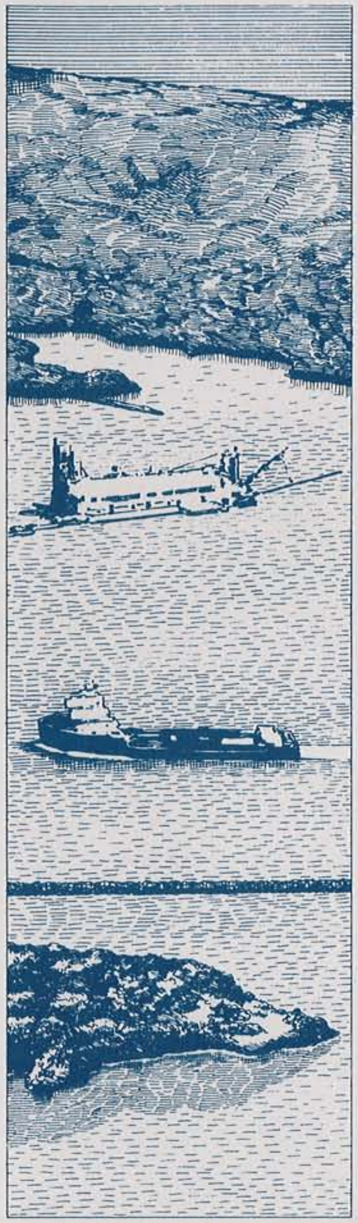
US Army Corps of Engineers



DREDGING RESEARCH PROGRAM

CONTRACT REPORT DRP-92-2

DREDGE MOORING STUDY RECOMMENDED DESIGN PHASE II REPORT

by

SOFEC, Inc.
6300 Rothway, Suite 100
Houston, Texas 77040

May 1992

Final Report

Approved For Public Release; Distribution Is Unlimited

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

Monitored by Coastal Engineering Research Center
US Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

Under Work Unit 32477 (DACW39-90-C-0075)

The Dredging Research Program (DRP) is a seven-year program of the US Army Corps of Engineers. DRP research is managed in these five technical areas:

Area 1 - Analysis of Dredged Material Placed in Open Water

Area 2 - Material Properties Related to Navigation and Dredging

Area 3 - Dredge Plant Equipment and Systems Processes

Area 4 - Vessel Positioning, Survey Controls, and Dredge Monitoring Systems

Area 5 - Management of Dredging Projects

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This report describes the design of a four-leg catenary anchor leg mooring and capsule buoy for the direct pump-out of Corps of Engineers hopper dredges. This is the second phase of a two-phase study. The companion report (phase I - conceptual design) describes operational conditions and operational criteria and buoy dimensions (28 ft long by 11 ft 6 in. wide by 7 ft 6 in. high). This report provides detailed information on: (a) structural calculations, (b) buoy stability, (c) piping system pressure loss analysis, (d) system time/resource analysis (during transport, assembly, and installation), and (e) an example bid proposal specification for procurement. The system time/resource analysis section describes the amount of dock space and staging area required (250 ft by 300 ft of dock space), crane requirements (a 50- to 60-ton crane), and time and personnel required for reach action. The report estimates the buoy could be assembled by five personnel and installed onsite by four personnel (including a diver) in 1 week or less (5 days minimum). With the addition of a second crane and second anchor handling vessel, the assembly and installation time could be reduced by 1 to 2 days.

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Hopper dredges
Single-point mooring buoy

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PREFACE

The study described herein was authorized as part of the Dredging Research Program (DRP) by Headquarters, U.S. Army Corps of Engineers (HQUSACE). Work was performed under the Dredging Equipment for Nearshore/Onshore Placement (DENOP) Work Unit 32477 of DRP Technical Area 3 (TA3), Dredge Plant Equipment and System Processes, at the Coastal Engineering Research Center (CERC), U.S. Army Engineer Waterways Experiment Station (WES). Messrs. Robert H. Campbell and Gerald E. Greener were the HQUSACE Chief and TA3 Technical Monitor, respectively, for the DRP. Mr. E. Clark McNair, CERC, was DRP Program Manager (PM), and Dr. Lyndell Z. Hales, CERC, was Assistant PM. Mr. William D. Martin, Chief, Estuarine Engineering Branch, Estuaries Division, Hydraulics Laboratory (HL), was Technical Manager of DRP TA3, which includes Work Unit 32477. The study was conducted under contract. At the start of the contract, the Principal Investigator on the DENOP Work Unit and Contract Monitor was Thomas A. Chisholm, Hydraulic Engineer, Engineering Applications Unit (EAU), Coastal Structures and Evaluation Branch (CSE), Engineering Development Division (EDD), CERC. Mr. James E. Clausner, Research Hydraulic Engineer, EAU, CSE, EDD, CERC, replaced Mr. Chisholm as the Principal Investigator on the DENOP work unit and also became Contract Monitor.

This report, "Dredge Mooring Study - Recommended Design - Phase II," was written by SOFEC, Inc., of Houston, TX, under contract No. DACW39-90-C-0075, during the period 16 March 1990 through 15 September 1991. Principal author at SOFEC, Inc. was Jerry A. Blair. Messrs. Chisholm and Clausner were under the direct supervision of Dr. Yen-hsi Chu, Chief, EAU, Ms. Joan Pope, Chief, CSE, Mr. Thomas W. Richardson, Chief, EDD, and under the general supervision of Dr. James R. Houston, Director, and Mr. Charles C. Calhoun, Jr., Assistant Director, CERC.

Ms. Sandra Staggs, Contracts Division, WES, provided oversight of the contracting process.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassell, EN.

Additional information can be obtained from Mr. E. Clark McNair, Jr., DRP Program Manager, at (601)634-2070 or Mr. James E. Clausner, Principal Investigator, at (601)634-2009.

DREDGE MOORING STUDY
Recommended Design
Phase II Report

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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:

Multiply	By	To Obtain
cubic feet per minute	0.02831685	cubic metres per minute
dead weight tons	1,016.0	kilograms
degrees (angle)	0.01745329	radians
feet	0.3048	metres
gallons	3.785412	cubic decimetres
inches	0.0254	metres
pound weight	453.6	kilograms
kilopounds feet	1,355.8	joules
kips per square inch	6.894757	megapascals
knots	0.5144	metres per second
miles	1,609.3	metres
pounds per square foot	47.88026	pascals
pounds per square inch	6.894757	kilopascals
short ton	907.2	kilograms
tons (mass)	907.1847	kilograms

SUMMARY

This report is phase II of a two-phase study whose purpose was to design a direct pump-out (DPO) facility for Corps of Engineers (CE) hopper dredges. At the beginning of the study (Aug 90), the CE did not have the capability for DPO of their hopper dredges in open water. The CE desired this capability to be able to respond to national emergencies (such as hurricanes) where the ability to quickly place sand on the beach is needed. The existence of a DPO facility would also allow an increased amount of suitable dredged material to be used beneficially; for example, to place sand on eroding beaches or to place fine-grained materials to supplement wetlands.

This study was contracted to SOFEC, Inc., of Houston, TX. The mooring system was designed to hold the CE Hopper Dredge Wheeler, the largest of the three CE hopper dredges. Operational conditions were a significant wave height of 6.0 ft, wind velocity of 30 knots, and a current velocity of 2 knots. The mooring system was designed for operation in a minimum depth of 30 ft and a maximum depth of 45 ft. The following operational criteria were also required for the mooring design: (a) transport by truck or rail, (b) rapid assembly with little or no diver support, and (c) installation with a minimum of lift support. The phase I report studied five conceptual mooring designs and identified a four-leg catenary anchor leg mooring (CALM) for more detailed study because it best met the operational criteria. To meet truck transportation requirements, a 28-ft-long by 11-ft 6-in.-wide, by 7-ft 6-in.- deep capsule buoy was designed. The anchor chains would be connected to a separate mooring table that is attached to the underside of the buoy. Each mooring leg would be 600 ft long and consist of 2-in.-diam chain and a 10,000-lb Navy Navmoor or 6,000-lb Bruce anchor. The approximate weights (in short tons) of the major components are: mooring buoy - 23.0; mooring table - 8.5; buoy piping - 3.0; and fluid swivel. The mooring system could be transported on as few as six "lowboy" flatbed tractor trailer trucks, or a single 40-ft by 120-ft deck barge.

This report describes the design details and installation procedures. Included are information on: (a) structural calculations, (b) buoy stability, (c) piping system pressure loss analysis, (d) system time/resource analysis (during transport, assembly, and installation), and (e) an example bid proposal specification for procurement.

The system time/resource analysis section describes the amount of dock space and staging area required (250 ft by 300 ft of dock space), crane requirements (a 50- to 60-ton crane), and time and personnel required for reach action. The report estimates that the buoy could be assembled by five personnel and installed onsite by four personnel (including a diver) in 1 week or less (5 days minimum). With the addition of a second crane and second anchor handling vessel, the assembly and installation time could be reduced by 1 to 2 days.

DREDGE MOORING STUDY
Recommended Design
Phase II Report
U. S. Army Corps Of Engineers
Waterways Experiment Station

SOFEC, Inc., Houston, TX
Contract No. DACW39-90-C-0075

July 15, 1991

1.0 INTRODUCTION

1. Direct Pump-Out (DPO) of hopper dredges has been used in Europe and the United States for the past 25 years for beach replenishment and nearshore placement of dredge material. More recently, direct pump out of dredges has been used in the development of seaport projects in the Middle and Far East and in the construction of artificial Islands in the Arctic region of Canada, in addition to beach nourishment projects in the United States.

2. The direct pump out method of off-loading hopper dredges has been a method which has gained in popularity to accomplish both the placement of dredge material into dredge fill locations and onto beach zones which require replenishment. The U.S. Army Corps of Engineers (CE) has found that there is a growing need to make beneficial use of maintenance material dredged by hopper dredges. Other than bottom dumping to create nearshore berms, most other forms of beneficial uses of dredged material require the ability to remove the material from the dredge's hoppers and place it in another location.

3. The direct pump out of a hopper dredge is accomplished by pumping through a pipeline which has been laid along the sea floor from the location that the dredge material is required to a location offshore in which the water depth is adequate for the dredge to operate. The dredge will normally fill its hoppers some distance away from the replenishment location. The dredging site is usually chosen to clear or create a channel or because of the quality of the material to be placed on the beach. The loaded dredge will then moor itself in some manner. The mooring may be a buoy or an anchor clump weight resting on the sea floor. The dredge will then connect to the subsea pipeline through a hose which is floating on the surface of the water. The dredge then discharges the dredge material through the pipeline and returns to the dredging site for more material.

2.0 PURPOSE OF THIS STUDY

4. SOFEC, Inc. was contracted by the U.S. Army Engineers Waterways Experiment Station, as part of the Dredging Research Program, to study methods for mooring hopper dredges for the purpose of direct pump out for beach replenishment and dredged material disposal. The Phase I study analyzed an array of commercial industry mooring system concepts with the goal of selecting the optimum cost effective mooring system for utilization as a DPO SPM. In addition to the mooring criteria the system was to satisfy the following requirements:

1. Modular component design for ease of transport by truck, rail or barge.
2. Buoy assembly launch weight limited to the capabilities of a 35 ton crane.
3. Modular buoy main components assembly in one 24 hour day.
4. Deployment to an operational status, from staging area dock to marine site, in one seven day week.
5. Minimum deployment, maintenance and retrieval diver support.
6. Buoy to exhibit enhanced marine towing capabilities over existing buoy systems.

5. The Phase I report recommended the adoption of a DPO SPM system composed of:

1. A modular buoy structure consisting of a capsule shaped buoy hull, mechanical swivel, mooring table with four chain support assemblies, a piping assembly with integral mooring hawser padeye, a hose swivel, a lifting frame to assist in anchor chain and hose installation/maintenance, and ancillary equipment (maintenance, navigation and safety).
2. A four leg catenary anchoring system consisting of stud link anchor chain pendants and high efficiency marine anchors.
3. A single hawser assembly consisting of a buoy mounting shackle and a polypropylene hawser rope with integral soft loop.
4. A hose system consisting of commercially available floating and underbuoy dredge hoses.

6. The following items, identified in the Phase I Report and during project meetings are presented in the Phase II Report:

    1. Discussion of Mooring Forces induced by the Dredge Vessel.

    2. Presentation of Buoy and Buoy Piping Structural Analysis.

    3. Analysis of Buoy Stability at Water Depths of 30 and 75 Feet.

    4. Analysis of Hose and Piping Flow Pressure Losses.

    5. Presentation of Hawser-Hose Entanglement Prevention Methods.

    6. Presentation of Hawser Load Monitoring Systems.

    7. Presentation of SPM Marine Deployment Positioning System Requirements.

    8. Resource Analysis of SPM Transportation Requirements.

    9. Time/Resource Analysis of SPM Assembly and Marine Installation.

    10. Time/Resource Analysis of SPM Recovery.

    11. Time/Resource Analysis of Buoy Emergency Recovery.

    12. Presentation of a Representative Bid Proposal Specification.

    13. Time/Cost Estimate for Consultant Preparation of SPM Contract Drawings.

3.0 DISCUSSION

7. A discussion of the items noted in Section 2 follows:

8. MOORING FORCES: The analysis of the mooring forces generated by the dredge vessels and DPO SPM buoy under various environmental scenarios was presented in the Dredge Mooring Study, Phase 1 Report. Maximum design hawser load was determined to be 100 kips. The design of the mooring system was based on this design hawser load. The reader is referred to Chapters 3 and 4 of the Phase 1 Report for review of the environmental parameters, characteristics of the dredge vessels, and the discussion of the analysis. The reader is referred to the following drawings for a graphic representation of the overall system and system components:

1.	Figure 3.1	Drawing 667-P2-1	System General Arrangement
2.	Figure 3.2	Drawing 667-P2-2	Typical Anchor Leg Arrangement
3.	Figure 3.3	Drawing 667-P2-3	Buoy Elevation
4.	Figure 3.4	Drawing 667-P2-4	Buoy Plan
5.	Figure 3.5	Drawing 667-P2-9	Exploded Buoy Isometric

9. BUOY and PIPING STRUCTURAL ANALYSIS: A presentation of the structural analysis of the DPO SPM system is presented in Appendix A.

10. BUOY STABILITY: A presentation of the buoy stability is presented in Appendix B. The buoy is analyzed in two water depths representing the range of anticipated usage, 30 feet through 75 feet. The analysis of the buoy weight and center of gravity location in both non-operational and operational configurations reveal the inherent stability of the recommended system design.

11. The initial charter of this study defined a water depth of 30 - 40 feet for the basic design criteria. However, operation of the system in depths up to 75 feet was considered for DPO in limited locations on the West Coast. Therefore, the scope of investigation was expanded to water depths of 75 feet. The result was the use of this buoy system design in water depths of 75 feet is a viable option. In water depths of 75 feet, the amount of operational freeboard available may be approaching a minimal acceptable limit. While the Philadelphia District stated that they had no problem with wave water on the deck of the buoy; it is recommended that the CE evaluate and respond with their preference for minimum freeboard on the buoy at various sea states. Specifically, at what level of personnel perception, due to comfort or safety, does the CE wish to limit the possibility

FIGURE 3.1

SYSTEM GENERAL ARRANGEMENT

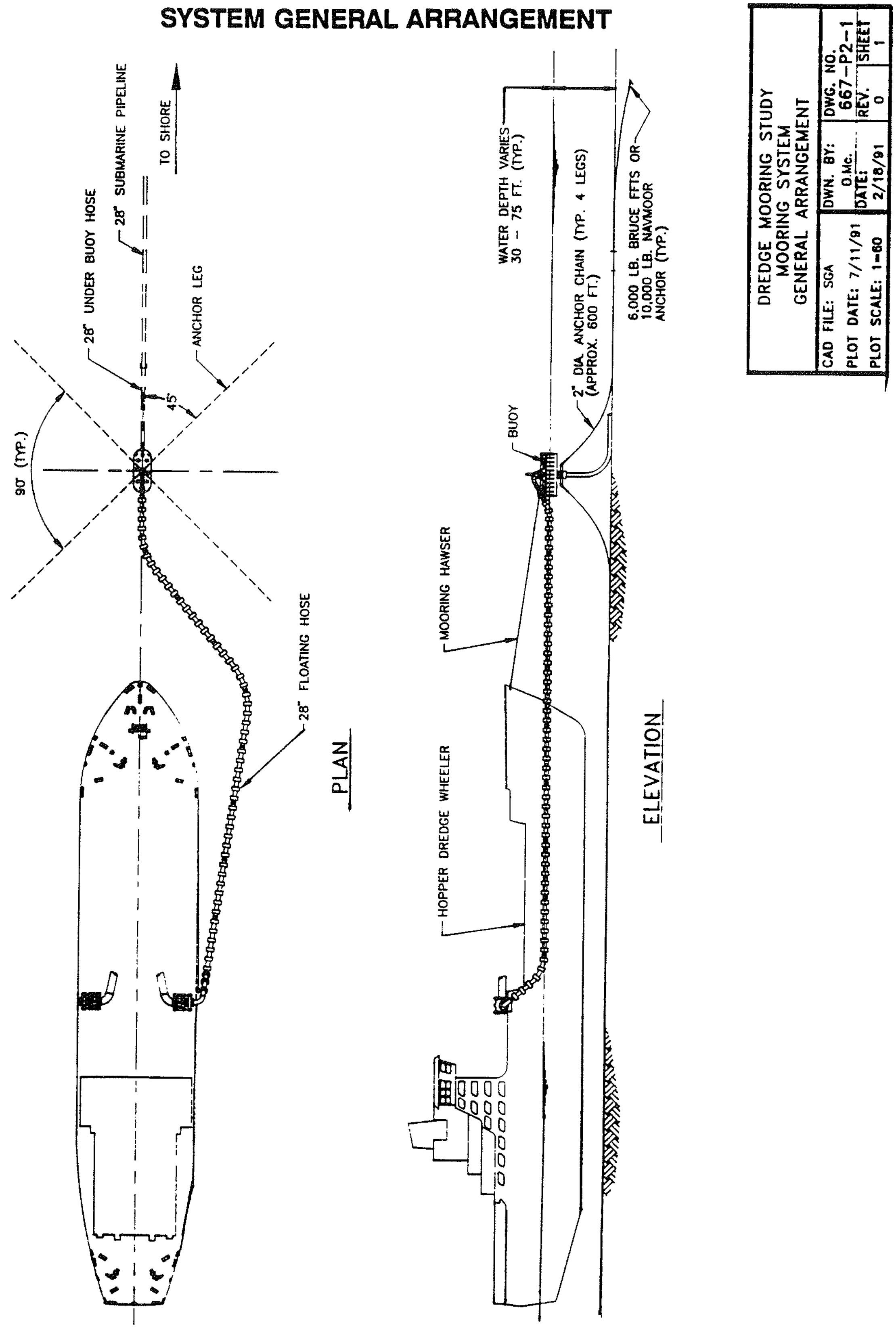
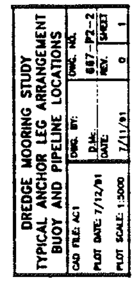


FIGURE 3.2

TYPICAL ANCHOR LEG ARRANGEMENT



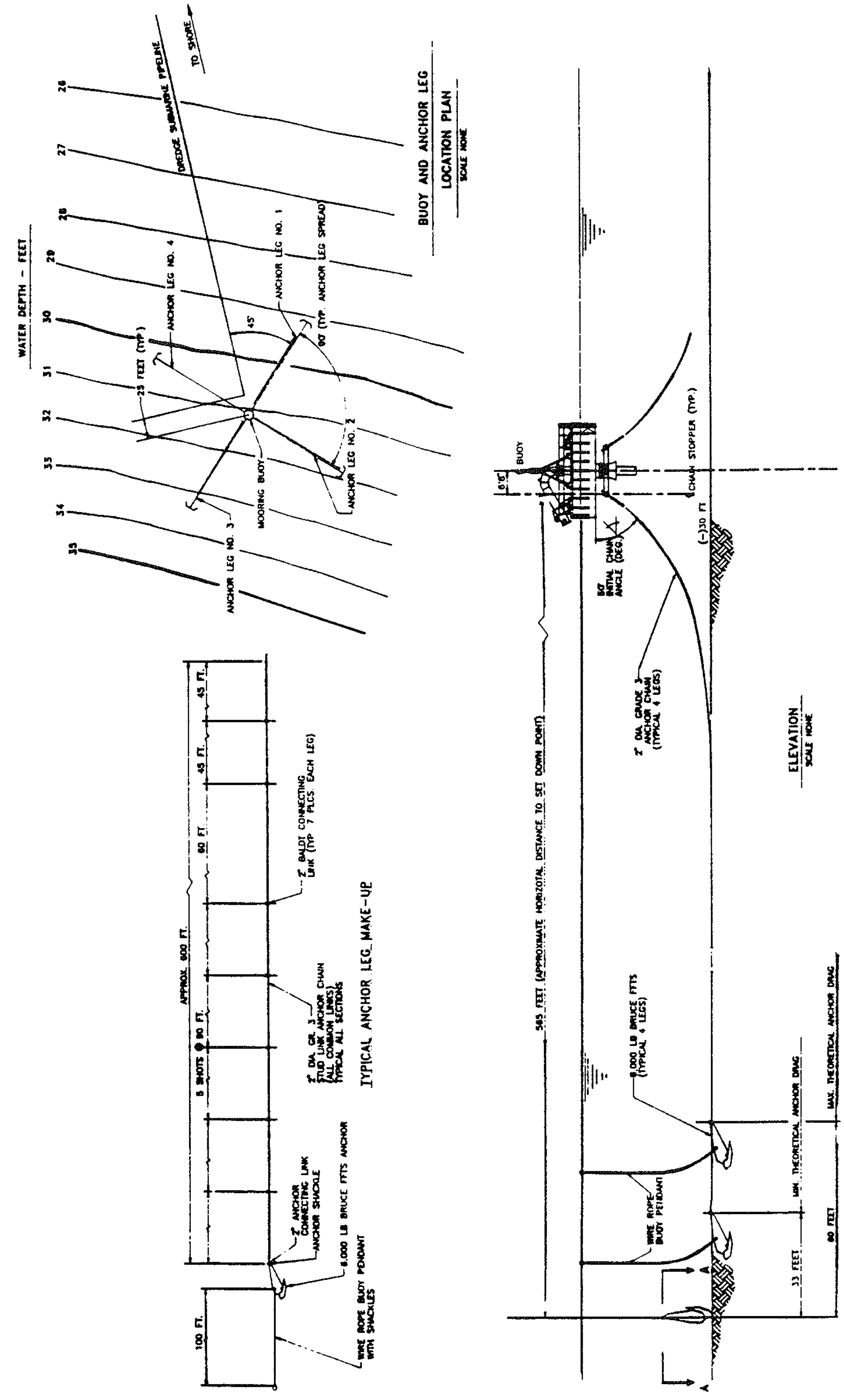


FIGURE 3.3

BUOY ELEVATION

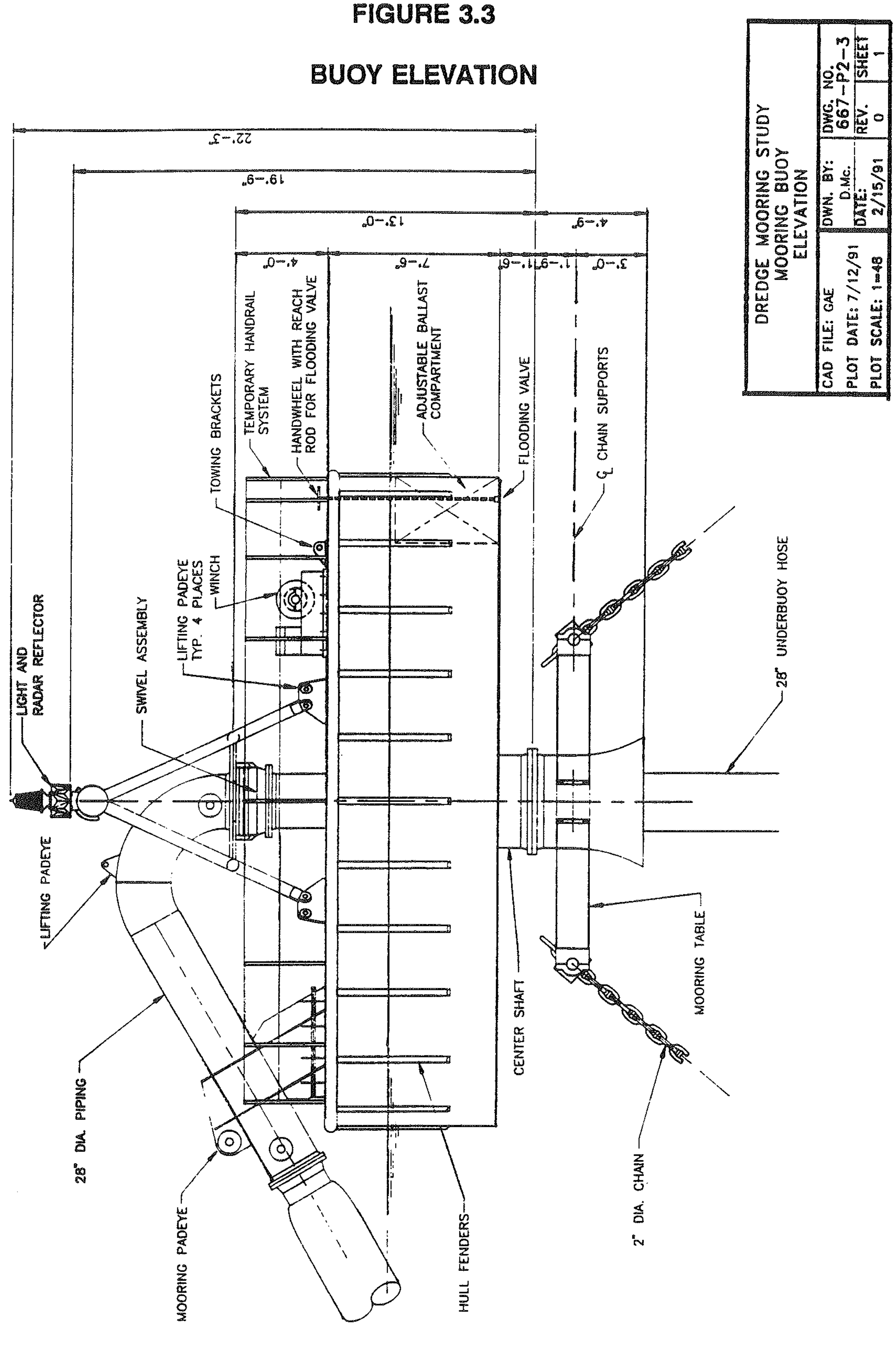
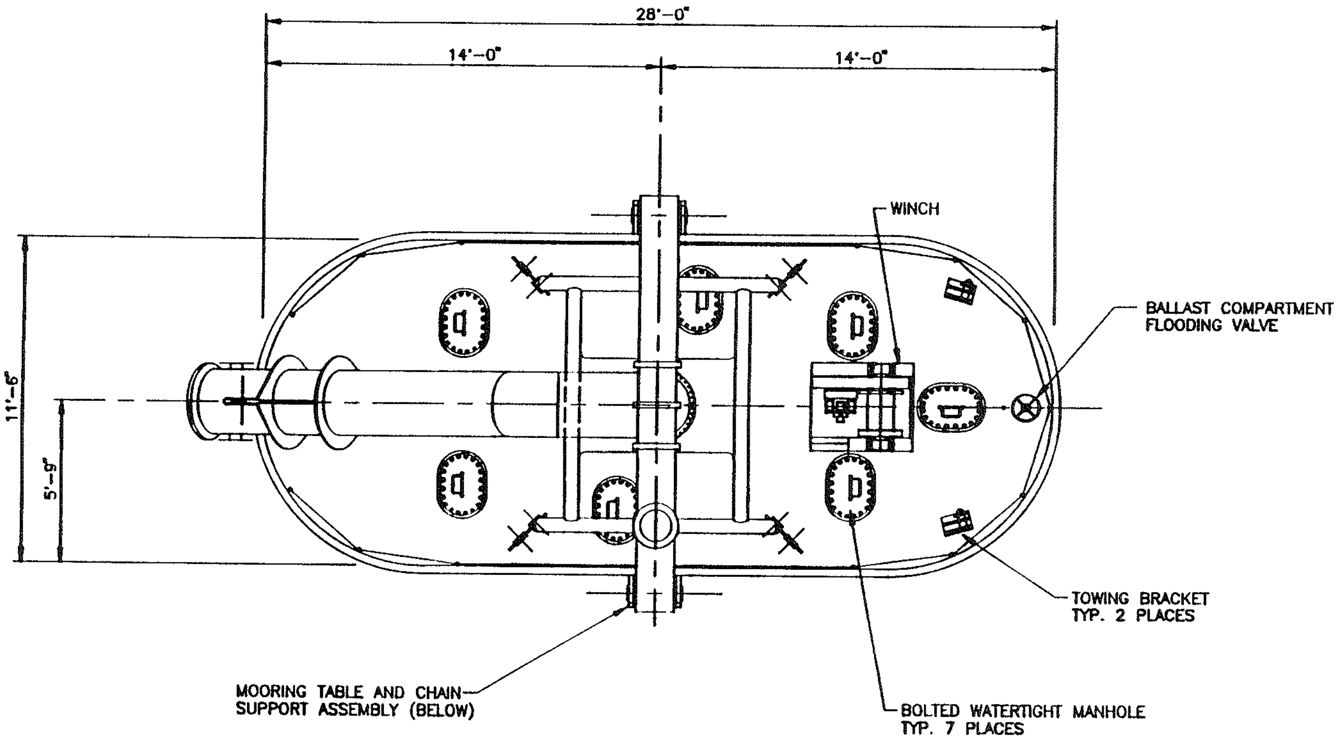


