3 Equipement		679.0K × 0.05 =		33.95K
E_4 Substructure about El. -27.0		Areas	Arm	Moment
C_1 Base Mat		36.040.	3.0.	108.12.
C_2 Riverside Proj.		5.030.	18.17	91.2
C_3 " "		40.260.	21.25.	855.5.
C_4 Main Body		170.083.	29.50.	5,017.5.
C_5 Ocean side proj.		22.338.	23.50.	524.9.
		273.75.		6,587.22
	Minus Areas			
Omit these areas				
C_6 Riverside proj.		2.25.	13.5.	30.4
C_7 " "		2.25.	17.25.	38.8
C_8 " "		0.10.	19.25.	1.9
C_9 " "		24.67.	19.25.	474.9
C_{10} " Stop log Slot		0.32.	19.25.	6.2
C_{11} Stop log opening in slab		0.45.	34.5.	15.5
C_{12} Riverside access opening		0.60.	34.5.	20.7
C_{13} Area beneath pump		9.97.	9.62.	95.9
C_{14} Riverside curved area		1.46.	16.25.	23.7
C_{15} Pump Area		2.61.	20.75.	54.2
C_{16} " discharge Chamb.		29.15.	38.0	1,107.7

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Stability Analysis
COMPUTED BY RAK CHECKED BY GFH DATE

Earthquake Force Case Va

Forces Acting Description	Factor	Area	Arm	Moment
C_{17} Pump Discharge Chamb.		5.10.	43.0.	219.3
C_{18} " " "		3.60.	41.0.	147.6
C_{19} " " "		7.75.	32.0.	248.0
C_{20} " " "		5.81.	25.0	145.33
C_{21} " " "		23.13.	27.5	636.1
C_{22} Stop log opening		0.35.	26.5	9.3
C_{23} " " "		0.40.	39.0.	15.6
C_{24} Area under equip rm.		0.65.	52.0.	33.8
C_{25}		1.23.	44.22	54.4
C_{26}		0.52.	46.0.	23.9
C_{27} Pump Opening in floor		0.57.	51.0.	29.1
		122.94.		3,418.39
				3,432.
				3,168.32
		150.81.		3,124.92

$$\frac{\Sigma M}{\Sigma V} = \frac{3,124.92}{150.81} = 20.72 \quad \text{above El. } -27.0$$

$$He = 0.05 \times 150.81 \times 160^{\#} = 1,131.075^{K}$$

Earthquake Hydrodynamic Forces.

$$Ce = \frac{51}{\sqrt{1 - 0.72\left(\frac{h}{1000\, t_e}\right)^2}} = \frac{51}{\sqrt{1 - 0.72\left(\frac{95.5}{1000(1)}\right)^2}}$$

$$Ce = 51.25$$

$$Pe_2 = 2/3\ Ce\alpha y\sqrt{hy} = 2/3 \times 51.25 \times 0.05 \times 30.0\sqrt{95.5 \times 30.0}$$

$$= 51.25\sqrt{2868.0} = 2.743^{K}$$

Total Pe for 66'-0" Monolith

$$Pe = 66.0' \times 2.743^{K} = 181.04^{K-1}$$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT: Fox Point Pump Station – 66'-0" Monolith
COMPUTATION: Stability Analysis
COMPUTED BY: R. A. K. CHECKED BY: GFH DATE:

Case Va cont.

Description		Kips Vertical ↓	Kips Vertical ↑	Kips Horizontal →	Kips Horizontal ←	Arm	Kip-feet Moment ↷	Kip-feet Moment ↶
Monolith D.L. & Equip.		24420.				50.0.		1,220,931.
W_1		37.				.75.		28.
W_2		49.				2.83.		140.
W_3		2,042.				13.5.		27,561.
W_4		651.				40.0.		26,040.
W_5		168.				44.0.		7,392.
W_6	$3.0' \times 42.4 \times 25.0' \times 2 \times 64.2$	408.				51.7.		21,110.
W_7	$16.1' \times 15.0' \times 1/2 \times 25.0' \times 2 \times 64.2$	385.				67.55.		26,020.
W_8	$18.2 \times 18.0 \times 50.0 \times 64.2$	1,052.				81.9.		86,126.
Uplift								
	$91.0 \times 1926 \times 66$		11,568.			45.5.	526,324.	
P_{W_1}	$1926 \times 30 \times 1/2 \times 66$				1907.	10.0.		19070.
P_{W_2}	$1926 \times 30 \times 1/2 \times 66$			1907.		10.0.	19,070.	
Earthquake								
E_1					14.54.	95.0.		1,381.
E_2					51.44.	74.0.		3,807.
E_3					33.95.	53.0.		1,799.
E_4					1,131.1.	20.72.		23,436.
EW_3	$2,042 \times 0.05$				102.1.	15.0.		1,532.
EW_4	651×0.05				32.5.	9.65.		314.
EW_5	168×0.05				8.4.	20.8.		175.
EW_6	408×0.05				20.4.	28.5.		581.
EW_7	385×0.05				19.3.	22.0.		424.
EW_8	$1,052 \times 0.05$				52.6.	19.5.		1,026.
P_e					181.04.	12.0.		2,172.
		29,212.	11,568.	1907.	3,554.		545,394.	1,471,065.
		17,644.			1,647.			925,671.

$$\frac{\Sigma M}{\Sigma V} = \frac{925,671.}{17,644.} = 52.46'$$

$$e = 52.46 - 45.5 = 6.96' \text{ toward bayside}$$

$$\frac{\Sigma H}{\Sigma V} = \frac{1,647}{17,644} = 0.093 < 0.65 \therefore ok$$

ARMY-NED-BOSTON

SUBJECT Fox Point Pump Station
COMPUTATION Stability Analysis
COMPUTED BY R.A.K. CHECKED BY GFH DATE

Case IVa (Cont.)

$$\text{Bearing} = \frac{17,644}{66 \times 91}\left(1 \pm \frac{(6)(6.96)}{91}\right) = 2.938\,(1 \pm 0.459) = \begin{array}{l} 4.29\ K/Ft^2 \\ = 1.59\ K/Ft^2 \end{array}$$

4.29 K/Ft² Bayside
1.54 K/Ft² Riverside

Case V b

Normal condition with water at elevation +3.0 on both sides and pumps not in operation.
Full dead load
Earthquake from bayside
Uplift uniform across the bottom

Description		Vertical		Horizontal		Arm	Moment	
No.	Factor	↓	↑	→	←		↻	↺
Monolith D.L. & Equip.		24,420.				50.0		1,220,931.
	Water							
W_{1-8}		4,792.						194,417.
U_1			11,568.				526,324.	
P_{W_1}					1907.			19,070.
P_{W_2}				1907.			19,070.	
	Earthquake							
E_{1-4}				1,231.			30,423.	
$E_{W_{3-8}}$				235.			4,052.	
P_e				181.04			2,172.	
		29,212	11,568	3,554	1,907		582,041.	1,434,418.
		17,644		1,647.				852,377.

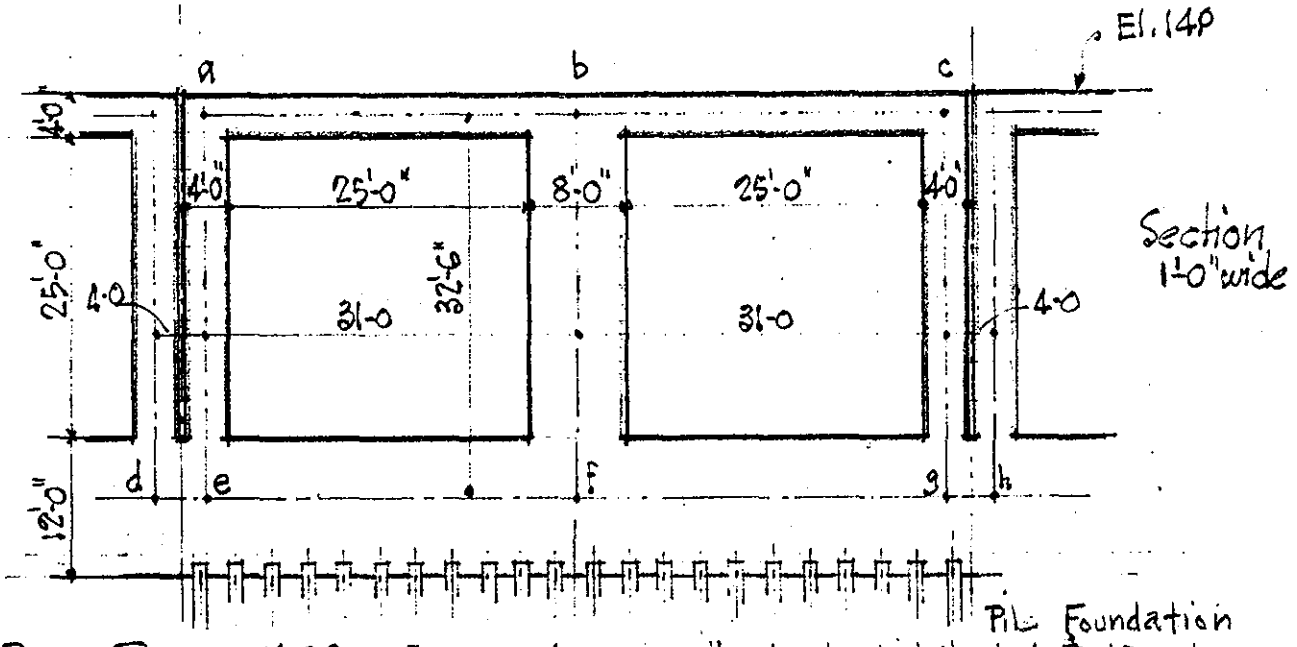
$$\frac{\Sigma M}{\Sigma V} = \frac{852,377}{17,644} = 48.31'$$

$$e = 48.31 - 45.5 = 2.81' \text{ Toward Bayside}$$

$$\text{Bearing Pressure} = \frac{17,644}{66 \times 91}\left(1 \pm \frac{6 \times 2.81}{91}\right) = 2.938\,(1 \pm 0.185) = \begin{array}{l} 3.48 \text{ Bayside} \\ = 2.39 \text{ Riverside} \end{array}$$

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY EYK CHECKED BY GFH / R.A.K. DATE 16 Dec. 1957

Case I. - Construction Period



Base Pres. = 5.28 KSF Assume pile loads distributed uniformly over base.

I ae $3 \times \overline{4}^3/12 = 16$ $K = 12 \times 16/32.5 = 5.9$
bf $3 \times \overline{8}^3/12 = 128$ $K = 12 \times 128/32.5 = 47.3$
ab $3 \times \overline{4}^3/12 = 16$ $K = 12 \times 16/31 = 6.2$
bc $= 6.2$
ef $3 \times \overline{11}^3/12 = 333$ $K = 12 \times 333/31 = 129$
fg $= 129$
de $K = 12 \times 333/4 = 1000$

Stiffeness

de = 5.9 / 5.9 + 6.2 = 0.49 ab = 0.51
ba = 6.2 / 6.2 + 47.3 + 6.2 = 0.10 bf = 0.80 bc = 0.10
fe = 129 / 129 + 47.3 + 129 = 0.42 fb = 0.16 fg = 0.42
ea = 5.9 / 5.9 + 1000 + 129 = 0.01
ed = 1000 / 1134.9 = 0.88
ef = 129 / 1134.9 = 0.11

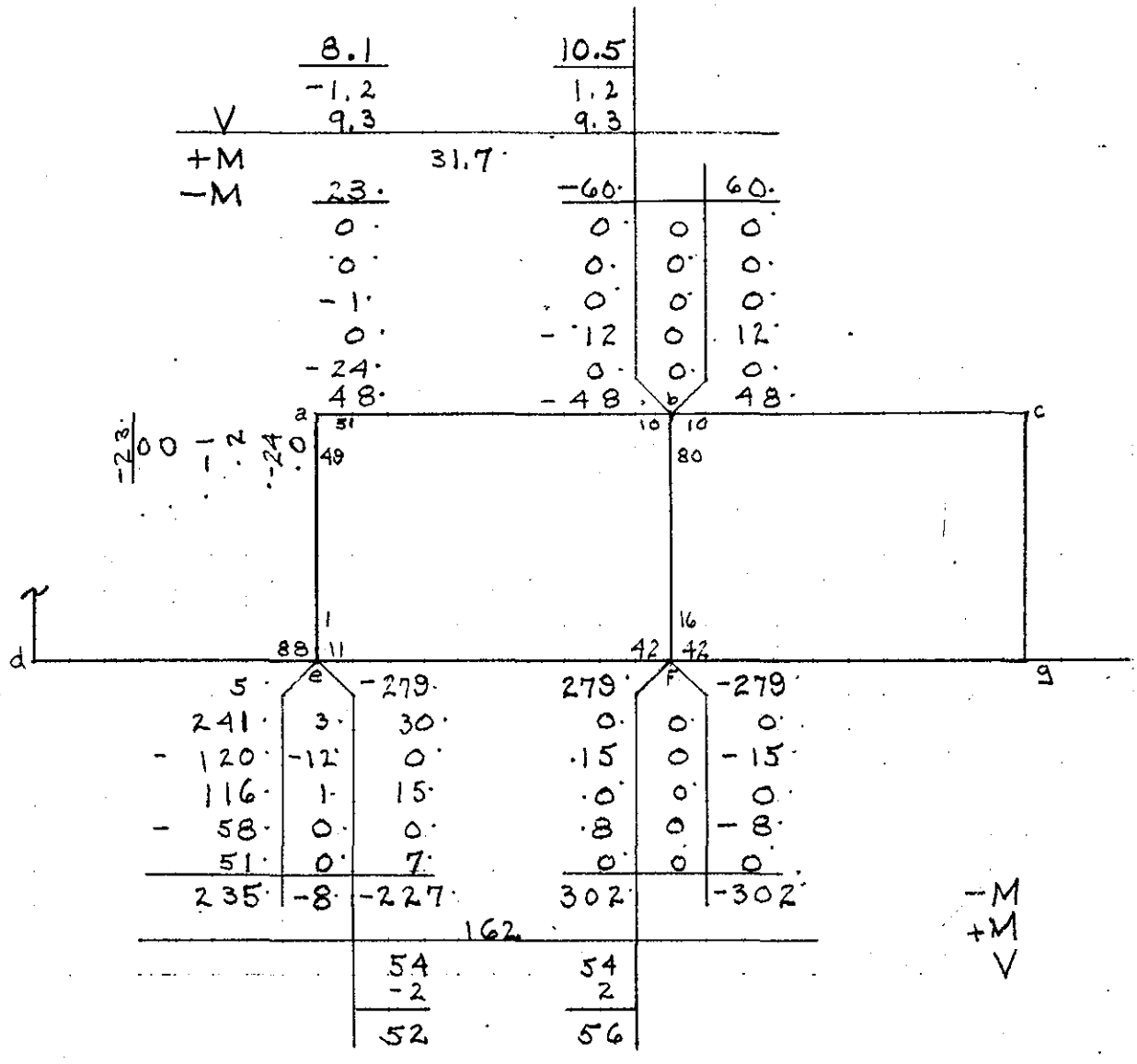
$M^F_{ab} = 4 \times 0.150 \times 31.0^2/12 = 48.0^{k'}$

$M^F_{ef} = [5.28 - (\overset{3.18}{0.150 \times 12.0})] \times 31.0^2/12 = 279.0^{k'}$

$M^F_{de} = \quad " \quad " \quad \times 4.0^2/12 = 4.6^{k'}$ Say. $5.0^{k'}$

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY R.A.K. DATE 16 Dec. 59

Case I (cont.)



$+M_{ab} = \left(13.50 \times 8.1 \times \frac{1}{2}\right) - 23.0 = 54.7 - 23.0 = 31.7^{k'}$

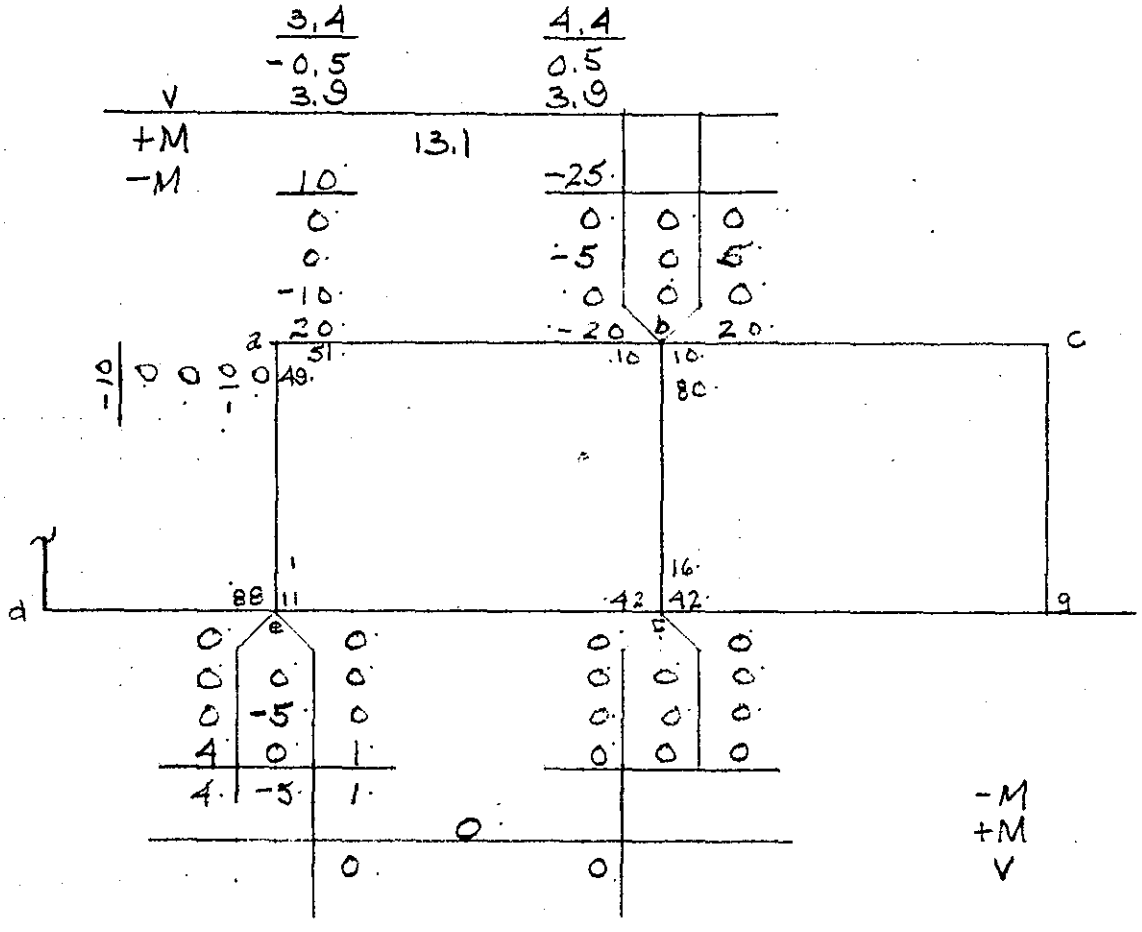
$+M_{ef} = \left(14.95 \times 52.0 \times \frac{1}{2}\right) - 227 = 389 - 227 = 162^{k'}$

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY R.A.A. DATE 16 Dec. 58

Case Ia - Same as Case I, but with 250 psf live load on roof.

$FEM_{ab} = \frac{1}{12} \times 0.250 \times 31.0^2 = 20.0$ k'

Distribution is for live load only



$+M_{ab} = \left(13.6 \times 3.4 \times \frac{1}{2}\right) - 10 = 23.1 - 10 = 13.1$

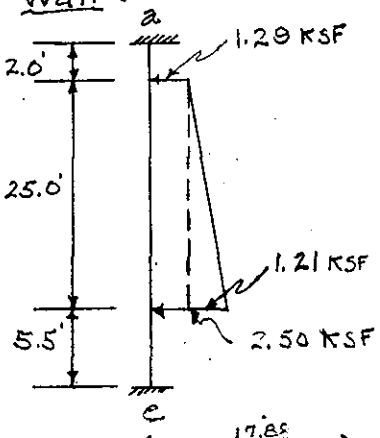
Add above moments + shears to Case I for final mom. + shears.

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GEH CHECKED BY R.A.K. DATE 17 Dec. 59

Case III: Hurricane; crest of significant wave to el. 23.75; maximum wave clapotis @ el. 33.32.

Base Pr. (assumed uniformly distributed) = 2.98 KSF
Uplift = 3.05 KSF

Wall:



$M^F_{ae} = (0.94^2)(4-2.8)(39.33 \times 32.5 \times \frac{1}{12}) = +113.0$
$(0.94^2)(5-2.8)(22.6 \times 32.5 \times 1/30) = +47.3$
$(0.17^2)(4-0.5)(13.74 \times 32.5 \times 1/12) = -3.7$
$(0.17^2)(5-0.5)(0.73 \times 32.5 \times 1/30) = -0.1$
$= +156.5^{K'}$

$M^F_{ea} = (0.94)(6-7.5+2.6)(39.33 \times 32.5 \times 1/12) = +110.0$
$(0.94)(10-9.4+2.7)(22.6 \times 32.5 \times 1/30) = +75.7$
$(0.17)(6-1.4+0.1)(13.74 \times 32.5 \times 1/12) = -29.7$
$(0.17)(10-1.7+0.1)(0.73 \times 32.5 \times 1/30) = -1.1$
$= +154.9^{K'}$

$V_a(\text{simple}) = \left(1.29 \times \overset{17.85}{25.0} \times \frac{18.0}{32.5}\right) + \left(\frac{1.21}{2} \times 25.0 \times \overset{6.21}{\frac{13.83}{32.5}}\right) = 24.32^K$

$V_e = \left(1.29 \times 25.0 \times \overset{14.40}{14.5/32.5}\right) + \left(\frac{1.21}{2} \times \overset{8.70}{25.0} \times \frac{18.67}{32.5}\right) = 23.10^K$

Deck: Net Pr. = 1.29 KSF UP − (9.75 x .0642) − (0.15 x 4.0)
= 1.29 − 0.626 − 0.60 = 1.29 − 1.23 = .06 KSF up.
neglect

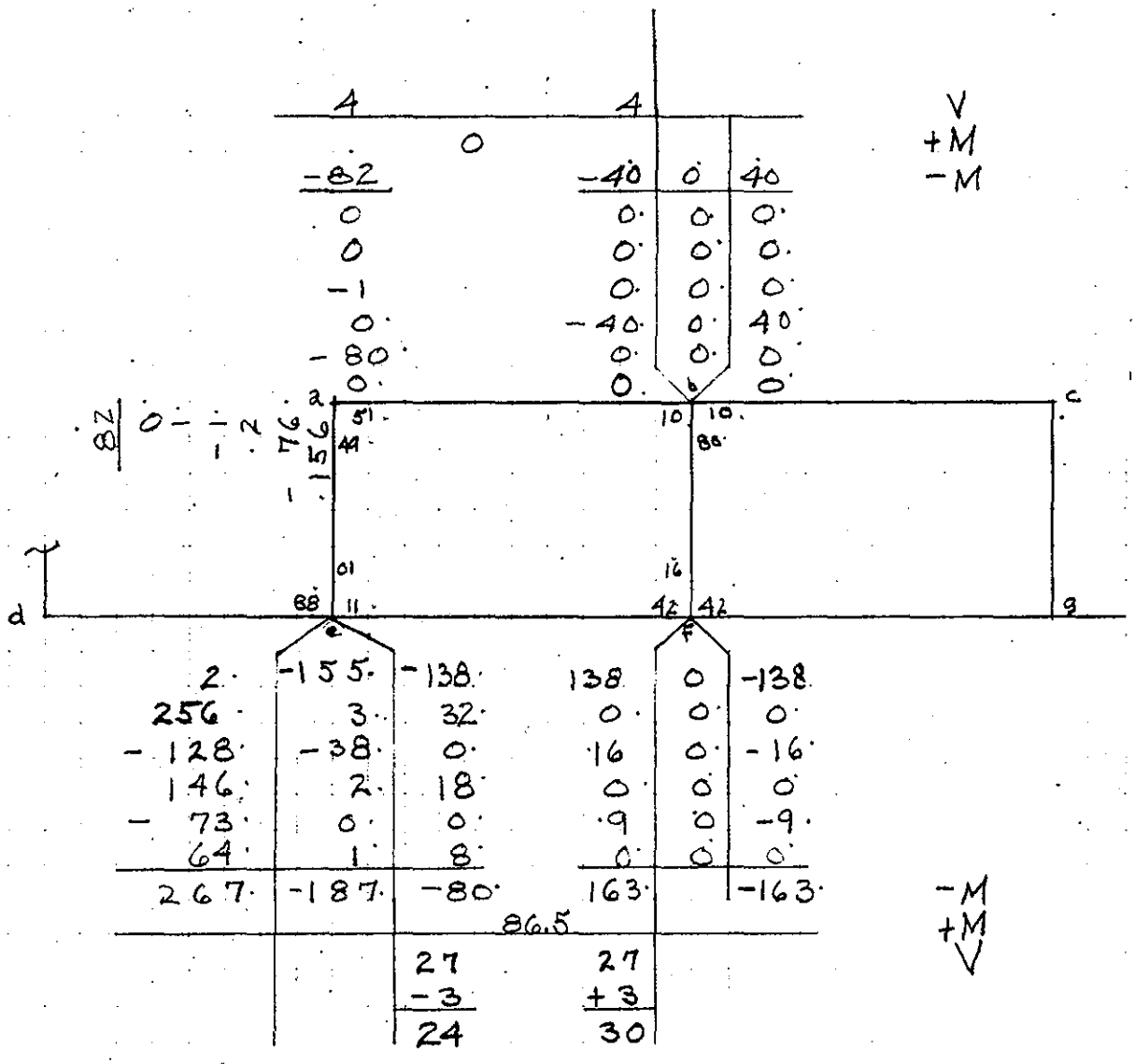
Base: Pr. Down = (12.0 x 0.15) + 2.50 = 4.30 KSF
Pr. Up = 2.98 + 3.05 = 6.03 KSF
Net Pr. = 6.03 − 4.30 = 1.73 KSF Up.

