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REPAIR, EVALUATION, MAINTENANCE, AND
REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-CS-28

CONCEPTS FOR INSTALLATION OF THE PRECAST
CONCRETE STAY-IN-PLACE FORMING SYSTEM
FOR LOCK WALL REHABILITATION IN
AN OPERATIONAL LOCK

by

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OTIC
APR 1 1990

December 1989
Final Report

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Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Under Contract No. DACW39-86-C-0014
Civil Works Research Work Unit 32273

Monitored by Structures Laboratory
US Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

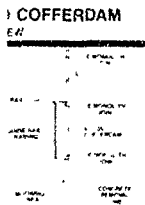
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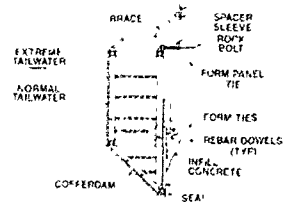
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	<u>Problem Area</u>		<u>Problem Area</u>
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GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

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COVER PHOTOS:

TOP — Precast panel installation, Lock 22, Miss. River

CENTER — Barge-mounted cofferdam concept

BOTTOM — Cofferdam details

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE		Approved for public release; distribution unlimited.			
4. PERFORMING ORGANIZATION REPORT NUMBER(S)		5. MONITORING ORGANIZATION REPORT NUMBER(S)			
		Technical Report REMR-CS-28			
6a. NAME OF PERFORMING ORGANIZATION BERGER/ABAM Engineers, Inc.		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION USAEWES Structures Laboratory		
6c. ADDRESS (City, State, and ZIP Code) 33301 Ninth Avenue South Federal Way, WA 98003-6395		7b. ADDRESS (City, State, and ZIP Code) 3909 Halls Ferry Road Vicksburg, MS 39180-6199			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION US Army Corps of Engineers		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract No. DACW39-86-C-0014		
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20314-1000		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO	PROJECT NO	TASK NO.	WORK UNIT ACCESSION NO. 32273
11. TITLE (Include Security Classification) Concepts for Installation of the Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation in an Operational Lock					
12. PERSONAL AUTHOR(S)					
13a. TYPE OF REPORT Final report		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) December 1989	15. PAGE COUNT 211
16. SUPPLEMENTARY NOTATION A report of the Concrete and Steel Structures problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	Concrete design, Stay-in-place forms, Lock wall rehabilitation, Underwater, Precast concrete		
<p>(Continue on reverse if necessary and identify by block number)</p> <p>Previous efforts in the design of a precast concrete panel stay-in-place forming system for repair of navigation lock walls resulted in a limited implementation of this repair procedure in an actual lock. This developmental work, performed by ABAM Engineers, Inc., under a contract with the US Army Engineer Waterways Experiment Station, is described in two reports, REMR-CS-7 and REMR-CS-14. To extend the application of this repair procedure, additional work was undertaken to develop concepts for installation of stay-in-place forms in an operational lock.</p> <p>In an operational lock, it is not possible to dewater or lower the tailwater level, and thus, some wall rehabilitation work must be performed underwater. In addition, it is necessary for the work to be coordinated around scheduled lock openings, and all ancillary lock equipment must be maintained in an operational condition.</p> <p style="text-align: right;">(Continued)</p>					
20. DISTRIBUTION AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS PT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)		22c. OFFICE SYMBOL

DD Form 1473, JUN 86

Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

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19. ABSTRACT (Continued).

During this study, operational and design criteria were developed to serve as the basis for design. A number of repair concepts were identified that satisfied the criteria. Schedule and cost estimates were prepared for the various concepts that served as the basis for selection of a preferred concept.

An installation procedure using a cofferdam was selected as the preferred repair method. A final design was completed for this concept. The design included the preparation of drawings and specifications for the repair of a generic lock to demonstrate the various aspects of the repair procedure. Cost and schedule assessments were part of this work.

The results of this developmental effort suggest that it is feasible to repair deteriorated navigation lock walls in an operational lock with only minor impact on costs. For the generic 600-ft-long by 110-ft-wide lock, repair costs are estimated at \$140 per sq ft and require 16 weeks for completion, assuming 5-day work weeks with 12-hour days.

Although the concepts described herein were developed specifically for installation of stay-in-place forms in an operational navigation lock, they are potentially applicable to other concrete walls requiring repair under water. Potential applications include tailrace wingwalls, floodwalls, and stilling basin walls.

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PREFACE

The study reported herein was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32273, "Rehabilitation of Navigation Locks," for which Mr. James E. McDonald is Principal Investigator. This work unit is part of the Concrete and Steel Structures Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program sponsored by HQUSACE. The Overview Committee at HQUSACE for the REMR Research Program consists of Mr. James E. Crews and Dr. Tony C. Liu. Technical Monitor for this study was Dr. Liu.

The study was performed by BERGER/ABAM Engineers, Inc., under Contract No. DACW39-86-C-0014 to the US Army Engineer Waterways Experiment Station (WES). The contract was monitored by a Technical Review Board consisting of Dr. Liu; Mr. Thurman Gaddie, Ohio River Division; Messrs. Don Logsdon and Denny Lundberg, US Army Engineer District, Rock Island; and Mr. McDonald, Chairman. Principal Investigators for BERGER/ABAM Engineers, Inc., were Messrs. Terry A. Nettles, and Elmer W. Ozolin.

The study was conducted at WES under the general supervision of Mr. Bryant Mather, Chief, Structures Laboratory (SL), and Mr. Kenneth L. Saucier, Chief, Concrete Technology Division (CTD), and under the direct supervision of Mr. James E. McDonald, Research Civil Engineer (CTD), the contracting officer's representative. Program Manager for REMR is Mr. William F. McCleese, CTD.

COL Larry B. Fulton, EN, was Commander and Director of WES during the publication of this report. Dr. Robert W. Whalin was Technical Director.



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CONTENTS

	<u>Page</u>
PREFACE	1
CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT	4
PART I: INTRODUCTION	5
Define and Quantify Project Objectives	6
Concept Development	6
Design of the Preferred Concept	6
PART II: PROJECT CRITERIA AND OBJECTIVES	7
PART III: CONCEPT DEVELOPMENT	8
Common Features	9
Tremie System External Support	11
Coffered System	15
External Pressure System	19
Steel Framework Scheme	21
Ribbed Panel Scheme	24
Additional Considerations	30
Concept Cost Estimates	31
Selection of Preferred System	37
Discussion	42
Recommendations	47
PART IV: FINAL DESIGN OF PREFERRED CONCEPT	48
Introduction	48
Cofferdam Features and Design	50
Navigation Protection Scheme	53
Schedule	54
Cost Estimate	55
Conclusions	59
REFERENCES	61

CONTENTS (continued)

	<u>Page</u>
APPENDIX A: RESULTS OF QUESTIONNAIRES	A1
APPENDIX B: PRELIMINARY CONCEPT DEVELOPMENT	B1
APPENDIX C: DRAWINGS	C1
APPENDIX D: CONSTRUCTION SPECIFICATIONS	D1
APPENDIX E: ALTERNATE COFFERDAM AND NAVIGATION PROJECTION CONCEPTS	E1
APPENDIX F: CALCULATIONS	F1

CONVERSION FACTORS,
NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inches	25.4	millimetres
feet	0.3048	metres
square feet	0.09290304	square metres
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
ounces (avoirdupois)	0.02834952	kilograms
pounds (mass)	0.4535924	kilograms
kips (force)	4.44822	kilonewtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per cubic yard	432.49842	kilograms per cubic metre
kips (force) per square inch	6.894757	megapascals
kips (force) per square foot	47.88026	kilopascals
inch-kips	112.9848	newton-metres
feet-kips	1.356	kilonewton-metres
foot-pounds (force)	1.356	newton-metres
square inches per square foot	6944.444	square millimetres per square metre

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use $K = (5/9)(F - 32) + 273.15$.

CONCEPTS FOR INSTALLATION OF THE PRECAST CONCRETE
STAY-IN-PLACE FORMING SYSTEM FOR LOCK WALL
REHABILITATION IN AN OPERATIONAL LOCK

PART I: INTRODUCTION

1. The Corps of Engineers has initiated a research effort to develop navigation lock wall repair concepts using precast concrete stay-in-place form panels. Background information describing why this work is being pursued is contained in Technical Reports REMR-CS-7 (Phase I) and REMR-CS-14 (ABAM Engineers Inc., 1987).

2. This developmental work has been carried out in phases. During Phase I (REMR-CS-7), a wide range of panel options were evaluated and an optimum system was selected for final design that included cost and schedule assessments. The second phase demonstrated the constructibility of the optimum system by completing a trial installation. The constructibility demonstration is described in REMR-CS-14.

3. Previous repair procedures required that locks be taken out of service for the duration of the repairs. The precast panel stay-in-place form repair concept potentially offers a means for maintaining the lock in an operating condition throughout the repair period. However, in a working lock, the lowest panel may have to be installed below the normal tailwater level. Maintaining the lock in an operating condition throughout the repair period would result in significant benefits to the shipping industry and thus, the third phase of this developmental program, to develop concepts for the installation of the lowest panel in a wet condition and in an operational lock, was initiated. This report presents the results of this investigation.

4. The approach to the Phase III work included the following discrete tasks, which involved Corps of Engineers' input and monitoring.

Define and Quantify Project Objectives

5. To develop a sound concept, typical operating conditions and physical lock features had to be described. A questionnaire was developed and distributed to Corps personnel to stimulate thought regarding operation and criteria issues. This information was compiled at a workshop and used to develop a consensus objective and final criteria.

Concept Development

6. A number of concepts that satisfied the objectives and criteria were developed during a brainstorming/value engineering effort. Participants included staff from the Corps of Engineers and ABAM Engineers Inc. (ABAM). The three most promising concepts were selected for a more thorough conceptual design and to develop cost estimates. Then one preferred concept was selected from the three for final design.

Design of the Preferred Concept

7. The design of the preferred concept was based on a generic lock, which has features similar to a number of the older locks needing repair. Drawings, specifications, and cost estimates have been prepared to define the optimum repair concept. These drawings and specifications must be adapted to a specific lock site when a real project is undertaken.

PART II: PROJECT CRITERIA AND OBJECTIVES

8. The goal for this phase of the research effort was to extend the development and design of the stay-in-place form concept for use in an operational lock. In an operating lock, it is not possible to install end bulkheads and draw down the pool level to complete repairs in a dry atmosphere. The key technical issues are how to install the lowest panel that will be partially or totally submerged, and what special provisions must be made for detailing or protecting partially completed work when the lock is open to traffic at the end of the work shift. The current development work was undertaken with the goal of using details developed during the previous two phases of this project to the maximum extent possible.

9. The initial task included defining typical conditions at a lock rehabilitation site that might be imposed on contractors performing the repairs or shippers using the lock. To facilitate this task, a questionnaire, identifying operational and criteria issues, was prepared and distributed to the Corps. Appendix A contains a copy of the questionnaire along with a summary of the responses. The information generated by the questionnaire was discussed at a meeting with key Corps design, construction, and operations staff. Following the meeting, design, operational, and construction criteria were defined for the development of the wet condition/operating lock installation.

10. Although the primary intent of the criteria was to guide concept development and to focus the final design, it is also useful information for contractors doing the repair work. A significant portion of the repair concept relates to actual construction methods and techniques. Contractors are typically responsible for developing these, but they are addressed here to assess feasibility. Because it is expected that contractors will suggest modifications to the preferred concept described later in this report, the criteria have been incorporated as part of the specifications (Appendix D: Section 1D - Reference Standards and Criteria). The reader is encouraged to review the criteria before continuing with the next section of this report.

PART III: CONCEPT DEVELOPMENT

11. A number of alternative repair concepts were developed that satisfied the project criteria and objectives. A repair concept is built up of basic features or components, which can be interchanged to develop new or alternate repair concepts or to optimize existing ones. The basic features or components include

- a. Work Sequence Alternates
- b. Panel Attachment Schemes
- c. Bottom Closure Schemes
- d. Panel Support Methods
- e. Infill Concrete Type and Placement Procedure
- f. Monolith Protection Schemes

12. To initiate concept development, a work session was held. The basic features were individually addressed and possible variations identified. The preferred components were then combined to develop potential repair concepts. Rough sketches from the work session are contained in Appendix B and include the following concepts.

- a. Several internal sacrificial support beam systems.
- b. Various cable-supported panel systems using erection trusses clamped to the monolith or braced from the lock floor.
- c. Two external pressure systems using hydrostatic head to balance the infill concrete pressures; one using a steel framework and typical panels and the other a special ribbed panel.
- d. Two variations of a sleeved rod system to support the panel and provide a tie to the monolith wall.
- e. A stiffleg support frame concept.
- f. Concepts using inclined dowel bars in conjunction with keeper plates for anchoring rebar in order to interlock the panel to the lock wall without use of direct connections.
- g. A panel system suspended from and braced by a work barge.
- h. A concept featuring a specially cast lower support ledge.

13. A number of features and potential repair concepts presented at the work session merited further study. The following three broadly defined repair concepts were selected for more detailed conceptual engineering development. The presentation of these concepts was structured to demonstrate the variations in available features. The concepts were not optimized during this task.

14. Tremie System features a method of installing the lowest panel from the surface in conjunction with underwater placement of infill concrete.

15. Coffered System allows repairs below the low pool level in a dry environment.

16. External Pressure System wherein the panels are not directly fastened to the lock wall monolith and the infill concrete pressures are resisted by the hydrostatic pressure due to the water in the lock chamber. This system was selected for further study because it is a departure from the previous developmental work and there may be some benefits to be realized.

17. Detailed descriptions and sketches of each of the above conceptual repair concepts are presented in the following sections of this report.

Common Features

18. Demolition procedures for deteriorated lock walls would be the same for all three repair concepts. All the concepts assume that demolition of an entire lock face is complete prior to panel installation. It is possible that a more favorable demolition sequence with respect to panel erection and infill placement would be to remove concrete on alternating monolith walls, leaving two vertical faces intact for end forms or sealing cofferdams.

19. Current demolition practice is to place a full-depth sawcut around the perimeter of the deteriorated concrete. In the wet condition, this work will have to be performed underwater using divers unless a longer term lock closure (one to two weeks) can be incorporated into the repair scheme to dewater the lock and facilitate the demolition work.

20. Work platforms must extend below the water level to support the divers and guide tracks will have to be installed for saws or other equipment. The guide tracks should minimize and simplify the work performed by divers. As a minimum, divers will be required to drill and set expansion anchors to secure the tracks. Ideally, the tracks should be designed to allow alignment and primary attachment above the normal low pool level.

21. With the current practice of delineating the demolition surfaces with full-depth sawcuts, overbreakage still occurs resulting in feather-edged conditions. Because repairs to date have been performed under dry conditions, it has been possible to take special measures to eliminate the feather-edging. The Wet Condition Repair Concepts were developed considering that feather-edged conditions will be repaired prior to placement of infill concrete. In all but the Coffered System, this work, if required, will be performed with diver assistance and thus, there will be cost impacts.

22. Clean-up efforts must be concurrent with the demolition work. The use of catch barges will minimize debris spillage into the lock chamber. If clean-up work isn't completed in the same work shift as the demolition, the bottom of the lock should be swept to verify draft clearances prior to opening the lock for traffic. Following the major demolition work, hand demolition work, as required, should be completed. Repair concepts with panels tied directly to the wall will not require extensive hand demolition follow-up as required for those concepts using indirect panel attachment methods.

23. Timing of infill concrete placement is critical with respect to reopening the lock to traffic. Schedules developed for all three concepts revealed that infill concrete placement will occur late in the work shift, leaving little time for curing prior to lock reopening. The panels are vulnerable without the infill concrete to provide support and thus, more extensive navigation protection devices may be required. Also, some of the concepts require erection frames or trusses to support the panels until the infill concrete has sufficiently cured. These devices may have to remain in place when the lock is reopened to traffic and would require protective measures. In addition, the infill concrete must remain undisturbed for an initial period sufficient to avoid shock, vibration, or internal disruption. New cements are available that have very rapid set times and strength gains.

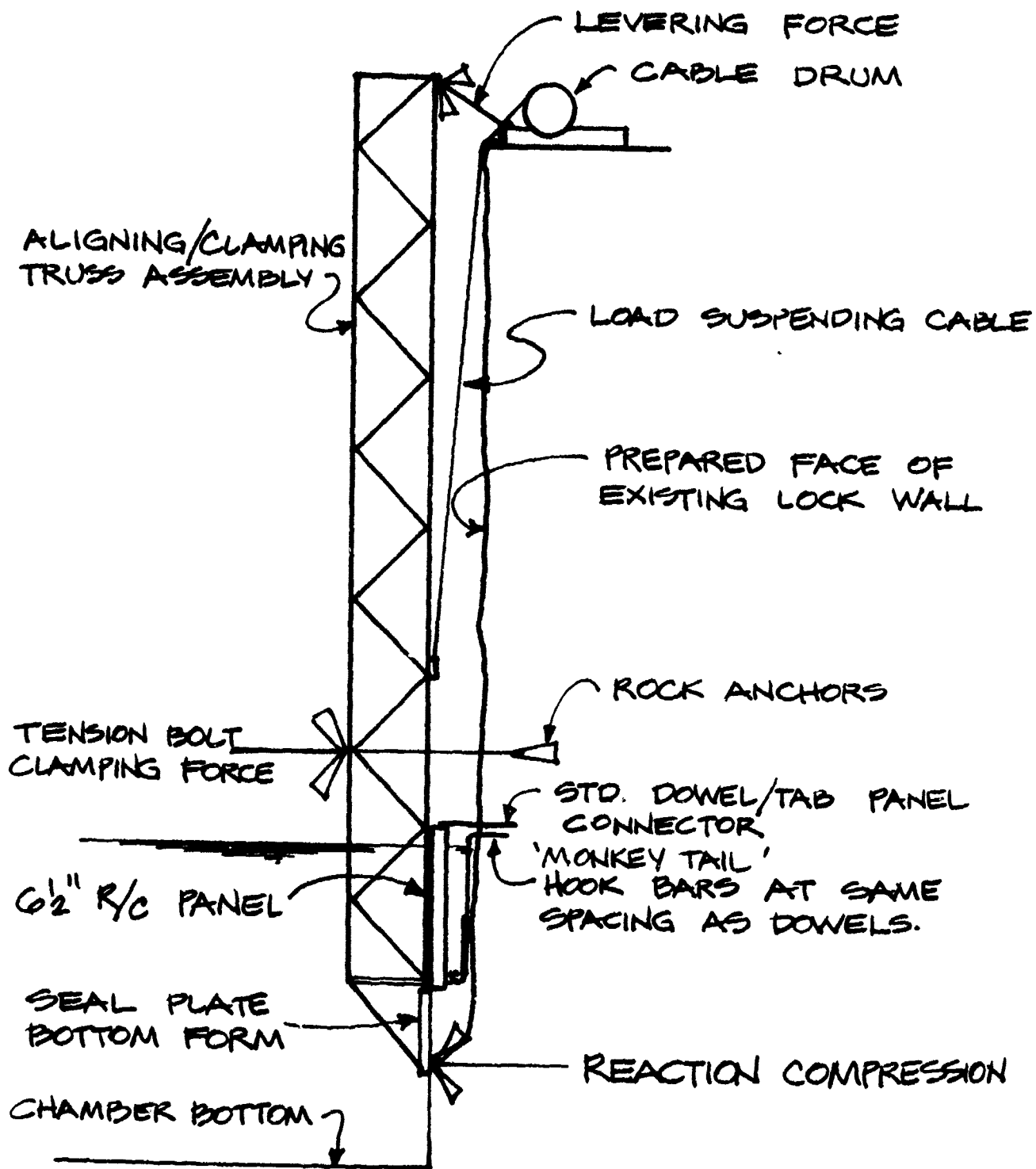
Their use would allow timely removal of erection frames/trusses and reduce the complexity of navigation protection devices. It may also be possible to use an infill material consisting of a preplaced aggregate injected with grout. However, this material has not been specifically investigated as part of this work.

Tremie System External Support

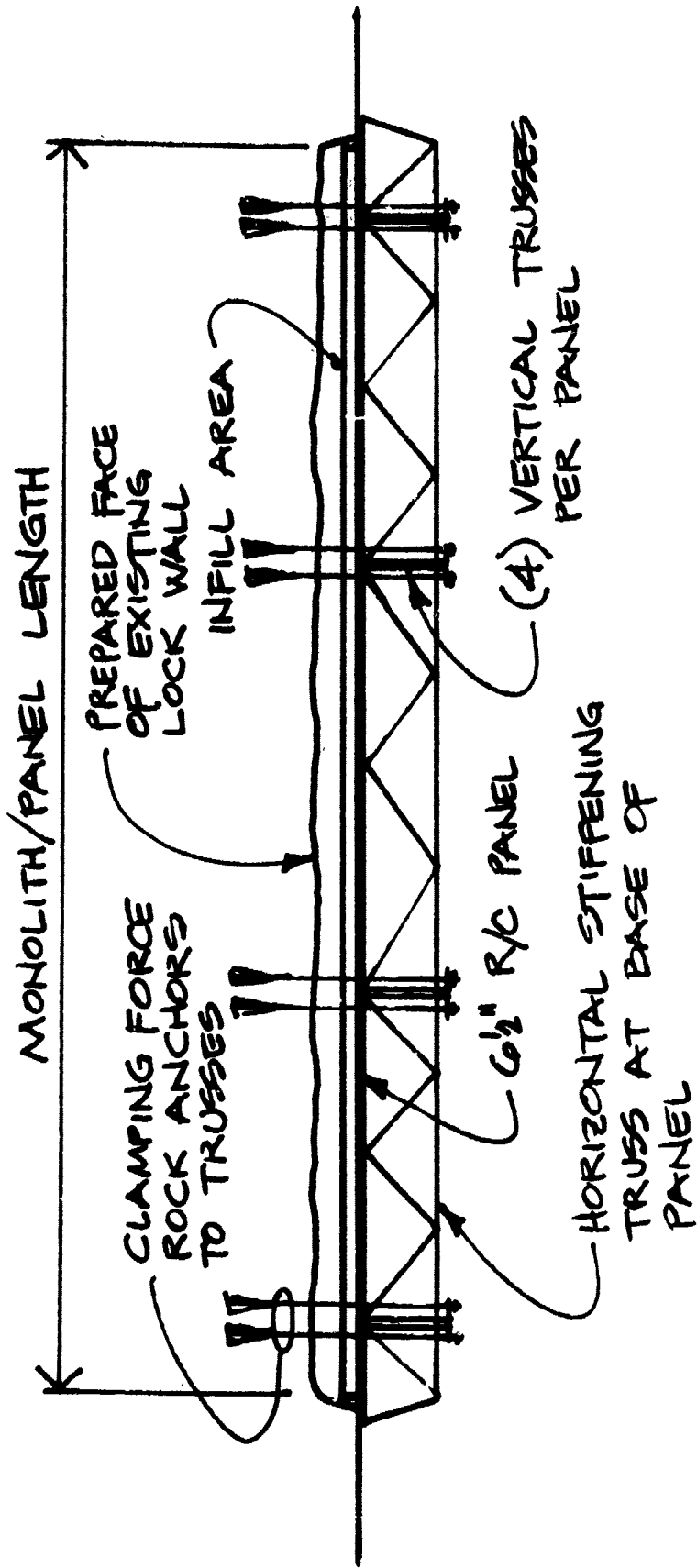
24. Two primary features underlying this concept were preserved during refinement and review of the scheme. One is the potential for assembly without underwater work; the second is the nearly unchanged details of the precast panels developed during Phase I work.

25. A prefabricated reusable aligning/clamping truss assembly is the principal piece of tooling required for erecting panels using this concept. This frame would be a series of lightweight trusses as illustrated in Figures 1 and 2. The precast reinforced concrete panel would attach to the frame with a self-releasing bottom edge detail and an unbolting top edge clamp detail. A continuous steel faced seal plate panel would be below the bottom edge of the precast panel. This seal plate is permanently attached to the frame and precisely aligned in the plane of the outer face of the precast panel to form the finish face of the infill tremie-cast concrete placement. The seal will have compressible closed cell gasket material around its edges to assure a leak proof fit with the existing monolith concrete.

26. The construction procedure will be to demolish the face material of the wall section being restored using contractor selected methods. The feasibility of this system requires at least a 15-in. depth of removal with 18 in. more desirable. Efforts should be made to make the removal as straight edged as possible around the perimeter of the demolition area. The face of the demolished lock wall section will then be drilled horizontally for the installation of eight rock anchors and a series of panel tie dowels and monkey-tail hook bars. This work is envisaged to be performed above the nominal tailwater pool elevation.



ELEVATION: TREMIE SYSTEM
 FIGURE 1



PLAN VIEW

ALIGNING/CLAMPING TRUSS ASSEMBLY

FIGURE 2

27. The bottom panel will be identical to the Phase I type panels, except no bottom edge leveling bolt hardware is necessary, and there will be a row of special bent bars protruding from the back face lower edge. These bent bars lap with the monkey-tail hook bars from the wall and fit into the infill area space when erected. The contractor will lift the panel onto the erection frame and clamp it securely along the top edge. A series of clamps to keep the bottom edge of the panel on the self-releasing bottom ledge of the frame will also be attached. These can be removed from above the water once the panel has been lifted into its final position and secured with dowel/tab panel connectors on the top edge.

28. The contractor will anchor four skid mounted winches on the top side of the lock wall, attach cables to hitches on the trusses, and lower the assembly down the face of the wall with a crane. The crane can be either barge mounted or on the lock wall. The panel will be fitted and aligned to its precise position and the winch cables drawn taut to hold the load. The clamping force anchor bolts will be installed and attached to their saddles on the trusses. The levering force will then be applied to the tops of the frames in order to effect the closure of the seal plate at the base of the panel.

29. Once the panel is fully clamped, a horizontal bar is lowered into the hook of the monkey-tail bar and the dowel/tab panel connectors are installed and attached to the panel. When this is completed, the temporary lower-edge clamps are removed and the space behind the wall is filled with tremie concrete up to the top edge of the panel.

30. When the infill has reached an initial set, the frame assembly can be removed and advanced to the next location. This is done by reversing the direction of the levering force at the top of the truss and springing the self-releasing seal plate free of the bottom. The clamping rock anchors are then removed and the truss assembly lifted out. Details for protection of the incomplete monolith and/or the truss assembly against possible contact with lock traffic will have to be addressed.

31. After the truss assembly is removed, the remaining panels required above the lower panel can be erected with the same details used in the Phase II demonstration. Concrete infill in the upper portion of each monolith can then be performed without need for tremie placement.

Coffered System

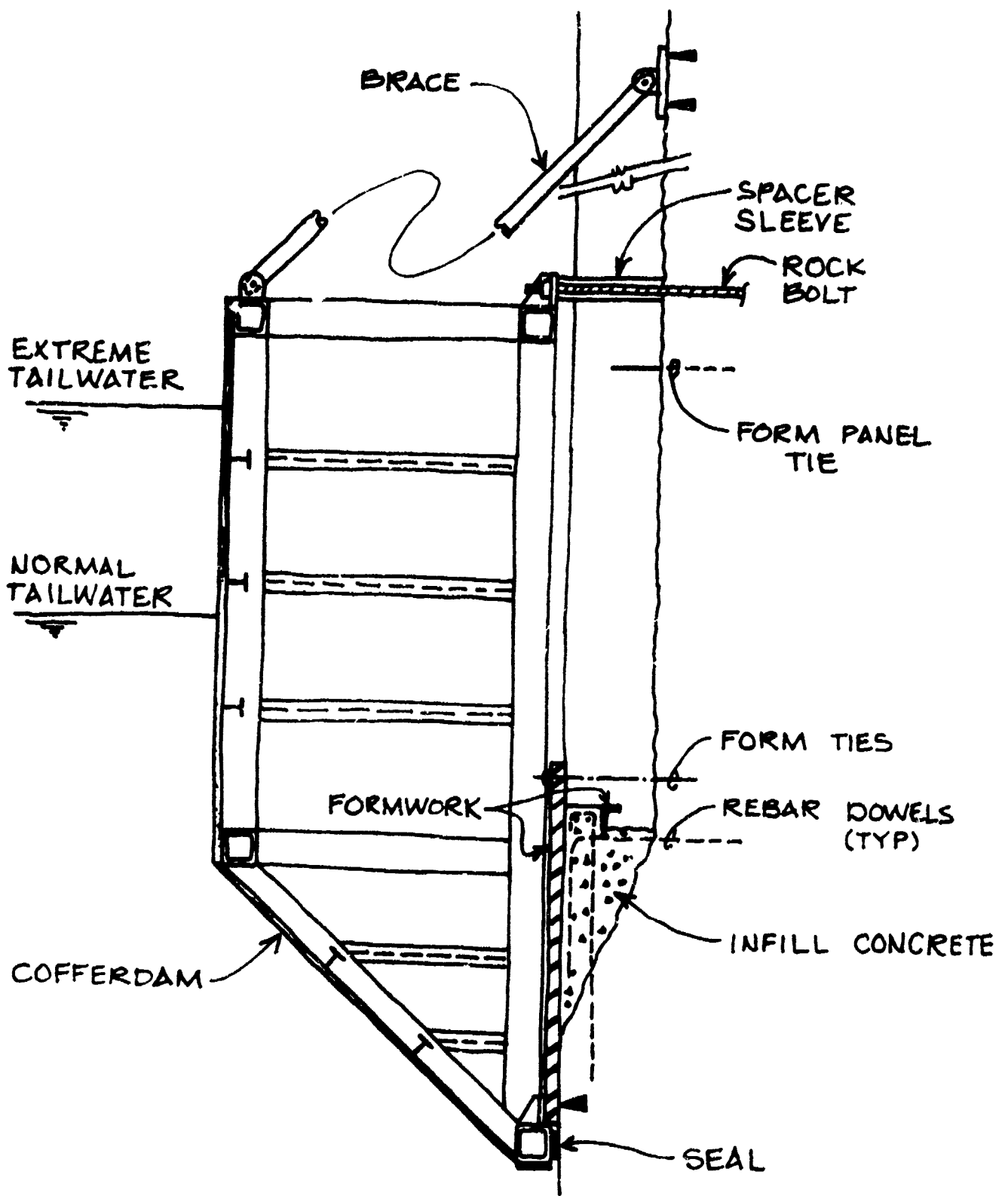
32. This system features the use of a cofferdam to dewater the lock surface below the normal tailwater level that allows all work to be performed under dry conditions using previously developed repair concepts. An additional positive feature of this system is that it allows complete inspection of the in situ lock face and repair work, resulting in a high quality repair.

33. The viability of this concept is highly dependent on the portability of the cofferdam. A cofferdam design, which allows for daily installation and removal, offers the greatest flexibility. A cofferdam could be left in place while the lock is reopened to traffic, but it would have to be narrower to conform to the space restrictions identified in the criteria and have more significant navigation protection installed.

34. The cofferdam may be stored on and installed from a work barge or from the top of the lock if sufficient space and access are available. An advantage of the barge is that it also provides a work platform adjacent to the repair area, making supplies and equipment readily accessible. For a work plan that requires a daily cofferdam installation and removal, one possible arrangement would be to mount the cofferdam on an adjustable framework on the barge. With this system, the barge would be floated in each day, positioned, and stabilized by ballasting onto spuds. The framework would be adjusted to the required position and snugged against the wall.

35. The more conventional installation is to attach the cofferdam directly to the lock wall using hanger braces, rock bolts, and expansion anchors. This concept is shown in Figure 3. To reduce the installation time, some preparatory work can be completed on the day before the cofferdam installation, such as drilling rock anchor holes and installing brackets for the braces.

36. To reduce cofferdam setup time, work should be planned so one vertical face is always available as a contact surface and reference plane for establishing the geometry of the rehabilitated surface. Further, the



ELEVATION: COFFERED SYSTEM
 FIGURE 3

cofferdam should have sufficient depth to extend below the lowest anticipated overbreakage plane.

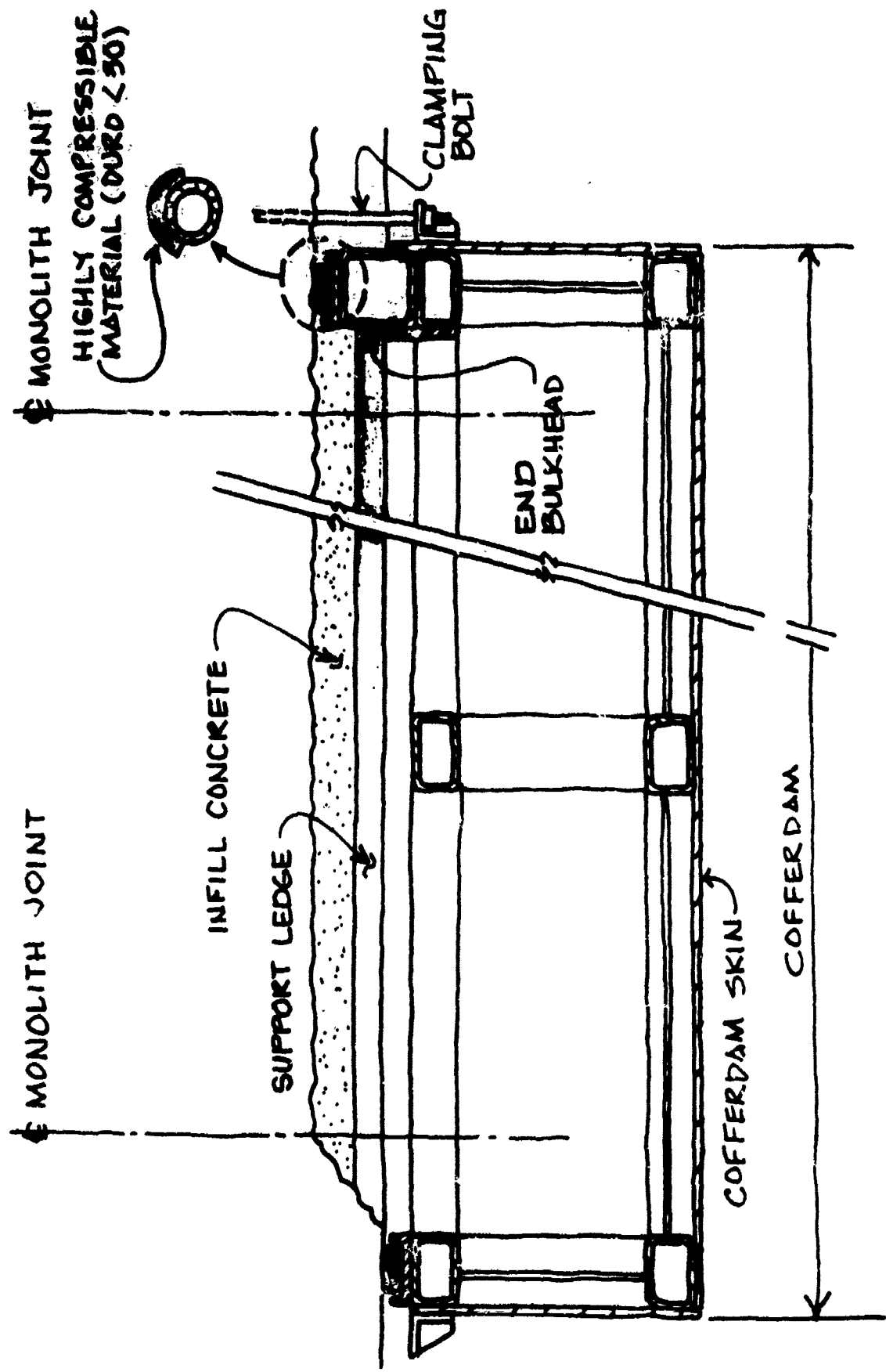
37. A detail of the cofferdam that should be considered is that one, or possibly both, vertical edges of the cofferdam will have to bear against the in situ face after demolition. A special demolition tool, such as a milling head, rotary grinder, or water jet, may be required to produce a reasonably smooth contact face to allow sealing the cofferdam. A guide track for this equipment can be incorporated into the cofferdam design as shown in Figure 4. An end bulkhead can be developed that sits in the same track that serves to seal the end of the bulkhead.

38. An initial clamping force will be required to provide enough contact pressure between the cofferdam seals and lock surface to reduce water flow into the cofferdam during initial stages of dewatering. This can be accomplished using expansion anchors or rock bolts; or for the barge mounted option, screw jacks, which react against the work barge, could be used.

39. After the cofferdam is dewatered, the lower edge can be inspected for overbreakage and feather-edged conditions. Areas of feather-edging can be prepared by conventional hand methods or using the same track mounted demolition tool used to prep the vertical contact surface. All other hand clean-up work necessary in the space behind the panels should be completed to above the low pool elevation while the cofferdam is still in place.

40. Drilling and grouting of rebar dowels and ties would follow the hand demolition and surface preparation. Drilling guides can be incorporated into the cofferdam design that would reduce drilling time and increase the accuracy of hole locations. Reusable steel forms for the lower closure pour can be developed, which are also attached to and referenced off of the cofferdam so the required tolerances are achieved.

41. Two schemes for refacing the lock were considered. One scheme is identical to the procedure developed during Phases I and II for dry installation. The lowest panel would be installed within the cofferdam, all tie connections completed, and the infill concrete placed, including the lower closure pour. It would be preferable to complete this work in one working day to avoid reinstalling the cofferdam a second time on the same



PLAN: COFFERED SYSTEM
 FIGURE 4

monolith. For this to be possible, the tie installation, curing period, and welding period would have to be significantly reduced. One potential means of reducing this time would be to use mechanical ties or rock anchors.

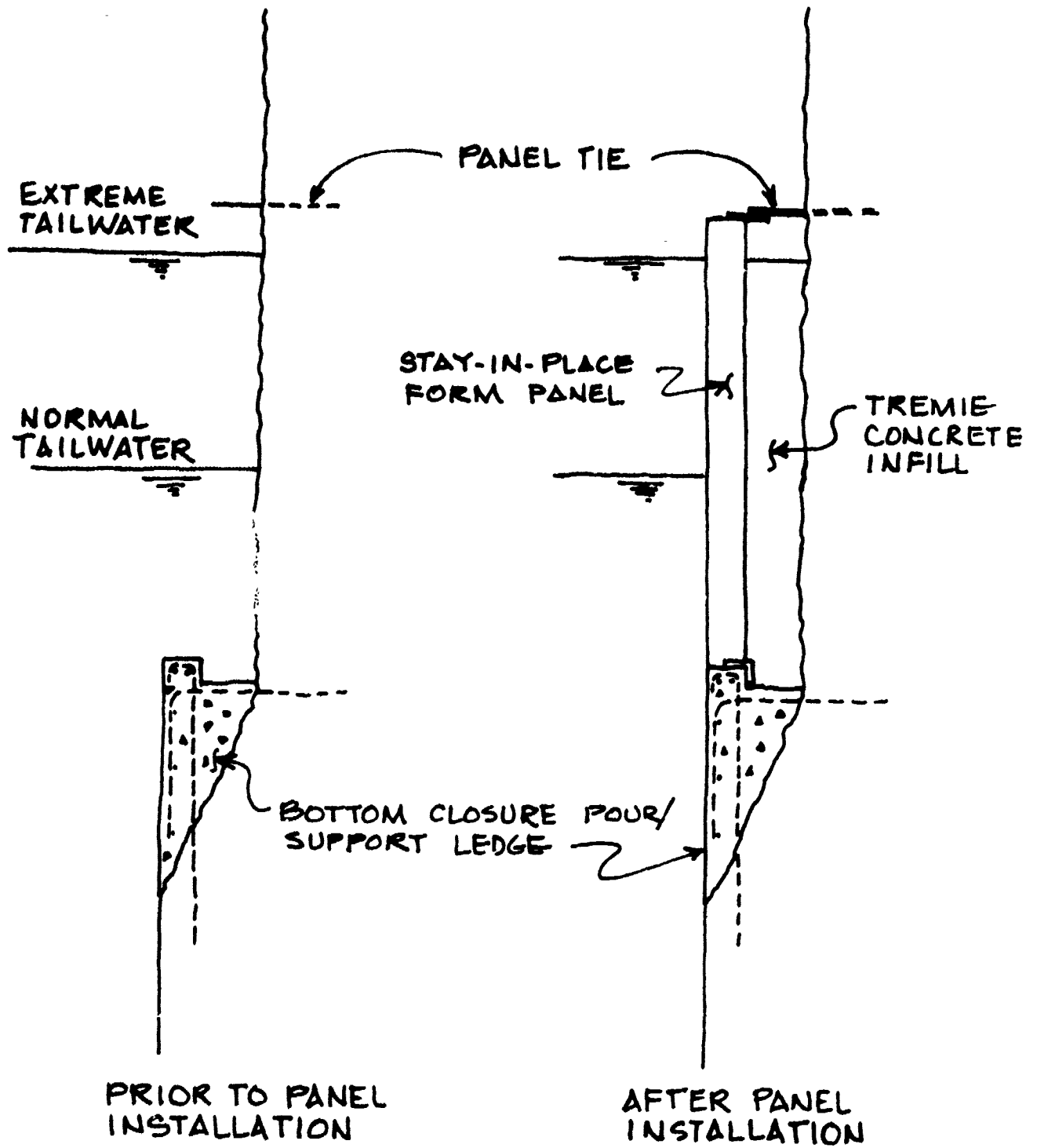
42. A second scheme involves completing only the lower closure pour in one work day. This is shown in Figures 3 and 5. The detail of the lower closure pour includes a formed ledge to simulate the top of a typical precast panel. This enables the installation of the lowest panel without reinstalling the cofferdam. In this case, the lowest panel would be identical to all other panels with a continuous alignment/bearing angle along the bottom edge. The infill concrete could be placed underwater in a tremied condition; or, if this is not desirable, the cofferdam could be reinstalled, dewatered, and the infill concrete placed under dry conditions.

43. The lower ledge must support the infill concrete pressure from the bottom panel so it must have sufficient strength when the infill concrete is place. If required, the work can be scheduled to allow additional time for the concrete to cure and gain strength. If the work is to be done on consecutive days, a special concrete mix will be required that has rapid set times and strength gain. Although the cofferdam will be removed at the conclusion of the work day, the lower closure forms may have to remain until the next work day to provide additional protection for the newly placed concrete. Temporary protection devices will have to be provided until wall panels are installed above the closure pour. Divers will have to assist with removing the formwork.

44. After installation of the lowest panel and infill concrete, the remaining panel installation will be in the dry and can continue using procedures previously developed and demonstrated during Phases I and II.

External Pressure System

45. Previous work on the stay-in-place form concept for lock wall rehabilitation incorporated welded rebar ties to resist infill concrete placement pressures and to tie panels to the lock wall. The External Pressure System relies on external hydrostatic pressure to counteract infill concrete pressures rather than using direct connections to the lock wall.



ELEVATION: COFFERED SYSTEM
 FIGURE 5

Overlapping dowels or dowels in conjunction with shear keys are provided to interlock the panel with the monolith in its finished state. The required hydrostatic pressures are developed by dewatering the area behind the panel and raising the lock pool level above the infill concrete lift height. Hydrostatic pressures will be higher than infill concrete pressures and will govern the panel or coffering system design.

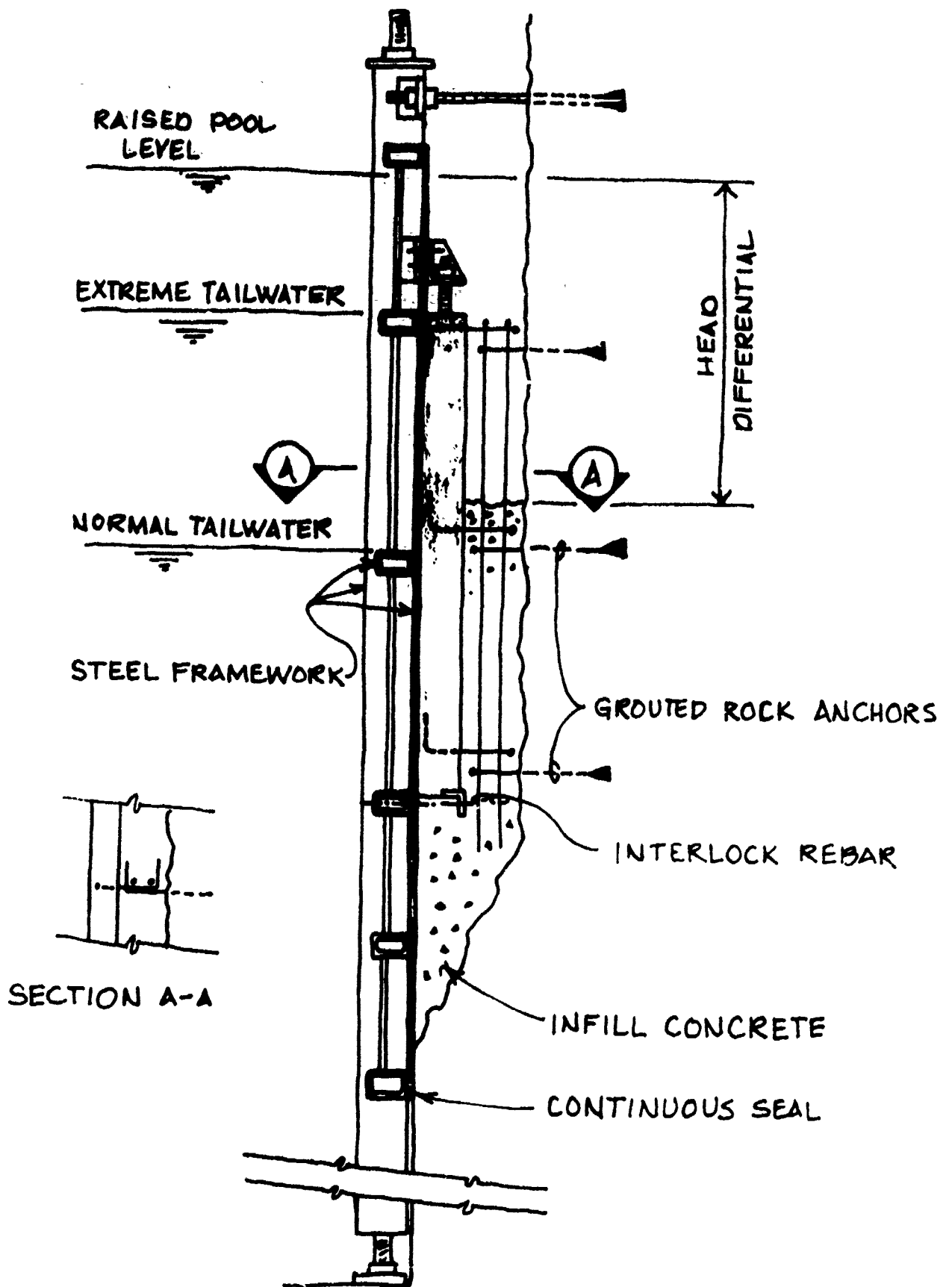
46. Two different external pressure schemes have been identified. One scheme uses a steel framework/grillage to enable sealing the void space behind the panel and dewatering the void. The second scheme uses the stay-in-place concrete form panel arranged so it performs the coffering function. Although the use of forms as cofferdams is not currently allowed by the Corps, this concept was considered nonetheless.

Steel Framework Scheme

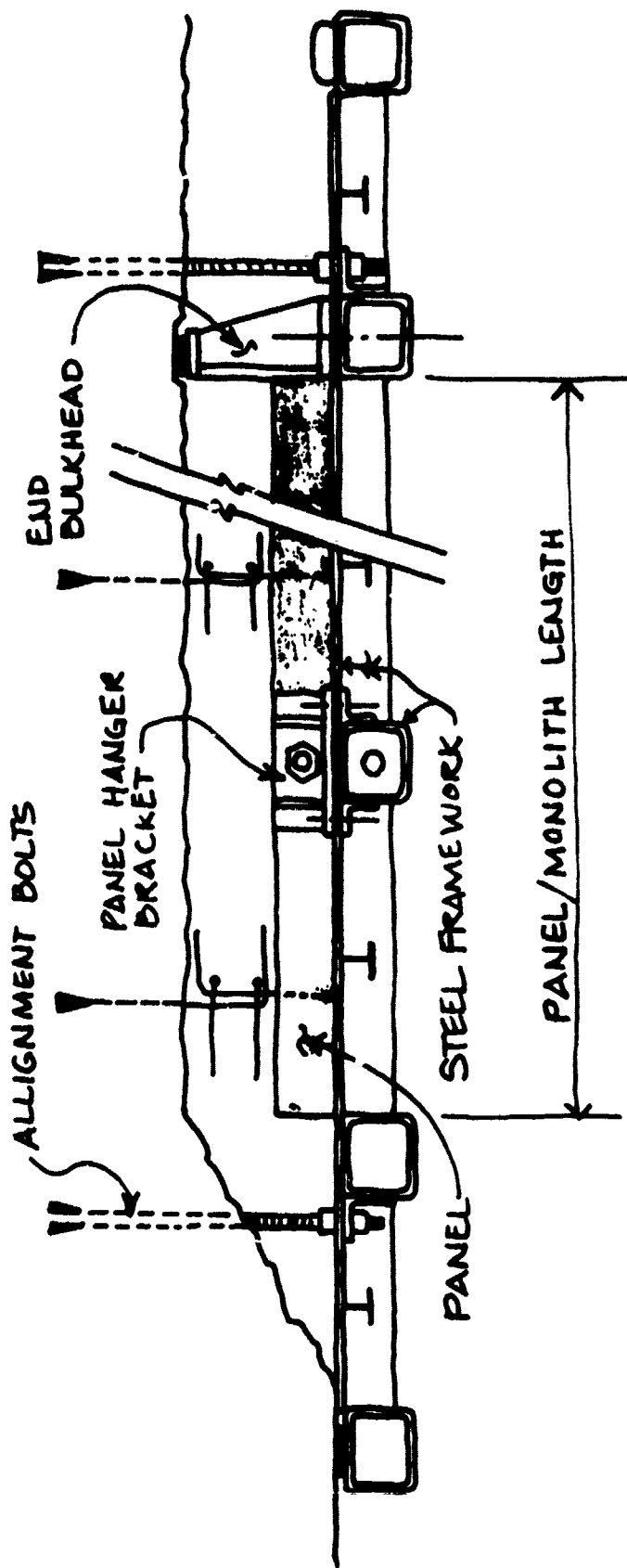
47. This concept features a steel framework/grillage to seal the area behind the panel and support the panel as shown in Figures 6 and 7. The precast panel is placed against the skin of a steel framework, aligned to the required position, and the area behind the panel dewatered. The hydrostatic pressure locks the panel and framework into position. Prior to placing infill concrete, the normal low pool level is raised a predetermined height above the infill concrete lift height to ensure that a net resisting force is present to hold the panel in position during infill placement.

48. The infill pressure is transferred directly to the steel framework and is opposed by external hydrostatic pressure. The steel framework must be designed to carry the full hydrostatic pressure in the dewatered condition, including the additional head when the normal pool level is raised. The main differences between the Steel Framework and Coffered System is that the Coffered System does not resist the infill pressure and is only designed for hydrostatic pressures of the normal pool level.

49. The steel framework uniformly supports the concrete panel, greatly reducing the resulting internal panel forces. The Phase I panel design was based on a simple-span condition with the supports being the upper and lower



ELEVATION: EXTERNAL PRESSURE SYSTEM
 STEEL FRAMEWORK SCHEME
 FIGURE 6



PLAN: EXTERNAL PRESSURE SYSTEM
STEEL FRAMEWORK SCHEME
FIGURE 7

ties. In this condition, the panel resists the entire infill concrete placement pressure and is designed for significant internal forces. The Steel Framework Scheme allows use of thinner panels with less reinforcement. However, handling considerations and projecting dowel embedment would limit reductions that could be realized. Another benefit of this scheme is a reduction in the number of reinforcing dowels that must be drilled, installed, and welded, thus reducing construction time and costs and eliminating welded tie connections.

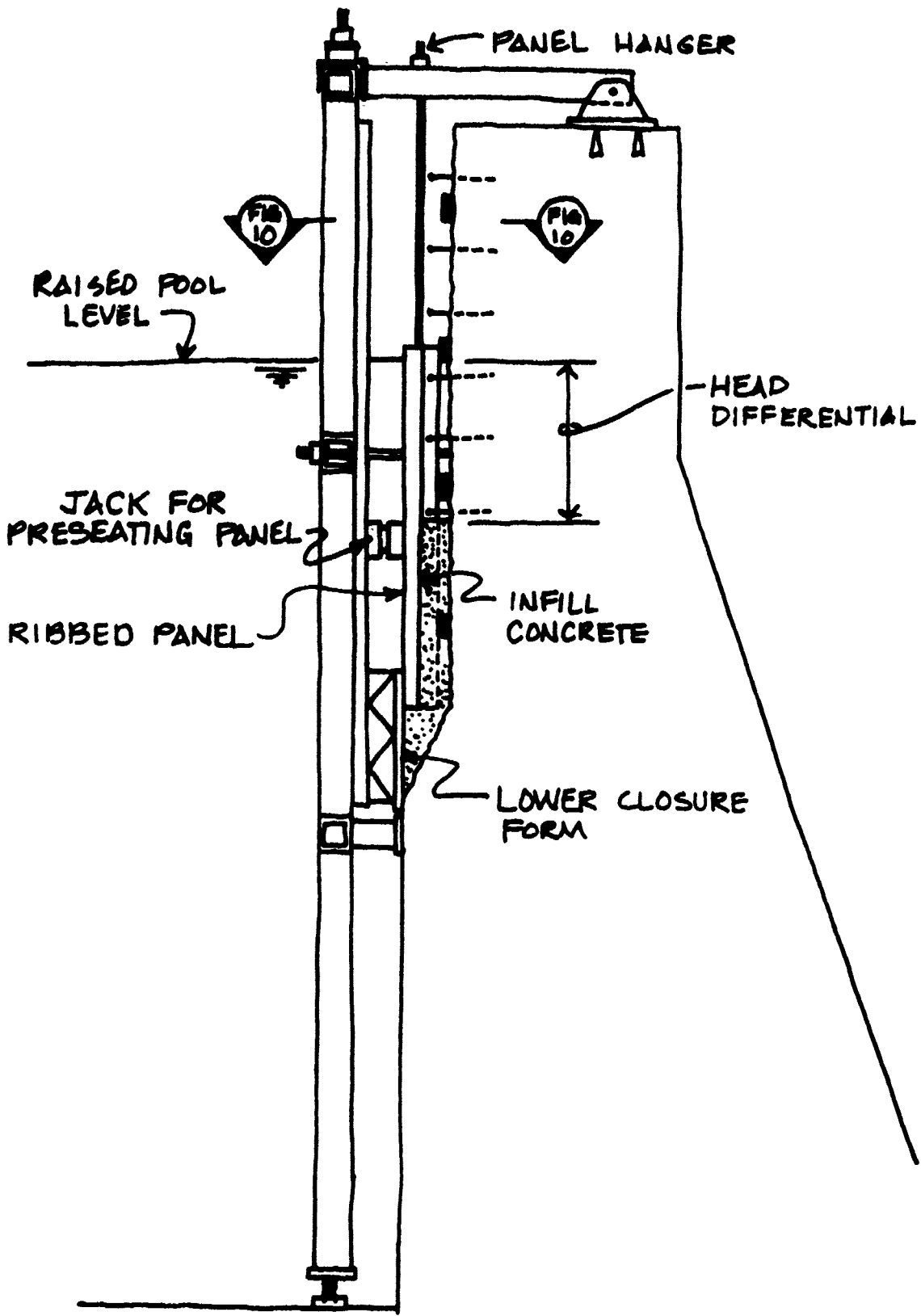
50. Installation of the steel framework is similar to the cofferdam. Watertight seals must be provided around the three perimeter edges of the framework. If surface preparation of seal contact points is required, a guide track can be designed and incorporated into the steel framework for the demolition device. This same track can be used for installing a watertight bulkhead that also serves as the end form for the infill concrete.

51. The steel framework must be supported off the lock floor or suspended from the top of the monolith. Figure 6 shows the framework supported from the lock floor. Screw jacks are provided inside of the support columns for vertical adjustment of the framework.

52. The form panels can be installed attached to the steel framework or after the formwork has been placed. The more positive interlock details would feature overlapping hooked dowel bars anchored by straight vertical bars as shown in Section A-A, Figure 6. However, overlapping dowels require that panels be swung into position horizontally during erection rather than lowered vertically, which complicates the erection procedure.