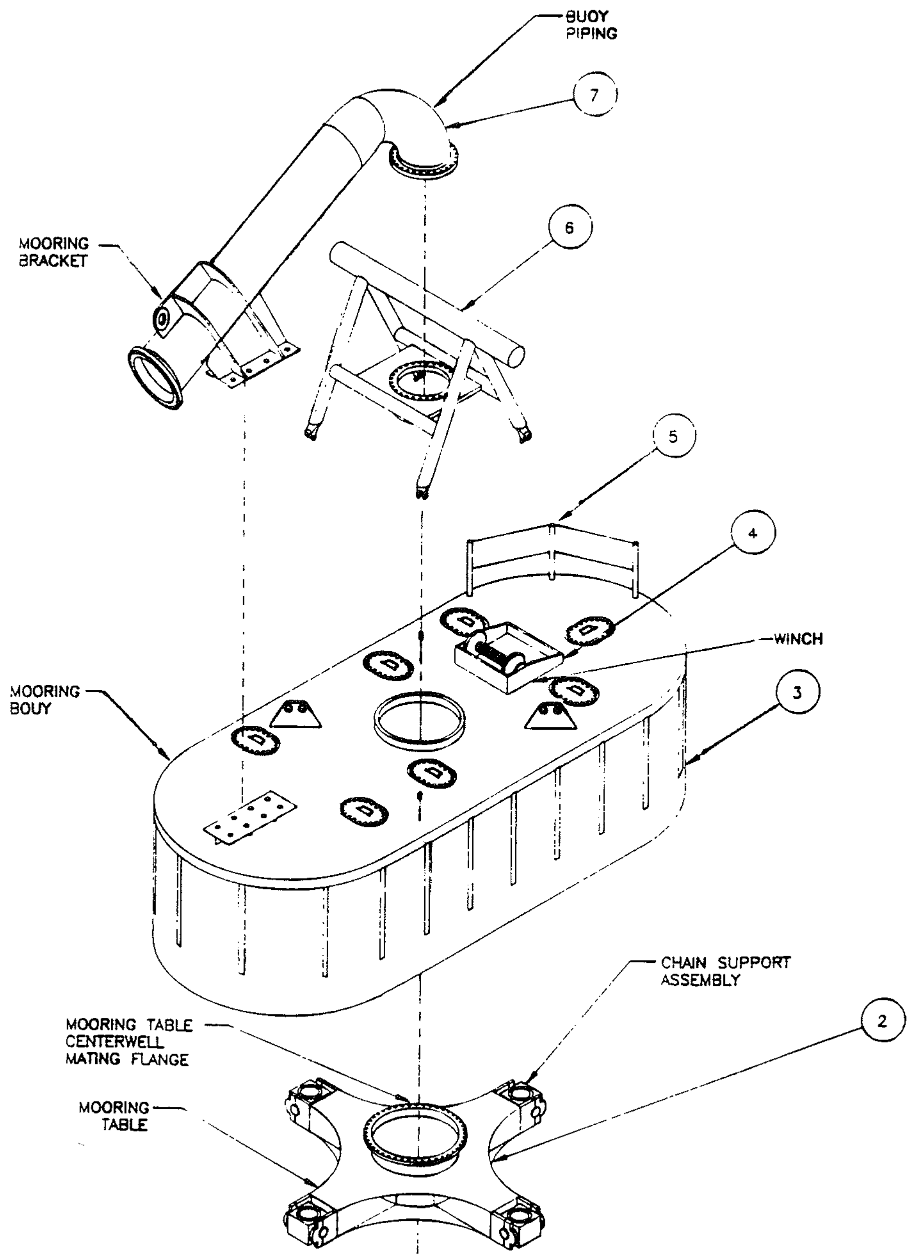
FIGURE 3.4
BUOY PLAN



DREDGE MOORING STUDY MOORING BUOY PLAN VIEW			
CAD FILE: GAP	DWN. BY: D.Mc.	DWG. NO. 667-P2-4	
PLOT DATE: 7/10/91	DATE: 2/15/91	REV. 0	SHEET 1
PLOT SCALE: 1=48			

FIGURE 3.5

EXPLODED BUOY ISOMETRIC



of wave water on the deck of the buoy. Note that this evaluation is based solely on psychological factors; since, the buoy is inherently stable and sea worthy. In addition, an increase in freeboard may require an increase in the buoy hull size which could affect the feasibility of shipping the buoy hull by over-the-road trucks.

12. Operation of the existing DPO SPM system in water depths of 75 feet will require a minimum of one additional shot (90 feet) of anchor chain per chain leg and an additional section (35 feet) of underbuoy hose.

13. HOSE and PIPING FLOW PRESSURE LOSS: A presentation of the analysis of the anticipated pressure drop (flow resistance) of the buoy hose and submarine pipeline is given in Appendix C for various particle sizes, percent solids in the dredge slurry, and flow rates. A representative sample of pressure drop graphs developed for the DPO SPM system, a sample problem and a computer program for use in calculating and plotting the pressure drop graphs are provided.

14. HAWSER/HOSE ENTANGLEMENT: Due to the proximity of the floating hawser and the surface hose string and the random wave action affecting both, it is difficult to determine a reliable method to insure the two will not become entangled. SOFEC, Inc. recommends the following courses of action to reduce the potential for hawser/hose entanglement:

1. Use short bolt studs at the surface hose flange connections to limit exposed thread surfaces to 1 - 2 threads beyond the fastener nuts.

2. Install lace-on covers over the hose flange joints of the two surface hoses adjacent to the buoy, to maintain a uniform outside hose diameter over the first 105 feet of hose from the buoy. In addition, provide a chafing cover at the flange joint connecting the surface hose string to the buoy piping assembly.

3. Install lace-on floats with covers on the hawser in a position that aligns with the surface hose flange joints.

15. HAWSER LOAD MONITORING SYSTEMS: At present, there are a number of companies that manufacture and market electronic load monitoring equipment which is suitable for marine applications. Most systems operate on low voltage direct current power sources and can be supplied to meet national code requirements for use in explosive environments. The systems normally incorporate a calibrated strain gage which is attached to a pin or a tension link. Accuracy is normally maintained to less than 2% of the maximum rated load of the unit. Additionally, the control unit of the system incorporates a damping circuit to reduce false signals due to transient load spikes. Typically, a set source voltage to the strain gage is modified by the change in the gage's resistance due to load and an electric signal is generated and amplified and relayed to a display meter or trip switch.

16. For the DPO SPM system, the load monitoring system could be set with "trip points" at 90% and 105% of hawser maximum load. When the "90% trip point" is exceeded, the load monitoring system could send a signal to a relay to flash a warning light on the buoy or sound the fog horn with a specific sequence code or by radio telemetry activate a similar warning device on the bridge of the dredge. At or above the "105% trip point", the load monitoring system could send a signal to a relay to continuously illuminate a warning light on the buoy or continuously sound the fog horn or by radio telemetry similarly activate a warning device on the bridge of the dredge.

17. The technology exists to allow continuous monitoring of the force on the mooring hawser by a buoy mounted strip recorder or through radio telemetry to a strip recorder on the dredge vessel or at a remote shore station, if that option is desired.

18. SPM MARINE DEPLOYMENT POSITIONING REQUIREMENTS: The positioning deployment of the DPO SPM system is based solely on the location of the buoy end of the submarine dredge slurry pipeline. Figure 3.2 depicts a typical location plan.
The set down point for the marine anchor is anticipated to fall within a ten feet radius of the design location. It is anticipated that a site survey of the proposed deployment area will be conducted prior to arrival of the SPM system. As a minimum, a soil sample should be obtained at the anticipated anchor sites to confirm adequate soil characteristics to set the anchors.

19. Actual location of the anchor legs and buoy can be established by marking methods on site, by shore based transit observation, by global positioning system equipment, or other suitable navigation locator methods which would provide sufficient accuracy. There is sufficient excess chain designed into the system to allow for final chain angle adjustment at the buoy and proper positioning of the buoy relative to the pipeline.

20. RESOURCE ANALYSIS: A resource analysis of the DPO SPM system is presented in Appendix D. The discussion focuses on transportation of the system, system assembly and marine deployment, system recovery, and emergency buoy recovery. Time lines are provided, as appropriate.

21. BID PROPOSAL SPECIFICATION: An example bid specification proposal for the DPO SPM system is presented in Appendix E.

22. TIME/COST ESTIMATE of SPM SYSTEM DRAWINGS. The bid price for services and the amount of time required to execute the design of the system and produce the engineering drawings to provide for fabrication and component acquisition of the system is dependent upon the requirements of the bid proposal specification and the capabilities of the marine architect or consulting firm. Resolution of a number of outstanding issues, as identified in the recommendations section of this report, would result in a systems design approach which would better serve the future needs, both operational and fiscal, of the CE. It is recommended that in the acquisition of the system, the mooring analysis is not divorced from the SPM component structural analysis. Seemingly slight variations

in the weights, center of gravity, system geometry, and other factors of the various components can produce adverse operational characteristics in the end product. A provisional schedule for system design and drafting of drawings without model testing is 6 - 10 weeks; the schedule for component acquisition and buoy fabrication is 24 - 30 weeks. If third party design/fabrication review and certification is desired, i.e., American Bureau of Shipping, add 3 -4 weeks to the above time estimates. Assume 1 - 2 weeks to prepare the system for staging at the CE designated test site and 1 week to test.

4. CONCLUSIONS AND RECOMMENDATIONS

23. CONCLUSIONS: The capsuled shaped buoy mooring system concept presented in this study is a lightweight, modular design, that is road transportable and easily assembled. The system is configured to be easily maintained or repaired and can be rapidly deployed. The DPO SPM system is shown fitted with a single line piping that meets the specified requirements of the DPO SPM mission of the CE.

24. RECOMMENDATIONS: The following points of clarification should be included in the bid specification developed by the CE:

1. Define minimum acceptable buoy freeboard relative to sea state.

2. During planning for system installation the CE will require a method to evaluate the distance a given dredge slurry can be pumped with on site equipment. Define CE's preference for accounting for flow resistance of the piping and hose systems, i.e., a table of graphs, a computer program, a set of "rules of thumb", etc.

3. Identify the requirement for a mooring hawser load monitoring system. Should a load monitoring system be desired, define the type of system and the range of capabilities needed.

4. Identify the navigational equipment/methods currently utilized by the CE for locating comparable SPM systems in a marine environment and comment on the suitability of current systems. Is the CE anticipating technology enhancements to their current global positioning systems?

5. Identify the current CE procedures, methods, and extent of hydrographic and geotechnical surveys at potential marine DPO SPM deployment sites.

6. Identify the current CE support vessel fleet and provide its capability. Does the CE have tender vessels, tugs, anchor handling vessels, or crane barges available to support the DPO SPM deployment or is rental equipment utilized?

7. The bid proposal specification in Appendix E is presented as a "first draft" example paper for modification by CE. Some items in the proposal will require input from the CE, such as soil parameters in Section 2.8 or dredge slurry characteristics in Section 2.10; other sections may require modification to customize the specification to insure acquisition of a component of equipment to the requirements of the CE.

DREDGE MOORING STUDY
Phase II Report

APPENDIX A
STRUCTURAL CALCULATIONS

July 15, 1991

SOFEC, Inc. - Houston, TX
Project No. 667

U.S. Army Corps of Engineers
Waterways Experiment Station

Contract No. DACW39-90-C-0075

DESIGN CALCULATIONS - DREDGE MOORING - PHASE 1

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DESIGN CALCULATIONS - DREDGE MOORING - PHASE I

1.0 Introduction

Contained in this report are Phase I calculations for the U.S. Army Corps of Engineers Dredge Mooring. The proposed concept is a 4-legged CALM system designed to be transported by road. The objective of this CALM is to moor a dredger vessel and provide a conduit for pumping its slurry ashore via a 28" flexible line.

The concept presented can be divided into the following major components. They are:

1) Anchors - 4 Total, 6 to 12 kips each
2) Chain Legs - 4 Total, 2" ORQ x 600 ft. each, 28 kips each
3) Mooring Table - 1 Total, 12' x 12' x 5', 16 kips
4) Buoy - 1 Total, 12' x 28' x 13', 44 kips
5) Piping - 1 Hard Spool, 3' x 5' x 16', 5 kips
   Also Flexible Underbuoy and Floating Hoses

It is anticipated that the buoy, mooring table and hard piping can be assembled using cranes onshore and lifted as a single assembly into the water. On location it is intended that a small crane or air winch be used to pull in the chains and hoses. No swivel design is presented since it is assumed the swivel flange currently in use by the private industry can be utilized. Phase II will consider the fluid swivel further as well as the underbuoy and floating hoses.

See Sections 2 & 3 for Design Criteria and Design Loads. Sketches are provided in Section 4. Calculations are included in Sections 5 through 8.

DESIGN CALCULATIONS - DREDGE MOORING - PHASE I

2.0 Design Criteria

2.1 Design Codes

Use the following standard codes:

a) ABS - Rules for Building & Classing SPM's (1975)

b) AWS D1.1 - Structural Welding Code (1990)

c) API RP2A - Fixed Offshore Platforms (18th Ed.)

In addition, AISC-ASD (9th Ed.) is used in areas not addressed by the specified standards or where the above standards allow its use.

2.2 Design Conditions

		OP'G #1	OP'G #2	SURVIVAL
a)	Still Water Depth [FT]	40.	40.	40.
b)	Bottom Conditions (No Soil Report)	Varies from Soft to Hard		
c)	Significant Wave Height [FT]	6.	-	10.
d)	Swell Height [FT]	-	12.	20.
e)	Period [S]	6.	11.	-
f)	Current [KNOTS]	2.	2.	-
g)	Wind [KNOTS]	30.	30.	-

DESIGN CALCULATIONS - DREDGE MOORING - PHASE I

2.0 Design Criteria (Cont'd)

2.3 Design Materials

Use the following materials:

a) Mild Steel - Non-Critical : ASTM A36 or ABS Gr. B
Fy = 34 ksi

b) Mild Steel - Critical : ASTM A516 Gr. 70
(w/ Charpy's 15 ft-lb @ 32 deg. F)
Fy = 38 ksi

c) Piping : ASTM A53 Gr. B, ASTM A106 Gr. B or API 5L Gr. B
Fy = 35 ksi

d) Bearings : Self-Lubricating Bronze Alloy on Stainless Steel

e) Chain : Grade U3

PROJECT Corps of Engrs - Dredge Mooring	**SHEET NO.** 3-1 **OF**
	JOB NUMBER 667
	PREPARED BY KELM **DATE** 2/91
SUBJECT Phase I	**CHECKED BY** **DATE**

3.0 DESIGN LOADS

3.1 HYDROSTATIC PRESSURES

a) SURVIVAL

DESIGN BUOY FOR 3FT OF HEAD OVER THE TOP DECK. THEN:

@ THE TOP DECK, $P = 3^{FT} \times 64^{PCF} = 190$ PSF

@ THE BOT. DECK, $P = (3^{FT} + 7.5^{FT}) \times 64^{PCF} = 670$ PSF

b) OPERATING

DESIGN BUOY FOR 0^{FT} HEAD @ TOP DECK

THE P RANGES FROM 0^{PSF} TO $7.5^{FT} \times 64^{PCF} = 480$ PSF @ THE BOT. DECK

3.2 MOORING LOADS

THE DESIGN HAWSER LOAD IS 100^{K}.

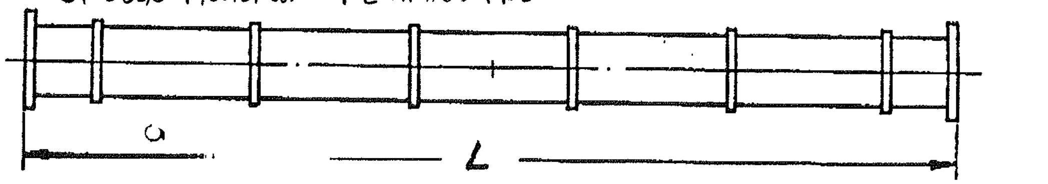
THIS IS ASSUMED TO BE APPLIED @ 15° TO BUOY DECK.

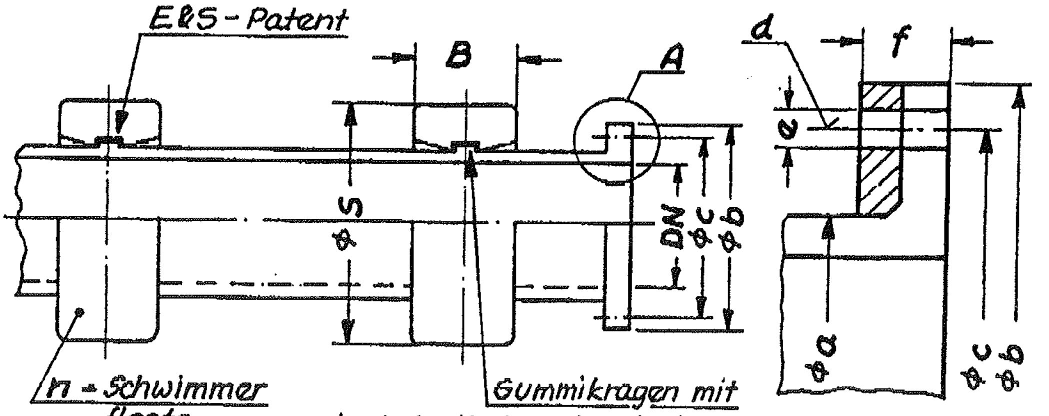
3.3 FLOATING HOSE LOADS

THE MAXIMUM (SURVIVAL) FLOATING HOSE LOAD IS ASSUMED TO EQUAL THE HAWSER LOAD - 100^{K}, APPLIED HORIZ (0° TO THE BUOY DECK).

HOSE DETAILS ARE SHOWN ON THE NEXT SHEET →

DREDGE MOORING - FLOATING HOSE





hochelastischen Aussteifungen   Detail A
rubber belts with high elastic steel supports

	Beschreibung:	Description:	mm	inch/ft.
DN	Innen-Φ des Schlauches	inner dia. of hose		27"
L	Länge ——— " ———	length —— " ——		37' 9"
–	Dicke Innengummi	thickness of inner rubber		1"
a	Außen-Φ des Schlauches	outer dia. of hose right		31 1/8"
	direkt hinter dem Flansch	behind the flange	—	—
b	Außen-Φ des Flansches	minimum o.d. of flange		37 3/8"
c	Lochkreis-Φ —— " ——	dia. of the bolt hole circle		35"
d	Anzahl der Schrb.-Löcher	number of bolt holes		24
e	Φ der Schraubenlöcher	dia. of bolt holes		1 3/8"
f	Gesamtdicke des Flansches	total thickness of flange		2 1/8"
ΦS	Außen-Φ der Schwimmer	outer dia. of floats		5'
B	Länge —— " ——	length —— " ——		27 1/2"
n	Anzahl —— " ——	number —— " ——		6
–	Gewicht Schlauch/Schwimmer	weight hose/floats		~1950k

Bei Anfragen od. Nachbestellungen bitte die untenstehende E&S-Nr. angeben!

In case of inquiry or order don't forget to quote the below mentioned E&S-no.!

E&S

Quotation no. 01664
Item 3

ISO/R 128 Methode E

	Datum	Name
Gezeichnet	190483	
Geprüft		
Normgepr.		

EDDELBÜTTEL & SCHNEIDER KG
P.O. Box 900337 · 2100 Hamburg 90 (Harburg) · West Germany
Telephone (40) 7 60 70 43 · Telex 2 17 772 eus d · Fax (40) 7 68 65 52

Änderungen:

Maßstab: ./.

Schwimmschlauch
Normalkonstruktion
Floating hose
standard design

22-99-5

Ersatz für

Ersetzt durch

		SHEET NO. 3-3	OF
		JOB NUMBER 667	
PROJECT	CORPS OF ENGRS - DREDGE MOORING	PREPARED BY KELM	DATE 2/91
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3.0 DESIGN LOADS (CONT'D)

3.4 CHAIN LOADS

FROM LOADS REPORT, LOADS @ VARIOUS ELEVATIONS ARE AS FOLLOWS: (BASED ON 40FT W.D., 2" CHAIN @ 55° PRETENSION ANGLE)

CONDITION	c/s HEIGHT	CHAIN ANGLE	TENSION	T_{HORIZ}	T_{VERT}	T_{VERT} x 4 LEGS
MEAN	32 FT	55 DEG	2.48 K	1.42 K	2.03 K	8.12 K
TROUGH	25.8	63.5	1.52	0.68	1.36	5.44
CREST	44.4	42.1	5.62	4.17	3.77	15.08

NOTE: MAY BE NECESSARY TO DECREASE PRETENSION ANGLE FROM 55° TO 50° OR LESS TO INCREASE THE RESISTANCE TO ROTATIONAL TORQUE (SEE SECT 7)

∴ FOR 50° ANGLE, HAVE THE FOLLOWING LOADS:

MEAN	32 FT	50 DEG	3.03 K	1.94 K	2.32 K	9.28 K

THEN FOR A MAXIMUM HAWSER LOAD = 100 K,

MEAN	32 FT	8.4 DEG	101. K	100. K	14.8 K	59.2 K

		SHEET NO. 3-4	OF
		JOB NUMBER 667	
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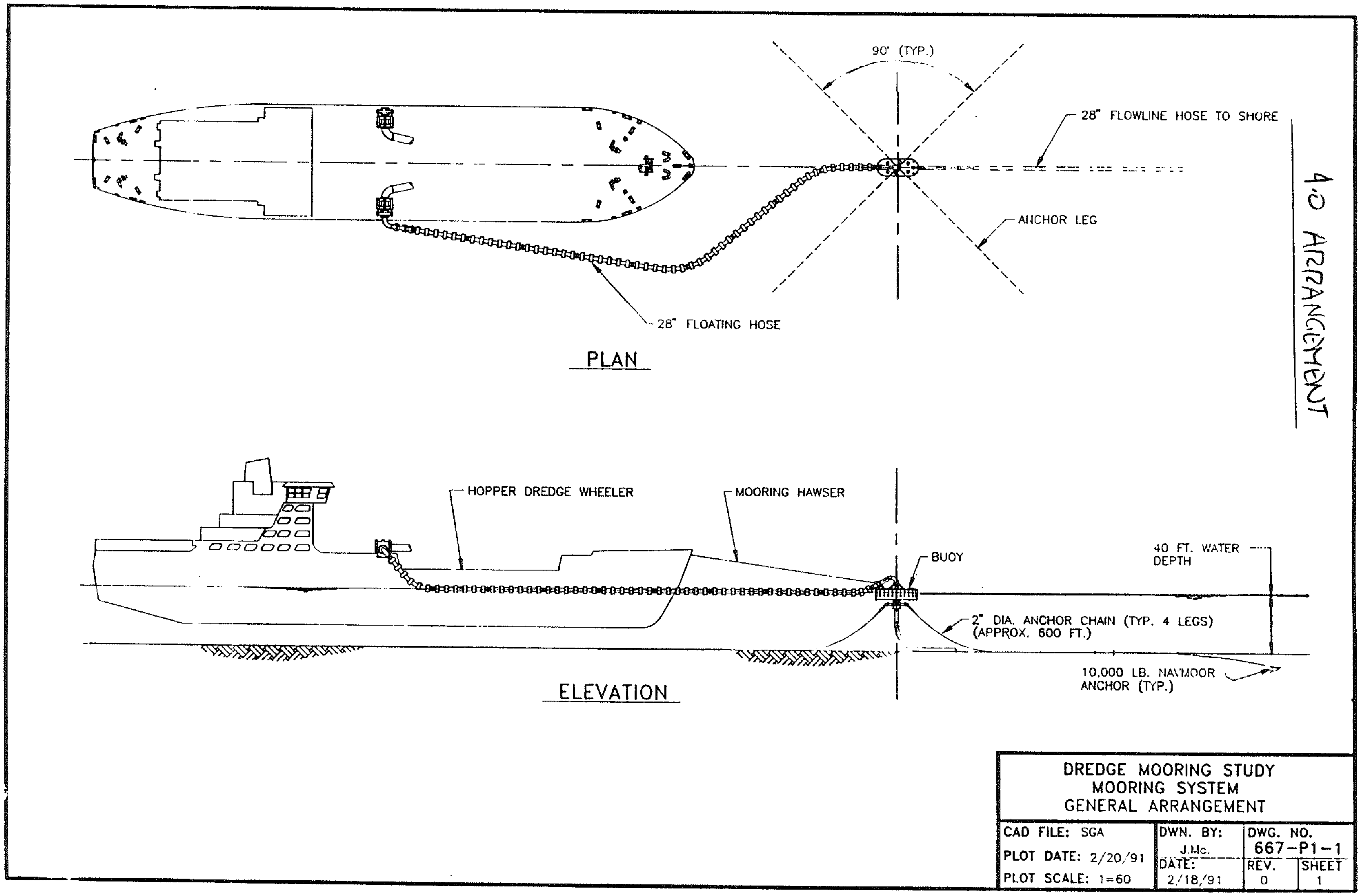
3.0 DESIGN LOADS (CONT'D)