$M^F_{ef} = \frac{1}{12} \times 1.73 \times 31.0^2 = 138.0^{K'}$

$M^F_{de} = \frac{1}{12} \times 1.73 \times 4.0^2 = 2.3^{K'}$

SUBJECT Fox Point Pump Station 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY R.A.K. DATE 17 Dec. 59

Case III Loading



$+M_{cF} = (13.88 \times 24 \times 1/2) - 80 = 166.5 - 80 = 86.5^{k'}$

$V_{ae} = 24.32^{k} - \left(\frac{187-82}{32.5}\right) = 24.32 - 3.22 = 21.10^{k}$

$V_{ea} = 23.10 + 3.22 = 26.32^{k}$

$V = 0$ @: $21.10 = (1.29x) + \left(\frac{1.21}{25.0} \times \frac{x^2}{2}\right)$ $\quad 872 (+710) = x^2 + 53.3x (+710)$

$\pm 39.77 = x + 26.65$

$(2.0 +)\ 13.12 = x$

$+M_{ae} = (21.10 \times 15.12) - (82.0) - \left(1.29 \times \frac{13.12^2}{2}\right) - \left(\frac{1.21}{25} \times \frac{13.12^3}{2 \times 3}\right) = +109^{k'}$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
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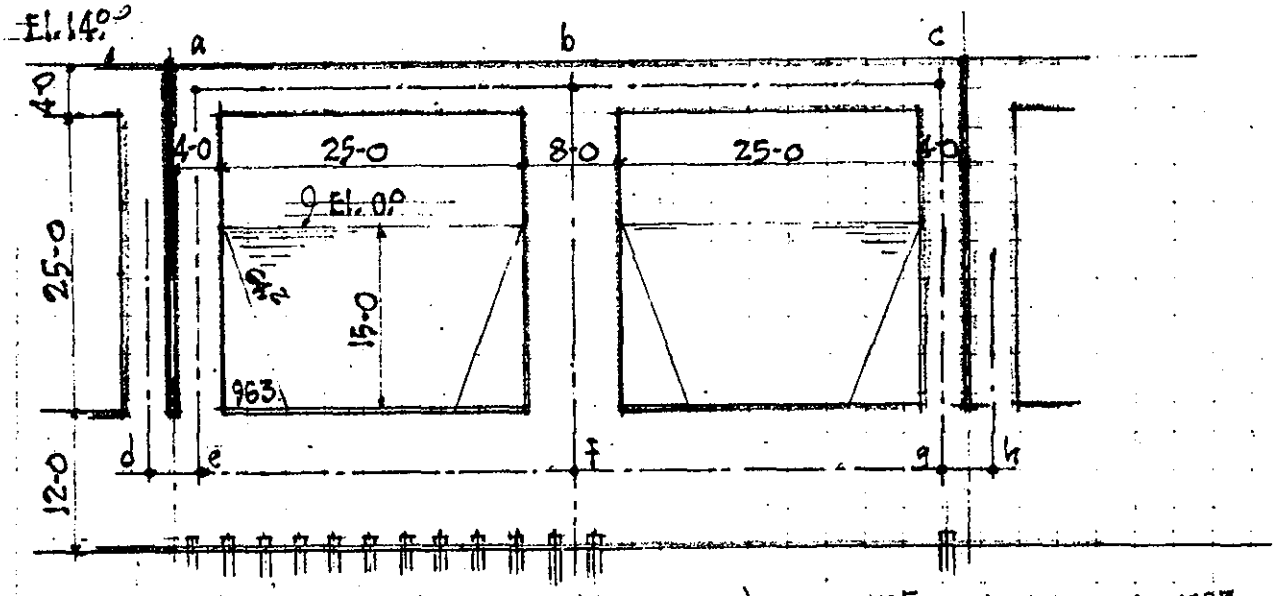
SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY G.F.M. E.T.K. CHECKED BY R.A.K. DATE 18 Dec. 1959

Case V Normal conditions with water inside at El. 0.0



Base Pr. (assumed uniformly distributed) = 3.98 KSF Uplift = 1.73 KSF

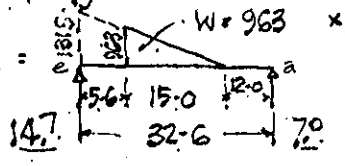
Net Base Pr. = (3.98 + 1.73) - (1.80 + 0.96) = 2.95 KSF

$M^F_{ab} = M^F_{bc} = 4 \times 150^{\#} \times 31^2/12 = 48^{K'}$

$M^F_{de} = 1/12 \times 2.95 \times 4.0^2 = 4.0^{K'}$

$M^F_{ef} = M^F_{fg} = 1/12 \times 2.95 \times 31.0^2 = 236.0^{K'}$

$M^F_{ea} =$



$\times 1/2 \times 15 = 7.23^K$

$= 0.63(10 - 6.3 + 1.2)(13.5 \times 32.5 \times 1/30) = 45.1$

$0.17(6 - 1.4 + 0.1)(5.3 \times 32.5 \times 1/12) = -11.4$

$0.17(10 - 1.7 + 0.1)(1.0 \times 32.5 \times 1/30) = -1.5$

$32.2^{K'}$

$M^F_{ae} = 0.63^2(5 - 1.9)(13.5 \times 32.5 \times 1/30) = 18.0$

less $= 0.17^2(4 - 0.5)(5.3 \times 32.5 \times 1/12) = -1.4$

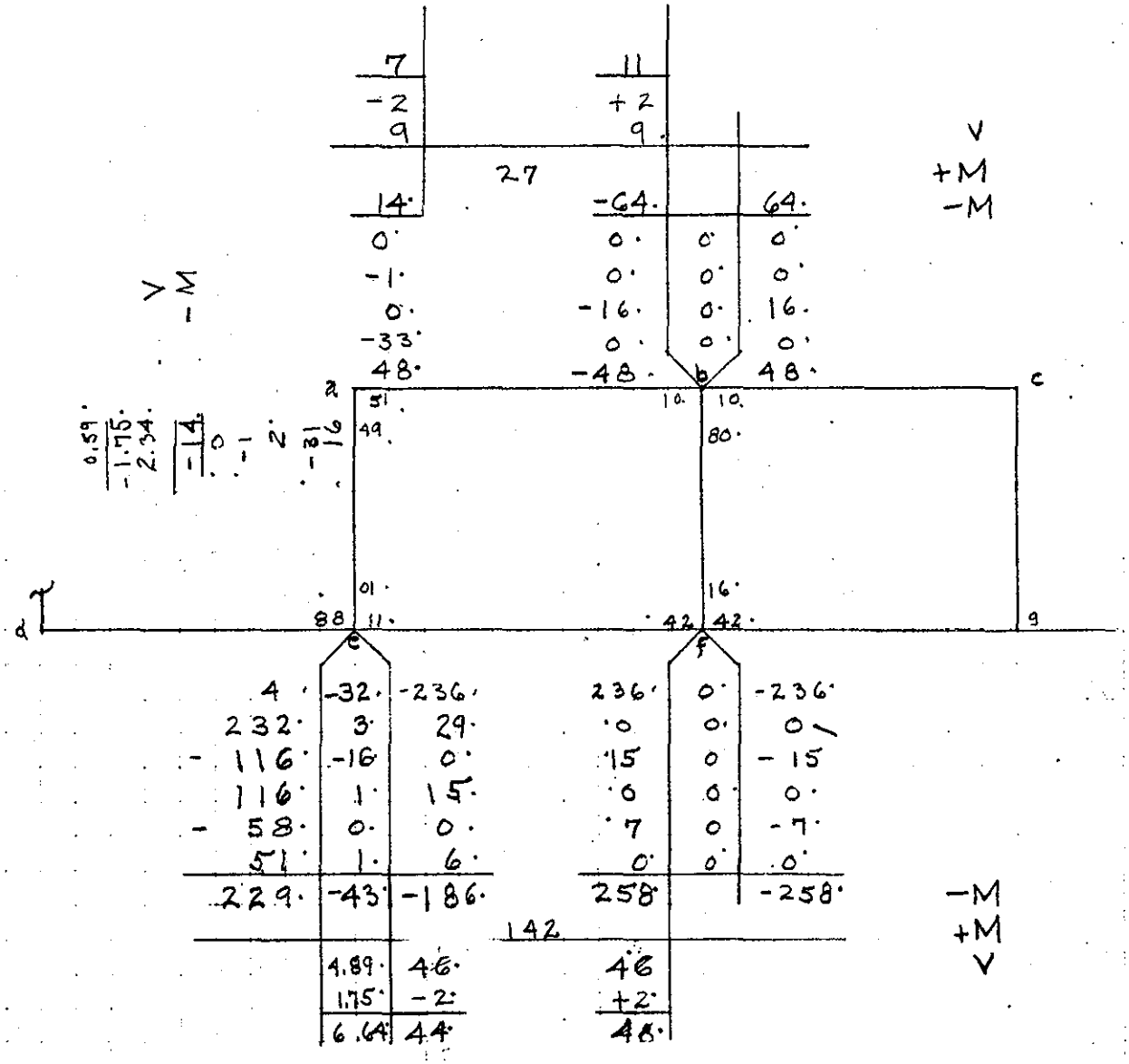
$= 0.17^2(5 - 0.5)(1.0 \times 32.5 \times 1/30) = -0.1$

$16.5^{K'}$

$R_a = 7.23 \times \frac{10.5}{32.5} = 2.34^K$ $R_e = 7.23 \times \frac{22}{32.5} = 4.89^K$

SUBJECT Fox Point Pump Station 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY [illegible] DATE 18 Dec. 59

Case V Loading:



$+M_{ef} = (14.9 \times 44 \times 1/2) - 186 = 328 - 186 = 142^{k'}$

$+M_{ab} = (11.68 \times 7 \times \tfrac{1}{2}) - 14 = 41 - 14 = 27^{k'}$

$+M_{ac}$ @ $V=0$ $\quad 0.59 = \frac{0.963}{15.0}\,\frac{x^2}{2} \quad x^2 = 18.4 \quad x = 4.3\ (+12.0)$

$+M_{ac} = 14.0 + (0.59 \times 16.3) - \left(\frac{0.963}{15.0} \times \frac{4.3^3}{6}\right) = 14.0 + 9.61 - 0.87 = 22.74^{k'}$

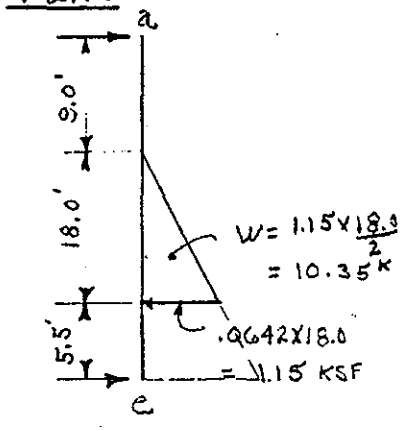
SUBJECT Fox Point Pump Station 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY R.A.K. DATE 18 Dec. 59

Case V a: Water @ el. +3.0 on both sides; pumps not operating; earthquake in landside direction.

Base Pr. = 4.29 KSF Uplift = 1.93 KSF

Net Base Pr. = (4.29 + 1.93) − (1.80 + 1.15) = 6.22 − 2.95 = 3.27 KSF

Wall:



$$M^F_{ac} = \frac{0.72^2(5-2.16)}{30}\left(.0642 \times \frac{23.5^2}{2}\right)(32.5) = +28.3$$

$$\frac{0.17^2(4-0.51)}{12}\left(1.15 \times 5.5\right)(32.5) = -1.7$$

$$\frac{0.17^2(5-0.51)}{30}\left(.0642 \times \frac{5.5^2}{2}\right)(32.5) = -0.1$$

$$26.5^{K'}$$

$$M^F_{ca} = \frac{0.72(10-7.20+1.55)}{30}\left(.0642 \times \frac{23.5^2}{2}\right)(32.5) = +60.1$$

$$\frac{0.17(6-1.36+0.87)}{12}\left(1.15 \times 5.5\right)(32.5) = -16.0$$

$$\frac{0.17(10-1.70+0.87)}{30}\left(.0642 \times \frac{5.5^2}{2}\right)(32.5) = -1.6$$

$$42.5^{K'}$$

$$M^F_{ab} = 48^{K'}$$

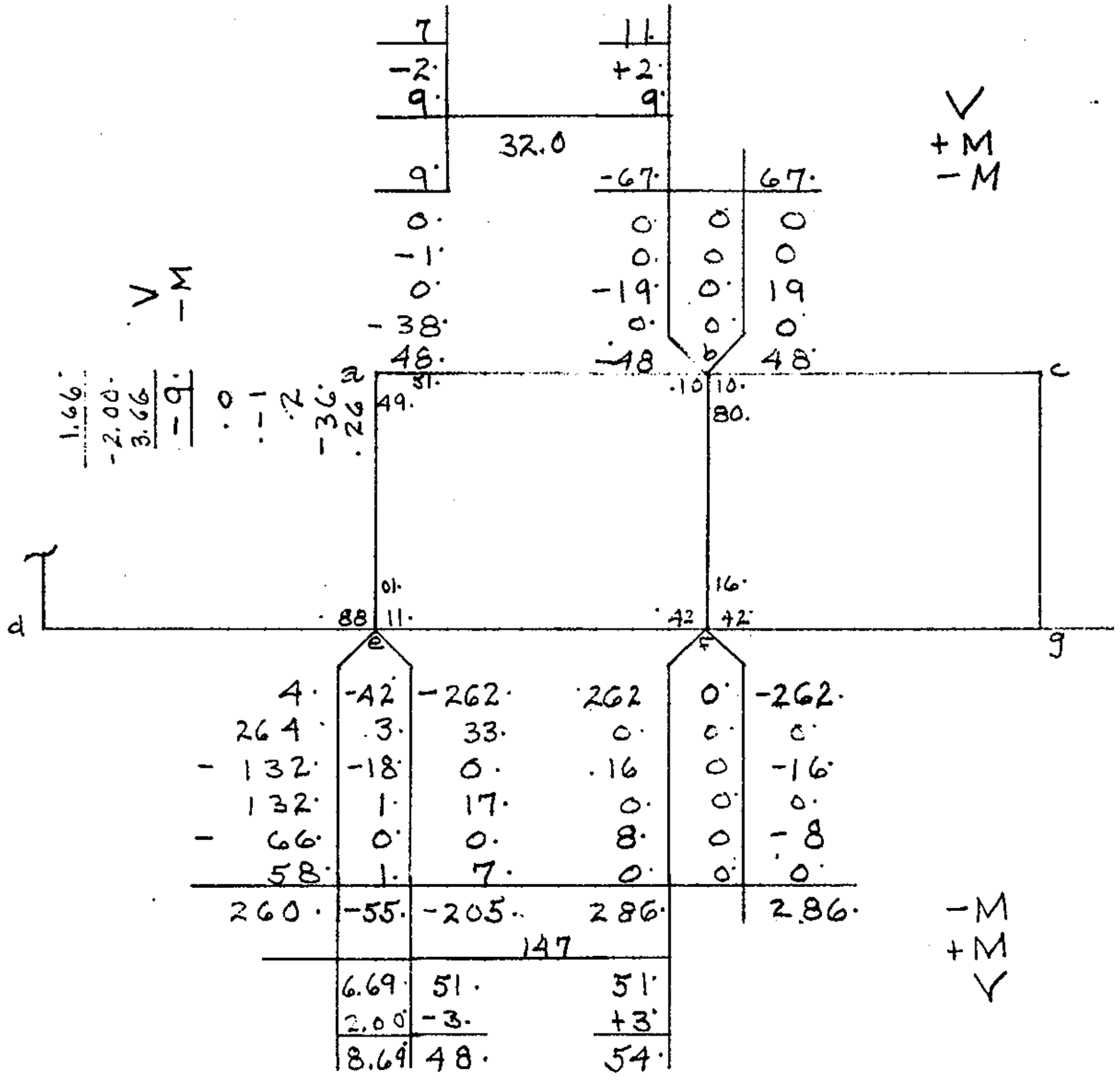
$$M^F_{de} = \frac{1}{12} \times 3.27 \times 4.0^2 = 4.0^{K'}$$

$$M^F_{ef} = \frac{1}{12} \times 3.27 \times 21.0^2 = 262^{K'}$$

$$R_a = 10.35 \times \frac{11.5}{32.5} = 3.66^K \qquad R_e = 10.35 \times \frac{21.0}{32.5} = 6.69^K$$

SUBJECT Fox Point Pump Station 66'-0" Monolith
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY R.A.K. DATE 18 Dec. 58

Case Va Loading:



$+M_{ab} = (11.68 \times 7.0 \times \frac{1}{2}) - 9 = 41 - 9 = 32.0^{k'}$

$+M_{ef} = (14.33 \times 48 \times \frac{1}{2}) - 205 = 352 - 205 = 147^{k'}$

$+M \max @ V = 0 \quad 1.66 = .0642 \frac{x^2}{2} \quad x^2 = 51.7 \quad x = 7.19' \ (+9.0)$

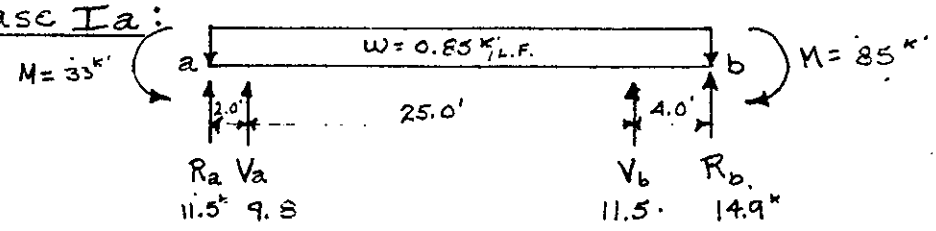
$+M = (1.66 \times 16.19) + (9.0) - (.0642 \times \frac{7.19^3}{6}) = 26.8 + 9.0 - 4.0 = 31.8^{k'}$

SUBJECT Fox Point Pump Station
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY R.A.K. DATE 21 Dec. 59

Roof Member - ab

$f'_c = 3000$ psi
$f_c = 1050$ psi
$f_s = 20000$ psi
$v = 90$ psi
u, top + exposed to sea water = 210 psi
u, others = 300 psi
$j = 0.885$
$K = 160$

Case Ia:



M_{ba}, at face $= 85 - (\frac{1}{3} \times 13.2 \times 8.0) = 85 - 35 = 50^{k'}$

M_{ab}, at face $= 33 - (\frac{1}{3} \times 10.65 \times 4.0) = 33 - 14 = 19^{k'}$

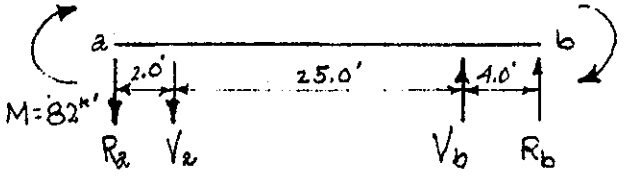
$+M = 44.8^{k'}$ $t = 48''$ $d = 43''$

$-A_s = \frac{50 \times 12}{20 \times .885 \times 43} = 0.79 \text{ in}^2$ $v = \frac{11500}{12 \times .885 \times 43} = 25.2$ psi

$\Sigma_o = \frac{11500}{210 \times .885 \times 43} = 1.44$ in $M_c = 0.160 \times 1.0 \times 43^2 = 296^{k'}$

$+A_s = \frac{44.8 \times 12}{20 \times .885 \times 43} = 0.71 \text{ in}^2$ Min Steel $= \frac{.0025}{2} \times 12 \times 43 = 0.65 \text{ in}^2$

Case III: Increase stresses by $33\frac{1}{3}\%$



$R_a = R_b = \frac{122}{31.0} = 4.0^k$

$V_a = V_b = 4.0^k$

$-M_{ab}$, at face $= 82 - (\frac{1}{3} \times 4.0 \times 4.0) = 82 - 5 = 77^{k'}$

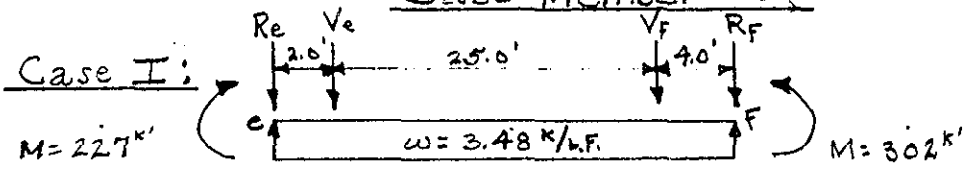
$-M_{ba}$, at face $= 40 - (\frac{1}{3} \times 4.0 \times 8.0) = 40 - 10 = 30^{k'}$

$-A_s = \frac{77 \times 12}{26.7 \times .885 \times 43} = 0.91 \text{ in}^2$

SUBJECT Fox Point Pump Station
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY [illegible] DATE 22 Dec. 59

Base Member - ef

Case I:



$R_e = 52^k$ $R_f = 56^k$ $V_e: 52.0 - (3.48 \times 2.0) = 45.04^k$
$V_f: 56.0 - (3.48 \times 4.0) = 42.08^k$

$-M_{ef}$, at face $= 227 - \left(\frac{1}{3} \times 48.52 \times 4.0\right) = 227 - 64 = 163^{k'}$

$-M_{fe}$, at face $= 302 - \left(\frac{1}{3} \times 49.04 \times 8.0\right) = 302 - 130 = 172^{k'}$

$+M = 162^{k'}$ $t = 11'\text{-}6''$ $d = 11 \times 12 = 132''$

$-A_s = \dfrac{172 \times 12}{20 \times .885 \times 132} = 0.89 \text{ in}^2$ $v = \dfrac{45040}{12 \times .885 \times 132} = 32 \text{ psi}$

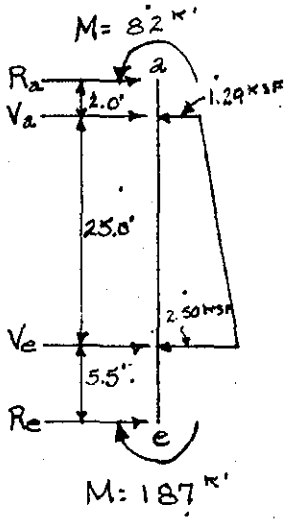
$\Sigma_o = \dfrac{45040}{210 \times .885 \times 132} = 1.84 \text{ in}$ $M_c = 0.160 \times 1.0 \times 132^2 = 2{,}790^{k'}$

$+A_s = \dfrac{162 \times 12}{20 \times .885 \times 138} = 0.80 \text{ in}^2$

SUBJECT Fox Point Pump Station
COMPUTATION Substructure - Section at Bayside Edge
COMPUTED BY GFH CHECKED BY DATE 22 Dec. 59

Wall Member - ae

Case III: Increase stresses by $33\frac{1}{3}\%$



$R_a = 21.10^k$ $R_e = 26.32^k$

$V_a = 21.10^k$ $V_e = 26.32^k$

$-M_{ae}$, at face $= 82.0 - (\frac{1}{3} \times 21.10 \times 4.0) = 82.0 - 28 = 54^{k'}$

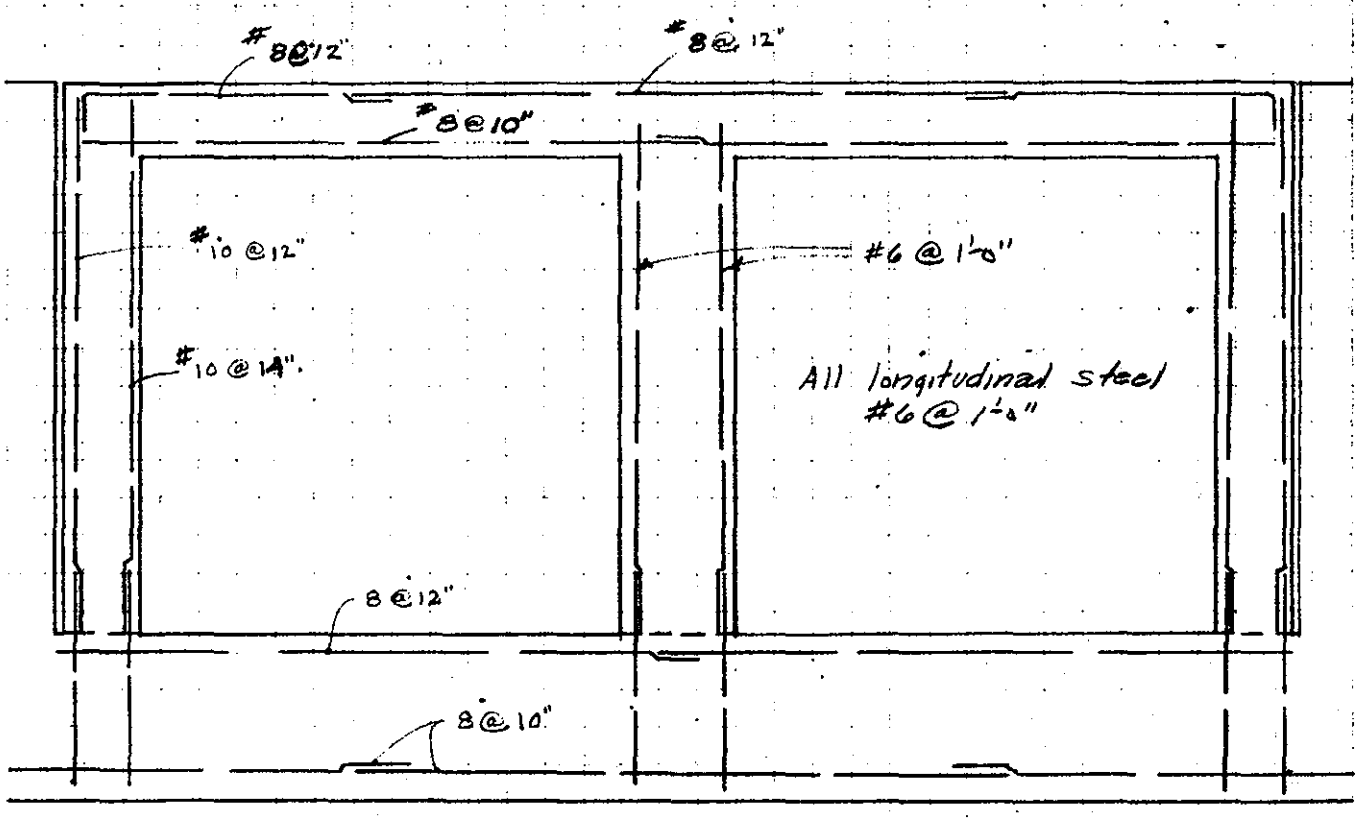
$-M_{ea}$, at face $= 187.0 - (\frac{1}{3} \times 26.32 \times 11.0) = 187 - 96 = 91^{k'}$

$+M = 109^{k'}$

$$-A_s = \frac{91 \times 12}{26.7 \times .885 \times 43} = 1.08 \text{ in}^2$$

$$v = \frac{26,320}{12 \times .885 \times 43} = 58 \text{ psi} \qquad \Sigma_o = \frac{26320}{210 \times .885 \times 43} = 3.29 \text{ in}$$

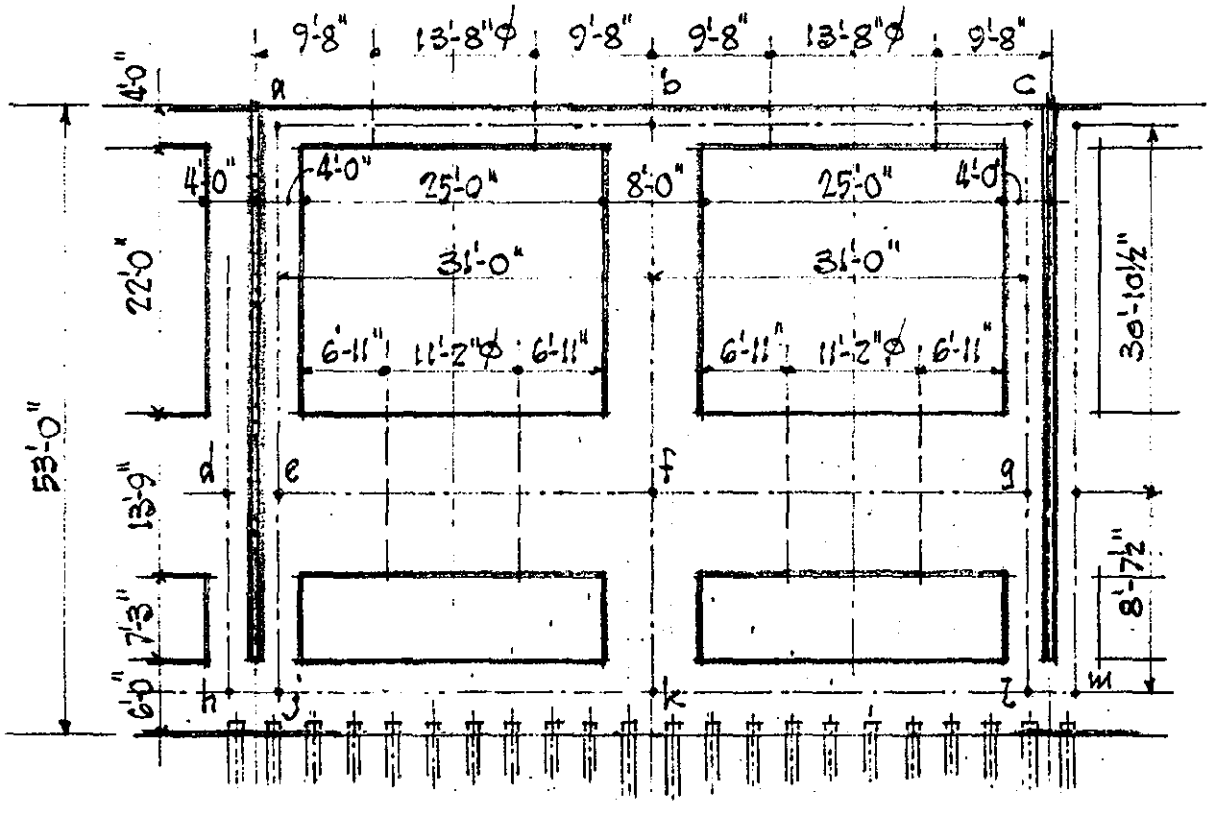
$$+A_s = \frac{109 \times 12}{26.7 \times .885 \times 43} = 1.29 \text{ in}^2 \qquad \text{Min. Steel} = \frac{.0025}{2} \times 12 \times 43 = 0.65 \text{ in}^2$$

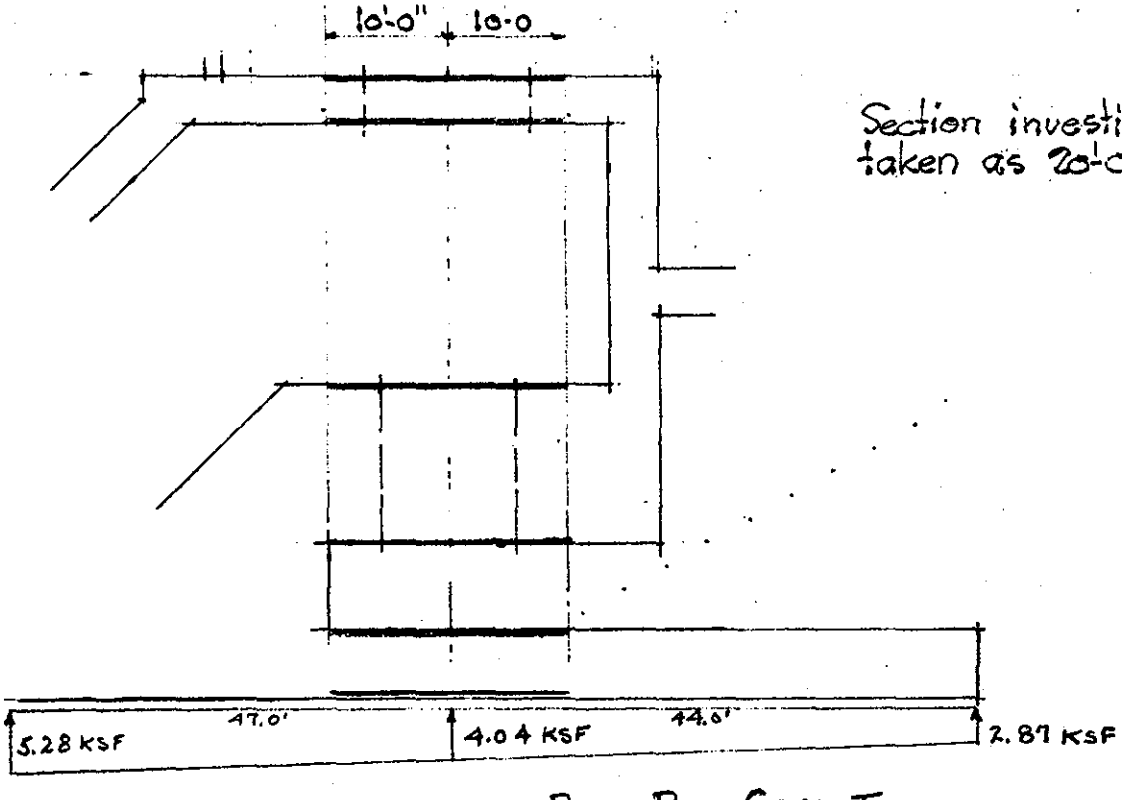


NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Transverse Sect. at ℄ of Pumps
COMPUTED BY E.P.R. CHECKED BY GFH DATE 11 Dec. 1959