Ribbed Panel Scheme

53. The Ribbed Panel Scheme is shown in Figure 8. In this scheme, the panel itself seals the area behind the panel and thus, must be designed to resist full hydrostatic pressure when the void is dewatered and the lock chamber flooded. The ribs extend vertically, resulting in a horizontal span for the flat-slab section of the panel. When dewatered, hydrostatic pressures are transferred from the slab to the ribs and into the lock wall at discrete grout pad locations. Grout pads for the outer ribs are



ELEV: RIBBED PANEL INSTALLATION
 FIGURE 8

continuous to allow sealing the vertical panel edge. A steel closure form is used at the bottom of the panel to completely seal the void and to serve as formwork for the lower closure pour. The ribs also stiffen the panel for handling, shipping, and erection that allows potentially larger panels when compared to flat-slab panels.

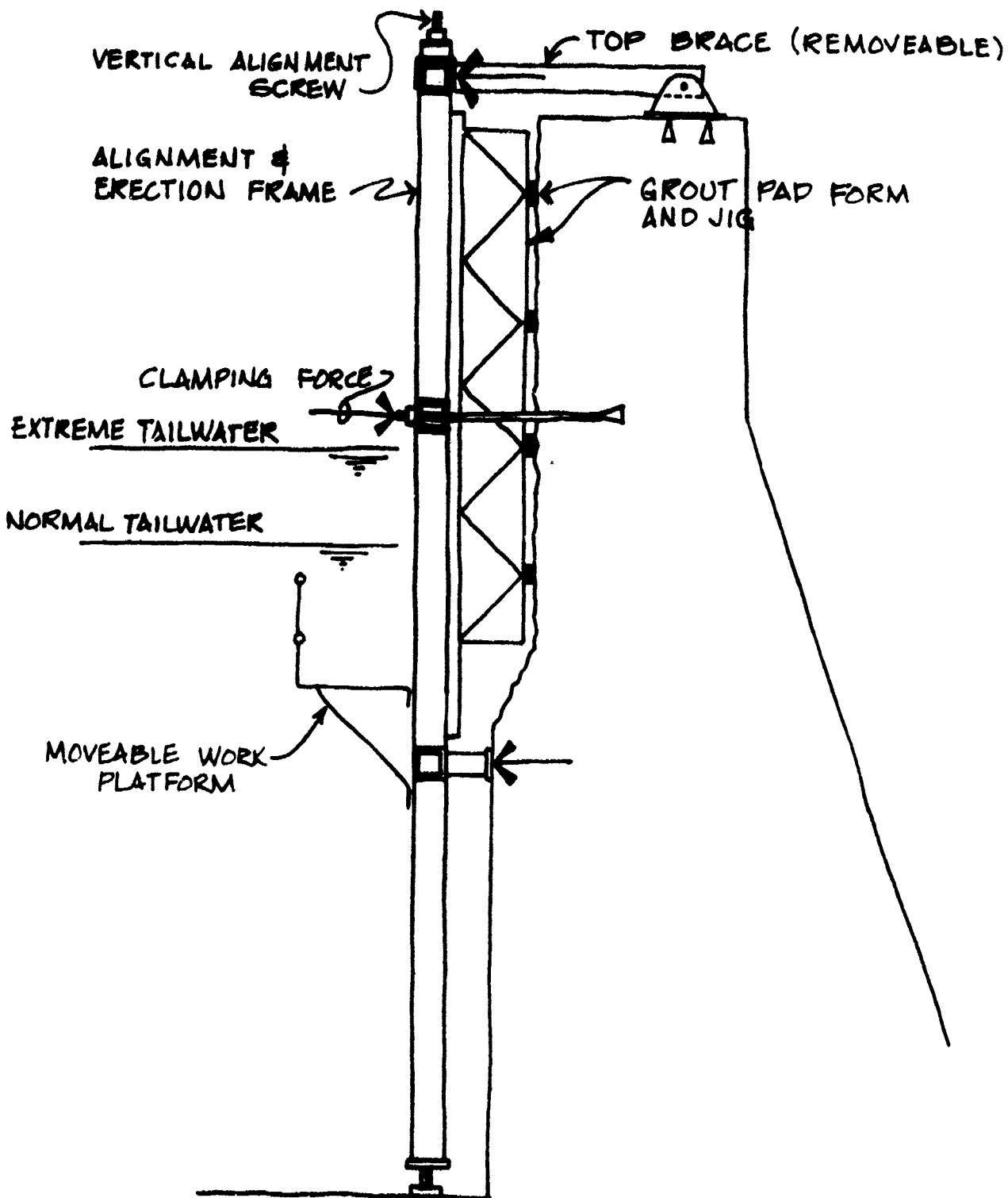
54. A principal advantage of the Ribbed Panel Scheme is the potential for using larger panels, thus eliminating panel joints and reducing erection time. Also, fewer ties and dowels are needed, reducing the dowel drilling and installation time compared to a typical flat panel system with welded form ties.

55. Because ribbed panels bear against the lock wall at grout pad locations, the first step in the installation procedure is to accurately locate and construct grout pads. A special erection and alignment frame can be developed for this purpose that also supports the panels until the infill concrete has cured. Figure 9 shows the erection frame with a jig containing grout pad forms. Some surface preparation may be required at the grout pad locations so a track can be incorporated into the erection frame to accommodate a demolition tool. A drilling template can also be incorporated as part of the erection frame for greater accuracy in locating dowels.

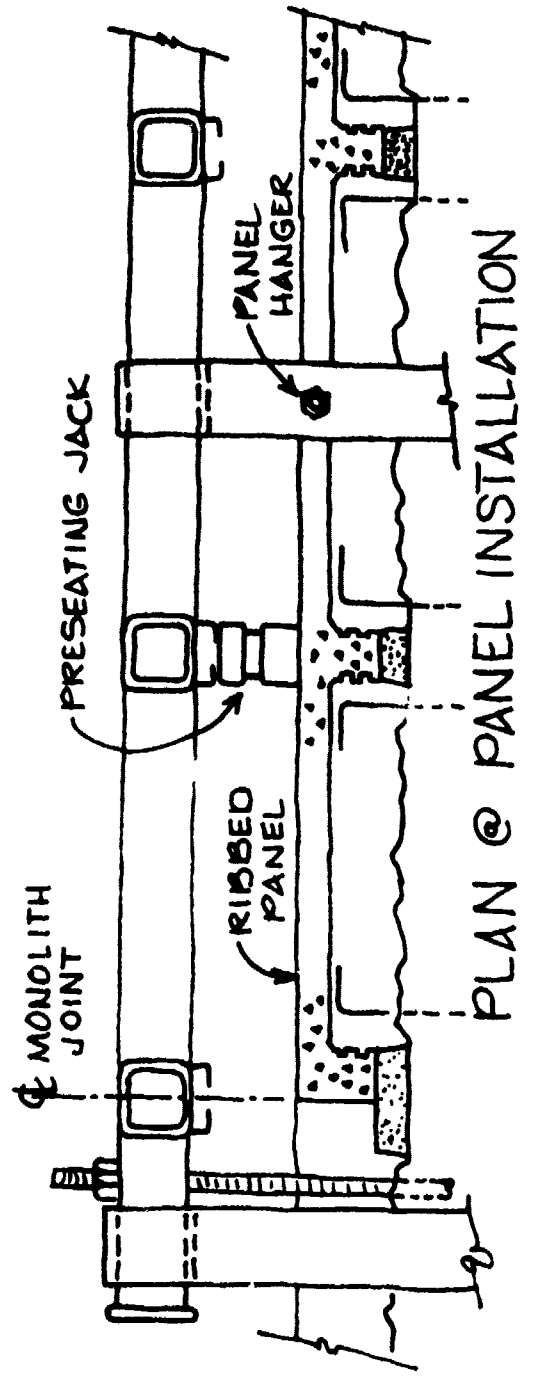
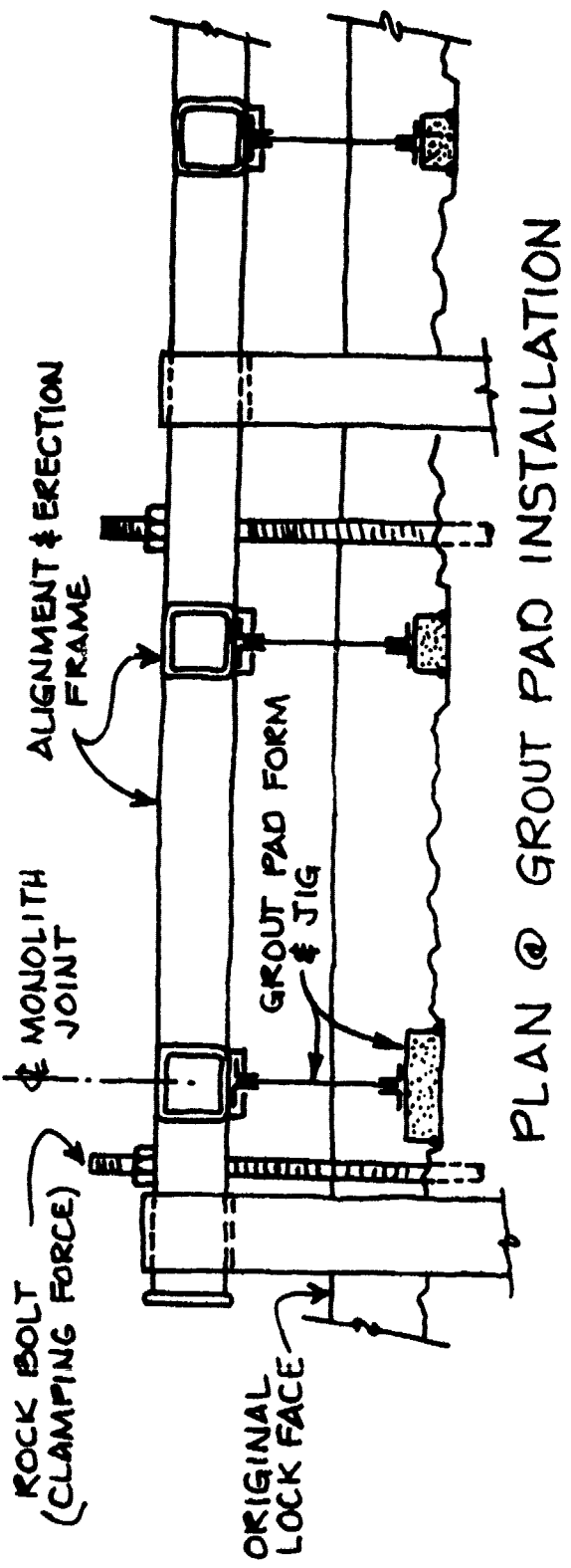
56. It is likely that one work shift will be required to perform miscellaneous surface clean-up tasks, to drill and install dowels, and to construct and cure grout pads for the full monolith height, eliminating subsequent grout pad jig installations. At the end of the work shift, the erection frame and grout pad jig can be removed and the necessary navigation protection devices installed.

57. On the following shift, the lowest panel can be installed. The erection frame is required to support the panel until the infill concrete is placed and adequately cured. With this concept, it is possible to incorporate welded ties at the top of the panel for additional panel stability, depending upon the location of the lowest grout pad.

58. There are several means of interlocking the ribbed panel to the lock wall. If panels are cast with the ribs down in the forms, it will not be possible to have projecting steel, either from the ribs or from the back face of the panel. In this case, form liners can be placed in the rib forms to create shear keys along the rib faces as shown in Figure 11. Dowels from

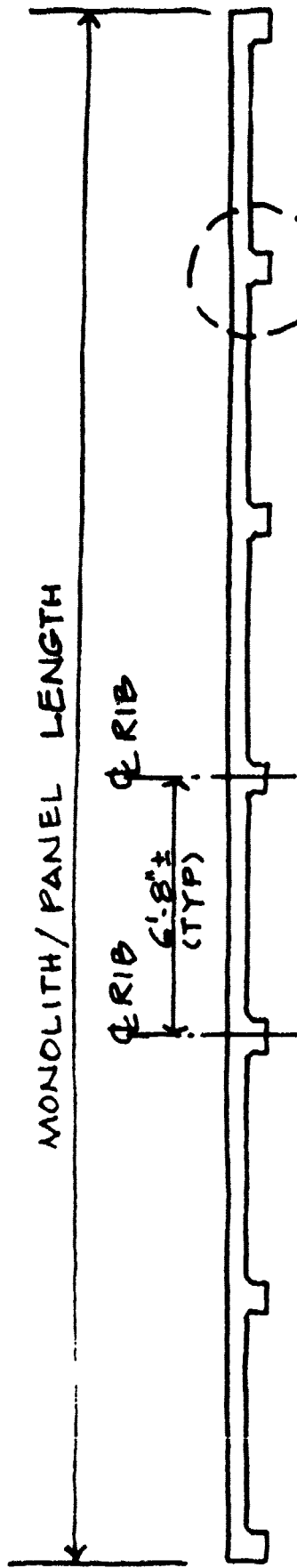


ELEVATION: GROUT PAD JIG
 FIGURE 9

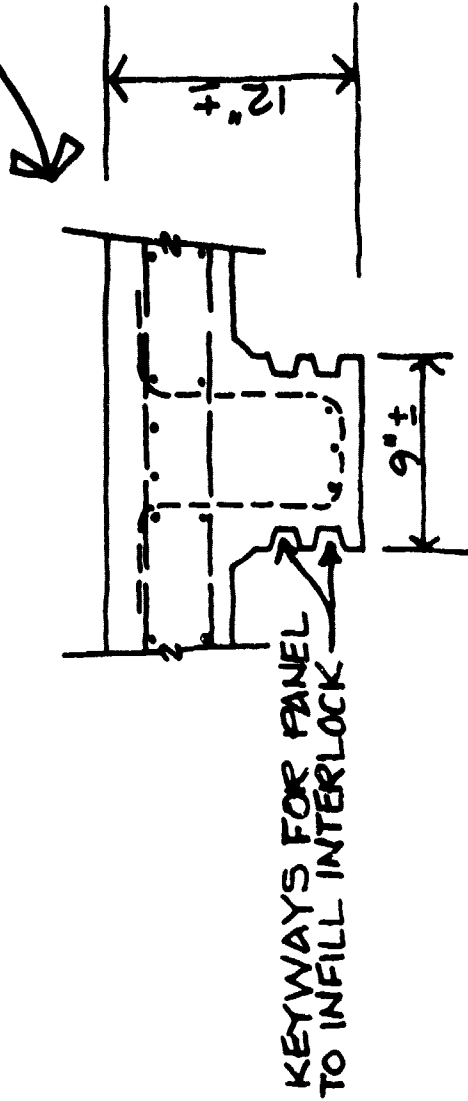


RIBBED PANEL CONCEPT

FIGURE 10



SECTION



DETAIL

RIBBED PANEL DETAILS

FIGURE 11

the monolith can be located in proximity to these shear keys to effect the interlocking mechanism. Another available interlock means is to install sleeves through the ribs, which then can have straight reinforcing bars installed after the panel is removed from the forms. Casting the panel face down in the form is preferable. This results in a better consolidated, denser panel face, enables better treatment of the bonding face, and allows reinforcing to project out of the panel.

Additional Considerations

59. Although both schemes include dewatering of the infill space, there is insufficient room to perform work behind the panels. Therefore, activities such as repair of feather-edges along the lower demolition plane and installation of dowels will have to be carried out underwater. Both schemes also require flooding of the lock chamber prior to infill concrete placement, which will impact work being completed at other locations in the lock. More thorough planning and coordination of the work is required for the external pressure concepts. The rate of concrete placement will also have to be monitored closely due to the reliance on only the external hydrostatic pressure to resist the infill concrete.

60. A concrete with rapid cure and strength gain would benefit this concept, enabling early removal of the erection frame. Otherwise, the erection frame would have to remain in the lock when it is reopened to traffic.

61. Lock refacing is typically completed to the top of the lock. At some point, there will be insufficient differential head available to continue this repair concept and the panels will have to be directly tied to the lock wall. However, both schemes can be designed to incorporate welded or mechanical ties.

Concept Cost Estimates

62. Cost estimates were prepared for the three concepts investigated during this conceptual design effort. The point of departure for the current estimates are the costs developed during Phase I (Technical Report REMR-CS-7, Table 3, page 39). Unit costs have been adjusted to account for inflation and to incorporate recent data for similar rehabilitation work at Lock and Dam 22 where precast panels were used.

63. The current estimates include all work required to complete an entire refacing project to demonstrate the relative impact of costs associated with installation of the lowest panel in a wet condition and maintaining the lock in operation.

64. The baseline costs were developed for repairs to locks taken out of service and dewatered. For repair work in a wet condition, additional costs for special tooling and equipment have been added to the baseline costs. Also, the special work sequencing required to complete components of work within allotted time periods and preparations for opening the lock to traffic must also be incorporated.

65. Bar chart schedules are included to address the work sequencing requirements. These are shown in Figures 12 through 15. The schedules identify key tasks and provide an estimate of labor hours required to complete each task. Recent site visits to two lock rehabilitation projects were very valuable in estimating labor requirements for individual tasks.

66. Labor costs were calculated using the estimated labor hours in the above schedules. Because the labor estimates in the schedule include only the general labor, supervisory and equipment operators were added to develop actual costs. A composite project staff was developed from the average general labor force in the schedules and is shown in Table 1. At the conceptual design level, only one crew was used to estimate costs. Overlapping work on adjacent monoliths will be required to level off peak labor force requirements and to maximize use of special tooling and equipment. For example, the cofferdam is required only one day during the repair process and work could be staggered so that work on five monoliths could progress simultaneously if additional crews and equipment were

Task	Day 1							Day 2							Day 3 (& 4)														
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9
1 Remove Navigation Prot - Prev Monolith	** (6)																												
2 Install Work Platforms	****(12)																												
3 Drill Dowel, Tie, and Rock Anchor Holes	***** (39)																												
4 Install Dowels and Ties	***** (26)																												
5 Position Top-side Winches and Levers	** (+)																												
6 Inspect Lower Edge for Overbreakage	**** (4,+)																												
7 Prep Areas of Overbreakage	** (6)																												
8 Install Navigation Protection Devices	**** (16)																												
9 Remove Work Platforms																													
10 Install Panel onto Erection Truss																													
11 Pressure Wash Monolith Surface																													
12 Lift Erection Truss/Panel into Position																													
13 Align Panel/Secure Truss																													
14 Complete Panel Top Tie Connections																													
15 Install Horizontal Interlock Rebar																													
16 Install Side Bulkhead Forms																													
17 Place Infill Concrete																													
18 Remove Erection Truss																													
19 Install Navigation Protection																													
20 Install Work Platforms - Remove Navig Pr																													
21 Remove Bulkhead Forms																													
22 Pressure Wash Monolith Face																													
23 Erect Second Panel																													
24 Align Panel & Connect Panel Ties																													
25 Erect Third Panel																													
26 Align Panel & Connect Panel Ties																													
27 Place Bulkhead Forms																													
28 Place Infill Concrete																													
29 Remove Work Platforms																													
30 Install Navigation Protection																													

NOTE: Panels 4 & 5 are installed on Day 4 following the same schedule as Day 3.

SCALE: Two asterisks represent 1-hour
 NOTE: Work Requiring Diver Assistance Is Noted By (+). Numbers In Parenthesis Indicate Labor Hours Excluding Divers and Equipment Operators.

TOTAL 139 HOURS
 13.9 WORKERS
 1 DIVE TEAM

TOTAL 82 HOURS
 8.2 WORKERS
 1 DIVE TEAM

TOTAL 83 HOURS
 8.3 WORKERS
 1 DIVE TEAM (Day 3 Only)

TOTAL HOURS PER MONOLITH - 387 HOURS

CONCEPTUAL CONSTRUCTION SCHEDULE
 TREMIE SYSTEM
 FIGURE 12

Task	Day 1							Day 2							Day 3							Day 4													
	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1 Remove Navigation Prot - Prev Monolith	** (6)																																		
2 Install Brace Hanger Brackets	***** (13)																																		
3 Prepare Cofferdam Seal Contact Surfaces	***** (8)																																		
4 Install Cofferdam																																			
5 Dewater Cofferdam																																			
6 Prep Overbreakage																																			
7 Drill Dowel and Form Tie Holes																																			
8 Install Dowels and Form Ties																																			
9 Set Formwork/Pressure Wash Monolith																																			
10 Place Support Ledger Concrete																																			
11 Remove Cofferdam																																			
12 Place Navigation Protection																																			
13 Install Work Platforms/Remove Navig Prot																																			
14 Remove Support Ledger Formwork																																			
15 Pressure Wash Monolith Wall																																			
16 Erect Lowest Panel																																			
17 Align Panel & Weld Ties																																			
18 Place Bulkhead Forms																																			
19 Place Infill Concrete for Lowest Panel																																			
20 Remove Work Platforms																																			
21 Place Navigation Protection																																			
22 Install Work Platforms/Remove Navig Prot																																			
23 Remove Bulkhead Forms																																			
24 Pressure Wash Monolith Face																																			
25 Erect Second Panel																																			
26 Align Panel & Weld Ties																																			
27 Erect Third Panel																																			
28 Align Panel & Weld Ties																																			
29 Place Bulkhead Forms																																			
30 Place Infill Concrete																																			
31 Remove Work Platforms																																			
32 Install Navigation Protection																																			

NOTE: Panels 4 & 5 are installed on Day 5 following the same schedule as Day 4.

TOTAL 73 HOURS
7.3 WORKERS
0 DIVE TEAM

TOTAL 82 HOURS
8.2 WORKERS
0 DIVE TEAM

TOTAL 65 HOURS
6.5 WORKERS
1 DIVE TEAM

TOTAL 79 HOURS
7.9 WORKERS
1 DIVE TEAM (Day 4 Only)

TOTAL HOURS PER MONOLITH - 378 HOURS

CONCEPTUAL CONSTRUCTION SCHEDULE
COFFERED SYSTEM
FIGURE 13

SCALE: Two asterisks represent 1-hour

NOTE: Work Requiring Diver Assistance Is Noted By (+). Numbers In Parenthesis Indicate Labor Hours Excluding Divers and Equipment Operators.

Task	Day 1							Day 2							Day 3 (6 4)							Day 5														
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6
1 Install Work Platform/Drilling Template	** (6)																																			
2 Inspect for Overbreakage	** (+)																																			
3 Surf Prep for Overbreakage	**** (4, +)																																			
4 Drill Holes for Rock Anchors/Ties	***** (18, +)																																			
5 Install and Grout Rock Anchors	***** (12, +)																																			
6 Prepare Seal Contact Surface	**** (8)																																			
7 Remove Work Platform/Drilling Template	** (6)																																			
8 Install Navigation Protection	** (6)																																			
9 Remove Navigation Protection																																				
10 Pressure Wash Monolith Surface																																				
11 Erect Steel Framework and Panel	** (6)																																			
12 Align Framework/Panel & Install Rebar	** (3)																																			
13 Dewater Void	**** (12)																																			
14 Raise Water Level in Lock Chamber	** (6)																																			
15 Place Infill Concrete	** (4)																																			
16 Place Navigation Protection	** (2)																																			
17 Remove Steel Framework and Navig Prot	**** (12)																																			
18 Adjust Framework/Attach Next Panel	** (6)																																			
19 Pressure Wash Monolith Surface	** (3)																																			
20 Install Steel Framework & Panel	**** (12)																																			
21 Align Framework & Panel	** (6)																																			
22 Dewater Void	** (4)																																			
23 Raise Water Level in Lock Chamber	** (2)																																			
24 Place Infill Concrete	**** (12)																																			
25 Place Navigation Protection Devices	** (6)																																			
26 Install Work Platforms - Remove Navig Pr	** (6)																																			
27 Complete Upper Panel Tie Connections	**** (6)																																			
28 Pressure Wash Monolith Face	** (3)																																			
29 Place Infill Concrete	**** (12)																																			
30 Remove Work Platforms	** (6)																																			

SCALE: Two asterisks represent 1-hour

NOTE: Work Requiring Diver Assistance is Noted By (+). Numbers in Parenthesis Indicate Labor Hours Excluding Divers and Equipment Operators

TOTAL 93 HOURS
9.3 WORKERS
2 DIVE TEAMS

TOTAL 51 HOURS
5.1 WORKERS
0 DIVE TEAM

TOTAL 63 HOURS
6.3 WORKERS
1 DIVE TEAM

TOTAL 93 HOURS
9.3 WORKERS
2 DIVE TEAMS

TOTAL HOURS PER MONOLITH - 270 HOURS

CONCEPTUAL CONSTRUCTION SCHEDULE
EXTERNAL PRESSURE SYSTEM - STEEL FRAMEWORK SCHEME

FIGURE 14

Task	Day 1							Day 2							DAY 3							Day 4												
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4
1 Install Alignment and Erection Frame	****(8)																														****(8)			
2 Inspect for Overbreakage	**(+)																														**(+)			
3 Surf Prep for Overbreakage	****(4,+)																														****(4,+)			
4 Drill Holes for Rock Anchors/Ties	***** (22,+)																														*****			
5 Install and Grout Rock Anchors	***** (15,+)																														*****			
6 Prepare Grout Pad Surfaces	****(8)																														****(8)			
7 Install Grout Pad Form & Jigs	****(8)																														****(8)			
8 Cast Grout Pads	****(12,+)																														****(8)			
9 Remove Erection Frame/Grout Pad Jigs	** (6)																														** (+)			
10 Install Navigation Protection	** (6)																														****(8)			
11 Remove Nav. Prot./Install Erection Frame	** (6)																														****(8)			
12 Pressure Wash Monolith Surface	****(12)																														****(8)			
13 Install Ribbed Panel	** (6)																														** (4)			
14 Align Panel/Weld Ties at Top of Panel	****(8)																														****(8)			
15 Dewater Void	** (2)																														** (2)			
16 Raise Water Level in Lock Chamber	***** (18)																														***** (18)			
17 Place Infill Concrete	** (6)																														** (6)			
18 Place Navigation Protection	****(12)																														****(12)			
19 Remove Navigation Protection	****(8)																														****(8)			
20 Remove Lower Closure Forms	** (4)																														** (4)			
21 Pressure Wash Monolith Surface	****(12)																														****(12)			
22 Install Second Panel	****(8)																														****(8)			
23 Align Panel/Complete Upper Tie Welds	** (6)																														** (6)			
24 Dewater Void	****(12)																														****(12)			
25 Raise Water Level in Lock Chamber	** (3)																														** (3)			
26 Place Infill Concrete	****(12)																														****(12)			
27 Remove Erection Frame	** (6)																														** (6)			
28 Place Navigation Protection	****(12)																														****(12)			
29 Install Work Platforms - Remove Navig Pr	** (3)																														** (3)			
30 Pressure Wash Monolith Face	****(12)																														****(12)			
31 Place Infill Concrete	** (6)																														** (6)			
32 Remove Work Platforms																																		

SCALE: Two asterisks represent 1-hour
NOTE: Work Requiring Diver Assistance Is
Noted By (+). Numbers In Parenthesis
Indicate Labor Hours Excluding Divers
and Equipment Operators.

CONCEPTUAL CONSTRUCTION SCHEDULE
EXTERNAL PRESSURE SYSTEM - RIBBED PANEL SCHEME
FIGURE 15

TOTAL 122 HOURS
12.2 WORKERS
2 DIVE TEAMS

TOTAL 68 HOURS
6.8 WORKERS
0 DIVE TEAM

TOTAL 74 HOURS
7.4 WORKERS
1 DIVE TEAM

TOTAL 122 HOURS
12.2 WORKERS
2 DIVE TEAMS

TOTAL 122 HOURS
12.2 WORKERS
2 DIVE TEAMS

TOTAL HOURS PER MONOLITH - 264 HOURS

TABLE 1
WORK FORCE COMPOSITION

	TREMIE SYSTEM	COFFERED SYSTEM	STEEL FRAMEWORK	RIBBED PANEL
Project Manager	1	1	1	1
Assistant Project Manager	1	1	1	1
Equipment Operators				
Large Crane Operator	1	1	1	1
Oiler	1	1	1	1
Small Crane Operator	1	1	1	1
Oiler	1	1	1	1
Fork Lift and/or Boom Truck	1	0	0	0
Miscellaneous Equipment	0	1	1	1
General Labor Force				
Erection Superintendent	1	1	1	1
Concrete Superintendent	1	1	1	1
Miscellaneous Trades				
Ironworkers/Welders	2	2	1	2
Carpenters	2	1	1	1
Cement Finishers	2	2	2	2
General Laborers	4	3	3	4
Contractor Quality Control	1	1	1	1
TOTAL	20	18	17	19
HOURS/DAY	200	180	170	190
NO. OF DAYS TO COMPLETE ONE MONOLITH	4	5	5	4
HOURS TO COMPLETE ONE MONOLITH	800	900	850	760
HOURS PER 40 MONOLITH LOCK	32,000	36,000	34,000	30,400

available. These considerations have been incorporated in a final cost estimate prepared for the preferred repair concept.

67. Unit prices for specific cost elements were kept the same for all concepts to ensure that costs were compared on an equivalent basis. Only major equipment or equipment specific to each concept have been included in the estimates. It has been assumed that miscellaneous general equipment will be on hand for performing the work and has been accounted for in the contractor's general overhead.

68. Costs for each of the four repair schemes are itemized in Tables 2 through 5 and are summarized as follows:

Tremie System	Table 2	\$164/sf
Coffered System	Table 3	\$165/sf
External Pressure System		
Steel Framework Scheme	Table 4	\$165/sf
Ribbed Panel Scheme	Table 5	\$172/sf

69. The cost analysis reveals that all concepts are relatively similar, suggesting that the final choice of a preferred alternative should be based on schedule and potential risk considerations rather than cost. The schedules show that either four or five shifts will be required to complete a monolith. The schedules also indicate that the 10-hour work shift defined in the criteria will be very tight with respect to completing major increments of the work. A 12-hour shift would be preferable to allow additional contingency time and to allow additional curing time for infill concrete, providing greater safety for removal of support devices and formwork.

Selection of Preferred System

70. Following release of a draft report presenting the conceptual design information, a meeting with representatives of the Corps of Engineers was held to perform a value engineering review and evaluate the three concepts. The review team critically examined features and weaknesses of each concept and prepared a consensus finding on the benefits and risks. A

TABLE 2
TREMIE SYSTEM COST ANALYSIS

Item Description	Unit	Quantity	Unit Costs	Total
1. COSTS BASED ON PHASE I WORK				
Concrete Removal	CF	51,200	\$ 45.00	\$2,304,000
Precast Panels (Fabricate Only)	SF	36,000	45.00	1,620,000
Form Ties and Dowels (Materials Only)	EA	3,900	25.00	97,500
Cast-In-Place Concrete	CY	120	3,000.00	360,000
Top Closure Pour (Materials & Labor)	CY	1,150	120.00	138,000
Infill Concrete (Materials Only)				
2. COSTS ESTIMATED BASED ON WET CONDITION INSTALLATION WITH OPERATIONAL LOCK				
TOOLING AND SPECIAL EQUIPMENT				
Erection Trusses	LB	23,500	2.00	47,000
Guide Tracks for Repair of Feather-Edge	LB	2,000	2.00	4,000
-Underwater Saw Cutting	LB	4,000	2.00	8,000
-Demolition Equipment	LS	1	20,000.00	20,000
Navigation Protection	MO	8	16,000.00	128,000
Manitowoc 4000 & Barge	MO	32	1,000.00	32,000
Skid Mounted Winches	LS	1	25,000.00	25,000
Underwater Demolition Equipment	LS	1	5,000.00	5,000
Miscellaneous Hydraulic Jacks & Rods				
LABOR				
General Labor Force	HR	32,000	40.00	1,280,000
Underwater Labor (Dive Team)	DAY	120	1,800.00	216,000
MATERIALS				
Lower Panel Reinforcing	LB	5,000	1.00	5,000
TOTAL				\$6,290,100
COST/SQ FT				\$ 164

ESTIMATE BASIS

1. Lock Chamber Dimensions: 600 feet long by 32 feet high
2. Work is completed using one set of tooling and equipment and one basic work crew
3. One monolith requires four days to complete
4. Costs do not include miscellaneous tools and small equipment

TABLE 3

COFFERED SYSTEM COST ANALYSIS

Item Description	Unit	Quantity	Unit Cost	Total
1. COSTS BASED ON PHASE I WORK				
Concrete Removal	CF	51,200	\$ 45.00	\$2,304,000
Precast Panels (Fabricate Only)	SF	36,000	45.00	1,620,000
Form Ties and Dowels (Materials Only)	EA	3,300	25.00	82,500
Cast-In-Place Concrete				
Top Closure Pour (Materials & Labor)	CY	120	3,000.00	360,000
Infill Concrete (Materials Only)	CY	1,150	120.00	138,000
2. COSTS ESTIMATED BASED ON WET CONDITION INSTALLATION WITH OPERATIONAL LOCK				
TOOLING AND SPECIAL EQUIPMENT				
Cofferdam	LB	21,500	2.00	43,000
Guide Tracks for Repair of Feather-Edge				
-Lower Saw Cut Inside Cofferdam	LB	1,000	2.00	2,000
-Demolition Equipment	LB	2,000	2.00	4,000
Guide Tracks for Prep of Seal Surfaces	LB	2,000	2.00	4,000
Navigation Protection	LS	1	20,000.00	20,000
Manitowoc 3000 & Barge	MO	9	12,500.00	112,500
Demolition Equip for Seal Pts, Feather-Ed	LS	1	25,000.00	25,000
LABOR				
General Labor Force	HR	36,000	40.00	1,440,000
Underwater Labor (Dive Team)	DAY	80	1,800.00	144,000
MATERIALS				
Lower Support Ledge Reinforcing	LB	5,000	1.00	5,000
Lower Support Ledge Armor	LB	8,600	2.00	17,200
TOTAL				\$6,321,200
COST/SQ FT				\$ 165

ESTIMATE BASIS

1. Lock Chamber Dimensions: 600 ft long by 32 ft high
2. Work is completed using one set of tooling and equipment and one basic work crew
3. One monolith requires five days to complete
4. Costs do not include miscellaneous tools and small equipment

TABLE 4

EXTERNAL PRESSURE SYSTEM - COST ANALYSIS
STEEL FRAMEWORK SCHEME

Item Description	Unit	Quantity	Unit Cost	Total
1. COSTS BASED ON PHASE I WORK				
Concrete Removal	CF	51,200	\$ 45.00	\$2,304,000
Precast Panels (Fabricate Only)	SF	36,000	45.00	1,620,000
Form Ties and Dowels (Materials Only) (Above Low Pool)	EA	2,700	25.00	67,500
Cast-In-Place Concrete	CY	120	3,000.00	360,000
Top Closure Pour (Materials & Labor)	CY	1,150	120.00	138,000
Infill Concrete (Materials Only)				
2. COSTS ESTIMATED BASED ON WET CONDITION INSTALLATION WITH OPERATIONAL LOCK				
TOOLING AND SPECIAL EQUIPMENT				
Steel Framework	LB	32,000	2.00	64,000
Dowel and Rock Anchor Drilling Template	LB	2,000	2.00	4,000
Guide Tracks for Repair of Feather-Edge	LB	2,000	2.00	4,000
-Lower Horizontal Saw (Below Low Pool)	LB	4,000	2.00	8,000
-Demolition Equipment	LB	4,000	2.00	8,000
Guide Tracks for Prep of Seal Surfaces	LS	1	20,000.00	20,000
Navigation Protection	MO	9	12,500.00	112,500
Manitowoc 3000 & Barge	LS	1	25,000.00	25,000
Demolition Equip for Seal Pts, Feather-Ed				
LABOR				
General Labor Force	HR	34,000	40.00	1,360,000
Underwater Labor (Dive Team)	DAY	120	1,800.00	216,000
MATERIALS				
Mechanically Anchored Dowels/Below Low Pool Level	EA	600	50.00	30,000

TOTAL \$6,341,000
COST/SQ FT \$ 165

ESTIMATE BASIS

1. Lock Chamber Dimensions: 600 ft long by 32 ft high
2. Work is completed using one set of tooling and equipment and one basic work crew
3. One monolith requires five days to complete
4. Costs do not include miscellaneous tools and small equipment

TABLE 5

EXTERNAL PRESSURE SYSTEM - COST ANALYSIS
RIBBED PANEL SCHEME

Item Description	Unit	Quantity	Unit Cost	Total
1. COSTS BASED ON PHASE I WORK				
Concrete Removal	CF	51,200	\$ 45.00	\$2,304,000
Precast Panels (Fabricate Only)	SF	36,000	45.00	1,620,000
Form Ties and Dowels (Materials Only) (Above Low Pool)	EA	3,180	25.00	79,500
Cast-In-Place Concrete	CY	120	3,000.00	360,000
Top Closure Pour (Materials & Labor)	CY	1,150	120.00	138,000
Infill Concrete (Materials Only)				
2. COSTS ESTIMATED BASED ON WET CONDITION INSTALLATION WITH OPERATIONAL LOCK				
TOOLING AND SPECIAL EQUIPMENT				
Erection and Alignment Frame	LB	17,000	2.00	34,000
Grout Pad Form Jigs (7)	LB	14,000	2.00	28,000
Dowel and Rock Anchor Drilling Template	LB	2,000	2.00	4,000
Guide Tracks for Repair of Feather-Edge				
-Lower horizontal Saw Cut	LB	2,000	2.00	4,000
-Demolition Equipment	LB	4,000	2.00	8,000
Guide Tracks for Prep of Grout Pad Surf	LB	4,000	2.00	8,000
Navigation Protection	LS	1	20,000.00	20,000
Manitowoc 4000 & Barge	MO	8	16,000.00	128,000
Demolition Equip for Local Surface Prep	LS	1	25,000.00	25,000
LABOR				
General Labor Force	HR	30,400	40.00	1,216,000
Underwater Labor (Dive Team)	DAY	120	1,800.00	216,000
MATERIALS				
Precast Panel Differential for Ribbed Panels	SF	36,000	10.00	360,000
Mech Anchored Dowels Below Low Pool	EA	960	50.00	48,000
TOTAL				\$6,600,500
COST/SQ FT				\$ 172

ESTIMATE BASIS

1. Lock Chamber Dimensions: 600 feet long by 32 feet high
2. Work is completed using one set of tooling and equipment and one basic work crew
3. One monolith requires four days to complete
4. Costs do not include miscellaneous tools and small equipment

comparison was made of the differing features against the general design criteria and specific experience of actual conditions during construction at lock sites. This comparison was used to select a preferred concept for a final design.

Discussion

71. During the concept review meeting, not only were three concepts examined in detail, but repair elements common to all three were addressed. These were primarily issues related to demolition. Feather-edged conditions along the bottom demolition plane were discussed and agreement was reached that these would not be repaired during the refacing project. If needed, these areas can be repaired at a later time when the lock is dewatered. The sequence of demolition was also discussed. Experience from other projects suggests that demolition of individual monolith faces would be fairly risky in regards to fracturing the edges of the adjacent monoliths be they old or newly replaced.

Tremie System

72. The best features for the Tremie System (Figure 1) were felt to also be the biggest risks or concerns. These included the indirect method of tying the panel to the lock walls and the ability to reliably prepare the surface just prior to placement. The indirect tie requires a good bond between the infill concrete and lock wall, raising the issue of cleanliness of contact surface between old and new concrete infill as it relates to contaminants in the river water. This concept also requires the use of rock bolts near the tailwater level. It was felt that the ability to install rock bolts so near the water line would pose significant difficulties on the contractor and affect the cost and/or the quality.

73. There was also question about the functional reliability and long-term durability of the bottom panel connection detail that precluded any direct tie back to the monolith. It was suggested that the sacrificial beam attachment concept, as presented in the initial brainstorming session, could alleviate this "positive attachment" concern. In response, it was

decided that this concept would be examined more thoroughly in light of its connection benefits to the tremie concept. The results of this review will be discussed later in this report.

74. The quality of the tremie pour was also a concern. It is known that the initial portion of a tremie pour is often inferior to the remainder of the placement and would be in a sensitive location in this application. One typically gets rock pockets and grout dilution and furthermore could get grout loss at locations of imperfect seal plate closure.

External Pressure System

75. The External Pressure System was viewed as a cofferdam in this application because it was required to provide the water separation between the chamber and the dry workspace at the face of the monolith being repaired. Corps Standards do not currently permit cofferdams as forms for concreting.

76. The main principle of this system is to use the benefits of the hydrostatic pressure on the chamber side of the panel to hold it in place during dewatering and placement of infill concrete. Concern was expressed about the likelihood of capillary-type leakage at the monolith joints that would degrade its reliability to adequately seal the work zone and allow for concreting to occur without blowing out the form. This could require substantial overpressures of chamber head in order to achieve an acceptable safety factor. It was also felt that a better panel-to-monolith connection should be developed to minimize the depth of demolition required to make a rebar tie as shown in Figure 6.

77. For the ribbed panel alternate to the External Pressure System concept, it was agreed by everyone that the tolerancing efforts required to establish the discrete point bearing pads as shown in Figure 9 would be impossible and would lead to major construction disruptions, costs, and claims and probably undesirable durability in the end. It was felt that the panel size suggested for this concept was most suitable for water transportation or site fabrication and that road transport might pose problems in some areas. In its defense, it was recognized that the ribs of the panel would provide a beneficial stiffness for handling.

78. Both external pressure schemes raised questions relative to reliability and safety. The loss of a seal during concreting could result in the loss of a panel, endangering workers, and possibly disrupting the normal cycle for lock operation.

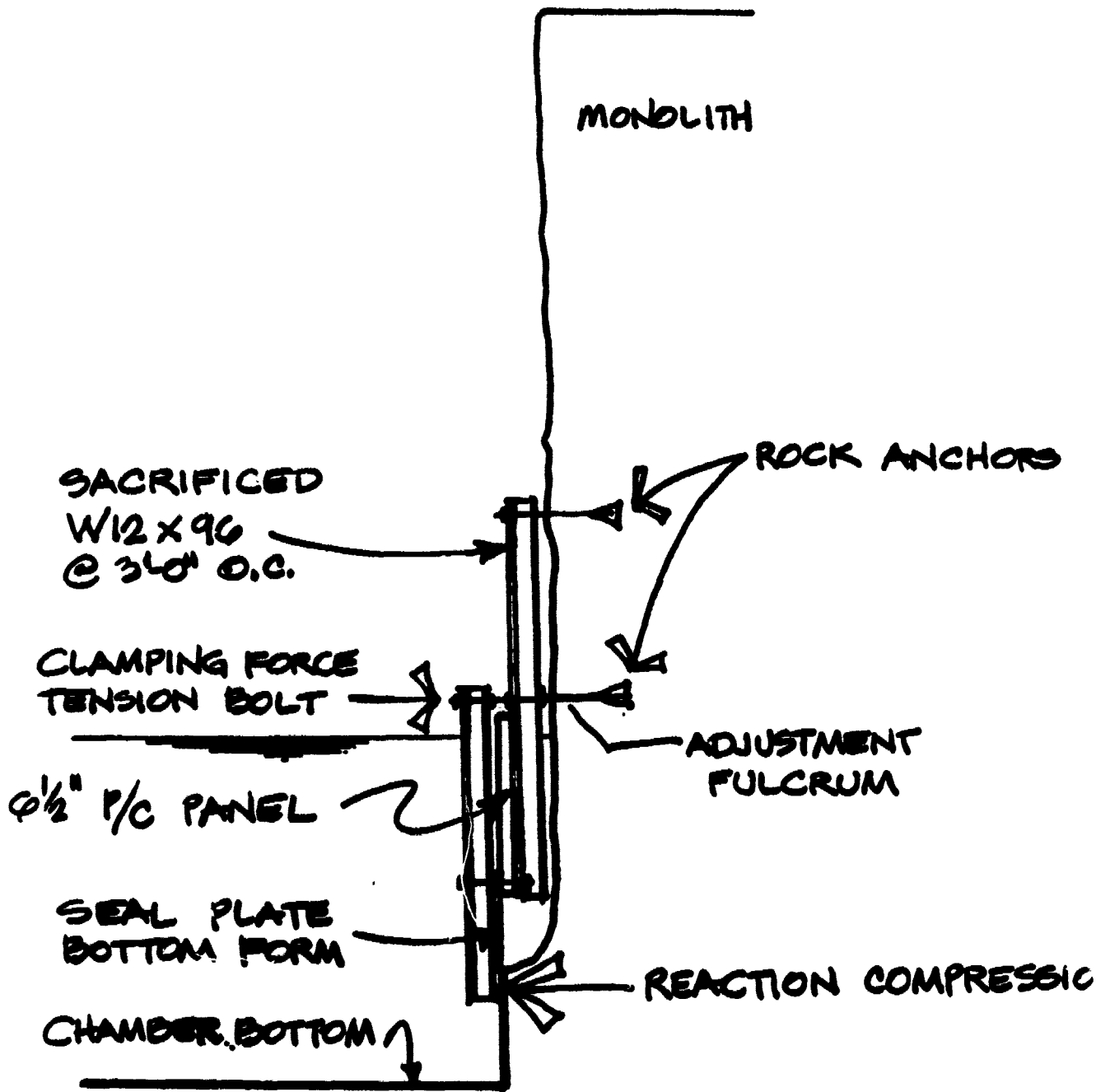
Coffered System

79. The Coffered System (Figure 3) was clearly the preferred choice in the discussion and review. It was felt that this system would provide the best means of dealing with unexpected situations on the face of the monolith because it provides full access and visibility after the cofferdam has been placed and dewatered. The design of the cofferdam must include methods of sealing against an uneven monolith face as leakage is still a potential problem. However, the depth of the coffer can be extended to provide a sump where minor leakage can be accumulated and discharged with pumps. Also, it is the most familiar method of marine work for most contractors and should be cost-effective. Experience shows that it is best (easiest) to drill the horizontal holes to receive the tie dowels after the panel has been set in place. This can be done easily with the Coffered System.

Sacrificial Beam Method

80. During the concept evaluation work session, the Sacrificial Beam Method was offered as a means of overcoming some of the concerns with lack of a direct connection between the panel and monolith face for the Tremie Concept. The following reports the results of a more detailed review of the Tremie System - Sacrificial Beam Method, wherein steel beams are used to support the bottom panels and tie the panels to the lock wall. This concept is included under the Tremie System Concept's category.

81. The beams tie the form panels to the lock wall and are attached to the wall above the low pool level, enabling erection work to be performed in the dry (see Figure 16). Prior to erection, the beams are attached to the form panels in a vertical position using inserts that are cast into the top and bottom panel edges. The inserts are designed to transfer the infill concrete pressure from the panel into the beam. The panel/beam assemblage is then erected and secured to the lock wall using rock bolts or other direct connections, which are made in the dry above the normal low pool level. The beams are cast into the infill concrete, hence the term sacrificial beam.



ELEVATION: TREMIE SYSTEM
SACRIFICIAL BEAM CONCEPT

FIGURE 16

82. In addition to sacrificial beams, the lower closure pour forms are also attached to the panel prior to erection. The lower form uses a clamping beam to provide sufficient pressure on the closure form seals. The clamping force is provided by a screw jack operated above the low pool level; the clamping force is obtained by levering against the lower edge of the panel or cantilevered end of the sacrificial beam. To reduce seal leakage and provide safety against a form failure, a minimum clamping force of two times the expected reaction due to infill placement is recommended. After the panel is erected and the lower forms clamped, the infill concrete is tremied into the space behind the panel.

83. The main drawback to this concept is the flexibility of the cantilevered support arrangement. Design of the sacrificial beams is controlled by stiffness rather than strength. Deflections of the lower cantilevered end of the sacrificial beam must be maintained on the same order of magnitude as the panel installation tolerances. This requires maximum deflections of approximately 1/4 in., which requires large beam sections or the need to compensate for the deflections through a series of adjustments to the clamping/levering forces. As an example, a sacrificial beam system using 8-in.-wide flange sections spaced every 3 ft along the panel will result in approximately 1/4-in. deflections with an infill concrete lift height of 2 ft (4.67 ft, including the lower closure pour). To enable a full panel height infill placement, it is estimated that a minimum 12-in.-wide flange will be required. An additional 5 to 6 in. of lock face demolition will be necessary to accommodate the larger beams, which also requires a greater amount of replacement concrete. It is estimated that the additional cost for the lock face demolition, concrete infill, and sacrificial beams to enable an infill concrete placement lift height of one panel may add approximately \$30/sq ft to the lock wall rehabilitation costs.

84. This concept also requires careful monitoring of the concrete placement rates so as not to overcome the sealing force and may impose adverse construction sequencing requirements for situations with partial panel infill placements. For these reasons and the associated higher costs, this concept has not been carried further in the development of a Tremie System.

Recommendations

85. It was concluded that the concept most in keeping with the methods, techniques, and equipment currently being used successfully by contractors on lock rehabilitation projects is the Coffered System, wherein work below the water line could be performed visibly, in a comfortable position, and a dry environment. It was further determined that this method would provide the most reliable quality control opportunities and therefore the most consistent end product.

86. Further discussions of the selected Coffered System were held to identify additional refinements. One suggestion was that the cofferdam should be braced against the width of the chamber to get a reliable reaction against the wall. The bottom edge of the demolished monolith face should be squared off with a prepared cut by saw or water jet cutter. All the lower panel concrete infill should be poured in the dry with the cofferdam in place. The precast panel forms can be braced against the cofferdam, which should be designed with this load in mind.

PART IV: FINAL DESIGN OF PREFERRED CONCEPT

Introduction

87. As noted in the previous section, the preferred concept includes the use of a cofferdam so lock rehabilitation work can be completed under dry conditions. To demonstrate the features of this repair concept, drawings and specifications were prepared for the rehabilitation of a generic navigation lock. Cost and schedule information have also been developed based on the final design presented in the drawings and specifications. This information can be compared to that for conventional cast-in-place repair procedures or for the stay-in-place form repair procedure for a nonoperational lock as presented in Phases I and II of this developmental project.

88. The drawings are in Appendix C. The generic lock has a total length of 600 ft and is 110 ft wide. It has been assumed that the top 38.5 ft of wall will be repaired requiring the installation of six, 6-ft-tall panels and a 2.5-ft top cast-in-place closure. Monoliths are assumed to be 30 ft wide with 16 monoliths to be refaced with stay-in-place concrete form panels along each lock wall face. Gate bay monoliths and monoliths at ladder locations are assumed to be repaired using conventional cast-in-place repair procedures.

89. The panel system shown in the drawings is identical to the one developed during Phase I with three exceptions. In lieu of using alignment screws to support the panel until placement and curing of the infill concrete, the panels have been suspended from the lock wall. This detail does not require surface preparation of the support ledge, thereby reducing the number of tasks to be completed within the cofferdam. A second modification includes the lower form tie. Rather than a welded connection, which is difficult to complete, a bolted connection is shown. Not only will this connection reduce the time needed to complete the connection, but it will also provide a means for fine adjustment of the panel alignment during the erection process.

90. The final modification includes the panel-to-panel joint detail. Some panel cracking has been experienced adjacent to joints at Lock and Dam 22 where precast concrete stay-in-place form panels were recently installed (dry condition installation). A slight draft or taper has been added at the panel edges, as shown in Section C, Drawing 5 of 6 (Appendix C), which has proven effective for other installations as reported in REMR-CS-22. Another possible method to alleviate the observed cracking would be to fill the space between panels with epoxy or cement grout.

91. Guide technical specifications have been included as Appendix D. They are in the Corps of Engineers' format and include requirements that are specific to this repair concept. Some paragraphs of the specifications include instructions and information that would not be normally included in contract specifications but that would be needed by the specification writer. Therefore, the specifications would have to be supplemented or adjusted for site-specific repair projects.

92. A critical element of this repair concept is for the cofferdam to be mobilized and fixed into position in the repair zone in a relatively short time. This is necessary to allow suitable time for other construction activities, such as the drilling and installation of ties, erection of the lower panel, and placement of backfill concrete. The work must be performed in a rapid, orderly fashion to enable completion within the time allotted for the limited closure of the lock.

93. As noted in the criteria, the lower pool elevation can fluctuate up to 6 ft above the low pool level. The cofferdam is designed to maintain a dry area over this 6-ft zone plus provide access for completing the lower form ties and installation of the lower closure pour formwork. Water leakage around the cofferdam seals is anticipated, requiring a sump below the bottom work platform. To accommodate these spatial requirements and provide a 1-ft freeboard, a 12-ft-deep cofferdam has been selected for the generic project. Plan dimensions of the proposed cofferdam is 5 ft wide by 35 ft to accommodate a typical 30-ft monolith. The physical size and depth of the cofferdam results in significant uplift or buoyancy forces, which must be resisted by the cofferdam assembly. The size of the cofferdam is a function of actual site conditions and contractor procedures so adjustments to the size of the cofferdam shown in the drawings would be expected on actual repair projects.

Cofferdam Features and Design

Cofferdam Types

94. Three generic types of cofferdams were evaluated during this study: a typical wall-supported cofferdam; a floating cofferdam, and a barge-mounted assembly. A wall-supported coffer assembly uses external devices, such as deadman or special frames attached to the wall to resist the buoyancy forces associated with dewatering of the cell. A floating cofferdam is a self-contained unit that requires a sophisticated ballasting sequence to resist the buoyancy forces. A barge-mounted cofferdam uses the mass of the barge and some ballasting water to resist the buoyancy forces. Conceptual designs were developed and evaluated for each of the cofferdam types.

95. The evaluation was based on the initial cost of the structure, the safety and performance of the structure, and the time and equipment required to deploy and demobilize the coffer assembly. For this study, an assumption was made that the coffer would be sealed against the lock wall and dewatered. One form panel would be completely installed, including placement of backfill concrete behind the panel, and the cofferdam demobilized and removed from the repair zone within one-repair cycle. Because the total lock closure time for a single-repair cycle has been limited to 10 hours per the criteria, the rapid deployment of the cofferdam is critical to the sequence.

Barge-Mounted Cofferdam

96. The barge-mounted cofferdam assembly was selected as the optimum system for the design parameters. It offers the greatest flexibility in the various water depths. It can be deployed rapidly and appears to have the best functional and safety features. Although the wall-supported cofferdam will work, the system appears to be rather difficult to deploy. The logistical problems associated with installing the anchor system for the cell make it unfeasible to rapidly and efficiently move the cell from one repair zone to another. The floating coffer cell concept has been used on other similar applications, but due to the critical nature of the ballasting sequence, it may not perform very well for the given operational water depths. In addition, there is potential for a catastrophic breach of the

seal if the ballasting sequence is not performed exactly properly. Conceptual sketches of the floating and wall-supported cofferdams are contained in Appendix E. The barge-mounted cofferdam is shown in the drawings in Appendix C.

97. A Barge-Mounted Cofferdam System consists of two discrete functional elements; the barge and the coffer. The barge provides the support for the cofferdam in the flooded mode and also houses the mooring system used to provide the initial precompression for the seal around the coffer. A rigid frame that is pin connected to the barge supports the cofferdam. The pin connection allows for an adjustment due to barge heel. Sliding attachments between the cofferdam and the rigid frame adjust for varying water depths. The cofferdam can be raised or lowered using either mechanical or hydraulic actuators as shown in Drawing A86029-3, Sheet 3 of 6.

98. The cofferdam is designed as a steel box section. The box system resists the global forces associated with precompression of the seal and the local forces associated with dewatering of the cell. Steel plate is used as the cladding material that is welded to beams spanning vertically to a horizontal beam on the top and a floor diaphragm on the bottom. Global horizontal forces are transmitted from the cladding plate to vertical beams, to the horizontal beams, and subsequently to the compression seals that contact the wall. Global vertical forces are transmitted from the floor cladding to a vertical frame, which in turn transmits the forces to hold-down devices attached to the barge. The barge is sequentially ballasted to resist the global uplift forces on the coffer.

99. Stability calculations and member sizing for the barge-mounted cofferdam are contained in Appendix F. Member sizing was carried to sufficient detail to enable sizing most structural elements, but it is not to the level of a final design. Cofferdam design is usually the contractor's responsibility. If specific design requirements will be imposed by the Corps of Engineers, the contractor should be provided with design criteria in the form of engineering technical letters or engineering manuals.