3.5 UNDERBUOY HOSE LOADS

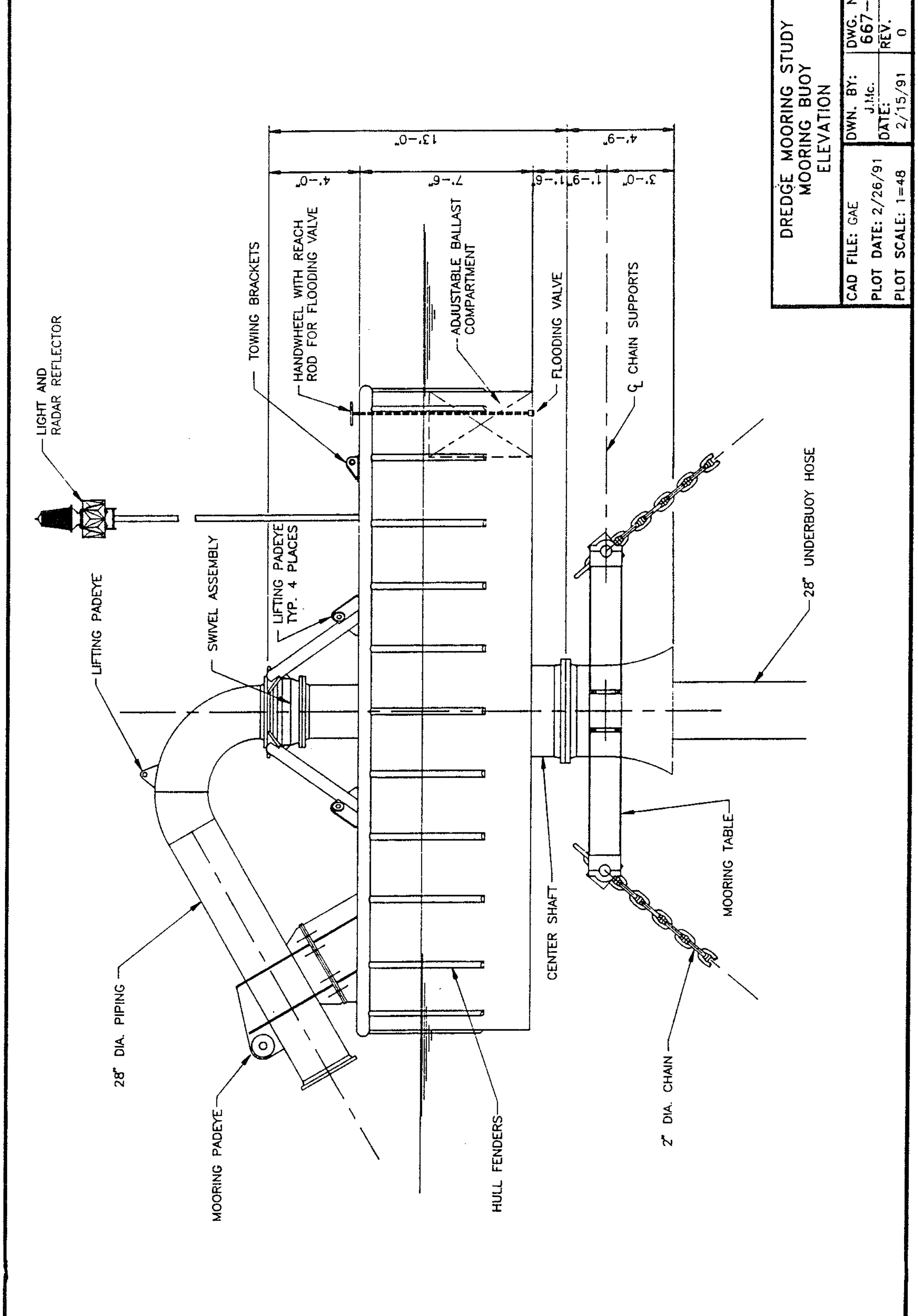
NO VENDOR DATA IS AVAILABLE. USE THE FOLLOWING WEIGHTS TAKEN FROM A BRIDGESTONE CATALOGUE:

WEIGHT IN AIR FULL OF PRODUCT (@ 80PCF) = 220 #/FT ↓

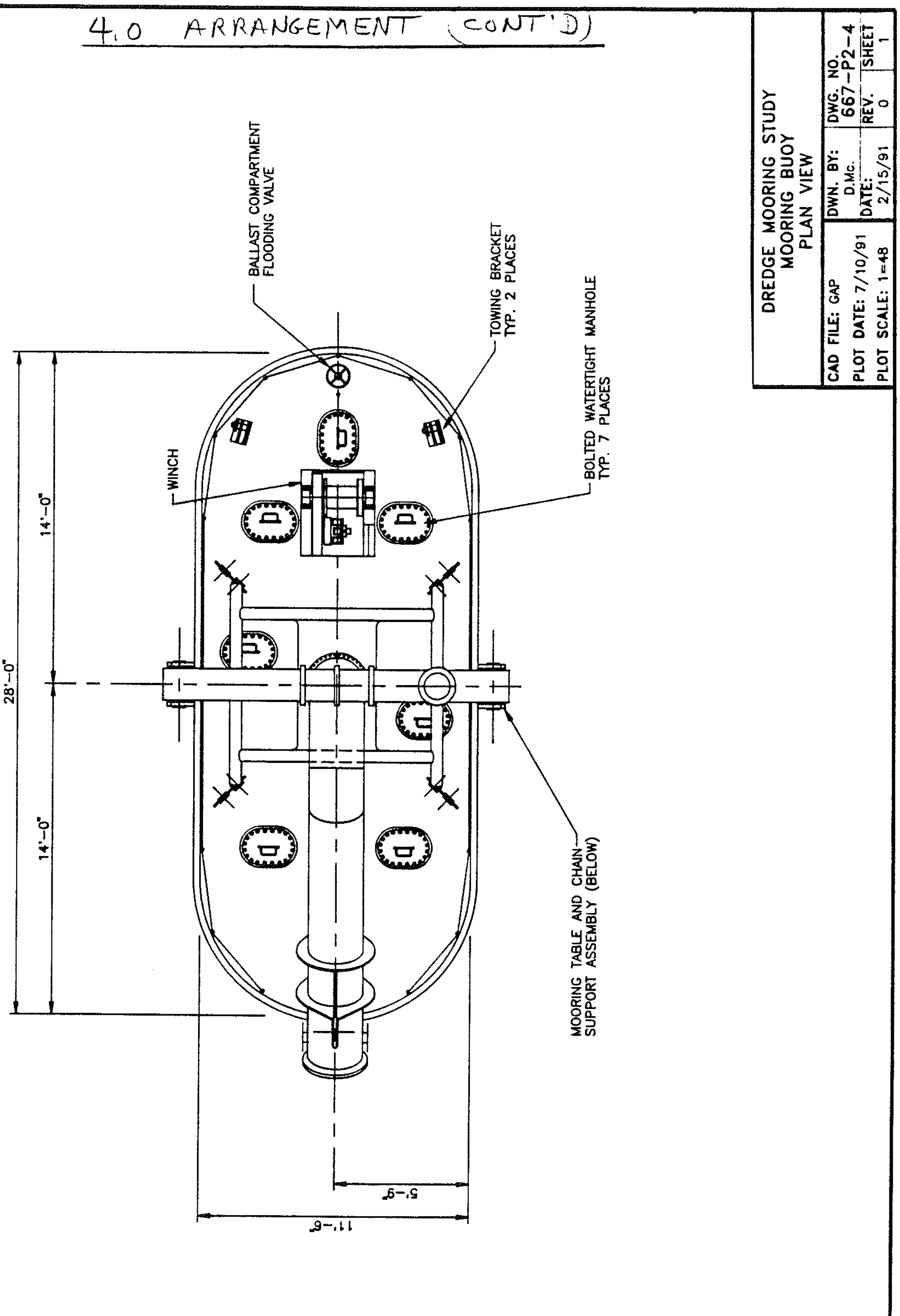
NET WEIGHT IN WATER — " ———— = 90 #/FT ↓


4.0 ARRANGEMENT
90° (TYP.)
28" FLOWLINE HOSE TO SHORE
ANCHOR LEG
28" FLOATING HOSE
PLAN
HOPPER DREDGE WHEELER
MOORING HAWSER
BUOY
40 FT. WATER DEPTH
2" DIA. ANCHOR CHAIN (TYP. 4 LEGS) (APPROX. 600 FT.)
10,000 LB. NAVMOOR ANCHOR (TYP.)
ELEVATION
DREDGE MOORING STUDY
MOORING SYSTEM
GENERAL ARRANGEMENT
CAD FILE: SGA
PLOT DATE: 2/20/91
PLOT SCALE: 1=60
DWN. BY: J.Mc.
DATE: 2/18/91
DWG. NO. 667-P1-1
REV. 0
SHEET 1

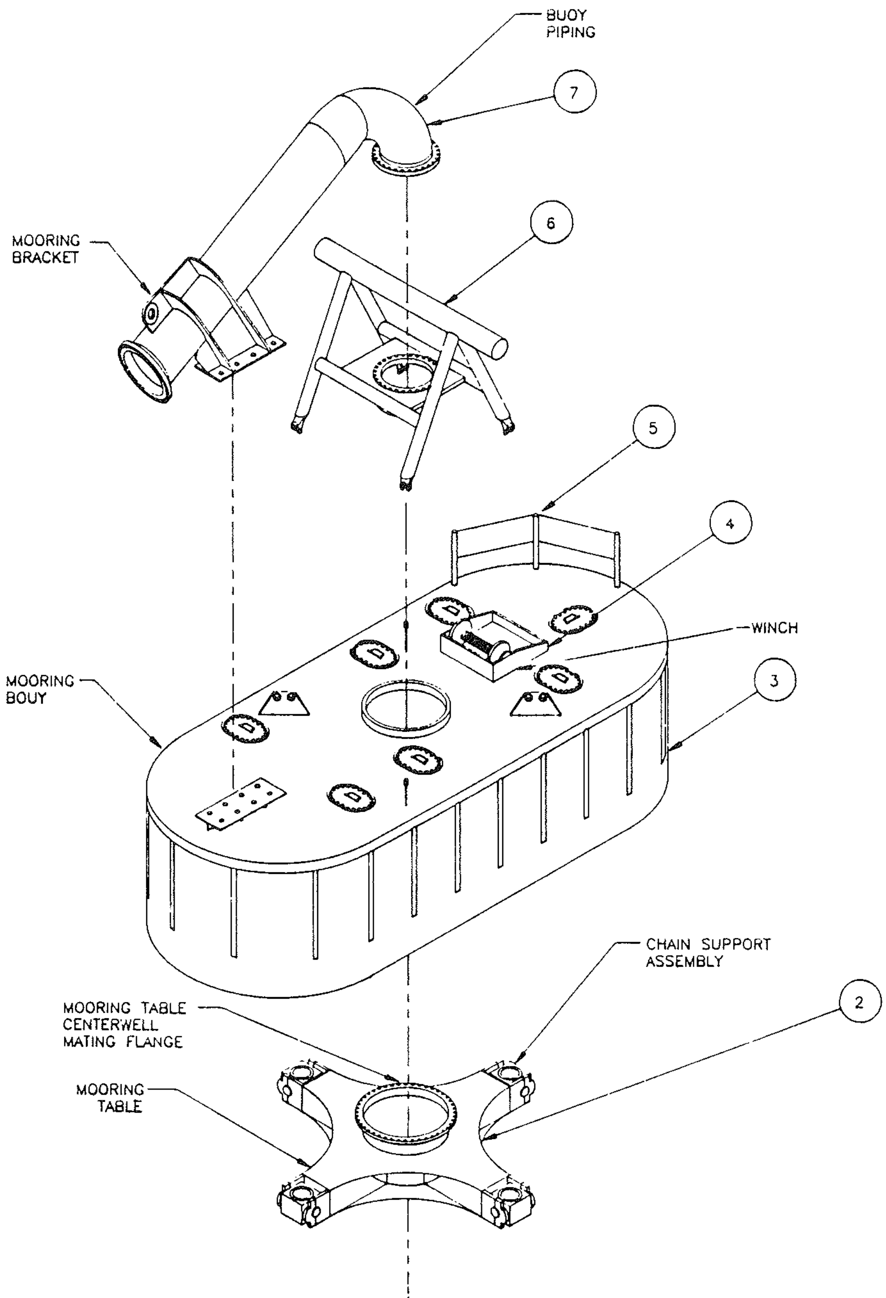
4.0 ARRANGEMENT (CONT'D)



4.0 ARRANGEMENT (CONT'D)



4.0 ARRANGEMENT (CONT'D)



DREDGE MOORING STUDY
CALM MOORING BUOY
EXPLODED ISOMETRIC VIEW

CAD FILE: EXPV	DWN. BY: D.Mc.	DWG. NO. 667-P2-9	
PLOT DATE: 7/15/91	DATE: 7/20/91	REV. 0	SHEET 1
PLOT SCALE: 1:96			

SHEET NO. 4-5 OF ____

JOB NUMBER 667

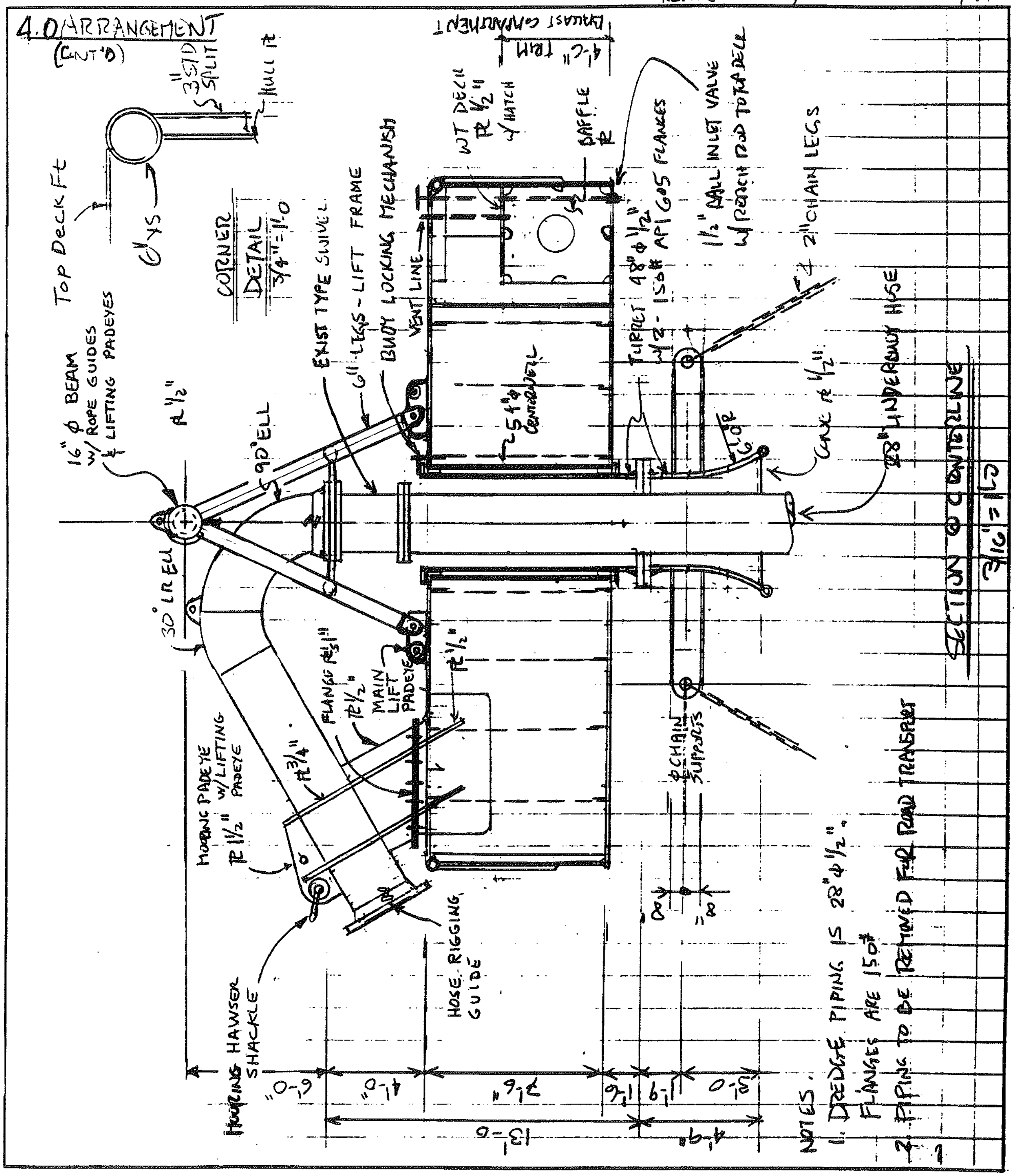
PROJECT Corps of Engrs - Dredge Mooring

PREPARED BY KELM DATE 2/91

SUBJECT Phase I

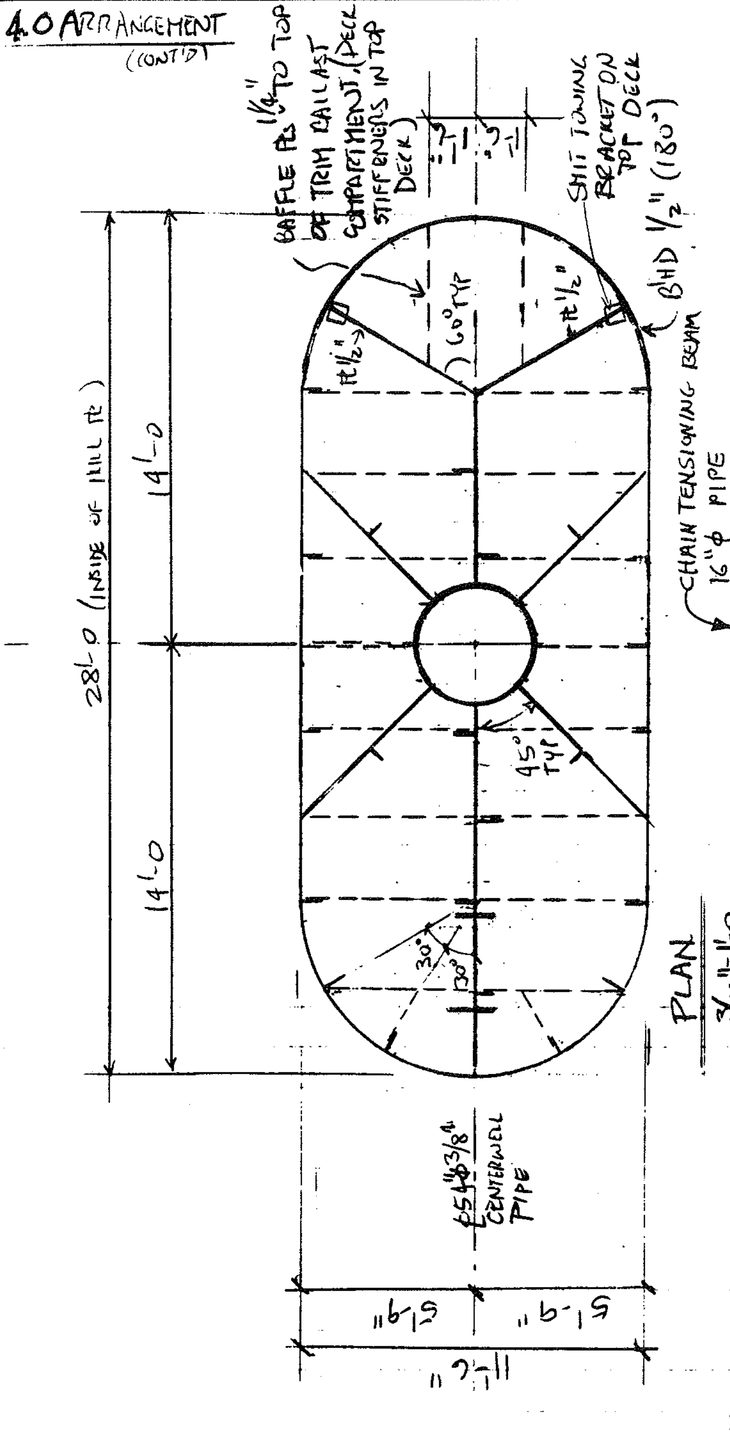
CHECKED BY ____ DATE ____

REVISED JAB 5/91

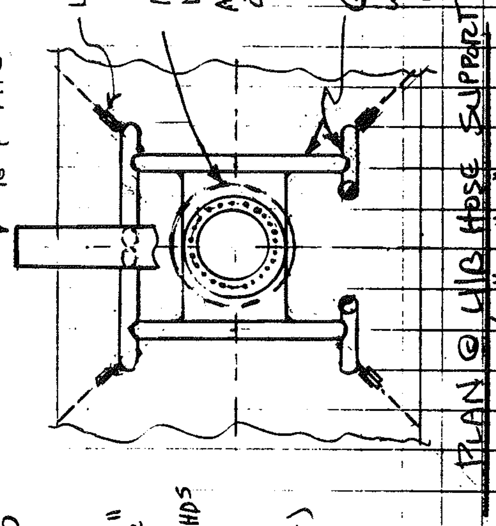


SHEET NO. 4-6 OF ____
JOB NUMBER 667
PROJECT Corp of Engrs Dredge Mooring
SUBJECT Phase I
PREPARED BY KELM DATE 2/91
CHECKED BY ____ DATE ____
REVISED JAB 5/91

4.0 ARRANGEMENT (CONT'D)



PLAN
3/16" = 1'-0



PLAN @ U/B HOSE SUPPORT
3/16" = 1'-0"

NOTES
1. UND. DECKS & EXT. B'HDS ARE 3/8" PL & INT. B'HDS ARE 5/16"
2. DECK STIFFENERS ARE 3/8" x 4" 4 1/2" @ TOP DECK & 7/8" x 7" 6" @ BOT. DECKS & B'HDS
3. TOP DECK HAS ALUMINUM HATCH TO EA COMPARTMENT AND INTERMEDIATE DECK (ABOVE TRIM BALLAST COMPARTMENT) HAS 1 HATCH (8 TOTAL)

SHEET NO. 4-7 OF ____
JOB NUMBER 667
PROJECT CORPS OF ENGINEERS - DREDGE MOORING
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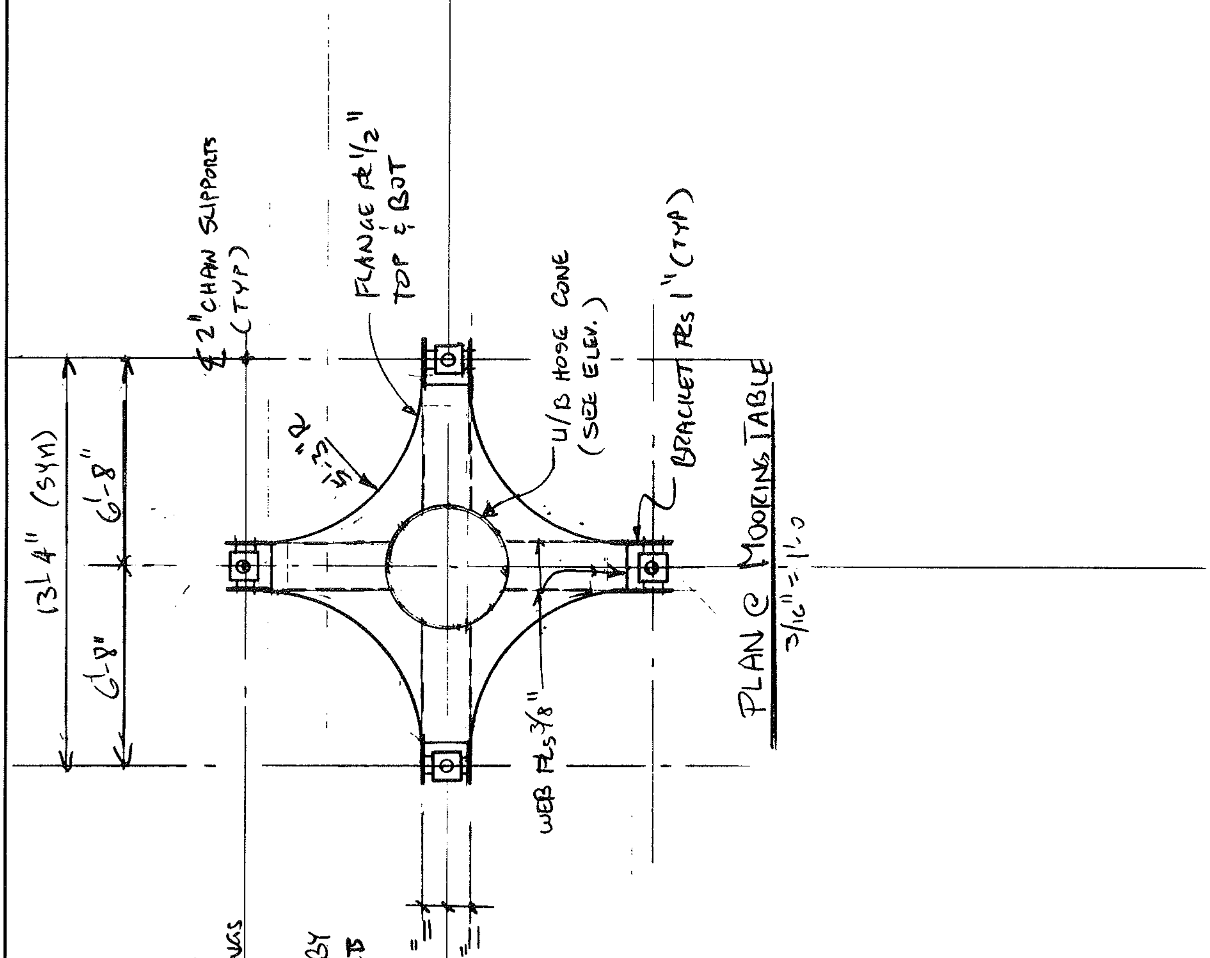
CHECKED BY ____ DATE ____