Section investigated taken as 20'-0" wide

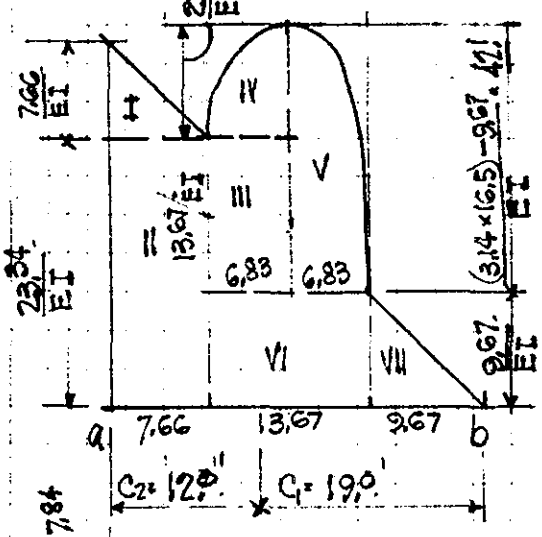
Base Pr. - Case I

SUBJECT Fox Point Pump Station – 66'-0" Monolith
COMPUTATION Substructure – Trans. Section at ℄ of Pumps
COMPUTED BY EPR CHECKED BY GFH DATE 14 Dec. 1959

Member ab $t = 4'-0''$ $b = 20'-0''$

Max. $I = 20 \times 4^3/12 = 107$ ft^4

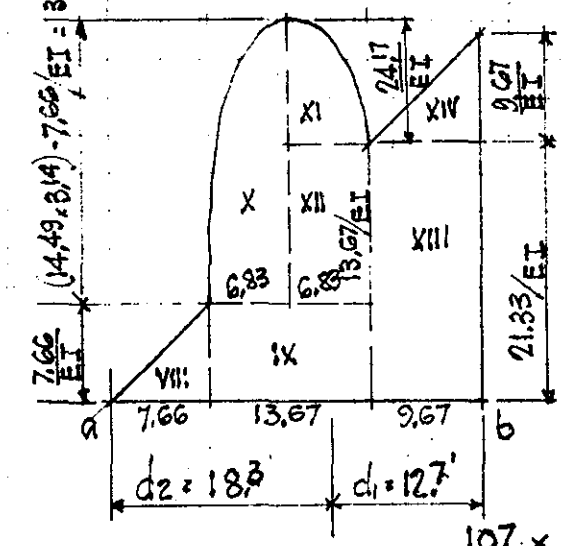
Min. $I = 6.83 \times 4^3/12 = 34$ ft^4 $\frac{107}{34} = 3.14$



I	7.66 × ½ × 7.66	=	29.50	× 28.45	=	840.0
II	7.66 × 23.34	=	179.00	× 27.17	=	4860.0
III	6.83 × 13.67	=	93.3	× 19.92	=	1860.0
IV	6.83 × ⅔ × 28.43	=	129.5	× 19.06	=	2470.0
V	6.83 × ⅔ × 42.1	=	193.0	× 13.94	=	2700.0
VI	13.67 × 9.67	=	132.0	× 16.50	=	2180.0
VII	9.67 × ½ × 9.67	=	46.5	× 6.45	=	300.0
			802.8			15210.0

$C_1 = 15210 \div 802.8 = 19.00'$

$C.O. = 12.0 / 19.0 = 0.633$



VIII	7.66 × ½ × 7.66	=	29.30	× 5.10	=	149.50
IX	13.67 × 7.66	=	105.00	× 14.49	=	1525.00
X	6.83 × ⅔ × 37.84	=	173.0	× 11.93	=	2065.00
XI	6.83 × ⅔ × 24.17	=	110.0	× 17.05	=	1870.00
XII	6.83 × 13.67	=	93.2	× 17.90	=	1670.00
XIII	9.67 × 21.33	=	206.0	× 26.16	=	5390.00
XIV	9.67 × ½ × 9.67	=	47.0	× 27.78	=	1295.00
			763.5			13964.5

$d_2 = 13964.5 \div 763.5 = 18.3'$

$C.O. = 12.7 \div 18.3 = 0.695$

$$S_{ab} = \frac{c_1 L\, 107}{D(c_1 - d_1)} = \frac{19 \times 31 \times 107}{763.5(19 - 12.7)} = 11.35\,E$$

$$S_{ba} = \frac{d_2 L\, 107}{C(c_1 - d_1)} = \frac{18.3 \times 31 \times 107}{802.8 \times 7.3} = 10.35\,E$$

$C.O.^{ab} \times S_{ab} = 0.633 \times 11.35 = 7.2$

$C.O._{ba} \times S_{ba} = 0.695 \times 10.35 = 7.2$

SUBJECT Fox Point Pump Station – 66'-0" Monolith
COMPUTATION Substructure – Trans. Section ℄ of Pumps
COMPUTED BY E.P.R. CHECKED BY GFH DATE 14 Dec. 1959

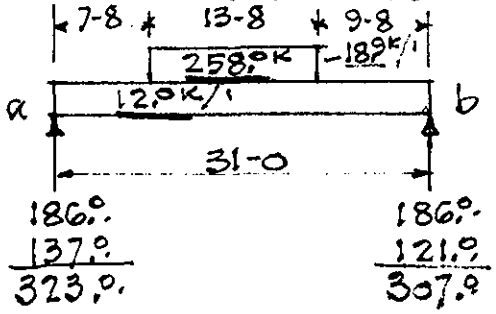
Wall ae $t = 3'\text{-}11''$ $b = 20'\text{-}0''$ $I = 20 \times \overline{3.92}^3/12 = \underline{101}\ ft^4$
$L = 24'\text{-}0''$

cg Same.

bf $t = 8'\text{-}0''$ $b = 20'\text{-}0''$ $I = 20 \times \overline{8}^3/12 = \underline{850}\ ft^4$
$L = 24'\text{-}0''$

				K/ΣK
Mem. ae	$K = \frac{4EI}{L} = \frac{4 \times 101 \times E}{24}$	$= 16.8E$	$= 16.8/16.8+11.35$	$= \underline{60\%}$
				$= 40\%$
ab		$= 11.35E$		
ba		$= 10.35E$	$= 10.35/162.70$	7%
bf	$K = \frac{4EI}{L} = \frac{4 \times 850 \times E}{24}$	$= 142.0\ E$	$= 142.0/10.35+142+10.35$	86%
bc		$= 10.35E$		7%

Case I Pump + Motor $85.0 + 173.0 = \underline{258.0^K}$
4'-0" Slab $= 20 \times 600^{\#} = \underline{12000^{\#}/l.f.}$



$M^F_{ab} = 12.0 \times \overline{31}^2/12 = 960.0$

$= \frac{18.9}{12 \times \overline{31}^2}\left[\overline{23.33}^3(124^{54} - 70) - \overline{9.67}^3(124^{15} - 29)\right] = 980.0$

$\underline{1940.0}$

$M^F_{ba} = 12.0 \times \overline{31}^2/12 = 960.0$

$= \frac{18.9}{12 \times (31)^2}\left[\overline{21.33}^3(124 - 64_{60}) - \overline{7.67}^3(124^{101} - 23)\right] = \underline{870.0}$

$\underline{1830.0}$

Mat Span $= 31'\text{-}0''$ Total Load $= 20 \times 31.0 \times (4.04^{3.14} - 0.90) = \underline{1960.0^K}$

M^F_{jk} $1960.0 \times 31/12 = \underline{5050.0^{K'}}$

$M^F_{hi} = 20 \times 3.14 \times 4^2/12 = \underline{145.0^{K'}}$

$I = 20 \times \overline{5}^3/12 = 208\ ft^4$ $K = 208/31 = 6.7$ 10%
$K = 208/4 = 52$ 75%

Walls je $I = 20 \times \overline{3.92}^3/12 = 101\ ft^4$ $K = 101/9.75 = 10.3$ 15%
kf $I = 20 \times \overline{8}^3/12 = 850\ ft^4$ $K = 850/9.75 = 87$

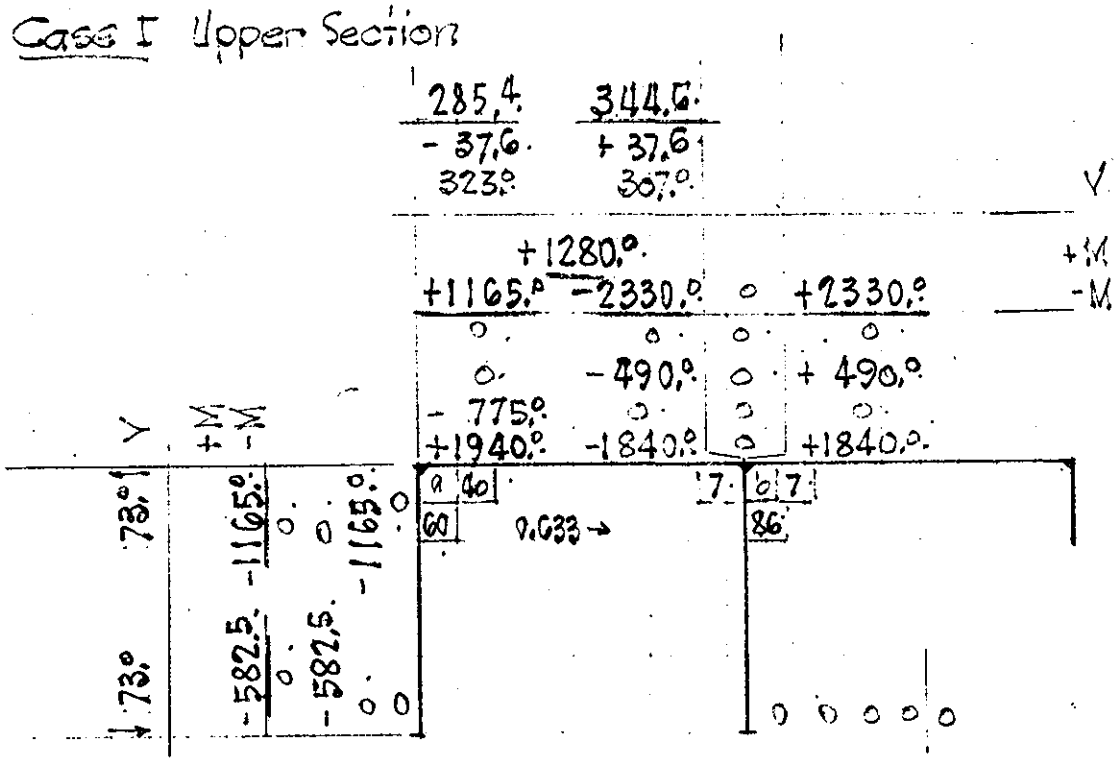
$jk = 6.7/6.7 + 87 + 6.7 = 6.7/100.4 = 7\%$
$kf = 87/100.4 = 86\%$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS, OF ENGINEERS, U. S. ARMY

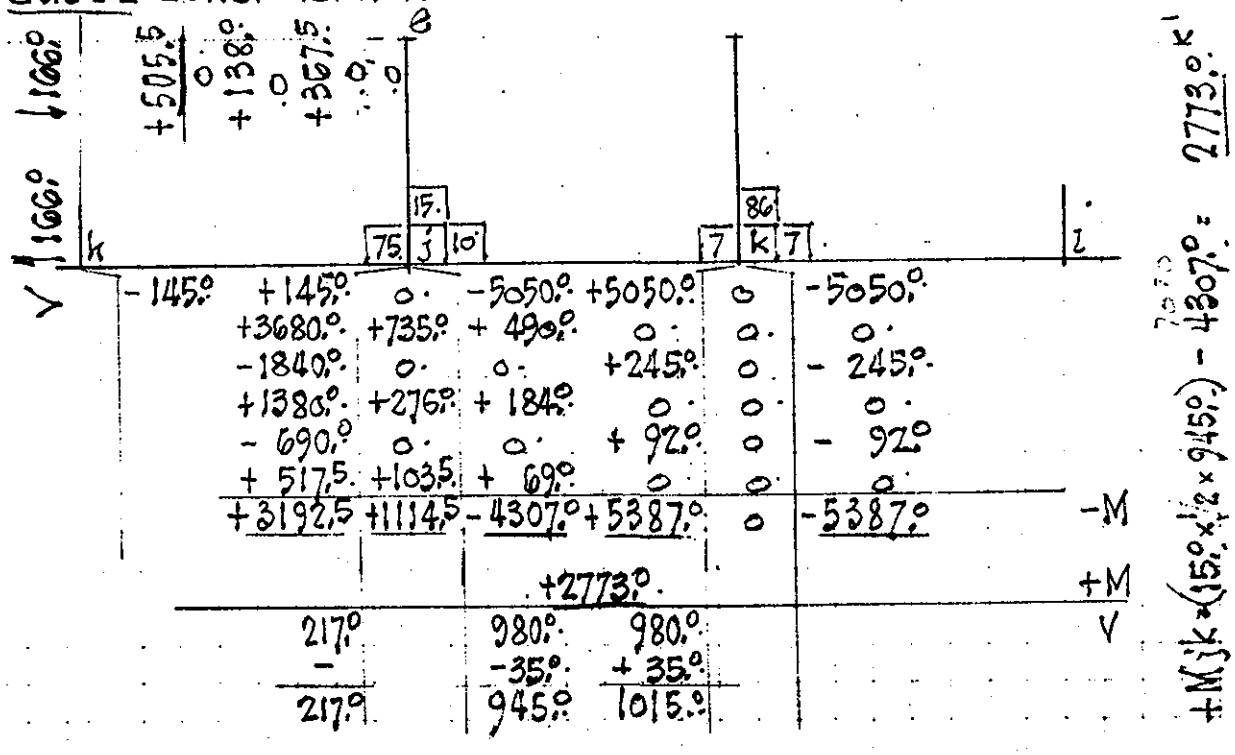
SUBJECT Fox Point Pump Station - 60'-0" Monolith
COMPUTATION Substructure - Transverse Section at ℄ Piers
COMPUTED BY EPR CHECKED BY GFH DATE 16 Dec 1959

Case I Upper Section



$$+M_{ab} = (13.92 \times 285.4) - (13.92 \times 12.0 \times 6.96) - (6.25 \times 18.9 \times 3.12) - 1165.0$$
$$= 3980.0 - 1165.0 - 370.0 - 1165.0 = \underline{1280.0^{k'}}$$

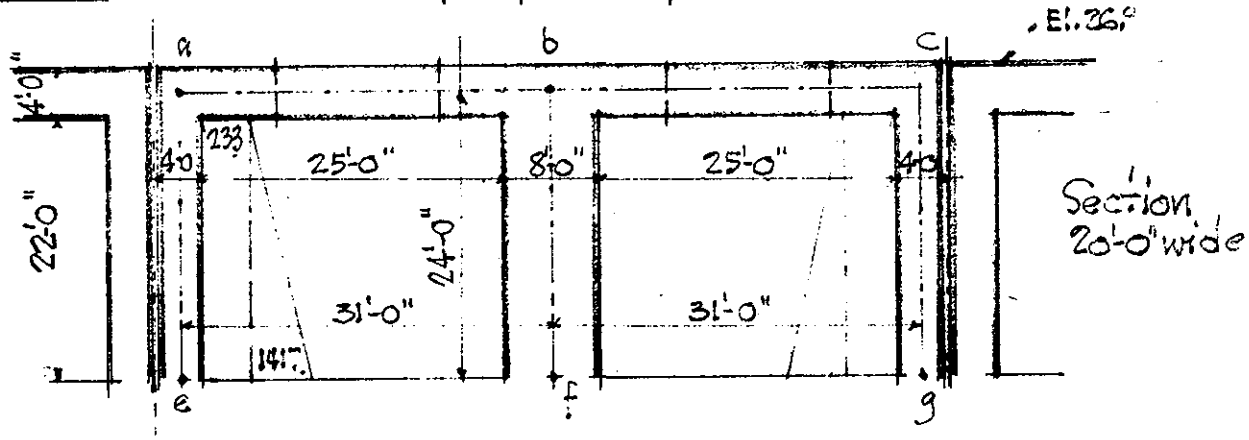
Case I Lower Portion



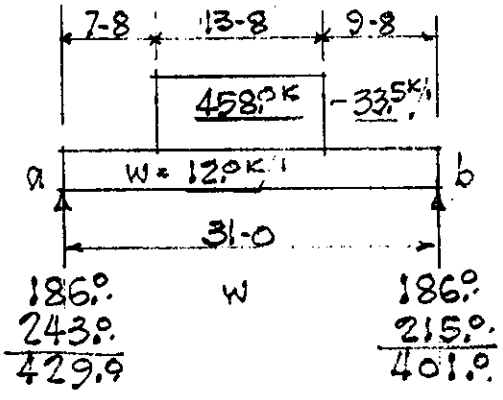
$+M_{ik} = (15.0 \times \frac{1}{2} \times 945.0) - 4307.0 = \underline{2773.0^{k'}}$

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Transverse Section at ℄ of Pumps
COMPUTED BY E.P.P. CHECKED BY EH DATE 15 Dec. 1950

Case II Hurricane with pumps in operation and water in cell.



Mem. ab and cb (Floor)

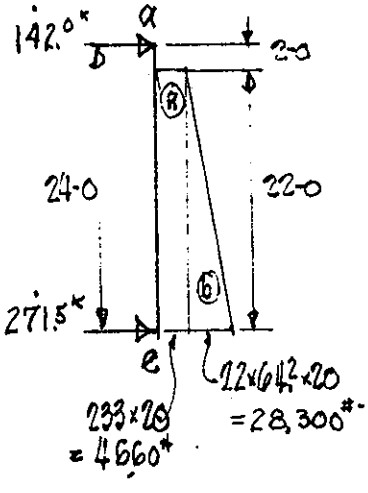


Pump & Motor = 258.0
Thrust = 200.0
458.0K

$M^F_{ab} = 12.0 \times \overline{31}^2/12 = 960.0$
$= 33.5 \times 980.0/18.9 = 1740.0$
2700.0K'

$M^F_{ba} = 12.0 \times \overline{31}^2/12 = 960.0$
$= 33.5 \times 870.0/18.9 = 1540.0$
2500.0K'

Walls ae & cg



ⓐ $4.66 \times 22.0 = 102.5K$ ⓑ $28.3 \times 1/2 \times 22 = 311.0K$

$R_T = 102.5 \times 11/24 = 47.0$
$= 311.0 \times 7.33/24 = 95.0$ 142.0K

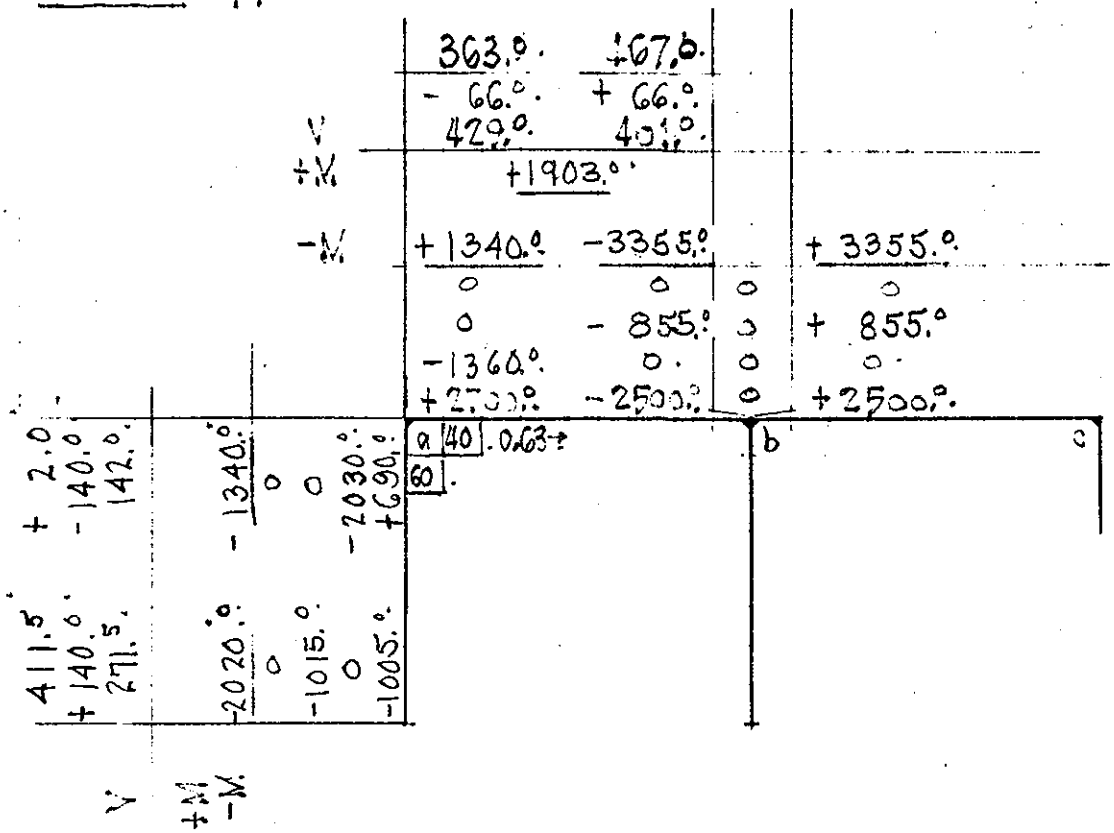
$R_B = 102.5 + 311.0 - 142.0 = 271.5K$

$M^F_{ae} = \overline{0.92}^2 (4 - 2.75)(102.5 \times 24.0 \times 1/12) = 217.0$
$= \overline{0.92}^2 (5 - 2.75)(311.0 \times 24.0 \times 1/30) = 473.0$ 690.0K'

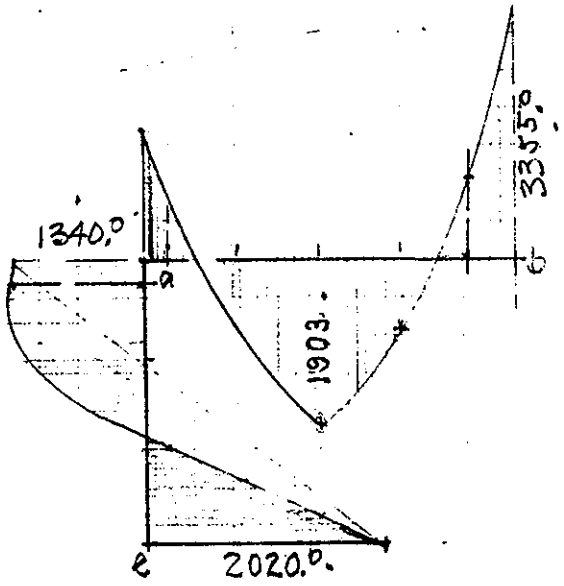
$M^F_{ea} = 0.92 (6 - 7.4 + 2.6)(102.5 \times 24.0 \times 1/12) = 227.0$
$= 0.92 (10 - 9.2 + 2.6)(311.0 \times 24.0 \times 1/30) = 778.0$ 1005.0K'

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Transverse Section at ℄ of Pumps
COMPUTED BY EPR CHECKED BY GFH DATE 16 Dec. 1959

Case II Upper Section



$$+M_{ab} = (13.62 \times 363) - \left(\frac{13.62^2}{2} \times 12.0\right) - \left(\frac{5.96^2}{2} \times 33.5\right) - 1340 = +1903^{k'}$$



Moment Diagram Sc. 1/2" = 1000.0 k'

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27 Sept 49

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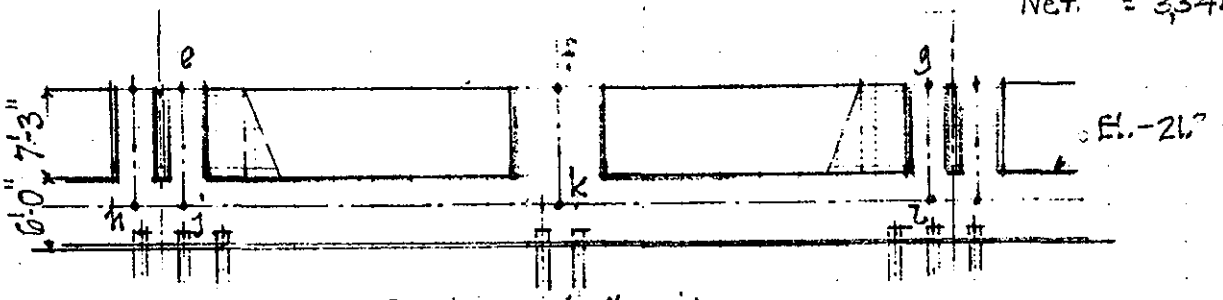
SUBJECT: Fox Point Pump Station — 66'-0" Monolith
COMPUTATION: Substructure — Transverse Section at ℄ Pumps
COMPUTED BY: E.P.P. CHECKED BY: GFH DATE: 15 Dec. 1950

Case II Lower Section - Cell full of water - Head to El. -3.0

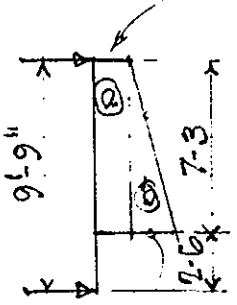
Base Pr. @ ℄ of pumps = 3130 psf Uplift = 2270 psf Total = 5400 psf
Pr. @ top of base = 18.0 × 64² = 1155 psf. Base Wt. = 6×150 = 900 psf Total = 2055 psf
Net = 3345 psf



Section 1'-0" wide

$M^F_{jk} = \frac{1}{12} \times 3.345 \times 31.0^2 = 268^{k'}$ $M^F_{hj} = \frac{1}{12} \times 3.345 \times 4.0^2 = 4.46^{k'}$

Mem. ej



(a) = 0.69 × 7.25 = 5.0 k

(b) = 0.47 × 7.25 × ½ = 1.7 k

$R_T = \left(5.0 \times \frac{6.13}{9.75}\right) + \left(1.7 \times \frac{4.92}{9.75}\right) = 4.0^k$

$R_B = 6.7 - 4.0 = 2.7^k$

$M^F_{ej} = 0.74^2(6 - 6 + 1.66)(5.0 \times 9.75 \times 1/12) = 5.0^{k'}$
$= 0.74^2(10 - 11 + 3.3)(1.7 \times 9.75 \times 1/15) = 1.9$
$6.9^{k'}$

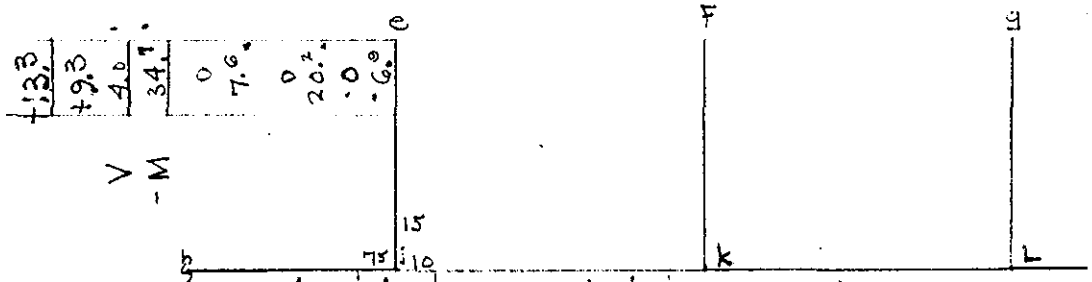
$M^F_{je} = 0.74^2(4 - 2.2)(5.0 \times 9.75 \times 1/12) = 4.0^{k'}$
$= 0.74^2(5 - 3)(1.7 \times 9.75 \times 1/10) = 1.8^{k'}$
$5.8^{k'}$

SUBJECT Fox Point Pump Station - 66'-0" Monolith

COMPUTATION Substructure Transverse [illegible]

COMPUTED BY GFH CHECKED BY EPR DATE

Case II: Lower Section



4.5	-5.8	-268.0	268	0	-268
202.0	40.4	26.9	0	0	0
-101.0	0	0	13.4	0	-13.4
75.7	15.2	10.1	0	0	0
-37.8	0	0	5.0	0	-5.0
28.3	5.7	3.8	0	0	0
171.6	55.5	-227.2	286.4		
		146.8			
	2.7	51.9	51.9		
	-9.3	-1.9	1.9		
	-6.6	50.0	53.8		

-M
+M
V

$+M_{jk} = \left(50.0 \times 14.95 \times \frac{1}{2}\right) - 227.2 = 374.0 - 227.2 = 146.8$

Member ej: M = 0 @ "x" from "e": $13.3x = \left(0.69\frac{x^2}{2}\right) + \left(.0642\frac{x^3}{6}\right) + 34.7$

$x^3 + 32.2x^2 - 1210x + 3245 = 0$

$216 + 1160 - 7250 + 3245 = -2629 \quad x = 6$

$125 + 805 - 6040 + 3245 = -1865 \quad x = 5$

$64 + 515 - 4840 + 3245 = -1016 \quad x = 4$

$27 + 300 - 3630 + 3245 = -58 \quad x = 3$

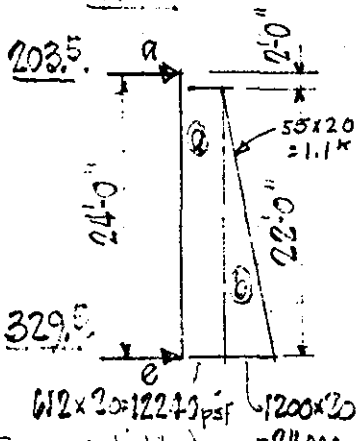
Say x = 3'-0" from top to point of inflection

SUBJECT Fox Point Pump Station - 66'-0" Manifold
COMPUTATION Substructure Transverse Section at ℄ Pump
COMPUTED BY E.P.P. CHECKED BY GFH DATE 16 Dec. 19[illegible]

Case III - D.L. + Equipment on Operating Floor with pumps in operation

Upper Section - Floor fixed end moments same as Case II

Walls — Section 20'-0" wide



(See stability analysis for lateral pres.)