100. The seal to the wall prevents water leakage into the dewatered coffer area. With water in the lock at maximum design level, the estimated water volume to be removed from the coffer area is approximately 2,442 cu ft

(= 18,300 gal). A deballasting pump capacity of 100 cfm (750 gpm) would allow the coffer to be dewatered in approximately one-half hour. After the cell has been dewatered, some minor leakage around the seal should be expected. Smaller dewatering pumps will most likely be required to keep the cell dry during operation.

101. The seal will have to accommodate a wide variety of surface textures due to the nature of blasting demolition. For the purpose of this study, a wall roughness amplitude of 4 in. has been established in the criteria. For this roughness, the seal material should be relatively compressible. Closed cell foam rubber is the most likely candidate for the seal material. Many commercially available products are available for this application.

Operational Sequence

102. The Barge-Mounted Cofferdam System is deployed in a specific operational sequence as depicted in Drawings A86029-2, Sheet 2 of 6, and A86029-3, Sheet 3 of 6 in Appendix C. When the lock is open for traffic, the barge assembly will be stored outside of the lock. When the lock is ready for repair work, the barge is tug assisted to the repair zone. If required, water in the lock is let out to the tailwater level. Mooring lines from the barge are then attached to the repair wall so that final positioning of the assembly is accomplished using deck winches mounted either on the barge or the lock wall. As the coffer seal contacts the repair zone, the cofferdam is lowered on the rigid frame until the seal for the end bulkhead engages and is precompressed on the repair ledge. (See Elevation 3, Drawing A86029-4, Sheet 4 of 6, Appendix C.) At this time, the mooring lines to the barge are tensioned in order to precompress the seal against the vertical face of the lock wall. Once the seal is precompressed, water is pumped out of the cofferdam. This water will most likely be lifted directly into ballast tanks on the barge to offset the net buoyancy on the cofferdam. Once the coffer is dewatered, work can be performed in the repair zone. When the work is completed, the cofferdam will be reflooded by discharging the water stored in the barge ballast tanks back into the coffer. When flooding is complete, the mooring lines are released, the coffer raised, and the barge is pushed out of the lock so that the lock can be opened to traffic.

Navigation Protection Scheme

103. Temporary navigation protection devices will be required to provide standoff for vessels so they don't contact the refaced lock wall, thus avoiding damage to repairs in progress or vessels using the lock. For an unrestricted mode of operation as defined in the criteria, the navigation protection system must not project more than 2 ft beyond the existing lock wall. With restricted operations imposed on lock usage, navigation protection can extend up to 10 ft from the lock wall face. A restricted mode of operation will require temporarily dismantling barge tows to get them through the lock, which is a very undesirable condition.

104. Specific criteria for design of navigation protection elements were not included in the operational and design criteria developed in the initial project stages. These criteria will, to a certain degree, depend on whether a restricted operation condition is imposed on lock use and what measures are taken at specific locks to assist with moving traffic through the lock (i.e., use of helper boats, installation of traveling keels, etc.). Criteria for design of new structures is contained in EM 1110-2-2602, Plate 6, but this criteria may be too extreme for the short-duration repair period. In addition, we assume that tow operators would be aware of ongoing construction activities and presumably use greater care in moving through the lock.

105. To size navigation protection elements for this study, an impact energy of approximately 27.4 ft-kip perpendicular to the walls was selected. This is based on a 14,650-kip vessel moving at a 10° angle of attack at 2 ft/sec (1.2 knots). The navigation protection elements must provide energy absorption and be able to provide protection for the full range of expected pool elevations; and if contact with newly repaired surfaces is expected, low contact pressures must be maintained.

106. Three concepts were considered; horizontal truss elements, vertical post configurations, and pneumatic or foam filled marine (cell) fenders. The truss was eliminated because of the problem of accommodating water level fluctuations. The post concept, shown in Appendix D, resulted in large deflections under the impact load and high contact pressures and isn't as easily deployable as the fender system. The pneumatic or foam

filled fenders were selected due to their low contact pressures, and because they float, they provide protection at the critical impact zones under any water level condition. Details of the marine fender system are shown in the drawings in Appendix C.

107. The total reaction for the fender upon the 27.4 ft-kip impact will be about 60.5 kips, resulting in a contact pressure of about 21 psi. Under this load, the net deflection will be about 2.5 ft. The critical situation with this magnitude of deflection occurs when the water level is just above a refaced wall section and the fender is bearing against the blasted wall surface. At this location, the floating fender must be 5 ft in diameter by 6-1/2 ft long (1.2 m x 2 m) to provide the necessary standoff and energy absorption capability. A fender of this size will require that the lock be placed in a restricted operation mode. The fenders are arranged in series and held in position by guidelines connected to deadman anchors. During operation of the lock, all fenders will be interconnected. When repair work is in progress, the fenders can be locally disconnected and swung out of the way as shown in Drawing A86029-2, Appendix C.

Schedule

108. Schedule assessments were performed to verify how this repair concept would satisfy the study's objectives and criteria. A schedule for the entire lock was prepared to determine the length of time that the lock would be in a restricted operation mode. A daily schedule was also prepared to evaluate whether the 10-hour work day criteria would be satisfied.

109. In developing the schedule for the entire lock, the space constraints for workers and equipment in a confined area had to be considered along with the sequential nature of the work. Drawing A86029-2, Sheet 2 of 6, depicts how work activities might be arranged on any given day and how the work front might progress under these circumstances. Based on this scenario, the minimum time required to complete the rehabilitation of the generic lock would be approximately 62 working days. This includes time for replacement of the ladder monolith near the center of the lock using conventional cast-in-place procedures but excluding the gate bay monoliths.

110. Figure 17 presents this information in bar chart form. Allowing time for contingency and assuming 5-day work weeks, lock rehabilitation would take approximately 16 weeks to complete. Two weeks would be saved if 6-day work weeks are used. Figure 17 does not show the lead time required for the panel precasting operation or for the fabrication of the cofferdam and outfitting of the barge.

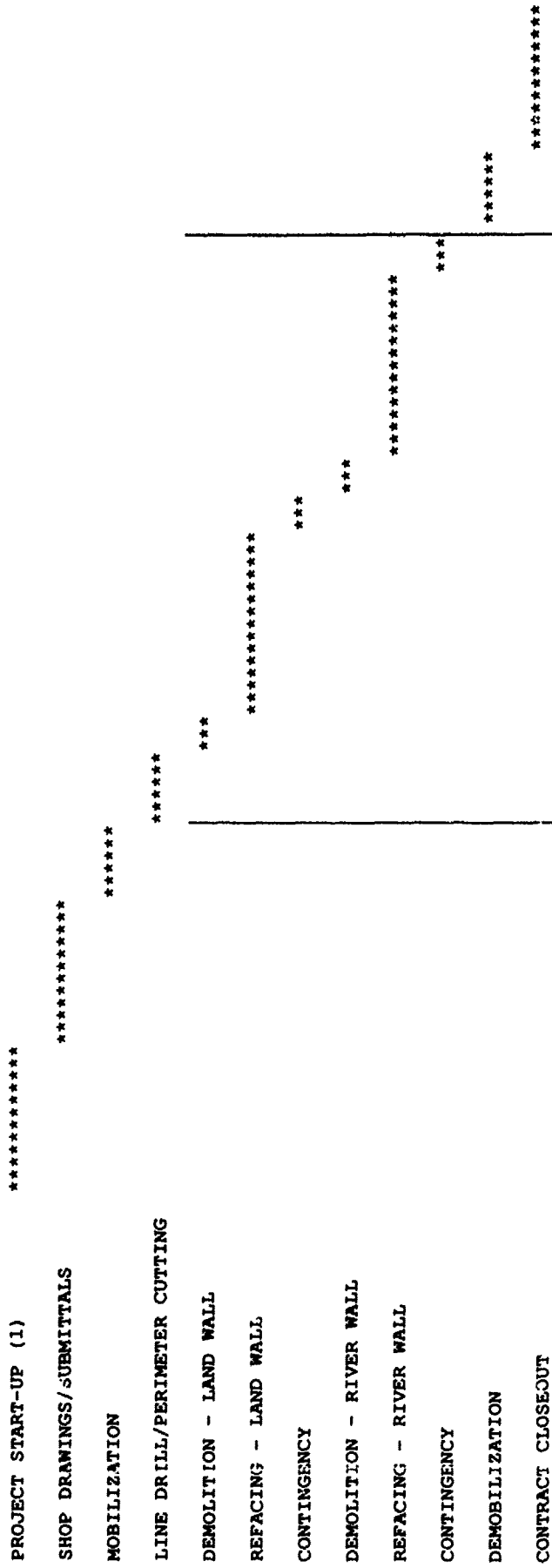
111. A daily schedule detailing specific work tasks is shown in Figure 18. This schedule suggests that a 10-hour work day will not be adequate for lock construction. While most of the construction activities can be completed in the 10-hour period previously specified, additional time is necessary for the backfill concrete to set and gain minimum strength prior to lock opening. Although the navigation protection system can be designed to minimize potential pressures from barge impacts, a minimum strength of 1000 psi should be specified at time of lock opening. Concrete mixtures capable of rapid strength gain can be developed from conventional materials but will require the use of site dispensed admixtures and careful monitoring of the entire backfill operation. Special cements or prepackaged mixtures are also available but these will have greater costs than the conventional material mixtures.

Cost Estimate

112. Costs for the rehabilitation of the generic lock using stay-in-place form panels in conjunction with a cofferdam are shown in Table 6. These were prepared in a manner similar to the concept cost estimates (See paragraphs 62 through 67). This estimate includes a more refined development of the labor requirements and reflects more accurate costs for the cofferdam and navigation protection. The estimated cost for rehabilitation of the generic lock is \$140/sq ft. This includes the two ladder monoliths at the center of the lock, which have been repaired assuming conventional cast-in-place repair procedures. Because the cost estimate includes a number of assumptions related to construction staffing and equipment, it is possible that an actual project might vary by $\pm 15\%$ from the generic

WEEKS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32



RESTRICTED LOCK OPERATION

NOTES: (1) Assumes panel precasting and cofferdam fabrication and outfitting have been completed.

LOCK REHABILITATION SCHEDULE
FIGURE 17

Task	HOURS											
	1	2	3	4	5	6	7	8	9	10	11	12
CONSTRUCTION MANAGEMENT CONSTRUCTION INSPECTION/QUALITY CONTROL	***** *****											
REMOVE NAVIGATION PROTECTION	**											
MOVE IN COFFERDAM BARGE & CRANE BARGE	**											
COFFERDAM OPERATIONS												
1 Position Cofferdam/Dewater	****											
2 Clean Monolith Surface	**											
3 Erect Panel A	**											
4 Drill Tie Holes (30 per Panel)	****											
5 Install Ties	****											
6 Complete Tie-to-Panel Connections	****											
7 Set Lower & Side Closure Forms	****											
8 Place Backfill Concrete	**											
9 Backfill Concrete Curing	****											
10 Remove Cofferdam/Lower & Side Forms	**											
WORK PLATFORM #1 OPERATIONS												
1 Install Work Platforms	**											
2 Clean Monolith Surface	**											
3 Erect Panel B	**											
4 Drill, Install, Connect Ties (15/Panel)	****											
5 Erect Panel C	**											
6 Drill, Install, Connect Ties (15/Panel)	****											
7 Set Side Closure Form	*****											
8 Place Backfill Concrete	**											
9 Backfill Concrete Curing	****											
10 Remove Work Platforms	**											
WORK PLATFORM #2 OPERATION												
1 Install Work Platforms	**											
2 Clean Monolith Surface	**											
3 Remove Side Closure Forms	**											
(Remaining activities are identical to Activities 3 to 14 for Work Platform #1)												
WORK PLATFORM #3 OPERATION												
1 Install Work Platforms	**											
2 Clean Monolith Surface	**											
3 Remove Side Closure Forms	**											
4 Erect Panel F	**											
5 Drill, Install, Connect Ties (15/Panel)	**											
6 Set Side Closure Form	****											
7 Place Backfill Concrete	*****											
8 Backfill Concrete Curing	**											
9 Remove Work Platforms	****											
REINSTALL NAVIGATION PROTECTION	**											
REMOVE COFFERDAM BARGE & CRANE BARGE	**											

SCALE: Two asterisks represent 1 hour
Number in parenthesis indicates labor hours.

CONSTRUCTION SCHEDULE FOR COFFERDAM REPAIR CONCEPT
FIGURE 18

TABLE 6

COST ESTIMATE FOR REHABILITATION OF A GENERIC NAVIGATION LOCK

Item Description	Unit	Quantity	Unit Cost	Total
Concrete Demolition	SF	39,270	\$ 50.00	\$1,963,500
Precast Panels (FOB Lock Site)	SF	34,560	25.00	864,000
Form Ties and Dowels (Mat'l Only)	EA	3,700	25.00	92,500
CIP Concrete				
Top Closure Pour (Labor & Mat'l)	CY	9	4,800.00	43,200.
Ladder Monolith	CY	107	2,400.00	256,800
Backfill Concrete (Mat'l Only)	CY	590	125.00	73,750
Labor - Refacing Only	HRS	34,500	45.00	1,552,500
Special Equipment & Tooling				
Navigation Protection	LS	1	65,000.00	65,000
Cofferdam	LS	1	80,000.00	80,000
Work Platforms (3 Sets)	MO	15	3,000.00	45,000
Tug and Crew	DAY	70	2,000.00	140,000
Crane Barge & Crane	MO	5	13,000.00	65,000
Supply Barge	MO	5	3,000.00	15,000
Cofferdam Barge	MO	5	5,000.00	25,000
Concrete Pumps (2 Sets)	MO	10	7,500.00	75,000
Miscellaneous Equipment	MO	5	22,000.00	110,000
Cofferdam Barge Outfitting	LS	1	50,000.00	50,000

TOTAL \$5,516,250
 COST/SQ FT \$ 140
 POTENTIAL RANGE (±15%) \$119 - \$162/SQ FT

COST ESTIMATE NOTES

1. See drawings in Appendix C for definition of the generic lock
2. Navigation protection costs have been based on surplus equipment
3. Cost Estimate Date: 12 July 1989

lock. The corresponding cost range would be \$119 to \$162/sq ft. For comparison, costs for an all cast-in-place repair, as shown in Table 1 of REMR-CS-7, were estimated at \$137/sq ft (1986 basis). A major component of this estimate is the demolition cost. The current estimate reflects a unit price nearly double than the one for Phase I. This is primarily due to higher clean-up costs in a wet lock and additional saw cutting costs.

113. One possible method of reducing the cost of this repair procedure would be to require that the cofferdam barge, cofferdam, navigation protection, and work platforms be delivered to the Corps at the conclusion of the project to be used for future rehabilitation projects.

Conclusions

114. This repair concept provides a means for keeping the lock in partial operation during rehabilitation. Not only does this benefit shippers using the lock but enables a choice of when the rehabilitation work is to be completed. Past repairs were performed only during periods when the locks could be taken out of service.

115. A phased development program has led to a limited implementation of this repair concept. A demonstration project extending the concept in a wet and operational lock would provide valuable information prior to its use at an actual lock site. However, due to the requirement for special equipment and tooling, such a demonstration project would be significantly more expensive than previous demonstration projects. However, the demonstration could demonstrate the following:

- Underwater Cutting to Define the Demolition Plane
- Other Demolition Techniques, such as Hydroblasting
- Rapid Deployment of the Cofferdam
- Special Rapid Cure Backfill Concrete Mixtures
- Use of Mechanical Ties to Assist with Panel Alignment
- New Bottom Panel Support Methods

116. The successful demonstration of these features would serve to reduce the number of additional items requiring development, as outlined in Paragraph 106 of REMR-CS-14, prior to full implementation of the repair

concept. The next logical extension of this repair concept would be to develop details for incorporating ladders and other typical lock hardware with the panels and for using stay-in-place form panels at locations of special geometry such as gate bays.

REFERENCES

ABAM Engineers Inc. 1987, "Design of a Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation," Technical Report REMR-CS-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

ABAM Engineers Inc. 1987, "A Demonstration of the Constructibility of a Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation," Technical Report REMR-CS-14, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

"Planning and Design of Navigation Lock Walls and Appurtenances," EM 1110-2-2602, June 1960, U.S. Department of the Army, Corps of Engineers, Washington, DC.

May, James G., and McDonald, James E. 1989 (June), "Monolith Joint Repairs: Case Histories," Technical Report REMR-CS-22, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

APPENDIX A: RESULTS OF QUESTIONNAIRES

**STAY-IN-PLACE FORMS FOR NAVIGATION LOCK REPAIR
PHASE III - WET CONDITION INSTALLATION**

QUESTIONNAIRE

Responder: SUMMARY
Title: _____
District: _____
Office Symbol: _____

I. BACKGROUND INFORMATION

Previous repairs to deteriorating navigational locks have included conventional cast-in-place concrete construction methods. Please indicate your level of experience with this type of rehabilitation:

- 1 NR (no response submitted)
- 1 No knowledge of repair procedure
- 5 Some knowledge of procedure but no direct involvement
- 14 Hands-on experience with actual repair
 - 5 Project management
 - 10 Design
 - 9 Construction

Please indicate your level of experience with the following features of lock wall repairs using the conventional cast-in-place concrete repair procedure:

- Familiarity with deteriorated conditions of lock wall surfaces
None 1 Some 6 Considerable 13 NR 1
- Familiarity with demolition techniques
None 2 Some 9 Considerable 9 NR 1
- Understanding of wall face preparation
None 1 Some 8 Considerable 11 NR 1
- Understanding of construction methods
None 1 Some 9 Considerable 10 NR 1

Experience with cracking problems of conventional repairs and the resulting concerns over long-term serviceability/durability

None 2 Some 7 Considerable 10 NR 2

How many projects have you been involved with directly?

4 3 0 1 1 4 2 0 5 12 5 5 3 6 4 4 0 3 NR 4 3

How many projects are you aware of?

8 7 1 NR 1 NR NR 2 20 18 10 7 9 9 10 9 0 8 NR 7 11

The following questions pertain to navigational lock repair using stay-in-place forms:

Have you read the Phase I report? Yes 13 No 7 NR 1

Have you read the Phase II report? Yes 10 No 10 NR 1

Have you watched the video report? Yes 8 No 12 NR 1

Have you inspected the demonstration installation after completion? Yes 3 No 17 NR 1

Do you think that lock wall rehabilitation using stay-in-place form panels is as viable as the conventional repair method?

More viable 4 About the same 12 Less viable 3 NR 2

Do you think this method can be used for localized repairs?

Yes 15 No 4 NR 2

Do you envision this repair procedure being used most frequently to repair entire lock wall surfaces or localized areas?

Entire surfaces 15 Localized repairs 3 DNR 2 Not at all 1

II. IDENTIFICATION AND DEFINITION OF KEY ISSUES

There are several key issues that are important in the development of procedures and details of navigation lock repair using stay-in-place form panels and, in particular, the installation of the lowest panel in a submerged condition. Please rate these in order of importance and provide comments as necessary. Note any issues that you feel should be added to this list.

Rating (see next page for Rating Summary)

_____ **Durability/Serviceability:** Do you feel that the wet condition installation presents any adverse or detrimental effects to the overall durability of the repair?

Yes 16 No 4 NR 1

Rating

_____ **Construction Cost:** Should this repair procedure be developed based on the absolute minimum construction cost?

Yes 2 No 18 NR 1

_____ **Construction Duration:** Should the development of the installation procedure be guided in the direction that reduces the overall construction period?

Yes 18 No 1 NR 2

_____ **Scheduled Lockages:** Should an installation procedure be developed that enables the greatest flexibility for use of the lock by vessels throughout the rehabilitation period?

Yes 18 No 2 NR 1

Additional Issues (please list)

1 The ability to grout behind the panels successfully without any voids occurring.

1 Stay-in-place forms are suitable for large major rehabilitation jobs. Localized repairs can be done during yearly maintenance shutdowns and result in a better quality product.

2 Significant bonding problems, especially in freeze-thaw circumstances between contact surfaces.

DNR Durability/Serviceability and Scheduled Lockages go hand in hand. Trying to work around tows affects quality of construction.

DNR Joint details appear critical to the installation -- a wet condition compounds the problem, especially bottom support.

DNR Panels subjected to freeze-thaw cycles may experience significant deterioration of joint material and material between the panels and the lock wall.

DNR Winter construction [in Minnesota].

Rating Summary	1	2	3	4	5	6
Durability/Serviceability	11	4	1	2		
Construction Cost		4	7	6	1	
Construction Duration	1	7	8	1	1	
Scheduled Lockages	4	2	2	9		1
Additional Issues	2	1				

Note: Three responders did not rate (DNR).

III. DEFINITION OF OPERATIONAL CONDITIONS

Please describe what you would consider a "typical" operations scenario for locks within your district:

How many lockages per day are typical?

Winter	Spring	Summer	Fall
<u>8</u>	<u>23</u>	<u>22</u>	<u>15</u>
<u>X</u>	<u>20</u>	<u>25</u>	<u>10</u>
<u>4</u>	<u>30</u>	<u>45</u>	<u>27</u>
<u>0</u>	<u>15</u>	<u>20</u>	<u>20</u>
<u>3</u>	<u>50</u>	<u>75</u>	<u>40</u>
<u>2-3</u>	<u>5-7</u>	<u>15-20</u>	<u>10-15</u>
<u>25</u>	<u>28</u>	<u>30</u>	<u>30</u>
<u>0</u>	<u>-</u>	<u>-</u>	<u>-</u>

The amount of time to complete one lockage cycle:

1/2 hr
1/2 hr
1/4 to 1-3/4 hrs
2 to 3 hrs
1/4 to 1/2 hr
2 hrs
20 min
1/2 to 3/4 hr

Percentage of capacity used during the typical lockage:

Winter	Spring	Summer	Fall	
<u>25</u>	<u>75</u>	<u>75</u>	<u>75</u>	
<u>X</u>	<u>75</u>	<u>75</u>	<u>25</u>	
<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>	(commercial)
<u>N/A</u>	<u>10</u>	<u>20</u>	<u>10</u>	(recreational)
<u>N/A</u>	<u>20</u>	<u>40</u>	<u>40</u>	
<u>4</u>	<u>67</u>	<u>100</u>	<u>1</u>	
<u>22</u>	<u>100</u>	<u>100</u>	<u>100</u>	
<u>85</u>	<u>85</u>	<u>85</u>	<u>85</u>	
<u>0</u>	<u>-</u>	<u>-</u>	<u>-</u>	

Please describe and quantify the type of traffic that use the locks.

Commercial Traffic:

Number/Day:	Winter	Spring	Summer	Fall
	<u>5</u>	<u>5</u>	<u>6</u>	<u>5</u>
	<u>X</u>	<u>3</u>	<u>4</u>	<u>4</u>
	<u>4</u>	<u>19</u>	<u>18</u>	<u>19</u>
	<u>3</u>	<u>5</u>	<u>10</u>	<u>4</u>
	<u>2-3</u>	<u>5-7</u>	<u>15-20</u>	<u>10-15</u>
	<u>25</u>	<u>28</u>	<u>30</u>	<u>20</u>
	<u>0</u>	<u>2</u>	<u>3</u>	<u>2</u>

Description:

Tug boats
Passenger vessels and tugs
Great Lakes freighter hauling, iron ore, grain, etc.
Tour boats, tug boats, fishing boats
Barge traffic
Tow boat with six standard barges
Tow boats

Typical Dimensions:

55 to 65 ft long, 20 ft wide
Varies
600 x 60 ft to 100 x 105 ft up to 70,000 tons each
30 x 100 ft (tour boat), 30 x 10 ft (tug and fishing)
15 barges with each at 35 x 135 ft
52 x 645 ft
NR

Please describe and quantify the type of traffic that use the locks.

Barge Traffic:

Number/Day:	Winter	Spring	Summer	Fall
	<u>5</u>	<u>6</u>	<u>6</u>	<u>5</u>
	<u>X</u>	<u>2</u>	<u>3</u>	<u>3</u>
	<u>N/A</u>	<u>1</u>	<u>2</u>	<u>1</u>
	<u>2</u>	<u>2</u>	<u>5</u>	<u>2</u>
	<u>2-3</u>	<u>5-7</u>	<u>15-20</u>	<u>10-15</u>
	<u>78</u>	<u>93</u>	<u>90</u>	<u>103</u>
	<u>0</u>	<u>2</u>	<u>3</u>	<u>2</u>

Description:

Scows/barges for grain, petrol, etc.
NR
Tug with barge hauling stone products, lumber, etc.
Tug boats
Barge tows
Tow boat with six standard barges
Tow boats

Typical Dimensions:

100 ft long, 30 ft wide
+40 ft
150 x 40 ft to 400 x 60 ft
30 x 10 ft
Tows consisting of 15 barges with each at 35 x 135 ft
52 x 525 ft
NR

Please describe and quantify the type of traffic that use the locks.

Recreational Traffic:

Number/Day:	Winter	Spring	Summer	Fall
	<u>5</u>	<u>58</u>	<u>42</u>	<u>42</u>
	<u>X</u>	<u>30</u>	<u>50</u>	<u>20</u>
	<u>N/A</u>	<u>16</u>	<u>42</u>	<u>7</u>
	<u>0</u>	<u>30</u>	<u>50</u>	<u>24</u>
	<u>-</u>	<u>-</u>	<u>5</u>	<u>-</u>
	<u>0</u>	<u>6</u>	<u>13</u>	<u>1</u>
	<u>0</u>	<u>12</u>	<u>24</u>	<u>12</u>

Description:

Motor yacht

NR

Tour boats, motorized and sail recreational craft

Sail boats, small boats to yachts

Pleasure craft

Pleasure craft

Pleasure craft, fishing boats

Typical Dimensions:

50 ft long, 15 ft wide

Varies

65 x 25 ft, 12 x 4 ft to 100 x 30 ft

5 to 120 ft long

16 to 90 ft

Varies

NR

Please describe and quantify the type of traffic that use the locks.

Military Traffic:

Number/Day:	Winter	Spring	Summer	Fall
	<u>4</u>	<u>2</u>	<u>2</u>	<u>1</u>
	<u>NR</u>	<u> </u>	<u> </u>	<u> </u>
	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>
	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
	<u>Very seldom</u>	<u> </u>	<u> </u>	<u> </u>
	<u>None</u>	<u> </u>	<u> </u>	<u> </u>
	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>

Description:

Jet fuel barges, landing craft
NR
U.S. Coast Guard, U.S. Navy

Typical Dimensions:

60 ft long x 30 ft wide
NR
140 x 37 ft to 300 x 74 ft

What are the average dimensions of the navigation locks in your district?

Overall Height (feet)	Lift Height (feet)	Width (feet)	Length (feet)	Extent Surface Deterioration Below Low Pool Level (feet)	Depth Surface Deterioration (feet)
30.0	15.0	110.0	600.0	1.0	1.0
25.0	15.0	110.0	600.0	0.1	0.5
-	-	110.0	600.0	limited	varies
40.0	10.0	110.0	600.0	-	-
40.0	15.0	110.0	600.0	1.0	0.75
32.0	2.0-3.0	80.0	600.0	1.0-2.0	7.0
40.0	13.0	110.0	600.0	minimal	0.2-1.5
54.0	30.0	110.0	800.0	-	-
25.9	8.2	56.0	720.0	15.0	10.0
31.0	11.0	110.0	600.0	3.0	1.0
-	15.0	110.0	600.0	2.0	0.5
25.0	3.0	73.0	600.0	-	-
40.0	17.0	44.4	495.0	10.0	1.0-1.5
56.0	21.0	88.0	1175.0	minimal	0.08
35.0	6.0	110.0	600.0	2.0	0.5
76.0	60.0	80.0	400.0	-	-

What construction-related restrictions would you foresee that would be imposed on any rehabilitation project?

To disallow rehabilitation which would reduce lock chamber width.

None desired by industry during navigation season.

The presence of contractor equipment and work crews inevitably impacts effectiveness of moving commercial traffic through locks.

Maximum amount of time that a lock could be taken out of operation (days):

Winter	Spring	Summer	Fall	NR <u>9</u>
<u>60</u>	<u>2</u>	<u>2</u>	<u>2</u>	
<u>75</u>	<u>60</u>	<u>60</u>	<u>60</u>	
<u>90</u>	<u>30</u>	<u>5</u>	<u>10</u>	
<u>16</u>	<u>2</u>	<u>2</u>	<u>2</u>	
<u>120</u>	<u>60</u>	<u>60</u>	<u>60</u>	(above Lock 19)
<u>60</u>	<u>60</u>	<u>60</u>	<u>60</u>	(below Lock 19)
<u>10</u>	<u>15</u>	<u>45</u>	<u>15</u>	
<u>90</u>	<u>-</u>	<u>-</u>	<u>-</u>	
<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	
<u>90</u>	<u>30</u>	<u>0</u>	<u>30</u>	
<u>70</u>	<u>0</u>	<u>0</u>	<u>0</u>	
<u>90</u>	<u>5</u>	<u>5</u>	<u>5</u>	

Maximum amount of time a lock could be closed on a daily, bi-daily, or other regular basis (hours):

Winter	Spring	Summer	Fall	NR <u>10</u>
<u>480</u>	<u>48</u>	<u>48</u>	<u>48</u>	
<u>24</u>	<u>8</u>	<u>4</u>	<u>8</u>	
<u>16</u>	<u>2</u>	<u>2</u>	<u>2</u>	
<u>24</u>	<u>4</u>	<u>4</u>	<u>4</u>	(above Lock 19)
<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	(below Lock 19)
<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	
<u>24</u>	<u>-</u>	<u>-</u>	<u>-</u>	
<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	
<u>24</u>	<u>12</u>	<u>8</u>	<u>12</u>	
<u>24</u>	<u>0</u>	<u>0</u>	<u>0</u>	
<u>24</u>	<u>8</u>	<u>8</u>	<u>8</u>	
<u>-</u>	<u>-</u>	<u>10</u>	<u>10</u>	

Is there a preferred time of the day to have the lock open to traffic?

Yes 6 No 5 When? 8:00 a.m. to 4:30 p.m. NR 11

Can the larger vessels be positioned to provide a 10-ft clear zone along one face of the lock?

Yes 7 No 7 NR 8

What is the maximum clearance that would be available for use during construction along one face of the lock? _____ft

NR 9

<u>35 ft</u>	<u>54 ft</u>	<u>56 ft</u>	<u>40 ft</u>
<u>5 ft full tows, 35 ft reduced tows</u>			
<u>30 ft</u>	<u>0 ft</u>	<u>15 ft</u>	<u>20 ft</u>
<u>1 ft</u>	<u>0 ft</u>	<u>0 ft</u>	<u>30 ft</u>

Can vessels be positioned to enable rehabilitation on opposite faces of lock walls over a 60-ft length of the lock?

Yes 3 No 11 NR 8

Are there other features that must be considered to maintain the lock in an operational condition during the rehabilitation period with respect to the area affected by the rehabilitation work?

Maintenance of Typical Lock Hardware Yes 8 No 9 NR 5
Interferences with Mechanical or Electrical Systems Yes 15 No 1 NR 6
Interferences with Gates Yes 15 No 2 NR 5
Completion of Demolition Work in Stages (Can an entire lock face be removed at one time or must the work proceed in a sequential, staged manner?) Yes 13 No 2 NR 7

Are there any special actions that can be taken to increase the efficiency or lockage turnaround time during the rehabilitation period?

Yes 12 No 2 NR 7

Provide helper boats to assist the tows in and out of locks

Eliminate width and use restrictions

Other Conditions (please list)

IV. TECHNICAL CONSIDERATIONS

The following questions pertain to the demolition of the deteriorated concrete:

What is the most likely condition of the lock wall face subsequent to the completion of the demolition?

NR 3
Reasonably smooth, well-defined plane surface (± 4 in.) 18
Moderately smooth, plane surface (± 8 in.) -
Highly irregular surface (greater than 12-in. variation) -

What average thickness of deteriorated concrete would be removed?

12 to 16 in.

Would it be practical to remove a greater amount of concrete immediately behind the lowest form panel if additional space is required to accommodate panel connections?

Yes 4 No 13 NR 4

Grinding machines which were developed by the mining industry are available for local excavations.

The usual removal method is blasting, which removes a uniform thickness.

What will be the typical condition of the bottom edge of the concrete demolition line using the most probable demolition method?

4 NR

4 Well-delineated plane that can provide panel support

6 Irregular plane that can be used to support panel but with _____ special hardware to account for greater elevation differences

7 No plane formed, concrete spalled off at its natural angle

Comments:

Well-delineated plane can be provided if full-depth sawcut is specified.

It is normal to specify 1-in.-deep sawcut; a wider sawcut can be detailed.

Are there demolition techniques available that can provide a smooth, well-defined plane (below low pool elevation) at least as wide as the panel thickness?

4 NR

3 None at this time considered as "proven technology"

10 Available but with a moderate cost penalty

4 Available but extremely costly

Comments:

Methods are available but these are not always successful.

Wire cutting is another possible method.

Sawcutting has been accomplished underwater on vertical cuts. Underwater sawcutting requires an air-driven saw.

Methods are available but require a dewatered lock.

Have you had any ideas for the stay-in-place form system different than those proposed and demonstrated during the work completed to date?

Panel size of 6 ft by 30 ft

NR 10 Suitable 6 Other Larger 5

Panel tie system

NR 13 Suitable 5 Other Mechanical 1

Panel joint detail

NR 14 Suitable 1 Other Stud anchors 1 1

Miscellaneous details

NR 14 Suitable 6 Other Preplaced aggregate and grout backfill

Are you aware of any recent developments in construction materials or methods which would be beneficial to the stay-in-place form concept?

NR 1

No 13

Yes 1 Description: (not provided)

V. OTHER CONSIDERATIONS

Please list any other considerations that you might have that have not been covered herein and would be pertinent to the development of the installation of the lowest form panel or the stay-in-place form concept.

On-site fabrication.

To what extent divers will be used.

Dewatering requirements.

Use bolted connection at bottom panel in lieu of welding, as currently developed through REMR program.

Underwater preparation of concrete surface and underwater cleaning of concrete surface would be difficult. Also, keeping the prepared surface clean until grouting is complete is difficult underwater.

Repair procedure is mainly applicable to large areas or entire locks and viable if excellent bond was assured between the panel and new concrete contact surfaces, especially in resisting freeze/thaw cycle separation.

Possible ice buildup behind panels.

Lock dewatering or localized dewatering to provide uniform bottom surface to install lowest panel (for precast system).

STAY-IN-PLACE FORMS FOR
NAVIGATION LOCK REHABILITATION

PHASE III - WET CONDITION INSTALLATION

List of Responders to Questionnaire

Office	Number
Waterways Experiment Station	1
Rock Island District Office	10
Chicago District Office	1
North Central Division Office	1
Nashville District Office	1
Pittsburg District Office	1
Norfolk District Office	1
New York District Office	1
North Atlantic Division Office	1
New England Division Office	1
Detroit District Office	1
St. Paul District Office	<u>1</u>
Total	21

D:A86029

STAY-IN-PLACE FORMS FOR
NAVIGATION LOCK REHABILITATION

PHASE III - WET CONDITION INSTALLATION

List of Attendees

Design Criteria Meeting
Rock Island District Office
29 September 1988

Attendee	Office
Jim McDonald	CEWES-SC-R
Denny Lundberg	CENCR-ED-DM
Jerry Wickersham	CENCR-ED-G
Eugene Ardine	CEORD-ED-T
Sam Doak	CENCR-ED-D
Warren Parr	CENCR-CD-P
Ed Karwatka	CENCR-ED-Q
Mike Edwards	CENCR-CD-Q
Jim Bigham	CENCR-ED-DS
Fred Joers	CENCR-ED-DS
Al Bondoc	CENCC-CO-OM
Joe Jacobazzi	CENCD-ED-TT
Steve Russell	CENCR-OD-MS
Ed Leuch	CENCR-OD-P
Terry Nettles	ABAM Engineers
Elmer Ozolin	ABAM Engineers

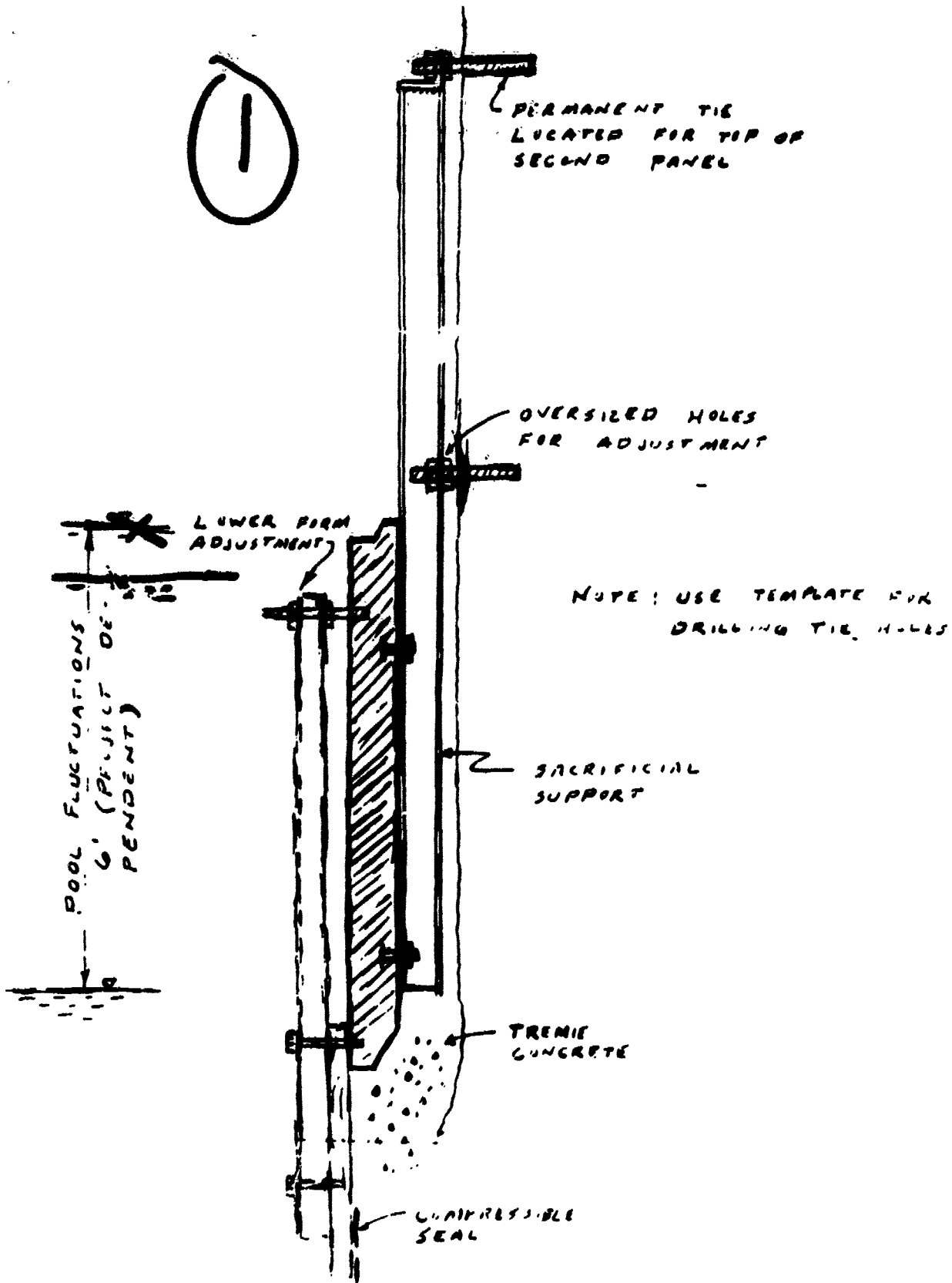
D:A66029

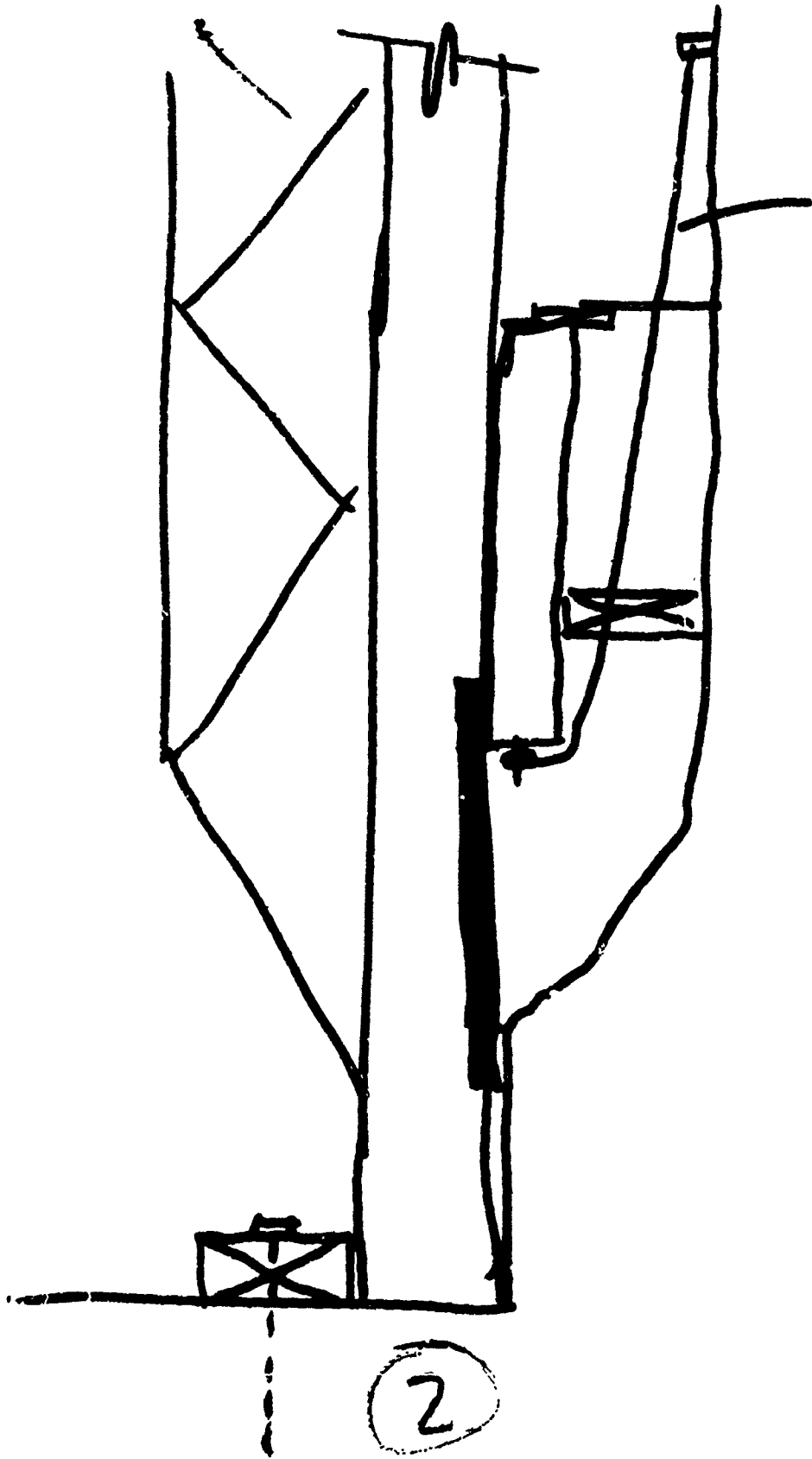
APPENDIX B: PRELIMINARY CONCEPT DEVELOPMENT

SUMMARY OF CONCEPTS DEVELOPED
DURING WORK SESSION

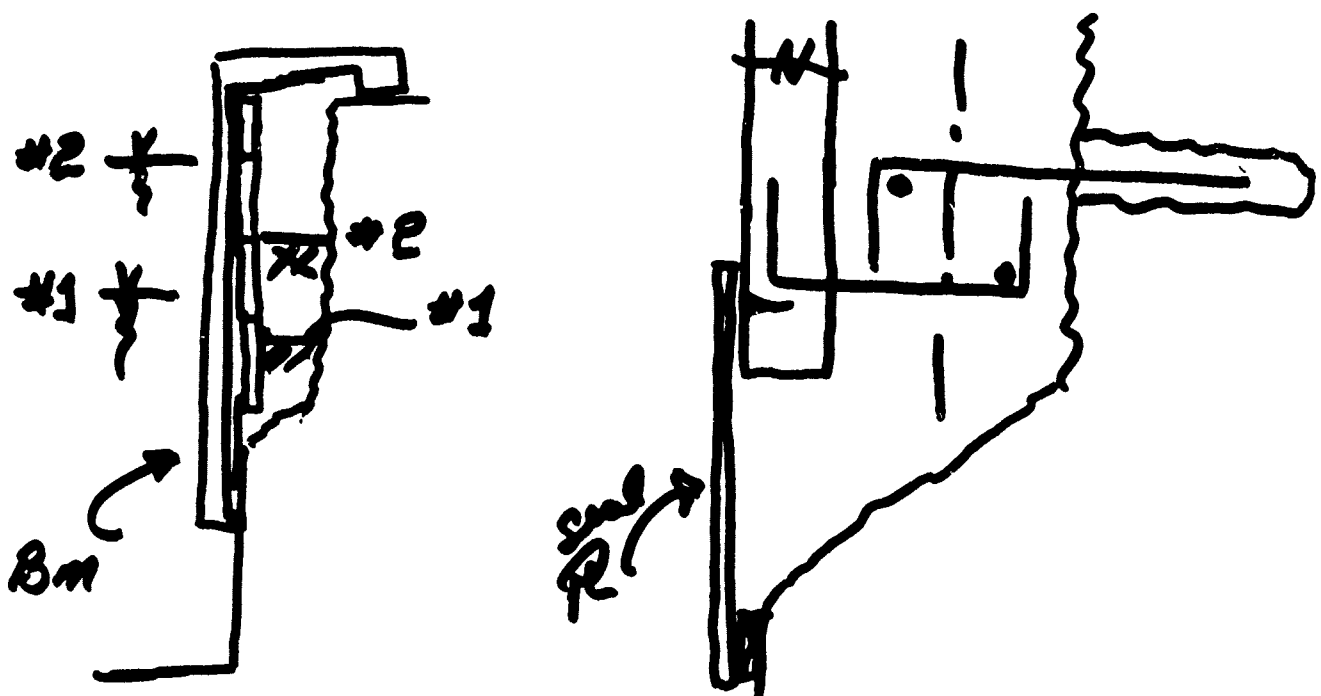
1	Sacrificial Interior Guide Beam Concept	B2
2	Wire Rope Hangers/External Brace Concept	B3
3	External Water Pressure Braced Scheme	B4
4	Threaded Rod Concept	B5
5	Doweled in Guide Bar	B6
6	Vertical Beam Support Means	B7
7	Diagonal Tie Scheme	B8/9
8	Barge-Braced Cofferdam Concept	B10
9	Scheme with CIP Lower Pour Base Ledge	B11
10	Ribbed Panel - External Pressure Scheme	B12
11	Sacrificial Rail System	B13
12	Hanging Panel Concept	B14

①



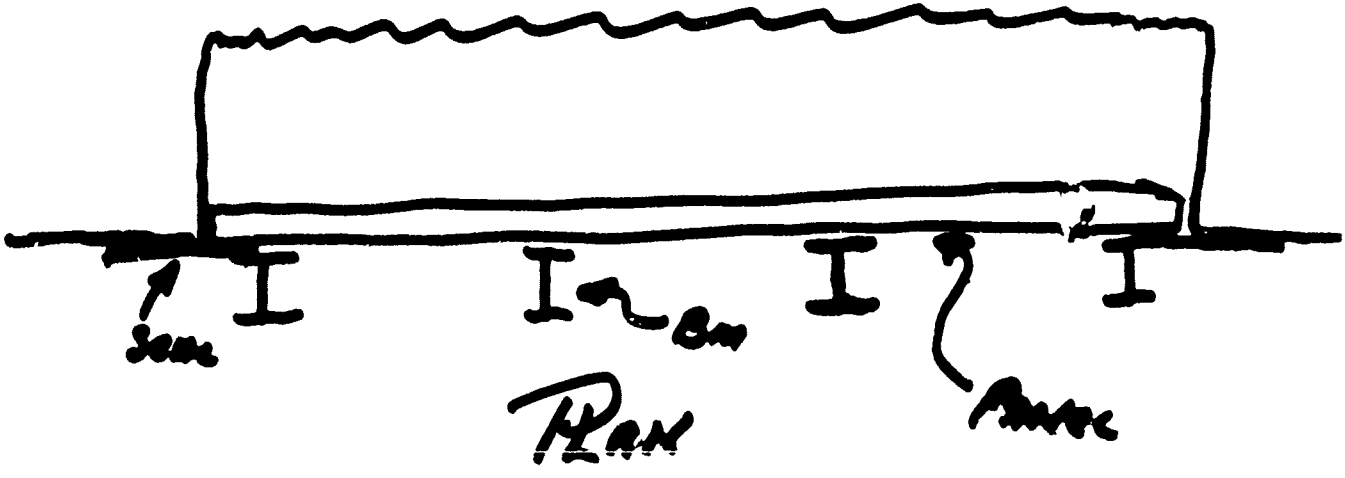


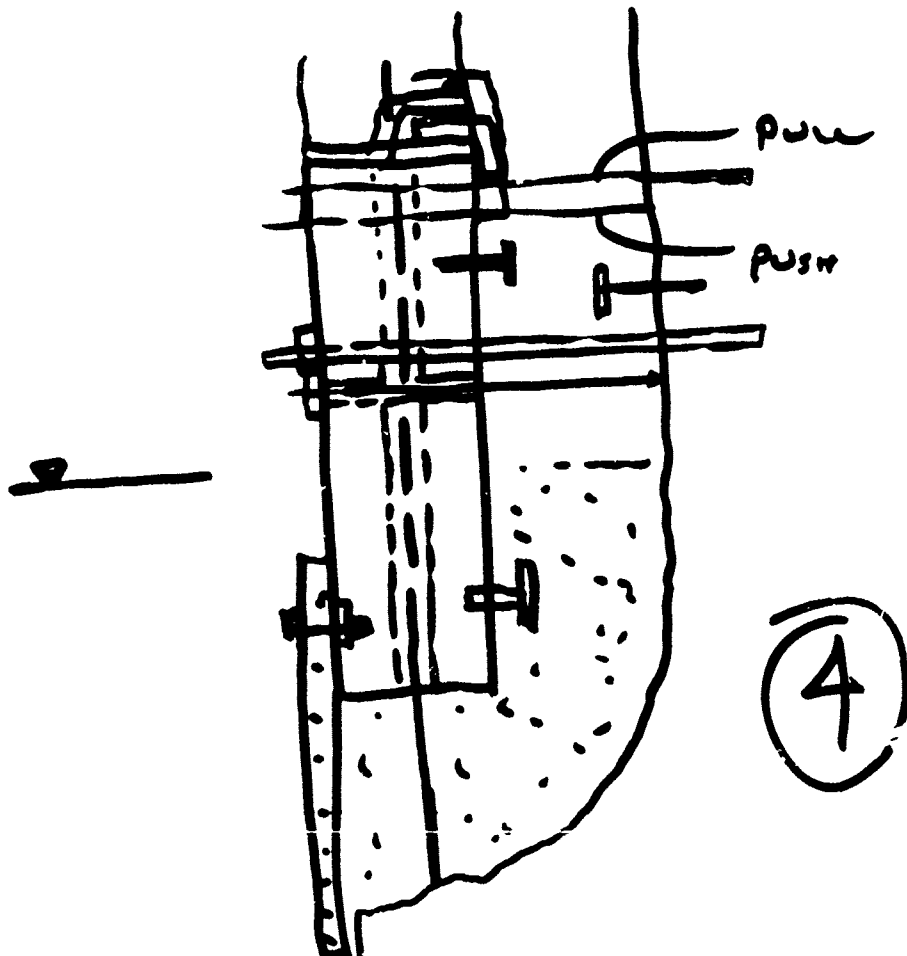
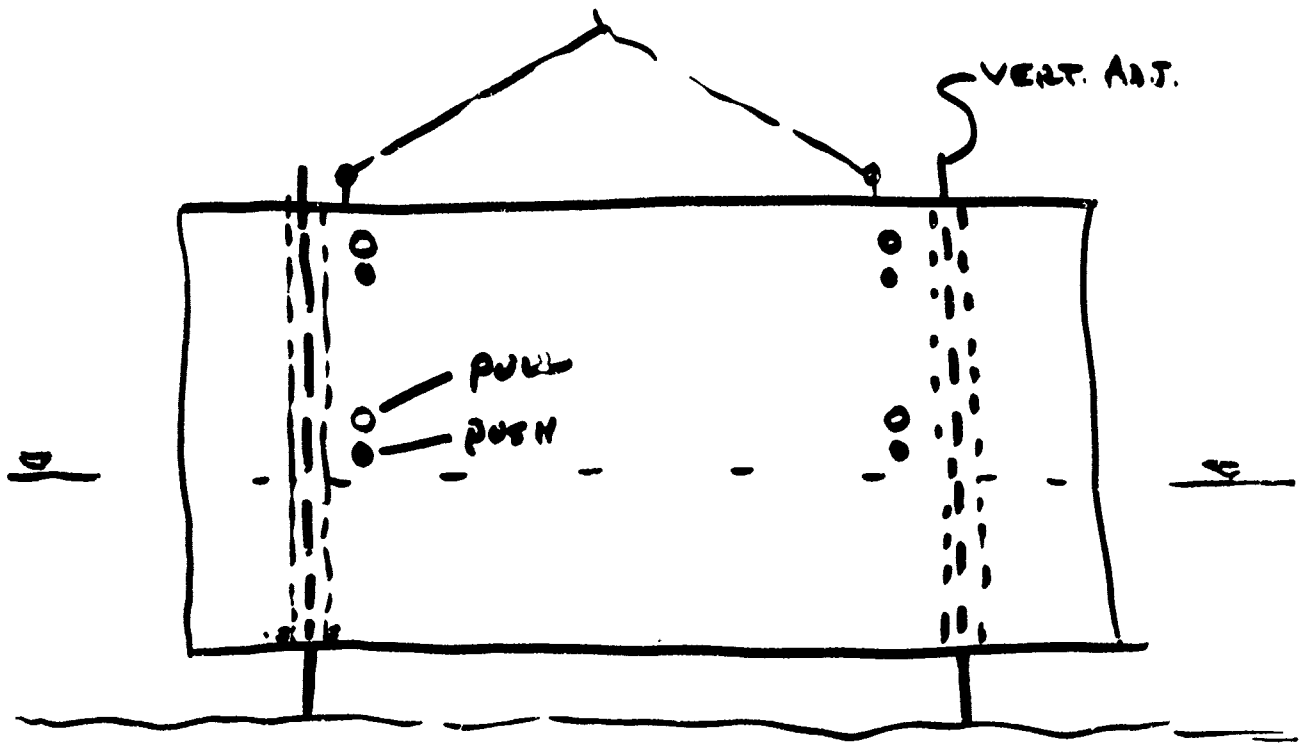
SACRIFICIAL
P/B STRAND
W/END LOOPS