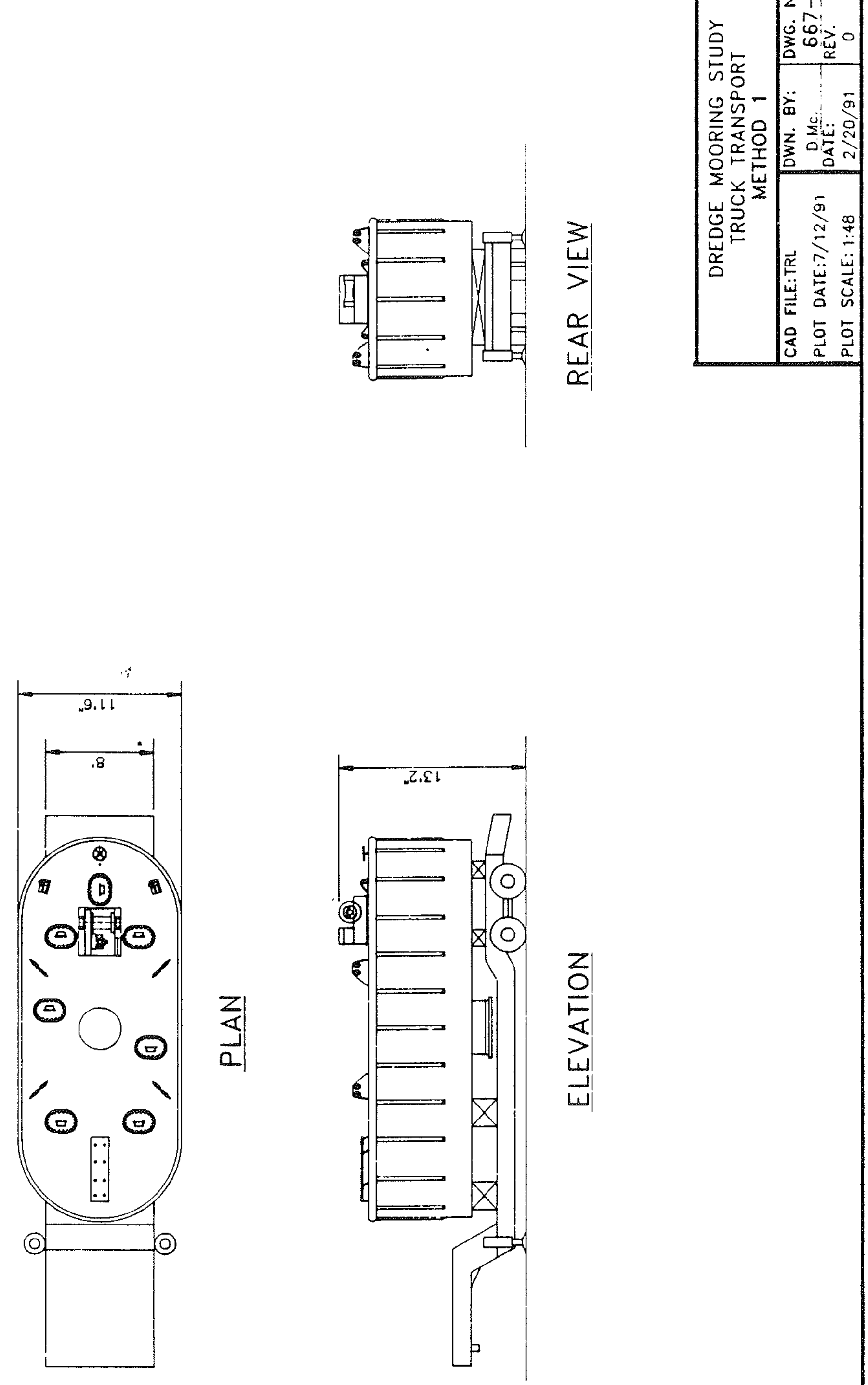
4.0 ARRANGEMENT (CONT'D)



NOTES

1. CHAIN STOPPERS ROTATE WITH SELF-LUBRICATED BRONZE BUSHINGS ON STAINLESS STEEL.
2. CHAINTABLE TO BE LIFTED BY TWO OR FOUR CHAIN SUPPORTS

4.0 ARRANGEMENT (CONT'D)



equipment:

standard

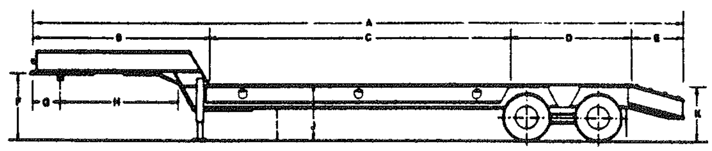
- **axle** — 5" diameter, tandem
  - **brakes** — 12¼" x 7½" air
  - **hub seals** — oil
  - **suspension** — underslung leaf spring
  - **wheels** — three spoke, cast steel, dual mount
  - **rims** — 6.75 x 17.5, one piece
  - **tires** — LB-25T: 9R 17.5, 16pr steel radial
    — LB-35T: 10R 17.5, 14pr steel radial
- **frame** — fabricated
  - **flanges** — high strength, low alloy
- **hitch** — SAE 2" king pin, 18" setting
- **floor** — 2" select oak
- **dovetail** — 36"
- **fittings**
  - **lash rings**
  - **mud flaps** — anti-sail
- **landing gear** — park stands, pin type
- **electrical** — ICC, 12-volt, 7-way plug
  - **wiring** — conduit, color-coded
- **finish** — sandblast, prime coat, two coats acrylic enamel

USE THIS TRAILER

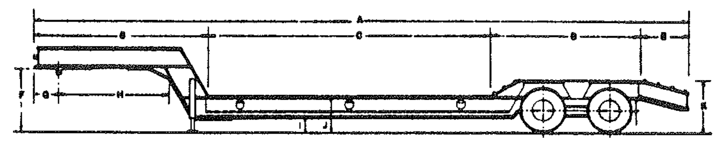
options

- **suspension** — single point
  — air ride
  — walking beam
  — booster axle
- **deck** — drop
  — drop side rail
  — beam type
- **hitch** — king pin: two position
  three position
  — inverted 5th wheel
  — detachable gooseneck
- **floor** — 2¼" Apitong hardwood
  - **full width gooseneck**
- **ramps** — load, mechanical and hydraulic:
  all steel
  wood top
  — motor grader
  - **dovetail** — eliminate
- **front end** — half pipe with cable sling
  - **rear end** — oilfield bumper
    — 7" tail roller
    — 9 5/8" tail roller
- **fittings**
  - **brackets** — swing out
  - **lash rings** — additional
  - **tool box**
  - **wheel well covers** — steel
- **landing gear** — twin, two-speed gear box, 12" sand pads
- **size** — length: additional
  — width: additional

specifications:



Level Deck	A	B	C	D	E	F	G	H	I	J	K
LB-25T	38'4"	10'2"	18'0"	7'2"	3'0"	49"	18"	78"	18"	36"	36"
LB-35T	38'8"	10'6"	18'0"	7'2"	3'0"	49"	18"	82"	18"	38"	38"



Drop Deck	A	B	C	D	E	F	G	H	I	J	K
LBD-25T	41'0"	10'8"	18'0"	9'4"	3'0"	49"	18"	78"	10"	26"	36"
LBD-35T	41'6"	11'2"	18'0"	9'4"	3'0"	49"	18"	82"	12"	28"	38"

model:	LB-25T	LB-35T
size:	8' x 18'	8' x 18'
capacity:	25 tons	35 tons
weight:	11,000# approximately	13,000# approximately
overall length:	38'3"	39'
swing clearance:	78"	82"

Legal capacity is governed by the DOT's GAWR. Some areas require ratings other than those shown. Consult your dealer for local requirements including axle and tire loadings.

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SUMMARY OF ANCHOR SIZING

ON THE FOLLOWING SHEETS A PRELIMINARY ANCHOR SIZING FOR THE DREDGE MOORING (4 LEGGED CALM) IS MADE.

THE REQUIRED ANCHOR AT EACH LEG IS A 10 KIP NAVMOOR.

THESE ANCHORS WILL NEED TO BE TRANSPORTED ON A 10 FT WIDE TRAILER WITH THE SHANKS REMOVED FROM THE FLUKES.

NOTE, IF ALLOWED TO BUY A BRITISH FABRICATED ANCHOR. A BRUCE FFTS 6 KIP ANCHOR. HOWEVER THIS COULD REQUIRE A 12 FT WIDE TRAILER TO TRANSPORT IN TWO PIECES.

PROJECT Corps of Engrs - Dredge Mooring		SHEET NO. 5-2	OF
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DESIGN ANCHORS FOR A HORIZ LOAD AT THE MUDLINE = HAWSER LOAD (CONSERVATIVE)

THEN SWL = 100^K,

NEED UHC = $100^K \times 2.0^{SF}$ = $\underline{200^K}$

ANCHORS MUST BE TRANSPORTABLE BY ROAD W/ $W_{MAX} = 50^K$ AND NO DIMENSION > 10^{FT}. ALSO, USE LOCALLY MADE ANCHOR. ALTHOUGH U.S. NAVY STOCKLESS IS MORE COMPACT, ITS EFFICIENCY IN SOFT SOILS IS VERY LOW AND SOFT SOILS WILL PROBABLY BE THE MORE COMMON OCCURENCE WHERE THIS SYSTEM IS INSTALLED.

∴ USE NAVMOOR ANCHORS:

FROM NCEL "HANDBOOK FOR MARINE GEOTECHNICAL ENGINEERING" (MAR 85), TABLE 7.5-1 (P.7-14),

$$\text{REQ'D ANCHOR WEIGHT} = W_A = 10^{\left[\frac{1}{b}\log_{10}\left(\frac{H_M}{H_R}\right)+1\right]} \quad [\text{KIPS}]$$

WHERE: H_M = UHC = 200^K

AND: b & H_R VARY W/ ANCHOR & SOIL →

PROJECT	CORPS OF ENGRS - DREDGE MOORING	SHEET NO.	5-3 OF
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FOR STATO/NAVMOOR ANCHORS

#	SOIL TYPE	H_R	b	W_A	$EFF = \frac{200^k}{W_A}$
1	CLAYS + SILTS (SOFT)	215^k	0.92	9.2^k	22
2	SANDS (HARD)	250	0.80	7.6^k	26

∴ REQUIRE AT LEAST A 9200LB NAVMOOR.

FROM MAY87 NCEL TECHDATA SHEET "THE NAVMOOR ANCHOR" (#87-05)
DESIGN DRAWINGS ARE AVAILABLE FOR 10000# NAVMOORS

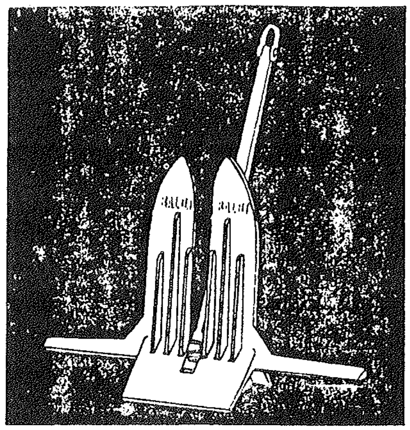
∴ USE 10^{KIP} NAVMOORS (4 TOTAL)

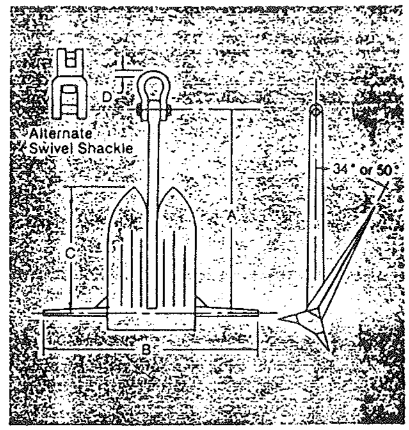
CHECK TO SEE IF TRANSPORTABLE:

NO CURRENT DRAWINGS ARE AVAILABLE, HOWEVER USE STATO DRAWINGS FROM A BALDT CATALOGUE: →

PROJECT	Corps of Engrs - Dredge Mooring	SHEET NO.	5-4	OF	
		JOB NUMBER	667		
		PREPARED BY	KELM	DATE	1/91
SUBJECT	PHASE I	CHECKED BY		DATE	

Stato® Mooring Anchor





INTERPOLATE BETWEEN A 9k & 12k ANCHOR

THEN FOR A 10k ANCHOR,

$A = 169'' > 120''$

$B = 179'' > 120''$

$C = 104''$

→

Anchor Weight	A	B	C	D
200	42	59	26	¾
3000	129	109	72	1¾
6000	144	143	92	2¼
9000	160	170	100	2¾
12000	186	197	113	3
15000	204	224	126	3¼
20000	210	230	129	3½
25000	226	246	137	4
30000	235	257	145	5
35000	248	271	153	5¼
40000	258	283	160	5½
45000	269	295	166	5¾
50000	277	303	171	6
60000	297	320	180	6
70000	310	336	191	6½
80000	322	350	200	6½
90000	345	366	206	7
100000	350	380	216	7½

All specifications in pounds and inches.
Intermediate sizes available upon request.

∴ A 10k NAVMOOR IS TRANSPORTABLE ON A 10FT WIDE TRAILER ONLY IF THE SHANK IS REMOVED.

NOTE THAT ADDITIONAL DESIGN INFORMATION IS GIVEN ON THE FOLLOWING TELECON & LETTER →

MEMORANDUM

Date : 30 January 1991

To : Wayne Herbrich

CC : COE

From : Ron Kelm

Reference : Corp. of Engineers Dredge Mooring - SOFEC # 667

Subject : Telecon RLK to Bob Taylor (NCEL) 805-982-5419

Called Bob to discuss anchors in general and for the referenced project:

1. He recommended Bruce's FFTS for this project. He would not advise using Vryhof's because theirs must be set on the bottom and cannot be dropped as can Bruce's and the Navmoor (Won't upright).

2. Said he tested 1, 6, and 10 kip anchors in very dense gravelly sand (phi = say 40 deg). Navmoor is the only one that buried. It had 30W whereas Bruce and Vryhof had 18W, although Vryhof claimed 50W.

3. Since our criteria includes soft soils, would be better to go with Bruce if okay to buy overseas. For either anchor, not knowing the soil conditions, would need to set the fluke angle for sand (32 deg) and reduce the mud capacity to 50 or 60 percent of the tabulated values. This gives Bruce the edge.

4. He said Bruce's advertized weights are what they ship. Vryhof will add considerable ballast sometimes to make their anchors perform to their curves. Some Navmoor suppliers provide a cast anchor rather than welded plate in which case the 10 kip anchor will weigh about 12 kips.

5. Either the Bruce or the Navmoor will disassemble easily for road transport: the Bruce at the shank, the Navmoor at the two stabilizers.

6. If we chose tandem (piggy-back) anchors, we can conservatively use the individual capacities although we would in actuality gain 50 percent (total = 3 x one anchor) by connecting the back anchor through the shank of the forward anchor. He also said they can be set simultaneously.

7. For more information on Navmoor anchors (perhaps drawings) we should call Ted Jones, of the Chesapeake Division of Navfac FP01 (in the Washington Navy Yard), his # is 202-433-3881.

8. A good contact on where to have the anchors built is Kevin Baker, VSE Corporation, 2760 Eisenhower Ave., Alexandria, VA, 703-329-2711. His company has had hundreds built for the Navy. They had their 10 kip anchors built by Customer Metals, and their 15 kip anchors were built by Skagit (The Winch Co.).

9. He had fairly recent prices for these two sizes: $1.70/lb. based on a 20% increase in advertised weight since a casting. (A 10 kip Navmoor costs $1.70x12000 = $20,400.). He also added that if we went to either of the above two fabricators we would not need to buy the drawings since they have them along with the molds.

Ron

BRUCE INTERNATIONAL LIMITED

ELM TREE HOUSE, ELM TREE ROAD, ONCHAN, ISLE OF MAN, BRITISH ISLES.
TEL: 0624-629203
FAX: 0624-622227
TELEX: 629062 BRUCEM G

TO	: SOFEC INC	YOUR REF:	TELECON (GC) 22/2/91
ATTN	: RON KELM	OUR REF:	GC/NO/91/8/7 1BI-19-17
FAX.NO	: 0101 713 462 8015	DATE:	22nd February, 1991

TOTAL NUMBER OF PAGES (INCLUDING THIS TOP PAGE) 4

* PLEASE NOTIFY THE FAX OPERATOR IMMEDIATELY IF ANY PAGES ARE INCOMPLETE OR ILLEGIBLE. *

SUBJECT: BUOY MOORING FOR ARMY CORPS OF ENGINEERS

Further to our telephone conversation of today, please be advised that the Mark 4 version of our (FFTS) anchor, which has 28.6 per cent more fluke area than the (FFTS) anchor tested by NCEL. By substituting $W \times 1.286^{3/2}$ for W into Table 2's equation for anchor system holding capacity, the following ultimate holding capacity equations for sand and mud are derived directly.

BRUCE (FFTS) MK4 $\quad H.C._{SAND} = 428 \left[\frac{W}{10} \right]^{0.94}$ Kips

BRUCE (FFTS) MK4 $\quad H.C._{MUD} = 354 \left[\frac{W}{10} \right]^{0.92}$ Kips

Where W = Weight of Anchor in Air in Kips (1 Kip = 1000 lbs)

Trials off Lousianna in September, 1990, of a 7 tonne Bruce (FFTS) Mk4 anchor witnessed by ABS yielded an ultimate holding capacity of 658 kips in very soft mud of shear strength gradient 10psf/ft. The anchor line used was 3-inch wire instead of 3-inch chain. The ultimate holding capacity equation using wire in mud is thus:

BRUCE (FFTS) MK4 $\quad HC_{MUD\ (wire)} = 439 \left[\frac{W}{10} \right]^{0.92}$ Kips

The 3-inch wire instead of 3 inch chain increased holding power by 24 per cent.

RECEIVED
FEB 22 1991

Therefore for a UHC of 200 kips, we calculate from the above equations that a 2500kg Bruce (FFTS) MK4 Anchor will be sufficient using 2 inch chain grade U3 in various seabed conditions.

Budget price for 4 off 2500kg Bruce (FFTS) Mk4 anchors @ PDS STG 7,325 each ex works UK including ABS survey and ABS Certificate of Witness of Proof Loading is PDS STG 29,300. ~$2,65/£ @ 1 £S = 2 US$

Please find faxed sales and freight drawings for the 2500kg Bruce (FFTS) Mk4 Anchors for your information, as requested.

If you require any further information, please do not hesitate to contact us.

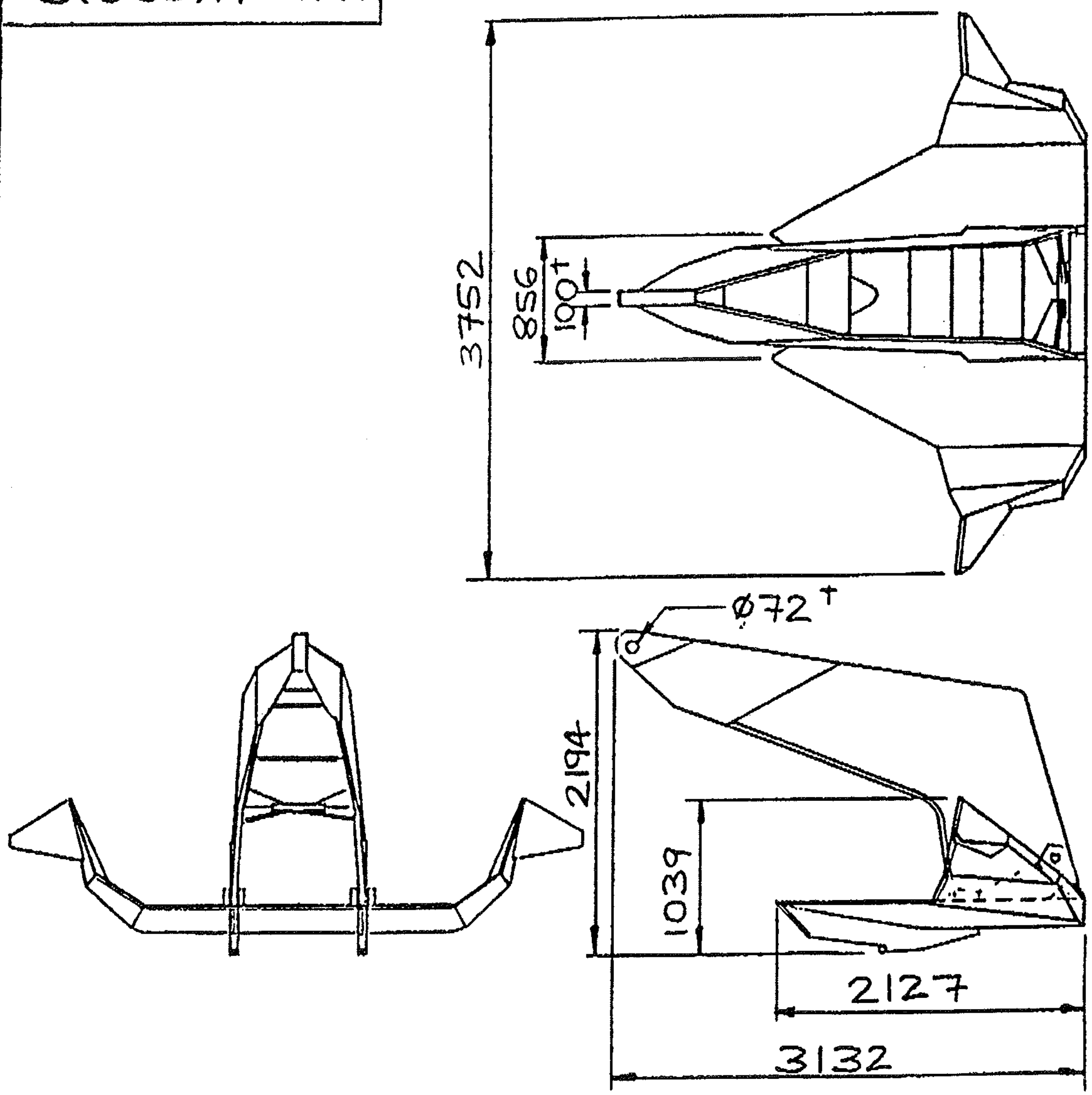
Regards,

Gavin Cleator

Gavin Cleator,
Sales Admin.

DRAWING No. B(066)1754A4

DO NOT SCALE DRAWING



DIMENSIONS IN MILLIMETRES

MATERIAL SEE PRODUCTION DRAWINGS	* TO BE ADVISED † OR BY ARRANGEMENT	INFORMATION ON THIS DRAWING IS THE PROPERTY OF BRUCE INTERNATIONAL LTD. AND IS SUPPLIED IN CONFIDENCE	0	-	5/7/90
SCALE NOT TO SCALE			ISSUE	MRS	DATE
USED ON B(066) * A0					

DRAWN	P.FOXTON	10/11/89	TITLE ANCHOR - MK4 FFTS 2500 kg	DRAWING No. B(066)1754 A4
SCALED	Peter Foxton	5/7/90		
CHECKED				BRUCE INTERNATIONAL LTD.

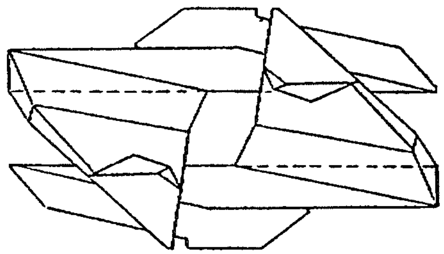
FREIGHT DIAGRAM

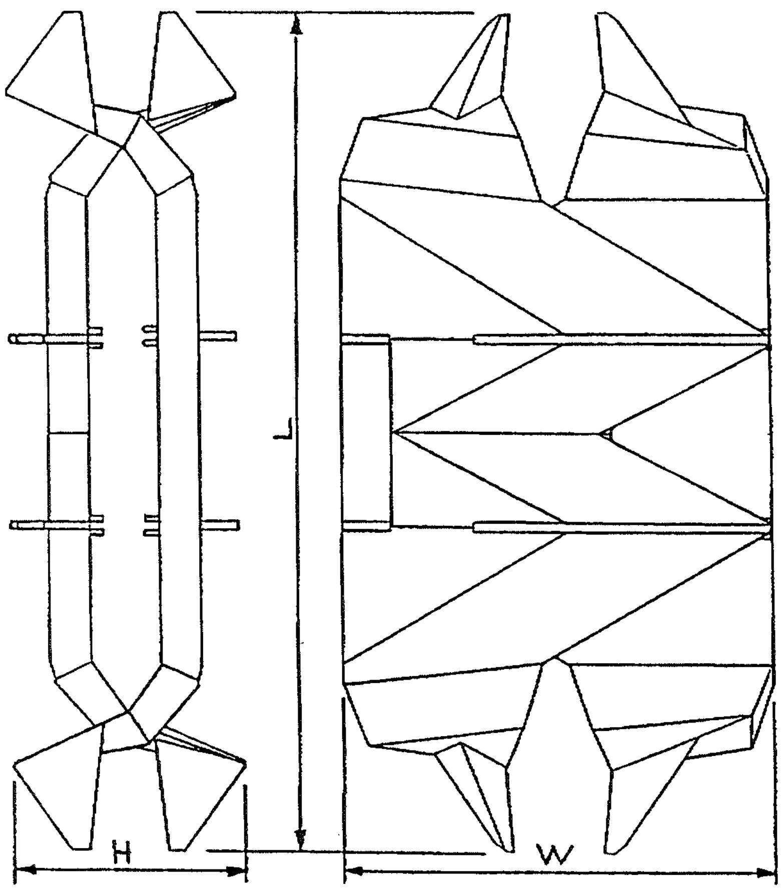
2500_ KG

MK4 FFTS.

FLUKES NESTED IN PAIRS.

L = 3752 mm.
H = 1039 mm.
W = 2127 mm.
CUBE = 8·3 m^3
WEIGHT = 2875 KG.