ⓐ 12.24 x 22.0 = 269.0K ⓑ 24.0 x ½ x 22.0 = 264.0K

R_T = 269.0 x 11/24 = 123.0
264.0 x 7.33/24 = 80.5 — 203.5K

R_B = 269.0 + 264.0 − 203.5 = 329.5K

M^F_{ae} = 269.0 x 217.0/102.5 = 570.0
264.0 x 473.0/311.0 = 400.0 — 970.0K'

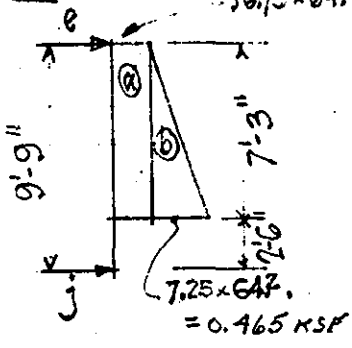
M^F_{ea} = 269.0 x 227.0/102.5 = 595.0
264.0 x 778.0/311.0 = 656.0 — 1251.0K'

Lower Section: Ave. Base Pr. = 2980 + (85 x 47/91) = 3024
Ave. Uplift = 1926 + (1124 x 44/91) = 2470 Total Pr. up = 5494 psf
Total Pr. Down = (64.2 x 24/91) + 900 = 1540 + 900 = 2440 psf
Net Pr. = 3050 psf

Mat M^F_{jk} = M^F_{kj} = 3.05 x 31²/12 = 2.44K'
M^F_{ji} = M^F_{ij} = 3.05 x 4²/12 = 4.06K'

Section 1'-0" Wide

Wall Mem. ej 16.75 x 64² = 1.075 KSF



ⓐ 7.25 x 1.075 = 7.8K'
ⓑ 7.25 x ½ x 0.465 = 1.61K'

R_T = (7.8 x 6.13/9.75) + (1.61 x 4.92/9.75) = 4.91 + 0.81 = 5.72K

R_B = 9.41 − 5.72 = 3.69K

M^F_{ej} = 0.74(3-6+1.05)(7.8 x 9.75 x 1/12) = 7.8K'
= 0.74(10-11+3.5)(1.61 x 9.75 x 1/15) = 1.8K'
9.6K'

M^F_{je} = 0.74²(4-2.2)(7.8 x 9.75 x 1/12) = 6.25
0.74²(5-3)(1.61 x 9.75 x 1/10) = 1.7
7.95K'

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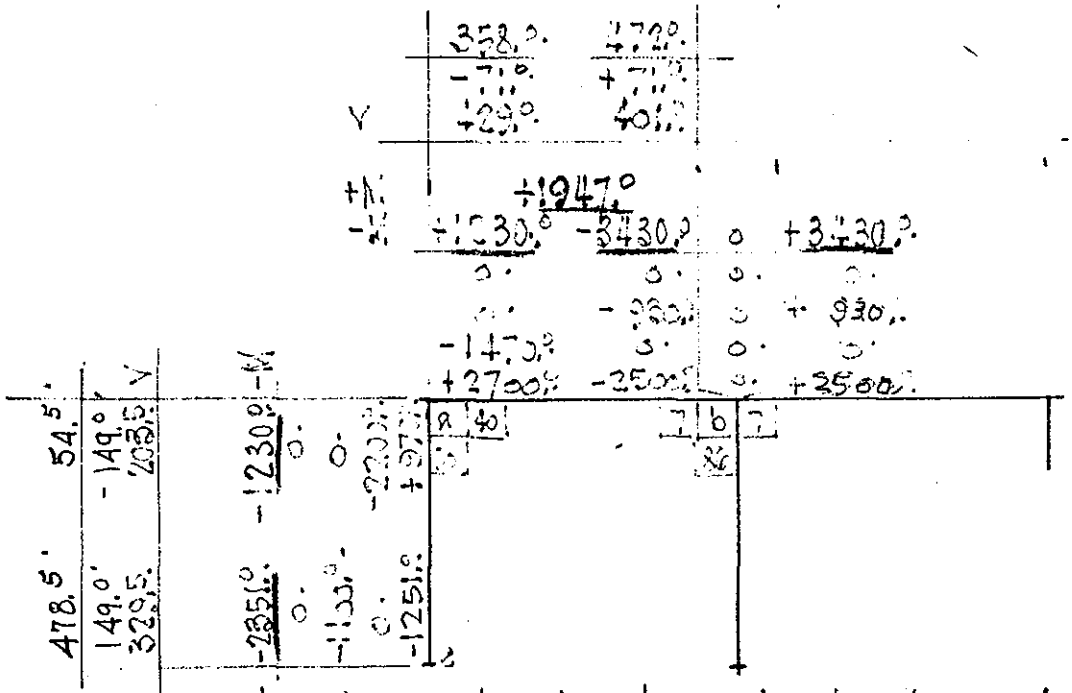
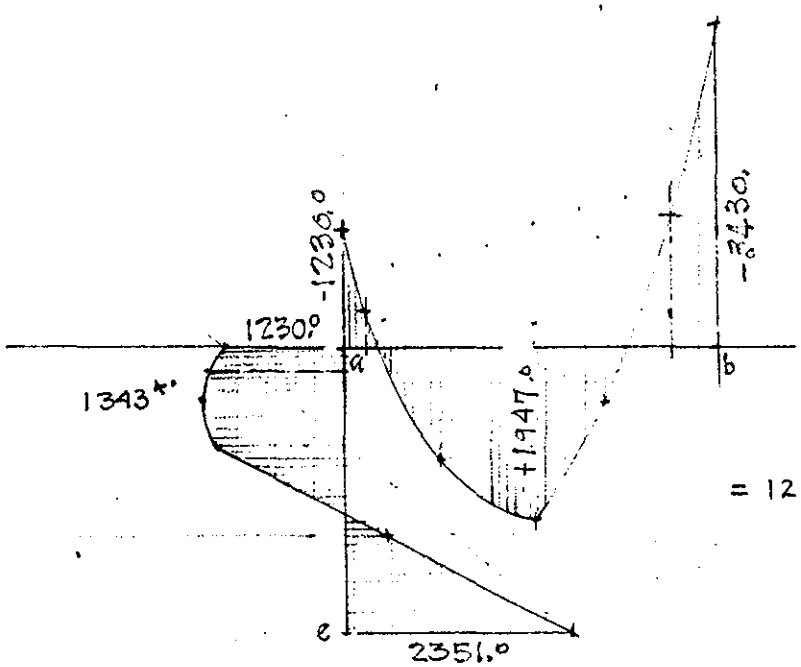
SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure Transverse Section [illegible]
COMPUTED BY E.P.R. CHECKED BY GFH DATE [illegible]

Case III - Upper Section



$+M_{ae} = (13.25 \times 358.0) - (13.25 \times 12.0 \times 6.62) - 5.58 \times 33.5 \times 2.79 - 1230.0$

$= 4750 - 1052 - 521 - 1230.0 = +1947^{k''}$



Member ae: $-M = Max$ @: "x" from a

$54.5 = 12.24x + \frac{1.1}{2}x^2$

$x^2 + 22.3x + 124.2 = 99 + 124.2$

$x + 11.15 = \pm 14.92$

$x = +3.77''$

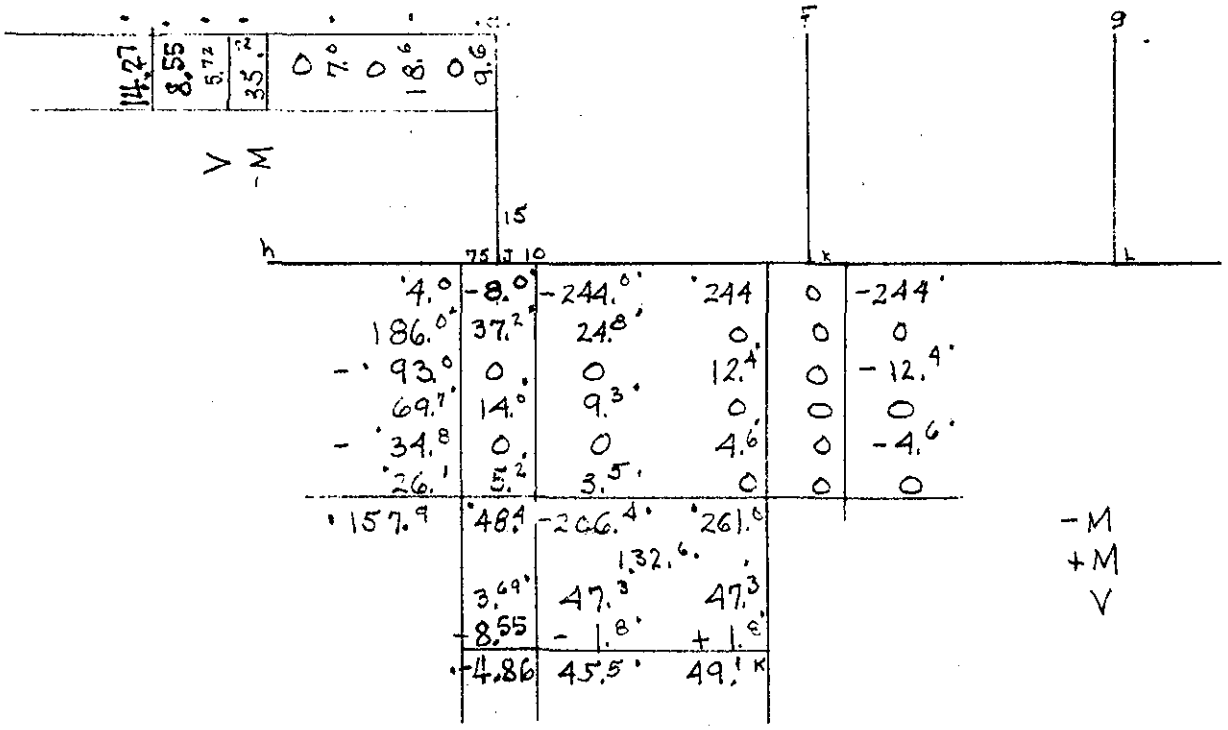
$Max\text{-}M = 1230 + (54.5 \times 3.77) - \left(12.24 \times \frac{3.77^2}{2}\right) - \left(\frac{1.1}{2} \times \frac{3.77^3}{6}\right)$

$= 1230 + 205 - 87 - 5 = 1343^{k'}$

Moment Diagram Sc. 1/2" = 1000'k

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Transverse Section @ ℄ Pumps
COMPUTED BY GFH CHECKED BY EPR DATE

Case III - Lower Section



$+M_{JK} = (45.5 \times \frac{1}{2} \times 14.9) - 206.4 = 339 - 206.4 = 132.6$ k'

$\text{Max} - M_{eJ} = 48.4 - (4.86 \times 2.5) = 48.4 - 12.2 = \underline{36.2}$ k'

SUBJECT Fox Point Pump Station — 66'-0" Navigation
COMPUTATION Substructure Transverse Section at ℄ Pumps
COMPUTED BY E.P.R. CHECKED BY GFH DATE 17 Dec. 1959

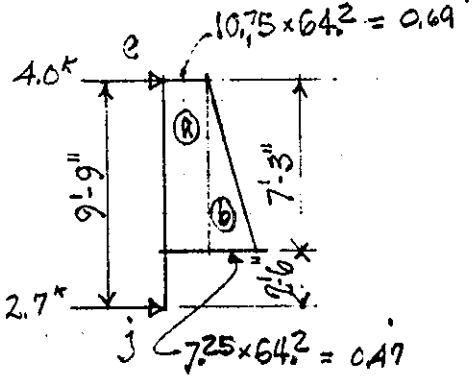
Case IV D.L. and Equipment on Operating Floor (El. 26.0)
Pumps operating
Upper Section Hydrostatic Loading and Lateral Loading same as Case III
∴ Moments on concrete structure above El. 0.0 same as computed for Case III.

Lower Section: Base Pr. = 2610 + (1000 × 47/91) = 3126 psf
1'-0" Wide Uplift = 1540 + (1510 × 44/91) = 2270 psf
Down Pr. = 900 + (64.2 × 18.0) = 2055 = −2055 psf
Net Pr. = 3,441 psf Up ↑

Mat M^F_{jk} = $3.44 \times \overline{31}^2 / 12$ = 276 k'

M^F_{jh} = $3.44 \times \overline{4}^2 / 12$ = 4.6 k'

Wall mem. ej Water surface at El. −3.0



ⓐ = 0.69 × 7.25 = 5.0 k'
ⓑ = 0.47 × 7.25/2 = 1.7 k'

$R_T = \left(5.0 \times \frac{6.13}{9.75}\right) + \left(1.7 \times \frac{4.92}{9.75}\right) = 4.0^k$

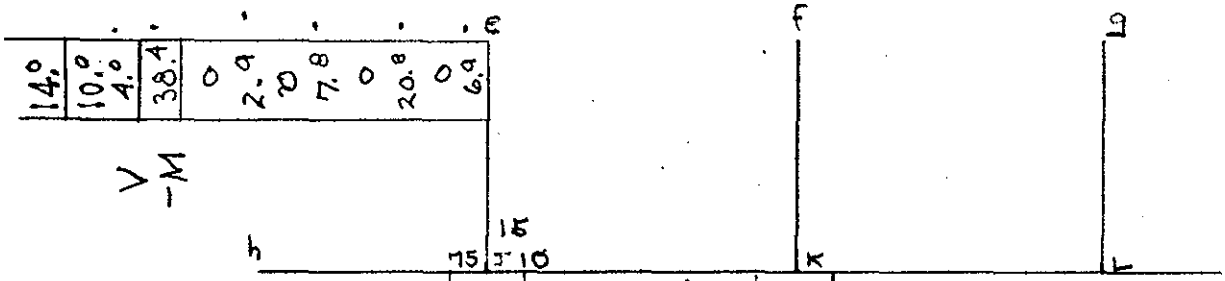
R_B = 6.7 − 4.0 = 2.7 k'

M^F_{ej} = 0.74(6 − 6 + 1.66)(5.0 × 9.75 × 1/12) = 5.0 k'
0.74(10 − 11 + 3.3)(1.7 × 9.75 × 1/15) = 1.9
6.9 k'

M^F_{je} = 0.74^2(4 − 2.2)(5.0 × 9.75 × 1/12) = 4.0
0.74^2(5 − 3)(1.7 × 9.75 × 1/10) = 1.8
5.8 k'

SUBJECT Fox Point Pump Station
COMPUTATION Substructure Transverse Section @ ℄ Pumps
COMPUTED BY GFH CHECKED BY EPR DATE

Case IV : Lower section



4.6	-5.8	-276	276	0	-276
208.0	41.5	27.7	0	0	0
- 104.0	0	0	13.8	0	-13.8
78.0	15.6	10.4	0	0	0
- 39.0	0	0	5.2	0	-5.2
29.3	5.8	3.9	0	0	0
- 14.6	0	0	2.0	0	-2.0
10.9	2.2	1.5			
173.1	59.3	-232.4	+297.0		
	2.7	53.3	53.3		
	- 10.0	- 2.1	2.1		
	-7.3	51.2	55.4		

-M
+M
V

$+M_{JK} = (15.0 \times \frac{1}{2} \times 51.2) - 232.4 = 384 - 232.4 = \underline{151.6}$ '

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SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure Transverse Section at ℄ Pump
COMPUTED BY E.P.R. CHECKED BY GFH DATE 17 Dec. 1959

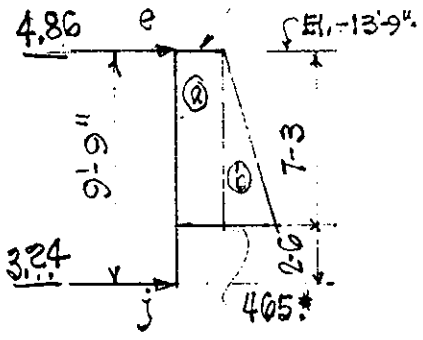
Case V Normal Condition
DL and Equipment on Operating Floor
Water to El. 0.0

Upper Section same as for Case I

Lower Section Average soil bearing and uplift = 4667 psf.
less mat & water = -2265
2402 psf.

Mat M^F_{jk} = $2.4 \times \overline{31}^2 / 12$ = 192.0 K' 1'-0" Wide Section
M^F_{jh} = $2.4 \times \overline{4}^2 / 12$ = 3.2 K'

Wall $13.75 \times 64.2 = 880^*$



ⓐ = 0.88 × 7.25 = 6.40 K
ⓑ = 0.47 × 1/2 × 7.25 = 1.70 K

R_T = 6.4 × 6.12 / 9.75 = 4.0
1.7 × 4.92 / 9.75 = .86 4.86

R_B = 8.10 − 4.86 = 3.24

M^F_{ej} = 0.75(6 − 6 + 1.66)(6.40 × 9.75 × 1/12) = 6.5
0.75(10 − 11.3 + 3.33)(1.7 × 9.75 × 1/15) = 1.7 8.2

M^F_{je} = 0.56(4 − 2.25)(6.4 × 9.75 × 1/12) = 5.1
0.56(5 − 3)(1.7 × 9.75 × 1/10) = 1.9 7.0

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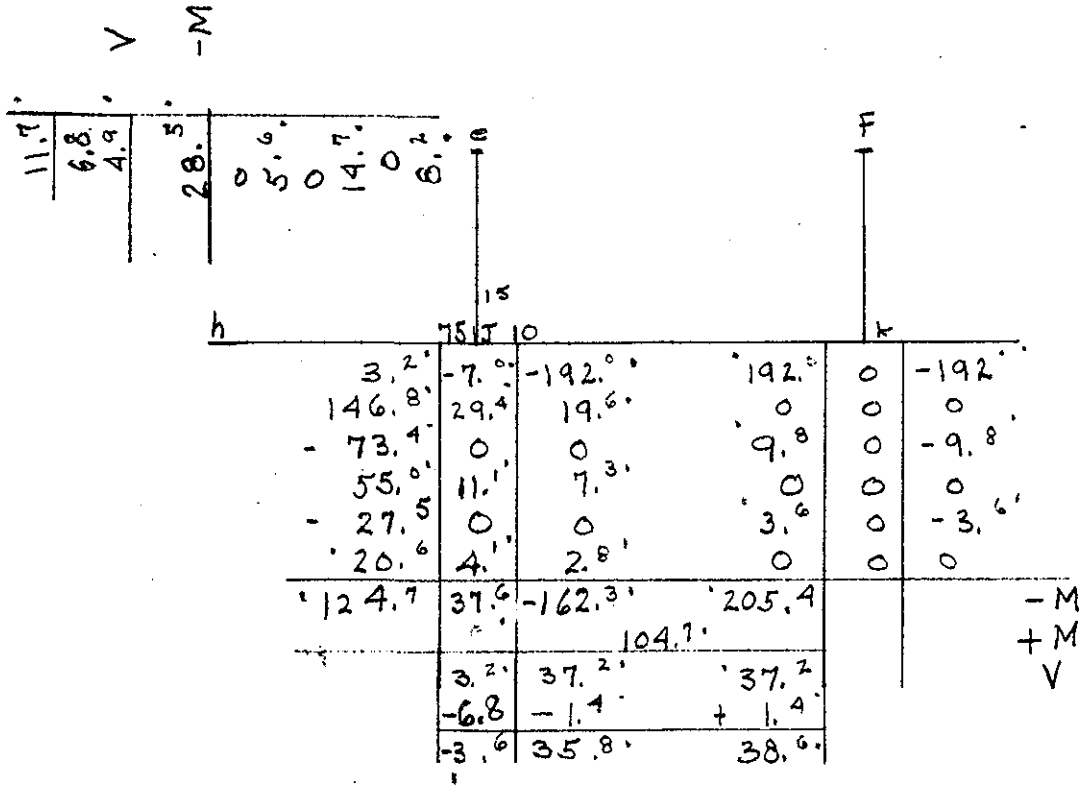
SUBJECT Fox Point Pump Station 66'-0" Monolith
COMPUTATION Substructure
COMPUTED BY GFH CHECKED BY E.P.R. DATE 5 Jan. 60

Case V - Lower Section



$$+M_{JK} = \left(35.8 \times 14.92 \times \tfrac{1}{2}\right) - 162.3 = +267 - 162.3 = 104.7^{K'}$$

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SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure Section on ℄ of Pumps
COMPUTED BY E.O.E. CHECKED BY GFH DATE 21 Dec. 1951

UPPER SECTION 20'-0" wide Ms in Kip feet

CASE	a / c	ab / cb	b	ae / cg	e / g	bf	f
I +	-1165.0	+1280.0	-2330.0	← →	+582.5	0	0
II ○	-1340.0	+1903.0	-3355.0	See Diagram	+2020.0	0	0
III ○	-1230.0	+1947.0	-3430.0	do	+2351.0	0	0
IV ○	Same as Case III.						
V +	-1165.0	+1280.0	-2330.0	← →	+582.5	0	0

Negative moments on outside of frame

Positive moments on inside of frame

LOWER SECTION 20'-0" wide

CASE	-jh / -lm	-je / -lg	+je / +lg	-e / -g	-jk / -lk	+jk / +lk	-kj / -kl
I +	-3193.0	-1115.0	0	+506.0	-4307.0	+2773.0	-5387.0
II ○	-3430.0	-1110.0	0	+695.0	-4530.0	+2930.0	-5720.0
III ○	-3150.0	-990.0	0	+705.0	-4120.0	+2650.0	-5200.0
IV ○	-3460.0	-1180.0	0	+768.0	-4640.0	+3010.0	-5940.0
V +	-2490.0	-750.0		+570.0	-3250.0	+2100.0	-4100.0

\+ Use normal stresses
○ Stresses increased 33⅓%

SUBJECT Fox Point Pump Station — 66'-0" Monolith
COMPUTATION Substructure — Section on ℄ of Pumps
COMPUTED BY EPR CHECKED BY GEH DATE 21 Dec. 1959

Upper Section Max. upper corner M = 1165.0 K' Case I

Corner ⓐ M reduced to face of wall
$= (1165.0 + 582.5)\frac{22}{24} - 582.5 = \underline{1023.0\ K'}$

t = 48"
d = 42.5"

$-M/bd^2 = 1023000/20 \times \overline{42.5}^2 = 28.$
$-A_s = 12 \times 1023/20 \times 20.0 \times j \times 42.5 = \underline{0.82\ \square''}$

~~Min. As = 12 × 42.5 × 0.0025 = 1.28 □"~~ Use #10 @ 12" Top. outer corner

V (floor slab) = 285.4 − (2.0 × 12.0) = 261.0 K
$v = 261000/12 \times 20 \times j \times 42.5 = \underline{28\ psi.}$

$u = 261000/20 \times 3.99 \times j \times 42.5 = \underline{87\ psi.}$

Outer Walls Case II outer face Upper end
−M = 1340.0 K'

t = 47"
d = 42.5"

$-M/bd^2 = 1340000/20 \times \overline{42.5}^2 = 37.$
$-A_s = 12 \times 1340/26.6 \times 20 \times j \times 42.5 = \underline{0.80\ \square''}$
Use #8 @ 12" outer face.

Lower end of wall +M = 2351.0 K'
$-A_s = 12 \times 2351.0/26.6 \times 20 \times j \times 42.5 = \underline{1.40\ \square''}$
#11 @ 12" inner face.

V (max. Case II) = 411,500#.
$v = 411500/12 \times 20 \times j \times 42.5 = \underline{45\ psi.}$

$u = 411500/20 \times 4.43 \times j \times 42.5 = \underline{123\ psi.}$

Middle Walls: Use #6 @ 12" o.c. ea. face vertical.

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pump House - 66'-0" Monolith
COMPUTATION Substructure Section on ℄ of Pumps
COMPUTED BY E.P.R. CHECKED BY GFH DATE 21 Dec. 1959

Floor at El. +26.0

Mem. ab +M = 1947.0 k' (Case III)

t = 48" d = 43.5" $+M/bd^2 = 1947000/6.33 \times \overline{43.5}^2 = 162$
$+A_s = 12 \times 1947/6.33 \times 26.6 \times j \times 43.5 = 3.60$ □"
min. As = 1.28 □"

8 - #11 @ 5" Bottom at side of pump

(Also see pages 44 & 45)

Corner b over center wall
Case III $-M = 3430.0 - (1/3 \times 8.0 \times 472.0) = 2170.0$ k'

t = 48" $-M/bd^2 = 2,170,000/20 \times \overline{42.5}^2 = 60$
d = 42.5" $-A_s = 12 \times 2,170/20 \times 26.6 \times j \times 42.5 = 1.30$ □"
#10 @ 12" Top over center wall

$V = 472.0 - (4 \times 12.0) = 424.0$ k
$v = 424000/12 \times 20 \times j \times 42.5 = 47$ psi

$u = 424000/20 \times 3.99 \times j \times 42.5 = 140$ psi

Lower Section
Outer Walls Corner j $M = 1,115.0 - (1/3 \times 5 \times 166.0) = 838.0$ k'

t = 47" b = 20'-0" d = 42.5" $M/bd^2 = 838000/20 \times \overline{42.5}^2 = 23$
$A_s = 12 \times 838/20 \times 20 \times j \times 42.5 = 0.67$ □"

$u = 166000/3.14 \times 20 \times j \times 42.5 = 70$ psi

Corner e M = 570.0 k' (Case V)
$A_s = 12 \times 570/20 \times 20 \times j \times 42.5 = 0.46$ □"

~~Min. As = 0.0025 × 12 × 42.5 = 1.28~~ □"

Use #8 @ 12" Vert. both faces

SUBJECT Fox Point Pump Station – 66'-0" Monolith.
COMPUTATION Substructure Section on ℄ of Pump
COMPUTED BY E.P.R. CHECKED BY GFH DATE 21 Dec. 1959

Lower Section (cont'd)

Mat Max. -M = 4307.0 - (1/3 × 4 × 945.0) = 3047.0 K' @ outer walls

b = 20'-0" t = 5'-0" = 60" d = 53.5".

$M/bd^2 = 3.047.000/20 \times \overline{53.5}^2 = 53.$

$As = 12 \times 3047.0/20 \times 20 \times j \times 53.5 = 1.92 \square''$ #11 @ 9½" Bot.

$Min. As = 12 \times 53.5 \times 0.0025 = 1.61 \square''$

At middle wall - Joint k

-M = 5387.0 - (1/3 × 8 × 1015.0) = 2687.0 K'

-M at outer walls will control.

V(max.) = 1015.0 - (4 × 12.0) = 967.0 K'

$v = 967000/240 \times j \times 53.5 = 85$ psi < 90.

$u = 967000/20 \times 1.27 \times 4.43 \times j \times 53.5 = 181$ psi < 300.

+M (betw. j and k) = 2773.0 K'

$+M/bd^2 = 2.773.000/20 \times \overline{53.5}^2 = 48.$

$+As = 12 \times 2.773.0/20 \times 20 \times j \times 53.5 = 1.75 \square''$

Use #11 @ 9½" Top.