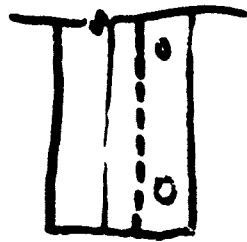


3

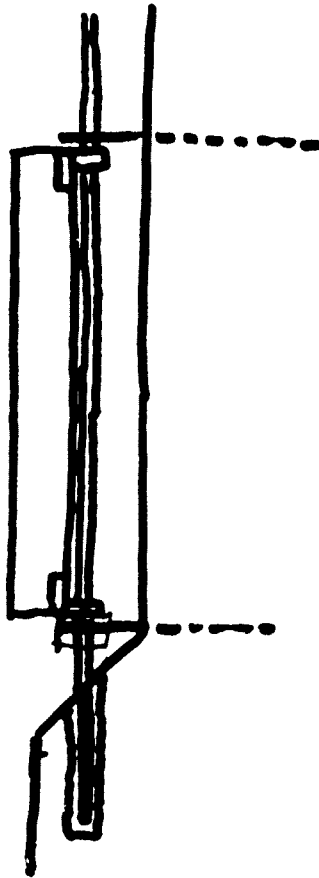
40' ± NOMINAL





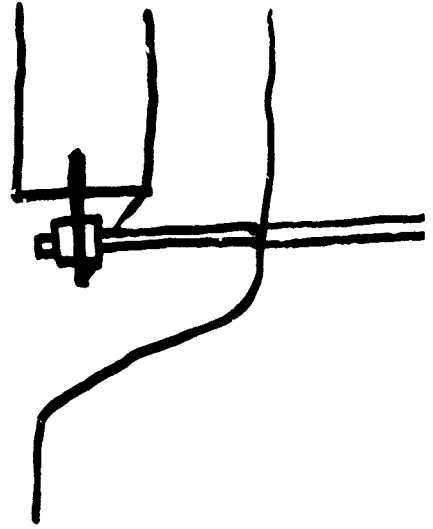
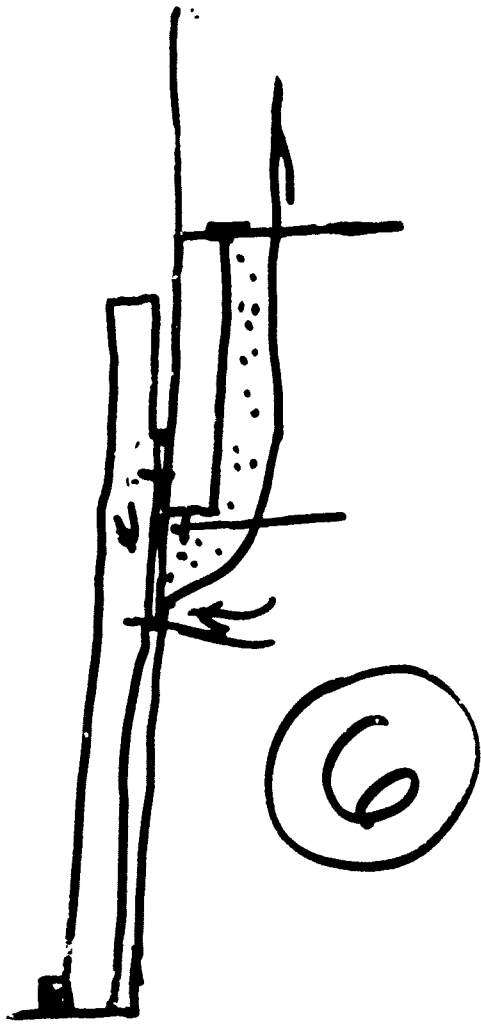


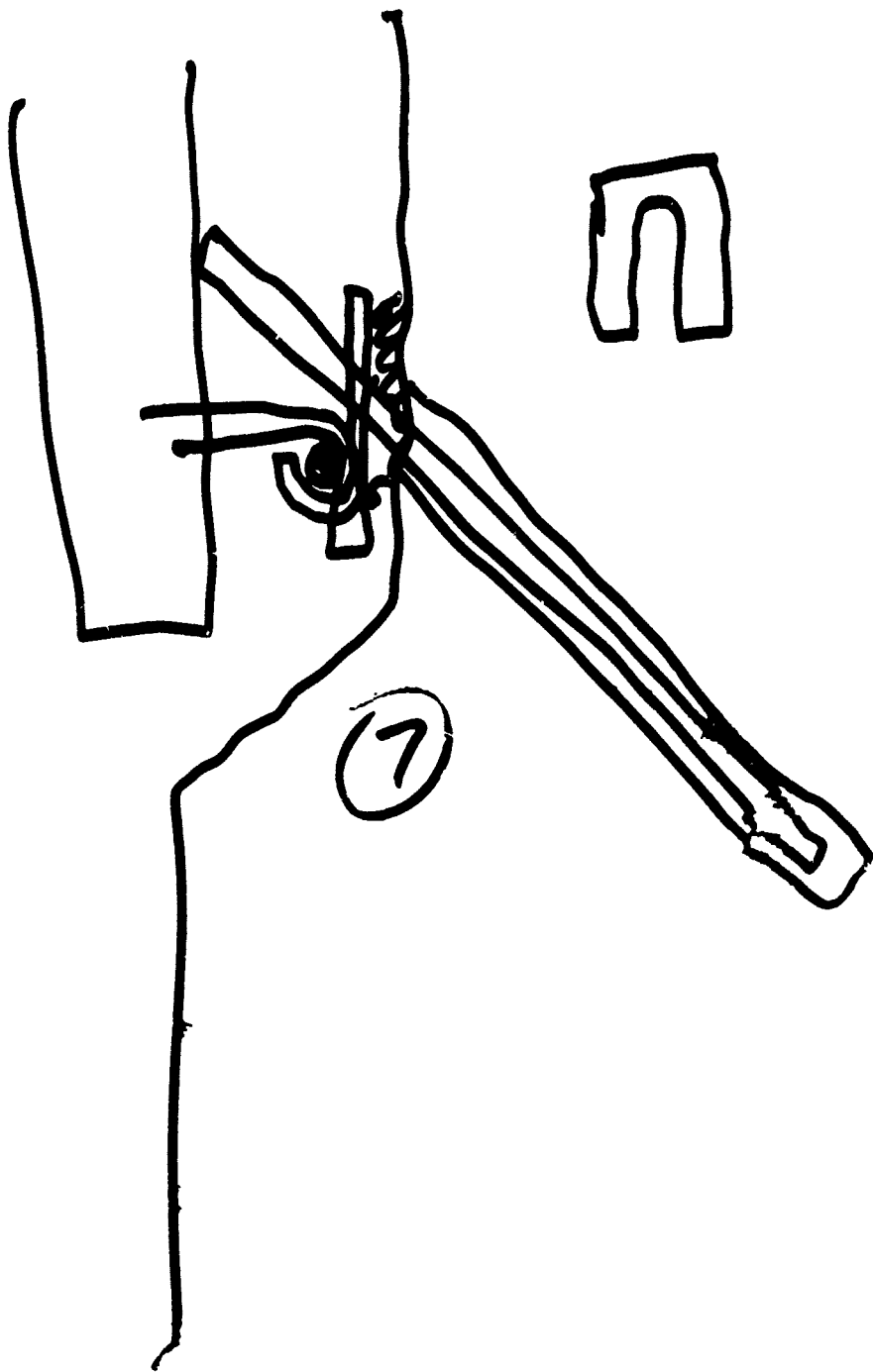
PLAN

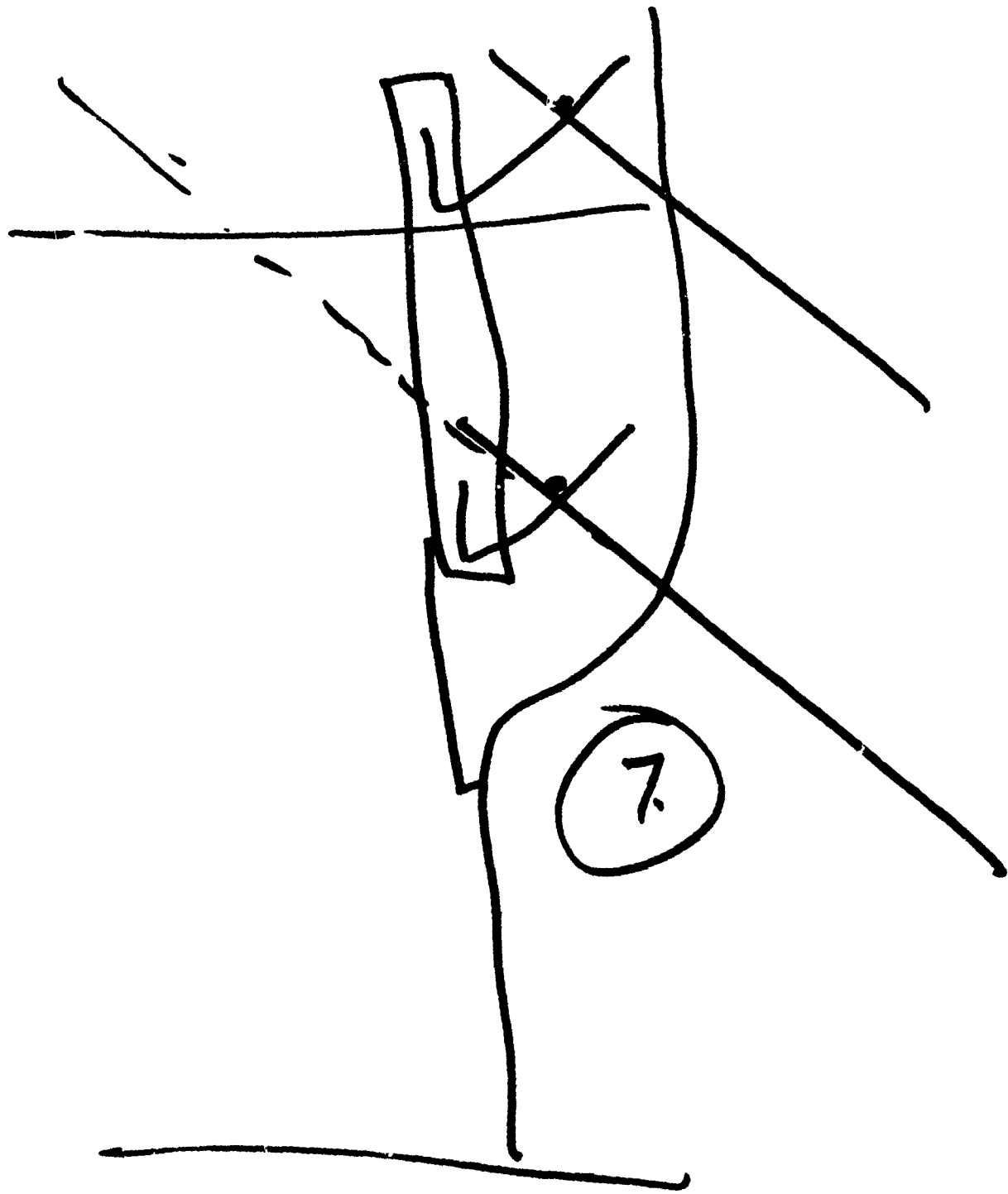


ELEV

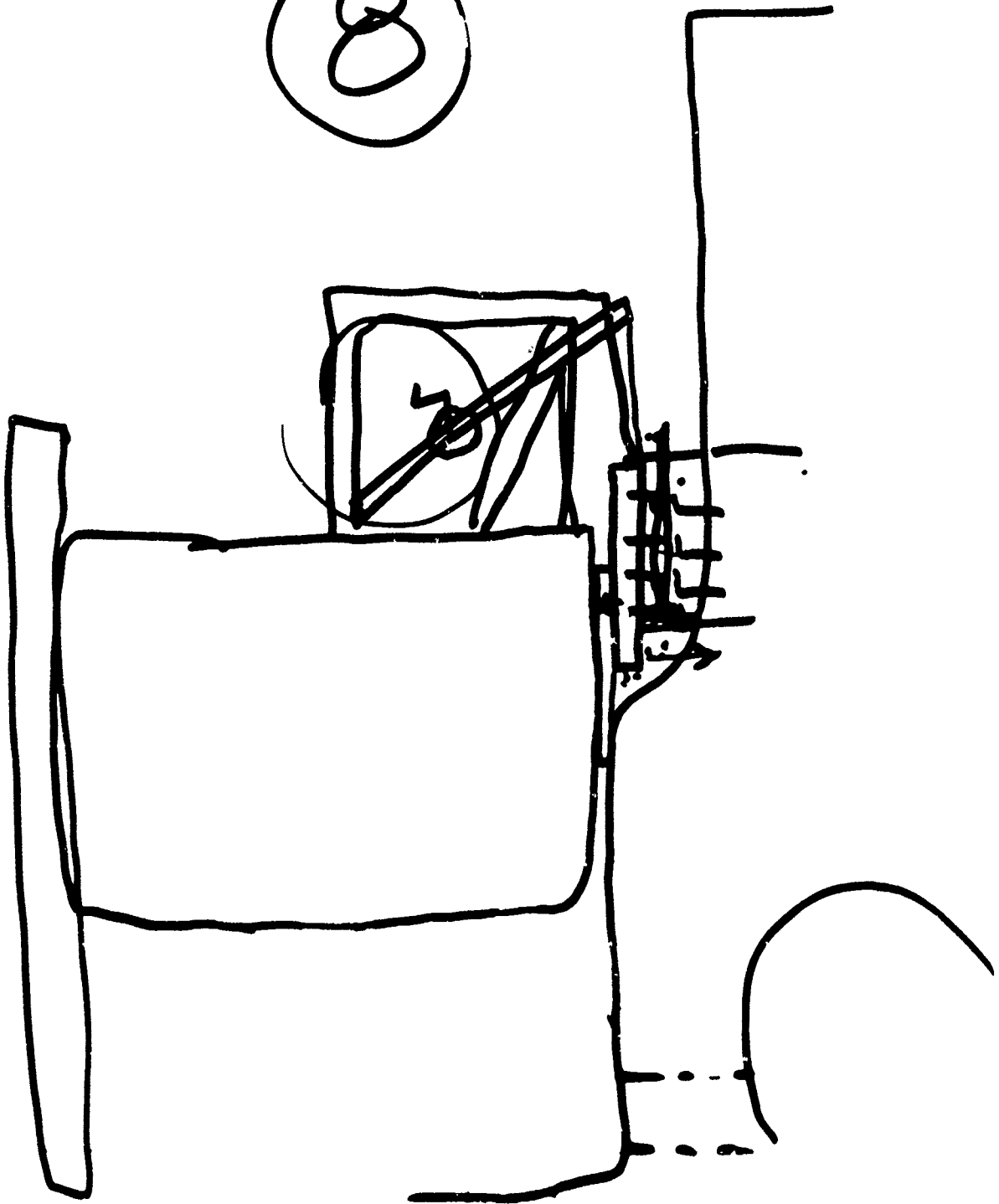
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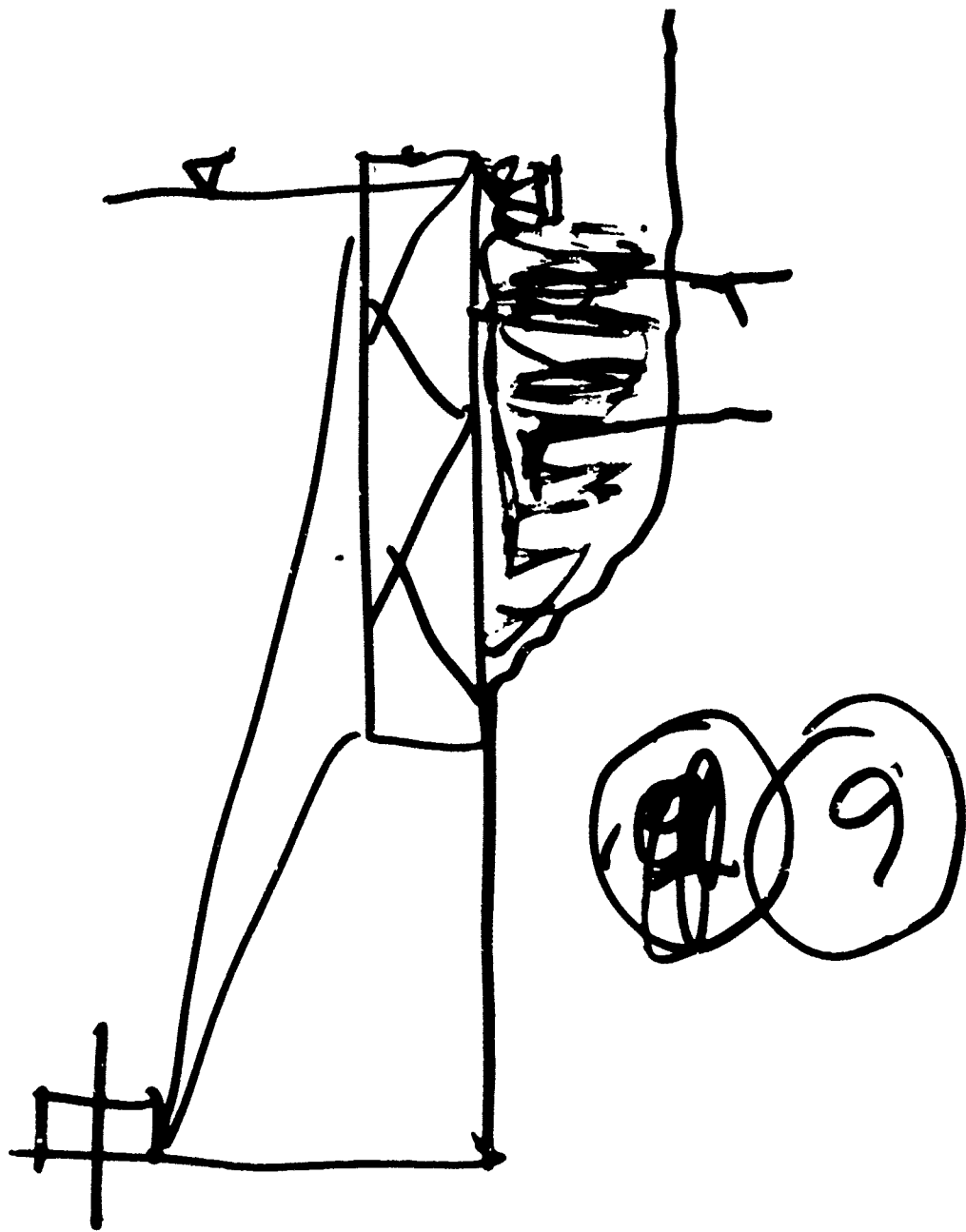


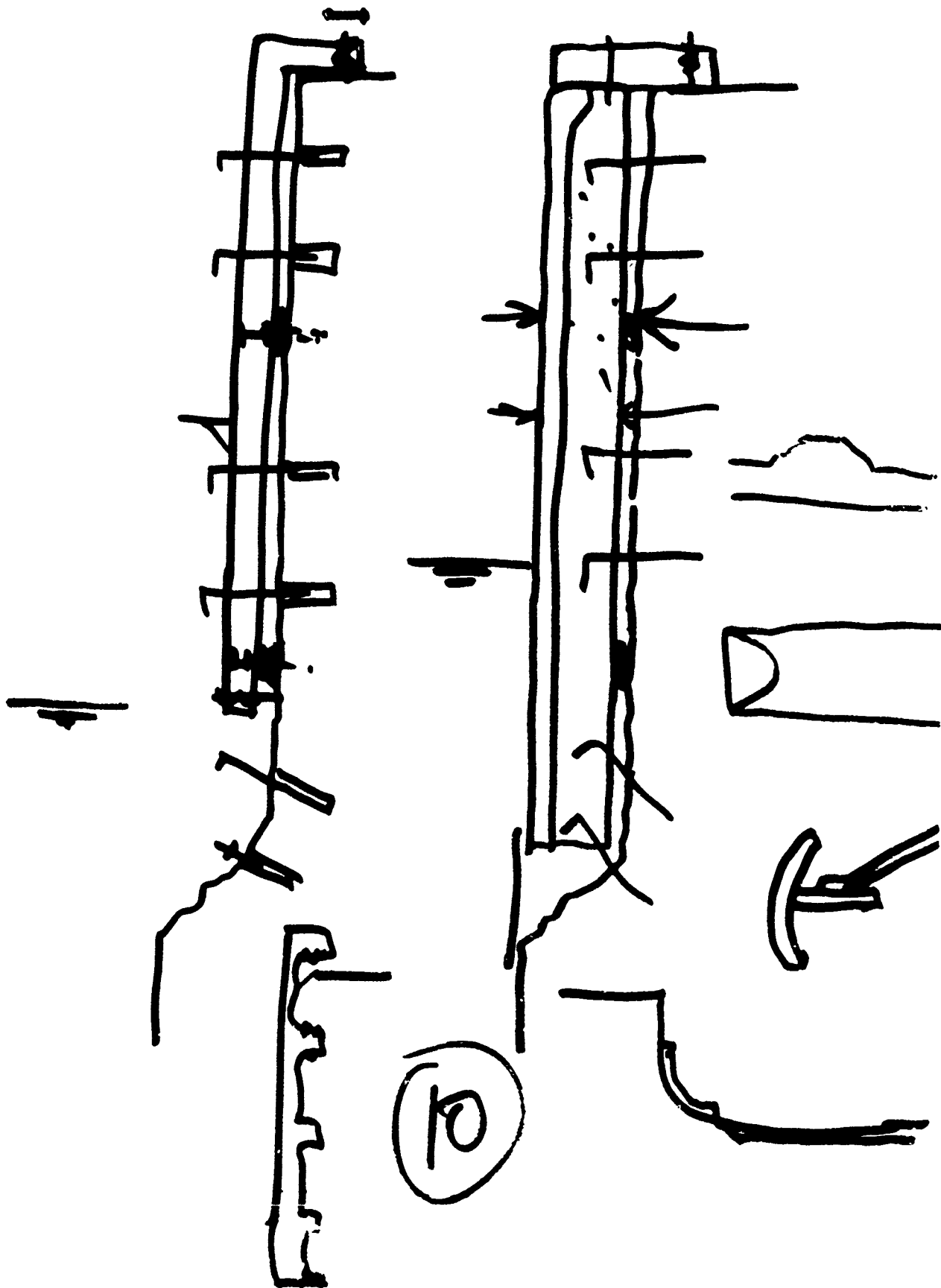


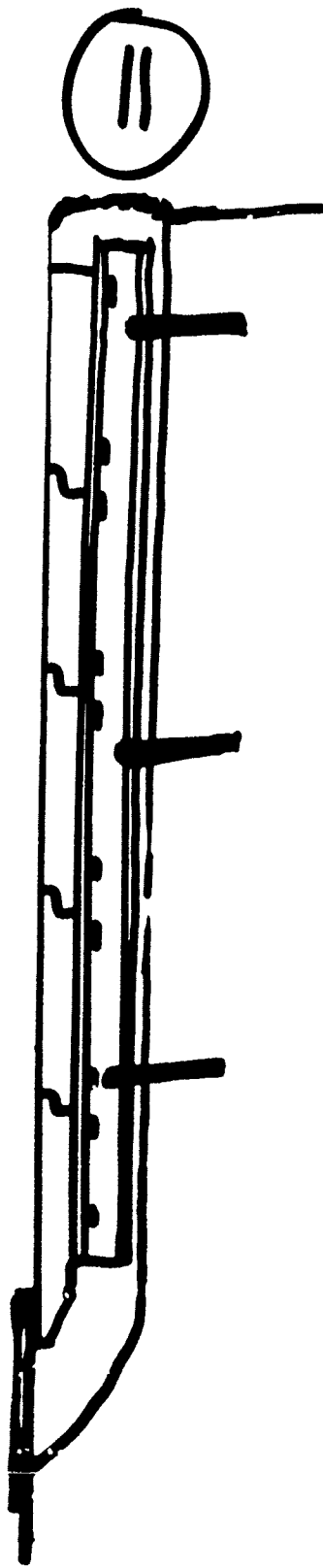


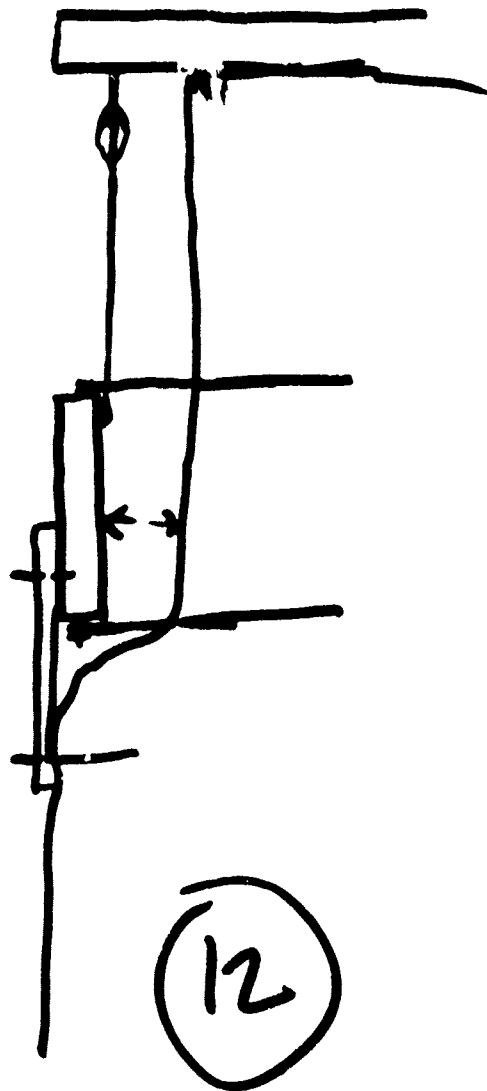
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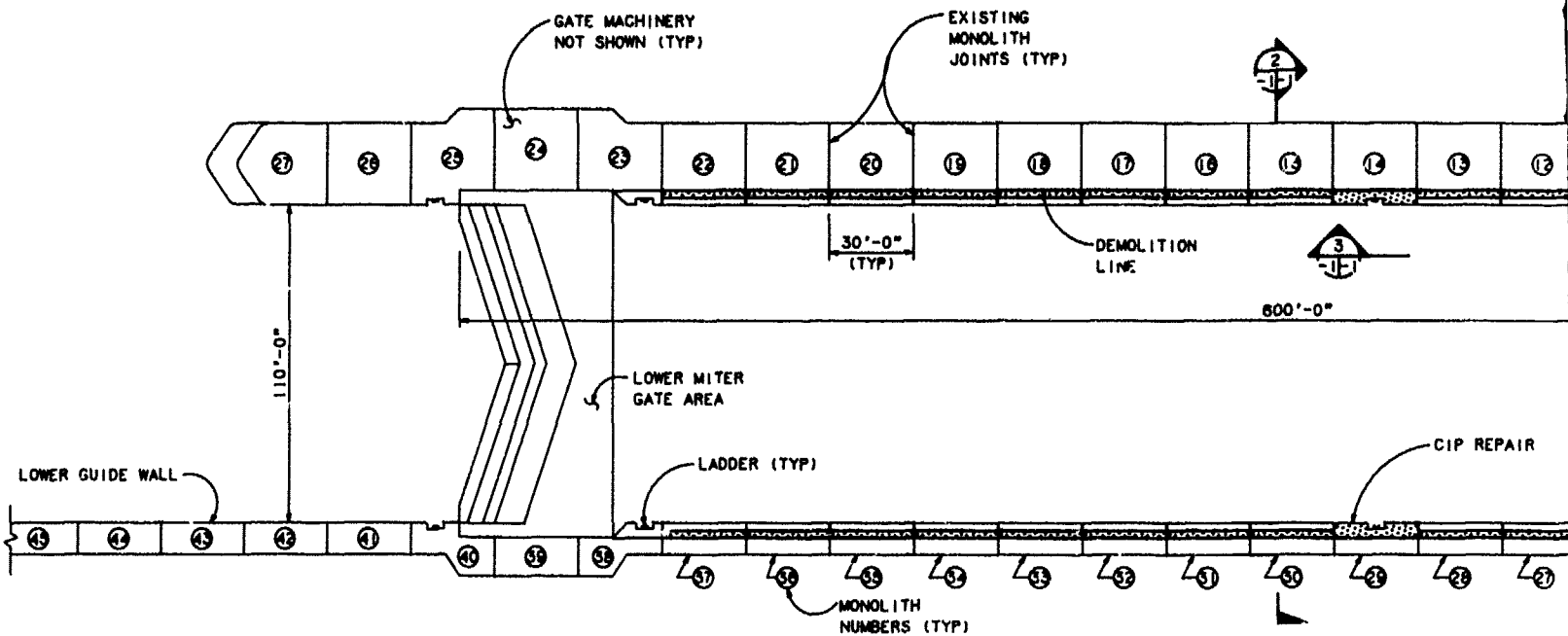




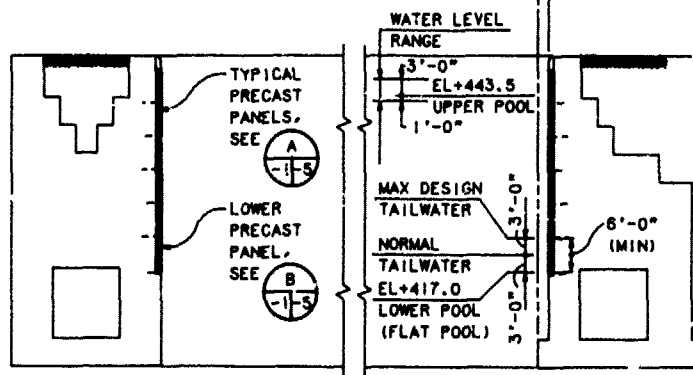




APPENDIX C: DRAWINGS

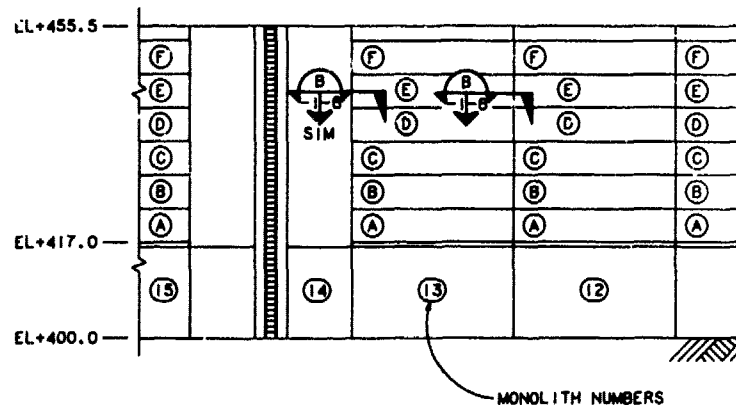


AVAILABLE CLEARANCE WHEN
LOCK IS IN OPERATION
NO USE RESTRICTIONS - 2 FT
W/WIDTH RESTRICTIONS - 10 FT



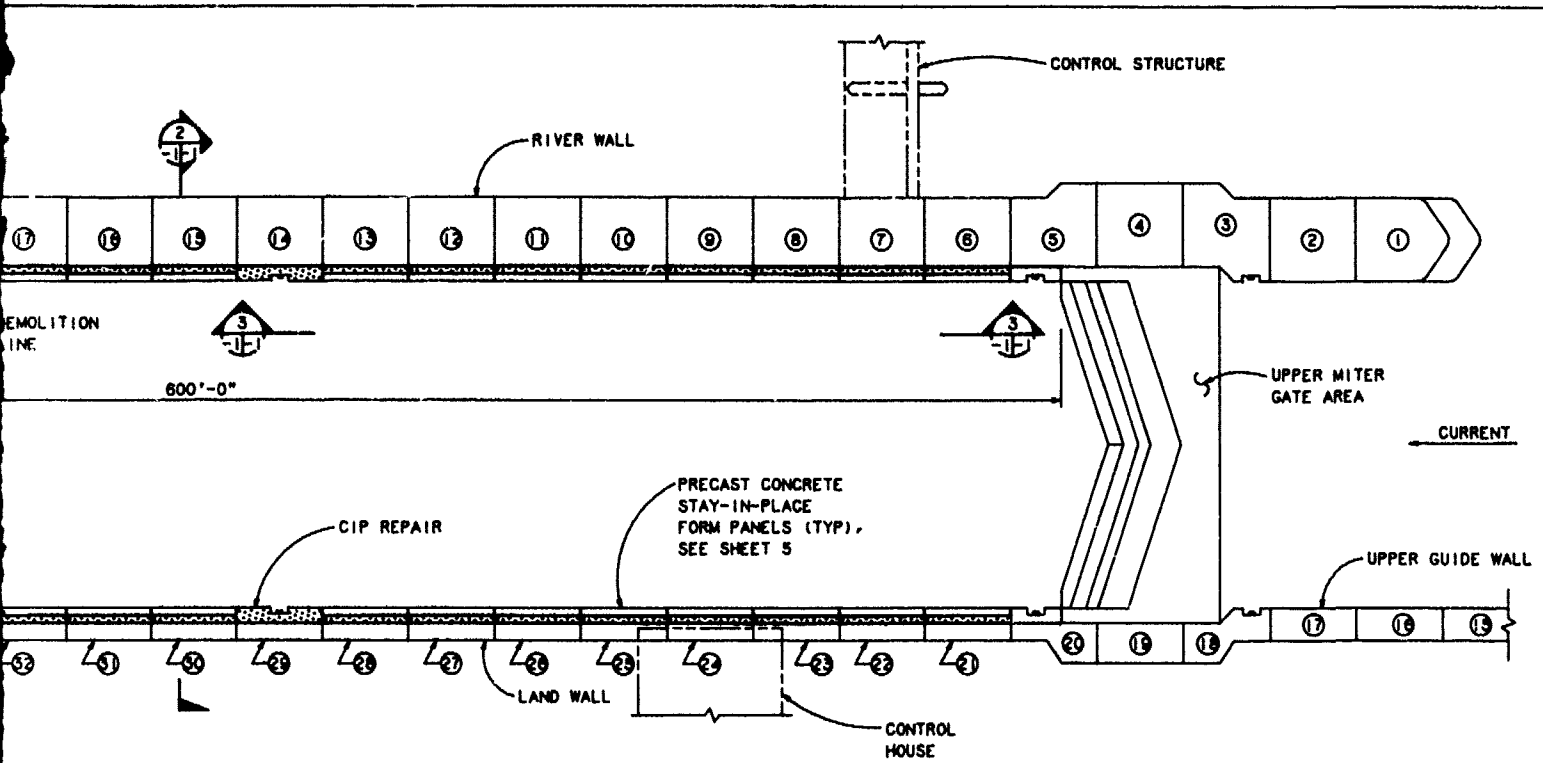
SECTION
SCALE: 1/16"=1'-0"

PLAN @ PANEL ELEVATION
SCALE: 1"=30'-0"

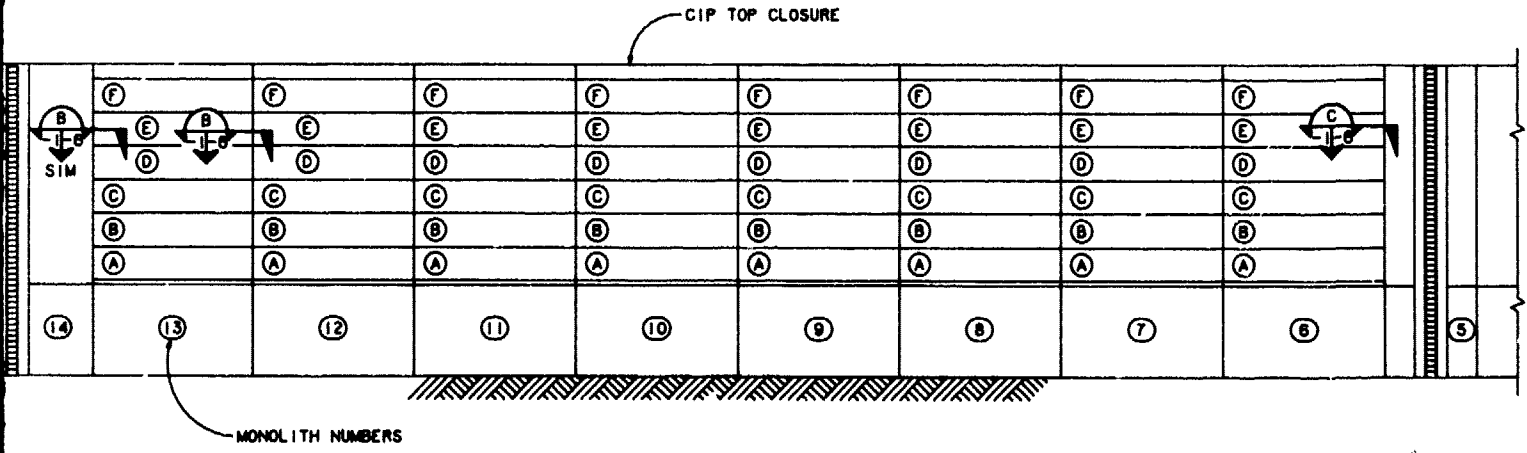


NOTES:

1. THESE DRAWINGS DEFINE THE WORK REQUIRED TO REHABILITATE THE LOCK WALLS FOR A GENERIC NAVIGATION LOCK USING PRECAST CONCRETE STAY-IN-PLACE FORM PANELS.
2. THE WORK WILL BE PERFORMED WHILE THE LOCK REMAINS OPERATIONAL. THIS REQUIRES THAT ALL LOCK UTILITY SYSTEMS SUCH AS ELECTRICAL AND MECHANICAL (GATES, VALVES, ETC) REMAIN FUNCTIONAL. THE LOCK SHALL BE MADE AVAILABLE TO RIVER TRAFFIC A MINIMUM OF 12 CONSECUTIVE HOURS EVERY DAY. THE WORK IN PROGRESS SHALL BE PROTECTED TO PREVENT DAMAGE TO NEW CONSTRUCTION OR DAMAGING THE WATERBORNE VESSELS USING THE LOCK. TO PROTECT INSTALLED PANELS, THE LOCK SHALL NOT BE REOPENED UNTIL THE BACKFILL CONCRETE HAS BEEN PLACED AND HAS ATTAINED THE REQUIRED MINIMUM STRENGTH.
3. THE DETERIORATED CONCRETE EXTENDS TO LOWER OR FLAT POOL LEVEL. HOWEVER, THE NORMAL TAILWATER MAY BE 0-TO 6 FT ABOVE FLAT POOL SO THE LOWEST PANEL WILL PROBABLY BE SUBMERGED. THE CONTRACTOR SHALL USE A COFFERDAM FOR INSTALLING THE LOWEST PANEL IN ORDER THAT ALL WORK FALLING BELOW THE NORMAL TAILWATER LEVEL IS PERFORMED UNDER "DRY" CONDITIONS.
4. ANY ACCEPTABLE DEMOLITION METHOD, AS NOTED IN THE SPECIFICATIONS, MAY BE USED TO REMOVE THE DETERIORATED CONCRETE. THE DEMOLITION SHALL BE PERFORMED IN A SEQUENCE THAT MAINTAINS AN ENTIRE LOCK WALL (LAND WALL OR RIVER WALL) AND AVAILABLE AS A CONTACT SURFACE FOR VESSELS USING THE LOCK. PRIOR TO DEMOLITION, THE ENTIRE PERIMETER OF THE AREA TO BE DEMOLISHED MUST BE DELINEATED WITH A FULL DEPTH CUT (SAWCUT OR HYDRODEMOLITION). SUBSEQUENT TO THE DEMOLITION AND CLEANUP, THE LOCK FLOOR SHALL BE SWEEPED TO VERIFY THAT THE CLEARANCE REQUIRED FOR NAVIGATION IS PROVIDED.
5. THE CONSTRUCTION METHODS AND SEQUENCES SHOWN IN THE DRAWINGS ARE FOR INFORMATION PURPOSES. IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO PROVIDE ALL TOOLING (COFFERDAMS, NAVIGATION PROTECTION DEVICES, WORK PLATFORMS, ETC) REQUIRED TO COMPLETE THE CONSTRUCTION.



PLAN @ PANEL ELEVATIONS
SCALE: 1"=30'-0"



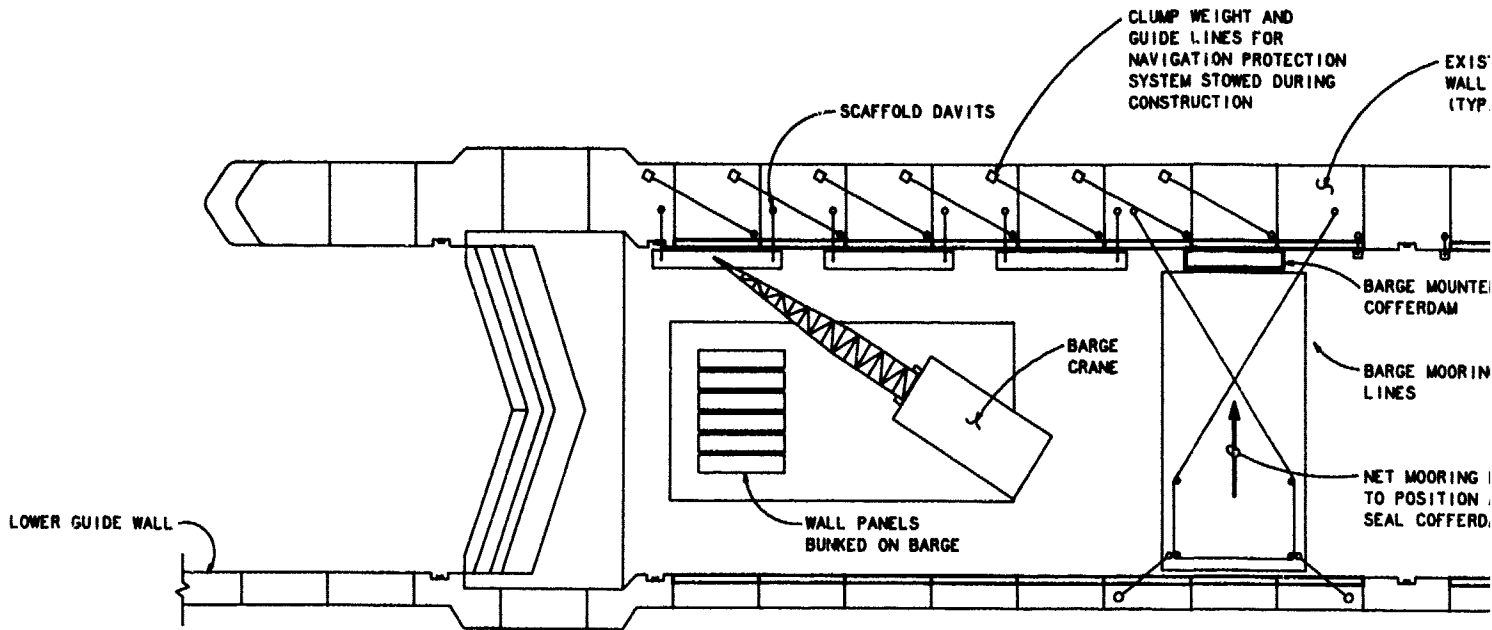
ELEVATION - RIVER WALL
SCALE: 1/16"=1'-0"

...METHOD, AS NOTED IN THE SPECIFICATIONS, MAY BE
...ORATED CONCRETE. THE DEMOLITION SHALL BE PERFORMED IN
...AS A ENTIRE LOCK WALL (LAND WALL OR RIVER WALL) INTACT
...ACT SURFACE FOR VESSELS USING THE LOCK. PRIOR TO
...PERIMETER OF THE AREA TO BE DEMOLISHED MUST BE
...DEPTH CUT (SAWCUT OR HYDRODEMOLITION). SUBSEQUENT TO
...UP, THE LOCK FLOOR SHALL BE SWEEPED TO VERIFY THAT THE
...NAVIGATION IS PROVIDED.

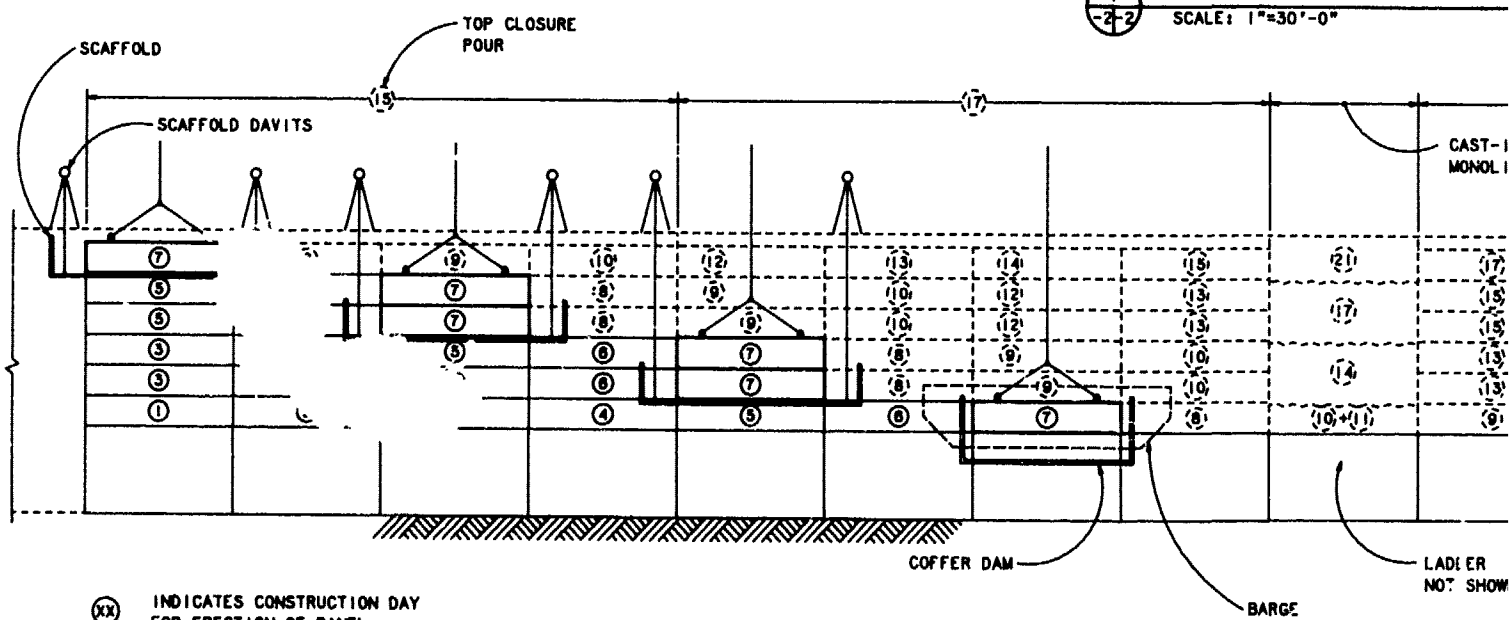
...AND SEQUENCES SHOWN IN THE DRAWINGS ARE FOR
...T SHALL BE THE CONTRACTORS RESPONSIBILITY TO PLAN AND
...ERDAMS, NAVIGATION PROTECTION DEVICES, WORK PLATFORMS,
...E THE CONSTRUCTION.

SYMBOL	DESCRIPTION	DATE	APPROVED

FILE NO. AB6029-345-GC	REVISIONS 1. GENERIC NAVIGATION LOCK WALL REHABILITATION 2. GENERAL ARRANGEMENT	U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VIGNONNE, MISS. AB6029-1
DESIGNER: E. OZOLIN	CHECKED BY: E. OZOLIN	DRAWN BY: T. NETTLES
	DATE: 12 JULY 1988	SCALE: AS NOTED
SHEET 1 OF 8		



1 PLAN - CONSTRUCT
-2-2 SCALE: 1"=30'-0"

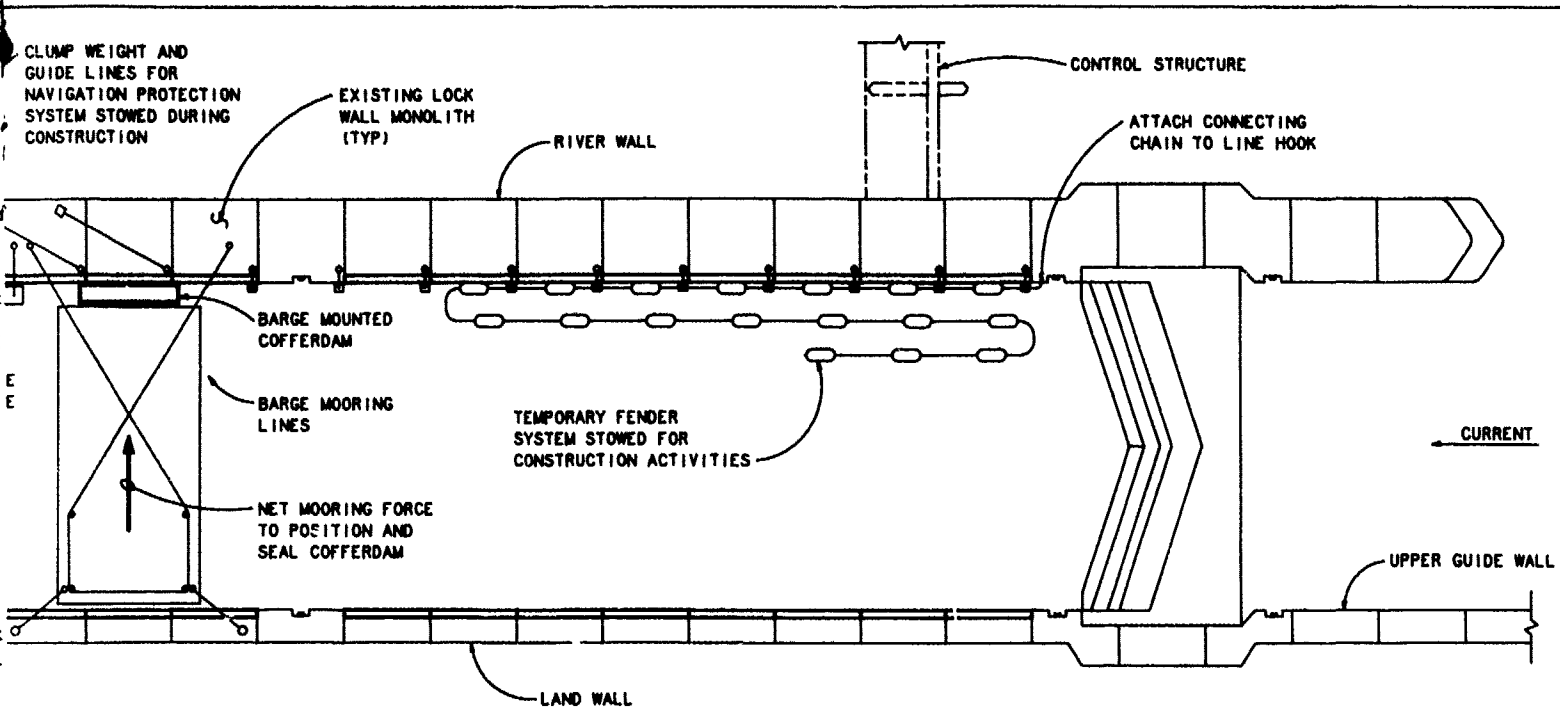


⊙ XX INDICATES CONSTRUCTION DAY FOR ERECTION OF PANEL

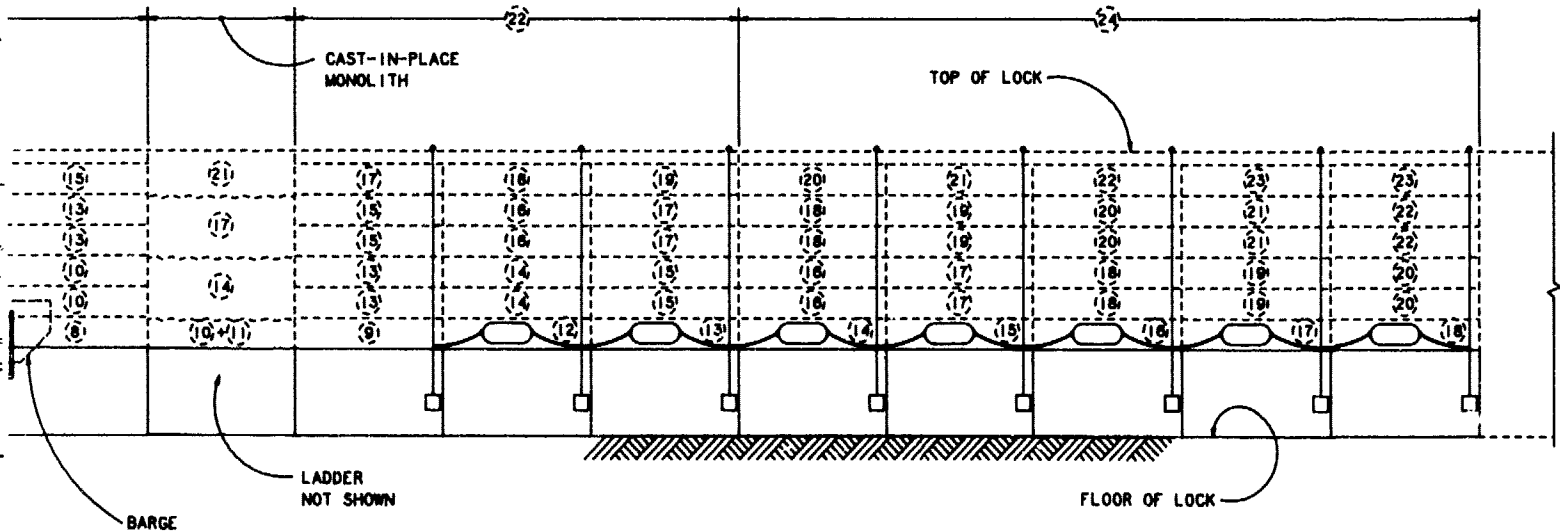
▭ PRECAST WALL PANEL

2 ELEVATION - CONSTR
-2-2 NO SCALE

NOTE: THIS DRAWING IS FOR INFORMATION PURPOSE TO DEMONSTRATE POSSIBLE WORK SEQUENCES. THE ACTUAL WORK SEQUENCE, EQUIPMENT, AND METHODS ARE THE CONTRACTOR'S RESPONSIBILITY AND MAY BE ENTIRELY DIFFERENT THAN SHOWN ON THIS DRAWING.



PLAN - CONSTRUCTION BARGE DAY 7
SCALE: 1"=30'-0"



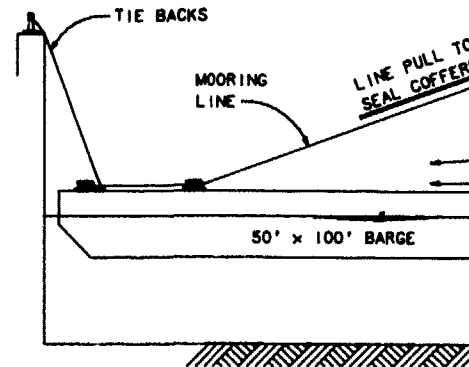
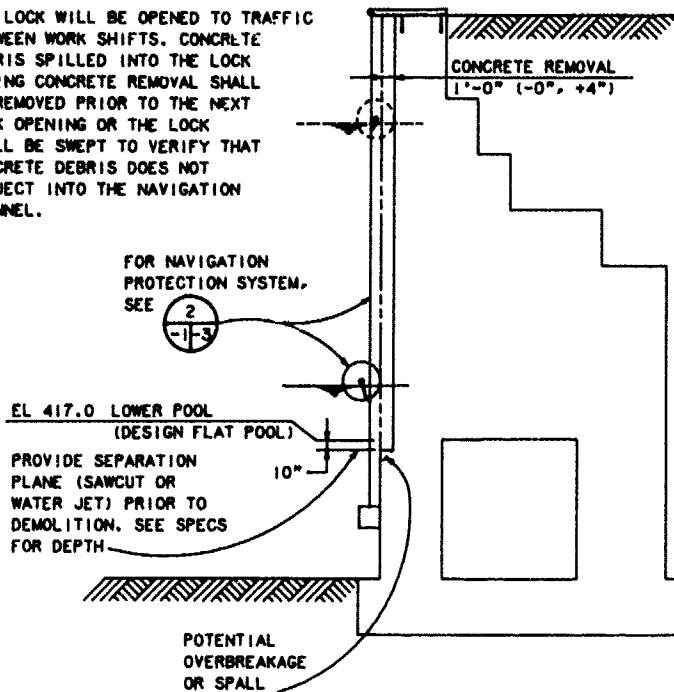
ELEVATION - CONSTRUCTION SEQUENCE
NO SCALE

SYN	DESCRIPTION	DATE	APPROVED

FILE NO. A86029-343-00	DESIGNER B. ALLEN	GENERIC NAVIGATION LOCK WALL REHABILITATION CONSTRUCTION SEQUENCE	U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICTOR H. MISS A86029-2
PROJECT NO. E. OZOLIN	CHECKER T. NETTLES		
DATE: 12 JULY 1988 R. MCHEN			
SCALE: AS NOTED		SHEET 2 OF 6	

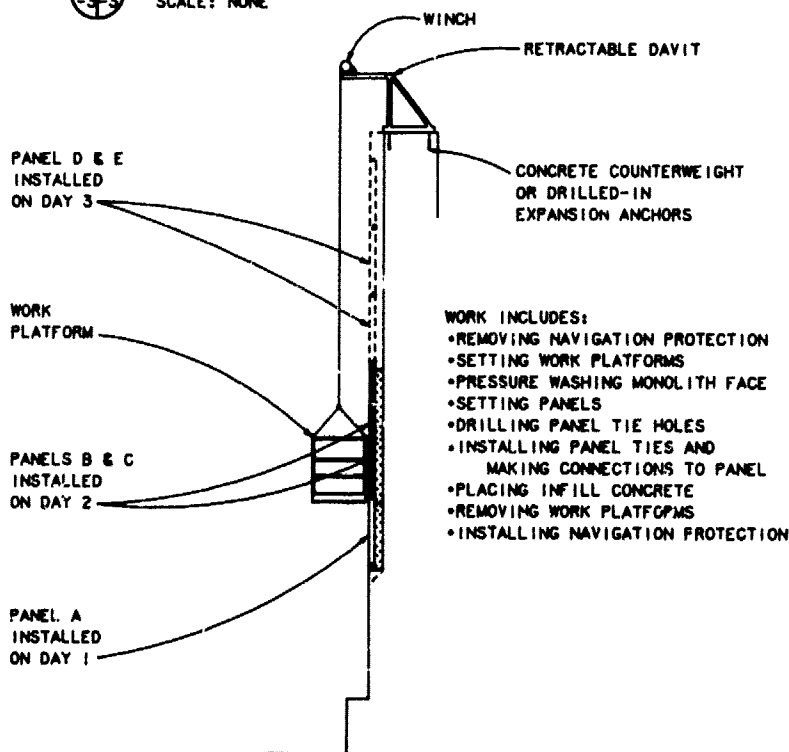
1. LOCK WILL REMAIN IN SERVICE DURING REHABILITATION INCLUDING CONCRETE DEMOLITION WORK.
2. ONE ENTIRE LOCK WALL FACE SHALL BE AVAILABLE AS A CONTACT SURFACE FOR TRAFFIC USING THE LOCK. CONCRETE REMOVAL SHALL BE SCHEDULED ACCORDINGLY.
3. THE LOCK WILL BE OPENED TO TRAFFIC BETWEEN WORK SHIFTS. CONCRETE DEBRIS SPILLED INTO THE LOCK DURING CONCRETE REMOVAL SHALL BE REMOVED PRIOR TO THE NEXT LOCK OPENING OR THE LOCK SHALL BE SWEEPED TO VERIFY THAT CONCRETE DEBRIS DOES NOT PROJECT INTO THE NAVIGATION CHANNEL.