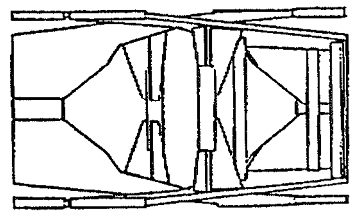
FREIGHT DIAGRAM

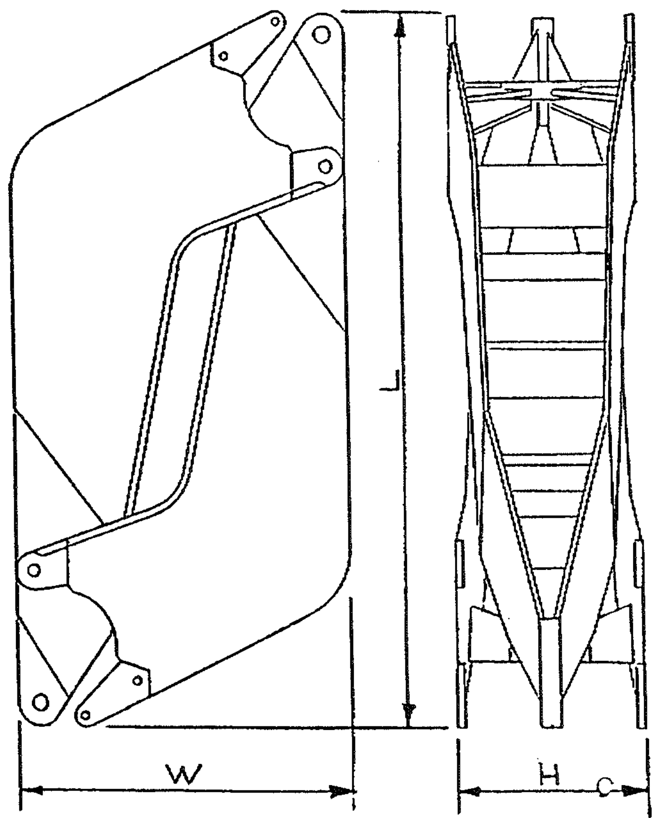
2500_KG

MK4 FFTS.

SHANKS NESTED IN PAIRS.

L = 3310 mm.
H = 894 mm.
W = 1596 mm.
CUBE = 4·7 m^3
WEIGHT = 2125 KG.





PROJECT COE - ARMY DREDGE	SHEET NO. 5-11 OF
SUBJECT ANCHORS	JOB NUMBER 667
	PREPARED BY JAB DATE 5-91
	CHECKED BY DATE

ESTIMATE DRAG & PENETRATION OF 2.5KG BRUCE FFTS ANCHOR:

2.5 KG FFTS	SOFT CLAY	MED CLAY	SAND
HOLDING CAPACITY	176 K	275 K	300 K
PENETRATION	31'	20'	9'
DRAG	150'	102'	59'
MOD. HOLD CAP.	@ 176 K	@ 200 K (72%)	@ 200 K (66%)
PENETRATION	31'	16'	7'
DRAG	150'	60'	33'

(MED CLAY and SAND:) ASSUMED LIMIT OF USEFUL ANCHOR MAT'L

SHEET NO. 6-1 OF ____
JOB NUMBER 667
PROJECT CORPS OF ENGINEERS - DREDGE MOORING PREPARED BY KGLM DATE 2/91
SUBJECT PHASE I CHECKED BY ____ DATE ____

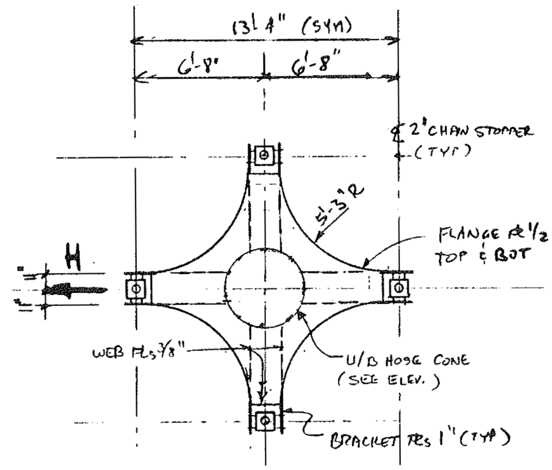
6.0 MOORING TABLE

PURPOSE OF MOORING TABLE IS TO TRANSMIT HAWSER LOAD FROM BUOY TO CHAINS.

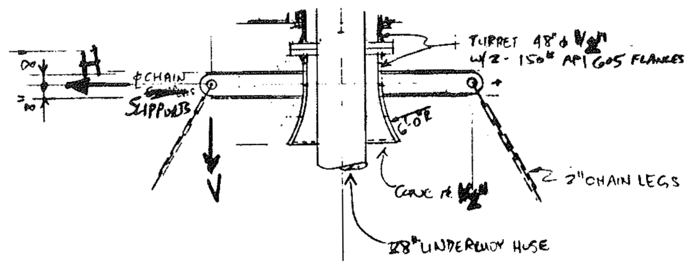
FROM SECT 3.4, MAXIMUM DESIGN LOADS ARE:

$H = 100^k$

$V = 14.8^k$



PLAN



ELEVATION

a) CHECK BEAM-TYPE STRESSES

SHEAR

$A_v = 2 \text{ PLs} \times \frac{3}{8}'' \times 16'' = 12 \text{ IN}^2$

$f_v = V/A_v = 14.8^k / 12 \text{ IN}^2 = 1.2^{KSI} = 0.035 F_Y < 0.4 F_Y$ ✓ ok. (← FOR ABS GRB)

SHEET NO. 6-2 OF ____
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6.0 MOORING TABLE (CONT'D)

AXIAL + BENDING

BY INSPECTION, CRITICAL SECTION IS 2^{FT} FROM CHAIN SUPPORT PIVOT.

$M = 2^{FT} \times V = 2 \times 14.8 = 29.6^{K\text{-}FT}$

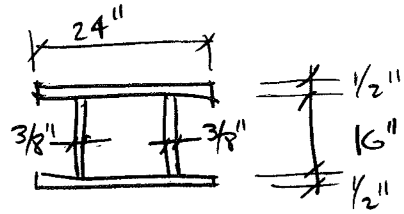
$P = H = 100^K$

SECTION PROPERTIES:

$S = 222.\ IN^3$

$I = 1890\ IN^4$

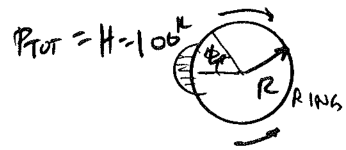
$A = 36.0\ IN^2$



$\sigma = \frac{P}{A} + \frac{M}{S} = \frac{100^K}{36.0\ IN^2} + \frac{29.6^{K\text{-}FT} \times 12}{222.\ IN^3} = 4.4^{KSI} = 0.13 F_Y < 0.6 F_Y$ ✓ ok.

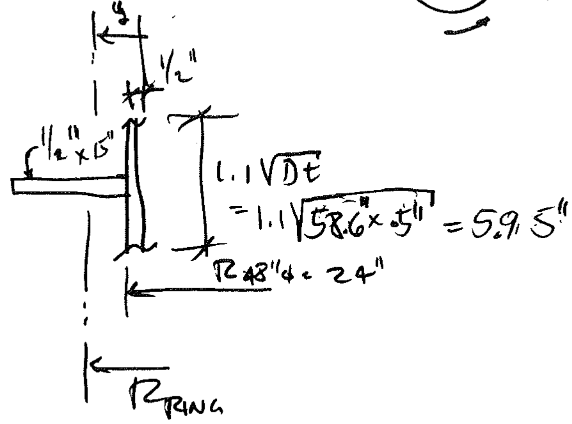
6.0 Mooring Table (cont'd)

b) Check Ring-Type Stresses



Conservative Ring-Type Loading:
(Case 20 – cos 2φ)

Section Properties @ $\phi = \pi/4$



$S = 27.7\ \text{in}^3$

$I = 269\ \text{in}^4$

$\bar{y} = 5.8\ \text{in}$

$R_{RING} = 29.3\ \text{in}$

$A = 10.5\ \text{in}^2$

$M = K_M\ 1.06\ P_{TOTAL}\ R = K_M \times 1.06 \times 100^k \times 29.3^{in} = 3100\ K_M$

$N = K_N\ 1.06\ P_{TOTAL} = K_N \times 1.06 \times 100^k = 106\ K_N$

Check @ $\phi = \pi/4$ & $3\pi/8$

ϕ	K_M	K_N	M	N	$\sigma = \frac{M}{27.7} + \frac{N}{10.5}$
$\pi/4$	0.025	0.40	77.5 k-in	42 k	6.8 ksi
$3\pi/8$	0.078	0.35	242.	37	12.3 ksi

∴ Max Stress = 12.3 ksi = 0.36 Fy < 0.6 Fy ✓ ok.

∴ Mooring Table is okay

SHEET NO. 7-1	**OF**
JOB NUMBER 667	
PREPARED BY KEM	**DATE** FEB 91
CHECKED BY	**DATE**

PROJECT CORPS OF ENGRS - DREDGE MOORING

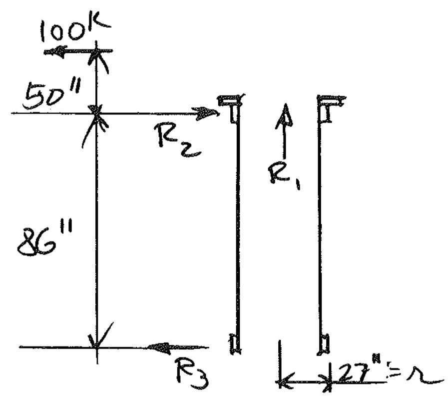
SUBJECT PHASE I

7.0 BEARINGS

a) COMPUTE TORQUE ON BRONZE BEARINGS

USE $\mu = 0.15$ & USE 100^K HORIZ HAWSER LOAD

DRAW FREEBODY:



COMPUTE REACTIONS

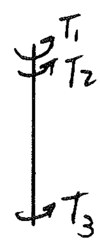
$R_1 = \cancel{25}\ 35^k$

$R_2 = 100^k \times \frac{136"}{86"} = \underline{158^k}$

$R_3 = 158^k - 100^k = \underline{58^k}$

$\downarrow w = 15^k + (1^k + 2^k + 2^k + 15^k) = 35^k$

DEAD WEIGHT TURRET; CHAIN VERT PULLS



COMPUTE TORQUES:

$T = \mu R r$

$T_1 = .15 \times 35^k \times 27" = 142$ k-IN

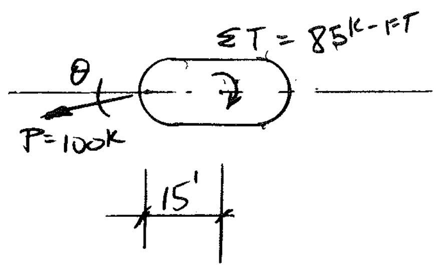
$T_2 = .15 \times 158^k \times 27" = 640$ k-IN

$T_3 = .15 \times 58^k \times 27" = 235$ k-IN

TOTAL TORQUE $= 1017$ k-IN $= \underline{85}$ k-FT

7.0 BEARINGS (CONT'D)

b) COMPUTE HAWSER ANGLE NEEDED TO OVERCOME BEARING TORQUES:



REQ'D HORIZ COMPONENT $= \frac{85^{k\text{-}1}}{15'} = 5.7^k$

REQ'D HAWSER ANGLE $= \theta = \sin^{-1}\left(\frac{5.7^k}{100^k}\right) = \underline{3.3°}$

c) CHECK MAX BEARING STRESS.

ASSUME TOP BEARING IS 54"φ × 3" WIDE

SAY SIMULTANEOUS HOSE LOAD IS EQUAL ($\frac{1}{2}$ IN THE SAME DIRECTION) TO THE HAWSER LOAD. ($P = 100^k + 100^k = 200^k$)

THEN $R_{TOP\ BEARING} = 2 \times R_2 = 2 \times 158^k = \underline{316^k}$

BEARING PRESSURE $= \frac{316^k}{3" \times 54"} = \underline{2.0^{ksi}} < 3.0^{ksi}$ ✓ ok.

PROJECT: CORPS OF ENGRS – DREDGE MOORING	SHEET NO. 7-3 OF
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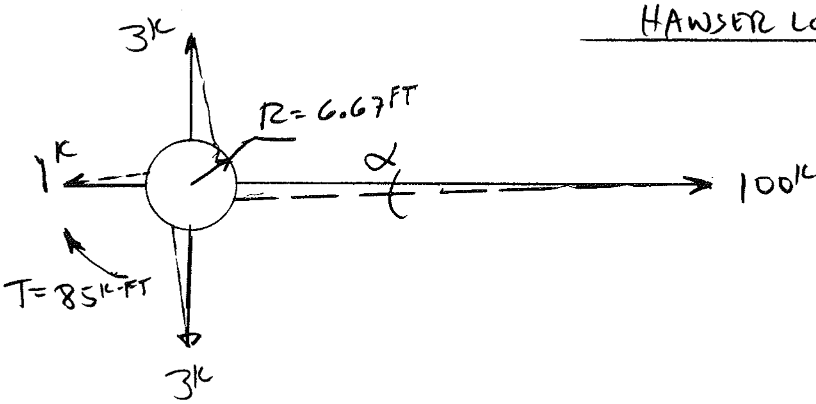
	CHECKED BY DATE

7.0 BEARINGS (CONT'D)

d) COMPUTE TORSIONAL RESISTANCE OF ANCHOR LEGS UNDER 100^k STEADY HAWSER LOAD:

CHAIN LOADS ARE:



∴ ANGLE AT WHICH CHAIN TABLE WILL ROTATE WHEN UNIT BEARING FRICTION IS OVERCOME IS: (IGNORE 3 LEGS)

$$\alpha = \sin^{-1}\left(\frac{85^{k\text{-}FT}/6.67^{FT}}{100^{k}}\right) = \underline{\underline{7.3^\circ}}$$

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		JOB NUMBER	667
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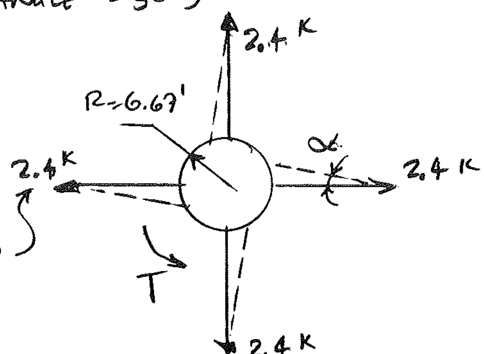
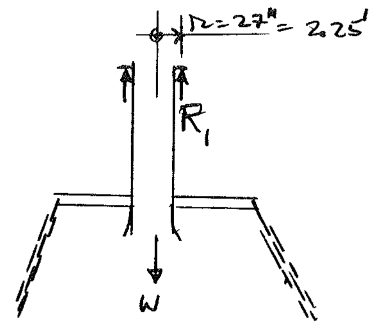
7.0 BEARINGS (CONT'D)

f) COMPUTE TORSIONAL RESISTANCE OF ANCHOR LEGS UNDER NO LOAD & BUOY AT LOW TIDE:
(INITIAL CHAIN ANGLE = 50°)



ASSUMES BUOY DROPS ~6 FT @ LOW TIDE
(HORIZ LOAD = 3K @ 50° INITIALLY)



$R_1 = W = 15^K + 4(2^K) = \underline{23^K}$
TURRET WEIGHT, CHAIN WEIGHT

$T_{BEARING} = \mu R_1 r = 0.15 \times 23^K \times 2.25' = \underline{7.8^{K\text{-}FT}}$

NOW COMPUTE ANGLE MOORINGTABLE WILL ROTATE BEFORE THE BEARING SLIPS:

$T = 4 \text{ LEGS} \times (2.4^K \times \sin\alpha) \times 6.67^{FT} \overset{SET}{=} T_{BEARING} \sim 7.8^{K\text{-}FT}$

$\sin\alpha = 0.122$

$\alpha = \underline{7.0°}$

∴ CHAINTABLE MAY ROTATE 7.0° BEFORE BEARING TORQUE IS OVERCOME

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PROJECT	CORPS OF ENGRS - DREDGE MOORING	PREPARED BY KELM	DATE 2/91
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8.0 BUOY SCANTLINGS

THE MAIN CALCULATIONS REQUIRED ARE TO VERIFY INTEGRITY AGAINST HYDROSTATIC PRESSURE

REF: SECT 4.0 FOR SKETCHES

REF: SECT 3.1 - DESIGN PRESSURES ARE:

	OPERATING	SURVIVAL	AIR TEST (@3PSI)
TOP DECK	0FT - 0 PSF	3FT - 190PSF	430 PSF
BOTTOM DECK	7.5 - 480	10.5 - 670	430

CHECK WHICH CONTROLS:

@ BOT. DECK, $\frac{P_{SUR}}{P_{OPG}} = \frac{670}{480} \approx 1.40$

AND $\frac{\sigma_{ALL\,SUR}}{\sigma_{ALL\,OPG}} = \frac{0.8F_y}{0.6F_y} = 1.33 < 1.40$

∴ SURVIVAL CONTROLS BOTH AT THE TOP & BOT DECK

ALSO NEED TO CHECK THE TOP DECK & BHDS FOR THE AIR TEST PRESSURE - CAN USE $\sigma_{ALL} = 0.8F_y$ SINCE 3PSI WILL BE TEMPORARY (ONLY 2 PSI IS HELD)

8.0 BUOY SCANTLINGS (CONT'D)

8.1 PLATING

a) HULL PLATING - 3/8"

FOR SIMPLICITY CHECK THE ENTIRE HULL FOR BOT. DECK HEAD = 10.5 FT

REF ABS 5.9.1a, WITH S = SPACING = 35 IN MAX

$$t_{MIN} = \frac{S\sqrt{H}}{460} + 0.10 \ [IN] = \frac{35\sqrt{10.5}}{460} + 0.10 = 0.347^{IN}$$

$$t_{ACTUAL} = 0.375^{IN} > 0.347 \quad \therefore \checkmark \text{ ok}$$

b) BULKHEAD PLATING - 5/16"

REF ABS 5.9.1b, TAKING ADVANTAGE OF 20% REDUCTION ALLOWED BY STEEL VESSEL RULES 22.23.2 BY SPECIFYING A PROPER PAINT JOB INTERNALLY (TO REDUCE SCANTLINGS WEIGHT)

$$t_{MIN} = \left[\frac{S\sqrt{H}}{254} + 0.10\right] \times 0.80 = \left[\frac{35\sqrt{10.5}}{460} + 0.10\right] \times 0.80 = 0.277 \ IN$$

$$t_{ACTUAL} = 0.3125^{IN} > 0.277 \therefore \checkmark \text{ ok.}$$

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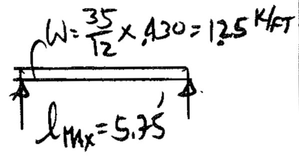
8.0 BUOY SCANTLINGS (CONT'D)

8.2 STIFFENERS

ALL ARE INTERNAL & COATED. ∴ USE AISC w/o A CORROSION ALLOW.

a) TOP DECK - 3/8" x 4 1/2"

FROM SECT 8.0, P = 430 PSF, $\sigma_{ALL} = 0.8\,F_y$



$$M = \frac{wl^2}{8} = \frac{1.25^{K/'} \times 5.75^2}{8} = 5.2^{K\text{-}FT} = \underline{62}^{K\text{-}IN}$$

SECTION PROPERTIES:

$S = 2.54\ IN^3$

$$\sigma = \frac{M}{S} = \frac{62}{2.54} = 24.4^{KSI} = \underline{0.72\,F_y} < 0.80\,F_y \;\therefore \checkmark\ ok.$$

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	CHECKED BY	DATE	

8.0 BUOY SCANTLINGS (CONT'D)

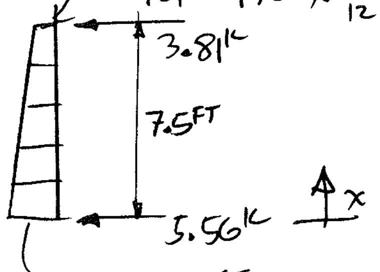
8.2 STIFFENERS (CONT'D)

b) BULKHEADS – 3/8" x 6"

NEED TO CONSIDER TWO LOADS – SURVIVAL & AIR TEST

SURVIVAL

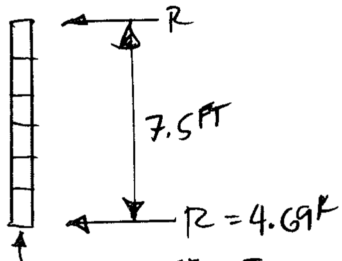
$w_{TOP} = 190^{PSF} \times \frac{35}{12} = 550\#/'$



$w_{BOT} = 670^{PSF} \times \frac{35}{12} = 1950\#/'$

$M_{MAX} = 8.86^{K\text{-}FT}$ @ $x = 3.5^{FT}$

AIR TEST

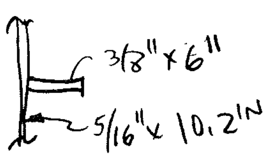


$W = 430^{PSF} \times \frac{35}{12} = 1250\#/'$

$M_{MAX} = 8.79^{K\text{-}FT}$ @ ℄

∴ SURVIVAL CONTROLS

SECTION PROPERTIES:



$S = 4.11 \; IN^3$

$\sigma = \frac{M}{S} = \frac{8.86^{K\text{-}FT} \times 12}{4.11} = 25.9 \; KSI = 0.76 F_y < 0.8 F_y$

∴ ✓ ok.

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PROJECT Corps of Engrs - Dredge Mooring

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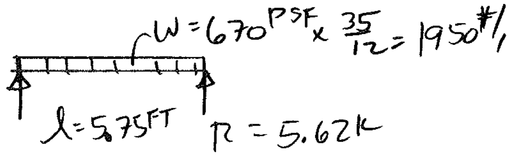
8.0 BUOY SCANTLINGS (CONT'D)

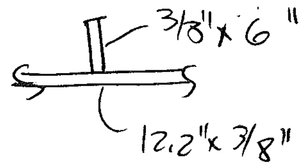
8.2 STIFFENERS (CONT'D)

c) BOTTOM DECK - 3/8" x 6"



$$M_{MAX} = \frac{Wl^2}{8} = 8.08^{K\text{-}FT}$$

SECTION PROPERTIES:



$S = 4.31 \text{ IN}^3$

$$\sigma = \frac{M}{S} = \frac{8.08(12)}{4.31} = 22.5^{KSI} = \underline{0.66 F_y} < 0.8 F_y \therefore \checkmark \text{ ok.}$$

SHEET NO. 9-1 OF

JOB NUMBER

PROJECT

SUBJECT

PREPARED BY JHU DATE JUL 91

CHECKED BY DATE

LOADS EXERTED BY FLOATING HOSES

FLOATING HOSE LOADS ARE INERITIAL LOADS. AS THE BUOY MOVES (& THEREFORE ACCELERATES) IT "DRAGS" (OR PUSHES) THE HOSES ALONG WITH IT.

MAXIMUM SURGE ACCELERATIONS OF MOORING BUOYS ARE IN THE RANGE OF 0.5 G'S.

AS A CONSERVATIVE ESTIMATE OF THE MAXIMUM AXIAL FORCE IN THE FLOATING HOSE STRING AT THE BUOY:

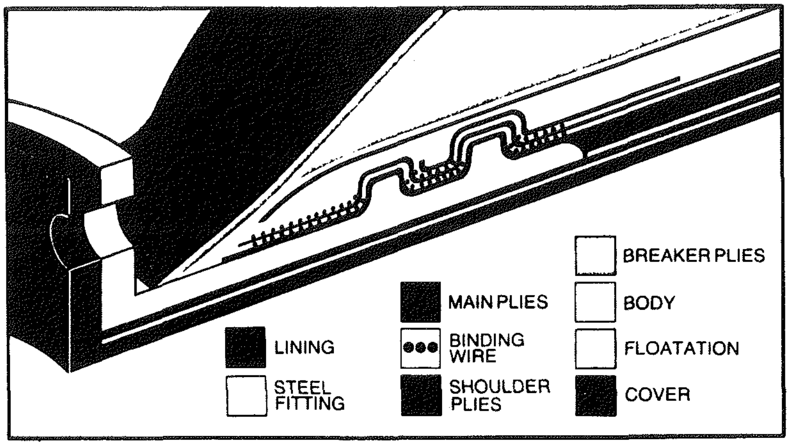
HOSE = 6866 LB (DUNLOP CATALOGUE)

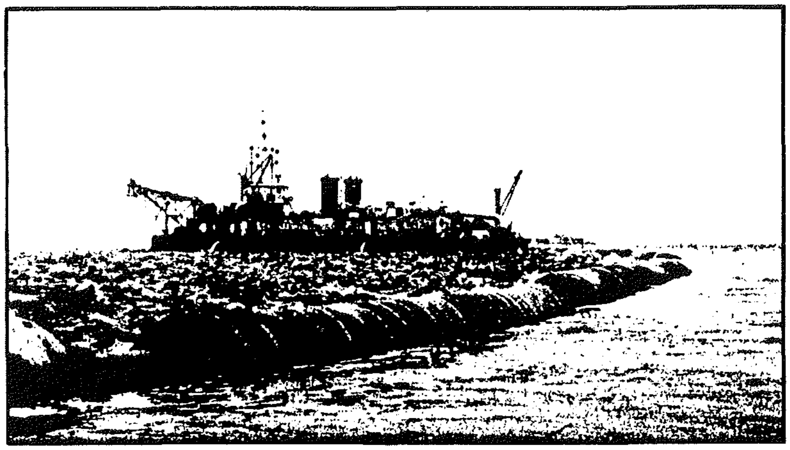
WATER = $[28/12]^2 * \frac{\pi}{4} * 35 * 62.4 = 9340$ LB

MAX HOSE LOAD = $[6866 + 9340] * 7 * 0.5 = 56.7$ kip, < 100 kip

NOTE: MAXIMUM HOSE LOAD OCCURS DURING SURVIVAL WITH NO VESSEL MOORED. MEAN LOADS ARE 10% - 15% of SURVIVAL.

DREDGEFLOTE SERIES DRG 720





A very tough hose with built-in buoyancy, recommended for hydraulic cutter suction and suction dredgers operating in the open sea, even when weather and sea conditions are extreme. Unlike traditional hoses with a wire helix, this hose will recuperate its circular section without lasting damage even if crushed, over-bent or exposed to momentary high vacuum conditions.

	bar	psi
DRG 720	20	290

The hose design allows resistance to an operating vacuum of 250 mm/hg (10 ins/hg).

A composite of natural and synthetic rubber developed to obtain high abrasion resistance. The lining includes open-weave fabric, increasing resistance to laceration, gouging and cut growth. **Standard Lining Thickness is 19mm (3/4″).** Thicker lining than the standard specification can be supplied.