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION

CORPS OF ENGINEERS, U. S. ARMY

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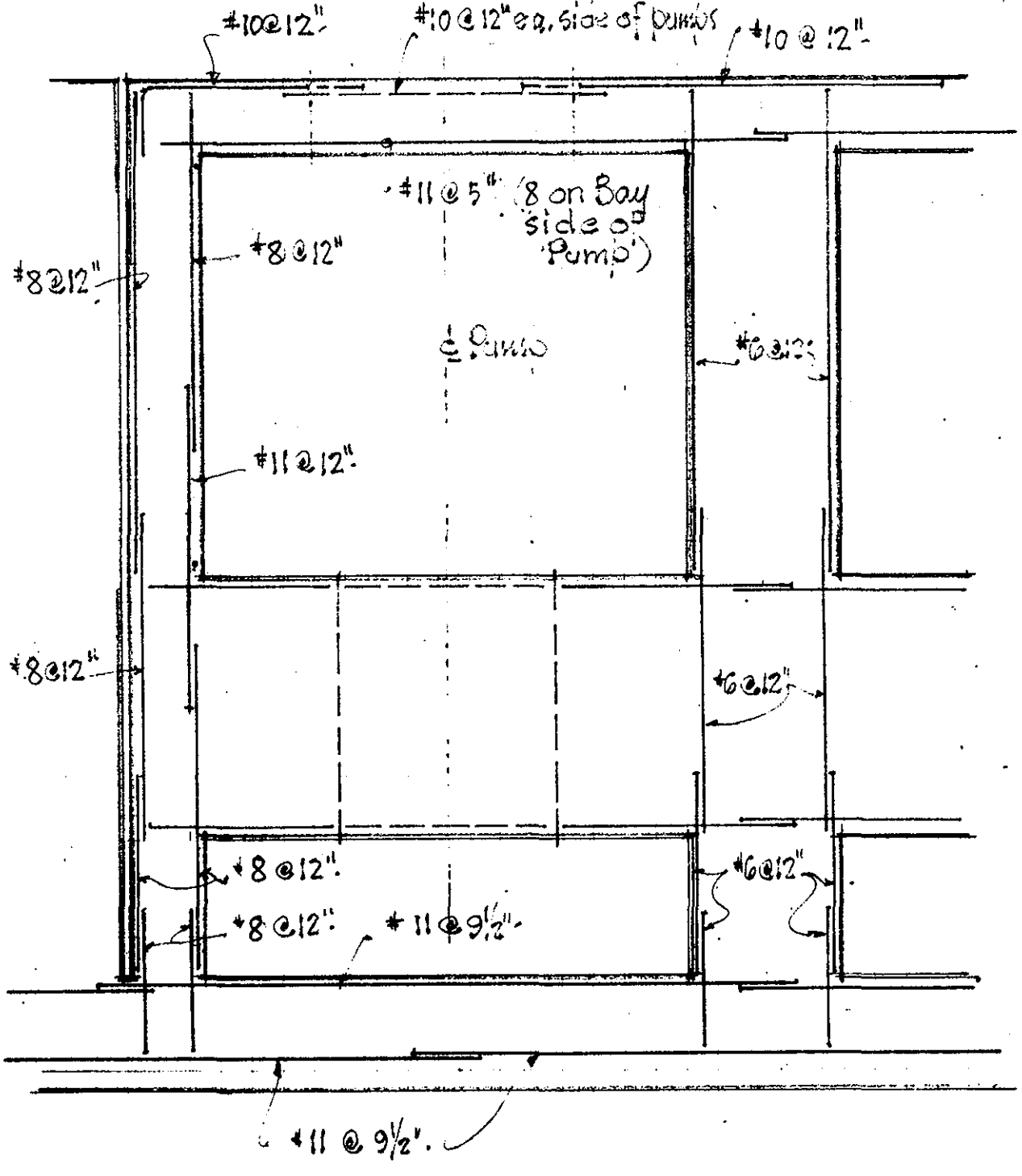
SUBJECT Fox Point Pump Station - 66'-0' Monolith

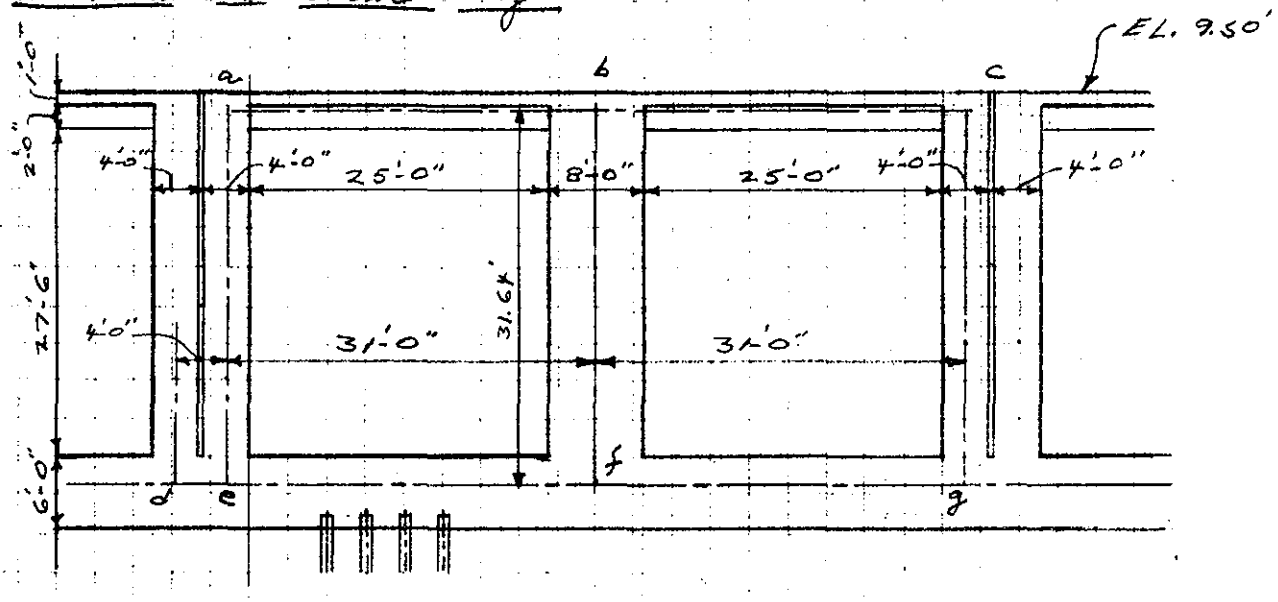
COMPUTATION Substructure - Section at ℄ Pumps

COMPUTED BY EPR CHECKED BY GFH DATE 21 Dec 1950



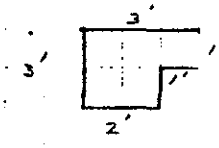
SUBJECT FOX POINT PUMPING STATION – 66'-0" MONOLITH
COMPUTATION Substructure – Section at Riverside End
COMPUTED BY R.N.W. CHECKED BY R.A.K. DATE 21 DEC. 59

Section at Land Edge



Frame Factors

member ab — piles spaced at 3'-0" o.c. — cross section of 3' section as below:



assume I of member ab equal to 3 of I for section shown at left (for 1' section)

e.g. $\frac{2(3)1.5 + 1(.5)}{7} = 1.36'$ from top

$$3\,I_{ab} = \frac{2(3)^3}{12} + 6(.14)^2 + \frac{1(1)^3}{12} + 1(.86)^2 = 5.44 \text{ ft}^4$$

$$I_{ab} = 1.81 \qquad K_{ab} = \frac{12(1.81)}{31} = 0.702$$

member ae $\quad K_{ae} = \frac{12(4.0)^3}{12\ 31.64} = 2.02$

member bf $\quad K_{bf} = \frac{12(8.0)^3}{12\ (31.64)} = 16.18$

member ef $\quad K_{ef} = \frac{12(5)^3}{12\ (31)} = 4.03$

member de $\quad K_{de} = \frac{12(5)^3}{12\ (4)} = 31.25$

Distribution Factors

$\frac{K_{ab}}{\Sigma K} = \frac{.702}{2.722} = .26 \qquad ae = .74$

$\frac{K_{ba}}{\Sigma K} = \frac{.702}{18.286} = .04 \qquad bf = .92$

$\frac{K_{ea}}{\Sigma K} = \frac{2.02}{37.3} = .05 \qquad ef = \frac{4.03}{37.3} = .11.$

$ed = \frac{31.25}{37.3} = .84.$

$\frac{K_{fe}}{\Sigma K} = \frac{4.03}{24.24} = .17. \qquad fb = .66.$

SUBJECT: FOX POINT PUMPING STATION - 66'-0" MONOLITH

COMPUTATION: Substructure - Section @ Riverside End.

COMPUTED BY: R.N.W. CHECKED BY: R.A.K. DATE: 22 DEC. 57

Case I - Construction Condition, no hydrostatic loading, no wind — D.L. of structure & equipment

Deck D.L. = $7(.15)\frac{1}{3} = 350$ #/FT

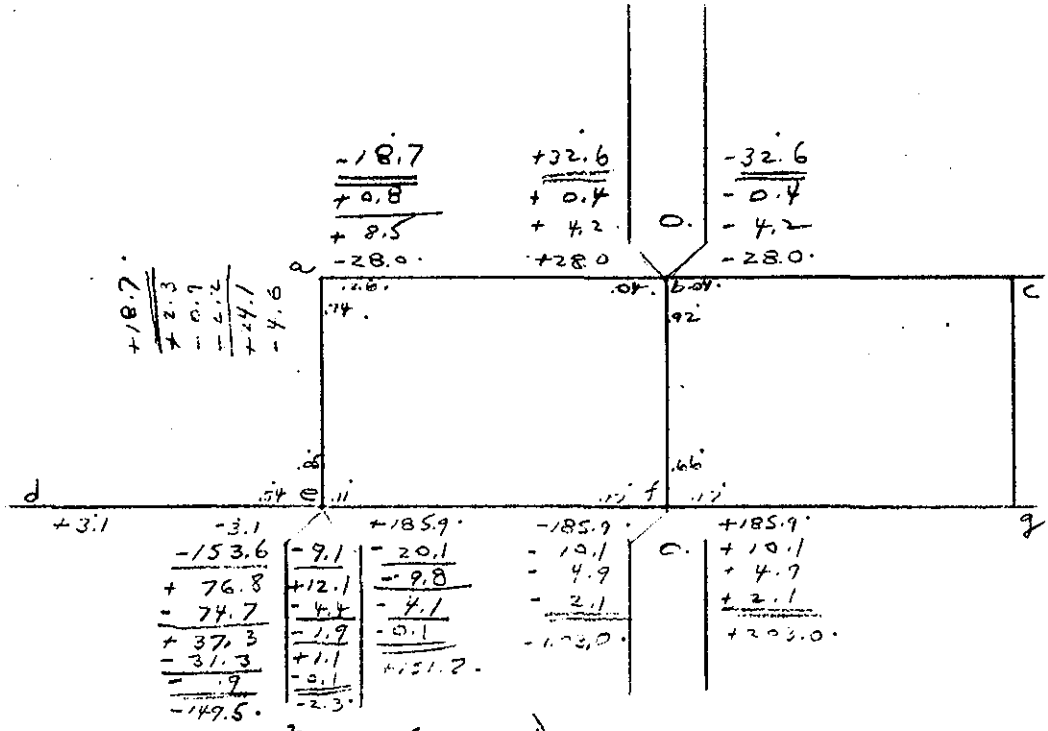
$M_{Fab} = M_{Fbc} = \frac{.35(31)^2}{12} = 28.0$ FT-K

average foundation pressure = 3221 psf (see stability)

$w = 3.221 - 6(.15) = 2.321$

$M_{Fef} = 2.321(31)^2 \frac{1}{12} = 185.9$ FT-K

$M_{Fed} = 2.321(4)^2 \frac{1}{12} = 3.1$ FT-K



$+M_{ab} = .35(31)^2\frac{1}{8} - \left(\frac{18.7+32.6}{2}\right) = 16.4$ K-FT

$+M_{ef} = 2.321(31)^2\frac{1}{8} - \left(\frac{151.8+203.0}{2}\right) = 101.4$ K-FT

$V_{ab} = .35(15.5) - \frac{13.9}{31} = 4.98^k$ $\qquad V_{ba} = .35(15.5) + \frac{13.9}{31} = 5.87^k$

$V_{ef} = 2.321(15.5) + \frac{51.2}{31} = 34.32^k$ $\qquad V_{fe} = 2.321(15.5) - \frac{51.2}{31} = 37.63^k$

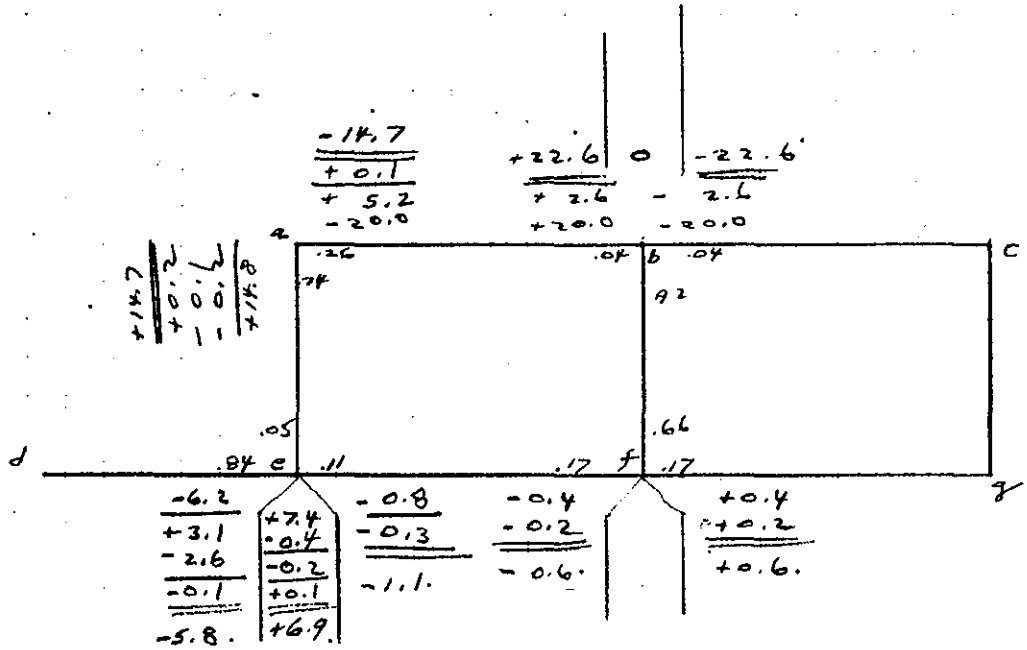
SUBJECT FOX POINT PUMPING STATION – 66'-0" MONOLITH

COMPUTATION Substructure – Section at Riverside End.

COMPUTED BY R.N.W. CHECKED BY R.A.K. DATE 23 DEC. 59

Case Ia – Case I plus 250 psf Live Load on deck

$$M_{Fab} = \frac{.25(31)^2}{12} = 20.02 \text{ K-FT}$$



$$+M_{ab} = .25(31)^2 \frac{1}{8} - \left(\frac{22.6+14.7}{2}\right) = 11.38 \text{ K-FT}$$

$$V_{ab} = .25(15.5) - \frac{7.9}{31} = 3.62^K$$

$$V_{ba} = .25(15.5) + \frac{7.9}{31} = 4.13^K$$

Add above values of moments & shears to values found in Case I analysis to obtain total case Ia results.

SUBJECT: FOX POINT PUMPING STATION - 66" MONOLITH

COMPUTATION: Substructure - Section at Riverside End

COMPUTED BY: [illegible] CHECKED BY: [illegible] DATE: 30 Dec 57

Case II

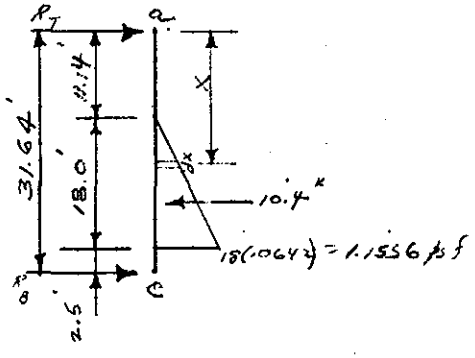
avg. foundation pressure = 3550. psf
avg. uplift " = 1760. psf
5310. psf } See stability

$M_{Fab} = M_{Fbc} = \frac{.55(31)^2}{12} = 28.0$ K-FT

For slab $w = 5.31 - 6(.15) - .064.2(12.0) = 3.254^k$

$M_{Fef} = M_{Ffg} = 3.254(31)^2 \frac{1}{12} = 260.6$ K-FT

for members a c & c-y



$R_T = \frac{8.5}{31.64}(10.4) = 2.794^k$

$R_B = \frac{23.14}{31.64}(10.4) = 7.606$

$M_{Fca} = \sum \frac{P_a b^2}{L^2}$. where $P = \frac{(x-11.14)}{18}(1.1556)dx$

$a = x$
$b = L - x$

$M_{Fac} = \sum \frac{P_a^2 b}{L^2}$

Reference: Parcel & Moorman, p. 157

$$M_{Fca} = \frac{1}{(31.64)^2}\int_{11.14}^{29.14} \frac{(x-11.14)(1.1556)dx}{18}\, x^2(31.64-x)$$

$$M_{Fca} = \frac{1}{(31.64)^2}\int_{11.14}^{29.14} (2.75x^3 - 22.63x^2 - 0.06x^4)dx = \underline{40.67} \text{ K-FT}$$

$$M_{Fac} = \frac{1}{(31.64)^2}\int_{11.14}^{29.14} \frac{(x-11.14)(1.1556)dx}{18}(x)(31.64-x)^2$$

$$M_{Fac} = \frac{1}{(31.64)^2}\int_{11.14}^{29.14} (109.53x^2 - 4.78x^3 + 0.06x^4 - 715.96x)dx = \underline{18.08} \text{ K-FT}$$

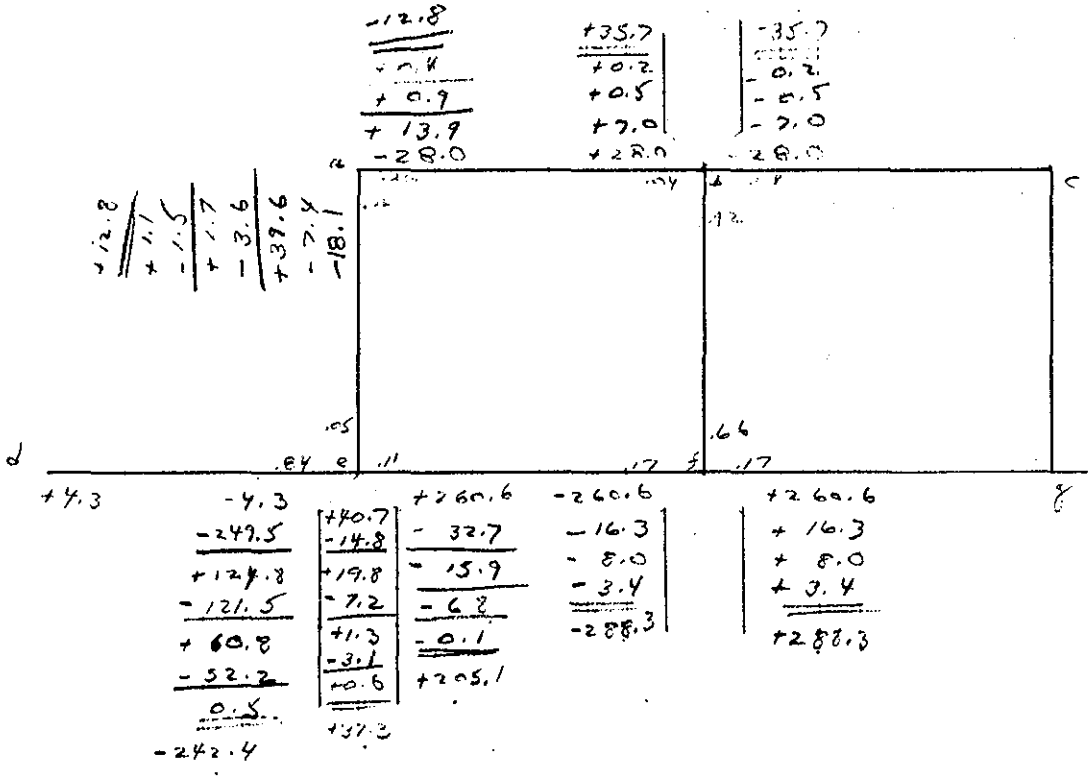
$M_{Fde} = 3.254(4)^2\frac{1}{12} = 4.34$ K-FT

SUBJECT [illegible] STATION 66 [illegible]

COMPUTATION Substructure - Section at Riverside End.

COMPUTED BY P.N.W. CHECKED BY R.A.K. DATE 30 DEC. 59

Case II cont'd

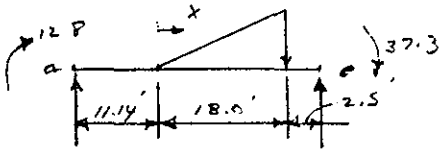


$$+M_{ab} = .35(31)^2\frac{1}{8} - \left(\frac{12.8+35.7}{2}\right) = 17.79 \text{ k-FT}$$

$$+M_{ef} = 3.2544(31)^2\frac{1}{8} - \left(\frac{205.1+288.3}{2}\right) = 144.23 \text{ k-FT}$$

$$V_{ab} = .35(15.5) - \frac{22.9}{31} = 4.69 \qquad V_{ba} = .35(15.5) + \frac{22.9}{31} = 6.16$$

$$V_{ef} = -3.2544(15.5) + \frac{83.2}{31} = 47.76 \qquad V_{fe} = -3.2544(15.5) - \frac{83.2}{31} = 53.12$$



$$R_a = 2.794 - \frac{50.1}{31.64} = 1.21057^k$$

$$R_e = 7.606 + \frac{50.1}{31.64} = 9.18943^k$$

point of zero shear:

$$1.21057 = \frac{.0642x^2}{2} \qquad x = 6.14$$

$$\text{pos } M_{ac} = 1.21057(17.28) - .0642(6.14)^3\frac{1}{6} + 12.8 = 31.24 \text{ k-FT}$$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT [illegible] PUMPING STATION - 66.0" MONOLITH
COMPUTATION Substructure - Section at Riverside End
COMPUTED BY [illegible] CHECKED BY R.A.K. DATE 31 DEC. 59

Case V - Normal condition with water to EL. 0.0

avg. foundation pressure = 2256 psf } see stability
avg. uplift = 1730 " } comps.
3986 psf

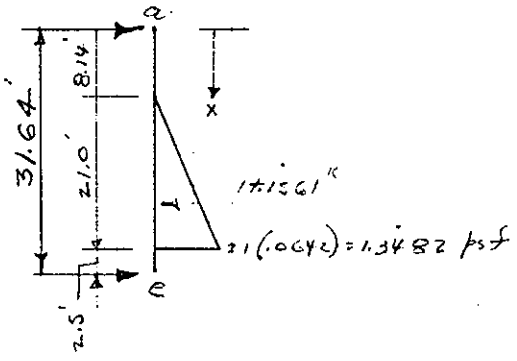
$M_{Fab} = M_{Fbc} = \frac{.35(31)^2}{12} = 28.0$ K-FT

For slab $w = 3.986 - 6(.15) - .0642(21.0) = 1.7378$

$M_{Fef} = M_{Ffg} = 1.7378(31)^2 \frac{1}{12} = 139.17$ K-FT

$M_{Fde} = 1.7378(4)^2 \frac{1}{12} = 2.32$ K-FT

For members a.e & cg



$R_T = \frac{9.5}{31.64}(14.1561) = 4.250$

$R_B = \frac{22.14}{31.64}(14.1561) = 9.906$

$M_{Fea} = \Sigma \frac{Pa^2b}{L^2}$ where $P = \frac{(x-8.14)(1.3482)}{21}dx$

$a = x$
$b = L - x$

$M_{Fae} = \Sigma \frac{Pa\,b^2}{L^2}$

$$M_{Fea} = \frac{1}{(31.64)^2}\int_{8.14}^{29.14} \frac{(x-8.14)(1.3482)}{21}dx\; x^2(31.64-x)$$

$$M_{Fea} = \frac{1}{(31.64)^2}\int (2.55387x^3 - .0642x^4 - 16.53443x^2)dx = 54.77 \text{ K-FT}$$

$$M_{Fae} = \frac{1}{(31.64)^2}\int_{8.14}^{29.14} \frac{(x-8.14)(1.3482)dx}{21}\; x(31.64-x)^2$$

$$M_{Fae} = \frac{1}{(31.64)^2}\int_{8.14}^{29.14} (97.33881x^2 - 4.58516x^3 + .0642x^4 - 523.14940x)dx$$

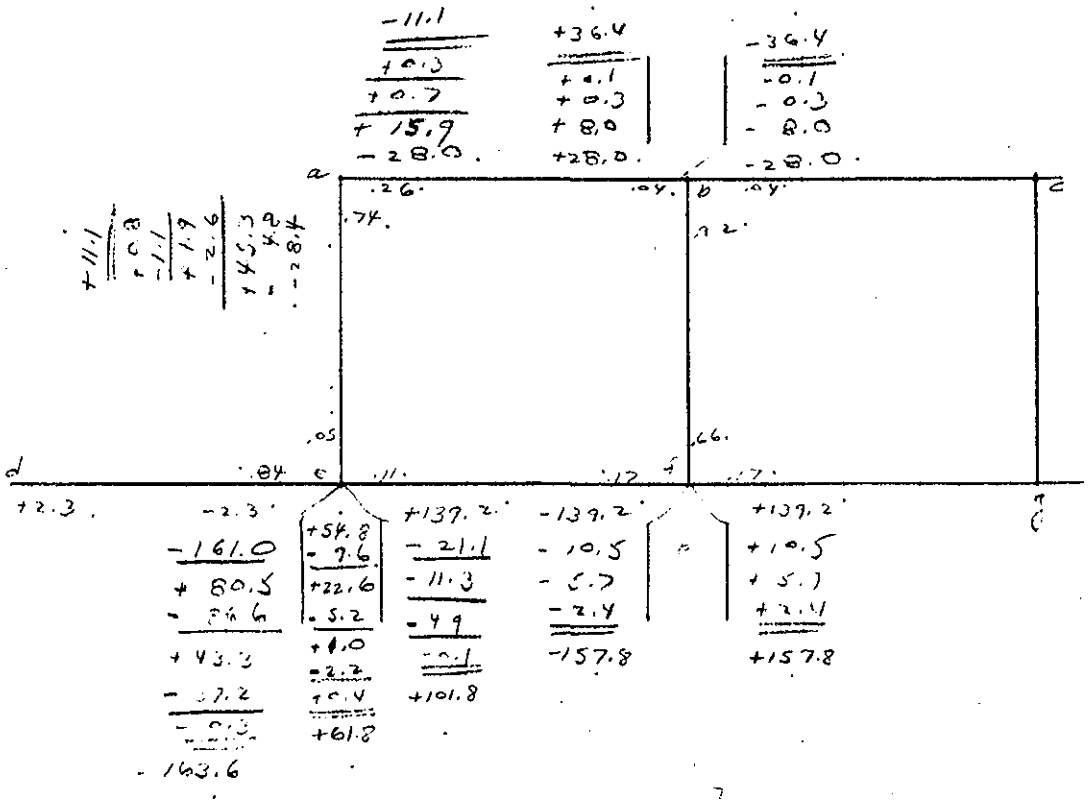
$= 28.37$ K-FT

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT FOX POINT PUMPING STATION – 66'0" MONOLITH
COMPUTATION Substructure – Section at Riverside End
COMPUTED BY [illegible] CHECKED BY R.A.K. DATE 4 JAN. 60

Case I · cont'd

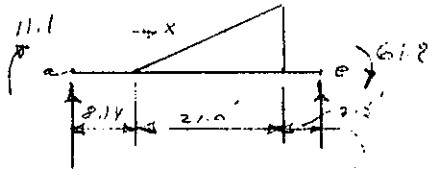


$+ M_{ab} = .35(31)^2 \frac{1}{8} - \left(\frac{11.1+36.4}{2}\right) = 18.29$ K-FT

$+ M_{ef} = 1.7378(31)^2 \frac{1}{8} - \left(\frac{101.8+157.8}{2}\right) = 78.95$ K-FT

$V_{ab} = .35(15.5) - \frac{25.3}{31} = 4.61$ $\qquad V_{ba} = .35(15.5) + \frac{25.3}{31} = 6.24$

$V_{ef} = -1.7378(15.5) + \frac{56}{31} = 25.13$ $\qquad V_{fe} = -1.7378(15.5) - \frac{56}{31} = 28.75$



$R_a = 4.25 - \frac{72.9}{31.64} = 1.94596$

$R_e = 9.906 + \frac{72.9}{31.64} = 12.21004$

point of zero shear:

$1.94596 = \frac{.0642 x^2}{2}$ $\qquad x = 7.78$

pos. $M_{ae} = 1.94596(15.92) - .0642(7.78)^3 \frac{1}{6} + 11.1 = 37.04$

SUBJECT Fox Point Pumping Station - 66'-0" Modality
COMPUTATION Substructure - Section of Riverside End
COMPUTED BY N.N.W. CHECKED BY R.A.K. DATE 6 JAN. 60

Case V b Normal condition with water to El. +3.0. Earthquake from bayside

avg. foundation pressure = 2550. } see stability comps.
avg. uplift = 1926.
4476. psf

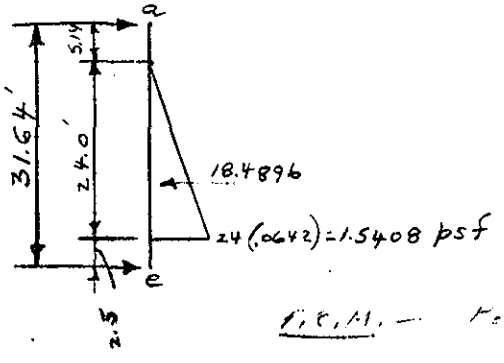
$$M_{Fab} = M_{Fbc} = \frac{.35(31)^2}{12} = 28.0 \text{ K-FT}$$

For Slab $w = 4.476 - 6(.15) - .0642(24) = 2.0352$

$$M_{Fef} = M_{Ffg} = 2.0352(31)^2 \tfrac{1}{12} = 163.0 \text{ K-FT}$$

$$M_{Fde} = 2.0352(4)^2 \tfrac{1}{12} = 2.71 \text{ K-FT}$$

For members aefg



$$R_T = \frac{10.5}{31.64}(18.4896) = 6.13592$$
$$R_B = \frac{21.14}{31.64}(18.4896) = 12.35367$$
} simple beam

F.E.M. — Reference: Design Manual for High Strength Steels, p. 127

$$R_a = \frac{wb^2}{540L^3}\left[56b^3 - 45b^2(L-2a) + 270e^2(L+2d)\right]$$

$$M_a = \frac{wb^2}{540L^2}\left[b^2(30L - 45a - 28b) - 270de^2\right]$$

$$M_e = M_a + R_1 L - \frac{wb^2 e}{2}$$

a = 5.14
b = 24.0
c = 2.5
w = .0642
e = 10.5
d = 21.14

$$R_a = \frac{.0642(24)^2}{540(31.64)^3}\left[56(24)^3 - 45(24)^2(21.36) + 270(10.5)^2(73.92)\right] = 5.23$$

$$M_a = \frac{.0642(24)^2}{540(31.64)^2}\left[(24)^2(30\times31.64 - 45\times5.14 - 28\times24) - 270(21.14)(10.5)^2\right] = 41.24$$