- WORK INCLUDES:
- SETTING AND DEWATERING COFF
 - DRILLING AND INSTALLING PAN
 - PRESSURE WASHING MONOLITH F
 - ERECTING PANEL
 - COMPLETING PANEL TIE CONNEC
 - INSTALL FORMWORK
 - PLACING BACKFILL CONCRETE
 - REMOVING COFFERDAM
 - INSTALLING NAVIGATION PROTE

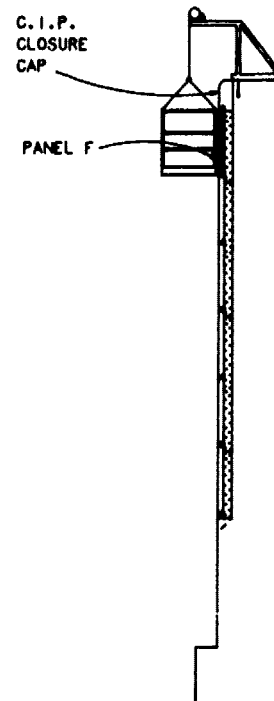


A SECTION - DEMOLITION REQUIREMENTS
SCALE: NONE

1 ELEVATION - DAY 1 CONSTRUCTION
SCALE: NONE



- WORK INCLUDES:
- REMOVING NAVIGATION PROTECTION
 - SETTING WORK PLATFORMS
 - PRESSURE WASHING MONOLITH FACE
 - SETTING PANELS
 - DRILLING PANEL TIE HOLES
 - INSTALLING PANEL TIES AND MAKING CONNECTIONS TO PANEL
 - PLACING INFILL CONCRETE
 - REMOVING WORK PLATFORMS
 - INSTALLING NAVIGATION PROTECTION



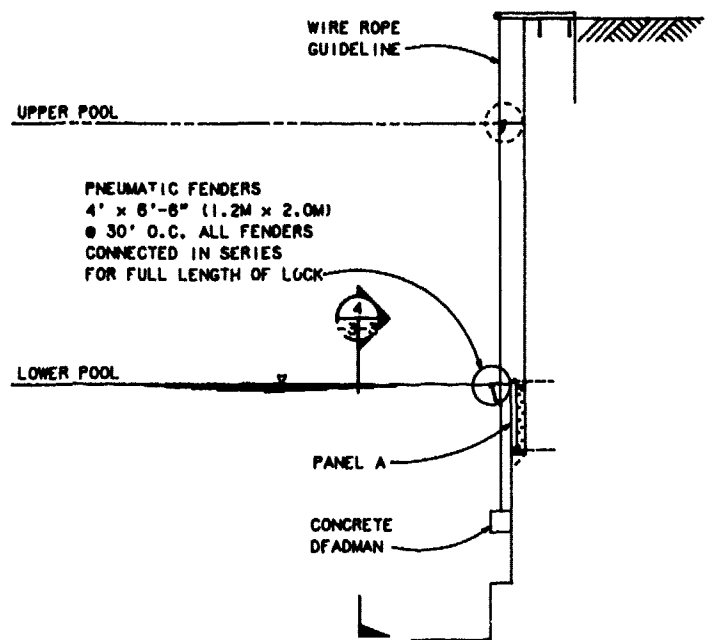
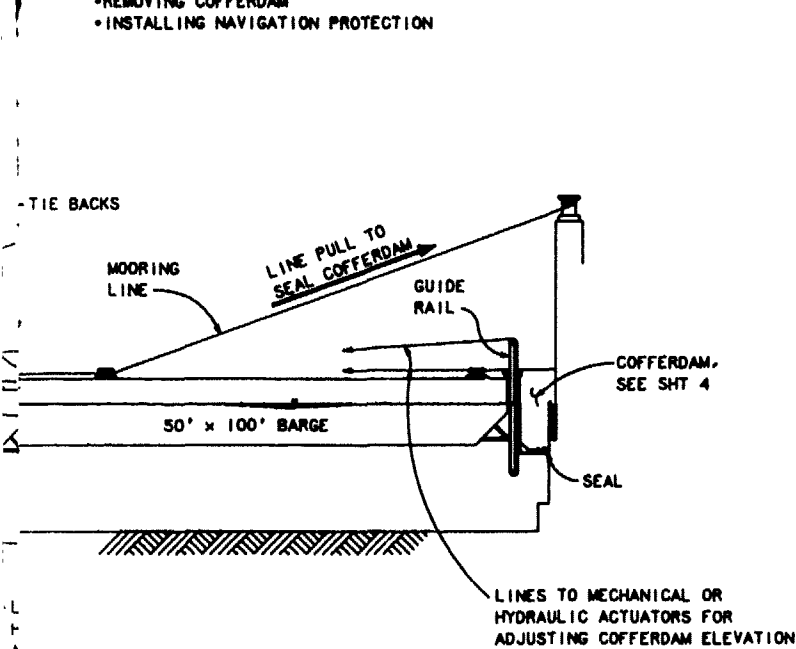
- WORK INCLUDES:
- REMOVING NAVIGATION PROTECT
 - INSTALLING WORK PLATFORMS
 - PRESSURE WASHING MONOLITH F
 - ERECTING PANELS
 - DRILLING TIE HOLES
 - INSTALLING PANEL TIES AND MAKING CONNECTIONS TO PA
 - DRILLING AND INSTALLING JOINT FOR C.I.P. CLOSURE CAP
 - PLACING INFILL CONCRETE
 - REMOVING WORK PLATFORMS
 - INSTALLING NAVIGATION PROTE

3 ELEVATION - DAY 2 & 3 CONSTRUCTION ACTIVITIES
SCALE: NONE

4 ELEVATION - DAY 4 CONSTRUCTION ACTIVITIES
SCALE: NONE

WORK INCLUDES:

- SETTING AND DEWATERING COFFERDAM
- DRILLING AND INSTALLING PANEL TIES
- PRESSURE WASHING MONOLITH FACE
- ERECTING PANEL
- COMPLETING PANEL TIE CONNECTIONS
- INSTALL FORMWORK
- PLACING BACKFILL CONCRETE
- REMOVING COFFERDAM
- INSTALLING NAVIGATION PROTECTION



DEMOLITION - DAY 1 CONSTRUCTION ACTIVITIES

2
-3-3

ELEVATION - NAVIGATION PROTECTION

SCALE: NONE

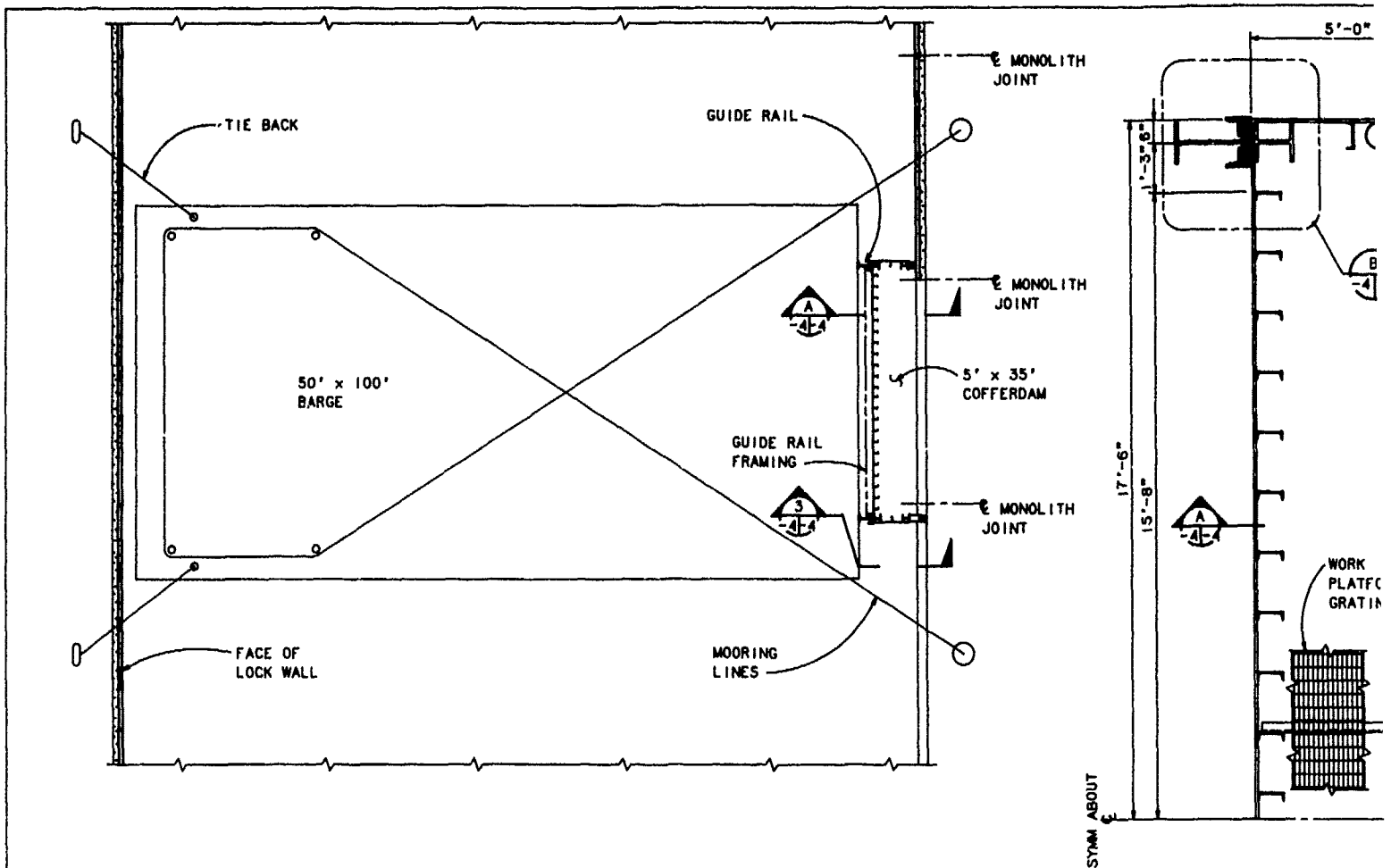
WORK INCLUDES:

- REMOVING NAVIGATION PROTECTION
- INSTALLING WORK PLATFORMS
- PRESSURE WASHING MONOLITH FACE
- ERECTING PANELS
- DRILLING TIE HOLES
- INSTALLING PANEL TIES AND MAKING CONNECTIONS TO PANEL
- DRILLING AND INSTALLING DOWELS FOR C.I.P. CLOSURE CAP
- PLACING INFILL CONCRETE
- REMOVING WORK PLATFORMS
- INSTALLING NAVIGATION PROTECTION

DEMOLITION - DAY 4 CONSTRUCTION ACTIVITIES

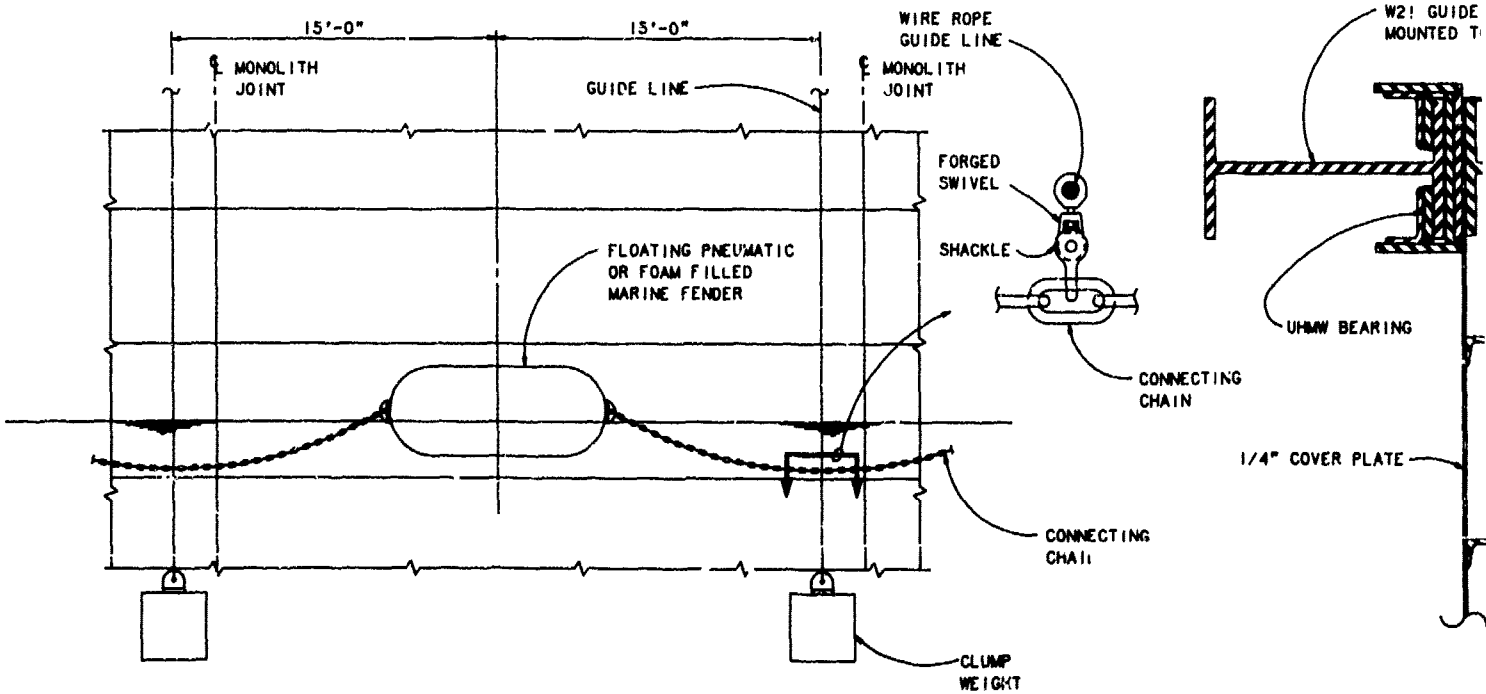
SYM	DESCRIPTION	DATE APPROVED

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DATE: 12 JULY 1988 SCALE: AS NOTED		



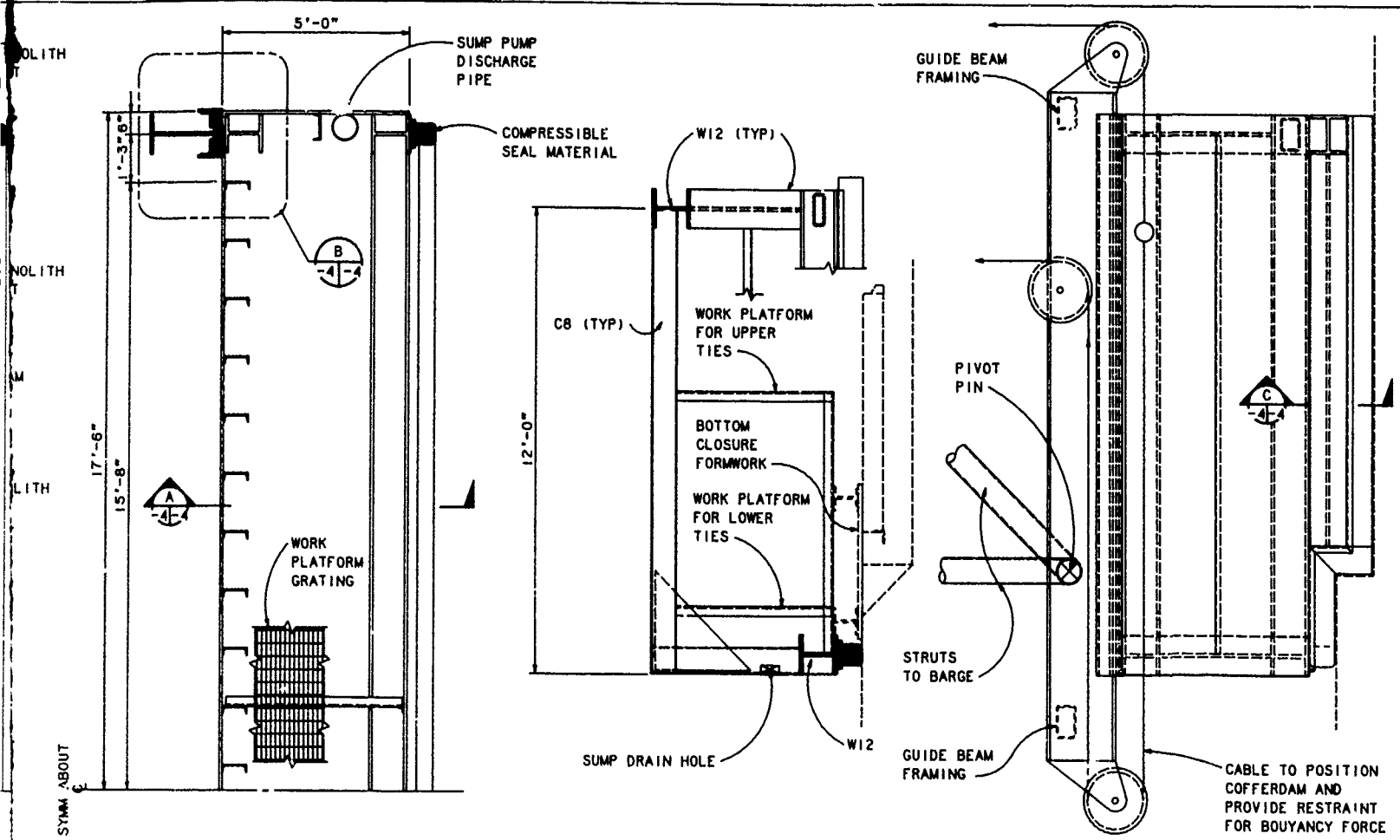
1 PLAN - BARGE AND COFFERDAM
SCALE: 3/32"=1'-0"

2 PLAN - PARTIAL
SCALE: 1/2"=1'-0"



4 ELEVATION - NAVIGATION PROTECTION
NO SCALE

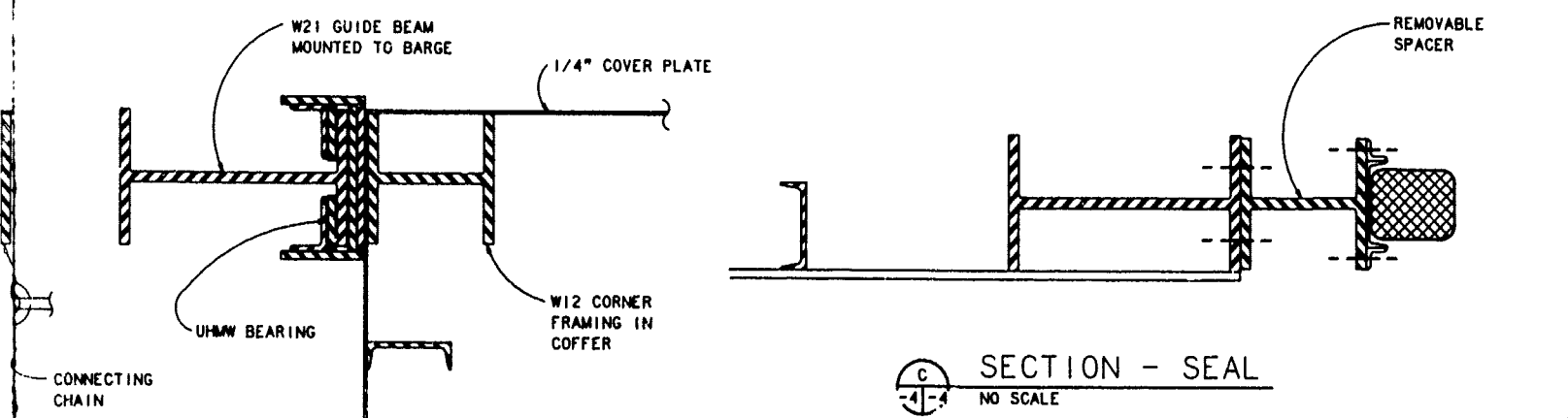
B SECTION - GU
SCALE: 1/2"=1'-0"



2 PLAN - PARTIAL COFFER
SCALE: 1/2"=1'-0"

A SECTION - COFFER
SCALE: 1/2"=1'-0"

3 ELEVATION - COFFER
SCALE: 1/2"=1'-0"



C SECTION - SEAL
NO SCALE

B SECTION - GUIDE BEAM
SCALE: 1 1/2"=1'-0"

FILE NO. AB6029-343-00

DESIGNED BY W. ALLEN

PROJECT ENG. E. OZOLIN

PREPARED BY T. NETTLES

ABRAM
CONSULTING ENGINEERS

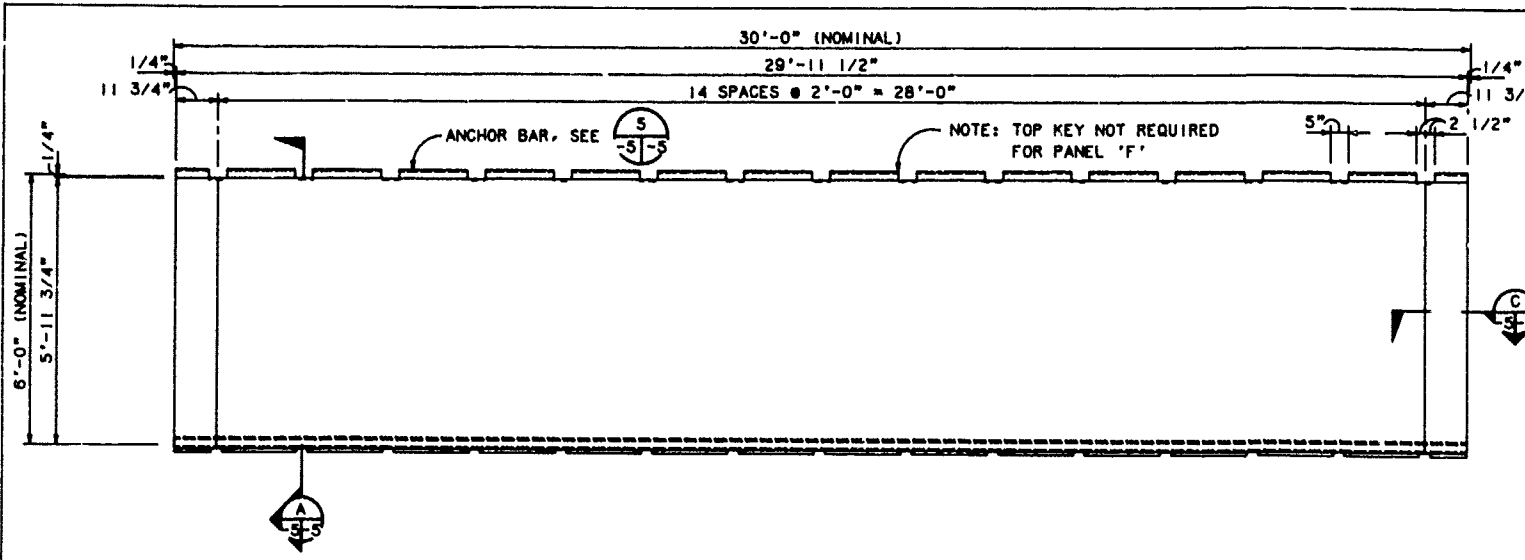
12000 10th Ave. S.W.
Burien, Ore., 97149
503-863-0100

SYMBOL	DESCRIPTION	DATE	APPROVED

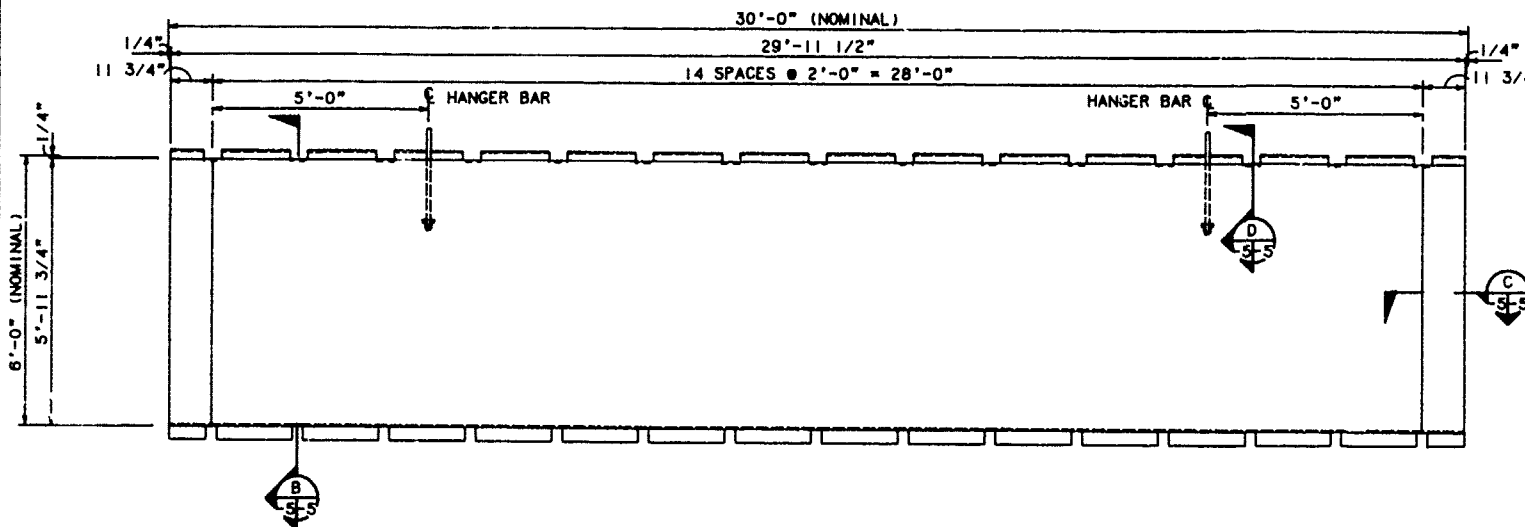
REVISIONS	DESCRIPTION

PROJECT: GENERIC NAVIGATION LOCK WALL REHABILITATION DRAWING NO.: AB6029-4 SHEET: 4 OF 8	U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICTOR H. HISS, JR. SCALE: AS NOTED
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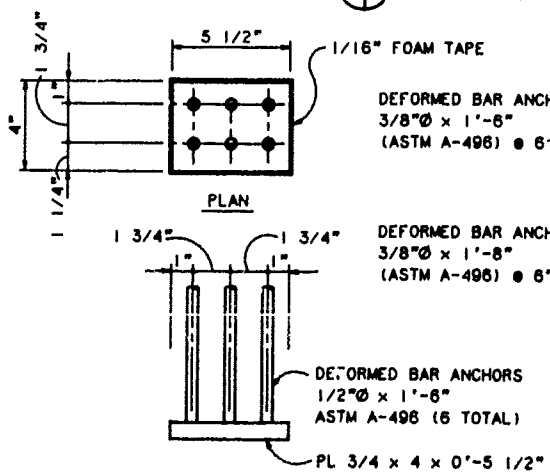
DATE: 12 JULY 1989



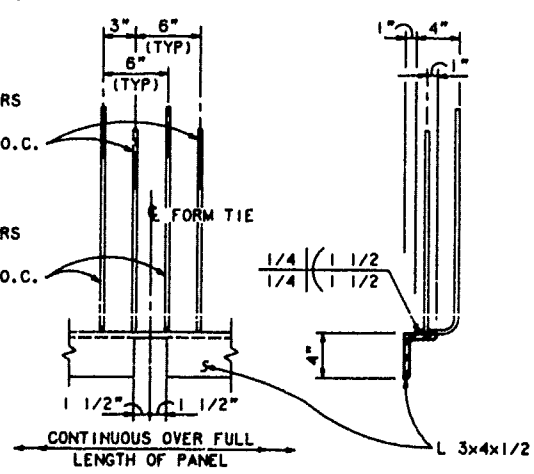
1 ELEVATION - PRECAST PANELS 'B', 'C', 'D', 'E' & 'F'
SCALE: 1/2"=1'-0"



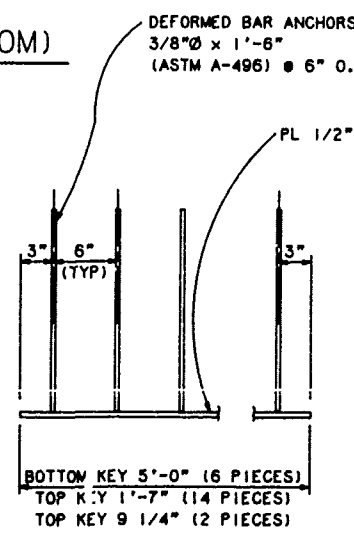
2 ELEVATION - PRECAST PANEL 'A' (BOTTOM)
SCALE: 1/2"=1'-0"



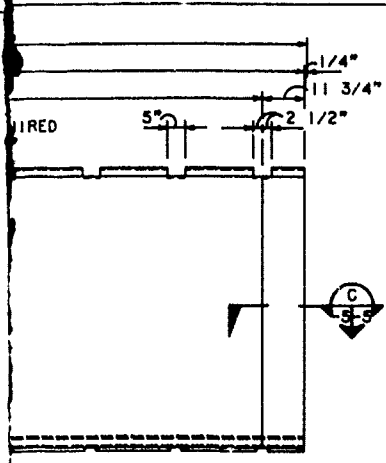
3 ELEVATION
DETAIL - TIE WELD
PLATE
SCALE: 3"=1'-0"



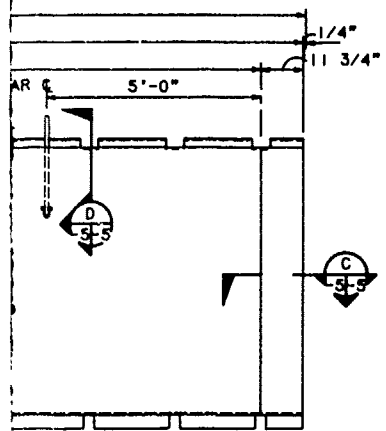
4 ELEVATION
DETAIL - ALIGNMENT
ANGLE
SCALE: 1 1/2"=1'-0"



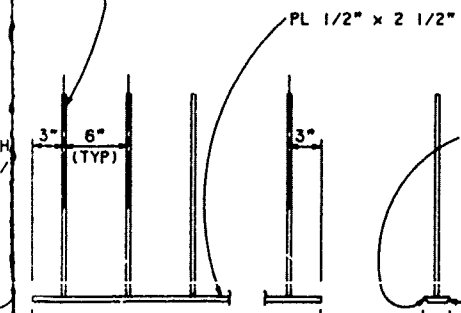
5 ELEVATION
DETAIL - ANCHOR
SCALE: 1 1/2"=1'-0"



' & 'F'

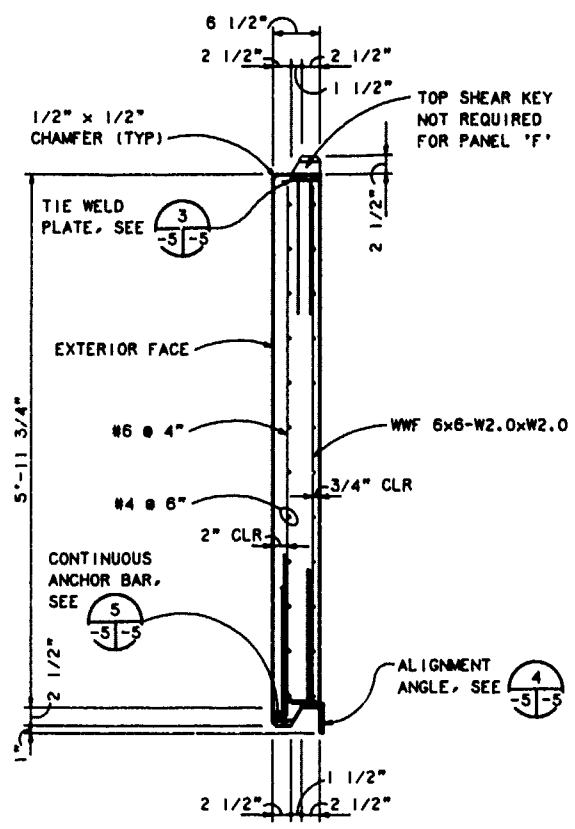


DEFORMED BAR ANCHORS
3/8"Ø x 1'-6"
(ASTM A-496) # 6" O.C.

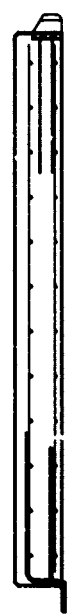


BOTTOM KEY 5'-0" (6 PIECES)
TOP KEY 1'-7" (14 PIECES)
TOP KEY 9 1/4" (2 PIECES)

ELEVATION SECTION
DETAIL - ANCHOR BAR
SCALE: 1 1/2"=1'-0"

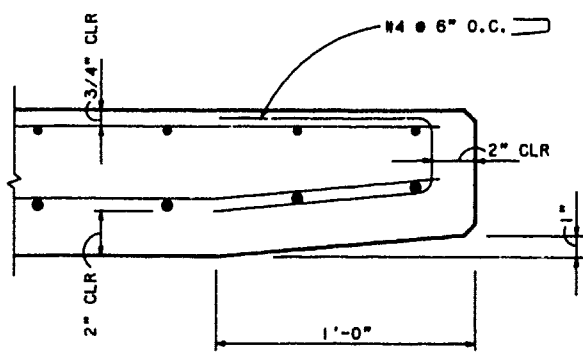


SECTION A-A
SCALE: 1"=1'-0"

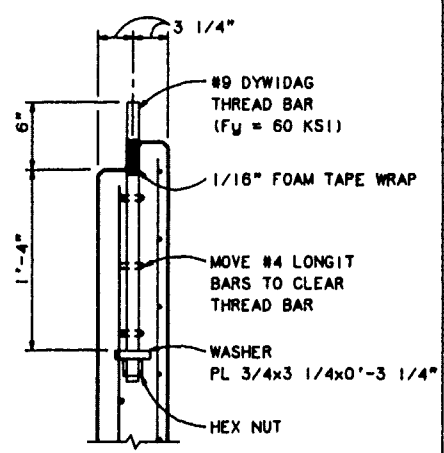


SECTION B-B
SCALE: 1"=1'-0"

NOTE: FOR INFORMATION NOT SHOWN, SEE **SECTION A-A**

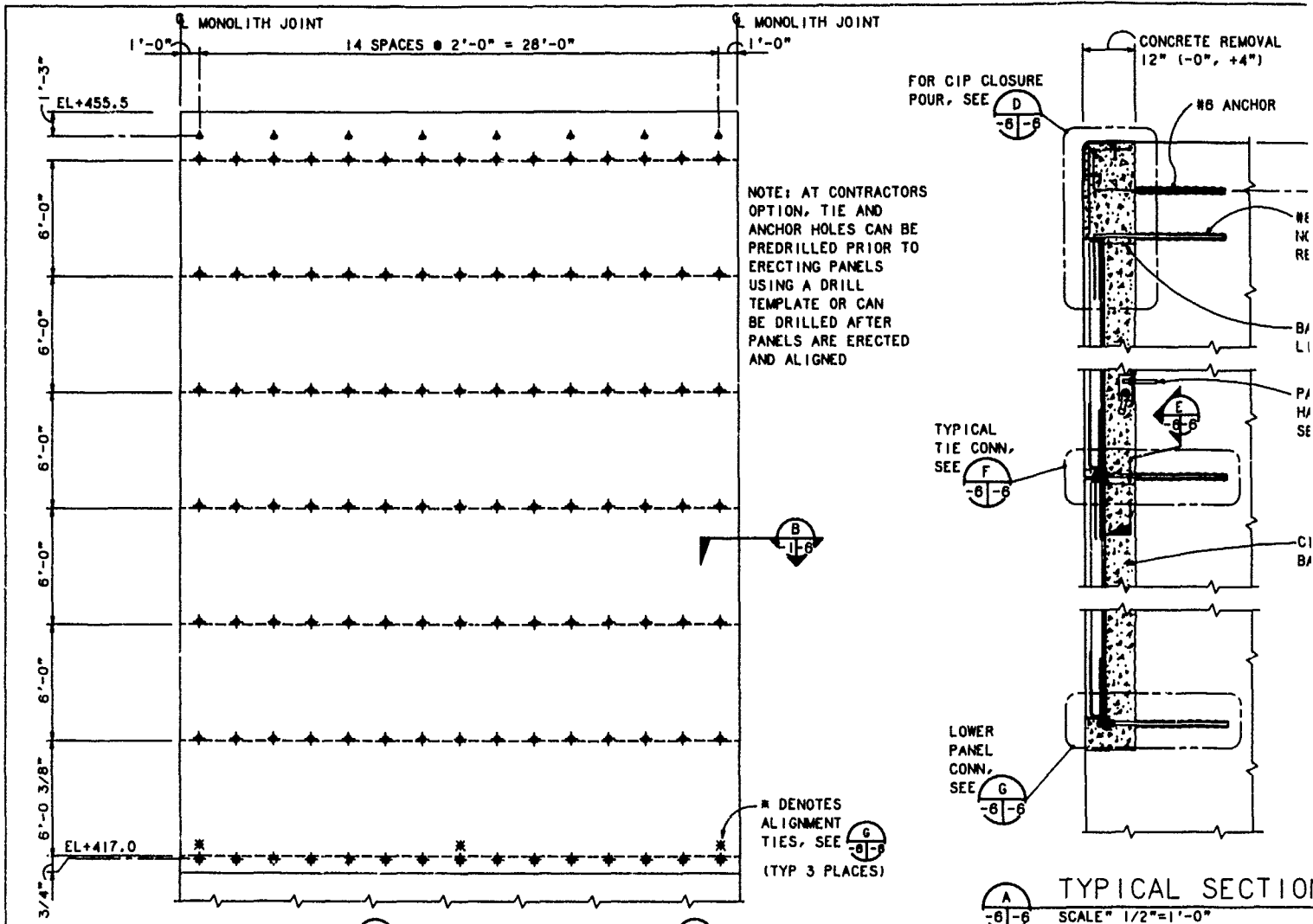


SECTION C-C
SCALE: 3"=1'-0"



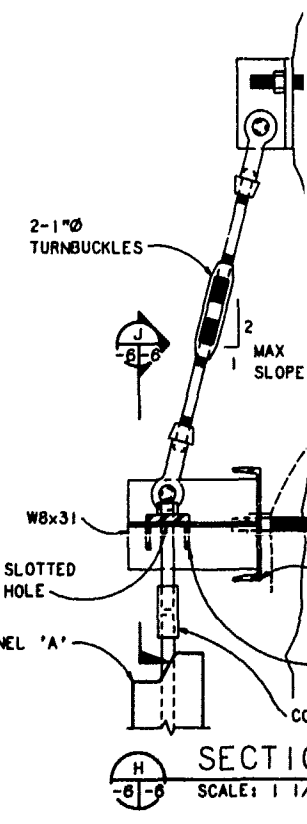
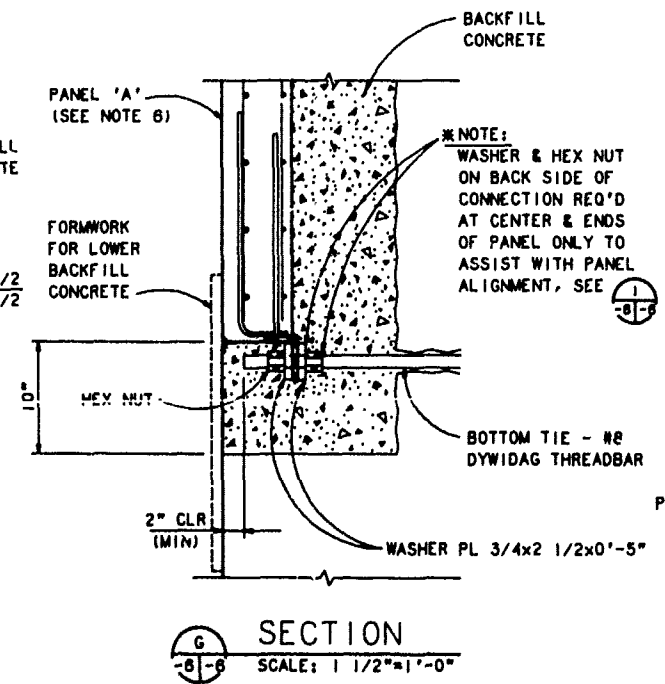
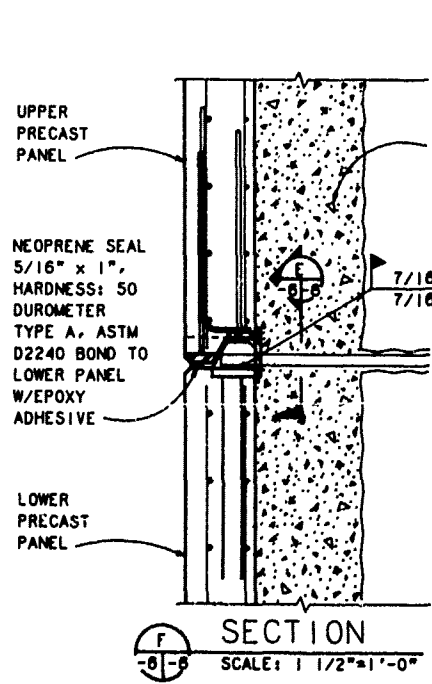
SECTION D-D
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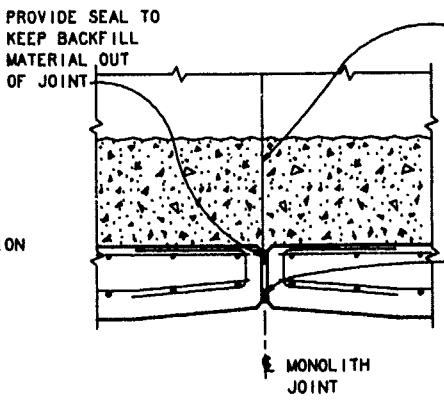
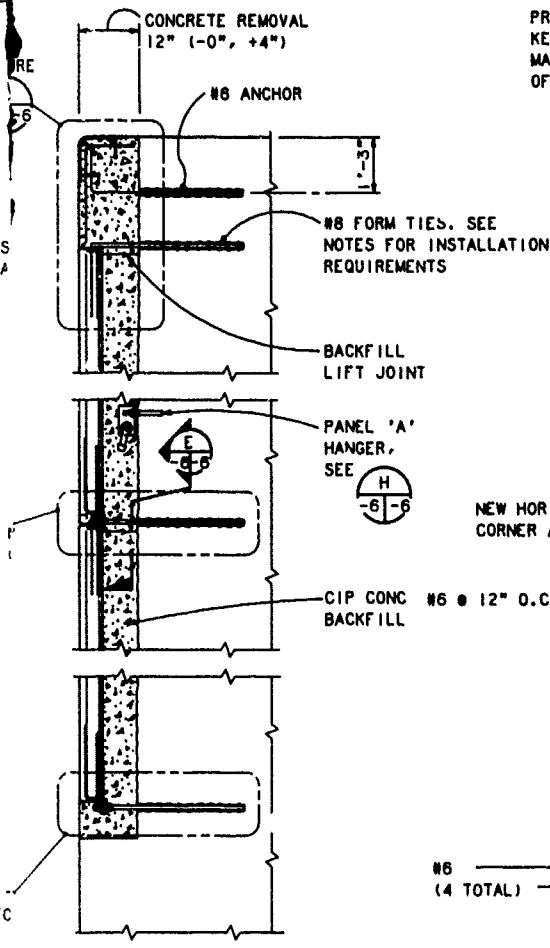
SYMBOL	DESCRIPTION	DATE	APPROVED
REVISIONS			
FILE NO. AB6029-343-00		APPROVED: _____	
DESIGNED BY: E. OZOLIN	CHECKED BY: _____	GENERIC NAVIGATION LOCK WALL REHABILITATION PRECAST PANELS	
DRAWN BY: E. OZOLIN	REVISION: _____		
CHECKED BY: T. NETTLES	REVISION: _____		
DESIGNED BY: _____	REVISION: _____		
		U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS <small>VICKSBURG, MISS.</small>	
<small>CONSULTING ENGINEERS</small> <small>12 JULY 1989</small>		AB6029-5	
SCALE: AS NOTED		SHEET 5 OF 6	



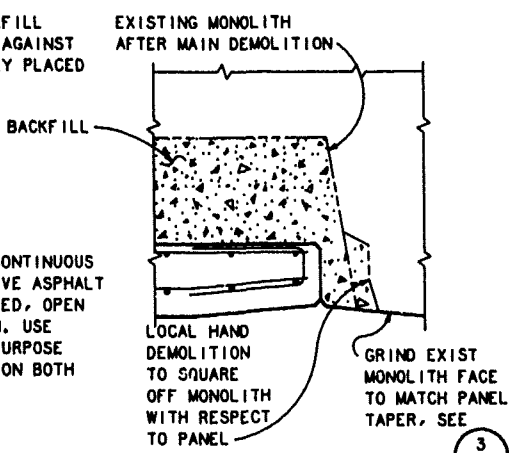
◆ #8 THREAD BAR TIES, SEE (C)-8-6 ▲ #8 REBAR ANCHOR, SEE (E)-8-6
 ◆ #8 REBAR TIES, SEE (F)-8-6

ELEVATION - FORM TIE & DOWEL LOCATIONS
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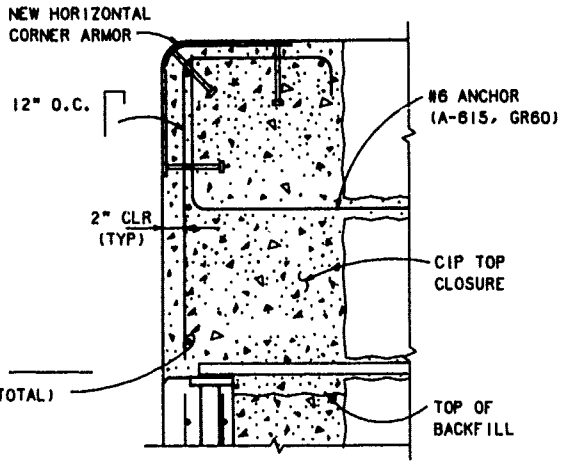




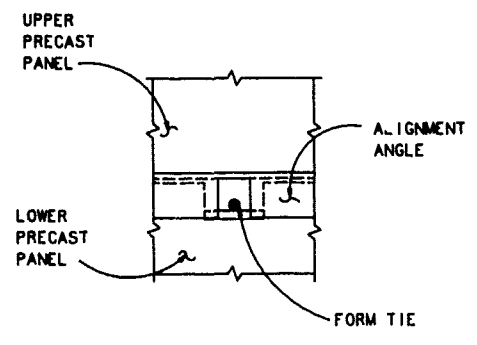
SECTION B
SCALE: 1 1/2"=1'-0"



SECTION C
SCALE: 1 1/2"=1'-0"



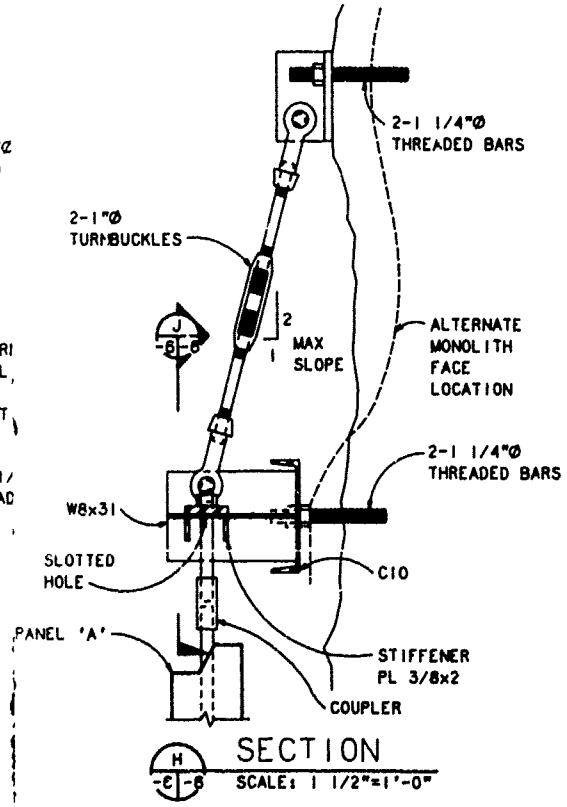
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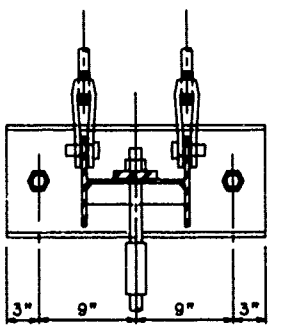
SECTION E
SCALE: 1 1/2"=1'-0"

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

- NOTES:
1. TIES AND ANCHORS SHALL BE TESTED TO ESTABLISH THE REQUIRED EMBEDMENT DEPTH. TESTING SHALL BE DONE USING SAME MATERIALS AND INSTALLATION PROCEDURES TO BE USED DURING INSTALLATION OF PRODUCTION TIES.
 2. TIES AND ANCHORS SHALL BE EMBEDDED TO DEVELOP IN TENSION AT LEAST 125 PERCENT OF SPECIFIED YIELD STRENGTH OF BAR.
 3. TIE AND ANCHOR HOLE DIAMETER SHALL BE PER BONDING MATERIAL MANUFACTURER'S RECOMMENDATIONS.
 4. HOLES FOR TIES SHALL BE DRILLED USING ROTARY-PERCUSSIVE EQUIPMENT. CORE DRILLED HOLES SHALL NOT BE PERMITTED.
 5. SEE SPECIFICATIONS FOR TESTING REQUIREMENTS FOR PRODUCTION TIES AND ANCHORS.
 6. PROPER ALIGNMENT OF PANEL 'A' IS CRITICAL TO THE ALIGNMENT OF SUBSEQUENT (UPPER) PANELS.



SECTION H
SCALE: 1 1/2"=1'-0"



SECTION J
SCALE: 1 1/2"=1'-0"

SYMBOL	DESCRIPTION	DATE	APPROVED
REVISIONS			
<p>PROJECT NO. A86029-343-10</p> <p>DESIGNED BY E. OZOLIN</p> <p>DRAWN BY E. OZOLIN</p> <p>CHECKED BY T. NETTLES</p> <p>SCALE: AS NOTED</p>		<p>GENERIC NAVIGATION LOCK WALL REHABILITATION</p> <p>ERECTION DETAILS</p> <p>SCALE: AS NOTED</p>	
<p>U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION</p> <p>CORPS OF ENGINEERS</p> <p>VICINIA, MISS.</p> <p>A86029-6</p>			
<p>ASAM CONSULTING ENGINEERS</p> <p>12 JULY 1988</p>		<p>SHEET 6 OF 6</p>	

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 1A
GENERAL PROVISIONS

PART 1 - GENERAL

1.1 SCOPE OF WORK

- A. This work consists of repairing deteriorated navigation lock wall surfaces with precast, stay-in-place concrete form panels in conjunction with cast-in-place concrete bonding layers. This work will be performed while maintaining the lock in an operational condition except for the specified daily window for construction operations.
- B. The work includes providing all materials, labor, inspections, tests, and supervision required for complete installation as shown on the drawings and described in these specifications.

1.2 PENALTIES

Because of the importance of maintaining the lock in an operational condition and the serious economic consequences of unscheduled shutdowns, a Schedule of Penalties is shown in the General Provisions of the project documents that shall be applied to hourly, daily, and weekly lock outages due to the Contractor's operations.

1.3 QUALITY CONTROL

- A. Contractor shall perform all work in accordance with referenced specifications and standards, these specifications and the plans.
- B. Contractor shall maintain records of tests and inspections as required to demonstrate compliance with referenced standards.

1.4 HOUSEKEEPING AND CLEANUP

- A. Contractor shall maintain work area in a neat and orderly fashion. Work area shall be cleaned daily at the close of work.
- B. Refuse, shipping and packaging materials, wasted material and products, and discarded samples shall be disposed of as required by the Corps.

END OF SECTION 1A

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 1C ALTERNATES

PART 1 - GENERAL

1.1 ALTERNATE METHODS

The construction methods, sequences, and schedules shown on the drawings and as specified herein are intended to indicate a baseline operation that can accomplish the work. They are not intended to limit the Contractor in his choice of methods.

It is the Contractor's responsibility to select suitable methods to complete the work. The baseline was developed in accordance with the criteria found in Section 1D, Reference Standards and Criteria. If the Contractor's methods differ from the baseline, they shall conform to the requirements of the criteria and shall be fully described in the work plan and schedule submitted in accordance with Section 1F, Submittals.

1.2 ALTERNATE MATERIALS

Written requests for substitution of alternates for specified materials, products, or processes shall be submitted in accordance with Section 1F, Submittals. Such requests will be considered only if sufficient information is attached to verify that the proposed alternate is equal or superior to the original item in all properties specified or described in the originally specified manufacturer's or supplier's data. Supporting data shall include the results of tests conducted by an independent testing laboratory and witnessed by a registered professional engineer.

1.3 DESIGN ALTERNATES

Contractor-proposed alternates to any of the design features shown on the plans shall be submitted for review with calculations and other pertinent information sufficient to show that the proposed alternate has at least the same capacity and function as the original detail and that it meets the criteria found in Section 1D, Reference Standards and Criteria.

END OF SECTION 1C

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 1D REFERENCE STANDARDS AND CRITERIA

PART 1 - GENERAL

1.1 REFERENCE STANDARDS

The reference standards referenced in this section are the U.S. Army Corps of Engineers Handbook for Concrete and Cement (CRD). All work shall be performed in accordance with the reference standards except as modified or specified in the drawings and specifications.