NOMINAL BORE		APPROX. OD		6M		10M		35FT		12M	
mm	inch	mm	inch	kg	lbs	kg	lbs	kg	lbs	kg	lbs
400	16	722	28.4	920	2029	1340	2955	1410	3109	1550	3418
500	20	866	34.1	1303	2873	1927	4249	2031	4478	2239	4937
600	24	1028	40.5	1609	3548	2373	5232	2500	5513	2755	6075
650	26	1159	45.6	1821	4015	2715	5987	2864	6315	3162	6972
700	28	1212	47.7	2003	4417	2955	6516	3114	6866	3431	7565
750	30	1257	49.5	2237	4933	3299	7274	3476	7665	3830	8445
800	32	1352	53.2	2542	5605	3752	8273	3954	8719	4357	9607
900	36	1473	58.0	3050	6725	4494	9909	4735	10441	5216	11501

NOTE: The weight per length includes built-in nipples with flanges.

DREDGE MOORING STUDY
Phase II Report

APPENDIX B
BUOY STABILITY

July 15, 1991

SOFEC, Inc. - Houston, TX
Project No. 667

U.S. Army Corps of Engineers
Waterways Experiment Station

Contract No. DACW39-90-C-0075

1 Buoy Weight and Center of Gravity.

1.1 The individual component parts of the DPO SPM buoy are illustrated on pages 3 through 6. The weight and relative location of each component on the buoy is depicted. The weight and center of gravity of the major end items is summarized. The origin of the reference frame is the centerline of the buoy hull centerwell and the bottom plate of the buoy hull.

1.2 The estimated dry weight (free floating displacement) of the DPO SPM buoy is 66.1 kips. The center of gravity is located on the centerline of the buoy centerwell and 3.27 feet above the bottom plate of the buoy hull. Note: The configuration of the buoy is non-operational, i.e., without anchor chains, hawser, hoses or ballast water for trim. This configuration would be representative of the buoy in a static free floating state. Anticipated average static freeboard of the buoy is 3.98 feet.

1.3 When the DPO SPM system is operating in 30 feet of water, the nominal weight of dredge slurry, hose and anchor chain that must be supported is 14.6 kips. Ballast water for buoy trim is 9.1 kips. Anticipated average static freeboard of the buoy is 2.72 feet.

1.4 When the DPO SPM system is operating in 75 feet of water, the nominal weight of dredge slurry, hose and anchor chain that must be supported is 26.2 kips. Ballast water for buoy trim is 9.1 kips. Anticipated average static freeboard of the buoy is 2.10 feet.

2 Free Floating Buoy Stability.

2.1 The free floating stability of the DPO SPM buoy is illustrated on pages 7 and 8. Referring to page 8, the graph illustrates the magnitude of the forces attempting to right the buoy at various stages of list. For this capsule shaped style of buoy, the list reference plane is the longitudinal centerline of the buoy hull. The graph illustrates that the maximum righting moment occurs at 50° list angle. Additionally, the graph indicates the buoy could list onto it side (90° list) and would right itself.

2.2 The importance of the free floating buoy stability is most significant during the installation process when the initial anchor chain pendant is hoisted into position and pretensioned in its chain support assembly. With this buoy design configuration, the dead weight of the hoisted chain will be supported 6'-8" from the centerline of the buoy hull and will induce an overturning moment, i.e. list. In a water depth of 75 feet, the chain weight is approximately 2.6 kips; therefore, the overturning moment is approximately 17 kip feet. Thus, the maximum list induced in the buoy during initial chain leg installation is less than 10°.

3 Intact Buoy Stability.

3.1 The remaining portion of this section depicts the intact (fully moored, operational configuration) stability of the DPO SPM buoy. Basically, the righting moments generated in the system in water depths of 30 through 75 feet are more than sufficient to maintain the buoy in an upright and stable condition.

CORP OF ENGINEERS - DREDGE MOORING - SOFEC # 667 - 10-JUN-91

WEIGHT AND CG ESTIMATE (Water Depth = 30')

BUOY HEIGHT = 7.50 [FT]
PROD. DENS. = 80 [PCF]
DISPLACEMENT = 18.79 [K/FT]

#	DESCRIPTION	LIFT/FF WEIGHT [K]	OPERATING WEIGHT[K]	XCG [FT] SYMMETRICAL FROM cl	YCG [FT] + FROM cl TO PIPEARM	ZCG [FT] + UP FROM BOT. DECK
1.0	Buoy					
1.1	Top Deck Pl 3/8"	4.26	4.26	0.00	0.00	7.52
1.2	Bot Deck Pl 3/8"	4.40	3.83	0.00	0.00	-0.02
1.3	Hull Pl 3/8"	5.46	5.13	0.00	3.20	3.75
1.4	Hull Pl 1/2"	2.58	2.42	0.00	-11.00	3.75
1.5	Long Bhds Pl 5/16"	1.71	1.71	0.00	3.62	3.75
1.6	Cross Bhds Pl 5/16"	2.26	2.26	0.00	0.00	3.75
1.7	Ballast Bhd Pls 1/2"	1.77	1.77	0.00	-9.75	3.75
1.8	Ballast Baffle Pls 1.25"	1.55	1.55	0.00	-11.50	2.25
1.9	Ballast WT Deck Pl 1/2"	0.71	0.71	0.00	-11.50	4.50
1.10	Centerwell Pipe 56"x3/8"	2.00	1.74	0.00	0.00	3.75
1.11	Turret 48" 150# Flange + Bolts	0.60	0.52	0.00	0.00	-1.30
1.12	Upper Deck Stiff 3/8"x4"	0.47	0.47	0.00	0.00	7.33
1.13	Lower Deck Stiff 3/8"x7"	0.82	0.82	0.00	2.00	0.29
1.14	Bhd Stiff 3/8"x7"	1.61	1.61	0.00	2.20	3.25
1.15	Top Rim Pipe 6"XS	1.97	1.97	0.00	0.00	7.20
1.16	Fenders Split Pipe 3" Std (22)	0.70	0.60	0.00	0.00	4.30
1.17	Bearing Assembly	1.30	1.20	0.00	0.00	3.75
1.18	Pipe Support Legs 6" Std	0.90	0.90	0.00	0.00	9.50
1.19	Pipe Beam	0.60	0.60	0.00	0.00	17.50
1.20	Lift Eyes 3/4"	0.25	0.25	0.00	0.00	7.80
1.21	P/S Ring Pl 1.5" + Bolts	0.51	0.51	0.00	0.00	11.45
1.22	P/S Bhd Ins Pl 1/2"	0.41	0.31	0.00	10.00	6.00
1.23	P/S Gusset Pls 1/2"	0.12	0.12	0.00	10.50	7.60
1.24	P/S Flange Pl 1" + Bolts	0.28	0.18	0.00	11.00	8.80
1.25	Winch	0.30	0.30	0.00	-7.50	9.00
1.26	Chain Table Lock Device	0.20	0.20	0.00	0.00	7.70
1.27	Anodes	0.50	0.33	0.00	0.00	-1.00
1.28	Swivel	1.90	1.90	0.00	0.00	10.00
1.29	Swivel Product	0.00	0.96	0.00	0.00	10.00
1.30	Turret Pipe 48"x1/2"	2.29	1.99	0.00	0.00	2.80
1.31	Towing Brackets & Bal. Piping	0.20	0.20	0.00	-11.00	7.60
1.32	Handrails	0.20	0.20	0.00	0.00	9.25
1.33	Mill Tol, Misc + Cont @ 7%	2.81	2.74	0.00	0.00	4.00
	Buoy Subtotal - Lift/FF	45.64		0.00	-0.85	4.48
	Buoy Subtotal - Operating		44.26	0.00	-0.91	4.70

CORP OF ENGINEERS - DREDGE MOORING - SOFEC # 667 - 10-MAY-91

2.0	Mooring Table					
2.1	Cone Pl 1/2"	1.45	1.27	0.00	0.00	-4.00
2.2	C/W 48" 150# Flange	0.48	0.42	0.00	0.00	-1.60
2.3	Top & Bot Flange Pls 1/2"	3.16	2.75	0.00	0.00	-3.25
2.4	Web Pls 3/8"	0.73	-1.77	0.00	0.00	-3.25
2.5	C/S Bracket Pls 1"	0.42	0.37	0.00	0.00	-3.25
2.6	Chain Supports 2"	8.00	6.96	0.00	0.00	-3.25
2.7	Anodes	0.20	0.13	0.00	0.00	-3.25
2.8	Mill Tol, Misc + Cont @ 10%	1.44	1.01	0.00	0.00	-3.25
	Chain Table Subtotal - Lift/FF	15.88		0.00	0.00	-2.80
	Chain Table Subtotal - Operating		11.14	0.00	0.00	-2.77
3.0	Piping					
3.1	28"150# WN Flange + Bolts	0.35	0.35	0.00	0.00	12.00
3.2	90 deg 28"x1/2" ELL	0.80	0.80	0.00	1.50	15.00
3.3	30 deg 28"x1/2" ELL	0.26	0.26	0.00	4.80	15.20
3.4	28"x1/2"x11' Pipe	1.62	1.62	0.00	11.00	12.00
3.5	28"150# WN Flange + Bolts	0.35	0.35	0.00	16.00	9.00
3.6	Hawser Padeye Pl 1.5"	0.20	0.20	0.00	14.50	12.00
3.7	Ring Pls 3/4"	0.36	0.36	0.00	12.50	11.00
3.8	Web Pl 1/2"	0.08	0.08	0.00	11.50	9.50
3.9	Flange Pl 1"	0.16	0.16	0.00	11.50	9.00
3.10	Piping Product	0.00	4.64	0.00	7.40	12.90
3.11	Mill Tol, Misc & Cont @ 10%	0.42	0.88	0.00	7.00	12.00
	Piping Subtotal - Lift/FF	4.60		0.00	8.47	12.25
	Piping Subtotal - Operating		9.70	0.00	7.89	12.55
4.0	Operation Loads					
4.1	2" Chain @ 50 Deg	0.00	8.12	0.00	0.00	-3.25
4.2	Spare Chain	0.00	0.50	0.00	0.00	-3.25
4.3	28" Underbuoy Hose + Product	0.00	3.30	0.00	0.00	8.00
4.4	Partial Floating Hose	0.00	3.50	0.00	20.00	7.00
4.5	Mooring Line	0.00	0.20	0.00	17.00	9.50
4.6	Trim Ballast	0.00	9.14	0.00	-12.00	2.25
	Op'n Loads Subtotal - Lift/FF	0.00		0.00	0.00	0.00
	Op'n Loads Subtotal - Operating		24.76	0.00	-1.47	1.83
	TOTAL WEIGHT & CG - LIFT/FF	66.12		0.00	0.00	3.27
	TOTAL WEIGHT & CG - OPERATING		89.86	0.00	0.00	3.83
	MEAN DRAFT [FT]	3.52	4.78			
	MEAN FREEBOARD [FT]	3.98	2.72			

CORP OF ENGINEERS - DREDGE MOORING - SOFEC # 667 - 10-MAY-91

WEIGHT AND CG ESTIMATE (Water Depth = 75')

BUOY HEIGHT = 7.50 [FT]
PROD. DENS. = 80 [PCF]
DISPLACEMENT = 18.79 [K/FT]

#	DESCRIPTION	LIFT/FF WEIGHT [K]	OPERATING WEIGHT[K]	XCG [FT] SYMMETRICAL FROM cl	YCG [FT] + FROM cl TO PIPEARM	ZCG [FT] + UP FROM BOT. DECK
1.0	Buoy					
1.1	Top Deck Pl 3/8"	4.26	4.26	0.00	0.00	7.52
1.2	Bot Deck Pl 3/8"	4.40	3.83	0.00	0.00	-0.02
1.3	Hull Pl 3/8"	5.46	5.13	0.00	3.20	3.75
1.4	Hull Pl 1/2"	2.58	2.42	0.00	-11.00	3.75
1.5	Long Bhds Pl 5/16"	1.71	1.71	0.00	3.62	3.75
1.6	Cross Bhds Pl 5/16"	2.26	2.26	0.00	0.00	3.75
1.7	Ballast Bhd Pls 1/2"	1.77	1.77	0.00	-9.75	3.75
1.8	Ballast Baffle Pls 1.25"	1.55	1.55	0.00	-11.50	2.25
1.9	Ballast WT Deck Pl 1/2"	0.71	0.71	0.00	-11.50	4.50
1.10	Centerwell Pipe 56"x3/8"	2.00	1.74	0.00	0.00	3.75
1.11	Turret 48" 150# Flange + Bolts	0.60	0.52	0.00	0.00	-1.30
1.12	Upper Deck Stiff 3/8"x4"	0.47	0.47	0.00	0.00	7.33
1.13	Lower Deck Stiff 3/8"x7"	0.82	0.82	0.00	2.00	0.29
1.14	Bhd Stiff 3/8"x7"	1.61	1.61	0.00	2.20	3.25
1.15	Top Rim Pipe 6"XS	1.97	1.97	0.00	0.00	7.20
1.16	Fenders Split Pipe 3" Std (22)	0.70	0.60	0.00	0.00	4.30
1.17	Bearing Assembly	1.30	1.20	0.00	0.00	3.75
1.18	Pipe Support Legs 6" Std	0.90	0.90	0.00	0.00	9.50
1.19	Pipe Beam	0.60	0.60	0.00	0.00	17.50
1.20	Lift Eyes 3/4"	0.25	0.25	0.00	0.00	7.80
1.21	P/S Ring Pl 1.5" + Bolts	0.51	0.51	0.00	0.00	11.45
1.22	P/S Bhd Ins Pl 1/2"	0.41	0.31	0.00	10.00	6.00
1.23	P/S Gusset Pls 1/2"	0.12	0.12	0.00	10.50	7.60
1.24	P/S Flange Pl 1" + Bolts	0.28	0.18	0.00	11.00	8.80
1.25	Winch	0.30	0.30	0.00	-7.50	9.00
1.26	Chain Table Lock Device	0.20	0.20	0.00	0.00	7.70
1.27	Anodes	0.50	0.33	0.00	0.00	-1.00
1.28	Swivel	1.90	1.90	0.00	0.00	10.00
1.29	Swivel Product	0.00	0.96	0.00	0.00	10.00
1.30	Turret Pipe 48"x1/2"	2.29	1.99	0.00	0.00	2.80
1.31	Towing Brackets & Bal. Piping	0.20	0.20	0.00	-11.00	7.60
1.32	Handrails	0.20	0.20	0.00	0.00	9.25
1.33	Mill Tol, Misc + Cont @ 7%	2.81	2.74	0.00	0.00	4.00
	Buoy Subtotal - Lift/FF	45.64		0.00	-0.85	4.48
	Buoy Subtotal - Operating		44.26	0.00	-0.91	4.70

2.0	Mooring Table					
2.1	Cone Pl 1/2"	1.45	1.27	0.00	0.00	-4.00
2.2	C/W 48" 150# Flange	0.48	0.42	0.00	0.00	-1.60
2.3	Top & Bot Flange Pls 1/2"	3.16	2.75	0.00	0.00	-3.25
2.4	Web Pls 3/8"	0.73	-1.77	0.00	0.00	-3.25
2.5	C/S Bracket Pls 1"	0.42	0.37	0.00	0.00	-3.25
2.6	Chain Supports 2"	8.00	6.96	0.00	0.00	-3.25
2.7	Anodes	0.20	0.13	0.00	0.00	-3.25
2.8	Mill Tol, Misc + Cont @ 10%	1.44	1.01	0.00	0.00	-3.25
	Chain Table Subtotal - Lift/FF	15.88		0.00	0.00	-2.80
	Chain Table Subtotal - Operating		11.14	0.00	0.00	-2.77
3.0	Piping					
3.1	28"150# WN Flange + Bolts	0.35	0.35	0.00	0.00	12.00
3.2	90 deg 28"x1/2" ELL	0.80	0.80	0.00	1.50	15.00
3.3	30 deg 28"x1/2" ELL	0.26	0.26	0.00	4.80	15.20
3.4	28"x1/2"x11' Pipe	1.62	1.62	0.00	11.00	12.00
3.5	28"150# WN Flange + Bolts	0.35	0.35	0.00	16.00	9.00
3.6	Hawser Padeye Pl 1.5"	0.20	0.20	0.00	14.50	12.00
3.7	Ring Pls 3/4"	0.36	0.36	0.00	12.50	11.00
3.8	Web Pl 1/2"	0.08	0.08	0.00	11.50	9.50
3.9	Flange Pl 1"	0.16	0.16	0.00	11.50	9.00
3.10	Piping Product	0.00	4.64	0.00	7.40	12.90
3.11	Mill Tol, Misc & Cont @ 10%	0.42	0.88	0.00	7.00	12.00
	Piping Subtotal - Lift/FF	4.60		0.00	8.47	12.25
	Piping Subtotal - Operating		9.70	0.00	7.89	12.55
4.0	Operation Loads					
4.1	2" Chain @ 50 Deg	0.00	16.71	0.00	0.00	-3.25
4.2	Spare Chain	0.00	0.50	0.00	0.00	-3.25
4.3	28" Underbuoy Hose + Product	0.00	6.30	0.00	0.00	8.00
4.4	Partial Floating Hose	0.00	3.50	0.00	20.00	7.00
4.5	Mooring Line	0.00	0.20	0.00	17.00	9.50
4.6	Trim Ballast	0.00	9.14	0.00	-12.00	2.25
	Op'n Loads Subtotal - Lift/FF	0.00		0.00	0.00	0.00
	Op'n Loads Subtotal - Operating		36.35	0.00	-1.00	1.14
	TOTAL WEIGHT & CG - LIFT/FF	66.12		0.00	0.00	3.27
	TOTAL WEIGHT & CG - OPERATING		101.45	0.00	0.00	3.36
	MEAN DRAFT [FT]	3.52	5.40			
	MEAN FREEBOARD [FT]	3.98	2.10			

DREDGE CALM BUOY

FREEFLOATING

CALM BUOY STABILITY CALCULATION
ANALYSIS RESULTS

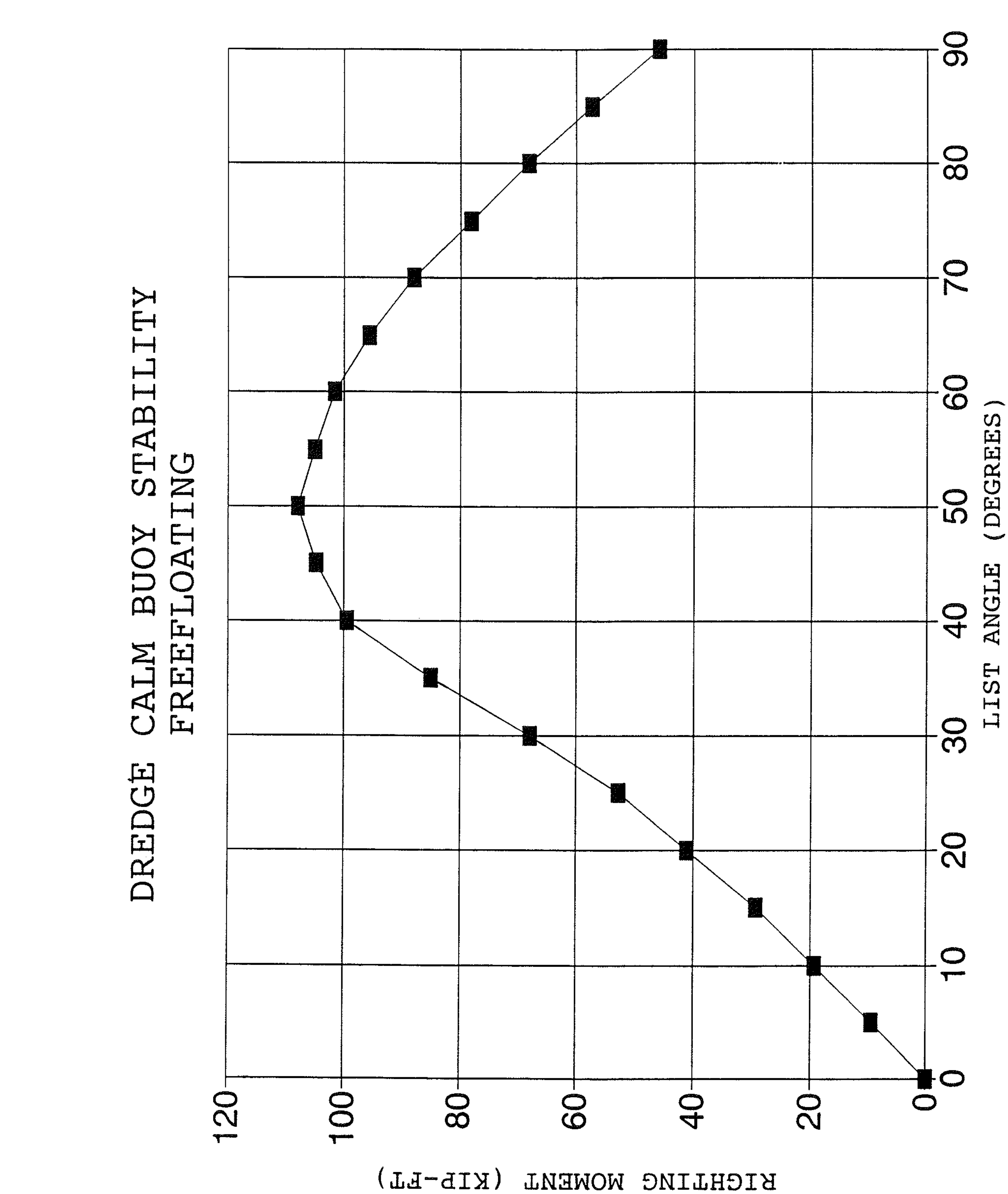
Operational Weight/CG's

Weight:	**-66.12**	(kips)
X-CG:	**0.000**	(feet)
Y-CG:	**0.000**	(feet)
Z-CG:	**3.270**	(feet)

Hose Weight

Weight:	**0.0**	(kips)

List Angle (deg)	Draft (feet)	Buoyant Force (kips)	Center of Buoyancy XCB (feet)	YCB (feet)	ZCB (feet)	W'Plane (ft^2)	Center of Gravity XCG (feet)	YCG (feet)	ZCG (feet)	Righting Arm in Y (feet)	Hyd'stat Righting Moment about X (kip*ft)	Mooring System Righting Moment about X (kip*ft)	Total Righting Moment about X (kip*ft)
0	*3.667*	*66.1*	*0.00*	*0.000*	*1.833*	*233*	0.00	0.000	3.271	0.000	0	0	0
5	*3.667*	*66.1*	*0.00*	*0.410*	*1.822*	*234*	0.00	0.285	3.259	0.125	8	0	8
10	*3.667*	*66.1*	*0.00*	*0.817*	*1.790*	*237*	0.00	0.568	3.221	0.249	16	0	16
15	*3.583*	*66.1*	*0.00*	*1.233*	*1.694*	*242*	0.00	0.847	3.160	0.386	26	0	26
20	*3.500*	*66.1*	*0.00*	*1.656*	*1.576*	*248*	0.00	1.119	3.074	0.537	36	0	36
25	*3.333*	*66.1*	*0.00*	*2.102*	*1.388*	*257*	0.00	1.382	2.965	0.720	48	0	48
30	*3.167*	*66.1*	*0.00*	*2.573*	*1.173*	*269*	0.00	1.635	2.833	0.938	62	0	62
35	*3.000*	*66.1*	*0.00*	*3.062*	*0.933*	*285*	0.00	1.876	2.679	1.186	78	0	78
40	*2.833*	*66.1*	*0.00*	*3.452*	*0.672*	*284*	0.00	2.103	2.506	1.349	89	0	89
45	*2.583*	*66.1*	*0.00*	*3.752*	*0.342*	*266*	0.00	2.313	2.313	1.439	95	0	95
50	*2.333*	*66.1*	*0.00*	*3.964*	*0.004*	*247*	0.00	2.506	2.103	1.458	96	0	96
55	*2.083*	*66.1*	*0.00*	*4.102*	*-0.34*	*229*	0.00	2.679	1.876	1.423	94	0	94
60	*1.833*	*66.1*	*0.00*	*4.179*	*-0.686*	*214*	0.00	2.833	1.635	1.346	89	0	89
65	*1.500*	*66.1*	*0.00*	*4.215*	*-1.073*	*203*	0.00	2.965	1.382	1.250	83	0	83
70	*1.167*	*66.1*	*0.00*	*4.201*	*-1.454*	*193*	0.00	3.074	1.119	1.127	75	0	75
75	*0.917*	*66.1*	*0.00*	*4.136*	*-1.786*	*187*	0.00	3.160	0.847	0.976	65	0	65
80	*0.583*	*66.1*	*0.00*	*4.042*	*-2.149*	*183*	0.00	3.221	0.568	0.821	54	0	54
85	*0.250*	*66.1*	*0.00*	*3.912*	*-2.50*	*181*	0.00	3.259	0.285	0.653	43	0	43
90	*0.083*	*66.1*	*0.00*	*3.750*	*-2.759*	*180*	0.00	3.271	0.000	0.479	32	0	32



DREDGE CALM BUOY STABILITY
FREEFLOATING
RIGHTING MOMENT (KIP-FT)
LIST ANGLE (DEGREES)
0
20
40
60
80
100
120
0
10
20
30
40
50
60
70
80
90

DREDGE CALM BUOY

INTACT-TROUGH (30 FT WATER DEPTH)

CALM BUOY STABILITY CALCULATION
ANALYSIS RESULTS

Chain No.	X (feet)	Y (feet)	Z (feet)	Plan Angle (deg)
	Chain Locations			
1	6.75	0.00	**-3.25**	**0**
2	0.00	6.75	-3.25	90
3	-6.75	0.00	-3.25	180
4	-0.00	-6.75	-3.25	270

Chain Radius: **6.75** (feet)
Chain Height: **-3.25** (feet)

Operational Weight/CG's

Weight: **-89.86** (kips)

X-CG: **0.000** (feet)
Y-CG: **0.000** (feet)
Z-CG: **3.830** (feet)

Hose Weight

Weight: **-3.0** (kips)