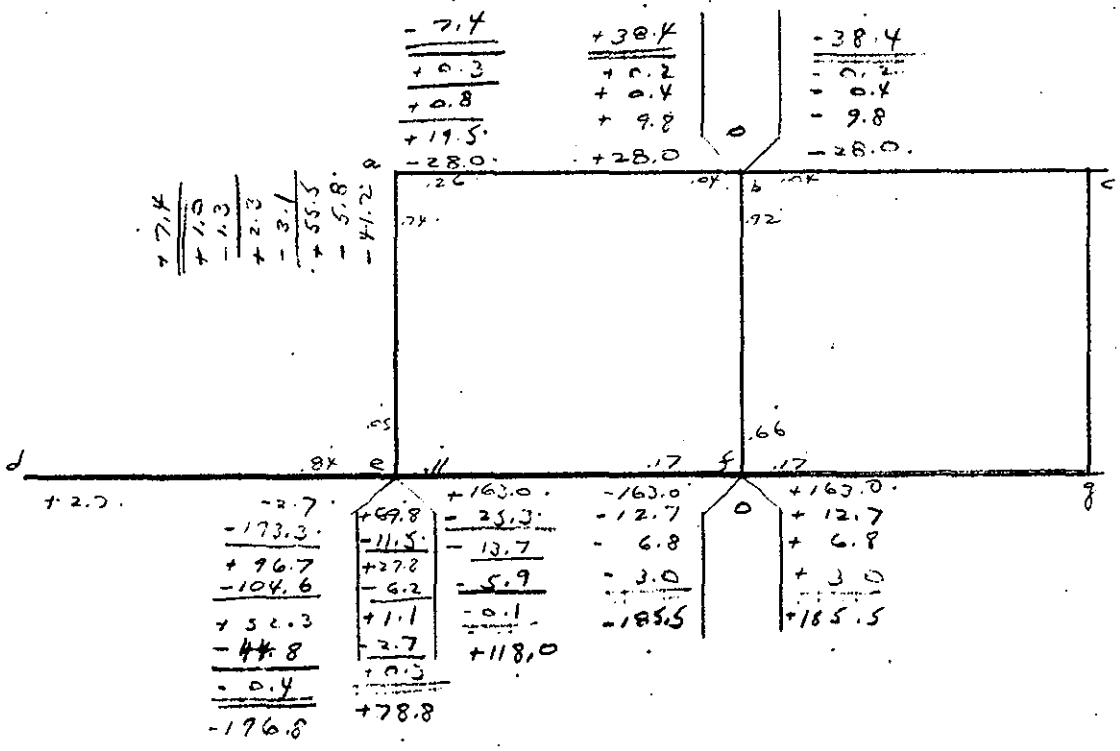
$$M_e = -41.24 + 5.23(31.64) - \frac{.0642(24)^2(10.5)}{2} = 69.78$$

SUBJECT FOX POINT PUMPING STATION — 66'-0" MONOLITH

COMPUTATION Substructure - Section at Riverside End

COMPUTED BY R.N.W. CHECKED BY R.L.K. DATE 6 JAN. 60

Case II b - cont'd

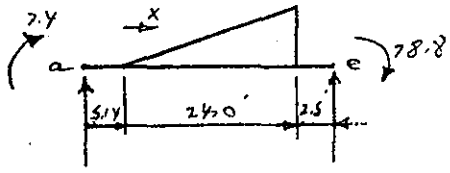


$$+M_{ab} = 35(31)^2\frac{1}{8} - \left(\frac{7.4+38.4}{2}\right) = 19.14 \text{ K-FT}$$

$$+M_{ef} = 2.0352(31)^2\frac{1}{8} - \left(\frac{1.8+185.5}{2}\right) = 92.73$$

$$V_{ab} = .35(15.5) - \frac{31}{31} = 4.425^k \qquad V_{ba} = .35(15.5) + \frac{31}{31} = 6.425^k$$

$$V_{ef} = -2.0352(15.5) + \frac{67.5}{31} = 29.37 \qquad V_{fe} = -2.0352(15.5) - \frac{67.5}{31} = 33.72^k$$



$$R_a = 6.14 - \frac{86.2}{31.64} = 3.41153$$

$$R_e = 12.35 + \frac{86.2}{31.64} = 15.07806$$

point of zero shear:

$$3.41153 = \frac{.0642(x)^2}{2} \qquad x = 10.31'$$

$$\text{pos. } M_{ac} = 3.41153(15.45) - .0642(10.31)^3\frac{1}{2}\frac{1}{3} + 7.4 = 48.38 \text{ K-F}$$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

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SUBJECT Fox Point Pump Station - 66'-0" Diameter
COMPUTATION Substructure - Section at Riverside Ave
COMPUTED BY E.P.L. CHECKED BY T.N.W. DATE 7 Jan 1950

Deck at El. +9.5 L.L. @ 250 psf
Tributary width 5'-6"

D.L.	5.5×150#	=	825
	2.0×150#×2.0	=	600
L.L	5.5×250#	=	1375
			2800 plf

For design of frame 600#/l.f. for 1'-0" width is used

Max -M (left) = 32.4K' Max. -M (center support) = 55.2K'

$V_L = (15.5 \times 600^{\#}) - \left(\frac{55.2 - 32.4}{31}\right)$ $V_R = 9.3 + 0.74 = \underline{10.04^K}$

$= 9.3 - 0.74 = \underline{8.56^K}$

$+M = (14.2 \times 8.56 \times \tfrac{1}{2}) - 32.4 = 61.0 - 32.4 = \underline{28.6^{K'}}$

Beam: 5'-6" Tributary width

Max. $V_L = (5.5 \times 8.56) - (2' \times 5.5 \times 0.6) = 47.2 - 6.6 = \underline{40.6^K}$ clear face

" $V_R = (5.5 \times 10.0) - (4 \times 5.5 \times 0.6) = 55.0 - 13.2 = \underline{41.8^K}$ clear face

$-M_L = (5.5 \times 32.4) - (\tfrac{1}{3} \times 4.0 \times 47.0)$ $-M_R = (5.5 \times 55.2) - (\tfrac{1}{3} \times 8 \times 55.0)$

$= 178.0 - 63.0 = \underline{115.0^{K'}}$ $= 304.0 - 146.0 = \underline{158.0^{K'}}$

$+M = 5.5 \times 28.6 = \underline{158.0^{K'}}$

Section 24"×36" d = 31.5"

$V_L = 41800 / 24 \times j \times 31.5 = \underline{53 \text{ psi}} < 90$

$-M/bd^2 = 158000 / 2 \times 31.5^2 = 79$

$-A_s = 12 \times 158 / 20 \times j \times 31.5 = \underline{3.4^{\square''}}$ 5-#8 Top over inner support

$-\Sigma o = 41800 / 2.0 \times j \times 31.5 = 7.2^{\square''}$

$+M = 158.0^{K'}$ $+A_s = \underline{3.4^{\square''}}$

5-#8 Bottom

$-M_L = 115.0^{K'}$ $-A_s = 2.5^{\square''}$ 4-#8T Beam: 24"×36"

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

PAGE A 112

SUBJECT FOX POINT PUMPING STATION - 66'0" MONOLITH
COMPUTATION Substructure - Section at Riverside End
COMPUTED BY R.N.W. CHECKED BY R.A.K. DATE 7 JUN. 60

Design of wall — 3'11" thick t = 47" j = .885
d = 42.5"

max. neg. M = 61.8 K-FT (Case V, normal stresses)

" M = 78.8 (Case Vb, increased stresses)

Design M = 61.8 - ⅓ Va = 61.8 - ⅓ (12.21)(5.0) = 41.45

$A_s = \frac{12(41.45)}{20(.885)(42.5)} = 0.66$ IN² #8 @ 1'0"

max. pos. M in wall = 37.04 K-FT (Case V)

$A_s = \frac{12(37.04)}{20(.885)(42.5)} = 0.59$ IN² use min #8 @ 12"

Design of Base Slab

max. neg. M at f = 288.3 K-FT (Case II - increased stresses)
" " " = 203.0 K-FT (Case I - normal stresses)

Design M = 288.3 - ⅓ Va = 288.3 - ⅓ (53.12)(8) = 146.6 K-FT

$A_s = \frac{12(146.6)}{26.6(.885)(55)} = 1.36$ #10 @ 11"
#11 @ 12" ←

check neg M at a

Design M = 205.1 - ⅓ (47.76)(4) = 141.4 same as above

Pos. M = 144.23 K-FT close to neg M use #11 @ 12"

$v = \frac{53120}{12(.885)(55)} = 91$ psi

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

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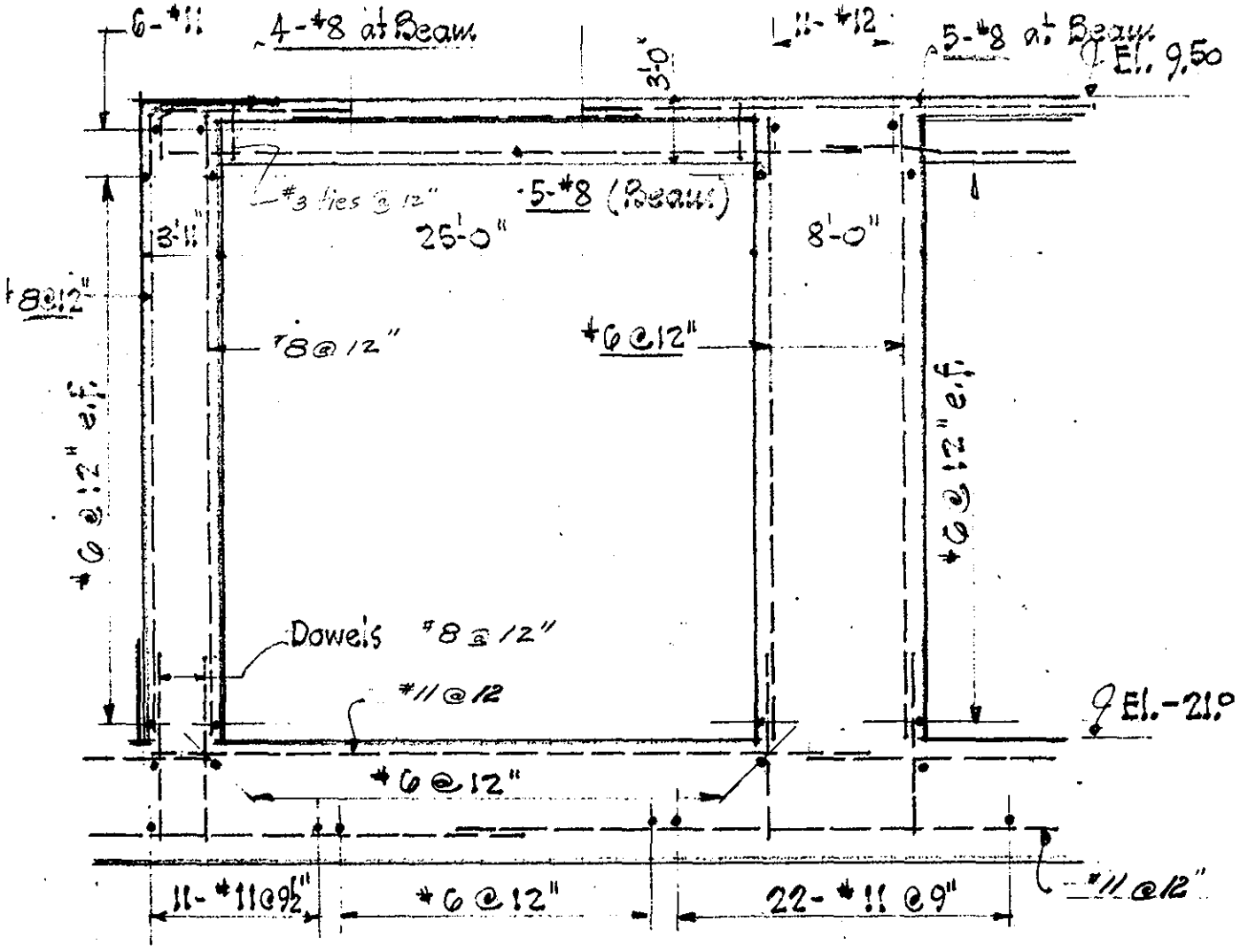
SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure ~ Section at Riverside Rd
COMPUTED BY _____ CHECKED BY _____ DATE 7 Jan. 1960



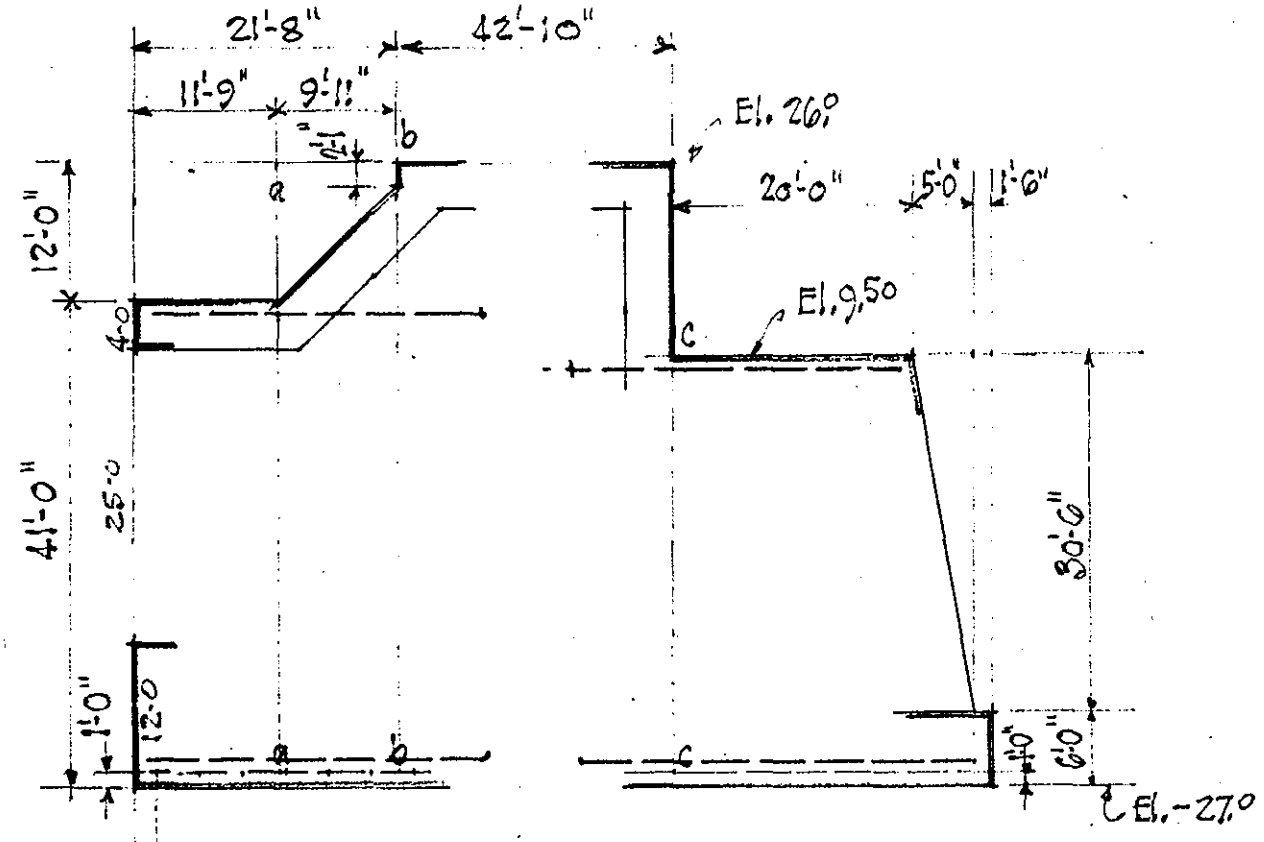
SECTION THRU UPSTREAM PASSAGES

Sc. 1/8" = 1'-0"

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Section parallel with transverse walls
COMPUTED BY E.P.R. CHECKED BY GFH DATE 18 Dec. 195?



	a	b		c		
Case I Construction	5280	4970	4710	2875	2870	Bearing
II	5540	5505	5475	5350	5270	Bearing + Uplift
III	6030	5895	5785	5295	4990	do
IV	5660	5595	5540	5300	5150	do
V Normal	5708	5455	5230	4280	3680	do

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure Transverse walls
COMPUTED BY E.P.R. CHECKED BY GFH DATE 18 Dec. 1959

Case I Section a-a ↑ 11.75 × 4.97 × 66.0 = 3850.0 × 5.88 = ↺ 22650.0
11.75 × 1/2 × 0.31 × 66.0 = 120.0 × 7.84 = 940.0
↑ 3970.0 ↺ 23590.0

↓ 4.0 × 150# × 11.75 × 66.0 = 465.0
25.0 × 150# × 11.75 × 16.0 = 705.0
12.0 × 150# × 11.75 × 66.0 = 1395.0 ↓ 2565.0 × 5.88 = ↺ 15080.0
↑ 1405.0K ↺ 8510.0K

Case V Section a-a ↑ 11.75 × 5.45 × 66.0 = 4250.0 × 5.88 = 25000.0
11.75 × 1/2 × 0.26 × 66.0 = 101.0 × 7.84 = 790.0
↑ 4351.0 ↺ 25790.0K

↓ Concrete (see above) = 2565.0
Water
11.75 × 64.2 × 15.0 × 50.0 = 570.0 3135.0 × 5.88 = ↺ 18400.0K
↑ 1216.0K ↺ 7390.0K

Case II Section a-a ↑ 11.75 × 5.51 × 66.0 = 4280.0 × 5.88 = 25,200.0
11.75 × 1/2 × 0.04 × 66.0 = 15.5 × 7.84 = 122.0
↑ 4295.5 ↺ 25,322.0

↓ Concrete = 2565.0
Water
11.75 × 64.2 × 25.0 × 50.0 = 945.0
11.75 × 64.2 × 9.75 × 66.0 = 488.0 ↓ 3998.0 × 5.88 = ↺ 23,500.0
↑ 297.5K ↺ 1,722.0K

NED FORM 223 — NEW ENGLAND DIVISION — CORPS OF ENGINEERS, U. S. ARMY

27 Sept 49 — PAGE A116

SUBJECT: Fox Point Pump Station — 66'-0" Monolith

COMPUTATION: Substructure — Transverse Walls

COMPUTED BY: EPR — CHECKED BY: GFH — DATE: 18 Dec. 1959

Section b-b

Case I

↑ 21.67 × 4.71 × 66.0 = 6760.0 × 10.83 = 73,000.0
21.67 × 1/2 × 0.57 × 66.0 = 410.0 × 14.50 = 5,950.0
↑ 7170.0 K — ↺ 78,950.0

↓ 11.75 × 150# × 4.0 × 66.0 = 465.0 × 15.80 = 7350.0
9.92 × 150# × 5.63 × 66.0 = 560.0 × 4.96 = 2780.0
21.67 × 150# × 2.5.0 × 16.0 = 1,300.0 × 10.83 = 14,100.0
(8.25)² × 150# × 1/2 × 16.0 = 81.5 × 2.75 = 224.0
(3.55)² × 150# × 1/2 × 50.0 = 47.5 × 1.18 = 56.0
21.67 × 150# × 12.0 × 66.0 = 2,580.0 × 10.83 = 28,000.0

↓ 5,034.0 — ↺ 52,510.0
↑ 2,136.0 — ↺ 20,440.0

Case II

↑ 21.67 × 5.48 × 66.0 = 7850.0 × 10.83 = 85,000.0
21.67 × 1/2 × 0.06 × 66.0 = 43.0 × 14.50 = 625.0
↑ 7893.0 — ↺ 85,625.0

↓ Concrete = 5034.0 — 52,510.0
Water
11.75 × 64.2 × 9.75 × 66.0 = 485.0 × 15.79 = 7,670.0
9.75² × 64.2 × 1/2 × 66.0 = 201.9 × 6.67 = 1,340.0
18.11 × 64.2 × 25.0 × 50.0 = 1,460.0 × 12.62 = 18,500.0
3.55² × 64.2 × 1/2 × 50.0 = 20.3 × 2.36 = 48.0
3.55 × 64.2 × 21.45 × 50.0 = 245.0 × 1.78 = 435.0
8.25² × 64.2 × 1/2 × 50.0 = 110.0 × 2.75 = 302.0

↓ 7555.3 — ↺ 80,807.0
↓ 337.7 K — ↺ 4,818.0 K'

Case V

↑ 21.67 × 5.23 × 66.0 = 7500.0 × 10.83 = 81,500.0
21.67 × 1/2 × 0.49 × 66.0 = 350.0 × 14.50 = 5080.0
↑ 7850.0 — ↺ 86,580.0

↓ Concrete = 5034.0 — 52,510.0
Water
18.11 × 64.2 × 15.0 × 50.0 = 880.0 × 12.62 = 11,100.0
3.55 × 64.2 × 11.45 × 50.0 = 131.0 × 1.77 = 232.0
3.55² × 64.2 × 1/2 × 50.0 = 20.3 × 2.36 = 48.0

↓ 6065.3 — ↺ 63,890.0
↓ 1785.0 — ↺ 22,690.0 K'

SUBJECT Fox Point Pump Station – 66'-0" Monolith
COMPUTATION Substructure Transverse Walls
COMPUTED BY EPR CHECKED BY GEH DATE 18 Dec. 1959

Section C-C
Case I

↑ 26.5 × 2.87 × 66.0	= 5030.0	× 13.25 =	68.000.0
26.5 × 1/2 × 0.7 × 66.0	= 625.0	× 8.83 =	5.525.0
	↑ 5655.0		73.525.0
↓ Concrete			
26.5 × 150# × 6.0 × 66.0	= 1.600.0	× 13.25 =	21.200.0
20.0 × 150# × 4.0 × 66.0	= 795.0	× 10.0 =	7950.0
2.0 × 150# × 4.0 × 50.0	= 60.0	× 20.0 =	1200.0
20.65 × 150# × 26.5 × 16.0	= 1.315.0	× 10.33 =	13600.0
4.35 × 150# × 1/2 × 26.5 × 16.0	= 139.0	× 22.10 =	3080.0
	↓ 3909.0		47.030.0
	↑ 1746.0 K		26.495.0 K

Case II

↑ 26.5 × 5.27 × 66.0	= 9230.0	× 13.25 =	123.000.0
26.5 × 1/2 × 0.08 × 66.0	= 70.0	× 8.83 =	620.0
	↑ 9300.0		123.620.0
↓ Concrete	= 3909.0	=	47.030.0
Water			
22.0 × 64.2 × 18.0 × 50.0	= 1.280.0	× 11.0 =	14.100.0
3.0 × 64.2 × 1/2 × 18.0 × 50.0	= 87.0	× 23.0 =	2.000.0
3.0 × 64.2 × 1/2 × 18.0 × 66.0	= 115.0	× 24.0 =	2.760.0
1.5 × 64.2 × 18.0 × 66.0	= 115.0	× 25.75 =	2.960.0
	↓ 5506.0		68.850.0
	↑ 3794.0		54.770.0

Case III

↑ 26.5 × 4.99 × 66.0	= 8750.0	× 13.25 =	116.000.0
26.5 × 1/2 × 0.31 × 66.0	= 270.0 ↑ 9020.0	× 8.83 =	2.380.0
↓ Concrete	= 3909.0	=	47.030.0
Water 21.05 × 64.2 × 24.0 × 50.0	= 1.630.0	× 10.5 =	17.[illegible].0
3.95 × 64.2 × 1/2 × 24.0 × 50.0	= 153.0	× 22.4 =	3.440.0
3.95 × 64.2 × 1/2 × 24.0 × 66.0	= 202.0	× 23.7 =	4.780.0
1.5 × 64.2 × 24.0 × 66.0	= 153.0	× 25.75 =	3.950.0
	↓ 6047.0		76.400.0
	↑ 2973.0 K		41.980.0 K

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure Transverse Walls
COMPUTED BY E.P.R. CHECKED BY GFH DATE 18 Dec. 1959

Section C-C (con'd)

Case IV ↑ 26.5 × 5.15 × 66.0 = 9000.0 × 13.25 = 120.000.0
26.5 × 1/2 × 0.15 × 66.0 = 13.0 × 8.83 = 115.0
↑ 9013.0 — 120.115.0

↓ Concrete
Water (see Case II) } ↓ 5506.0 — 68.850.0
↑ 3507.0 — 51.265.0

Case V ↑ 26.5 × 3.69 × 66.0 = 6450.0 × 13.25 = 85.500.0
26.5 × 1/2 × 0.6 × 66.0 = 525.0 × 8.83 = 4.650.0
↑ 6.975.0 — 90.150.0

↓ Concrete 3909.0 — 47.030.0
Water
22.55 × 64.2 × 21.0 × 50.0 = 1.525.0 × 11.28 = 17.200.0
3.45 × 64.2 × 1/2 × 21.0 × 50.0 = 117.0 × 22.70 = 2.660.0
3.45 × 64.2 × 1/2 × 21.0 × 66.0 = 155.0 × 23.85 = 3.680.0
1.5 × 64.2 × 21.0 × 66.0 = 134.0 × 25.75 = 3.460.0
↓ 5.840.0 — 74.030.0
↑ 1.135.0K — 16.120.0K

Section C-C t = 35'-6" d = 35'-0" = 420"

M (outer walls) = 25% × 54770.0 = 13700.0
b = 8'-11"
M/bd² = 13.700.000 / 3.92 × 420² = 20
As = 12 × 13700 / 27 × j × 420 = 16.3□" 11 - #11 T&B
u = 3.794.000 × .25 / 11 × 4.43 × j × 420 = 52 psi
V = 3.794.000 × 0.25 / 47 × j × 420 = 54 psi

Outer Walls

Inner Walls 22 - #11 T&B

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure Transverse Walls
COMPUTED BY E.P.R. CHECKED BY GFH DATE 18 Dec. 1959

Section b-b Max. total M = 26440.0 K'

Outer walls = 0.25 × 26440.0 = 6,600.0 K'

b = 3'-11" t = 40'-0" d = 39'-6" = 474"

M/bd^2 = 6,600,000 / 3.92 × 474^2 = 7.5 Outer Walls

As = 12 × 6,600.0 / 26.6 × j × 474 = 7.1 □" 5-#11 T & B

V = 2,136.0 × 0.25 = 535.0 K

u = 535,000 / 5 × 4.43 × j × 474 = 58 psi

v = 535,000 / 47 × j × 474 = 27 psi

Inner Walls 10-#11 T & B

Section a-a Max. total M = 8,510.0 K'

Outer Walls = 0.25 × 8,510.0 = 2,125.0 K'

As = 12 × 2125 / 20.0 × j × 474 = 3.04 □" 2-#11 T & B

V = 0.25 × 1405.0 = 350.0 K

u = 350,000 / 2 × 4.43 × j × 474 = 94 psi

Inner Walls 4-#11 T & B

SUBJECT Fox Point Barrier - Providence, R.I.
COMPUTATION Pump House Stopgates
COMPUTED BY LSP CHECKED BY RNW DATE 11 Dec 59

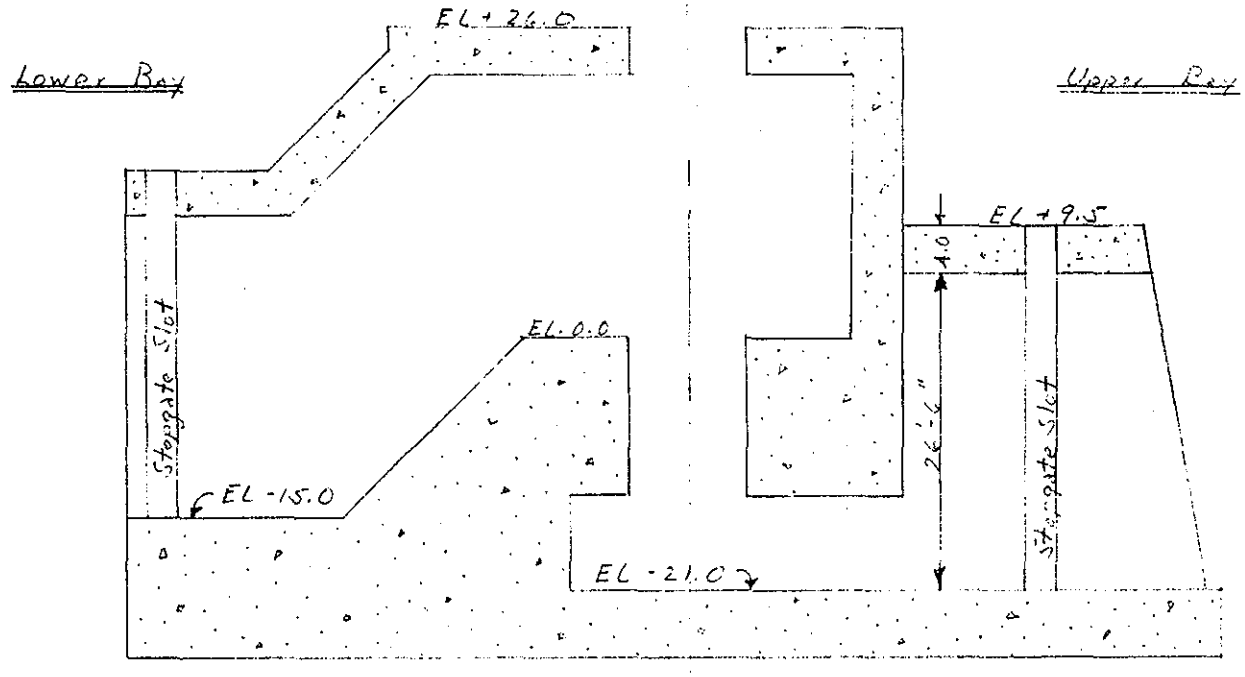
General

The stopgates are to be designed such that they can be used interchangeably in the upper & lower bay slots. The need of using the stopgates in the lower bay slot would be very infrequent, consequently, there appears to be no need to design the stopgates in the lower bay slots with the cavity unwatered and under storm conditions. Since the upper bay sill is 6.0' below the lower bay sill the critical loading will be with the stopgates in the upper bay slots and the cavity unwatered. Storm effects will be minor for which an increase in head of 2.0' is allowed.