1.2 OPERATIONAL AND CONSTRUCTION CRITERIA

- A. Operational Lock Definition: An operational lock must have one complete chamber face intact and available as a contact surface for traffic using the lock. At some sites, it will be required that the wall under construction also remain available as a contact surface. Gates at both ends of the lock must remain operable and electrical utilities and mechanical equipment shall remain functional, even on the lockwall undergoing rehabilitation.
1. Auxiliary means to assist in moving traffic through the lock or to maintain clearance between the new construction and the barge may be required. Such measures might include temporary winches and/or helper boats.
 2. Temporary protection shall be provided to protect newly rehabilitated surfaces from impact loadings and prevent damage to barges or other vessels using the lock.
- B. Dry and Wet Conditions
1. Under dry conditions, lock rehabilitation work can be completed without dewatering the immediate work surface or needing special construction techniques. The dry condition will occur for an operable lock, but it will be a temporary situation only. At the end of the normal daily work cycle, the lock is opened to traffic and the rehabilitation work may not be complete when the panels become submersed and are exposed to lock traffic. The work must be sufficiently complete, however, including the installation of navigational protection measures, to ensure that the potential damage during lock use is minimized.

2. In a wet condition, panels will be installed underwater or become submerged during lockages and thus, special construction procedures will be necessary. Figure 1 defines the limits for the wet condition installation as described herein. The water levels in the lock, as shown in the construction drawings, are referenced with respect to lower and upper pool elevations under conditions of zero flow and thus are termed "flat pool elevations." Under normal conditions, there will be flow in the channel and the water level in the lock will be different than the flat pool elevation. Because the lower pool is influenced by the control structure downstream, it also is referred to as the "tailwater level."
 3. Based on experience to date, minimal deterioration has been observed below the lower pool (flat pool) elevation; therefore, no lockwall resurfacing will be required below this point. At most sites during normal flow conditions, the tailwater level varies between 0 to 3 ft above the flat pool; therefore, the bottom panel will be installed with a probable water depth of 3 ft above the lowest edge of the panel.
 4. Dimensions of the lowest panel will be selected to enable installation of the subsequent panel in the vertical direction under dry conditions. During more extreme flow conditions, the tailwater level can be significantly above the flat pool. For the generic lock, a maximum design tailwater level of 6 ft above flat pool has been assumed in developing panel details and spatial requirements for construction tooling. As a result, a minimum panel height of 6 ft has been used to ensure that the next panel can be installed under dry conditions. Adjustments to the basic repair concept must be incorporated for tailwater conditions in excess of those assumed.
- C. Lock Operation Scenarios: The governing traffic with respect to lock width and length are barge tows that can be made up of several barge strings placed side by side (three wide maximum). Other craft using the locks are usually less than half of the lock width.

The preferred operational scenario is for the placement of no width restrictions on the tows using the lock. This condition provides the most efficient lock cycle time and enables more traffic to pass through the lock.

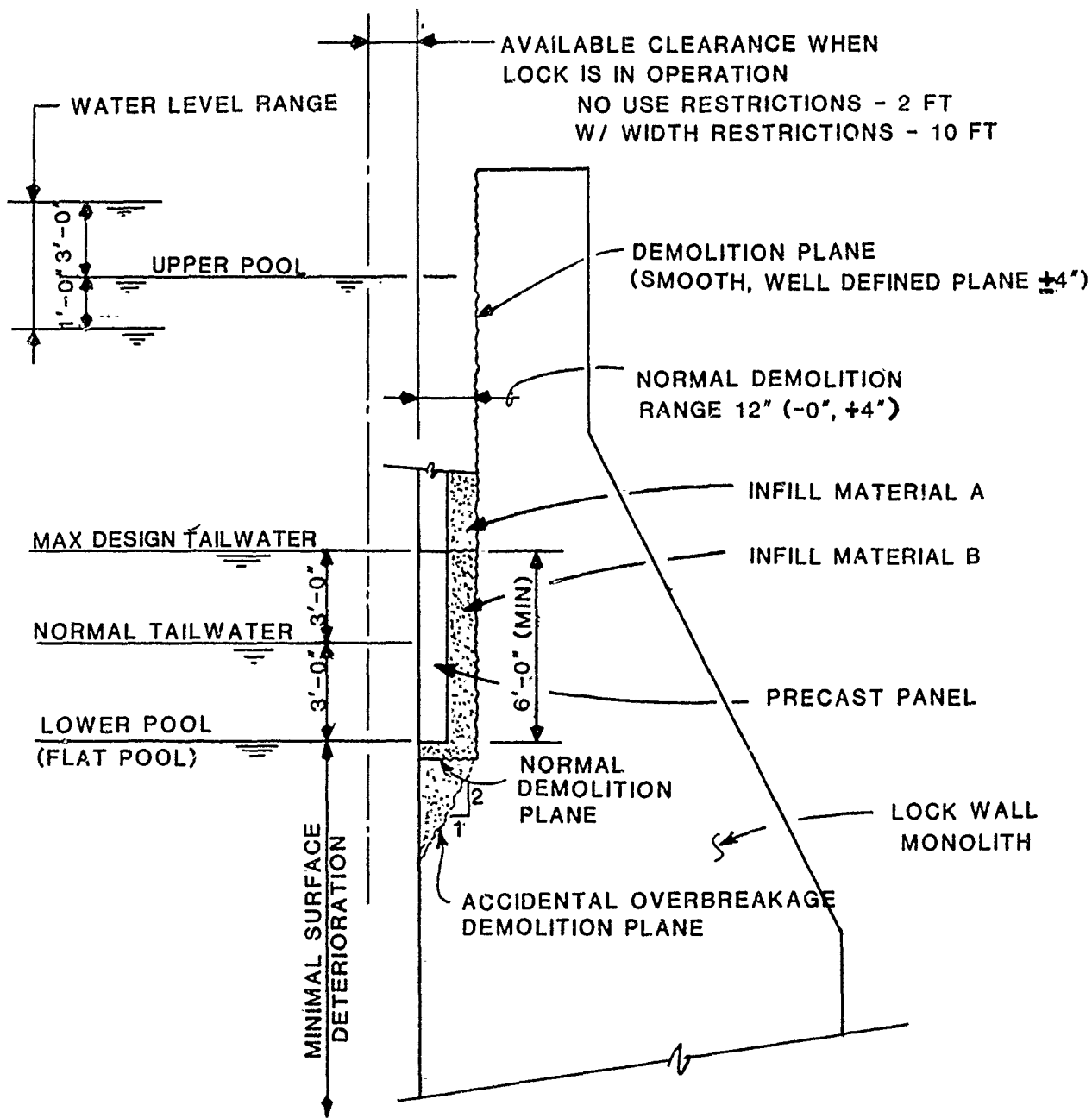


FIGURE 1
OPERATIONAL & CONSTRUCTION CRITERIA

The less favorable scenario is to impose a width restriction on the lock, which requires the removal of one barge string. In the case of the Mississippi River, the tows consist of three strings of 35-ft-wide barges or two strings of 54-ft barges. The reduction of one barge string would provide a net clearance of 40 or 56 ft, respectively, for the 110-ft-wide locks. At other locks, the net available clearances would differ, but still be greater than 10 ft, which is an appropriate clearance for construction techniques using such features as cofferdams, external bracing, or work platforms that might remain in place when the lock is opened to traffic. Therefore, a maximum 10-ft clearance will be available for such construction equipment and protection hardware that will remain in place during periods of lock operation.

The preferred scenario for opening the lock for operation will be to have the infill material placed behind the form panel and the necessary impact protection features installed. A less desirable situation, and one requiring more significant protection in place, is to open the lock with only the form-tie connections holding the panel.

- D. Lock Demolition: Conventional line drilling and blasting demolition techniques are an economical and proven method and thus have been assumed as the baseline methods for removing the deteriorated concrete. The resulting surface will be a reasonably smooth, well-defined plane (± 4 in.). If a panel/tie system requiring greater depth of excavation is developed, it will be evaluated assuming a deeper excavation over the full height of the monolith.
1. Based on past experience, a 12-in. minimum thickness of deteriorated concrete will be removed; however, contractors usually remove more than is required, so up to 16 in. will be considered in the development of construction details.
 2. Although saw cutting is commonly used to define planes and prevent feather edging, breakouts occur and means of accommodating them will be incorporated in the development of panel support means.
- E. Construction Details
1. A normal construction work week of five 12-hour days has been established as the typical work shift. The remaining 12 hours in each work day, along with weekends and holidays, shall be available for lock operation.

2. The preferred construction sequence is to install the lowest panel and place the infill material prior to installing the remaining panels for a given monolith. This will provide bearing strength for supporting the subsequent panels and infill material. To allow for greater construction flexibility, bottom panel support details that can accommodate several panels without infill concrete in place would be the next preferred condition.
3. Different infill materials may be used for the lowest panels installed in a dry condition.
4. Surface preparation is critical in obtaining good bond between the form panel/monolith surface and the infill material. Cleaning of these surfaces should be performed in the same 12-hour work period as placement of the infill concrete.

1.3 DESIGN CRITERIA

A. Panel Size

1. Length: Coincident with monolith joints
2. Width: 6-ft minimum
3. Thickness: 6-1/2 in.

B. Panel Materials

1. Concrete

- a. Minimum 28-day compressive strength:
 $f'_c = 6500$ psi
- b. Water/cement ratio < 0.40
- c. Entrained air, 5 to 7%
- d. Minimum cement content, 540 cu yd/lb

2. Reinforcing

- a. Mild steel reinforcing, ASTM A 615, Grade 6 or ASTM A 706, Grade 60, weldable
- b. Welded wire fabric, ASTM A 185
- c. Rebar on face of panel exposed to lock can be epoxy coated if corrosion is a concern.

- C. Panel-to-Monolith Interlock: The concrete bonding capabilities of the infill concrete shall be neglected. Positive interlock will be provided by form ties doweled into the monolith and directly attached to the panel or by separate dowels projecting from the monolith face and back face of the panel. The dowels projecting from each face shall be No. 6 bars on a 4-ft grid or the equivalent reinforcement area of $0.028 \text{ in}^2/\text{sf}$.
- D. Infill Material Placement Pressure: 1.25 ksf, maximum.
- E. Panel Design Load Factor: $1.3(1.4D + 1.7L)$
- F. Tie Design Load Factor: 3.0
- G. Serviceability Requirements
 - 1. Cover: Facing lock surface, 2 in.; facing monolith, $3/4$ in.
 - 2. Crack Widths: < 0.01 in.
- H. Other Concrete Design Requirements
 - 1. "Strength Design for Reinforced Concrete Hydraulic Structures," EC 1110-2-267 (in publication), U.S. Department of the Army, Corps of Engineers, Washington, DC
 - 2. American Concrete Institute Building Code Requirements for Reinforced Concrete (ACI 318)
- I. Hardware and Miscellaneous
 - 1. American Institute of Steel Construction
 - 2. Manual of Steel Construction.

END OF SECTION 1D

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 1E
SPECIAL PROJECT PROCEDURES

PART 1 - GENERAL

1.1 REQUIREMENTS

Special procedures are required because of the need to return the lock to operational status daily after the 12-hour construction period has ended and because the lock cannot be dewatered below the low pool elevation.

1.2 CONSTRUCTION OPERATIONS DURING DAILY 12-HOUR SHIFT

Because of the importance of returning the lock to operational status daily (except weekends) after the 12-hour construction shift, the Contractor shall prepare a detailed work plan that describes the operations to occur during the shift.

- A. Separate descriptions shall be included for each major activity, e.g., Lockwall demolition, coffered installation of bottom row panels, installation of upper panels, etc.
- B. Each description shall include a shift schedule showing that the work, cleanup, and installation of protection can be completed before the shift ends.
- C. Fallback plans for restoring the lock to operational status in the event of equipment failure or other disruptions shall be prepared and included in the work plan.
- D. No work on the lockwall shall be started until the work plan has been approved.

1.3 REMOVAL OF DEMOLITION DEBRIS

Debris from the demolition of deteriorated lockwall faces shall be removed from the lock on a daily basis. Care shall be taken during all demolition operations to avoid clogging inlet structures or damaging exposed piping, conduit, and other lock fixtures. If such damage is likely, temporary protection shall be provided.

1.4 CONSTRUCTION OPERATIONS DURING PERIODS OF LOCK OPERATION

The Contractor may conduct support operations in the vicinity of the locks at any time provided that they do not interfere with lock operation or the progress of vessels through the locks. Such

work shall be identified and described in the Contractor's work plan and the project schedule.

1.5 PROTECTION OF LOCKWALL UNDER CONSTRUCTION

All lockwall exposed by demolition of the deteriorated face, all newly placed precast lockwall panels, and all fresh infill concrete shall be protected from the impact of all vessels during the period that the lock is operational in accordance with Section 2G, Protection of Lockwall During Construction.

- A. Newly placed precast lockwall panels without infill concrete support shall be protected by a structural frame that isolates the panel completely from fender system reactions.
- B. Fresh infill concrete shall be protected by the navigation protection system for a minimum of seven days from the date of pour.

1.6 COFFERED INSTALLATION OF BOTTOM PRECAST LOCKWALL PANELS

Cofferdam(s) shall be used to install the bottom tier of precast lockwall panels (panel type "A") in a dry condition.

- A. Cofferdam(s) shall be designed, fabricated, and operated in accordance with Section 2F, Cofferdams.
- B. Prior to using the cofferdam(s) in a production operation, a demonstration installation shall be performed to demonstrate that the operation can be performed in the time shown in the daily work schedule.
 - 1. The demonstration installation shall be performed on a lockwall face that has had the deteriorated concrete removed.
 - 2. Two complete deployment and removal cycles performed in the scheduled time or less shall constitute the demonstration.

END OF SECTION 1E

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 1F
SUBMITTALS

PART 1 - GENERAL

1.1 PROCEDURES

Submittals shall be made to the Contracting Officer at the location and in the time frame specified in the contract documents for the project.

1.2 SCHEDULE

A project progress schedule shall be prepared and submitted within 15 days of the notice of award and updated throughout the duration of the work. The schedule shall contain sufficient detail to provide effective monitoring of project progress and shall include, as a minimum

- A. Detailed critical path construction schedule
- B. Dates for major submittal items such as shop, cofferdam, and placement drawings, work plan, construction sequence, etc.
- C. Schedule of qualification tests

1.3 SUBMITTALS

Submittal requirements are specified in the individual sections of these specifications and in the reference standards. These include but are not limited to

- A. Project schedule
- B. Quality control plan
- C. Work plan
- D. Concrete mixture proportions and test data
- E. Qualification test procedures and results
- F. Mill certificates
 - 1. Concrete components
 - 2. Reinforcing steel
 - 3. Adhesives and grout

- G. Manufacturers' descriptive literature and installation recommendations
 - 1. Adhesives and grout
 - 2. Anchors
 - 3. Fenders
- H. Welder qualifications and weld procedures
- I. Shop and erection or operation drawings
 - 1. Cofferdam
 - 2. Precast panels
 - 3. Lockwall protection system
- J. Inspection reports
 - 1. Precast concrete production
 - 2. Site operations
- K. Concrete test report

END OF SECTION 1F

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 1G
QUALITY CONTROL

PART 1 - GENERAL

1.1 SCOPE OF WORK

This work includes preparation and implementation of a quality control plan that will enable the Contractor to complete the work in accordance with the plans and specifications and document that compliance.

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Section 1F, Submittals
- B. Quality control requirements specified in individual sections
- C. Quality control requirements specified in the reference standards

1.3 QUALITY CONTROL PLAN

The Contractor shall prepare and submit a detailed quality control plan that fully describes the personnel, methods, and documentation that will be followed in completing the work in accordance with the contract documents. No work covered by the plan shall be performed until the plan has been approved by the Contracting Officer. The plan shall include, as a minimum

- A. Implementation
 - 1. General description of work covered by quality control effort
 - 2. Objectives of quality control plan
 - 3. Responsibility and authority
 - 4. Communication
 - 5. Document control and records

B. Inspections

1. Categories of inspection
 - a. Preparatory inspections
 - b. Initial inspections
 - c. Follow-up inspections
 - d. Safety inspections
2. Lockwall demolition, surface preparation, and tie installation
3. Steel fabrication
4. Precast panel production
5. Panel erection
6. Cast-in-place concrete
7. Protection system deployment and operation
8. Final inspection

C. Inspection forms and checklists

END OF SECTION 1G

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 2E
CONCRETE REMOVAL

PART 1 - GENERAL

1.1 SCOPE OF WORK

The work consists of the demolition and removal of concrete, concrete reinforcement, location of electrical conduit before removal of concrete, and embedded items, as shown on the drawings.

1.2 SUBMITTALS

The procedures proposed for the accomplishment of demolition work shall be submitted for approval. The procedures shall provide for safe conduct of the work, careful removal and disposition of materials, protection of property that is to remain undisturbed, coordination with other work in progress, and timely disconnection of utility services. The procedures shall include a detailed description of the methods and equipment to be used for each operation and the sequence of operations. No work shall commence until the Contractor has received the Contracting Officer's approval in writing.

1.3 QUALITY CONTROL

The Contractor shall establish and maintain a quality control system for the work under this section to assure compliance with the contract requirements and maintain records of his quality control for all construction operations, including but not limited to, the following:

- A. Concrete removal
- B. Protection
- C. Cleaning of remaining concrete surfaces
- D. Sandblasting equipment and material
- E. High-pressure, water-jet equipment
- F. Cleaning up of debris
- G. Disposition of material

A copy of these records and tests, as well as the records of corrective action taken, will be furnished to the Government as directed by the Contracting Officer.

PART 2 - PRODUCTS

Not used.

PART 3 - EXECUTION

3.1 METHOD OF CONCRETE REMOVAL

- A. The Contractor may use blasting, grinding equipment of the "Roto-Header" type, water-jet equipment for horizontal surfaces, drilling or coring equipment, or hand-held air or hydraulic driven chipping hammers. Hand methods will be permitted. Expansive grouts for concrete removal will not be allowed. Boom or vehicle mounted or otherwise heavy duty pavement impact breakers or drop balls where the blow energy exceeds approximately 1000 ft-lbf will not be permitted. All horizontal and vertical edges shall be cut clean, straight, and smooth, using either concrete saw or water jet to full depth in areas where blasting is used for concrete removal. All other removal methods shall require a minimum of 3 in. unless otherwise noted on the drawings. Cutting and line drilling will be allowed prior to lock closure provided the following conditions are met:

1. No disruptions to navigation will be allowed.
2. The Contractor must ensure that no electrical lines will be damaged during these operations.
3. All plans for sawcutting and line drilling shall be approved by the Contracting Officer.

Precautions shall be taken to prevent chipping hammers and chisels from vibrating on reinforcing steel or electrical conduit. If drilling or coring is employed and should reinforcing steel be encountered, the following applies. For drilling, the drill should be stopped, removed, and the hole abandoned with a new hole started in the vicinity. For coring, the operation should be stopped and not resumed in that location until other removal methods have been used insuring the bar has been bypassed or its integrity insured. All demolition equipment shall be subject to the review and approval of the Contracting Officer.

- B. Concrete Removal by Blasting: Removal of the existing concrete may be done by light blasting. All removals may be accomplished by other methods as approved by the Contracting Officer in the procedures submitted under 2E-2, Submittals. Blasting shall be done as specified herein.

1. Detailed Blasting Plan: A detailed blasting plan shall be submitted to the Contracting Officer for approval. The plan shall include, but not be limited to, the diameter, depth, and spacing of drilled holes; the size and location of charges; the blasting sequence; method and location of handling, transporting, and storing explosives; monitoring plan and equipment; and personnel that will be working with explosives. The plan shall consist of a narrative plus sketches that completely describe all blasting.
2. Experience Statement: The Contractor shall submit a statement of experience to the Contracting Officer listing similar types of demolition work performed and stating by name the personnel that will be doing the blasting. The blasting superintendent shall have a minimum of five years of blasting experience.
3. Public Notice: The Contractor shall publicly advertise the nature of the operations to be undertaken and the controls to be established. All property owners and occupants within 800 feet minimum of the site shall be notified no less than two weeks prior to blasting operations. All injuries or losses to persons or property by reason of blasting shall be borne by the Contractor.
4. Vibration Engineering Personnel and Monitoring Equipment: Vibration engineering personnel and equipment of this project shall be approved by the Contracting Officer based on demonstrated experience in this specialty. Each blast shall be monitored by at least three 3-component seismographs. The field data and logs will be submitted, in duplicate, to the Contracting Officer along with a summary report and analysis.
5. Spacing and Location: The spacing and location of holes and loading of charges shall be submitted to the approval of the Contracting Officer. Blast hole alignment shall be carefully controlled to avoid intersection of adjacent holes or excessive spacing near the bottom of the excavation.
6. Safety Requirements: The handling, transporting, and storing of explosives and all blasting shall be performed in accordance with federal, state and location requirements.

3.2 PROTECTION

Before beginning any cutting or demolition work, the Contractor shall carefully survey the existing work and examine the drawings and specifications to determine the extent of the work. The Contractor shall take all necessary precautions to insure against

damage to existing work to remain in place, structures, utilities, serial, and submarine crossings. Any such damage shall be repaired by the Contractor at his expense. Existing form ties and other embedded items other than reinforcement exposed during the concrete removal operations shall, unless otherwise directed, indicated on the drawings or specified, be cut off flush at the breakout depth. It shall be anticipated that form ties, embedded steel items and reinforcing will be encountered, and any costs incurred in cutting and/or removing such items will be included in the cost of concrete removal. All work and Contractor operations shall comply with the requirements of Section 1A, General Conditions.

3.3 CONCRETE REMOVAL

Concrete shall be removed only to such depths as indicated or as directed by the Contracting Officer at the locations shown on the drawings. After the surfaces have been cut back as specified and the deteriorated concrete has been removed, any remaining deteriorated concrete in loose or shattered areas that may have resulted from the action of the demolition tools as determined by the Contracting Officer shall be removed at no cost to the Government.

3.4 CLEANING SURFACES

All cleaning operations will be done to the satisfaction of the Contracting Officer. River water may be used for initial cleaning operations. Clean water shall be used for all final cleaning operations. A preliminary washing as soon as the chipping and trimming are completed shall be done to remove loose materials and dust particles. Final cleaning of the surfaces to which the new concrete is to be bonded shall be done by high-pressure water jet or by wet sandblasting followed by washing with air/water jet. Any remaining excess water shall be removed with an air-jet. Final cleaning shall remove all laitance, carbonation, scum, dirt, oil, grease, and loose or disintegrated concrete. Overcutting resulting in undercutting of coarse aggregate will be cause for additional required surface chipping. Any such additional chipping shall be performed as determined necessary by the Contracting Officer at no cost to the Government. Final cleaning shall be delayed as long as practical, preferably just prior to concrete placement. All work shall be protected from contamination during all phases of cleanup prior to resurfacing.

- A. Sandblasting: Sand for sandblasting shall be hard, not readily broken down, and sufficiently dry to feed through the equipment satisfactorily. Specially prepared dried sand from which particles passed by the 2.36-mm (8) sieve and retained on the 600- μ m (30) sieve shall be used unless otherwise authorized (U.S. standard sieves). Sandblasting equipment shall be operated at an air pressure of approximately 100 sq in./lb.

B. High-Pressure, Water-Jet: The high-pressure, water-jet pump shall supply a minimum of 6.0 gallons/minute, with a nozzle pressure of 6000 psi. Pressures shall be adjusted to accomplish the required cleaning as herein specified. Pump shall be equipped with a pressure gauge.

3.5 DISPOSAL OF BROKEN CONCRETE

Disposal of all broken concrete resulting from the demolition and construction operations shall become the responsibility of the Contractor and shall be disposed of off Government property. The Contractor shall take all necessary precautions to prevent the misplacement of broken concrete into the river or lock chamber. Disposal of materials other than broken concrete shall become the responsibility of the Contractor and shall be disposed of at his own expense outside the limits of the Government reservations as specified in Section 1A, General Provisions. All material that is accidentally misplaced into the river or lock chamber shall be removed and disposed of accordingly.

PART 4 - MEASUREMENT AND PAYMENT

4.1 MEASUREMENT

The volume of concrete removal to be paid for under unit prices will be determined from the dimensions and notes shown on the drawings. Such volume will be computed to the nearest one-tenth of a cubic foot. No removal shall be done outside the pay lines shown without approval of the Contracting Officer. Additional concrete removal solely for the convenience of the Contractor will not be paid for by the Government.

4.2 UNIT PRICE PAYMENT

Payment for concrete removal will be made at the contract unit price/cu ft, including embedding metals, for Item No. 12a, "Upper Guidewall Resurfacing, Concrete Removal"; Item No. 13a, "Gate Bay Concrete Removal"; Item No. 14a "Lower Guidewall Resurfacing, Concrete Removal"; Item No. 15a, "Horizontal Resurfacing, Concrete Removal"; Item No. 17a, "Lock Chamber Resurfacing, Concrete Removal", and Item No. 20c(1), "Lock Electrical Work, Duct Bank, Concrete Removal". Such price shall include full compensation for all plant, labor, materials, and supplies required to complete the work as shown on the plans, in accordance with the specifications, or as required by the Contracting Officer.

END OF SECTION 2E

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 2F COFFERDAMS

PART 1 - GENERAL

1.1 SCOPE OF WORK

This work consists of fabricating, supplying, and erecting temporary cofferdam(s) to the extent shown on the drawings for the purpose of providing a dry environment for the installation of the bottom row of precast lockwall panels and their support base, a portion of which are always below the level of the lower pool. The work includes all labor, materials, support vessels, rigging and other equipment, and incidentals necessary for the installation, use, and removal of the cofferdam(s).

1.2 SUBMITTALS

The Contractor shall submit the following items for review. No work on the cofferdam(s) shall begin until the submittals have been approved.

- A. Shop drawings of the cofferdam(s)
- B. Calculations for structural design, buoyancy and stability, rigging forces, seal geometry, etc.
- C. Operation/erection drawings showing the configuration of all equipment necessary for deployment of the cofferdam(s)
- D. Schedule indicating the time required to deploy and remove the cofferdam(s) to be included in the work plan

1.3 DESIGN

Cofferdam design shall be performed by a licensed professional engineer who shall stamp and sign the design calculations and all drawings.

1.4 SAFETY

- A. All cofferdam(s) and related equipment shall conform to the safety requirements of applicable federal, state, and local regulations.
- B. The cofferdam(s) shall be equipped with a positive support system that will prevent it(them) from falling in the event that a seal is breached and buoyancy lost.

1.5 OWNERSHIP

Upon completion of this project, ownership of the cofferdam system shall revert to the Corps of Engineers. All equipment shall be in serviceable condition when delivered, and any damage affecting serviceability shall be repaired at no cost to the government.

PART 2 - PRODUCTS

2.1 MATERIALS

Materials shall be of the type, size, and grade as shown on the plans. If the Contractor proposes a cofferdam system substantially different from that as shown on the plans, his design shall indicate the type, size, and grade of all material to be used and shall clearly demonstrate the suitability of such material to its application.

PART 3 - EXECUTION

3.1 COFFERDAM INSTALLATION

Cofferdam installation shall be permitted only during the designated work period. At the conclusion of the work shift, the cofferdam shall be removed from the lock chamber.

PART 4 - MEASUREMENT AND PAYMENT

4.1 PAYMENT

Payment for all work in this section shall be at the lump-sum price for cofferdam(s) shown in the project bid document. Such price shall include full compensation for all plants, labor, materials, and supplies required to complete the work as shown on the plans and in accordance with the specifications.

END OF SECTION 2F

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 2G
PROTECTION OF LOCKWALL
DURING CONSTRUCTION

PART 1 - GENERAL

1.1 SCOPE OF WORK

The work consists of furnishing and deploying a navigation protection system to protect the lockwall under construction from damage by vessels using the locks while they are operational, including removal, storage and redeployment on a daily basis (except weekends).

1.2 SUBMITTALS

- A. Shop and erection or deployment drawings of the protection system
- B. Design calculations
- C. Schedule of deployment and removal procedure to be included in the work plan

1.3 PROTECTION

The pneumatic fender system shown on the plans is meant to show the minimum protection required. The Contractor may use other protection schemes provided that the system proposed meets the following requirements.

- A. Protection shall be deployed along the entire extent of lockwall under construction and shall extend at least 10 ft beyond the edge of completed repairs or original lockwall face. Protection shall be effective for the full height of wall exposed to vessel impact for the full range of water levels.
- B. Repairs shall be considered complete, for the purpose of protection requirement only, when all infill concrete for the full height of the lockwall in any tier of panels has cured for at least seven days.
- C. If the protection system uses cushioning action, the reaction shall be applied over a smooth contact area, and the contact pressure shall not exceed 30 psi at full expected deflection of the cushion.

- D. The protection system shall be configured to minimize the potential for snagging passing vessels, and shall be designed to resist longitudinal loads from vessels.

1.3 OWNERSHIP

Upon completion of this project, ownership of the navigation protection system shall revert to the Corps of Engineers. All equipment shall be in serviceable condition when delivered, and any damage affecting serviceability shall be repaired at no cost to the government.

PART 2 - PRODUCTS

Not used.

PART 3 - EXECUTION

- 1.1 Protection for all lockwall under construction shall be in place and functional before the lock is opened to traffic and shall remain so the entire time the lock is open to traffic.
- 1.2 Storage of the protection system during the construction shift shall be in a location that poses no hazard to navigation and that shall not obstruct construction operations. Storage location shall be approved by the contracting officer.

PART 4 - MEASUREMENT AND PAYMENT

4.1 PAYMENT

Payment for work in this section shall be at the lump-sum price for protection shown in the project bid document. Such price shall include full compensation for all plant, labor, materials, and supplies required to complete the work as shown on the plans and in accordance with the specifications.

END OF SECTION 2G

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 3A FORMWORK FOR CONCRETE

PART 1 - GENERAL

1.1 RELATED WORK SPECIFIED ELSEWHERE

- A. Cast-in-Place Concrete: Section 3E.
- B. Concrete Reinforcement: Section 3C.

1.2 REFERENCE STANDARDS

- A. American Concrete Institute (ACI) Standards: ACI 347-78, Recommended Practice for Concrete Formwork
- B. U.S. Department of Commerce, National Bureau of Standards (NBS) Product Standard: PS 1-83, For Construction and Industrial Plywood

1.3 SUBMITTALS

- A. Shop Drawings: Drawings and computations for all formwork required shall be submitted at least 30 days before either fabrication on site or before delivery of prefabricated forms. The drawings and data submitted shall include the type, size, quantity, and strength of all materials of which the forms are made, the plan for jointing of facing panels, details affecting the appearance, and the assumed design values and loading conditions.
- B. Manufacturers' literature shall be submitted for plywood, concrete, form hard board, for accessories, prefabricated forms, and form coating.

1.4 DESIGN

- A. The design and engineering of the formwork, as well as its construction, shall be the responsibility of the Contractor. The formwork shall be designed for loads, lateral pressure and allowable stresses in accordance with Chapter 1 of ACI Standard 347. Forms shall have sufficient strength to withstand the pressure resulting from placement and vibration of the concrete and shall have sufficient rigidity to maintain specified tolerances. For Class A finish, the design shall be made to limit deflecting of facing material between studs as well as deflection of studs and walers to 0.0025 times the span.

- B. Forms shall be configured so as not to impede the operation of the navigation protection system used to protect the lockwall under construction during operation of the lock.

1.5 FIELD QUALITY CONTROL

Forms and embedded items shall be inspected in sufficient time prior to each concrete placement by the Contractor in order to certify to the Contracting Officer that they are ready to receive concrete. The results of each inspection shall be reported in writing.

PART 2 - PRODUCTS

2.1 FORMS

Forms shall be fabricated with facing materials that produce the specified construction tolerance and surface requirements of Section 3E. Class A finish shall apply to all surfaces. The form-facing material shall be composed of new, well-matched tongue and groove lumber or new plywood panels conforming to NBS Product Standard PS-1, Grade B-B, concrete form Class I.

2.2 FORM ACCESSORIES

Ties and other similar form accessories to be partially or wholly embedded in the concrete shall be of a commercially manufactured type. After the ends or end fasteners have been removed, the embedded portion of the metal ties shall terminate not less than 2 in. from any concrete surface, either exposed to view or exposed to water. Plastic snap ties may be used in locations where the surface will not be exposed to view. Form ties shall be constructed so that the ends or end fasteners can be removed without spalling the concrete.

2.3 FORM COATING

Form coating shall be of a commercial formulation of satisfactory and proven performance that will not bond with, stain, or adversely affect concrete surfaces and will not impair subsequent treatment or concrete surfaces depending upon bond or adhesion nor impede the wetting of surfaces to be cured with water or curing compounds.

PART 3 - EXECUTION

3.1 INSTALLATION

Forms shall be mortar tight, properly aligned, and adequately supported to produce concrete surfaces meeting the surface requirements of and conforming to construction tolerances of Section 3E. Where concrete surfaces are to be permanently exposed to view, joints in

form panels shall be arranged to provide a pleasing appearance. Where forms for continuous surfaces are placed in successive units, care shall be taken to fit the forms over the completed surface so as to obtain accurate alignment of the surface and to prevent leakage of mortar. Forms shall not be reused if there is any evidence of surface wear and tear or defects that would impair the quality of the surface. All surfaces of forms and embedded materials shall be cleaned of any mortar from previous concreting and of all other foreign material before concrete is placed in them.

3.2 CHAMFERING

All exposed joints, edges, and external corners shall be chamfered by molding placed in the forms unless the drawings specifically state that chamfering is to be omitted or as otherwise specified. Chamfered joints shall not be permitted where earth or rockfill is placed in contact with concrete surfaces. Chamfered joints shall be terminated a sufficient distance outside the limit of the earth or rockfill so that the end of the joints will be clearly visible.

3.3 COATING

Forms for exposed or painted surfaces shall be coated with form oil or a form-release agent before reinforcement is placed in final position. The coating shall be used as recommended in the manufacturer's printed or written instructions. Forms for unexposed surfaces may be wet with water in lieu of coating immediately before placing concrete, except that in cold weather with probable freezing temperatures, coating shall be mandatory. Surplus coating on form surfaces and coating on reinforcing steel and construction joints shall be removed before placing concrete.

3.4 REMOVAL

- A. Forms shall not be removed without approval and all removal shall be accomplished in a manner that will prevent injury to the concrete. Forms shall not be removed before the expiration of the minimum time indicated below, except as otherwise directed or specifically authorized. When conditions of the work are such as to justify the requirement, forms will be required to remain in place for a longer period.
- B. Unsupported Concrete: Formwork for walls, columns, sides of beams, gravity structures, and other vertical-type forms not supporting the weight of concrete shall not be removed in less than 24 hours. The time depends on temperature, lift heights, and type and amount of cementitious material in the concrete. Where forms for columns, walls, and sides of beams also support formwork for slabs or beam soffits, the removal time of the latter shall govern.

PART 4 - MEASUREMENT AND PAYMENT

4.1 PAYMENT

No separate payment will be made for formwork and all costs in connection therewith shall be included in the contract price for the item of work to which the work is incidental.

END OF SECTION 3A

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 3B
EXPANSION, CONTRACTION AND
CONSTRUCTION JOINTS IN CONCRETE

PART 1 - GENERAL

1.1 SCOPE

This section covers the materials, techniques, and workmanship requirements for forming expansion, contraction, and construction joints in concrete structures.

1.2 RELATED WORK SPECIFIED ELSEWHERE

Major requirements for concrete work are specified in Section 3E, Concrete.

1.3 APPLICABLE STANDARDS

The following standards of the issues listed below, but referred to thereafter by basic designation only, form a part of this specification to the extent indicated by the references there:

- A. American Society for Testing and Materials (ASTM) Standards (with corresponding U.S. Army Corps of Engineers Handbook for Concrete and Cement (HRD) Specifications where indicated):
1. D 1751-83 (CRD-C 508) Preformed Expansion Joint
Fillers for Concrete Paving and
Structural Construction (Non-
extruding and Resilient
Bituminous Types)
 2. D 1752-84 (CRD-C 509) Preformed Sponge Rubber and Cork
Expansion Joint Fillers and
Concrete Paving and Structural
Construction
 3. D 2628-81 (CRD-C 531) Preformed Polychloroprene
Elastomeric Joint Seals
for Concrete Pavements
 4. D 2835-72 (CRD-C 532) Lubricant for Installation of
Preformed Compression Seals in
Concrete Pavements

B. Federal Specifications (with corresponding CRD standards where indicated):

- | | |
|--|--|
| 1. TT-S-00227E (COM-NBS)
Am-3 (CRD-C 506) | Sealing Compound,
Elastomeric Type, Multi-
component (for caulking,
sealing, and glazing in
Buildings and Other
Structures) |
|--|--|

1.4 SUBMITTALS

Certified manufacturer's test reports shall be provided for premolded expansion-joint filler strips, compression seals and lubricant to verify compliance with the applicable specification.

PART 2 - PRODUCTS

- 2.1 Expansion Joint Filler Strips, Premolded: Shall conform to ASTM D 1751 or ASTM D 1752, Type I. Resin-impregnated fiberboard shall not be used.
- 2.2 Joint Sealants and Seals: Field-molded sealants shall conform to Federal Specification TT-S-00227E (COM-NBS), Type II for vertical joints and Type I for horizontal joints, Class A. Bond breaker material shall be polyethylene tape, coated paper, metal foil or similar type materials. The back-up material shall be compressible, nonshrink, nonreactive with sealant, and nonabsorptive material type such as extruded butyl or polychloroprene foam rubber.

PART 3 - EXECUTION

3.1 INSTALLATION

Joint locations and details, including materials and methods of installation of joint fillers, shall be as specified, shown on the drawings, and as directed. In no case shall any fixed metal be continuous through an expansion or contraction joint.

- A. Expansion Joints: Premolded filler strips shall have oiled wood strips secured to the top thereof and shall be accurately positioned and secured against displacement to clean, smooth concrete surfaces. The wood strips shall be slightly tapered, dressed and of the size required to install filler strips at the desired level below the finished concrete surface and to form the groove for the joint sealant or seals to the size shown on the drawings. Material used to secure premolded fillers and wood strips to concrete shall not harm the concrete and shall be compatible with the joint sealant or seals. The wood strips shall not be removed until after the concrete

curing period. The groove shall be thoroughly cleaned of all laitance, curing compound, foreign materials, protrusions of hardened concrete and any dust that shall be blown out of the groove with oil-free compressed air. Joints shall not be sealed when the sealant, air, or concrete temperature is less than 40°F. Bond breaker and back-up material shall be installed where required. Joints shall be primed and filled flush with joint sealant in accordance with the manufacturer's recommendations or as otherwise required by the drawings.

- B. Construction Joints: Joints requiring a bond breaker shall be coated with curing compound or with bituminous paint. Waterstops shall be protected during application of bond breaking material to prevent them from being coated.

PART 4 - MEASUREMENT AND PAYMENT

4.1 PAYMENT

No separate payment will be made for expansion and contraction joint, and all costs in connection therewith shall be included in the contract price for the item of work to which the work is incidental.

END OF SECTION 3B

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 3C
CONCRETE REINFORCEMENT

PART 1 - GENERAL

1.1 SCOPE OF WORK

The work covered by this section consists of furnishing all equipment, materials, and labor for providing and placing steel bars, welded steel wire fabric, and accessories for concrete reinforcement.

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Formwork: Section 3A, "Formwork for Concrete".
- B. Joints: Section 3B, "Expansion, Contraction, and Construction Joints in Concrete".
- C. Concrete: Section 3E, "Concrete".

1.3 REFERENCE STANDARDS

The following publications of the issues listed below form a part of this specification to the extent indicated by the references thereto but are referred to thereafter by basic designation only.

- A. American Concrete Institute (ACI) Standards:
 - 1. SP-66-1980 ACI Detailing Manual
 - 2. ACI 315-80 Details and Detailing of Concrete Reinforcement
 - 3. ACI 318-83 Building Code Requirements for Reinforced Concrete
- B. American Society for Testing and Materials (ASTM) Standards:
 - 1. A 370-86 Mechanical Testing of Steel Products
 - 2. A 497-86 Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement
 - 3. A 615-86 Deformed and Plain Billet Steel Bars for Concrete Reinforcement

4. A 706-86 Low-Alloy Steel Deformed Bars for Concrete Reinforcement

5. E 94-84a Radiographic Testing

C. American Welding Society (AWS) Code:

D 1.4-79 Structural Welding Code - Reinforcing Steel

1.4 SUBMITTALS

The Contractor shall submit the following items to the Contracting Officer for approval:

- A. Shop drawings shall be in accordance with specified requirements and shall include the following:
1. Reinforcement steel schedules showing quantity, size, shape, dimensions, weight per ft and total weights, and bending details.
 2. Details of bar supports showing types, sizes, spacing, and sequence.
- B. Test Reports: Certified test reports of reinforcement steel showing that the steel complies with the applicable specifications shall be furnished for each steel shipment and identified with specific lots prior to placement. Three copies of the ladle analysis shall be provided for each lot of steel and the Contractor shall certify that the steel furnished conforms to the ladle analysis.

1.5 QUALITY ASSURANCE

The Contractor shall have required material tests performed by an approved laboratory and certified to demonstrate that the materials are in conformance with the specifications. Tests shall be performed and certified at the Contractor's expense. Mechanical testing of steel shall be in accordance with ASTM A 370, except as otherwise specified herein or required by the material specifications. Tension tests shall be performed on full cross section specimens using a gage length that spans the extremities of specimens with welds or sleeves included. The ladle analysis shall state the percentages of carbon, phosphorous, manganese, and sulfur present in the steel.

PART 2 - PRODUCTS

2.1 Steel bars shall conform to the size and length shown on drawings. All bars shall conform to ASTM A 615, Grade 60, deformed.

2.2 Accessories:

- A. Bar supports shall conform to ACI 315. Supports for formed surfaces exposed to view or to be painted shall be plastic protected wire, stainless steel or precast concrete supports. Precast concrete supports shall be wedge shaped, not larger than 3-1/2 x 3-1/2 in., of thickness equal to that indicated for concrete cover and shall have an embedded hooked tie wire for anchorage. If formed surface is exposed to view, precast concrete supports shall be the same quality, texture and color as the finish surface.
- B. Wire ties shall be 16-gauge or heavier black annealed wire.
- C. Steel Welded Wire Fabric: ASTM A 497 wire spacing and sizes as indicated on the drawings. For wire with a specific yield strength (fy) exceeding 60,000 psi, fy shall be the stress corresponding to a strain of 0.35%.

PART 3 - EXECUTION

3.1 PLACEMENT

Reinforcement steel shall be placed as specified and as shown on contract drawings and approved shop drawings. Placement details of steel and accessories not specified or shown on the drawings shall be in accordance with ACI 315 and ACI 318 or as directed by the Contracting Officer. Steel shall be fabricated to shapes and dimensions shown, placed where indicated within specified tolerances and adequately supported during concrete placement. At the time of concrete placement, all steel shall be free from loose, flaky rust, scale (except tight mill scale), mud, oil, grease, or any other coating that might reduce the bond with the concrete.

- A. Hooks and Bends: Steel may be shop or field bent. All steel shall be bent cold unless otherwise authorized. No steel bars shall be bent after being partially embedded in concrete unless indicated on the drawings or otherwise authorized.
- B. Welding of steel will not be permitted except as shown on the drawings.

C. Placing Tolerances:

1. Spacing: The spacing between adjacent bars and the distance between layers may not vary from the indicated position by more than one bar diameter nor more than 1 in.
2. Concrete Cover: The minimum concrete cover of main reinforcement steel and the allowable tolerances shall be as follows:

<u>Minimum Cover</u>	<u>Variation</u>
6"	+1/2"
4"	+3/8"
3"	+3/8"
2"	+1/4"

- D. Splicing: Proposed splices in all reinforcement shall be submitted to the Contracting Officer for approval. Bar laps may be placed in contact and securely tied or may be spaced transversely apart to permit the embedment of the entire surface of each bar in concrete, but shall not be spaced farther apart than one-fifth the required length of lap, or 6 in.
- E. Existing reinforcement exposed during concrete removal shall be wire brushed clean and will remain in place unless directed otherwise.

PART 4 - MEASUREMENT AND PAYMENT

4.1 PAYMENT

Furnishing and placing reinforcement bars and steel welded wire fabric will be paid at the contract unit price per lb for Item No. 12c, "Upper Guidewall Resurfacing, Steel Reinforcement", Item No. 13c, "Gate Bay Resurfacing, Steel Reinforcement", Item No. 14c, "Lower Guidewall Resurfacing, Steel Reinforcement", and Item No. 17d, "Lock Chamber Resurfacing, Steel Reinforcement". Such prices shall constitute full compensation for furnishing all materials and performance of all work as indicated on the drawings and specified herein. Steel in laps indicated on the drawings or required by the Contracting Officer will be paid for at the contract unit price. No payment will be made for the additional steel in laps, which are authorized for the convenience of the Contractor. No separate payment will be made for accessories of which payment shall be included in the contract unit price for the items of work to which the accessories are incidental.

END OF SECTION 3C

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 3D
CONCRETE AND MACHINERY ANCHORS AND
PRECAST CONCRETE PANEL TIES

PART 1 - GENERAL

1.1 SCOPE OF WORK

This section covers the anchors employed for anchoring, new concrete to existing concrete (nonprestressed concrete anchors), sector base anchors, and machinery anchors and miscellaneous anchor bolts, including qualification testing and quality control testing.

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Section 3C, Concrete Reinforcement
- B. Section 5A, Hardware and Appurtenances

1.3 REFERENCE STANDARDS

U.S. Army Corps of Engineers Handbook for Cement and Concrete, CRD-C 621-83, Nonshrink Grouts.

1.4 SUBMITTALS

- A. Manufacturer's descriptive literature, material certification, and installation recommendations for all adhesive and grout products.
- B. Manufacturer's certification that material is suitable for proposed application.
- C. Mixture proportions and certified lab tests for grout.
- D. Description of pull test setup.
- E. Qualification and quality control pull test results.
- F. Anchor installation inspection reports.

1.5 QUALIFICATION AND QUALITY CONTROL TESTS

A. Qualification Tests:

- 1. General: Qualification tests will be made at the start of construction. Anchors shall be pull load tested by the Contractor in the presence of a Government inspector. Qualification test anchor installation will be used to

establish installation procedures for the remaining anchors. Minimum embedment for anchors shall be as shown on the drawings

2. Testing Apparatus: The test setup shall be submitted in writing by the Contractor, with appropriate sketches and specifications, for the approval of the Contracting Officer.
3. Test Loading: Test anchors shall be subjected to a test load of 125 percent of the specified yield strength of the bar prior to installation of permanent anchors. Location of test anchors shall be determined by the Contracting Officer. Test anchors will be embedded into concrete as shown on the drawings. In addition to initial testing, 2% of all the permanent anchors will be tested. Permanent anchors shall be loaded to 20 kips during testing. The Contracting Officer may direct installation and testing of additional anchors.
4. Testing: The test load for three anchors of each type shall be applied at three equal increments. The strain gage reading shall be taken and recorded at the beginning and at the end of each load cycle. The final load shall be maintained for 1 hour and the dial readings shall be recorded at 15-minute intervals. At the end of 1 hour, the anchor shall be unloaded and the net movement of the anchor shall be determined. Test results will be reported to the representative of the Contracting Officer prior to installation of permanent anchors. A minimum of three anchors shall be tested and approved by the Contracting Officer before installation of permanent anchors. The test load for the 2% of all permanent anchors to be tested shall be applied at one increment of 20 kips for reinforcing steel anchors and 10 kips for fully threaded rods on a pass or fail basis, as determined by the Contracting Officer. Unacceptable anchors will be incorporated into the work but shall not be counted upon to reduce the number of required acceptable anchors and will not be paid for.
5. Sector Base Anchors: All existing sector base anchors shall be pull-tested in accordance with Paragraph 4, Pull Tests for Anchors. Any failed anchors shall be drilled out and replaced.

1.6 QUALITY CONTROL

- A. General: The Contractor shall establish and maintain quality control for all operations to assure compliance with contract

requirements and maintain records of his quality control for all construction operations, including, but not limited to the following:

1. Testing and certification of materials and equipment.
 2. Installation of anchors and ties.
- B. Reporting: A copy of these records and tests, as well as corrective action taken, will be furnished to the Government daily.

PART 2 - PRODUCTS

- 2.1 Resin grout (concrete anchors) shall be polyester resin cartridges. These cartridges shall have a casing of a saturated polyester providing an optimum resistance to moisture, with a relatively high frangibility for complete mixing during installation. The cartridges shall contain two distinct fractions of unsaturated polyester resin and catalyst without an intervening mechanical membrane to assure proper mixing. The resin shall be a high strength polyester, highly filled with nonreactive inorganic aggregate of suitable mesh size. The catalyst shall contain peroxide, highly filled with a nonreactive inorganic filler. The compressive strength of the mixed and cured resin shall be 16,000 psi. Gel and cure times of cartridges shall be as specified by the manufacturer and as approved by the Contracting Officer. The material shall be thixotropic and of such viscosity that the anchor can adequately mix the material. All cartridges shall be inspected prior to insertion to see that the polyester resin components have not hardened and to see that they meet the above requirements. Cartridges that are older than 6 months shall not be used.
- 2.2 Nonshrink Grout (Sector Base Anchors): Descriptive literature of the grout proposed for use shall be furnished together with a certificate from the manufacturer stating that it is suitable for the application or exposure for which it is being considered. In addition, a detailed plan shall be submitted for approval, showing equipment and procedures proposed for use in mixing and placing the grout.
- A. Prepackaged material requiring only the addition of water will be accepted on the basis of certified laboratory test results showing that the material meets the requirements of CRD-C 621. When fine aggregate is to be added, the Contractor shall also furnish for approval the design mix proportions together with certified copies of laboratory test results indicating that the mix is in conformance with the requirements of CRD-C 621.
 - B. Mixture proportions using a volume-change controlling ingredient shall be submitted for approval. The submittal shall include the design mix proportions of all ingredients and

certified copies of laboratory test results indicating that the materials and the mix is in conformance with the requirements of CRD-C 621.

- 2.3. Anchors: Concrete anchors shall be of the type and sizes indicated on the drawings.
- 2.4 Ties: Precast concrete panel ties shall be weldable grade reinforcing steel conforming to the requirements of ASTM A 706, Grade 60.
- 2.5 Sector Base Anchors: Anchors shall be ASTM A 572, Grade 42, 1-1/2 in. diameter, grouted in place with all necessary hex and jam nuts.

PART 3 - PREPARATION

- 3.1 Before drilling for anchors and ties, the Contractor shall locate the electrical conduit in lockwalls to avoid damage to the electrical conduit.
- 3.2 Installation of Resin Grout: Installation procedures shall be as recommended by the resin manufacturer and as specified hereinafter. Manufacturer's recommendations shall be in writing and shall be submitted to the Contracting Officer for approval prior to installation of the anchors. The holes shall be drilled to the depth as required by the drawings. The holes shall be thoroughly washed prior to the insertion of epoxy cartridges. The diameter of the hole shall be in accordance with the recommendations of the manufacturer. For the anchor portion in existing concrete or rock, high-viscosity, 3-minute set, cartridges shall be used. The size of cartridges shall be as recommended by the manufacturer and as approved by the Contracting Officer. Cartridges shall be inserted and carefully pushed into the hole. Care shall be taken not to puncture the cartridges. Anchor or tie rods shall be inserted into the cartridge-filled hole and rotated at a speed of 120 to 160 revolutions per minute for a period of about 10 seconds. Before and during rotation, the anchor or tie rods shall be fully inserted into the hole. After rotation is complete, the anchor shall be held in still position for a period of 50 seconds or until the resin in rock or existing concrete sets up. Then the drill or other rotating tool may be removed.

PART 4 - MEASUREMENT AND PAYMENT

- 4.1 Furnishing, Installing, and Testing Anchors: Payment for furnishing, installing, and testing concrete and precast concrete panel anchors will be made for acceptable anchors at the contract unit price each for the various types of anchors. Such prices shall

constitute full compensation for furnishing all materials and performance of all work as indicated on the drawings and as specified herein.

- 4.2 Machinery Anchors and Miscellaneous Anchor Bolts: No separate payment will be made for miscellaneous fastenings and anchor bolts and all costs in connection therewith shall be included in the applicable contract price for the item to which the work pertains. Miscellaneous anchors include anchor bolts for fastening machinery, handrails, and other items to concrete.
- 4.3 Pull Tests for Existing Sector Base Anchors: No separate payment will be made for pull tests for existing sector base anchors, but all costs in connection therewith shall be included in the contract price for the item to which the work pertains.

END OF SECTION 3D

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 3E
CAST-IN-PLACE CONCRETE

PART 1 - GENERAL

1.1 SCOPE OF WORK

The work includes all materials and workmanship required for production, delivery, placing, and curing of cast-in-place concrete.

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Section 3A, Formwork for Concrete
- B. Section 3G, Precast Concrete
- C. Section 3D, Concrete, Machinery, and Precast Concrete Panel Anchors

1.3 REFERENCE STANDARDS

- A. American Concrete Institute, 1983. "Building Code Requirements for Reinforced Concrete" (ACI 318-83), ACI Standards 1963, Detroit, Michigan.
- B. Gustafson, David P. et al, 1984. "Specifications for Structural Concrete for Buildings", ACI-301-84, American Concrete Institute, Detroit, Michigan.

1.4 SUBMITTALS

- A. Submit trial concrete mixture proportions and test results as specified in Paragraph 2.1.a, below.
- B. Submit mill certificates or supplier's certification for all concrete components.
- C. Contractor shall submit batch monitoring test results for infill concrete placements as required by Paragraph 3.3.3.b, below.
- D. Contractor shall prepare a written procedure for placing concrete, identifying sequence, maximum allowable lift height and placing rate, placing schedule, and a checklist of inspections to be made. Contractor's proposed methods of concrete placement, consolidation, and curing shall be submitted to the Contracting Officer for review.

1.5 QUALITY CONTROL

- A. All work shall be performed in accordance with ACI 301 and 318 as applicable.
- B. Contractor shall maintain records of tests and inspections in accordance with the Contractor Quality Control Plan and make copies of such records available to the Contracting Officer on request.

1.6 PLACEMENT DEMONSTRATION

Contractor shall make a demonstration pour to establish the feasibility of the proposed mix, placement procedures, and pour duration.

- A. Placement shall be into a confined space that accurately simulates the configuration of infill concrete behind precast panels.
- B. Concrete shall be mixed as a full batch using the same equipment proposed for production pours.
- C. Compressive tests shall be made 1, 2, 4, and 12 hours after initial set of the concrete as well as at 28 days.
- D. No production pours shall be made until a demonstration pour has been successfully completed and the results approved by the Contracting Officer.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Quick-Setting Infill Concrete: Because of the need to reopen the lock to traffic immediately after completion of the construction shift, concrete shall be made using a commercial quick-setting blended cement, such as Pyramerc, manufactured by Lone Star Industries, Houston, Texas, or Portland Cement used in conjunction with accelerating admixtures to provide the specified strength gain. Cast-in-place concrete materials shall conform to the following requirements:
 - 1. Cement: Cement shall conform to the requirements of ASTM C 150. Blended cement shall conform to the requirements of ASTM C 595 (modified).
 - 2. Aggregate: Aggregate shall conform to the requirements of ASTM C 33.

3. Air-entraining admixture: Material shall conform to ASTM C 260.
4. Water-reducing admixture: Material shall conform to ASTM C 494, Type E.
5. Water-reducing admixture, high range: Material shall conform to ASTM C 494, Type F.
6. Pozzolan: Pozzolan shall conform to ASTM C 618.

B. Prior to commencing operations, the Contractor shall furnish the proportions of all ingredients that will be used in the manufacture of quick-setting cast-in-place concrete. The mixture proportions shall be accompanied by test results from an independent commercial testing laboratory, attesting that the proportions selected will produce concrete of the required quality. Testing shall fully document the strength gain specified below. Cast-in-place concrete mixture shall be designed to satisfy the following requirements.

1. Compressive Strength: Compressive strength shall be at least as shown for the time after initial set of the concrete:
 - a. 1000 psi at 1 hour
 - b. 1500 psi at 2 hours
 - c. 2500 psi at 4 hours
 - d. 3000 psi at 12 hours
2. Maximum coarse aggregate size: 31.5 mm(1-1/4 in.) nominal
3. Minimum entrained air: 4 to 7%
4. Maximum water/cement ratio: 0.5
5. Minimum cement plus fly ash content: 450 lb/cy (five-sack mixture)
6. Slump: 4-1/2 in. \pm 1/2 in.

C. Reinforcing: Mild steel reinforcing shall be new billet steel bar conforming to the requirements of ASTM A 615, Grade 60.