List Angle (deg)	Draft (feet)	Buoyant Force (kips)	Center of Buoyancy XCB (feet)	Center of Buoyancy YCB (feet)	Center of Buoyancy ZCB (feet)	W'Plane (ft^2)	Center of Gravity XCG (feet)	Center of Gravity YCG (feet)	Center of Gravity ZCG (feet)	Righting Arm in Y (feet)	Hyd'stat Righting Moment about X (kip*ft)	Mooring System Righting Moment about X (kip*ft)	Total Righting Moment about X (kip*ft)
0	*4.833*	*86.4*	*0.00*	*0.000*	*2.417*	*279*	0.00	0.000	3.986	0.000	0	0	0
5	*4.833*	*86.4*	*0.00*	*0.399*	*2.409*	*280*	0.00	0.347	3.967	0.052	4	5	10
10	*4.833*	*86.5*	*0.00*	*0.799*	*2.384*	*284*	0.00	0.691	3.918	0.108	9	10	20
15	*4.667*	*86.6*	*0.00*	*1.202*	*2.259*	*289*	0.00	1.029	3.839	0.173	15	16	30
20	*4.500*	*86.7*	*0.00*	*1.611*	*2.115*	*297*	0.00	1.358	3.732	0.253	22	21	43
25	*4.333*	*86.7*	*0.00*	*2.029*	*1.952*	*308*	0.00	1.671	3.583	0.358	31	26	57
30	*4.167*	*86.8*	*0.00*	*2.433*	*1.760*	*297*	0.00	1.982	3.433	0.451	39	31	70
35	*4.167*	*87.1*	*0.00*	*2.754*	*1.614*	*277*	0.00	2.268	3.239	0.486	42	37	79
40	*4.000*	*87.3*	*0.00*	*3.066*	*1.344*	*271*	0.00	2.535	3.021	0.531	46	43	89
45	*3.833*	*87.5*	*0.00*	*3.349*	*1.043*	*261*	0.00	2.781	2.781	0.568	50	49	98
50	*3.667*	*87.7*	*0.00*	*3.572*	*0.728*	*243*	0.00	3.005	2.521	0.567	50	54	104
55	*3.500*	*88.0*	*0.00*	*3.733*	*0.409*	*229*	0.00	3.204	2.244	0.529	47	60	107
60	*3.333*	*88.2*	*0.00*	*3.842*	*0.090*	*218*	0.00	3.379	1.951	0.463	41	66	107
65	*3.167*	*88.5*	*0.00*	*3.906*	*-0.224*	*210*	0.00	3.523	1.643	0.383	34	72	105
70	*3.000*	*88.8*	*0.00*	*3.932*	*-0.531*	*203*	0.00	3.640	1.325	0.292	26	77	103
75	*2.833*	*89.2*	*0.00*	*3.924*	*-0.828*	*200*	0.00	3.729	0.999	0.195	17	83	100
80	*2.500*	*89.5*	*0.00*	*3.902*	*-1.20*	*197*	0.00	3.788	0.668	0.114	10	88	98
85	*2.333*	*89.8*	*0.00*	*3.835*	*-1.469*	*199*	0.00	3.818	0.334	0.017	2	94	95
90	*2.000*	*90.1*	*0.00*	*3.750*	*-1.809*	*199*	0.00	3.819	0.000	-0.069	-6	99	93

DREDGE CALM BUOY

INTACT-MEAN WATER (30 FT WATER DEPTH)

CALM BUOY STABILITY CALCULATION
ANALYSIS RESULTS

Chain No.	Chain Locations X (feet)	Y (feet)	Z (feet)	Plan Angle (deg)
1	6.75	0.00	**-3.25**	**0**
2	0.00	6.75	-3.25	90
3	-6.75	0.00	-3.25	180
4	-0.00	-6.75	-3.25	270

Chain Radius: **6.75** (feet)
Chain Height: **-3.25** (feet)

Operational Weight/CG's

Weight:	**-89.86**	(kips)
X-CG:	**0.000**	(feet)
Y-CG:	**0.000**	(feet)
Z-CG:	**3.830**	(feet)

Hose Weight

Weight:	**-3.3**	(kips)

List Angle (deg)	Draft (feet)	Buoyant Force (kips)	Center of Buoyancy XCB (feet)	YCB (feet)	ZCB (feet)	W'Plane (ft^2)	Center of Gravity XCG (feet)	YCG (feet)	ZCG (feet)	Righting Arm in Y (feet)	Hyd'stat Righting Moment about X (kip*ft)	Mooring System Righting Moment about X (kip*ft)	Total Righting Moment about X (kip*ft)
0	*5.000*	*89.9*	*0.00*	*0.000*	*2.500*	*279*	0.00	0.000	3.830	0.000	0	0	0
5	*5.000*	*90.0*	*0.00*	*0.400*	*2.492*	*280*	0.00	0.333	3.812	0.067	6	8	14
10	*5.000*	*90.0*	*0.00*	*0.801*	*2.469*	*284*	0.00	0.664	3.764	0.137	12	16	28
15	*4.833*	*90.1*	*0.00*	*1.204*	*2.345*	*289*	0.00	0.988	3.688	0.216	19	24	43
20	*4.667*	*90.2*	*0.00*	*1.613*	*2.203*	*297*	0.00	1.305	3.585	0.308	28	31	59
25	*4.500*	*90.3*	*0.00*	*2.028*	*2.043*	*302*	0.00	1.604	3.440	0.424	38	39	78
30	*4.333*	*90.4*	*0.00*	*2.412*	*1.848*	*287*	0.00	1.904	3.297	0.508	46	47	93
35	*4.333*	*90.7*	*0.00*	*2.718*	*1.698*	*268*	0.00	2.177	3.109	0.541	49	56	105
40	*4.167*	*90.9*	*0.00*	*3.016*	*1.430*	*262*	0.00	2.433	2.899	0.583	53	64	117
45	*4.000*	*91.2*	*0.00*	*3.290*	*1.131*	*259*	0.00	2.668	2.668	0.622	57	73	130
50	*4.000*	*91.5*	*0.00*	*3.464*	*0.903*	*242*	0.00	2.882	2.418	0.582	53	82	135
55	*3.833*	*91.7*	*0.00*	*3.638*	*0.582*	*229*	0.00	3.073	2.152	0.565	52	90	142
60	*3.667*	*92.0*	*0.00*	*3.760*	*0.263*	*219*	0.00	3.239	1.870	0.521	48	99	147
65	*3.500*	*92.4*	*0.00*	*3.838*	*-0.051*	*211*	0.00	3.376	1.574	0.462	43	106	149
70	*3.333*	*92.8*	*0.00*	*3.877*	*-0.358*	*206*	0.00	3.486	1.269	0.391	36	113	149
75	*3.000*	*93.2*	*0.00*	*3.883*	*-0.653*	*201*	0.00	3.568	0.956	0.315	29	119	149
80	*2.833*	*93.6*	*0.00*	*3.874*	*-1.024*	*201*	0.00	3.623	0.639	0.251	24	126	150
85	*2.500*	*93.9*	*0.00*	*3.828*	*-1.379*	*201*	0.00	3.650	0.319	0.178	17	133	150
90	*2.333*	*94.3*	*0.00*	*3.750*	*-1.628*	*202*	0.00	3.649	0.000	0.101	10	140	150

DREDGE CALM BUOY

INTACT-CREST (30 FT WATER DEPTH)

CALM BUOY STABILITY CALCULATION
ANALYSIS RESULTS

Chain No.	Chain Locations X (feet)	Y (feet)	Z (feet)	Plan Angle (deg)
1	6.75	0.00	**-3.25**	**0**
2	0.00	6.75	-3.25	90
3	-6.75	0.00	-3.25	180
4	-0.00	-6.75	-3.25	270

Chain Radius: **6.75** (feet)
Chain Height: **-3.25** (feet)

Operational Weight/CG's

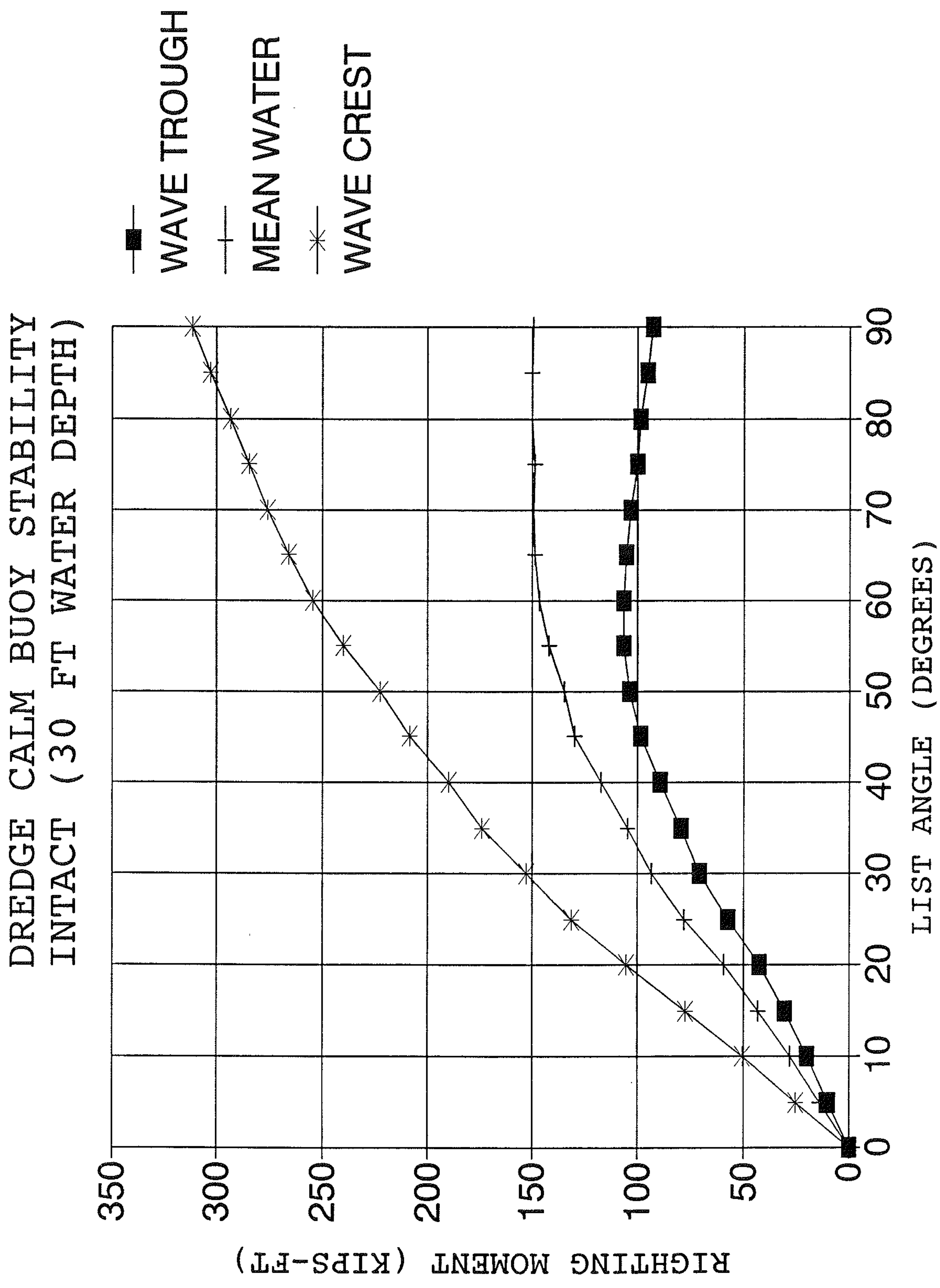
Weight: **-89.86** (kips)

X-CG: **0.000** (feet)
Y-CG: **0.000** (feet)
Z-CG: **3.830** (feet)

Hose Weight

Weight: **-3.9** (kips)

List Angle (deg)	Draft (feet)	Buoyant Force (kips)	Center of Buoyancy XCB (feet)	YCB (feet)	ZCB (feet)	W'Plane (ft^2)	Center of Gravity XCG (feet)	YCG (feet)	ZCG (feet)	Righting Arm in Y (feet)	Hyd'stat Righting Moment about X (kip*ft)	Mooring System Righting Moment about X (kip*ft)	Total Righting Moment about X (kip*ft)
0	*5.333*	*96.9*	*0.00*	*0.000*	*2.667*	*279*	0.00	0.000	3.553	0.000	0	0	0
5	*5.333*	*97.0*	*0.00*	*0.403*	*2.659*	*280*	0.00	0.309	3.534	0.094	9	16	25
10	*5.333*	*97.1*	*0.00*	*0.808*	*2.637*	*284*	0.00	0.615	3.489	0.193	19	32	51
15	*5.333*	*97.3*	*0.00*	*1.218*	*2.602*	*289*	0.00	0.916	3.417	0.302	29	48	77
20	*5.167*	*97.4*	*0.00*	*1.628*	*2.466*	*293*	0.00	1.208	3.320	0.420	41	64	105
25	*5.000*	*97.5*	*0.00*	*2.007*	*2.297*	*273*	0.00	1.484	3.182	0.523	51	80	131
30	*4.833*	*97.7*	*0.00*	*2.344*	*2.093*	*258*	0.00	1.762	3.051	0.582	57	96	153
35	*4.667*	*98.0*	*0.00*	*2.649*	*1.857*	*249*	0.00	2.014	2.876	0.635	62	112	174
40	*4.667*	*98.4*	*0.00*	*2.885*	*1.671*	*235*	0.00	2.249	2.680	0.636	63	127	190
45	*4.500*	*98.7*	*0.00*	*3.130*	*1.385*	*236*	0.00	2.465	2.465	0.665	66	143	209
50	*4.500*	*99.1*	*0.00*	*3.304*	*1.161*	*233*	0.00	2.661	2.232	0.643	64	159	222
55	*4.333*	*99.4*	*0.00*	*3.495*	*0.841*	*227*	0.00	2.835	1.985	0.660	66	174	240
60	*4.167*	*99.8*	*0.00*	*3.638*	*0.523*	*218*	0.00	2.987	1.724	0.651	65	190	255
65	*4.000*	*100.3*	*0.00*	*3.736*	*0.211*	*212*	0.00	3.110	1.450	0.626	63	203	266
70	*3.833*	*100.8*	*0.00*	*3.796*	*-0.10*	*207*	0.00	3.208	1.168	0.588	59	217	276
75	*3.667*	*101.3*	*0.00*	*3.823*	*-0.389*	*204*	0.00	3.281	0.879	0.542	55	230	285
80	*3.500*	*101.8*	*0.00*	*3.821*	*-0.67*	*201*	0.00	3.329	0.587	0.492	50	243	293
85	*3.167*	*102.3*	*0.00*	*3.802*	*-1.024*	*199*	0.00	3.351	0.293	0.451	46	257	303
90	*3.000*	*102.8*	*0.00*	*3.750*	*-1.275*	*197*	0.00	3.347	0.000	0.403	41	270	311


DREDGE CALM BUOY STABILITY
INTACT (30 FT WATER DEPTH)
RIGHTING MOMENT (KIPS-FT)
LIST ANGLE (DEGREES)
WAVE TROUGH
MEAN WATER
WAVE CREST
0
50
100
150
200
250
300
350
10
20
30
40
50
60
70
80
90

DREDGE CALM BUOY

INTACT-TROUGH (75 FT WATER DEPTH)

CALM BUOY STABILITY CALCULATION
ANALYSIS RESULTS

Chain No.	X (feet)	Y (feet)	Z (feet)	Plan Angle (deg)
1	6.75	0.00	**-3.25**	**0**
2	0.00	6.75	-3.25	90
3	-6.75	0.00	-3.25	180
4	-0.00	-6.75	-3.25	270

(Chain Locations: X, Y, Z)

Chain Radius: **6.75** (feet)
Chain Height: **-3.25** (feet)

Operational Weight/CG's

Weight: **-101.45** (kips)

X-CG: **0.000** (feet)
Y-CG: **0.000** (feet)
Z-CG: **3.360** (feet)

Hose Weight

Weight: **-5.9** (kips)

List Angle (deg)	Draft (feet)	Buoyant Force (kips)	Center of Buoyancy XCB (feet)	YCB (feet)	ZCB (feet)	W'Plane (ft^2)	Center of Gravity XCG (feet)	YCG (feet)	ZCG (feet)	Righting Arm in Y (feet)	Hyd'stat Righting Moment about X (kip*ft)	Mooring System Righting Moment about X (kip*ft)	Total Righting Moment about X (kip*ft)
0	*5.500*	*98.2*	*0.00*	*0.000*	*2.750*	*279*	0.00	0.000	3.470	0.000	0	0	0
5	*5.500*	*98.3*	*0.00*	*0.405*	*2.743*	*280*	0.00	0.302	3.454	0.103	10	13	23
10	*5.333*	*98.4*	*0.00*	*0.808*	*2.637*	*284*	0.00	0.602	3.412	0.206	20	26	47
15	*5.333*	*98.5*	*0.00*	*1.218*	*2.602*	*289*	0.00	0.896	3.343	0.322	32	40	71
20	*5.167*	*98.6*	*0.00*	*1.628*	*2.466*	*293*	0.00	1.183	3.250	0.445	44	53	97
25	*5.000*	*98.7*	*0.00*	*2.007*	*2.297*	*273*	0.00	1.455	3.121	0.552	55	66	120
30	*4.833*	*98.7*	*0.00*	*2.344*	*2.093*	*258*	0.00	1.726	2.990	0.618	61	79	140
35	*4.833*	*99.0*	*0.00*	*2.616*	*1.933*	*239*	0.00	1.975	2.821	0.641	63	91	154
40	*4.667*	*99.2*	*0.00*	*2.885*	*1.671*	*235*	0.00	2.208	2.632	0.677	67	103	170
45	*4.667*	*99.5*	*0.00*	*3.086*	*1.463*	*228*	0.00	2.423	2.423	0.663	66	114	180
50	*4.500*	*99.7*	*0.00*	*3.304*	*1.161*	*233*	0.00	2.619	2.197	0.685	68	126	195
55	*4.333*	*100.0*	*0.00*	*3.495*	*0.841*	*227*	0.00	2.793	1.956	0.702	70	138	208
60	*4.167*	*100.2*	*0.00*	*3.638*	*0.523*	*218*	0.00	2.946	1.701	0.692	69	150	219
65	*4.167*	*100.5*	*0.00*	*3.703*	*0.296*	*211*	0.00	3.073	1.433	0.630	63	158	222
70	*4.000*	*100.9*	*0.00*	*3.769*	*-0.01*	*207*	0.00	3.175	1.156	0.594	60	167	227
75	*3.667*	*101.2*	*0.00*	*3.823*	*-0.389*	*204*	0.00	3.252	0.871	0.571	58	175	233
80	*3.500*	*101.6*	*0.00*	*3.821*	*-0.67*	*201*	0.00	3.305	0.583	0.516	52	183	236
85	*3.167*	*101.9*	*0.00*	*3.802*	*-1.024*	*199*	0.00	3.332	0.291	0.470	48	192	240
90	*3.000*	*102.3*	*0.00*	*3.750*	*-1.275*	*197*	0.00	3.333	0.000	0.417	43	200	243

DREDGE CALM BUOY

INTACT-MEAN WATER (75 FT WATER DEPTH)

CALM BUOY STABILITY CALCULATION
ANALYSIS RESULTS

Chain No.	X (feet)	Y (feet)	Z (feet)	Plan Angle (deg)
1	6.75	0.00	**-3.25**	**0**
2	0.00	6.75	-3.25	90
3	-6.75	0.00	-3.25	180
4	-0.00	-6.75	-3.25	270

(Chain Locations: X, Y, Z)

Chain Radius: **6.75** (feet)
Chain Height: **-3.25** (feet)

Operational Weight/CG's

Weight:	**-101.45**	(kips)
X-CG:	**0.000**	(feet)
Y-CG:	**0.000**	(feet)
Z-CG:	**3.360**	(feet)

Hose Weight

Weight: **-6.3** (kips)

List Angle (deg)	Draft (feet)	Buoyant Force (kips)	Center of Buoyancy XCB (feet)	YCB (feet)	ZCB (feet)	W'Plane (ft^2)	Center of Gravity XCG (feet)	YCG (feet)	ZCG (feet)	Righting Arm in Y (feet)	Hyd'stat Righting Moment about X (kip*ft)	Mooring System Righting Moment about X (kip*ft)	Total Righting Moment about X (kip*ft)
0	*5.667*	*101.5*	*0.00*	*0.000*	*2.833*	*279*	0.00	0.000	3.360	0.000	0	0	0
5	*5.667*	*101.5*	*0.00*	*0.407*	*2.826*	*280*	0.00	0.293	3.344	0.114	12	16	28
10	*5.500*	*101.6*	*0.00*	*0.812*	*2.722*	*284*	0.00	0.582	3.303	0.230	23	32	56
15	*5.500*	*101.7*	*0.00*	*1.225*	*2.687*	*289*	0.00	0.867	3.237	0.358	36	49	85
20	*5.333*	*101.8*	*0.00*	*1.630*	*2.550*	*282*	0.00	1.145	3.146	0.485	49	65	114
25	*5.167*	*101.9*	*0.00*	*1.994*	*2.376*	*262*	0.00	1.409	3.022	0.585	60	81	141
30	*5.167*	*102.0*	*0.00*	*2.296*	*2.243*	*238*	0.00	1.671	2.895	0.625	64	97	161
35	*5.000*	*102.2*	*0.00*	*2.584*	*2.007*	*230*	0.00	1.912	2.731	0.672	69	111	180
40	*4.833*	*102.5*	*0.00*	*2.847*	*1.746*	*227*	0.00	2.137	2.547	0.710	73	125	197
45	*4.833*	*102.8*	*0.00*	*3.045*	*1.541*	*220*	0.00	2.345	2.345	0.700	72	139	210
50	*4.667*	*103.0*	*0.00*	*3.257*	*1.242*	*225*	0.00	2.534	2.126	0.723	74	152	227
55	*4.667*	*103.3*	*0.00*	*3.403*	*1.011*	*223*	0.00	2.703	1.893	0.700	72	166	238
60	*4.500*	*103.6*	*0.00*	*3.558*	*0.694*	*217*	0.00	2.850	1.646	0.708	73	180	253
65	*4.333*	*103.9*	*0.00*	*3.670*	*0.382*	*211*	0.00	2.972	1.386	0.698	73	190	263
70	*4.167*	*104.3*	*0.00*	*3.744*	*0.078*	*206*	0.00	3.071	1.118	0.673	70	200	270
75	*4.000*	*104.7*	*0.00*	*3.784*	*-0.214*	*202*	0.00	3.145	0.843	0.639	67	210	277
80	*3.667*	*105.1*	*0.00*	*3.809*	*-0.582*	*200*	0.00	3.195	0.563	0.614	64	220	284
85	*3.500*	*105.4*	*0.00*	*3.790*	*-0.849*	*197*	0.00	3.221	0.282	0.569	60	230	290
90	*3.167*	*105.8*	*0.00*	*3.750*	*-1.188*	*196*	0.00	3.222	0.000	0.528	56	240	296

DREDGE CALM BUOY

INTACT-CREST (75 FT WATER DEPTH)

CALM BUOY STABILITY CALCULATION
ANALYSIS RESULTS

Chain No.	X (feet)	Y (feet)	Z (feet)	Plan Angle (deg)
1	6.75	0.00	**-3.25**	**0**
2	0.00	6.75	-3.25	90
3	-6.75	0.00	-3.25	180
4	-0.00	-6.75	-3.25	270

(Chain Locations)

Chain Radius: **6.75** (feet)
Chain Height: **-3.25** (feet)

Operational Weight/CG's

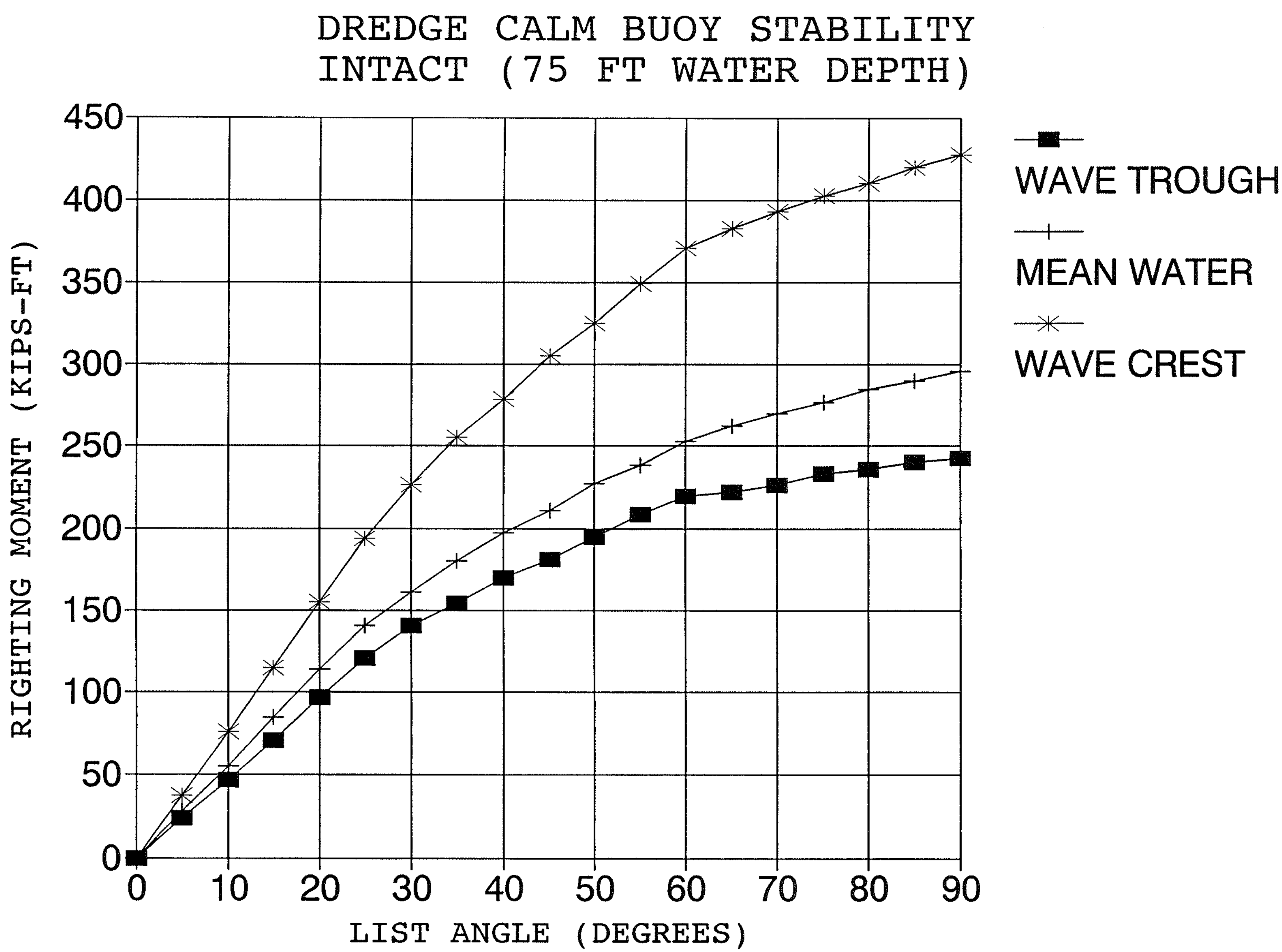
Weight: **-101.45** (kips)

X-CG: **0.000** (feet)
Y-CG: **0.000** (feet)
Z-CG: **3.360** (feet)

Hose Weight

Weight: **-7.5** (kips)

List Angle (deg)	Draft (feet)	Buoyant Force (kips)	Center of Buoyancy XCB (feet)	YCB (feet)	ZCB (feet)	W'Plane (ft^2)	Center of Gravity XCG (feet)	YCG (feet)	ZCG (feet)	Righting Arm in Y (feet)	Hyd'stat Righting Moment about X (kip*ft)	Mooring System Righting Moment about X (kip*ft)	Total Righting Moment about X (kip*ft)
0	*6.167*	*109.0*	*0.00*	*0.000*	*3.083*	*279*	0.00	0.000	3.129	0.000	0	0	0
5	*6.167*	*109.1*	*0.00*	*0.403*	*3.077*	*280*	0.00	0.272	3.114	0.131	14	23	38
10	*6.000*	*109.2*	*0.00*	*0.808*	*2.974*	*284*	0.00	0.542	3.075	0.266	29	47	76
15	*5.833*	*109.3*	*0.00*	*1.218*	*2.857*	*284*	0.00	0.807	3.013	0.411	45	70	115
20	*5.833*	*109.4*	*0.00*	*1.628*	*2.783*	*244*	0.00	1.066	2.928	0.562	62	93	155
25	*5.667*	*109.5*	*0.00*	*2.007*	*2.596*	*228*	0.00	1.310	2.810	0.697	77	117	193
30	*5.667*	*109.6*	*0.00*	*2.344*	*2.449*	*207*	0.00	1.555	2.693	0.789	87	140	227
35	*5.500*	*109.9*	*0.00*	*2.649*	*2.213*	*203*	0.00	1.778	2.540	0.871	96	160	256
40	*5.500*	*110.3*	*0.00*	*2.885*	*2.024*	*194*	0.00	1.987	2.368	0.898	99	180	279
45	*5.333*	*110.6*	*0.00*	*3.130*	*1.755*	*196*	0.00	2.180	2.180	0.950	105	200	305
50	*5.333*	*110.9*	*0.00*	*3.304*	*1.542*	*192*	0.00	2.355	1.976	0.949	105	220	325
55	*5.167*	*111.2*	*0.00*	*3.495*	*1.251*	*199*	0.00	2.511	1.758	0.984	109	240	349
60	*5.000*	*111.5*	*0.00*	*3.638*	*0.946*	*210*	0.00	2.647	1.528	0.991	111	260	371
65	*5.000*	*111.9*	*0.00*	*3.736*	*0.721*	*204*	0.00	2.760	1.287	0.976	109	273	383
70	*4.833*	*112.4*	*0.00*	*3.796*	*0.421*	*199*	0.00	2.850	1.037	0.946	106	287	393
75	*4.667*	*112.8*	*0.00*	*3.823*	*0.125*	*194*	0.00	2.919	0.782	0.904	102	300	402
80	*4.333*	*113.2*	*0.00*	*3.821*	*-0.24*	*192*	0.00	2.965	0.523	0.856	97	313	410
85	*4.167*	*113.7*	*0.00*	*3.802*	*-0.509*	*189*	0.00	2.988	0.261	0.814	93	327	419
90	*3.833*	*114.1*	*0.00*	*3.750*	*-0.847*	*189*	0.00	2.988	0.000	0.762	87	340	427



DREDGE CALM BUOY STABILITY
INTACT (75 FT WATER DEPTH)
RIGHTING MOMENT (KIPS-FT)
450
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
LIST ANGLE (DEGREES)
WAVE TROUGH
MEAN WATER
WAVE CREST

DREDGE MOORING STUDY
Phase II Report

APPENDIX C
PIPING SYSTEM PRESSURE LOSS ANALYSIS

July 15, 1991

SOFEC, Inc. - Houston, TX
Project No. 667

U.S. Army Corps of Engineers
Waterways Experiment Station

Contract No. DACW39-90-C-0075

APPENDIX C
SYSTEM FLUID LOSS ANALYSIS

1 Introduction

Pressure losses in settling slurries are sensitive to the particle size(s) of the solid, the specific gravity of the solids, and the volume concentration of the solids. Experiments have been conducted for given combinations of line diameter, solid size, solid concentration and solid density. From such experiments equations which include the above factors have been developed to express the pressure losses in slurry systems.