Data:

Reference Axis = 0.0 Mean Sea Level (MSL)
Upper Bay Sill EL. = -21.0' (MSL)
Upper Bay Head EL = +5.5' (MSL)
Clear Opening 25' x 26'-6"
Mean High Water EL +3.0
Design Head (With 2.0' Freeboard) = 21+5 = 26.0'
Design Stresses based on EM 1110-1-2101 dated 6 January 58 "Working Stresses for Structural Design"
Basic Low Carbon Structural Steel Stress = 24,000 psi

Layout



Pump Station - Substructure Section

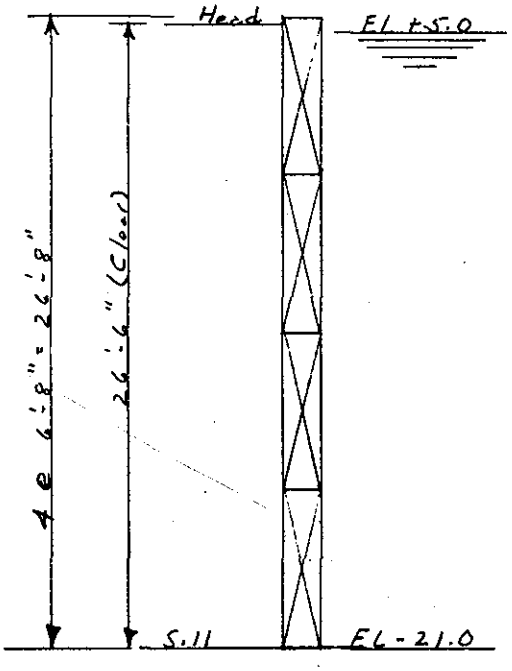
SUBJECT Fox Point Barrier - Providence, R.I.
COMPUTATION Pump House Stopgate
COMPUTED BY L.S.P. CHECKED BY R.N.W. DATE 14 Dec 57

Design Stresses

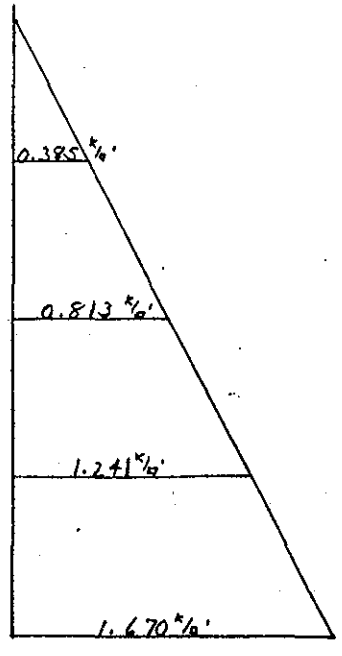
Basic Stress = 24,000 psi
Tension on extreme fibers = 24,000 psi
Compression on extreme fibers = 24,000 psi for $\frac{Ld}{bt} < 500$
Shear on webs = 14,000 psi
Tension = 24,000 psi
Compression with $L/r < 120$ = 17,000 - K
Bearing (Fitted Stiffners) = 27,000 psi
Welding (24,000 psi Basic Stress)
Shearing Stresses
Fillet weld 15,000 psi (throat of fillet)
Butt weld 14,000 psi (throat of butt weld)
Tensile & Compressive stresses same as basic metal

4 Section Plan

4 Sections @ 6'-8" = 26'-8"



Stopgate Section

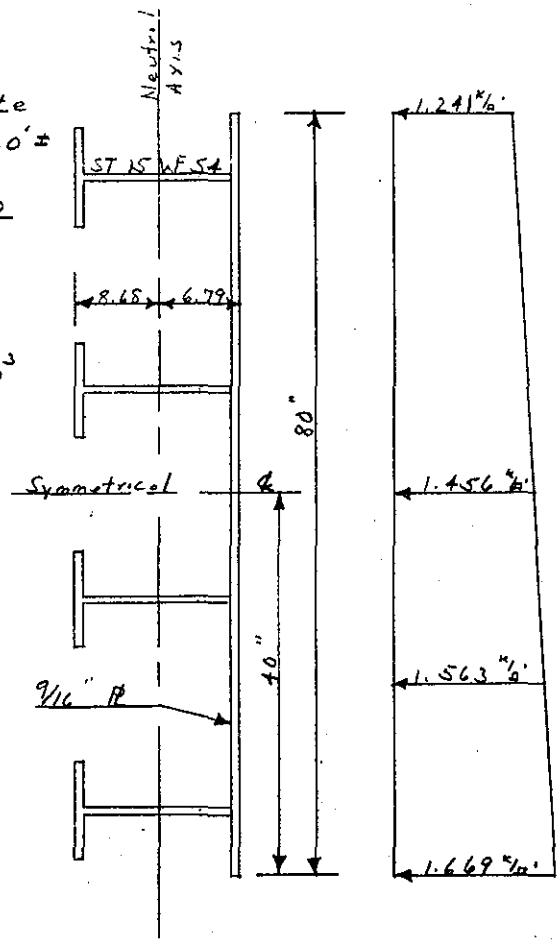


Hydrostatic Pressure Diagram

SUBJECT Fox Point Barrier - Providence, R.I.
COMPUTATION Pump House Stopgate
COMPUTED BY LSP CHECKED BY N.A.W. DATE 14 Dec 57

Trial Section

Design is based upon loading of the lower half of stopgate. Span of stopgate to centerline of bearing = 25' + 2(1') = 27.0' ±



$$\text{Max. Moment} = \frac{1}{8} w l^2 = \frac{1}{8} \times 1.563\ ^{K}/_{\square'} \times \overline{27.0}^2 \times \frac{40}{12}$$

$$= +475'^{K}$$

$$\text{Min. Sect. Mod} = \frac{M}{f_{all}} = \frac{475'^{K} \times 12}{24} = 237.5\ in^3$$

Sect. Mod. Provided

Neutral Axis

Toe	$2 \times 15.88 = 31.76\ in^2 \times 4.03 =$		128
Plate	$0.562 \times 40 = 22.50 \times 15.19 =$		342
	Area = 54.26 in^2		470

$$\bar{x} = \frac{M}{a} = \frac{470}{54.26} = 8.68\ in$$

Moment of Inertia

Toe	$2\ I_o = 2 \times 349.5 =$	699
	$A\bar{y}^2 = 31.76 \times \overline{4.65}^2 =$	687
PL	$I_o = \frac{40 \times \overline{0.562}^3}{12} =$	—
	$A\bar{y}^2 = 22.50 \times \overline{6.51}^2 =$	954
		2,340 in^4 = I_T

$$\text{Sect. Mod. Toe Flange} = \frac{I}{c} = \frac{2{,}340\ in^4}{8.68} = 270\ in^3$$

$$\text{Sect. Mod. Plate Flange} = \frac{I}{c} = \frac{2{,}340\ in^4}{6.79} = 345\ in^3$$

Actual Stresses

$$\text{Toe Flange} \quad f = \frac{M}{S} = \frac{475{,}000'^{\#} \times 12''/_{ft}}{270\ in^3} = +21{,}100\ ^{\#}/_{\square''} < 24{,}000\ ^{\#}/_{\square''} \quad \underline{\text{Sat}}$$

$$\text{PL Flange} \quad f = \frac{475{,}000'^{\#} \times 12''/_{ft}}{345\ in^3} = -16{,}500\ ^{\#}/_{\square''} < {}^{*}24{,}000\ ^{\#}/_{\square''} \quad \underline{\text{Sat}}$$

* No lateral deflection will occur since weight of stopgate above will restrict any movement.

SUBJECT Fox Point Barrier - Providence, R.I.
COMPUTATION Pump House Stopgate
COMPUTED BY L.S.P. CHECKED BY R.W.W. DATE 14 Dec 51

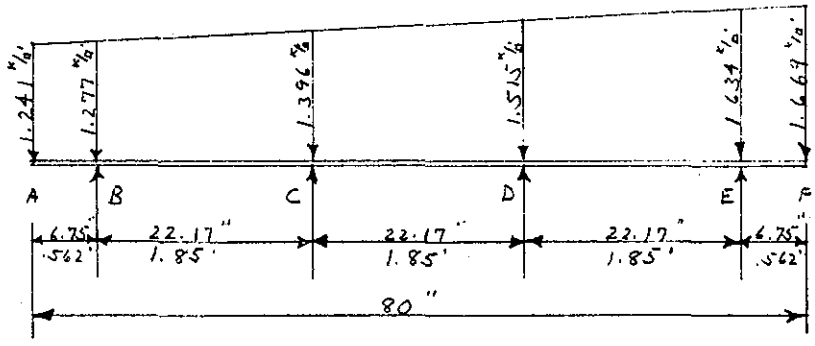
Shear in Web @ N.A

$$V = \frac{40}{12} \times 1.563\,^{k}/_{\square'} \times \frac{27'}{2} = 70.5^{k}$$

$$Q \quad 2 \times 10.5 \times 0.76 = 16.0 \times 8.30 = 133$$
$$2 \times 7.92 \times 0.548 = 8.7 \times 3.96 = \underline{34.5}$$
$$167.5 = Q$$

$$v = \frac{70{,}500^{\#} \times 167.5\,in^{3}}{2{,}340\,in^{4} \times 2 \times 0.548} = 4{,}600\,^{\#}/_{\square''} < 14{,}000\,^{\#}/_{\square''} \quad \underline{\text{Sat}}$$

Simplate
By Moment Distribution



Fixed End Moments
Variation in loading between supports is slight hence a uniform load is assumed (between supports)

$$M_{BA} = \frac{1.259 \times \overline{0.562}^{2}}{2} = 0.199\,'^{k} = 2390\,''^{\#}$$

$$M_{BC} = M_{CB} = \tfrac{1}{12} \times 1.337 \times \overline{1.85}^{2} = 0.381\,'^{k} = 4{,}580\,''^{\#}$$

$$M_{CD} = M_{DC} = \tfrac{1}{12} \times 1.455 \times \overline{1.85}^{2} = 0.415\,'^{k} = 4{,}990\,''^{\#}$$

$$M_{DE} = M_{ED} = \tfrac{1}{12} \times 1.575 \times \overline{1.85}^{2} = 0.449\,'^{k} = 5{,}400\,''^{\#}$$

$$M_{EF} = \frac{1.652 \times \overline{0.562}^{2}}{2} = 0.261\,'^{k} = 3{,}140\,''^{\#}$$

SUBJECT: Fox Point Barrier - Providence, R.I.
COMPUTATION: Pump House Stoplogs
COMPUTED BY: L.C.P. CHECKED BY: P.N.W. DATE: 15 Dec 59

Stiffness Factors

Since E, I, & L are constant K will be the same for all three spans. However, B & E are assumed hinged.

$K_{BC} = \frac{3}{4} \times 1 = \frac{3}{4}$ $\qquad \frac{.75}{1.75} = 0.428$

$K_{CD} = 1$

$K_{DE} = \frac{3}{4} \times 1 = \frac{3}{4}$ $\qquad \frac{1}{1.75} = 0.572$

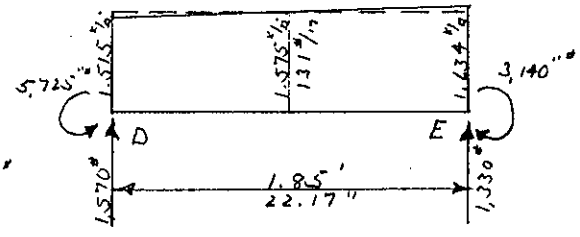
Distribution

A	B	C		D		E	F
		.428	.572	.572	.428		
FEM +2390	-4550"#	+4990	-4990"#	+4990	-5400"#	+5400	-3140"#
	+2190	+1635			-1130	-2260	
		-293	-392	+880	+660		
			+440	-196			
		-188	-252	+112	+84		
			+56	-126			
		-24	-32	+72	+54		
			+36	-16			
		-16	-20	+9	+7		
+2,390	-2,390	+5154	-5154	+5,725	-5,725	+3,140	-3140

Span DE is most critical

$$R_D = \frac{+5,725 - 3,140 + \frac{131 \times \overline{22.17}^2}{2}}{22.17}$$

$$= \frac{+2,585 + 32,200}{22.17} = \frac{34,685}{22.17} = 1,570\#$$



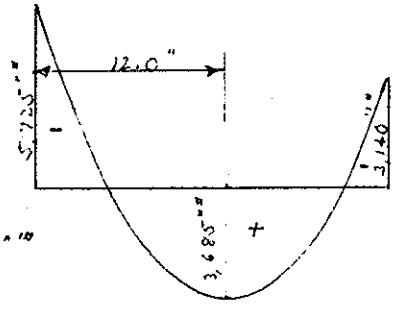
$R_E = 131 \times 22.17 - 1,570\# = 1,330\#$

Max Positive moment @ point of 0 shear

Pt. of 0 shear $= \frac{1570}{131} = 12''$ from D

$$+M_{max} = +1,570 \times 12 - 5,725 - \frac{131 \times \overline{12}^2}{2}$$

$$= +18,850 - 5,725 - 9,440 = +3,685''\#$$



Moment Diagram

SUBJECT Fox Point Barrier - Providence, R. I.
COMPUTATION Pump House Stoplogs
COMPUTED BY LSP CHECKED BY R.N.W. DATE 15 Dec 49

Max. Moment is @ Pt. D = -5,725 "#

Sect. Mod of $\frac{9}{16}$" plate $= \frac{bh^2}{6} = \frac{12 \times \overline{0.562}^2}{6} = 0.631 \text{ in}^3$

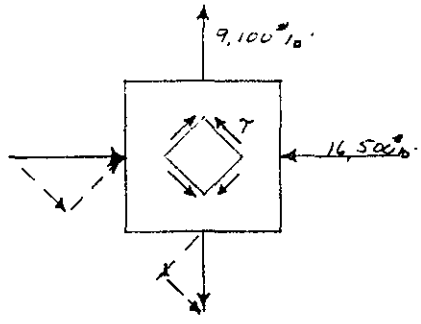
$$f = \frac{M}{S} = \frac{5,725 \text{ "\#}}{0.631} = \pm 9,100 \text{ \#/□"} < 24,000 \text{ \#/□"} \quad \underline{\text{Sat}}$$

Combined Stresses in Skinplate (Shear)

$$\tau_{max} = \frac{1}{2}(\sigma_{max} - \sigma_{min}) = \frac{1}{2}\left[+9,100 - (-16,500)\right]$$

$$= \frac{1}{2}(25,600) = 12,800 \text{ \#/□"} < 14,000 \text{ \#/□"}$$

$\underline{\underline{\text{Sat}}}$



Welding of Tee to Skinplate

Stresses are transferred from web to skinplate through horizontal shear. Max. transfer of stress occurs at point of maximum shear, i.e. at ends

$$V_{max} = \frac{70.5}{2} = 35.25 \text{ \#/web}$$

$$Q = 20 \times 0.562 \times 6.51 = 73.1$$

$$v = \frac{VQ}{I} = \frac{35,250 \text{ \#} \times 73.1 \text{ in}^3}{2,340 \text{ in}^4} = 1,100 \text{ \#/in}$$

Allowable shear stress in fillet weld = 15,000 #/□" (Throat area)

For $\frac{1}{16}$ Weld Allowable $= 15,000 \text{ \#/□"} \times \frac{1}{16} \times .707 = 663 \text{ \#/}\frac{1}{16}$

No. of $\frac{1}{16}$" Weld Reqd $= \frac{1,100}{663} = 2$

Minimum Size Fillet for plate $\frac{1}{2}$ to $\frac{3}{4}$" is $\frac{1}{4}$"

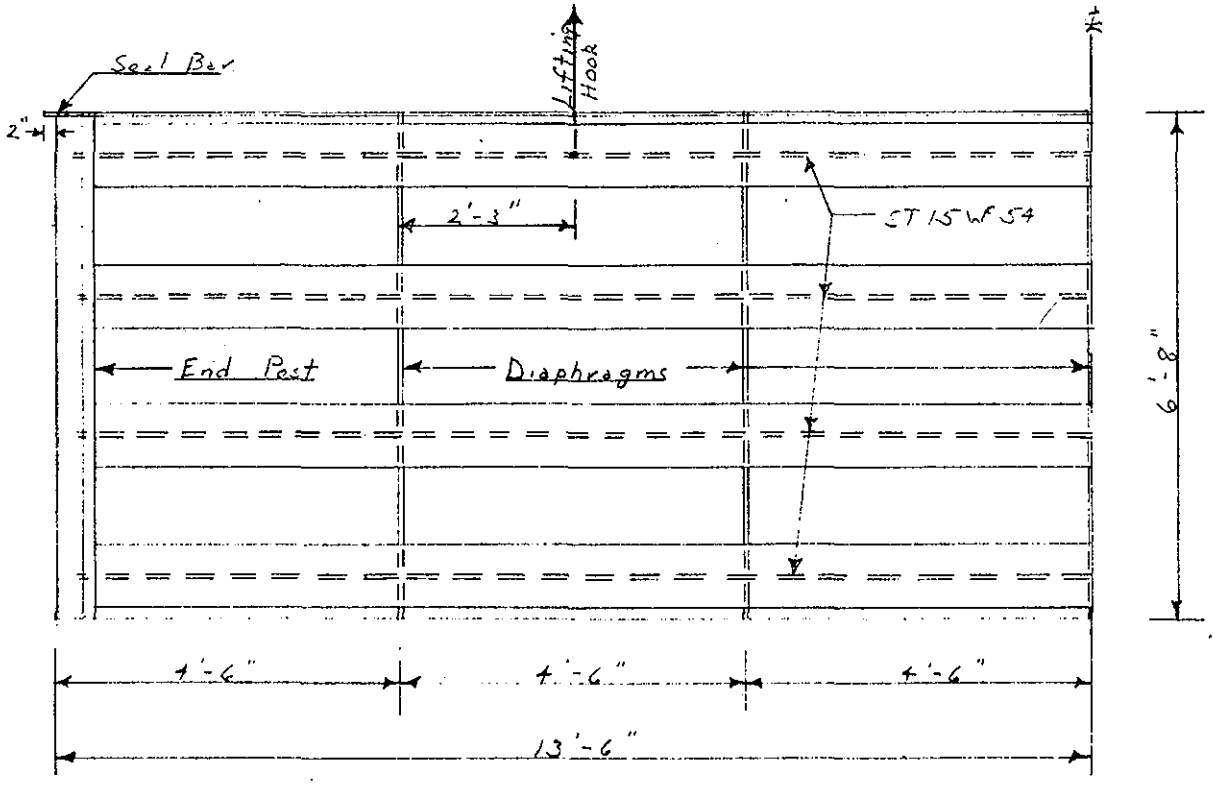
$\underline{\underline{\text{Use Fillets of } \frac{1}{4}\text{"}}}$ (both sides)

SUBJECT Fox Point Barrier - Providence, R. I.
COMPUTATION Pump House Sluicegate
COMPUTED BY L.S.P. CHECKED BY R.N.W. DATE 16 Dec 59

Diaphragms

Diaphragms are to serve dual function
(a) Transmission of vertical loads from horizontal members to lifting hooks.
(b) Provide stiffness to prevent "racking"

Tentative spacing of diaphragms



Half Inner-Face Elevation

(a) Transmission of Vertical Loads

Approximate wt. of Gate

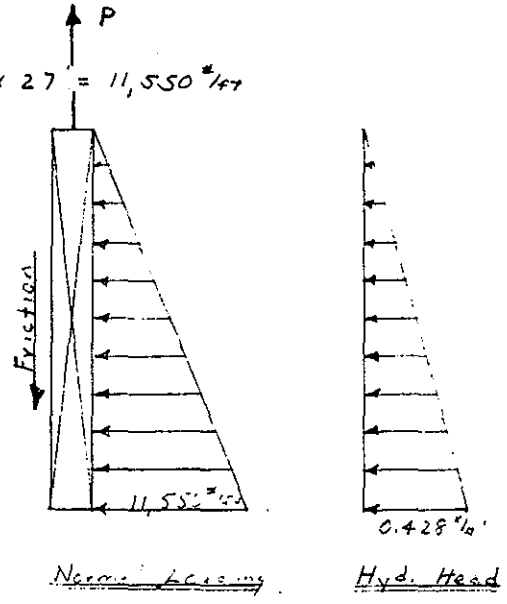
9/16 Pl. to	153 #/ft x 27' =	4,200 #
4 Tees	4 x 54 x 27' =	5,900
Diaph (1/3 +)	7 x 25.5 #/ft x 6.67 =	1,200
		11,300
33 % seals, hoist welds, etc		3,700
		15,000 #

SUBJECT Fox Point Barrier - Providence, R.I.
COMPUTATION Pump House Stopgate
COMPUTED BY LSP CHECKED BY RHN DATE 17 Dec 59

Maximum vertical load transmission occurs when the stopgate are in place and the cavity unwatered. With this condition the loading will include frictional force as well as the dead load of the structure.

Frictional Force (Static)

The hydrostatic head that will produce the maximum normal force (N) will vary from 0 to 6.67' since any greater head would overtop the stopgate and fill the cavity and equalize the pressure thereby eliminating the frictional force.



Normal Stress Intensity = $64.2 \times 6.67' \times 27' = 11{,}550\ \#/ft$

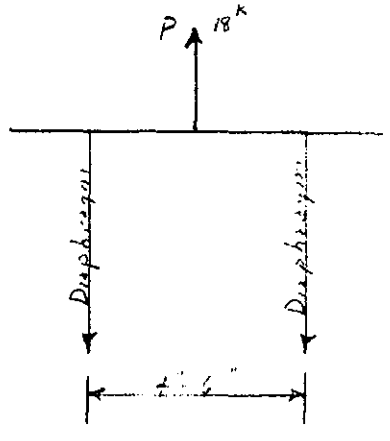
Total $N = 11{,}550 \times \frac{6.67}{2} = 38{,}500^{\#}$

Coefficient of Static Friction
(Ref: Civil Engr. Handbook; Merriman & Wiggin p 133)
Metal on Metal ... 0.25 to 0.15
However since stopgate guides will undoubtedly be corroded a more reasonable assumption is Iron on Stone ... 0.70 to 0.50
Use 0.50

$F_{Total} = fN = 0.50 \times 38{,}500 = 19{,}250^{\#}$

Say 20^{K}

Total Vertical Load = $20^{K} + 15^{K} = 35^{K}$
Total Vertical Load per Hook = $18^{K} \pm$



It is assumed that only the two adjacent diaphragms will take the load

$A_{req} = \frac{P}{f_{all}} = \frac{18{,}000^{\#}}{24{,}000^{\#}} = 0.75\ in^2$

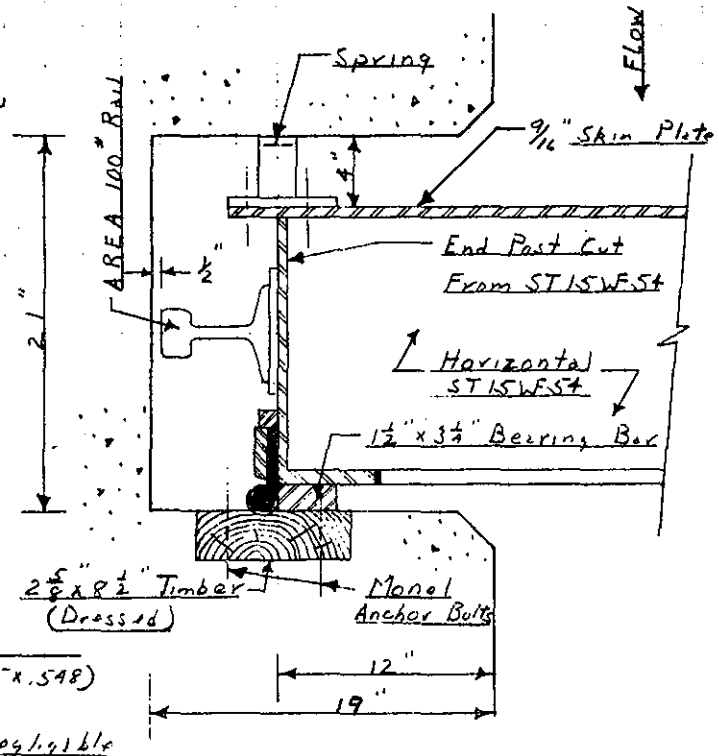
Minimum thickness of ⅜" controls

However for rigidity a ½ inch plate is selected.

SUBJECT Fox Point Barrier - Providence, R.I.
COMPUTATION Pump House Stopgates
COMPUTED BY LSP CHECKED BY R.N.W. DATE 17 Dec 59

End Posts

By notching the flange of the tee sections and framing them into the end posts, a better transmittion of stresses results. Since the web has not changed the shear remains the same. A check must be made on the stresses caused by the weight of stoplogs above and the hydrostatic loading.



Stopgate Slot Detail
(Scale 3/32" = 1")

Vertical Loading

4 Stoplogs @ $15^k = 60^k$

$$f = \frac{P}{a} = \frac{60{,}000}{(27 \times 12 \times 0.562) + (2 \times 15 \times .548)}$$

$$= \frac{60{,}000}{182 + 16} = 300\ \#/\square'' \quad \underline{\text{Negligible}}$$

Hydrostatic Loading

$$M_{max} = \frac{1}{12} \times 1.70\ ^k/_{\square'} \times \overline{1.25}^2 = 0.222\ ^{'k} = 2660\ ''\#/ft$$

$$S_{web} = \frac{bh^2}{6} = \frac{12 \times \overline{0.548}^2}{6} = 0.602\ in^3$$

$$f_{act} = \frac{2660\ ''\#}{0.602\ in^3} = 4{,}430\ \#/\square'' \quad \underline{\text{Negligible}}$$

Combined Stresses (Vert & Hyd.) - Negligible

Bearing Bar

Maximum Loading = 70.5^k (Per 40" Section)

Allowable Bearing on Wood Perpendicular to Grain = 600 #/□" for Red or White Oak - Ref.: National Design Spec. for Stress Grade Lumber - Nat. Lumber Mfg. Ass. - 1957 - Table 1

$$\text{Area Reqd} = \frac{70.5^k}{0.600\ ^k/_{\square''}} = 117.5\ in^2$$

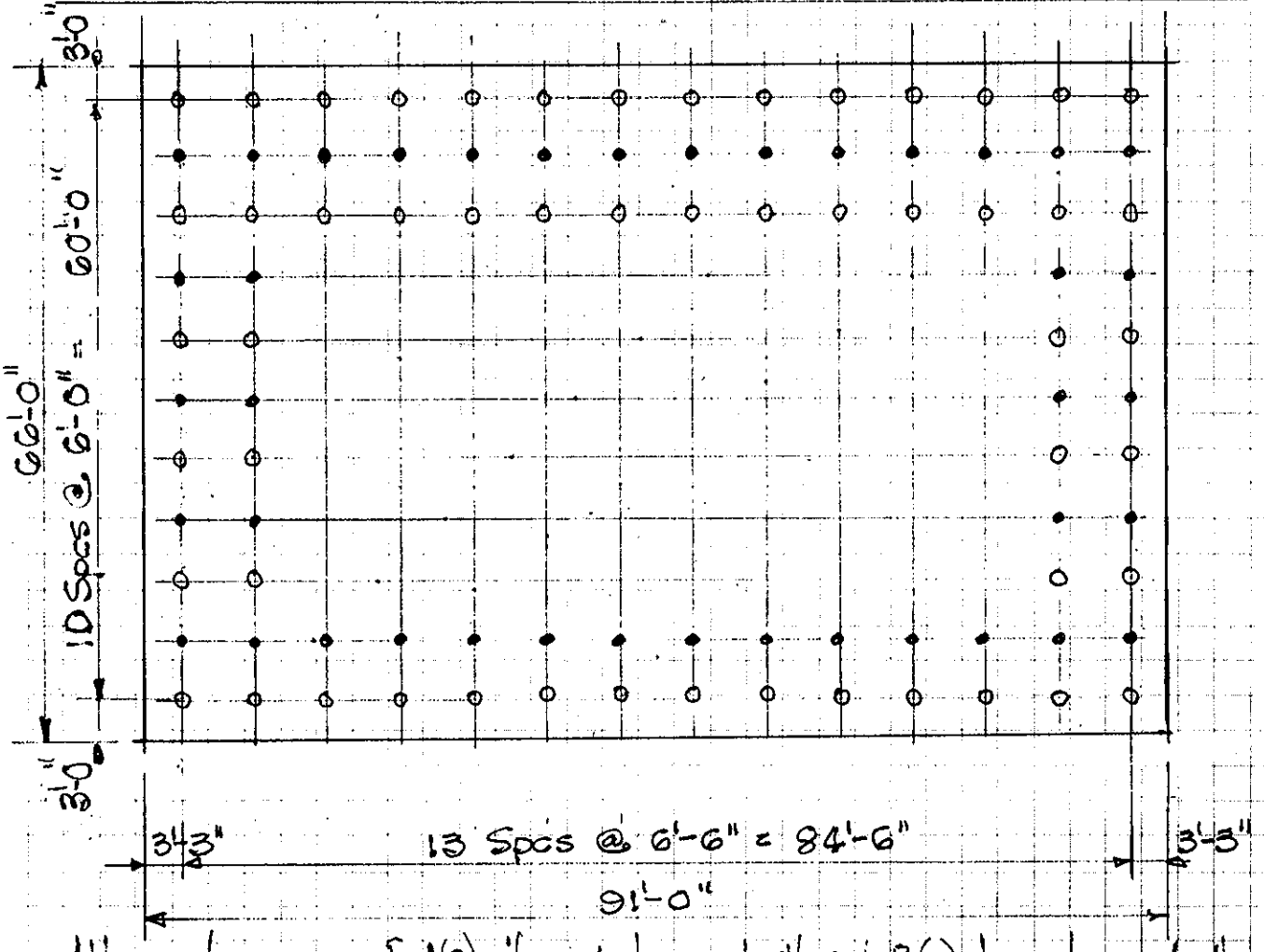
$$\text{Width Bar Reqd} = \frac{117.5}{40} = 2.94\ in$$

Thickness Reqd = 1 1/2" (for proper mounting of seal)

Bar Selection 1 1/2" x 3 1/4"

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Steel Piles
COMPUTED BY E.P.R. CHECKED BY Cmt DATE 31 Mar. 1960

For pile analysis use Elastic Center Method as illustrated in "Substructure Analysis and Design" by Paul Andersen (Second Edition - 1956 - P. 174)



Alternate rows of A(o) piles upstream batter & B(•) downstream batter
No. of piles = 11 × 14 = 154

Due to symmetry elastic center of both A & B pile occur at center

PMI of one row = $2[3^2+9^2+15^2+21^2+27^2+33^2+39^2]$ = 8192 ft^4

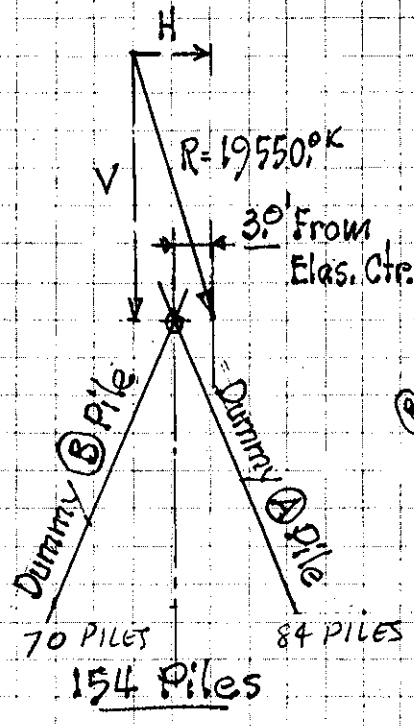
Total PMI = 8192 × 11 = 90000 ft^4

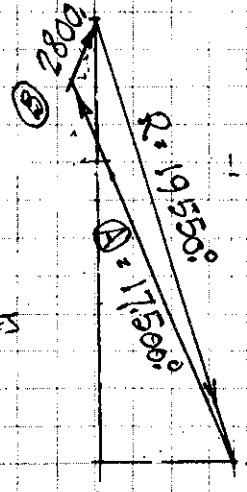
Pile Section 14 BP 117

Allowable Loads -	Normal (Case V)	180.0K
	Case I and II	270.0K
	Tension	60.0K

SUBJECT Fox Point Pump Station - 66'-0" Monolith
COMPUTATION Substructure - Steel Piles
COMPUTED BY E.P.R. CHECKED BY Cmt DATE 31 Mar. 1960

Case II - Hurricane V = 18700.° H = 5552.°
Resultant cuts base 42.5' from upstream edge





Dist. of R from E.C. normal to R
= 3.° × 18.7/19,550 = 2.88'

M = 2.88 × 19550.° = 56,300.°K'

Ⓐ Max.
$= \frac{17500.°}{84} + \frac{56300 \times 39}{90000}$ (.625)
= 209 + 24.5 = 233.5 K/Comp. Land edge

Ⓐ Min.
209 − 24.5 = 184.5 K/Comp. Bay Edge

Ⓑ Max.
$+\frac{2800}{70} + 24.5$ = 64.5 K/Comp. Land edge

Ⓑ Min.
+ 40.° − 24.5 = 15.5 K/Comp. Bay Edge

ΣH components of battered piles must equal external H

8.° Ⓐ ½ (233.5 + 184.5) 84 × 5/13 = 6750.°

30.° Ⓑ − ½ (64.5 + 15.5) 70 × 5/13 = − 1080.°

5670.° K

SUBJECT Fox Point Pump Station – 66'-0" Monolith
COMPUTATION Substructure – Steel Piles
COMPUTED BY E.P.R. CHECKED BY Cmt DATE 28 Apr. 1960

Case I - Construction

V = 24450.° K H = 0
V cuts base 50'-0" from Land edge
e = 50 - 45.5 = 4.5' toward Bay and from E.C.