2.2 ACCESSORIES

- A. Hardware and accessories shall be incorporated into the work as shown on the drawings.
- B. Joint seals and joint filler materials shall be as shown on the drawings and specified in Section 3B.

PART 3 - EXECUTION

3.1 PREPARATION

The Contractor shall inspect all existing work prior to placing cast-in-place concrete to verify that such work is complete and ready to receive concrete.

- A. The Contractor shall notify the Contracting Officer at least 24 hours in advance of any concrete placement.
- B. All embedded items and reinforcement shall be securely tied to prevent movement during concrete placement and consolidation activities.
- C. Formwork for cast-in-place concrete shall be in accordance with ACI 301.

3.2 CONCRETE MIXING, PLACING, AND CURING

Production, conveying, placing, consolidation, and curing of concrete shall be performed in accordance with ACI 301 and the following requirements.

- A. Truck mixers may be used with written approval of the Contracting Officer. When admixtures are dispensed into the truck at the site, truck capacities and batch sizes shall be selected that enable thorough and complete mixing of all constituent materials.
- B. All exposed concrete surfaces shall be cured by application of absorptive mats or fabric kept wet continuously for a minimum of seven days after concrete placement. Membrane curing shall not be used.
- C. The Contractor shall measure precast panel movements and deflections before and after placing concrete. The measurements shall be taken at all four panel corners and at the top, bottom, and midheight along a vertical line passing through the middle of the panel. The Contractor shall submit his proposed measuring procedures to the Contracting Officer for review. Panels that exceed the tolerances specified in Section 3E shall be brought to the attention of the Contracting Officer. Other cast-in-place concrete work shall meet the requirements of Section 3.4.

3.3 INSPECTIONS AND TESTS

- A. The Contractor shall be responsible for inspection and testing of cast-in-place concrete activities to ensure that the work conforms in all respects to the drawings and specifications.

Records of inspections and tests shall be maintained for the Contracting Officer's review.

- B. The Contractor shall provide the following necessary quality control and testing services for each batch of concrete placed:
1. Four sets of three concrete specimens shall be cast, cured, and tested to determine the concrete compressive strength when the lock is open to traffic at 7 and 12 hours and 28 days. The fourth set shall be a spare for use when the test at opening is questionable.
 2. Determine slump of concrete mixture at time of placement.
 3. Determine air content of concrete mixture at time and point of placement.

3.4 CONSTRUCTION TOLERANCES

Variation in alignment, grade, and dimensions of the structures from the established alignment, grade, and dimensions shown on the drawings shall be within the tolerances specified in the following tables.

Construction Tolerances for Structures

- | | |
|--|---|
| 1. Departure from established alignment | 1 in. |
| 2. Department from established grades | 1 in. |
| 3. Variation from the level, plumb, or from the grades indicated on the drawings | Exposed, 10 ft - 1/2 in.
Backfilled, 10 ft - 1 in. |
| 4. Variation in cross-sectional dimensions | Minus - 1/4 in.
Plus - 1/2 in. |

3.5 SURFACE REQUIREMENTS

The surface requirements for the various classes of finish shall be as hereinafter specified. Allowable irregularities are designated "abrupt" or "gradual" for purposes of providing for surface variations. Offsets resulting from displaced, misplaced or mismatched forms, sheathing or loose knots in sheathing, or other similar forms of defect, shall be considered "abrupt" irregularities. Irregularities resulting from warping, unplaneness or similar uniform variations from planeness, or true curvature, shall be considered "gradual" irregularities. "Gradual" irregularities will be checked

for compliance with the prescribed limits with a 5-ft template consisting of a straightedge for plane surfaces and a shaped template for curved or warped surfaces. In measuring irregularities, the straightedge or template may be placed anywhere on the surface in any direction, with the testing edge held parallel to the intended surface.

<u>Class of Finish</u>	<u>Abrupt, Inches</u>	<u>Irregularities</u>	<u>Gradual, Inches</u>
A	1/8		1/4

3.6 APPEARANCE

All surfaces that are permanently exposed shall be cleaned, if stained or otherwise discolored, by a method that does not harm the concrete and that is approved by the Contracting Officer.

3.7 CLEANUP

Contractor shall dispose of wasted concrete in accordance with Corps' requirements. Mixer trucks, pumps, tools, and placing equipment shall be cleaned in designated areas only and wash water and spoil shall be contained as required.

END OF SECTION 3E

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 3F
PRESSURE GROUTING

PART 1 - GENERAL

1.1 RELATED WORK SPECIFIED ELSEWHERE

- A. Concrete Reinforcement: Section 3C
- B. Cast-in-Place Concrete: Section 3E

1.2 APPLICABLE PUBLICATIONS

American Society for Testing and Materials (ASTM) Publication.
(The publication forms a part of this specification to the extent referenced and is referred to in the text by the basic designation only.)

- A. C 881-78 (R 1983), Epoxy-Resin-Base Bonding Systems for Concrete.

1.3 SUBMITTALS

The Contractor shall submit to the Contracting Officer the following items for approval:

- A. Materials: Descriptive data of the materials to be used and instructions on the mixing and use of the epoxy grout.
- B. Equipment: Descriptive data on the epoxy injection system, percussion drill, and drill bits, including product names, sizes, etc.
- C. Epoxy Injection Procedure: The procedure for conventional grouting of reinforcement and injection method of crack repair. The procedures shall include the Contractor's plan for protecting the health of personnel and the environment.
- D. Drilled Hole Log: Shall be submitted as specified in Paragraph 3.2.

PART 2 - MATERIALS

Not used.

PART 3 - EXECUTION

3.2 CONVENTIONAL REINFORCEMENT METHOD

This method consists of cleaning and sealing the crack after drilling holes as shown on the plan, filling the holes and crack plane with epoxy pumped under low pressure (50 to 80 psi), and placing a reinforcing bar into the drilled holes. The hole shall be filled from the bottom to the top of the hole. During drilling, the Contractor shall keep a log of the hole drilled. The log shall show, but not be limited to, the depth of any rebar encountered and the depth of all voids encountered.

3.3 EPOXY INJECTION METHOD

The Contractor shall clean the cracks of oil, grease, dirt, or fine particles of concrete with water or effect solvent that would prevent the epoxy from bonding. The surface cracks shall then be sealed to keep the epoxy from leaking out. The Contractor shall use bonded flush fittings when the cracks are not V-grooved. The epoxy components shall be mixed in accordance with the manufacturer's instructions. The Contractor shall use hydraulic pumps, paint pressure pots, or air-actuated caulking guns. If the crack is vertical, pumping of epoxy shall begin from the lowest elevation of the crack to the highest elevation. If the crack is horizontal, work shall progress continuously from one end to the other. After the epoxy has been cured, the surface seal shall be removed.

PART 4 - MEASUREMENT AND PAYMENT

- 4.1 The measurement for epoxy grouting will be made on the actual volume of grout used. Payment for grout shall include the cost of all labor, materials, and the use of all equipment and tools required to complete the grout work. Payment therefore will be made at the contract lump sum for Item No. 16.a, "Mobilization and Demobilization", at the contract unit price each for Item No. 16.b, "Portals", and at the contract unit price per cu ft for Item No. 16.c, "Pressure Grouting".

END OF SECTION 3F

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 3G PRECAST CONCRETE

PART 1 - GENERAL

1.1 SCOPE OF WORK

The work includes all materials and workmanship required for fabrication, delivery, handling, and erection of precast concrete stay-in-place form panels.

1.2 RELATED WORK

- A. Cast-in-Place Concrete: Section 3E
- B. Hardware and Appurtenances: Section 5A
- C. Expansion, Contraction, and Construction Joints in Concrete: Section 3B

1.3 REFERENCES

- A. American Concrete Institute, 1983. "Building Code Requirements for Reinforced Concrete" (ACI 318-83), Detroit, Michigan.
- B. American National Standards Institute, September 1979. "Structural Welding Code-Reinforcing Steel", Standard D1.4-79, American Welding Society, Miami, Florida.
- C. Gustafson, David P. et al, 1984. "Specifications for Structural Concrete for Buildings", ACI-301-84, Detroit, Michigan.
- D. Prestressed Concrete Institute, 1985. Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products, third edition, Chicago, Illinois.
- E. Prestressed Concrete Institute, 1985. PCI Handbook: Precast and Prestressed Concrete, Chicago, Illinois.

1.4 SUBMITTALS

- A. Contractor shall submit shop and erection drawings for all precast elements. Drawings shall indicate fabrication details, reinforcing, connection details, support items, dimensions, and temporary attachments and work.

- B. Contractor shall submit details showing proposed methods of lifting, handling, storing, and erection precast elements.
- C. Weights of precast elements shall be computed and listed on shop drawings.
- D. Contractor shall submit results of tests on materials as specified in Paragraphs 2.1 and 3.3.
- E. Concrete mixture proportions and qualifying data shall be provided.
- F. Catalog cuts of other miscellaneous products to be incorporated into the work such as nonshrink grout, joint seals, tie and dowel bonding agents, etc., shall be provided.

1.5 QUALITY CONTROL

- A. All work shall be performed in accordance with PCI Design Handbook - Precast and Prestressed Concrete, and ACI 301 Structural Concrete for Building.
- B. Precast concrete work shall be performed by either experienced fabricators qualified in accordance with PCI MNL-116, Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products, or shall be performed by an on-site developed precasting facility meeting the requirements of PCI MNL-116.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Delivery, storage, and handling of precast concrete elements shall be performed in such a manner as not to adversely affect their appearance or use. Panels shall not be lifted from the forms until panel strength has reached $0.7 f'_c$.
- B. Design of lifting embedments and handling devices shall be the responsibility of the Contractor. Contractor shall provide details of proposed lifting methods, attachments, and devices for review by the Contracting Officer. Handling embeds shall not be installed in the exposed exterior face of the panels.
- C. Panels shall be lifted only from suitably designed lifting hardware embedded into the panel or with the use of slings properly placed and rigged to prevent damage to the panels.
- D. Panels shall be adequately supported at all times with suitable cribbing and bracing during shipping and storage to prevent inadvertent damage from incidental loads or movements. Panels greater than 15 ft. in length shall be stored in a vertical position.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Concrete: Precast concrete materials shall conform to the following requirements:
1. Cement: Cement shall conform to the requirements of ASTM C 150.
 2. Aggregate: Aggregate shall conform to the requirements of ASTM C 33.
 3. Air-entraining admixture: Material shall conform to ASTM C 260.
 4. Water-reducing admixture: Material shall conform to ASTM C 494.
 5. Pozzolan: Pozzolan shall conform to ASTM C 618.
- B. Mixture Proportions: Precast concrete mixture shall be designed to satisfy the following requirements. Prior to operations, the Contractor shall furnish the proportions of all ingredients that will be used in the manufacture of precast concrete panel elements.

Concrete mixture proportions shall be selected to satisfy the following requirements. The proportions may be based on past field experience or on trial mixtures in accordance with ACI 318, Paragraphs 4.2 and 4.3. Contractor shall provide data demonstrating that the proposed mixture satisfies the following requirements:

1. Minimum 28-day compressive strength: 6500 psi
 2. Maximum coarse aggregate size: 3/4 in. nominal
 3. Minimum entrained air: 5 to 7%
 4. Maximum water cement ratio: 0.40
 5. Minimum cement content: 540 lb/cy (six-sack mixture)
 6. Slump: 3-1/2 in. \pm 1/2 in.
- C. Reinforcing: Mild steel reinforcing steel shall be new billet steel bar conforming to the requirements of ASTM A 615, Grade 60.
- D. Ties: Weldable grade reinforcing steel conforming to the requirements of ASTM A 706, Grade 60, shall be used for form ties.
- E. Prestressing strand: Prestressing strand, if used, shall conform to the requirements of ASTM A 416, Grade 270.

- F. Welded wire reinforcement: Welded smooth wire fabric shall conform to the requirements of ASTM A 185.

2.2 ACCESSORIES

- A. Hardware and accessories shall be incorporated into the work as shown on the drawings. Hardware and accessories shall be fabricated in accordance with Section 5A.
- B. Bearing pads and horizontal joint seals shall be preformed neoprene material of the size, dimensions, and characteristics shown on the drawings. Vertical joint seals shall be an asphalt- or neoprene-rubber-impregnated, open-cell foam as specified in Section 3B.

2.3 FABRICATION

- A. Precast panels shall be fabricated to the dimensions shown on the drawings. Dimensional tolerances shall not exceed those specified in Paragraph 2.4.
- B. All reinforcing, inserts, hardware, and appurtenances shall be located as required and securely anchored to prevent movement during concrete placement.
- C. Contractor shall moist-cure precast panels until the concrete reaches a minimum strength of $0.7 f'_c$. Precast concrete panels may be steam cured. Control of concrete temperature during the steam cycle shall be maintained per the guidelines of PCI MNL-116.
- D. Panels shall not be erected until concrete strength has reached 6500 psi.

2.4 TOLERANCES

- A. Dimensional tolerances for precast panel fabrication:
1. Length: $\pm 1/2$ in.
 2. Width: $\pm 1/4$ in.
 3. Thickness: $\pm 1/2$ in., except $\pm 1/16$ in. at alignment angle contact surfaces
 4. Edge squareness: $\pm 1/8$ in.
 5. Planeness (measured with respect to a straight lines drawn between any two opposite edges):
 - a. Outside surface: $\pm 1/4$ in.
 - b. Inside surface: $1/2$ in.

6. Location of embedments: $\pm 1/8$ in.
- B. Location tolerance for precast panel erection:
1. Plumbness or vertical alignment over full height of monolith section: $\pm 1/2$ in.
 2. Variation in horizontal alignment per three monolith widths: $\pm 1/2$ in.
 3. Precast element joint-to-joint alignment:
 - a. Horizontal joints: $\pm 3/16$ in.
 - b. Vertical joints: $\pm 3/16$ in.

2.5 FINISH

Precast panels shall have a smooth, dense finish on the outside, exposed surface such as is typical of steel form or high density overlaid plywood forms. The inside panel surface shall be clean, free of laitance, and shall be intentionally roughened to an approximate amplitude of 1/4 in. Surfaces that contact alignment hardware shall be trowel-finished. The surface shall be cleaned by high-pressure water spray immediately prior to erection.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Contractor shall inspect and survey all existing work prior to fabricating and installing panels. Dimensional discrepancies shall be immediately brought to the attention of the Contracting Officer.
- B. Contractor shall prepare a written procedure for erection indicating lifting, temporary bracing, support and alignment methods. Sequence of operations and inspection hold points shall be identified.

3.2 ERECTION

- A. Precast panels shall be erected as shown on the drawings. Tolerances shall be as specified in Paragraph 2.4.
- B. Panel form ties shall be securely fastened. Temporary supports and braces shall be used as necessary to maintain alignment.
- C. Form tie holes shall be drilled into the monolith with suitable concrete drilling equipment. Ties shall be installed per the requirements of Section 3D.

3.3 INSPECTIONS AND TESTS

- A. Contractor shall be responsible for inspection of panel fabrication and erection activities to ensure that the work conforms in all respects to the drawings and specifications. A record of inspections and inspection results shall be maintained for Contracting Officer's review.
- B. Contractor shall inspect precast panel form prior to casting to ensure dimensional configuration and location of all embedded items.
- C. Contractor shall inspect panels after installation to ensure that they conform to location tolerance and that they are securely tied and braced for infill concrete placement loads.
- D. Contractor shall sample and test concrete used in panel fabrication as follows:
 - 1. A minimum of two sets of three concrete specimens shall be cast, cured, and tested for each batch of concrete to determine the concrete compressive strength at 7 and 28 days. Contractor may make additional specimens to monitor strength gain during concrete curing.
 - 2. Determine slump of concrete mixture at time of placement.
 - 3. Determine air content of the concrete at time and point of placement.
- E. Contractor shall provide to the Contracting Officer, for independent testing and analysis, such additional cast specimens of concrete as may be requested.

3.4 CLEANUP

- A. Contractor shall immediately remove spills or runs of epoxy, grout, or other materials used in the construction from the outside surface of precast panels.
- B. Contractor shall maintain work areas clean and free of rubble, discarded product containers, packaging and shipping materials, and other refuse.

END OF SECTION 3G

APPENDIX D: CONSTRUCTION SPECIFICATIONS

SECTION 5A HARDWARE AND APPURTENANCES

PART 1 - GENERAL

1.1 SCOPE OF WORK

- A. The work shall consist of furnishing all labor, materials, and equipment for fabrication and furnishing of hardware and appurtenances as shown on the drawings and as described in the specifications.
- B. Hardware and appurtenances include:
 - 1. Top curb armor
 - 2. Panel joint assemblies
 - 3. Panel alignment assemblies
 - 4. Form ties
 - 5. Panel hanger assemblies

1.2 REFERENCE STANDARDS

- A. American Institute of Steel Construction, 1986. Manual of Steel Construction, 8th edition, Chicago, Illinois.
- B. American Welding Society Structural Welding Committee, 1985 (February). "Structural Welding Code - Steel", AWD1.1-85, American Welding Society, Miami, Florida.
- C. Steel Structures Painting Council, 1985. "Commercial Blast Cleaning", SSPC-SP-6, Volume 2, Steel Structures Painting Council Painting Manual - Systems and Specifications, 4th edition, Pittsburg, Pennsylvania.

1.3 QUALITY CONTROL

- A. Fabricator Qualifications: The fabricator shall be experienced in the fabrication and working of metals, including cutting, bending, forming, welding, and finishing. Fabrication of metal hardware and appurtenances shall be performed in accordance with the AISC Code.
- B. Welder Qualifications: Fabricators supplying welded components shall employ only welders, operators, and tackers qualified as outlined in AWS D1.1. Welding practices shall conform to AWS D1.1.

1.4 SUBMITTALS

- A. Contractor shall submit complete shop drawings indicating all shop and erection details, including materials of construction, finishes, methods of fastening, and location of cuts, copes, connections, holes, fasteners, and welds.
- B. Contractor shall submit certificates of welder's qualifications prior to start of work of this section.
- C. Contractor shall submit mill certificates for structural steel indicating specification compliance for chemical properties, tensile strength, yield point, and elongation.
- D. Contractor shall submit catalog cuts and certificates of compliance for concrete anchors, fasteners, headed studs, and other commercial products incorporated into the work.

PART 2 - PRODUCTS

2.1 STEEL

- A. Structural steel shapes, plates, and bars shall conform to ASTM A 36, unless otherwise noted.
- B. Steel pipe shall conform to ASTM A 53, Type E or S, Grade B, unless noted otherwise.

2.2 BOLTING MATERIALS AND FASTENERS

- A. Bolting material shall be either ASTM A 307 or A 449 as shown on the drawings. Bolts shall be furnished with matching nuts and washers.
- B. Headed studs shall conform to ASTM A 108.
- C. Deformed bar anchors shall conform to ASTM A 496.

2.3 OTHER MATERIALS

All other materials not specifically described but required for a complete and proper installation shall be as selected by the Contractor subject to approval by the Contracting Officer.

PART 3 - EXECUTION

3.1 FABRICATION

- A. All structural and miscellaneous steel for hardware and appurtenances shall be fabricated in accordance with the reviewed shop drawings and shall conform to the requirements of the AISC Manual of Steel Construction.
- B. Welding of steel hardware and appurtenances shall conform to AWS D1.1 of the Structural Welding Code. Type, size, and spacing of welds shall be as indicated on the reviewed shop drawings. Welding shall be accomplished in a manner that will minimize distortion of the finished parts. Weld splatter and oxides on finished surfaces shall be removed. Unless otherwise noted, headed studs and deformed bar anchors shall be welded using automatically-timed stud welding equipment. The Contractor shall perform tests, as recommended by the welding equipment manufacturer, to verify proper operation and settings of the welding equipment.

3.2 SURFACE PREPARATION AND PROTECTIVE COATINGS

- A. After fabrication, all steel surfaces shall be blast-cleaned in accordance with SSPC-SP-6, Commercial Blast Cleaning.
- B. Iron and steel surfaces to be embedded in concrete in the completed work shall be uncoated.
- C. All exposed surfaces of hardware and appurtenances shall be given a shop coat of zinc-rich, rust-inhibitive primer. The dry film thickness of the primer shall be a minimum of 2 mils. The steel surface shall be prepared and the primer applied in accordance with the coating manufacturer's recommendations.
- D. Steel surfaces to be uncoated shall be free of loose rust, mill scale, oil, and grease.

3.3 INSPECTION AND TESTING

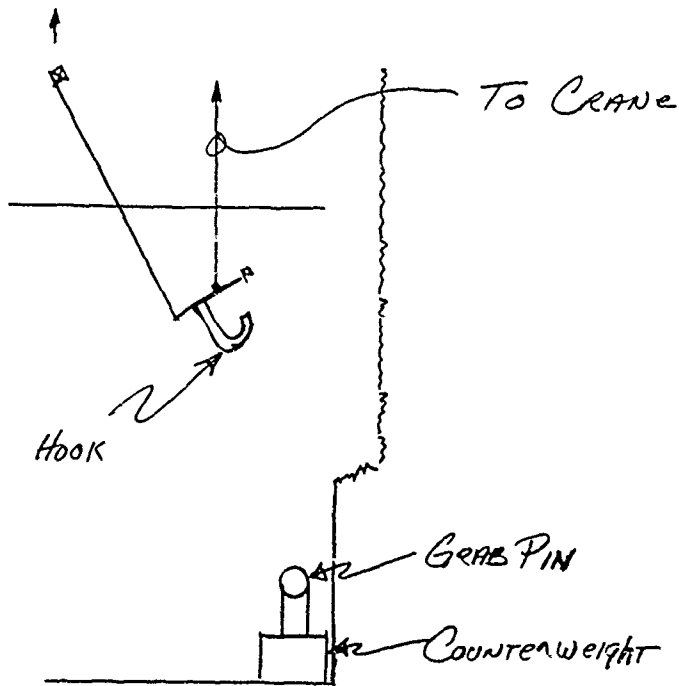
- A. The Contractor shall perform such inspections and tests to ensure that all work is performed in full compliance with the contract documents.
- B. Inspection and testing of welding shall be in accordance with AWS D1.1, Section 6.

- C. Material and workmanship will be subject to inspection by the Contracting Officer. Testing and inspection will in no way relieve the Contractor of responsibility to furnish materials and construction in full compliance with the contract documents and to provide a quality control program.

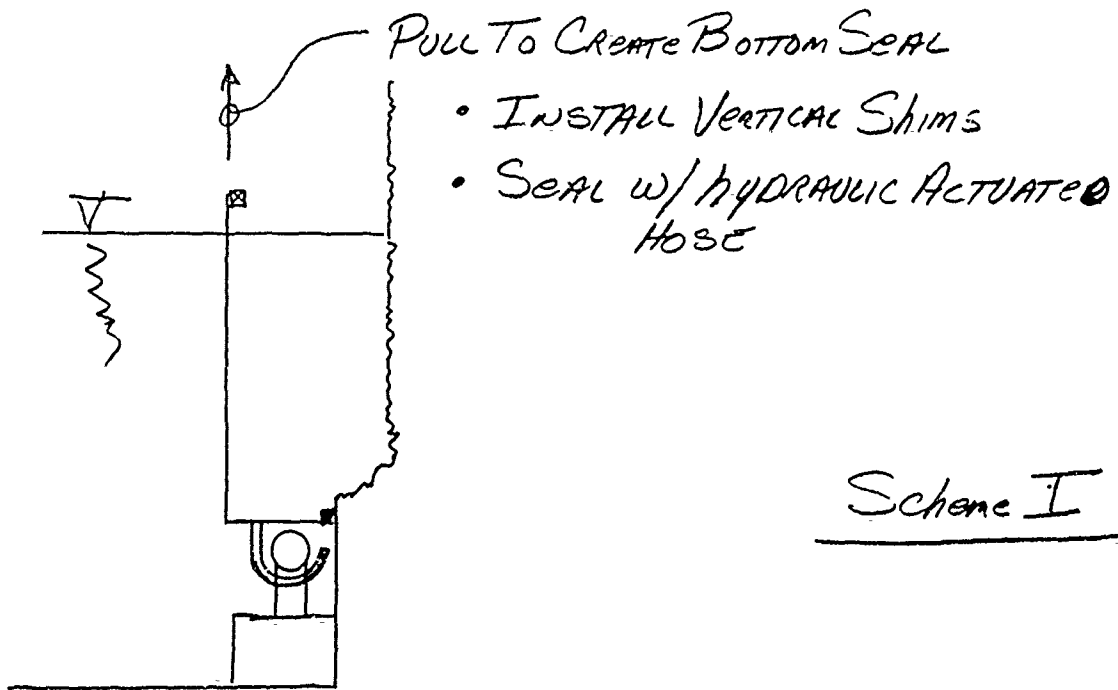
END OF SECTION 5A

APPENDIX E: ALTERNATE COFFERDAM AND
NAVIGATION PROJECT CONCEPTS

LOOK @ ATTACHMENT Schemes



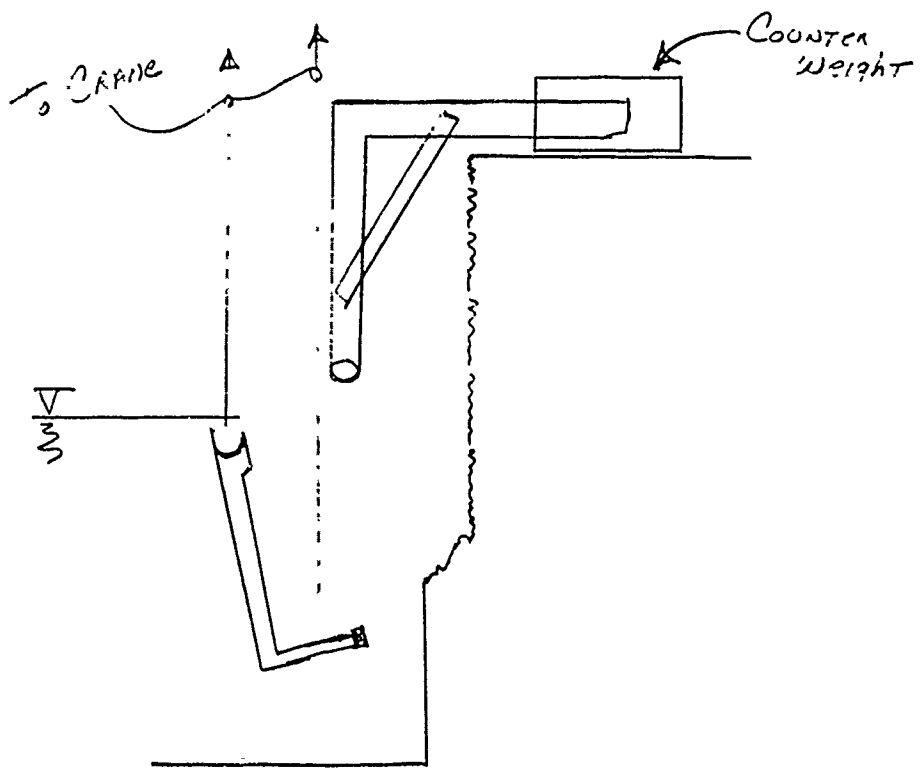
① LOWER COFFER



Scheme I

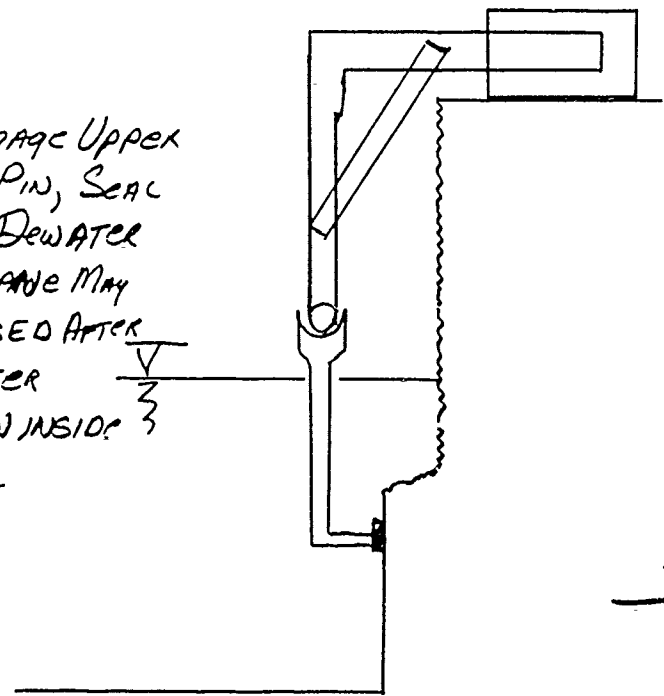
② ENGAGE COFFER DAM

WALL SUPPORTED COFFERDAM CONCEPT



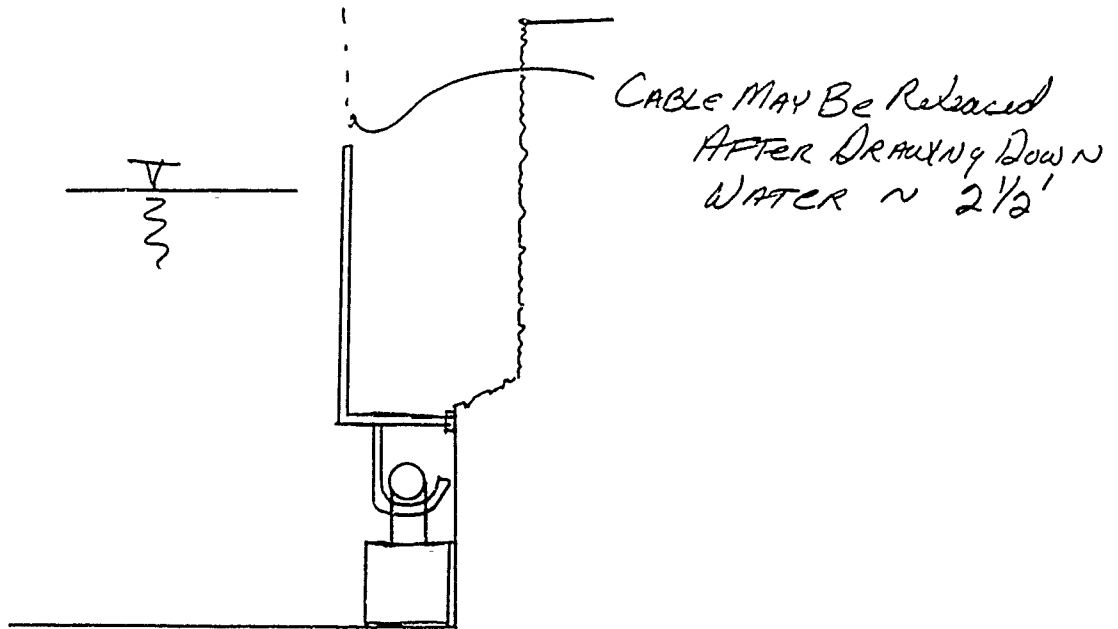
STEP 1 - INSTALL COUNTERWEIGHT + LOWER COFFER CELL

STEP 2 Engage Upper
Roller Pin, Seal
Edges, Dewater
Cell. CRANE MAY
Be Released After
2 1/2' WATER
DRAWN DOWN INSIDE
The CELL



Scheme II

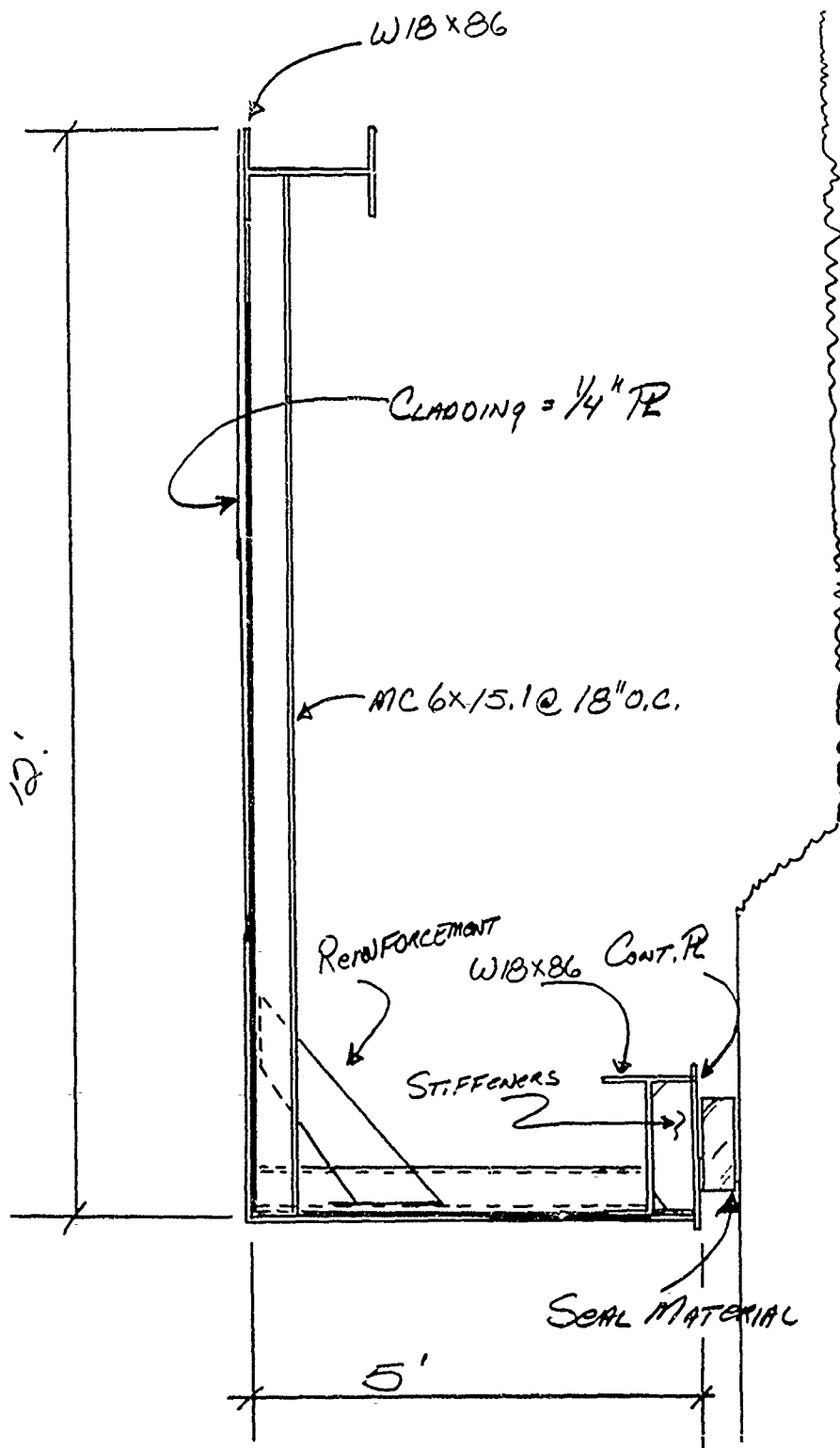
WALL SUPPORTED COFFERDAM CONCEPT



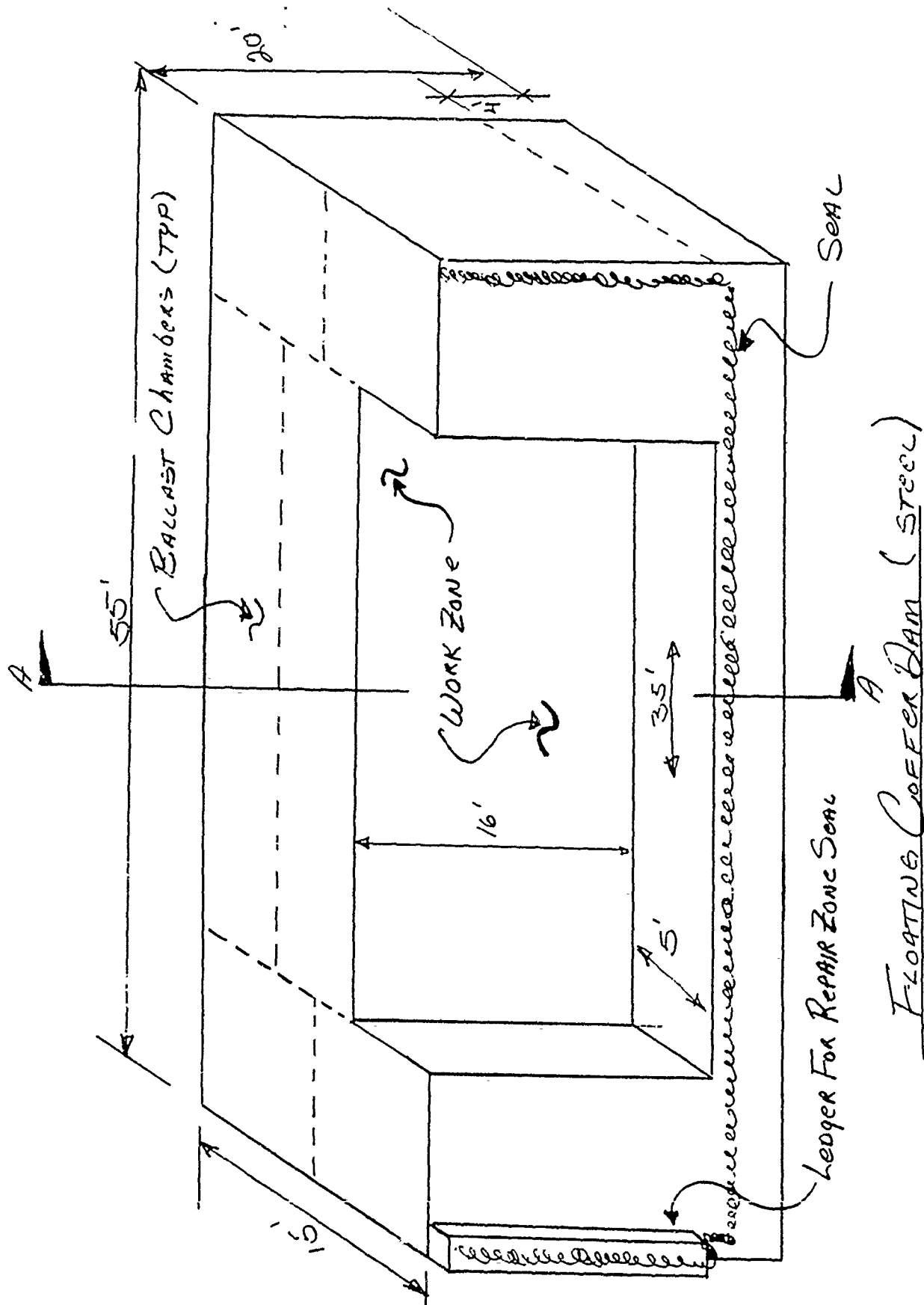
③ DE WATER COFFER CELL

Scheme I

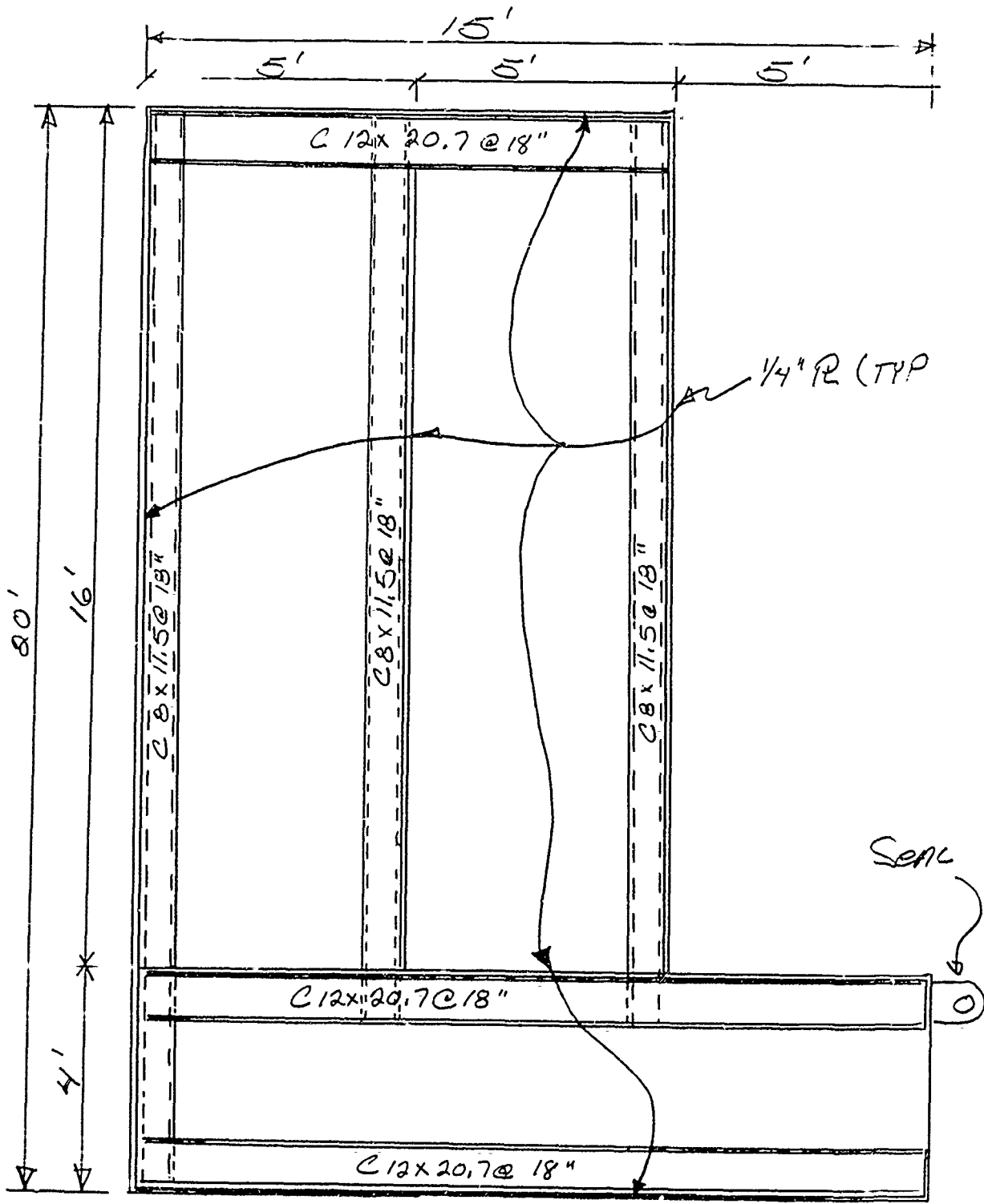
WALL SUPPORTED COFFERDAM CONCEPT



WALL SUPPORTED COFFERDAM CONCEPT

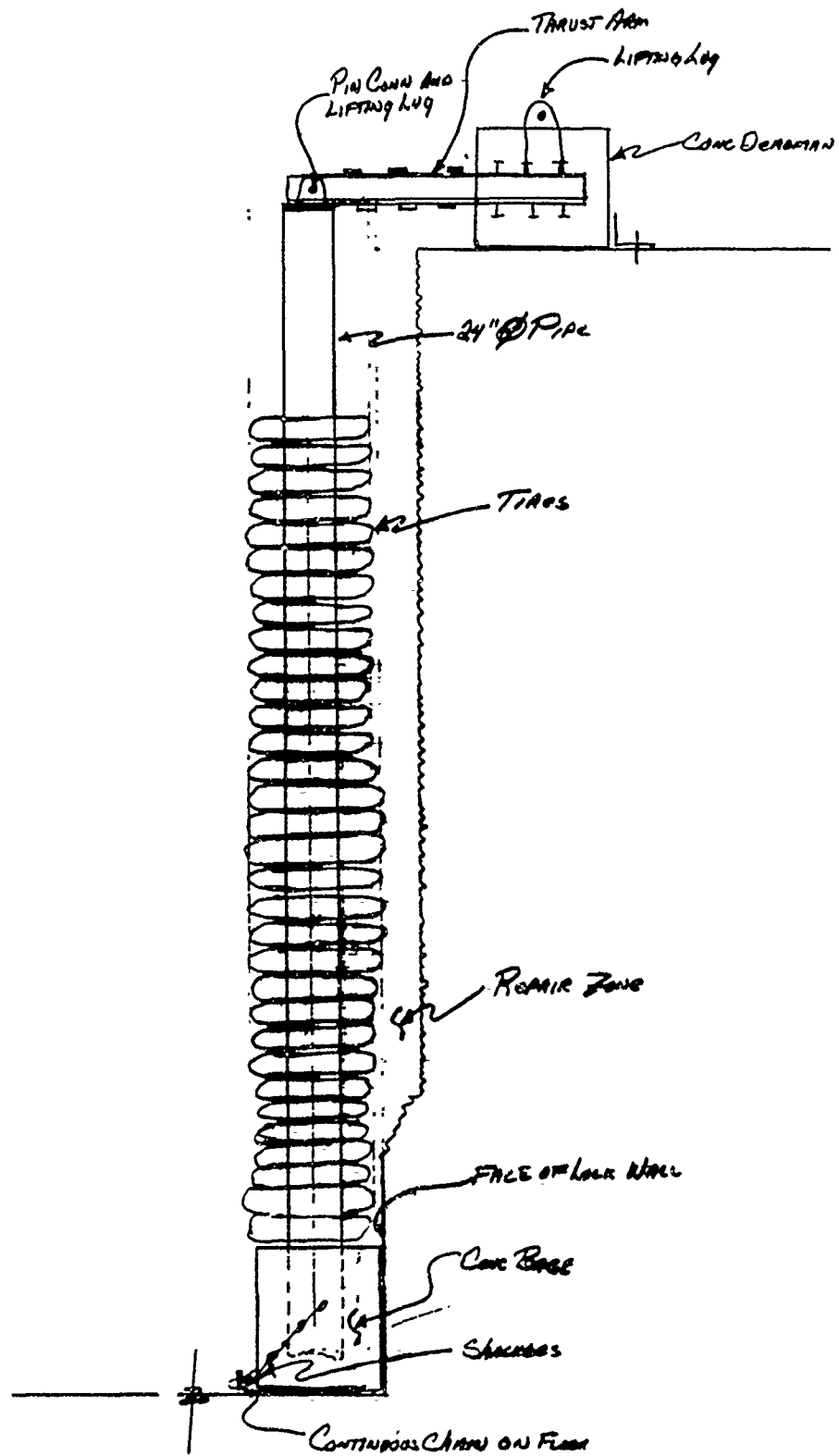


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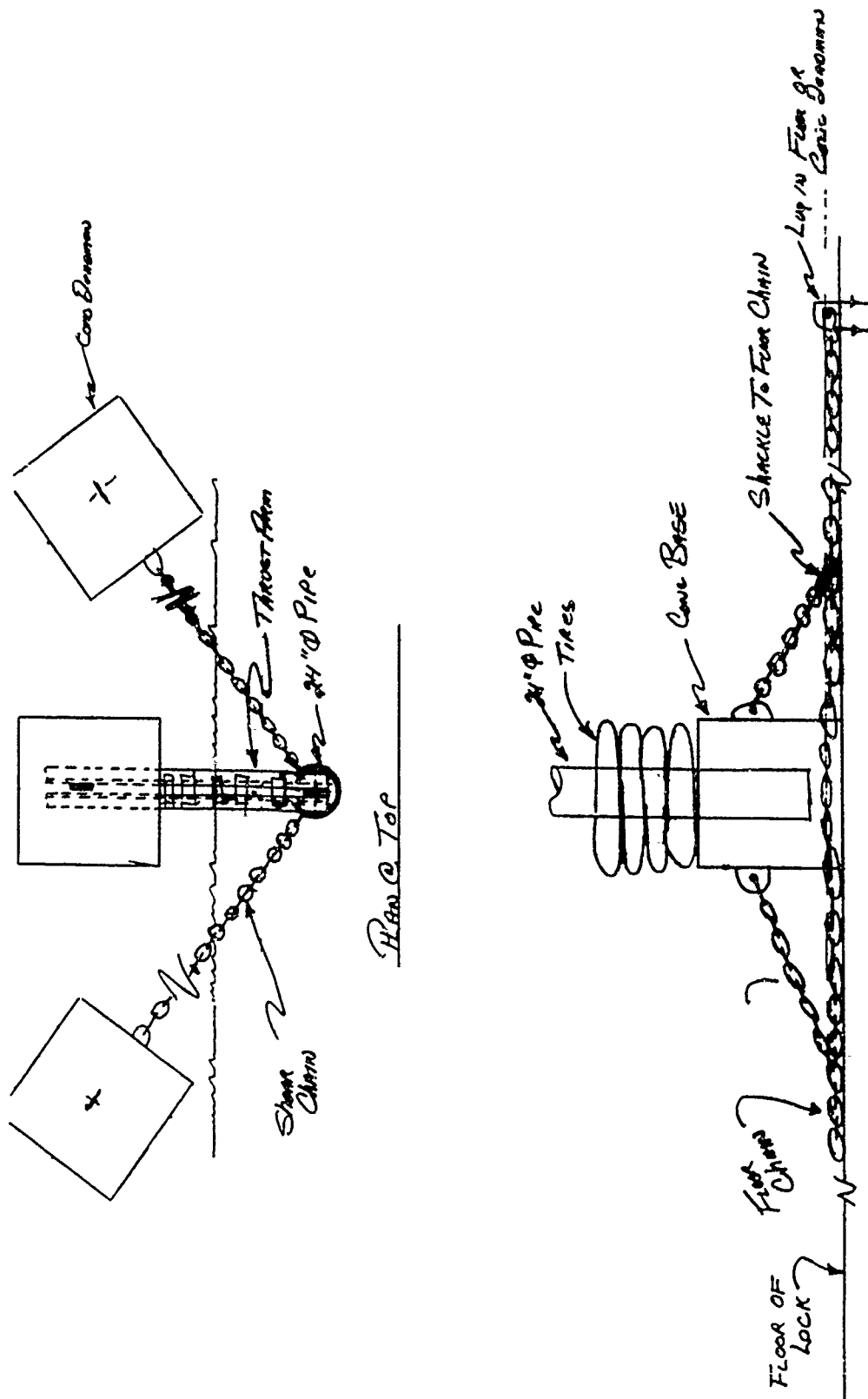


SECTION - FLOATING COFFER CELL (A-A)
 3/8" = 1'-0"

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NAVIGATION PROTECTION CONCEPT
 (VERTICAL PIPE/POST SYSTEM)

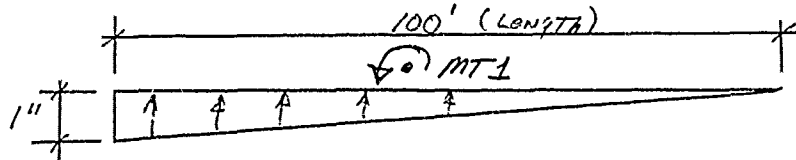


NAVIGATION PROTECTION CONCEPT
(VERTICAL PIPE / POST SYSTEM)

APPENDIX F: CALCULATIONS

- 1) POSITION BARGE IN PLAN VIEW
- 2) LOWER COFFER DAM ON GUARD RAILS UNTIL
THE ONE CORNER RESTS ON THE
REPAIR LEDGE
- 3) TIGHTEN THE MISSING LINES TO PRECOMPRESS
THE SEAL (TOTAL PRECLAMP FORCE $R_{90} \cong 40^k$)
- A) DEWATER THE WORK ZONE

LOOK @ GLOBAL STABILITY OF SYSTEM



ESTIMATE MOMENT TO TRIM 1"

$$\begin{aligned} \text{TOTAL UPLIFT} &= \frac{1}{12} \text{ ft} \times 50' \times \frac{1}{2} \times 100' \times .062 \text{ k/ft}^3 \\ &= 12.9 \text{ k} \end{aligned}$$

$$\begin{aligned} \text{MTL} &= 12.9 \text{ k} \times \left(\frac{100}{2} - \frac{2(100)}{3} \right) \\ &= 12.9 \text{ k} \times 16.7' \\ &= 215 \text{ k/ft} \quad (\text{Moment Rgd TO TRIM 1"}) \end{aligned}$$

LOOK @ VOL WATER VOIDED IN THE COFFER

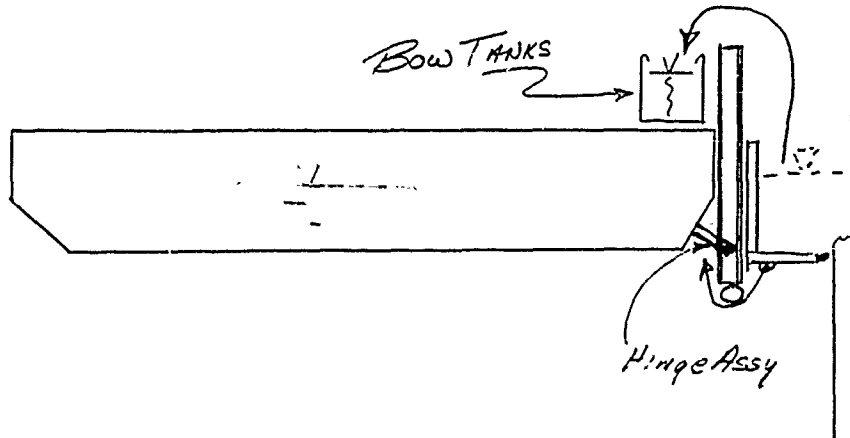
$$\text{VOL} = 12' \times 5' \times 35' = 2100 \text{ ft}^3$$

$$\text{WT OF WATER} = 2100 \times .062 = 130.2 \text{ k}$$

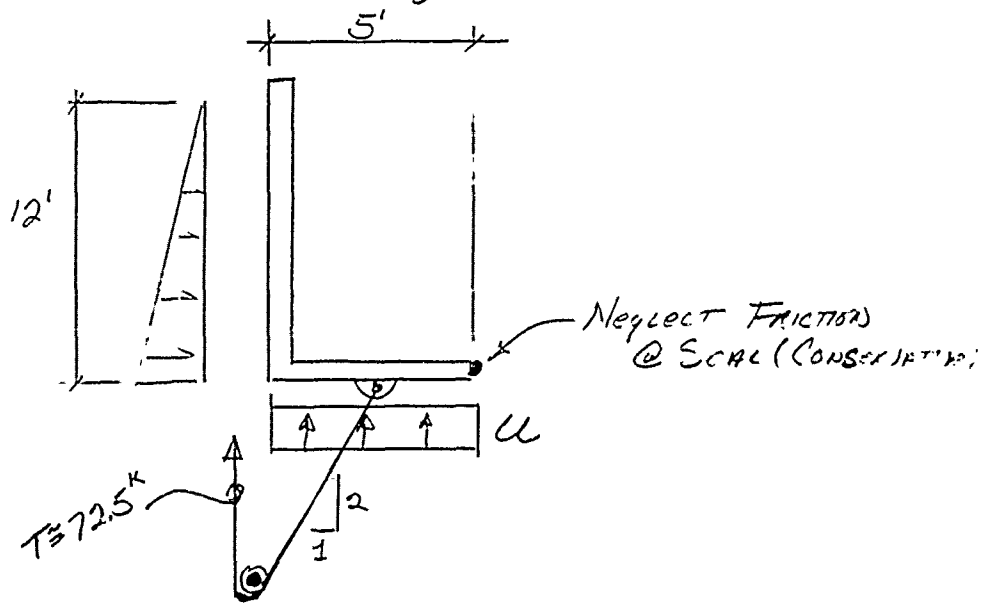
$$\begin{aligned} \text{INDUCED MOMENT} &\approx 130.2 \text{ k} \times 60' \\ &= 7812 \text{ k/ft} \end{aligned}$$