M = 4.5 × 24450.° = 110,000.° K'

Ⓐ batters

Max. = $\left(\frac{24450}{2 \times 84} \cdot \frac{13}{12}\right) + \left(\frac{110{,}000 \times 39}{90000}\right) = 156.^5 + 48 = 204.^5$ K Comp. Bay Edge

Min. = 156.5 - 48 = 108.5 K Comp. Land edge

Ⓑ batters

Max = $\left(\frac{24450}{2 \times 70} \times \frac{13}{12}\right) + \left(\frac{110000 \times 39}{90000}\right) = 189 + 48 = 237.^{0}$ K Comp. Bay Edge

Min. = 189 - 48 = 141.° K Comp. Land Edge

Case V - Normal

V = 17802.° K H = 0
e = 5.15' from E.C. toward Bay
M = 5.15 × 17802 = 91500.'#

Ⓐ batters

Max. = $\left(\frac{17802}{2 \times 84} \cdot \frac{13}{12}\right) + \left(\frac{91500 \times 39}{90000}\right) = 115.° + 40.° = 155.°$ K Comp. Bay Edge

Min. = 115.° - 40.° = 75.° K Comp. Land Edge

Ⓑ batters

Max. = $\left(\frac{17802}{2 \times 70} \cdot \frac{13}{12}\right) + 40$ (138) = 178.° K Comp. Bay Edge

Min. = 138 - 40 = 98.° K Comp. Land Edge

B1

FOX POINT

PUMPING STATION - DESIGN MEMO

COOLING WATER CANAL SLUICE GATES

B DESIGN COMPUTATIONS

Required Hoist Capacity

Gate Opening 10'-0" x 15'-0"		
Unbalanced head for hoist loading		6 Ft.
Hydrostatic load on gate 11 x 15.25 x 6 x 62.5		63,130 Lbs.
Friction load on 8 wheels - 63,130 x .002		126 lbs.
Friction Side Seal 15.5 x 12 x 2.5 x 2.6 x 2		2,418 lbs.
Friction Top Seal 11 x 12 x 2.5 x 2.6		860 lbs.
Stem Wt. 2 - 5" ϕ x 32 x 67#		4,300 lbs.
Gate (est.)		8,000 lbs.
		15,704 lbs.
	25% Overload	3,930
	Total	19,634 lbs.
For selection of hoist use load of		20,000 lbs.
Rate of opening gate		12 in. per min.
Motor HP = (20000 x 1)/33000 x 55%		1.10 HP

Unsupported length of stem 24'-6"	294 inches
Max. Stem diameter	6"
Root diam. of threaded section	5.58"
Radius of gyration 6" 6/4	1.5"
Radius of gyration 5.58" 5.58/4	1.395
l/r of 6" ϕ 294/1.5	196
l/r of 5.58" ϕ 294/1.395	210.5

$$f = \frac{17,000}{1 + N'} \quad ; \quad N' = \frac{l^2}{16,000\ r^2} = 86436/16000 \times 1.95 = 2.77$$

f = 17,000/1 + 2.77	= 4500 psi
Area @ root	24.5 sq. in.
Safe load on stem 4500 x 24.5	110,000 lbs.

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pumping Plant
COMPUTATION Voltage Selection (ELECTRICAL)
COMPUTED BY J. D. Campbell CHECKED BY DATE 12-28-59

PUMPING STATION DM #10

Comparative Price Summary - 11KV vs 4KV Motors

	4KV	11KV
Motors (4KV 5@$190,000, 11KV 5@$229,000)	$950,000	$1,145,000
Motor leads 40'/Motor = 200' total (4KV @ $25/ft 11KV @ $11/ft)	5,000	2,200
Switchgear (4KV-250MVA, 11KV-500MVA w/reactors)	89,955	125,470
" Installation	22,500	31,300
2-9300/11,625KVA Power Transformers @ $46,300	92,600	—
Transformer Installation	9300	—
Totals	$1,169,355	$1,303,970

Dollar Difference $1,303,970 - 1,169,355 = $134,615

4KV costs $135,000 less than 11KV

Comparative Price Summary - 2.3KV vs 4KV Motors

The only differences between 2.3KV and 4KV are in the Motor leads and in the Reactors required at 2.3KV To limit duty on breakers.

	4KV	2.3KV
Motor leads (4KV @ $25/ft, 2.3KV @ $40/ft)	$5,000	$8,000
Current limiting Reactors 2 @ $10,250	—	20,250
" " " Installation	—	2030
Totals	$5000	$30,280

Dollar difference = $30,280 - $5000 = $25,280
4KV costs $25,000 less than 2.3KV.

SUBJECT Fox Point Pumping Plant
COMPUTATION Pump Motor Selection (ELECTRICAL)
COMPUTED BY J. D. Campbell CHECKED BY DATE 12-28-59

Power Transformer Ratings

Synchronous Motors (Efficiency = 96%)

$$\text{Motor KW} = \frac{4700 \times .746}{.96} = 3660\,\text{KW}$$

Total for 5 pumps = 5(3660) = 18,300 KVA @ 1.0 P.F.

Station Service = 300 KVA

Total = 18,600 KVA

$$\text{Transformer OA rating} = \frac{18,600}{2} = 9300\,\text{KVA}$$

FA rating = 1.25(9300) = 11,625 KVA

Squirrel Cage Motors (Efficiency = 96%)

Motor KW = 3660 KW

Total for 5 Pumps = 5(3660) = 18,300 KW @ .9 P.F.

$$\text{Total Motor KVA} = \frac{18,300}{.9} = 20,400\,\text{KVA}$$

Station Service = 100 KVA

Total = 20,500 KVA

$$\text{Transformer OA rating} = \frac{20,500}{2} = 10,250\,\text{KVA}$$

FA rating = 1.25(10,250) = 12,800 KVA

Difference in FA ratings = 12,800 − 11,625 = 1175 KVA

$$\text{Difference Per Motor} = \frac{1175(2)}{5} = 470\,\text{KVA}$$

@ \$4.20/KVA = (4.20)(470) = \$2210 per Motor

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Pumping Plant
COMPUTATION Pump Motor Selection
COMPUTED BY J. D. Campbell CHECKED BY (ELECTRICAL) DATE 12-28-59

Per Unit Cost Comparison - Synchronous vs Squirrel Cage Motors (All prices from Westinghouse)

Costs of Auxiliaries

	Synchronous	Sq. Cage
Switchgear	$13,300	$9755
" Installation	3320	2440
Exciter M-G Set & Control ($\frac{\$14,800 \times 2}{5}$)	5920	—
" " " Installation	592	—
Station Service Transformers	1700*	949**
" " " Installation	170	100
Increase in Power Transformer Rating	—	2210
Totals for motor Auxiliaries	$25,002	$15,454

* 2-300KVA Transformers - $\frac{2 \times \$4240}{5} = \$1700$/unit

** 2-112.5KVA Transformers - $\frac{2 \times \$2370}{5} = \$949$/unit

Total Comparative costs

	Synchronous	Sq. Cage
Motor	$190,000	$249,000
Auxiliaries	25,002	15,454
Totals	$215,002	$264,454

Dollar Difference = $264,454 - $215,002 = $49,452

Note: Only items which are different in cost were considered.

SUBJECT Fox Point Pumping Plant
COMPUTATION Supply Cable & Transformer Ratings
COMPUTED BY J. D. Campbell CHECKED BY Kes DATE 12-8-59

Design Conditions

1. Maximum load

$$\text{FW/Main Pump} = \frac{4700(.746)}{.96} = 3660\ \text{KW @ 1.0 P.F.}$$

for 5 Pumps = 5(3660) = 18,300 KVA

5 exciters @ $\frac{30\text{KW}}{.90} = 33.4$ = 167 KVA

Lighting & Misc. = 50 KVA

Maximum demand load = 18,517 KVA

$$\text{current, } I = \frac{18{,}517}{\sqrt{3}(11)} = 972 \text{ amps @ 11KV (Cable)}$$

$$I = \frac{18{,}517}{\sqrt{3}(4)} = 2670 \text{ amps @ 4KV (Bus duct)}$$

2. Load factor

assume 24 hour operating cycle as follows:

a - Full-load for 6 hours

b - 500 KVA load for 12 hours

c - Full-load for 6 hours

$$\text{Average load} = \frac{6(18{,}517) + 12(500) + 6(18{,}517)}{24 \text{ hours}}$$

$$= \frac{111{,}000 + 6000 + 111{,}000}{24 \text{ hours}}$$

$$= \frac{228{,}000}{24} = 9500 \text{ KVA}$$

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum load}} \times 100$$

$$= \frac{9500}{18{,}517} \times 100 = 51.2\% \text{ - Say } 50\%$$

3. Supply cable design based on 2 full-capacity circuits, each designed to carry 18,517 KVA at 50% load factor. Use Butyl rubber insulated, shielded, neoprene jacketed cables, 13,000 volt grounded neutral, 85°C copper temp.

1250 MCM has a capacity of 1040 amps
So 3-1250 MCM cables in 3-4" ducts/ckt. could carry the load.

However, the power company is using 2-3/C 500 MCM Paper & Lead cables for each circuit. splicing will be easier if we install two cables per phase.

600 MCM has a capacity of 490 amps.
So 2-600 MCM/phase/circuit are good for 2x490 = 980 amps and will be used.

A duct bank of 4-5" ducts for power cables, 2-spare 5" ducts and 2-4" control cable ducts will be installed.

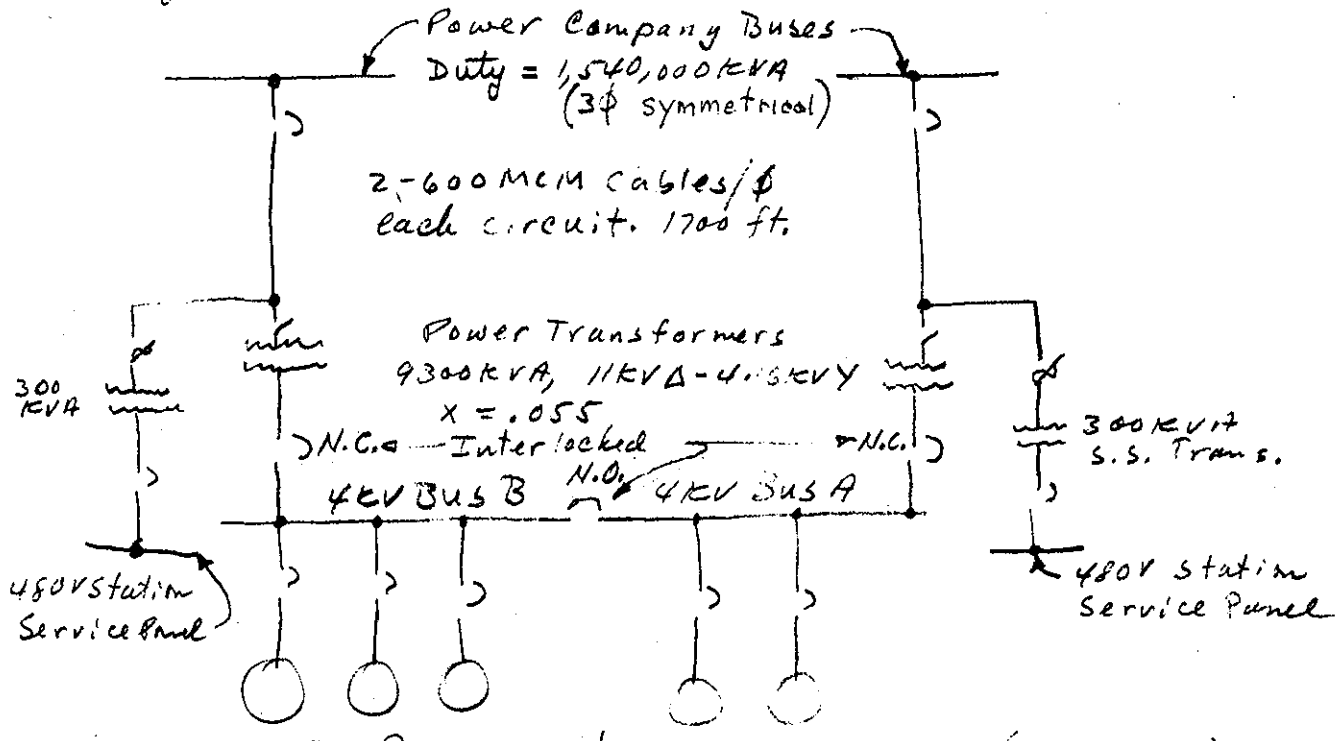
4. Transformer Capacity:

Each power transformer will carry a normal load of $\frac{18,517}{2}$ KVA = 9259 KVA say 9300 KVA

With one supply cable circuit or transformer out of service, the remaining transformer will be loaded to 18,517 KVA or an overload of 100% above its self-cooled rating. With forced-air cooling, the transformer rating will be 1.25 x 9300 = 11,625 KVA. and the load will be $\frac{18,517}{11,625} \times 100 = 159.5\%$ or 59.5% overloaded.

General Electric Co. predicts a loss of transformer life of between 4 and 10% for each such operation on overload.

SUBJECT Fox Point Pumping Plant
COMPUTATION Circuit Breaker Duties
COMPUTED BY J. D. Campbell CHECKED BY Yes DATE 12-14-59



5 - Pump Motors - each 4700HP (3660 KVA)

4KV, $X'_d = 0.30$, $X''_d = 0.18$

Method used - ASA Standard C37.5-1953

Converting Impedances to Per Unit on 10,000 KVA Base

Power Co. System $X = \frac{10,000}{1,540,000} = .0065$

Cable Z: Z of 3-1/c 600MCM in Transite = .0284 + j.0422

for each circuit = $.0422\left(\frac{1.7}{2}\right) = .0358\ \Omega$

$X_{pu} = .0358\left(\frac{10}{(11)^2}\right) = .00296$

$R_{pu} = .00198$

Power Transformers

$X_{pu} = .055\left(\frac{10}{9.3}\right) = .0592$

$R_{pu} = .01\left(\frac{10}{9.3}\right) = .0108$

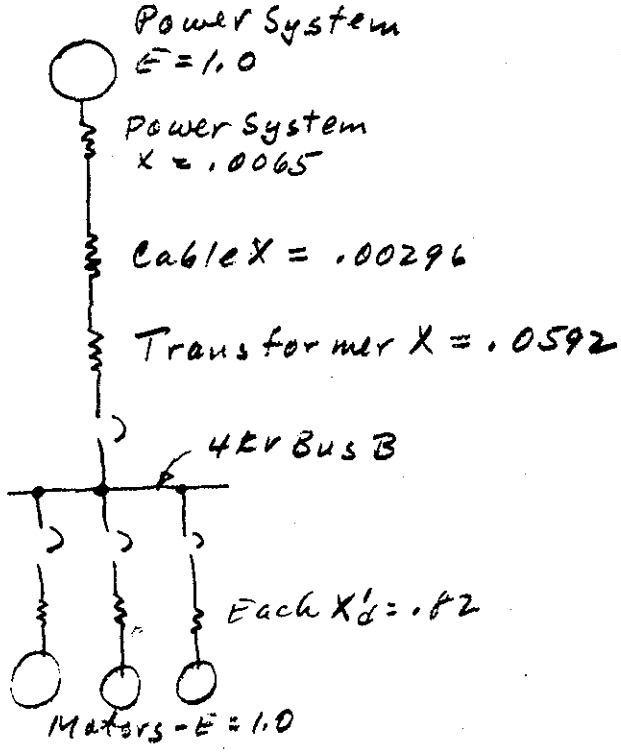
Pump Motors $X'_d = 0.30$ $X''_{d\,pu} = .18\ \frac{10,000}{3660} = .5$

$X_{d\,pu} = 1\ \frac{10,000}{3660} = 2.73$ $X'_{d\,pu} = .30\left(\frac{10,000}{3660}\right) = .82$

SUBJECT Fox Point Pumping Plant
COMPUTATION Circuit Breaker Duties
COMPUTED BY J.D. Campbell CHECKED BY Kes DATE 12-15-54

Fault on 4KV Bus B - (Bus tie open)

Reactance Diagram



Contribution from power system:

Total Z = .0065 + .00296 + .0592 = .0687

Contribution = $\frac{10,000}{.0687}$ = 146,000 KVA Symmetrical

for 8 cycle breakers, no multiplier required

Rating of transformer secondary ACB:

Normal I = $\frac{18,517}{\sqrt{3}\,(4)}$ = 2670 Amps

∴ Use 3000 A, 350 MVA Breaker, 4160 V

(Smallest ACB having 3000A normal rating)

Bus Rating (Bus tie closed, one power transformer out.)

Contribution from System = 146,000 KVA

Contribution from each motor = $\frac{10,000}{.82}$ = 12,200 KVA

SUBJECT Fox Point Pumping Plant
COMPUTATION Circuit Breaker Duties
COMPUTED BY J. D. Campbell CHECKED BY Fls DATE 12-15-59

Bus rating = 146,000 + 5(12,200) = 146,000 + 61,000

= 207,000 KVA Symmetrical

Asymmetrical Rating = 1.5(207,000) = 311,000 KVA

$I = \frac{311,000}{\sqrt{3}(4)} = 44,900$ Amps

<u>Bus tie ACB Rating</u> (Bus tie closed, one power trans. out)

Breaker duty for fault on Bus A = 146,000 + 3(12,200)

= 182,600 KVA Sym.

Use 250 MVA, 2000 Amp, 4160V Breaker

<u>Motor Breaker Rating</u> (Bus tie closed, one power trans. out)

Breaker duty = 146,000 + 4(12,200)

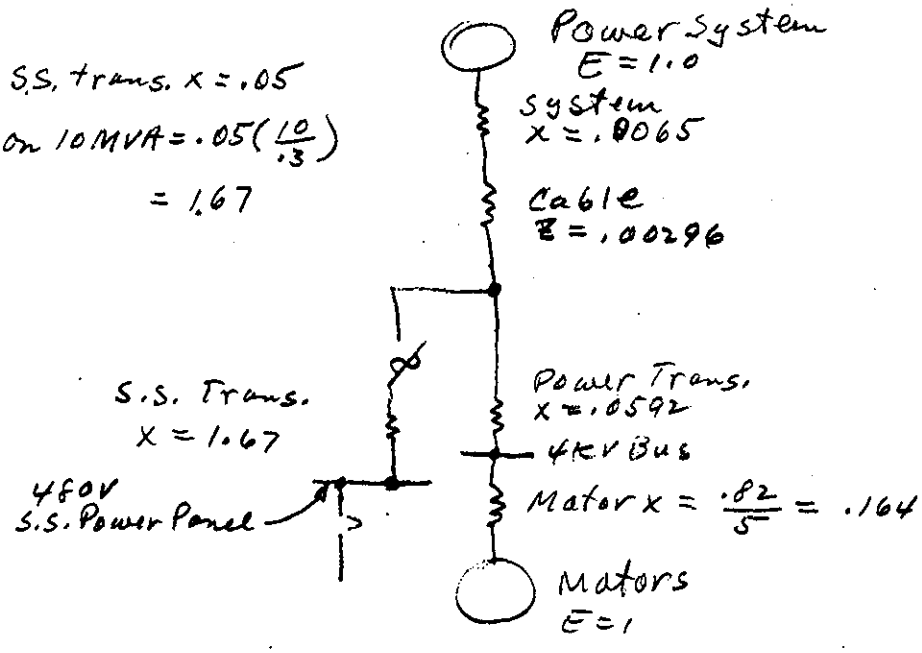
= 194,800 KVA

Normal $I = \frac{3660}{\sqrt{3}(4)} = 528$ Amps

Use 250 MVA, 1200 Amp., 4160V breaker.

SUBJECT Fox Point Pumping Plant
COMPUTATION Station Service System Duties
COMPUTED BY J. D. Campbell CHECKED BY Kes DATE 12-15-59

Rating of Station Service Transformer Primary Fuses



Fault at primary of station service transformer

Contribution from system $= \frac{10,000}{.0065 + .00296} = \frac{10,000}{.0095}$

$= 1,050,000$

Contribution from Motors $= \frac{10,000}{.164 + .0592} = \frac{10,000}{.223}$

$= 44,800$ KVA

Fuse duty $= 1,050,000 + 44,800 = 1,094,800$ KVA Symmetrical

This is above the rating of available fuses so a non-fused interrupter switch will be used.

SUBJECT Fox Point Pumping Station
COMPUTATION Station Service System Duties
COMPUTED BY J. D. Campbell CHECKED BY Kea DATE 12-15-59

Rating of 480 volt S.S. breakers

$$\text{Primary } X = \frac{10,000}{1,094,800} = .00914$$

$$\text{Duty at 480 V panel} = \frac{10,000}{.00914 + 1.67} = 5950 \text{ KVA symmetrical}$$

$$\text{Symmetrical } I = \frac{5950}{\sqrt{3}\,(480)} = 7160 \text{ amps}$$

$$\text{Asymmetrical } I = 1.25(7160) = 8950 \text{ amps}$$

$$\text{Normal } I = \frac{300}{\sqrt{3}\,(480)} = 361 \text{ amps}$$

480V Motor contribution to fault = 5(361) = 1805 amps

480V breaker duty = 8950 + 1805 = 10,755 amps

∴ Use 15,000 amp I.C. breakers (asy.)

SUBJECT Fox Point Pumping Plant
COMPUTATION Motor Starting Voltage Drops
COMPUTED BY J. D. Campbell CHECKED BY DATE 1-5-60

* Motor Starting Limits

Assumed starting current = $5 I_{FL}$ at rated voltage

Minimum Allowable Starting Torque = 30% of T_{FL}
" " Pull-in Torque = 100% of T_{FL}
" " Pull-out Torque = 100% of T_{FL}
" " Voltage at starting = 80% of normal

* These data will be adjusted when more accurate data is available on the equipment.

SUBJECT Fox Point Pumping Plant
COMPUTATION Motor Starting Voltage Drops
COMPUTED BY J. D. Campbell CHECKED BY Yes DATE 1-4-69

Starting One Motor - Others idle

(All Z's are Per Unit on 10 MVA Base)

$E = 1.0$

System $Z = 0 + j\,.0065$

Cable $Z = .00198 + j\,.00296$

Trans. $Z = .0108 + j\,.0592$

see sheet C7

$= .013 + j\,.069$

$= .0704 \angle 78.4°$

Motor - Starting $I = 5 \times I_{FL}$ @ .20 P.F.

$= 5\left(\frac{3660}{10{,}000}\right) \angle -78.5° = 1.83 \angle -78.5°$

Starting $Z = \frac{1}{1.83} \angle 78.5° = .546 \angle 78.5° = .109 + j\,.535$

Total $Z = .013 + j\,.069 + .109 + j\,.535 = .122 + j\,.604$

$= .618 \angle 78.6°$

$I = \frac{1}{.618 \angle 78.6°} = 1.62 \angle -78.6°$

Motor Voltage $= IZ = 1.62 \angle -78.6° (.546 \angle 78.5°) = .885 \angle 0°$

Actual Voltage $= .885(4160) = 3680$ Volts

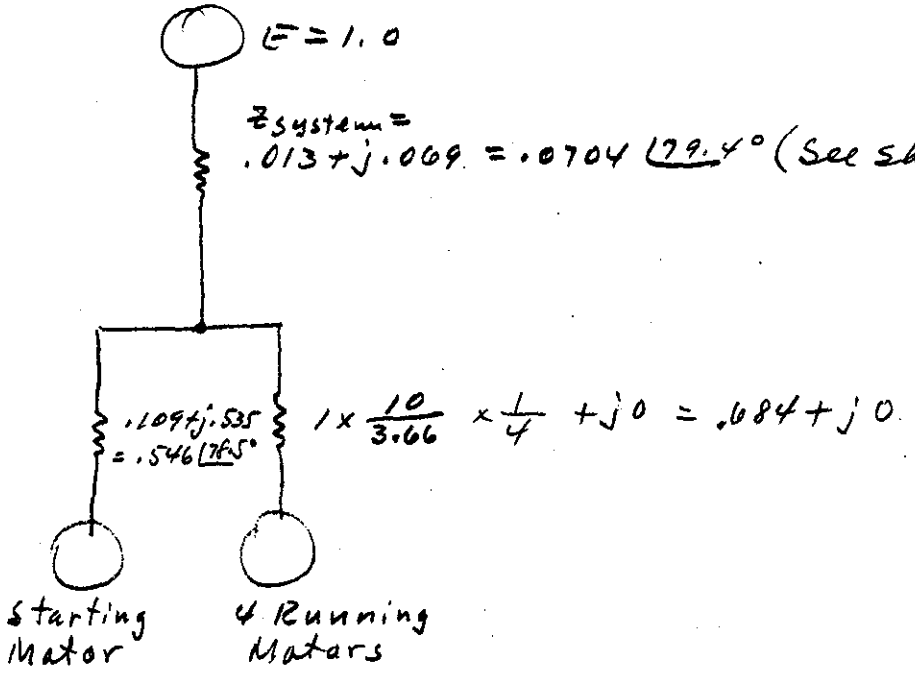
Voltage - % of motor rating $= \frac{3680}{4000} \times 100 = 92\%$

Starting Torque $= (40\%)(.92)^2 = 34\%$

Pull-in Torque $= (125\%)(.92)^2 = 103\%$

SUBJECT Fox Point Pumping Plant
COMPUTATION Motor Starting Voltage Drops
COMPUTED BY J. D. Campbell CHECKED BY JDS DATE 1-4-60

Starting 1 Motor - other 4 running - One transformer out



$$\text{Total load } Z = \frac{(.546\angle 78.5^\circ)(.684\angle 0^\circ)}{.793 + j.535} = \frac{.373\angle 78.5^\circ}{.956\angle 34^\circ}$$

$$= .39\angle 44.5^\circ = .278 + j.273$$

$$\text{Total } Z = .278 + j.273 + .013 + j.069 = .291 + j.342$$

$$= .45\angle 49.6^\circ$$

$$\text{Total } I = \frac{1\angle 0^\circ}{.45\angle 49.6^\circ} = 2.23\angle -49.6^\circ$$

$$\text{Voltage Drop} = I_{total} Z_{system} = (2.23\angle -49.6^\circ)(.0704\angle 79.4^\circ)$$

$$= .157\angle 29.8^\circ = .136 + j.078$$

$$\text{Bus Voltage} = 1 + j0 - .136 - j.078 = .864 - j.078$$

$$= .868\angle -5^\circ$$

$$\text{Actual Voltage} = .868(4.16) = 3.61\text{ kV}$$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT Fox Point Pumping Plant
COMPUTATION Motor Starting Voltage Drops
COMPUTED BY J. D. Campbell CHECKED BY Kss DATE 1-4-60

Voltage - % of motor rating = $\frac{3.61}{4} \times 100 = 90\%$

Starting torque = $40\% (.90)^2 = 32.6\%$

Pull-in Torque = $125\% (.90)^2 = 102\%$

Pull-out Torque - (running motors) = $150\% (.90)^2 = 122\%$

Voltage drops will be less than those calculated above and torques correspondingly higher because of the contribution of reactive current by the running motors. See G.E. Industrial Power Systems Data Book Section .211 Page 108.