\therefore Will Change TRIM $\sim 36''$

VOL OF WATER REMOVED FROM COFFER SHOULD
BE PLACED IN BOW TANKS OF BARGE
TO REDUCE TRIM



LOOK @ HOLD DOWN FORCE REQUIRED



$$UPLIFT = 12' \text{ OF head} \times 5' \times 35' \times .062 \text{ K/ft}^3$$

$$= 130 \text{ K}$$

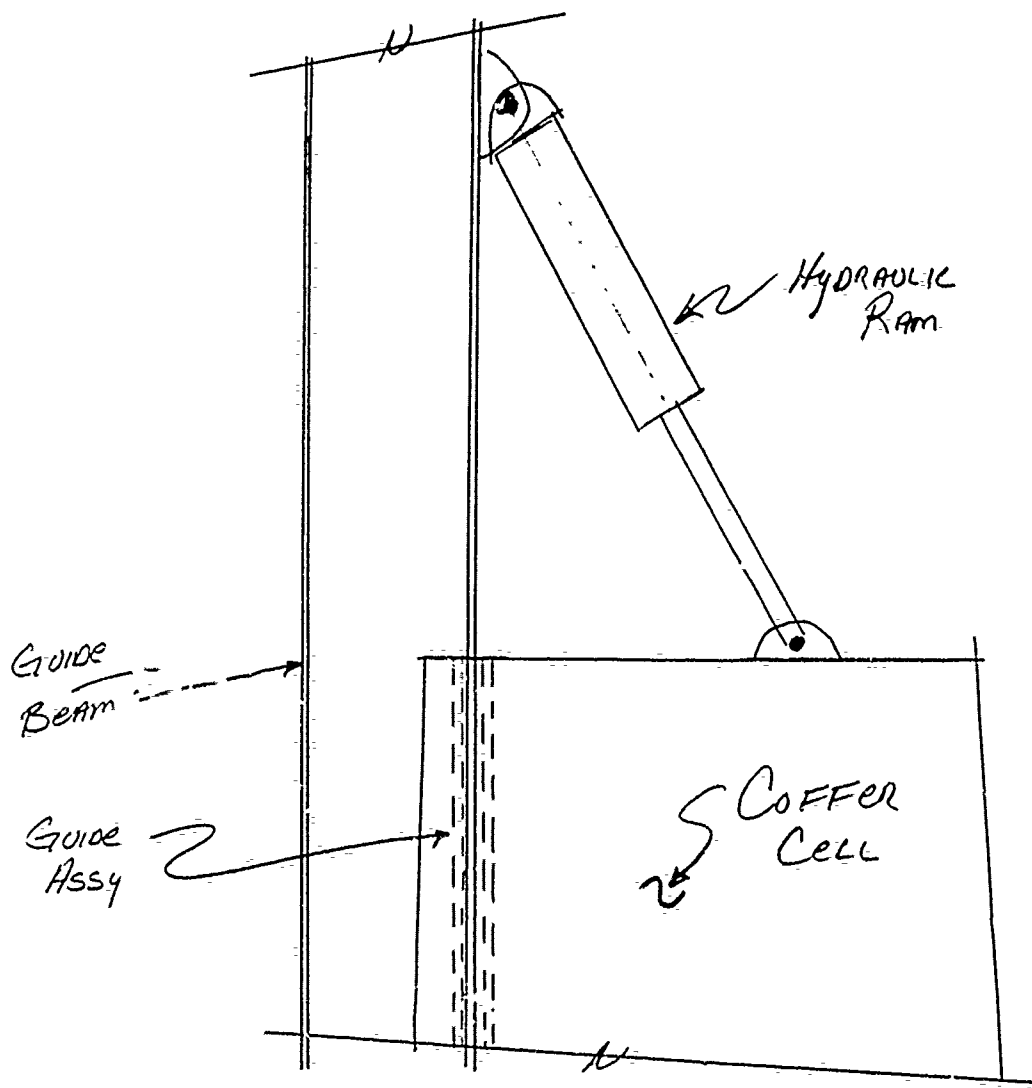
$$\text{LINE TENSION } R_{80} = \sqrt{130^2 + \left(\frac{130}{2}\right)^2}$$

$$= 145 \text{ K}$$

USE 2 LINES \rightarrow 72.5 K/line

USE 1 1/2" 6x24 WIRE ROPE (BREAK STRENGTH = 126 K)

Note: COULD USE HYDRAULIC RAMS IN LIEU OF DECK WINCHES TO APPLY HOLD-DOWN FORCES FOR THE COFFER



US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 12 ft

Coffer Dimensions Water Weight = 62 pcf

Depth = 15 ft
Length = 35 ft
Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clamping (kips)
1.00	10.85	24.96
2.00	21.70	47.74
3.00	32.55	68.36
4.00	43.40	85.80
5.00	54.25	103.88
6.00	65.10	117.18
7.00	75.95	129.12
8.00	86.80	138.88
9.00	97.65	146.48
10.00	108.50	151.90
11.00	119.35	155.16
12.00	130.20	156.24

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 11 ft

Coffer Dimensions Water Weight = 62 pcf

 Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clamping (kips)
1.00	10.85	22.79
2.00	21.70	43.40
3.00	32.55	61.85
4.00	43.40	78.12
5.00	54.25	92.23
6.00	65.10	104.16
7.00	75.95	113.93
8.00	86.80	121.52
9.00	97.65	126.95
10.00	108.50	130.20
11.00	119.35	131.29
12.00	130.20	130.20

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 10 ft

Coffer Dimensions Water Weight = 62 pcf

Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clawing (kips)
1.00	10.85	20.62
2.00	21.70	39.06
3.00	32.55	55.34
4.00	43.40	69.44
5.00	54.25	81.38
6.00	65.10	91.14
7.00	75.95	98.74
8.00	86.80	104.16
9.00	97.65	107.42
10.00	108.50	108.50
11.00	119.35	107.42
12.00	130.20	104.16

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Coffers Cells File: COE1.pc

Depth of Water to Seal = 9 ft

Coffer Dimensions Water Weight = 62 pcf

 Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clamping (kips)
1.00	10.85	18.45
2.00	21.70	34.72
3.00	32.55	48.83
4.00	43.40	60.76
5.00	54.25	70.53
6.00	65.10	78.12
7.00	75.95	83.55
8.00	86.80	86.80
9.00	97.65	87.89
10.00	108.50	86.80
11.00	119.35	83.55
12.00	130.20	78.12

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 8 ft

Coffer Dimensions Water Weight = 62 pcf

 Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clamping (kips)

1.00	10.85	16.28
2.00	21.70	38.38
3.00	32.55	42.32
4.00	43.40	52.08
5.00	54.25	59.68
6.00	65.10	65.18
7.00	75.95	68.35
8.00	86.80	69.44
9.00	97.65	68.35
10.00	108.50	65.18
11.00	119.35	59.68
12.00	130.20	52.08

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 5 ft

Coffer Dimensions Water Weight = 62 pcf

 Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

 Drawdown Uplift Clamping
 (ft) (kips) (kips)

1.00	10.85	9.77
2.00	21.70	17.36
3.00	32.55	22.79
4.00	43.40	26.04
5.00	54.25	27.13
6.00	65.10	26.04
7.00	75.95	22.79
8.00	86.80	17.36
9.00	97.65	9.77
10.00	108.50	0
11.00	119.35	11.94
12.00	130.20	26.04

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 6 ft

Coffer Dimensions Water Weight = 62 pcf

 Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clamping (kips)
1.00	10.85	11.94
2.00	21.70	21.70
3.00	32.55	29.30
4.00	43.40	34.72
5.00	54.25	37.98
6.00	65.10	39.06
7.00	75.95	37.98
8.00	86.80	34.72
9.00	97.65	29.30
10.00	108.50	21.70
11.00	119.35	11.94
12.00	130.20	0

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 7 ft

Coffer Dimensions Water Weight = 62 pcf

Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clamping (kips)
1.00	10.85	14.11
2.00	21.70	26.04
3.00	32.55	35.81
4.00	43.40	43.40
5.00	54.25	48.83
6.00	65.10	52.00
7.00	75.95	53.17
8.00	86.80	52.00
9.00	97.65	48.83
10.00	108.50	43.40
11.00	119.35	35.81
12.00	130.20	26.04

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 4 ft

Coffer Dimensions Water Weight = 62 pcf

 Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

 Drawdown Uplift Clamping
 (ft) (kips) (kips)

1.00	10.85	7.60
2.00	21.70	13.02
3.00	32.55	16.28
4.00	43.40	17.36
5.00	54.25	16.28
6.00	65.10	13.02
7.00	75.95	7.60
8.00	86.80	0
9.00	97.65	-9.77
10.00	108.50	-21.70
11.00	119.35	-35.81
12.00	130.20	-52.00

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Coffor Cells File: COE1.pc

Depth of Water to Seal = 3 ft

Coffer Dimensions Water Weight = 62 pcf

Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clamping (kips)
1.00	10.85	5.43
2.00	21.70	8.68
3.00	32.55	9.77
4.00	43.40	8.68
5.00	54.25	5.43
6.00	65.10	0
7.00	75.95	-7.60
8.00	86.80	-17.36
9.00	97.65	-29.30
10.00	108.50	-43.40
11.00	119.35	-59.68
12.00	130.20	-78.12

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

Statics for Cofferd Cells File: COE1.pc

Depth of Water to Seal = 2 ft

Cofferd Dimensions Water Weight = 62 pcf

 Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

Drawdown (ft)	Uplift (kips)	Clamping (kips)
1.00	10.85	3.26
2.00	21.70	4.34
3.00	32.55	5.26
4.00	43.40	0
5.00	54.25	-5.43
6.00	65.10	-13.42
7.00	75.95	-22.79
8.00	86.80	-34.72
9.00	97.65	-48.43
10.00	108.50	-65.00
11.00	119.35	-83.53
12.00	130.20	-104.16

US ARMY CORPS OF ENGINEERS - LOCK WALL REHABILITATION

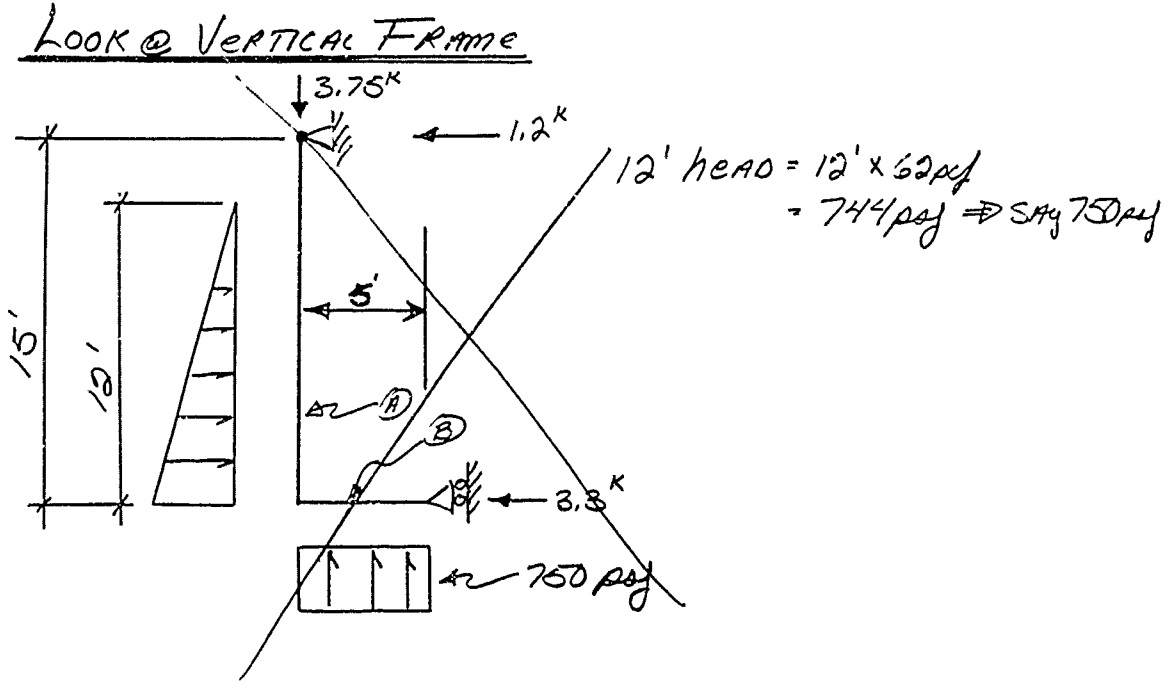
Statics for Coffers Cells File: COE1.pc

Depth of Water to Seal = 1 ft

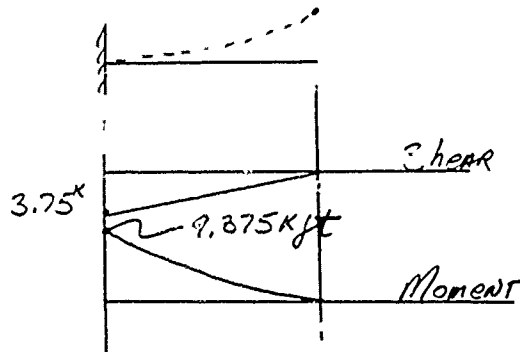
Coffer Dimensions Water Weight = 62 pcf

Depth = 15 ft
 Length = 35 ft
 Width = 5 ft

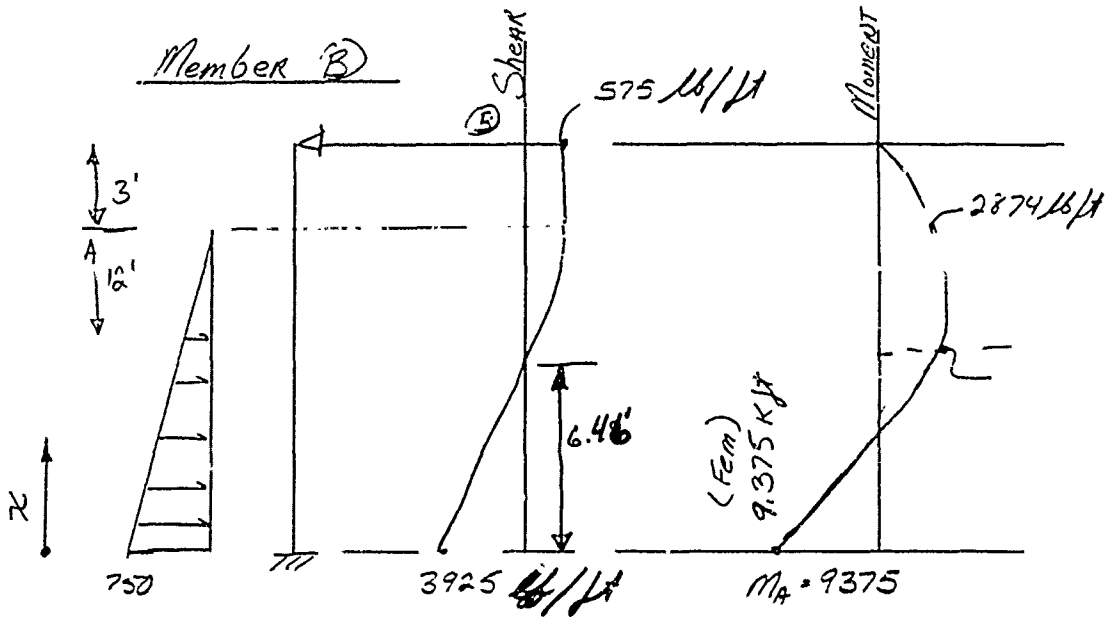
Drawdown (ft)	Uplift (kips)	Clamping (kips)
1.00	10.85	1.09
2.00	21.70	0
3.00	32.55	-3.26
4.00	43.40	-8.60
5.00	54.25	-16.20
6.00	65.10	-26.00
7.00	75.95	-37.90
8.00	86.80	-52.00
9.00	97.65	-68.30
10.00	108.50	-86.80
11.00	119.35	-107.42
12.00	130.20	-130.20



Member (A)



LOOK @ VERTICAL FRAME



$$w = 750 - \frac{750}{12} x$$

$$V = V_A - 750x + \frac{62.5x^2}{2}$$

$$M = -M_A + \left[V_A x - \frac{750x^2}{2} + \frac{62.5x^3}{6} \right]$$

@ $x = 12$

$$M = -9375 + 12V_A - 54000 + 18000$$

$$= -45375 + 12V_A$$

$$V_B = 4500 - V_A \Rightarrow M_B = V_B \times 3' = -45375 + 12V_A$$

Solve For $V_A \Rightarrow V_A = 3925 \text{ lb}$
 $V_B = 575 \text{ lb}$

Solve For x @ $V = 0 = 7.71'$ (Position of max +ve Moment)

X	V	M	
0	-3925.00	-9375.00	← MAX -ve Moment / ft of COFFER
1.00	-3206.25	-5814.58	
2.00	-2550.00	-2941.67	
3.00	-1956.25	-693.75	
4.00	-1423.00	991.67	
5.00	-956.25	2177.68	
6.00	-550.00	2925.00	
7.00	-206.25	3297.92	
7.71	-0.02	3369.32	← Max +ve Moment / ft of Coffe
8.00	75.00	3358.33	
9.00	293.75	3168.75	
10.00	450.00	2791.67	M12
11.00	543.75	2209.58	
12.00	575.00	1725.00	1725.00

Assume 18" RIB SPACING

$$M_{max} = 1.5' \times \frac{9375 \text{ lb-ft/ft}}{1000} = 14.1 \text{ K-ft}$$

Assume $F_b = 24 \text{ ksi}$

$$R_{req} S_{req} = \frac{M}{F_b} = \frac{14.1 \text{ K-ft} \times 12}{24} = 7 \text{ in}^3$$

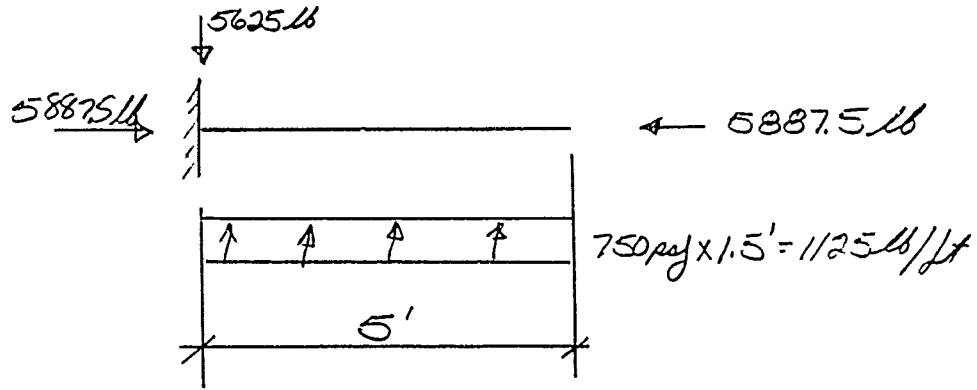
Need C7x14.75 @ 18" [$S = 7.78 \text{ in}^3$]

USE C8x11.5 [$S = 8.14 \text{ in}^3$]

OR W8x10 [$S = 7.81 \text{ in}^3$]

FOR VERT RIBS AND FLOOR PANEL

LOOK @ BM / COLUMN ACTION FOR FLOOR BEAM



- ~~Laterally~~ LATERALLY SUPPORTED BY FLOOR TR DIAPHRAGM

Assume C8x11.5

$$P/A = \frac{5887.5 \text{ lb}}{3.38 \text{ in}^2} = 1.7 \text{ ksi}$$

$$M/S = \frac{9375 \times 12}{8.14} = 13.8 \text{ ksi}$$

$$F_a \approx 21.5 \text{ ksi}$$

$$23.8 \text{ ksi}$$

$$\frac{P}{F_a} + \frac{F_b}{F_b} = \frac{1.7}{21.5} + \frac{13.8}{23.8}$$

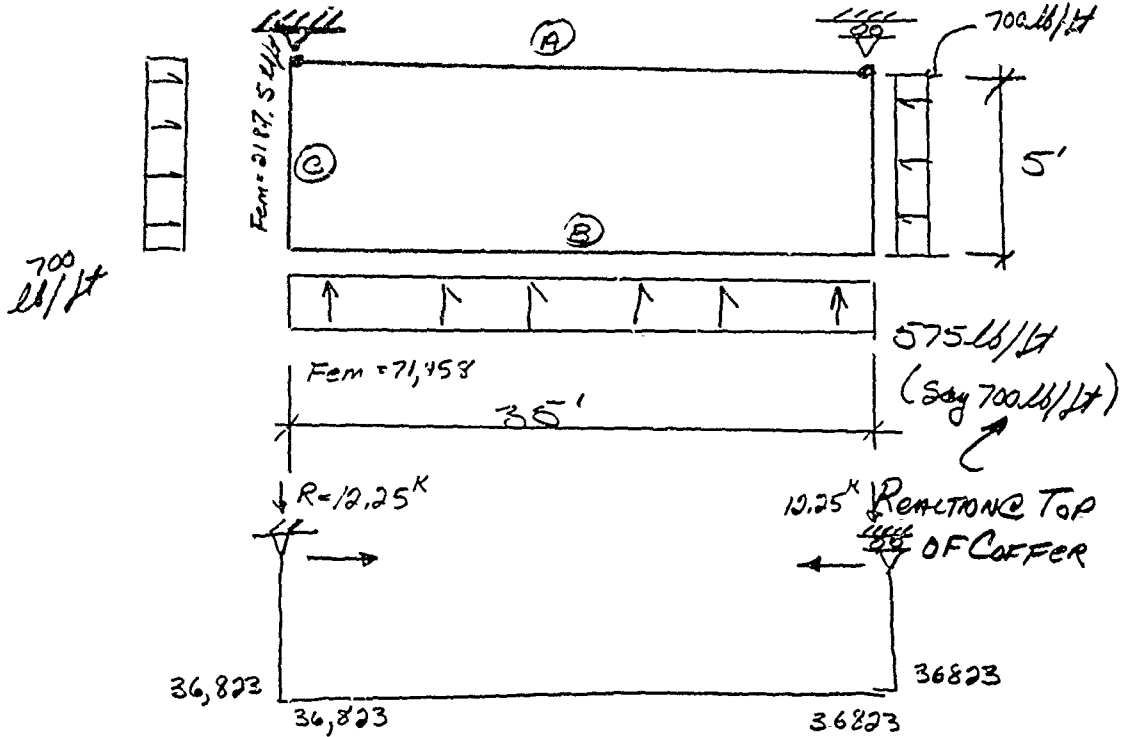
$$= 0.08 + 0.58$$

$$= 0.66 \therefore < 1 \rightarrow \text{OK}$$

USE C8x11.5 FOR WALL +

FLOOR RIBS (@ 18" SPA)

LOOK @ TOP BEAM (COMPLETE FRAME)



FIND $T \rightarrow$

$$36,823 = \uparrow + \downarrow + \uparrow$$

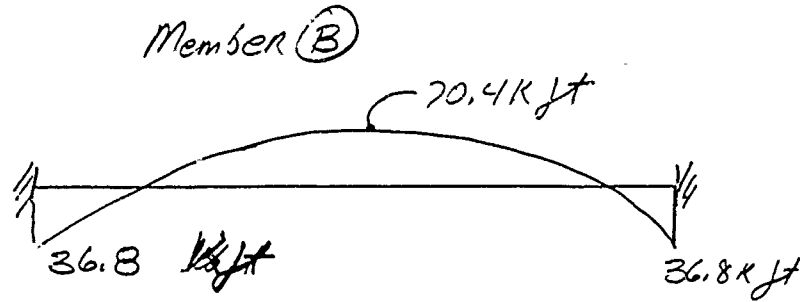
$$36,823 \text{ lb/ft} = 21,875 + T \times 5$$

$$T = 6927 \text{ lb} - 1312.5$$

\therefore TOTAL REACTION = 5614.5 kips

LOOK @ MAX MOMENTS

LOOK @ MAX MOMENTS (Member B)



CONTINUOUS ^{LATERAL} SUPPORT w/WALL

$$\phi_{\text{Reqd}} \approx \frac{M}{F_b} = \frac{70.4 \times 12}{24 \text{ ksi}} = 35.2 \text{ in}^3$$

W14x26 is OK →

USE W14x65 ($\phi = 87.9 \text{ in}^3$)

FLANGE WIDTH = 12" FOR DETAILING

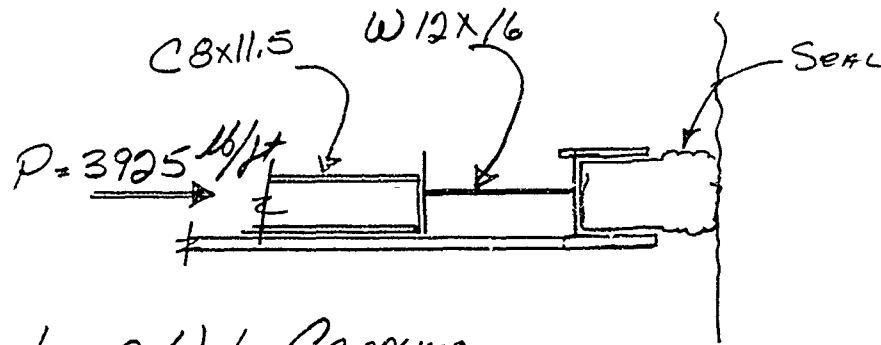
LOOK @ TENSION STRUT

Net Tension $\approx 5.6^k$

$$A_s (\text{reqd}) = \frac{0.6 \times 36}{5.6} = 3.9 \text{ in}^2$$

USE 6x10x3/8" Tube ($A_s = 11.1 \text{ in}^2$)
BUT BEERY ENOUGH FOR ABUSE

LOOK @ LOWER SEAL BEAM



LOOK @ WEB CRIPPLING

$$\begin{aligned}
 \text{MAX ALLOWABLE REACTION (PER FT OF LENGTH)} &= 0.75 F_y t (N + K) \\
 &= 0.75 (36 \text{ ksi}) (12") (0.390) \\
 &= 126 \text{ k/ft} \gg 3.9 \text{ k/ft} \therefore \text{OK}
 \end{aligned}$$

Project COE Lock Wall Rehab

Sheet _____ of _____

Job No A30067

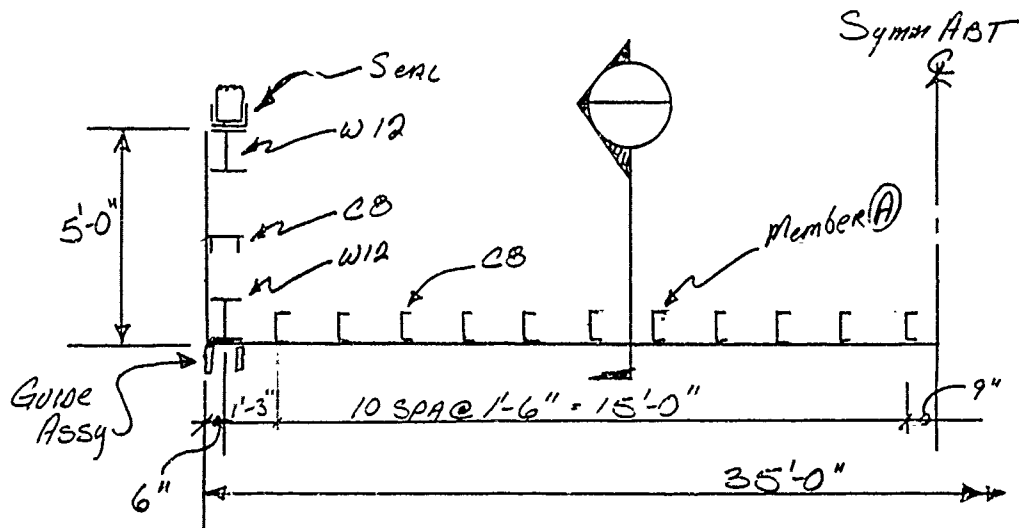
Designer WA

Date 21 Jun 39

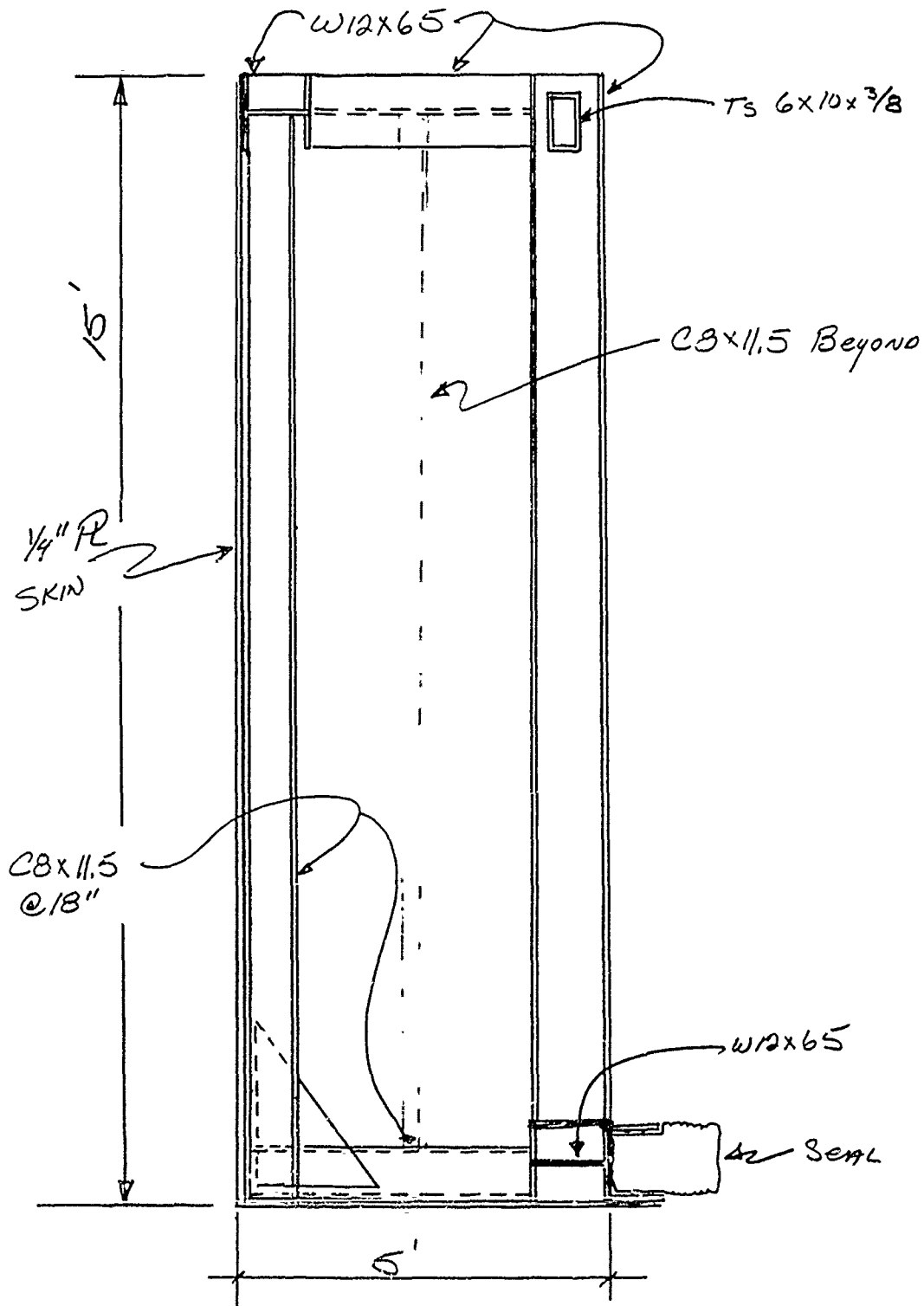
ABAM
CONSULTING ENGINEERS

Subject Barge Mounted Coffin

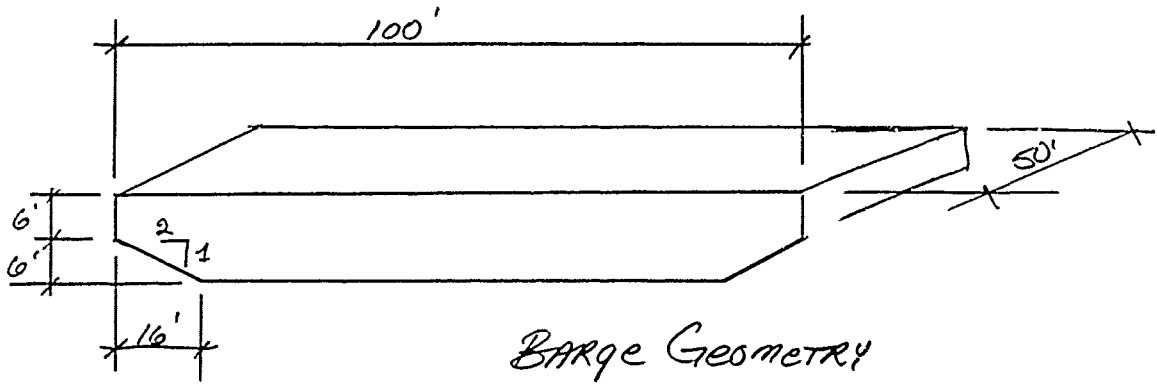
Size The Members



PLAN - COFFER DAM

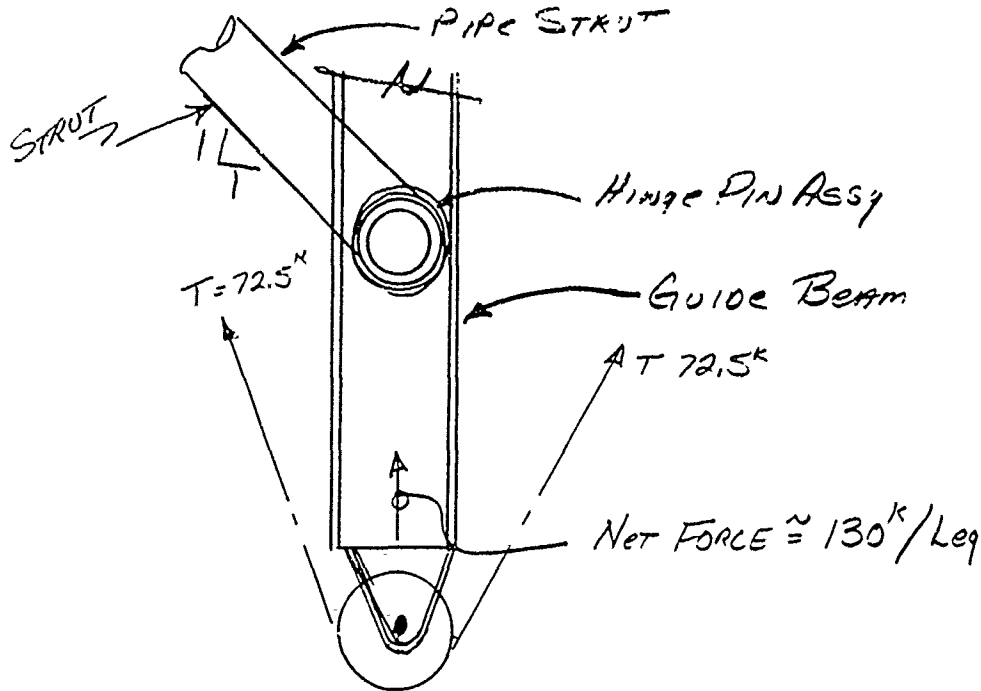


SECTION - COFFIN CELL



Look @ Hinge Pin Assy

Hinge Pin is Used To Accomodate Change
IN TRIM OF BARGE RELATIVE TO THE
COFFER



$$\text{COMPRESSION FORCE IN STRUT} = 130^k \sqrt{2} \\ \approx 185^k$$

IF STRUT IS 10' LONG, WILL NEED
A PIPE 10 x .365t FOR STRUT

Note: @ BARGE, STRUT TO BE ATTACHED
TO PRIMARY LONGITUDINAL MEMBERS
(BULKHEADS) OF BARGE

Project COE Lock Repair

Sheet _____ of _____

Job No A15553

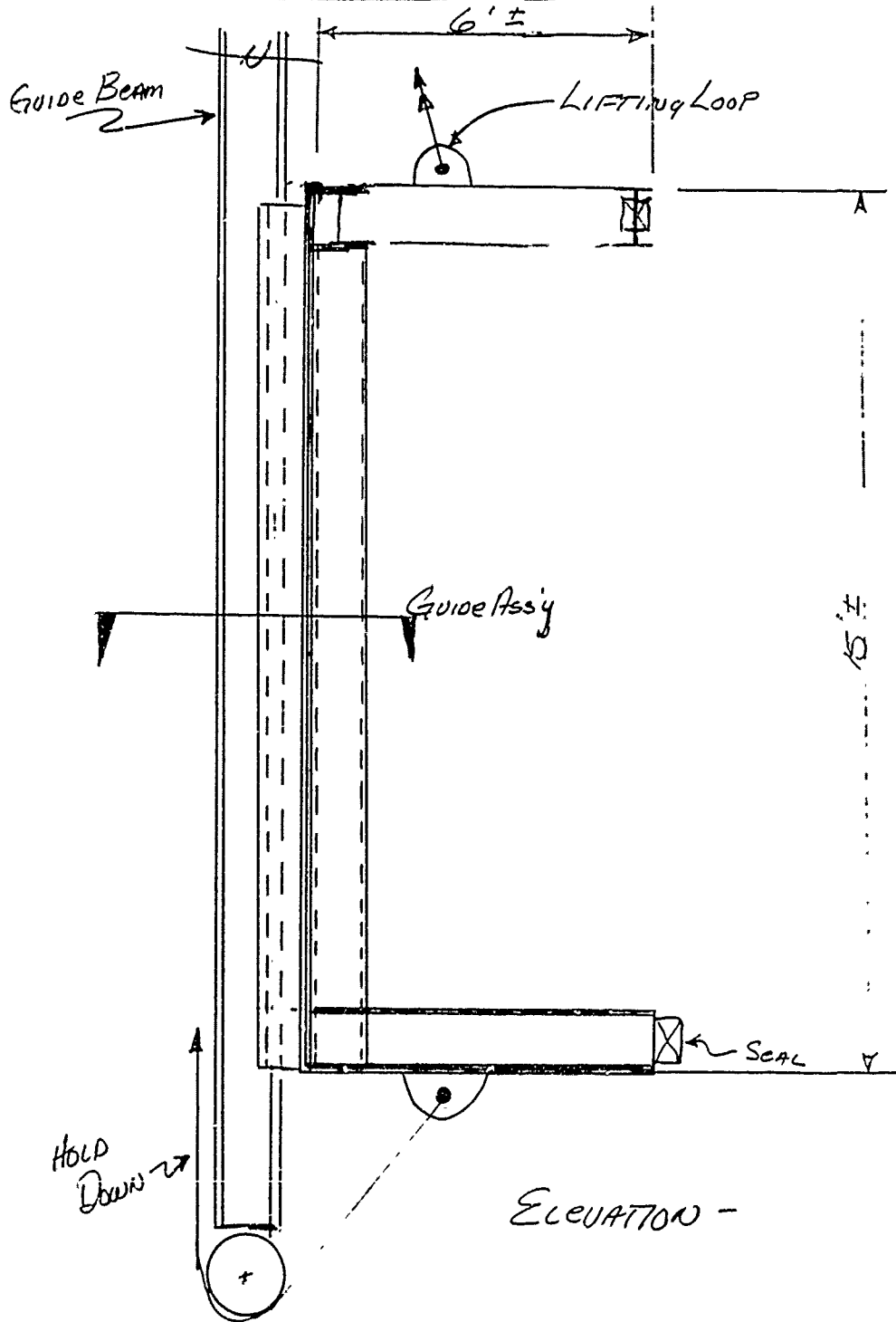
Designer NA

Subject BARGE MOUNTED COFFER

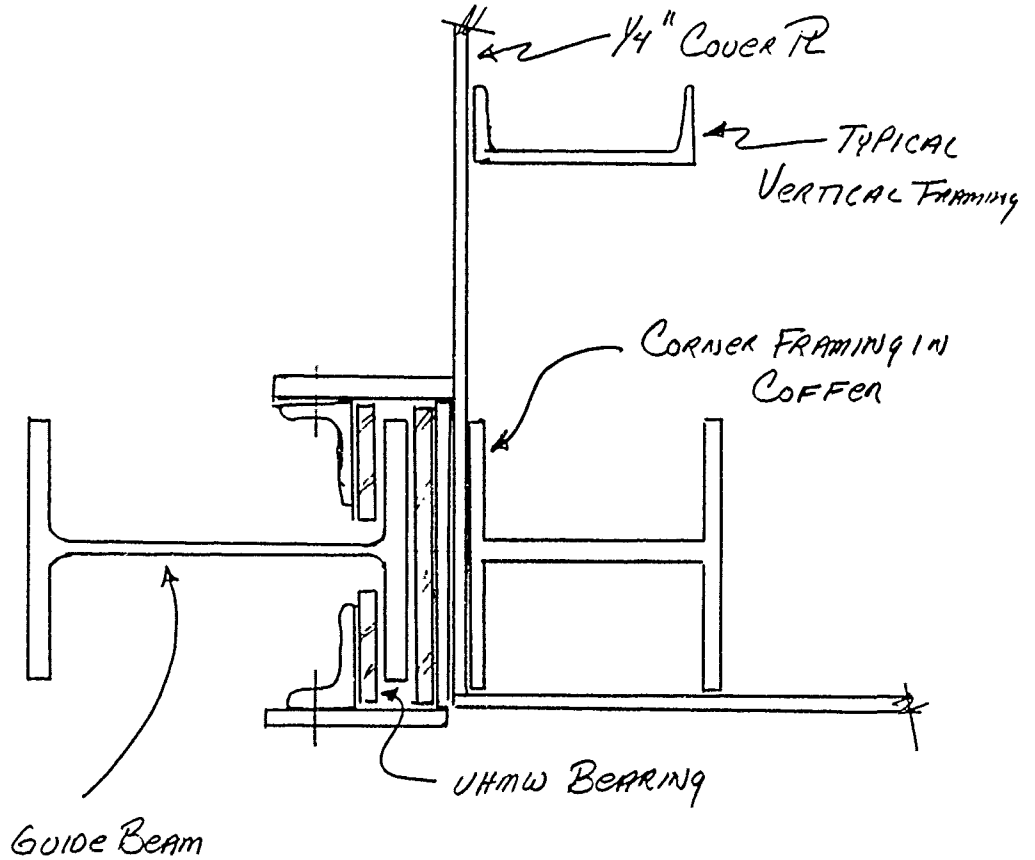
Date 22 Jun 91

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LOOK 3 The COFFER DETAILING



ENG-001/2-84



SECTION - GUIDE ASSY

ESTIMATE WEIGHTS OF COFFER CELL

VERT RIBS = 24 RIBS x 15' x 11.5 lb/ft = 4140 lb
 VERT COLUMNS = 4 x 15' x 65 lb/ft = 3900 lb
 HORIZ BMS = [2 x (35') + 4 x 5'] x 65 = 5850 lb
 SKIN (1/4" PL) = [2 x 5 x 15 + 1 x 35 x 15] 10.2 psf = 6885 lb
 TUBE 35' x 48.85 lb/ft = 1710 lb

22,485 lb

SAY 25 KIPS ← COFFER WT

ESTIMATE WEIGHT OF BARGE MOUNTED GUIDE ASSY

2 ea W18 x 97 x 35' = 6790 lb
 STRUTS (Est) ⇒ 6 ea x 12' x 40.5 lb/ft = 2915 lb
 PIN ASSY (Est 2 ea @ 1000 lb ea) 2000 lb

11,705 lb

SAY 12 K ← GUIDE ASSY WT

Project C&E Lock REHAB

Sheet _____ of _____

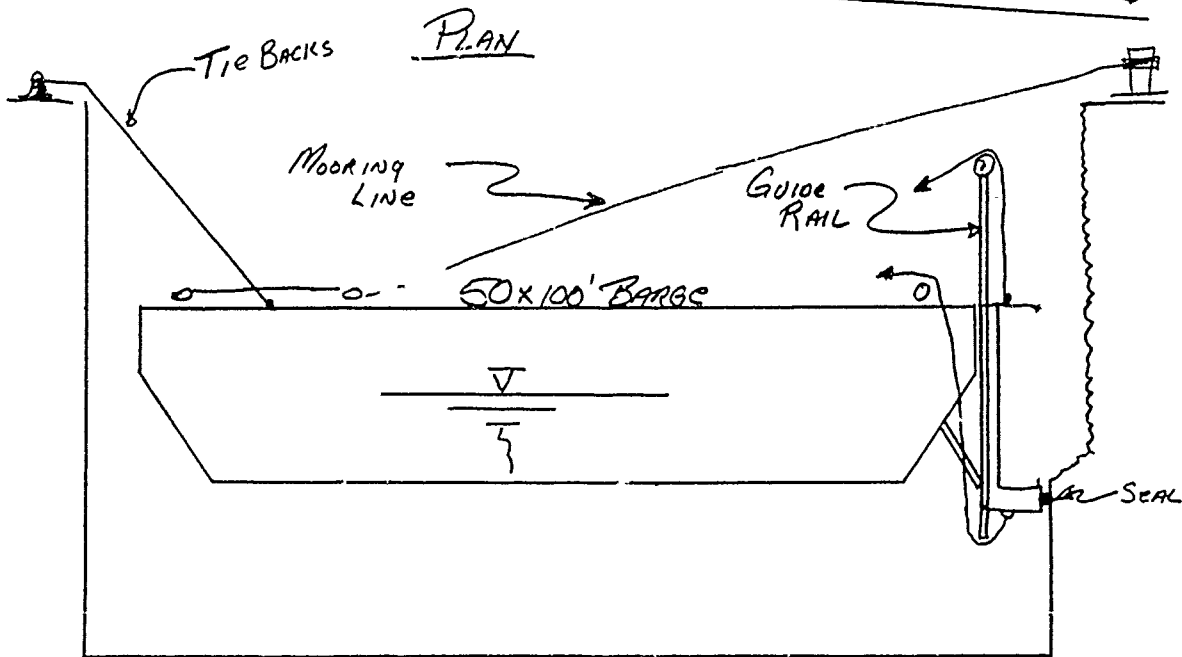
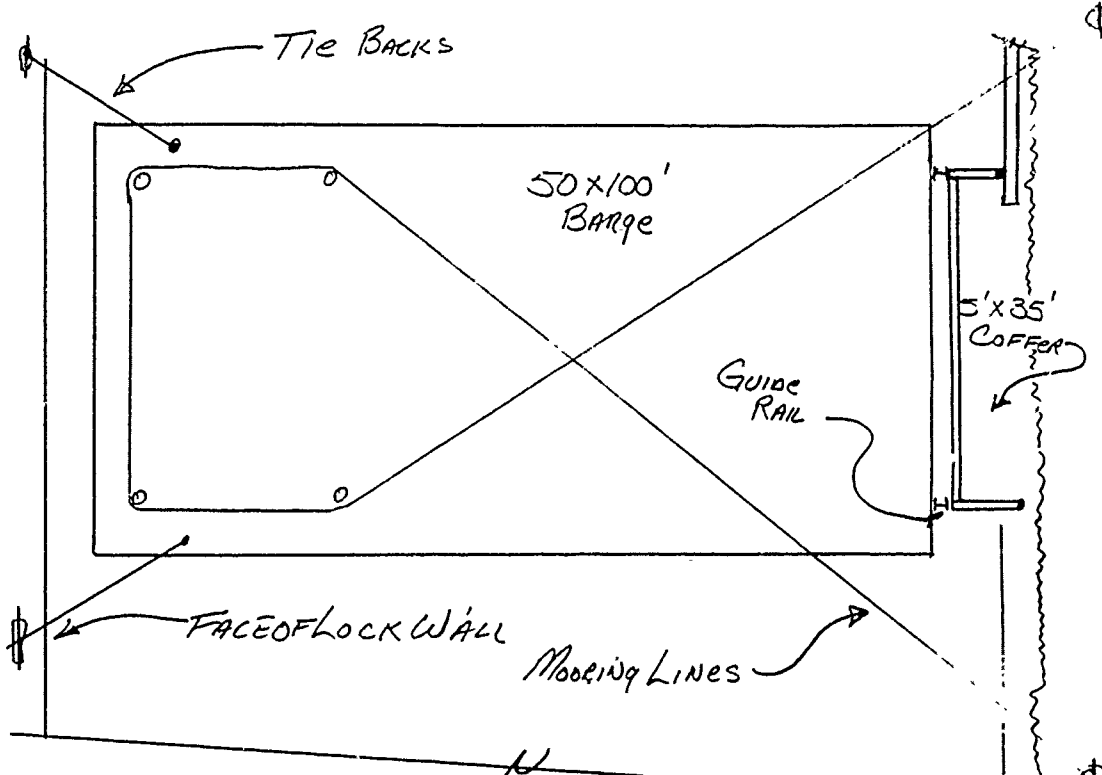
Job No A36029

Designer WA

Subject BARGE MOUNTED COFFER

Date 20 JUN 89

ABAM
CONSULTING ENGINEERS



SECTION

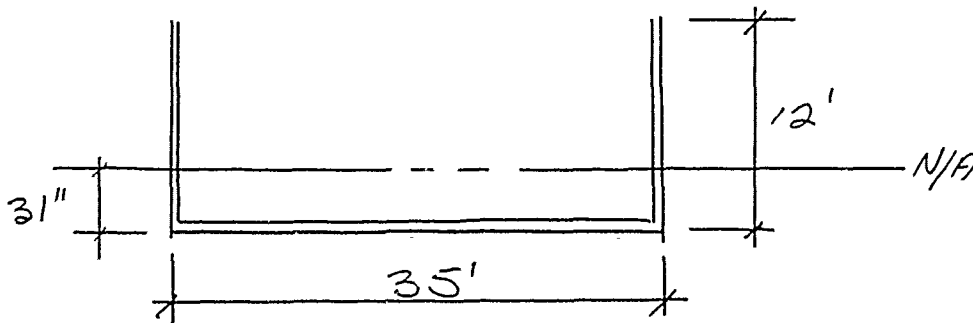
LOOK @ SEAL MATERIAL

- Assume Roughness Amplitude of Wall $\approx 4"$
- Assume 8" Thick Block of Closed Cell Foam is to Compress 4" ($\frac{1}{2}$ height)

~~Let Bearing Surface = 6" Wide~~

$$\therefore \text{Bearing SFC} \approx \frac{6" \times 12"}{ft} = 72 \text{ in}^2/\text{FT}$$

- Assume 'U' Shaped Seal



@ 12' head, Clamping Force $\approx 156^k$

@ 6' head, Clamping Force $\approx 39^k$ ∇ Governs

Avg Force/Unit Length of Seal = $\frac{39^k}{59ft} = 0.66^k/ft$

FIND SPRING COEF. FOR 4" DEFLECTION Spring Coef

$$\frac{0.66^k}{4" \Delta} = 0.165 \frac{k}{in} \approx \frac{165 lb/ft}{in} = K_{SPR}$$

$\approx 14 \text{ psf/in} \nabla \text{ GRASSY ...}$

Look @ Δ For 12' head

$$P = 156^k$$

$$\text{Avg FORCE/UNIT LENGTH} = \frac{156}{59} = 2.64^k/\text{ft}$$

$$\Delta = \frac{2.64}{.165} = 16''$$

\therefore IT WOULD BE APPROPRIATE TO ALTER THE WIDTH OF THE SEAL TO BE COMPATIBLE w/ THE DEPTH OF WATER. (i.e. a seal for 12' head = 4x the width of seal for 6' head, OR THE SPRING COEF. FOR A 12' head should be \sim 4x stiffer than that for a 6' head ~~←~~

Project COE Lock Wall Repair

Sheet _____ of _____

Job No. 1786259

Designer WMA

Date 14 Jun 89

ABAM
CONSULTING ENGINEERS

Subject Temporary Fender System

PNEUMATIC FENDERS

BARGE WEIGHT = 8150 KIPS (Barge @ 35' x 12')

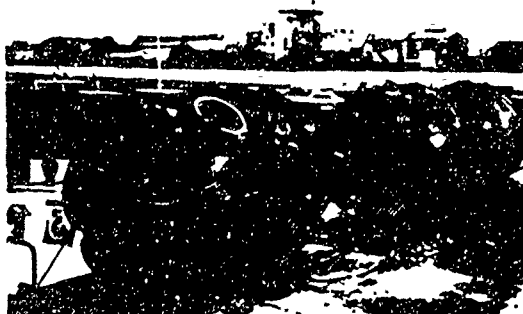
APPROACH VELOCITY = 2 FT/Sec

APPROACH ANGLE = 10°

$$\begin{aligned} \text{TOTAL KINETIC ENERGY (L)} &= \frac{1}{2} mV^2 \\ &= \frac{27.4}{15.3} \text{ KJ} \\ &= \frac{3.8}{2.1} \text{ ton-metres} \end{aligned}$$

FOR FUNCTION, USE 1.2 M Ø MINIMUM (~ 4' Ø)

To



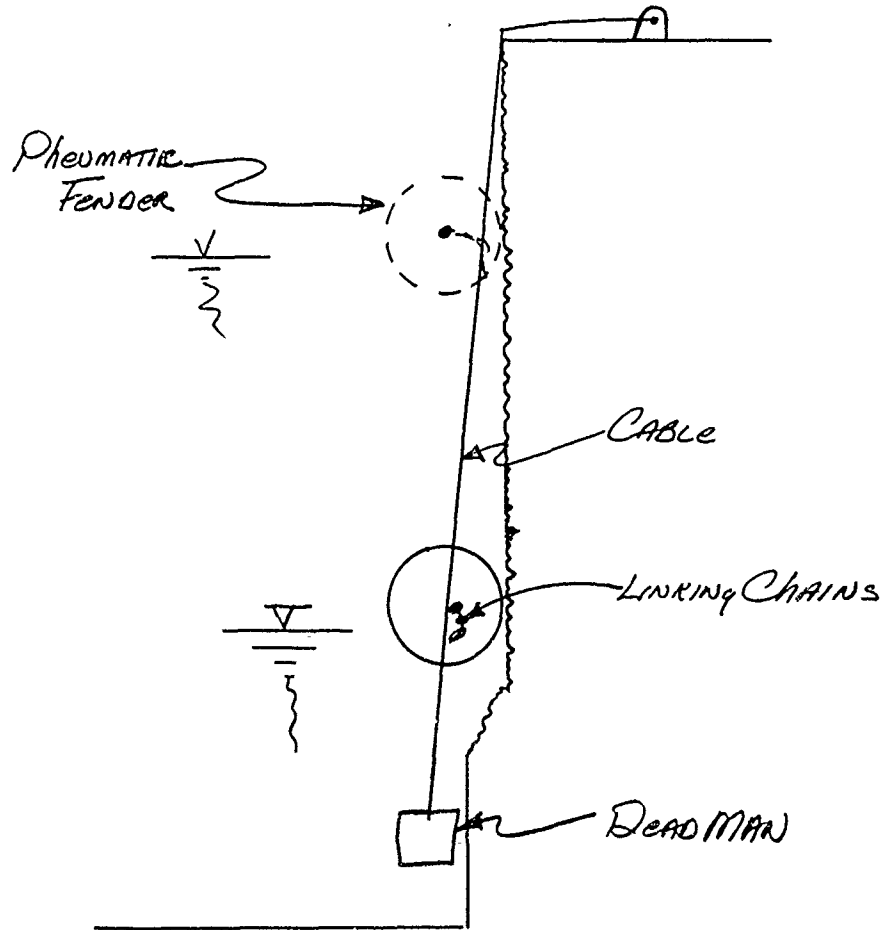
REF:
SHIBATA
PNEUMATIC
FENDERS

∴ Total Reaction
= 27.4^{TON} ≈ 60.5^K

∴ Boreing Pressure ≈ 3

Size		Product's Weight			Normal International Pressure	Performance					
Length	Thickness of the Cylinder part	Wire Net type	Sponge type	Reaction		Internal Pressure 0.1 kg/cm ² (at 60% deflection)			Internal Pressure 0.3 kg/cm ² (at 60% deflection)		
						Reaction	Absorption Energy	Surface Reaction	Reaction	Absorption Energy	Surface Reaction
(m Ø)	(m L)	(mm)	(kg)	(kg)	(kg / cdl)	(ton)	(ton·m)	(t / m ²)	(ton)	(ton·m)	(t / m ²)
1.5	3.0	12	290	730	0.3	10.9			62.0	14.0	14.7
	2.5	12	245	595	0.3				52.0	12.0	
1.2	2.5	11	190	420	0.3				40.0	8.4	
	2.0	11	144	325	0.3				33.0	5.0	
1.0	1.8	11	135	295	0.3				30.0	5.4	
	2.0	10	110		0.3				29.0	4.0	
0.7	1.5	10	85		0.3	22.0	3.1				
	1.5	9	60		0.3	13.0	1.6				
0.6	1.2	9	43		0.3	10.0	1.0				

ENG-001/2-84



SECTION - PNEUMATIC FENDER

Project COE LOCK WALL REPAIR

Sheet _____ of _____

Job No. 86029

Designer WJA

Subject TEMPORARY FENDER SYSTEM

Date 14 JUN 89

ABAM
CONSULTING ENGINEERS