In actual service situations are often encountered in which the solid particles are not uniform in size and the control of the concentration is not precise. Counterbalancing these variations in conditions is the fact that for the flowrates considered the pressure drop is insensitive to particle size for particles sizes from 0.4 mm up to 1 mm and beyond. Thus for a given duct size and particles 0.4 mm to 1.0 mm, the pressure drop is dependent on the flowrate and concentration of the solid by volume.

As most sand used for beach replenishment is in the 0.2 mm to 0.3 mm range, graphs for 0.2 mm particle size can be used in the estimating pressure drop for a given hose and pipe configuration.

2 Equations Used

The formulas used to generate the pressure drop graphs are based on pages 112 - 114 of APPLIED FLUID DYNAMICS HANDBOOK by Robert D. Belvins (Van Nostrand Reinhold Co. Inc., 1984) and from a publication from DUNLOP entitled PRESSURE DROP, CAPACITY / VELOCITY GRAPHS.

The primary factors/variables in this situation are :

D	hose or pipe diameter
PDIA	particle diameter
CON	volume fraction of the solid
FLOW	flowrate in cubic feet per minute
V	mean velocity - determined by D and FLOW
Cdd	particle drag coefficient at flowing conditions
Ree	Reynolds No.
e	absolute duct roughness

The equations used are those formulated by Durand and Condolios.

The ranges studied by Durand and Condolios are:

Line diameter from 1.5 to 23 inches
Particle diameter from 0.008 to 1.00 inches (0.2 to 25.4 mm)
Concentrations from 2% to 22.5% by volume

The equations are:

Fl = Liquid Friction Factor
$= [1.14 - 2 * .43438 * LOG(e / D + 26.25 / Ree^{0.9})]^{-2}$

Fs = Solids contribution to overall friction factor
$= 81 * Fl * CON * [32.2 * D / 12 / V^2 / Cdd^{0.5} * (SGSLD - 1)]^{1.5}$

DEL_P = Pressure drop over length L
$= 62.4 / 32.2 * SGL * V^2 / 2 * 1200 / D * (Fl + Fs) / 144$

A combination of line diameter and particle diameter were selected for which the line losses in psi per 100 feet were calculated for several values of solid concentration as the flow rate was varied.

The roughness used for the hose is 0.01 inch as advised by Dunlop Ltd., a manufacturer of hoses. The absolute roughness used for the pipe is 0.06 inches, which corresponds to commercial steel pipe with general rust.

The particle sizes used are:

0.1 mm	-	Very fine sand
0.2 mm	-	Fine sand
0.4 mm	-	Medium sand
0.8 mm	-	Coarse sand
1.0 mm	-	Very coarse sand

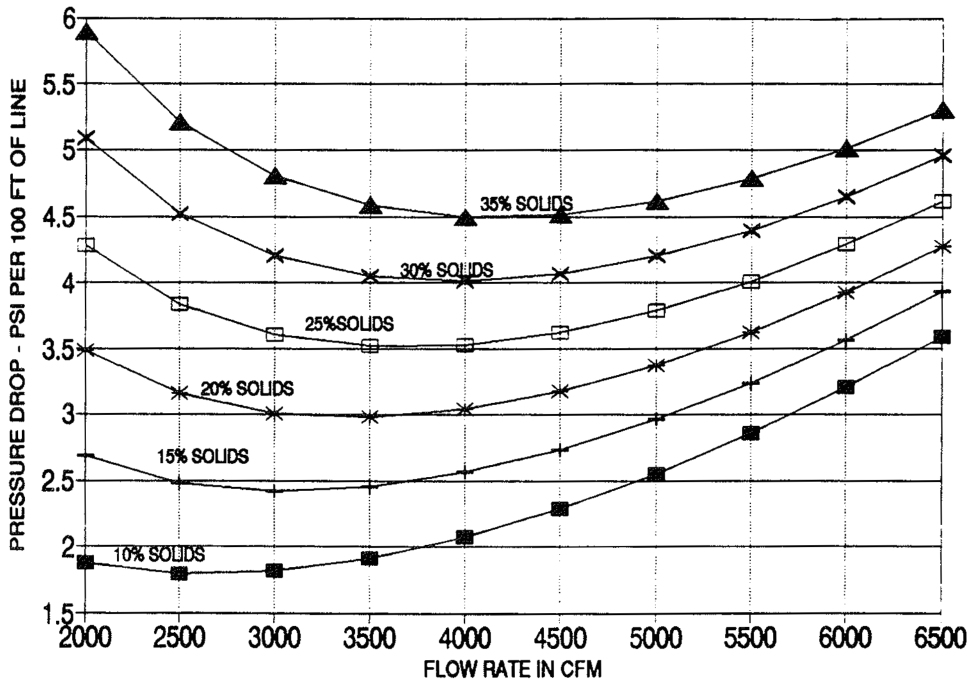
A listing of the Basic program which was used to generate the tables used to create the pressure drop graphs can be found at the end of this appendix.

A graph of the function used for the drag coefficient (Cd) for the particles can be found after the program listing.

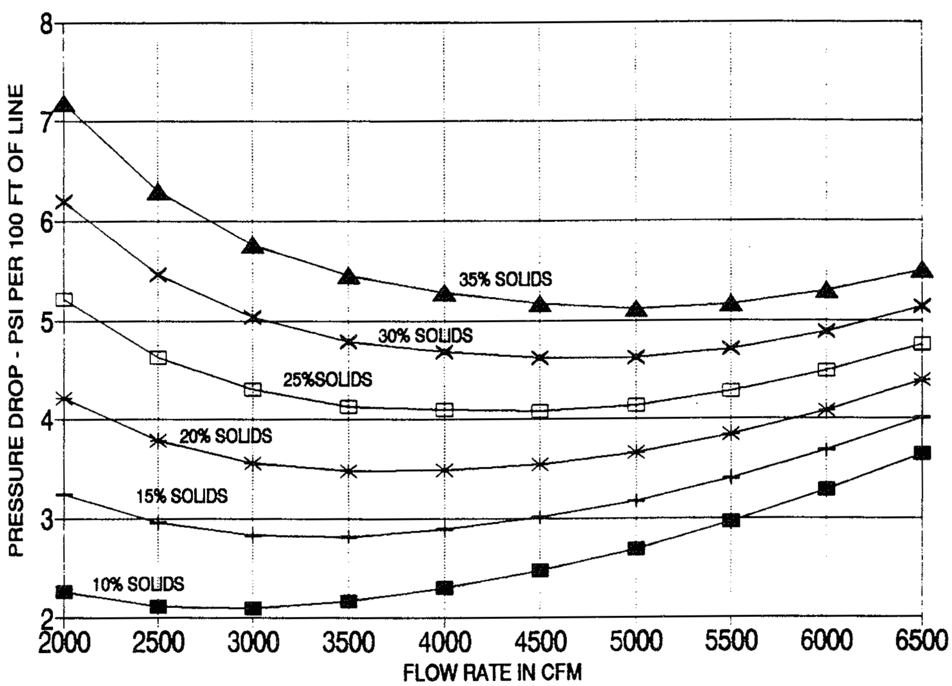
3 Results

The results are to be found in the following pressure drop vs flowrate and solids concentration graphs for various particle sizes. As stated above, it is recommended that the graphs for 0.8 mm particle size be used for estimating pressure drops.

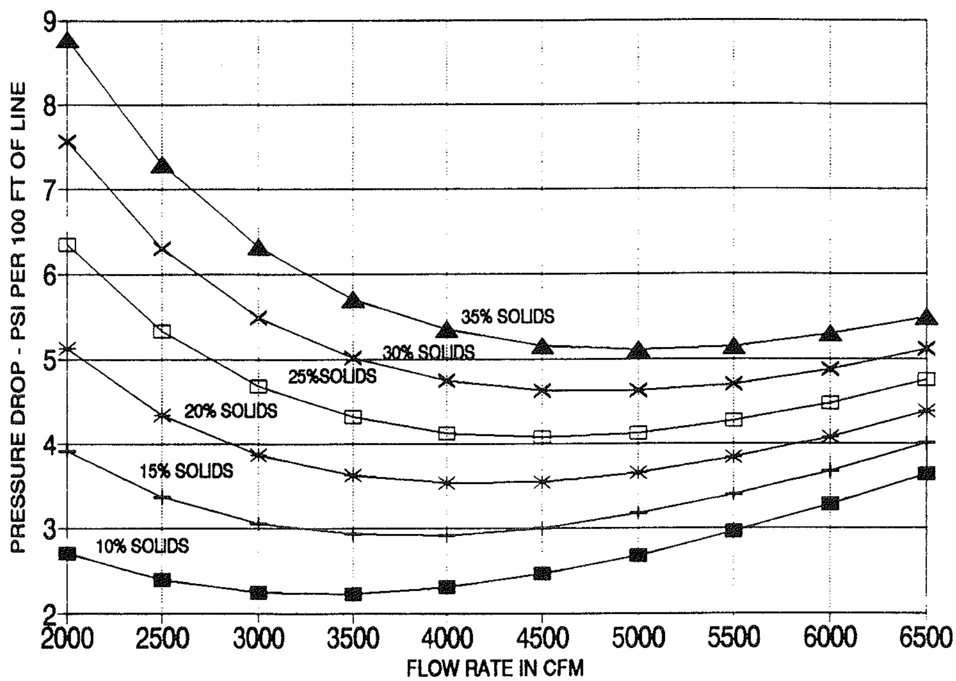
PRESSURE DROP/FLOW RATE GRAPHS
HOSE BORE 28 INCHES - 0.1mm PARTICLES



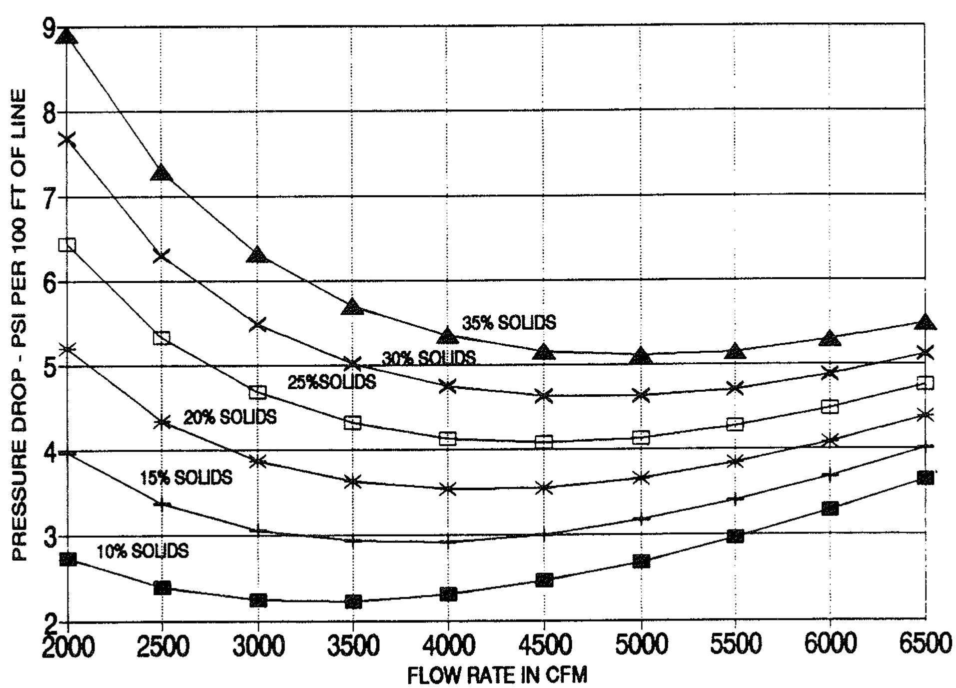
PRESSURE DROP/FLOW RATE GRAPHS
HOSE BORE 28 INCHES - 0.2mm PARTICLES



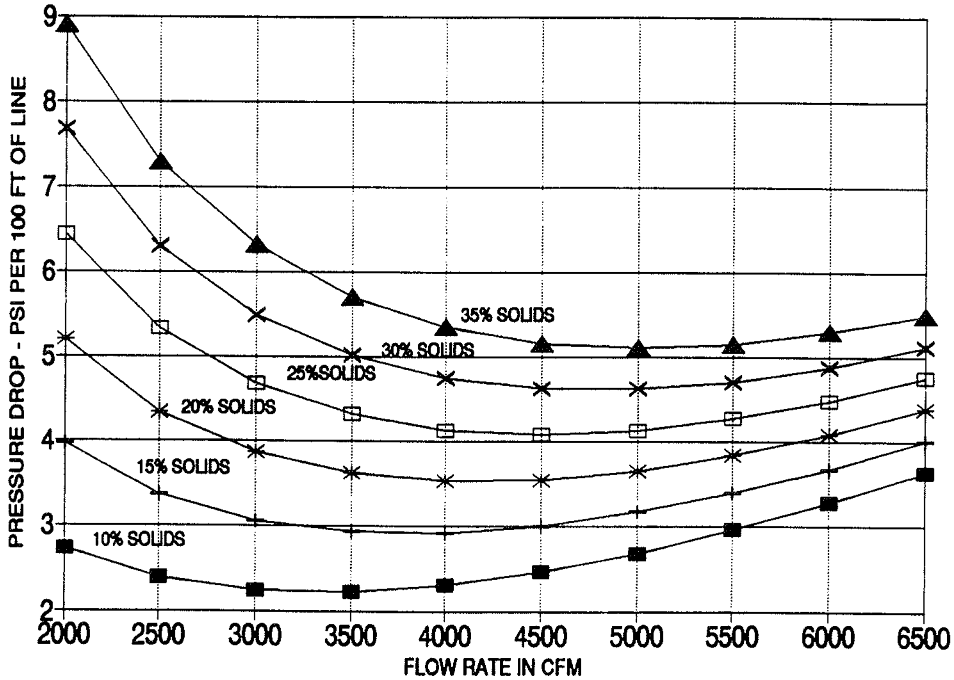
PRESSURE DROP/FLOW RATE GRAPHS
HOSE BORE 28 INCHES - 0.4mm PARTICLES



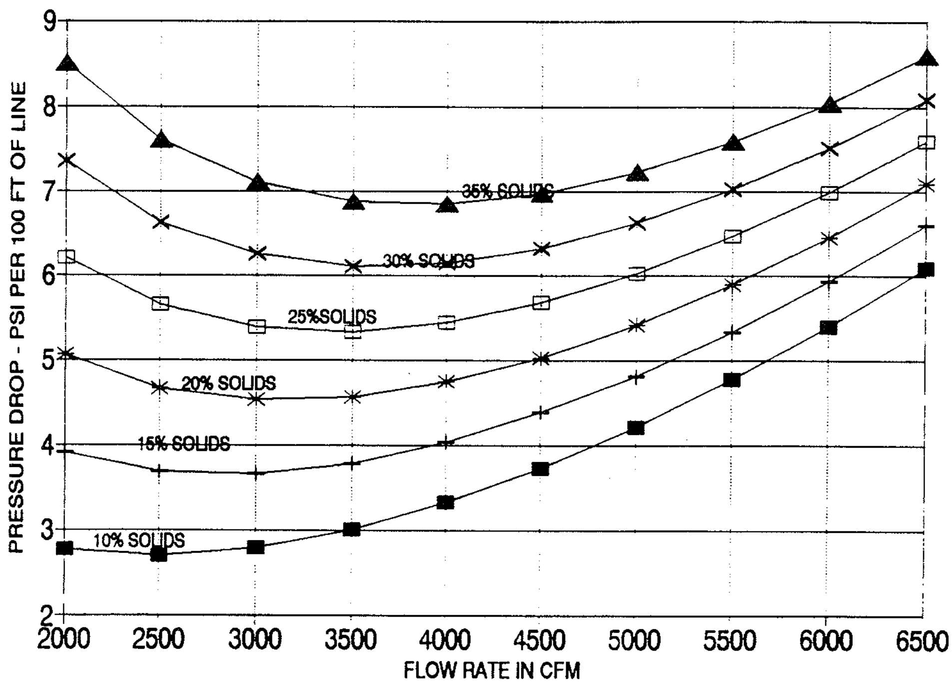
PRESSURE DROP/FLOW RATE GRAPHS
HOSE BORE 28 INCHES - 0.8mm PARTICLES



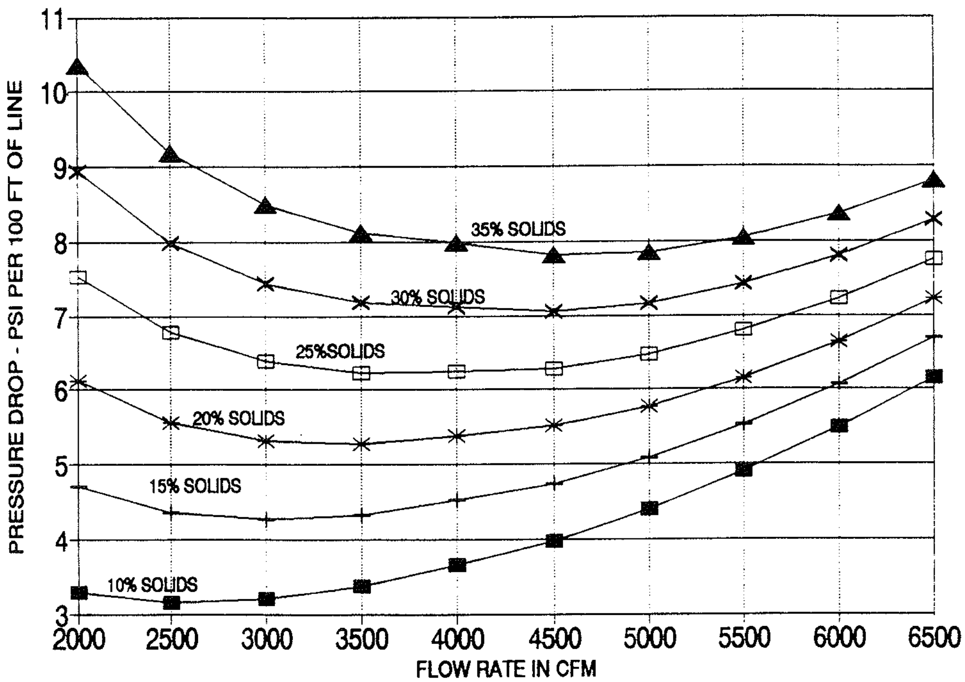
PRESSURE DROP/FLOW RATE GRAPHS
HOSE BORE 28 INCHES - 1.0mm PARTICLES



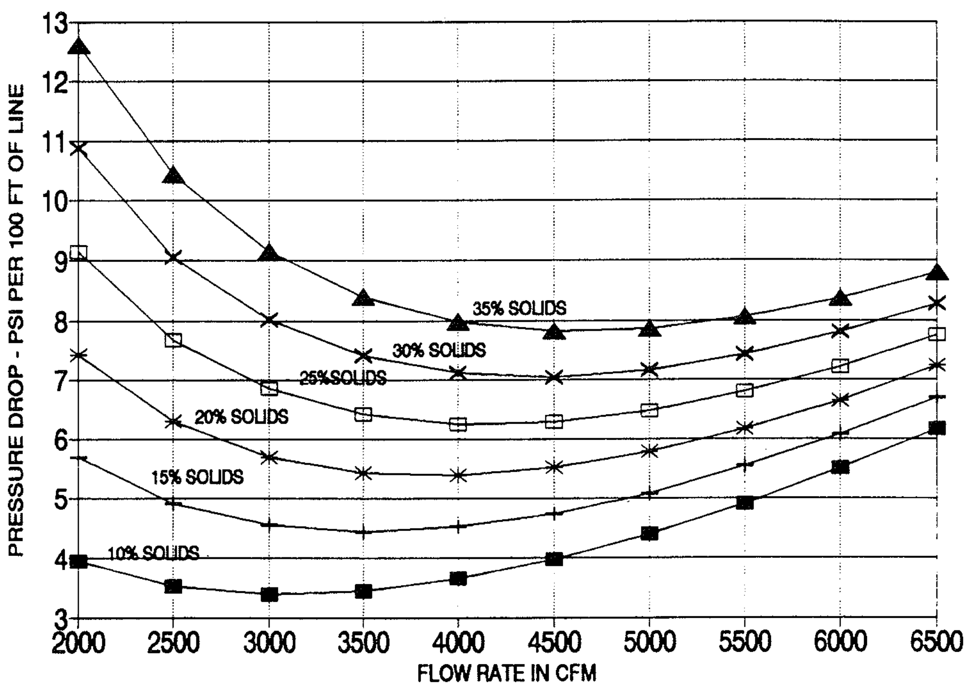
PRESSURE DROP/FLOW RATE GRAPHS
PIPE BORE 27.25 INCH - 0.1mm PARTICLES

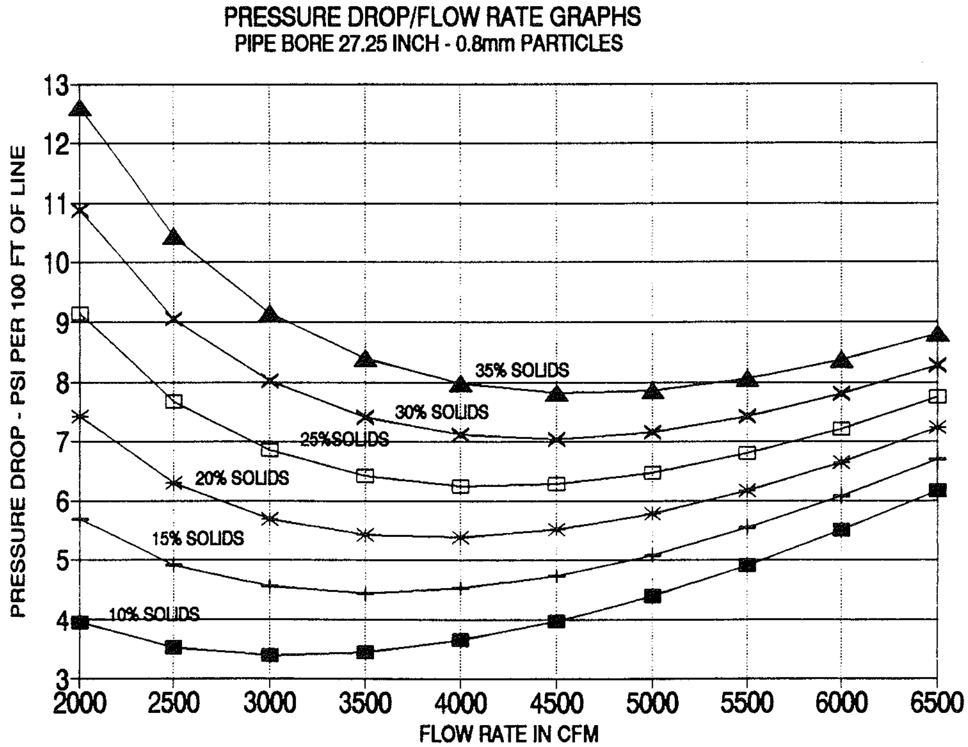


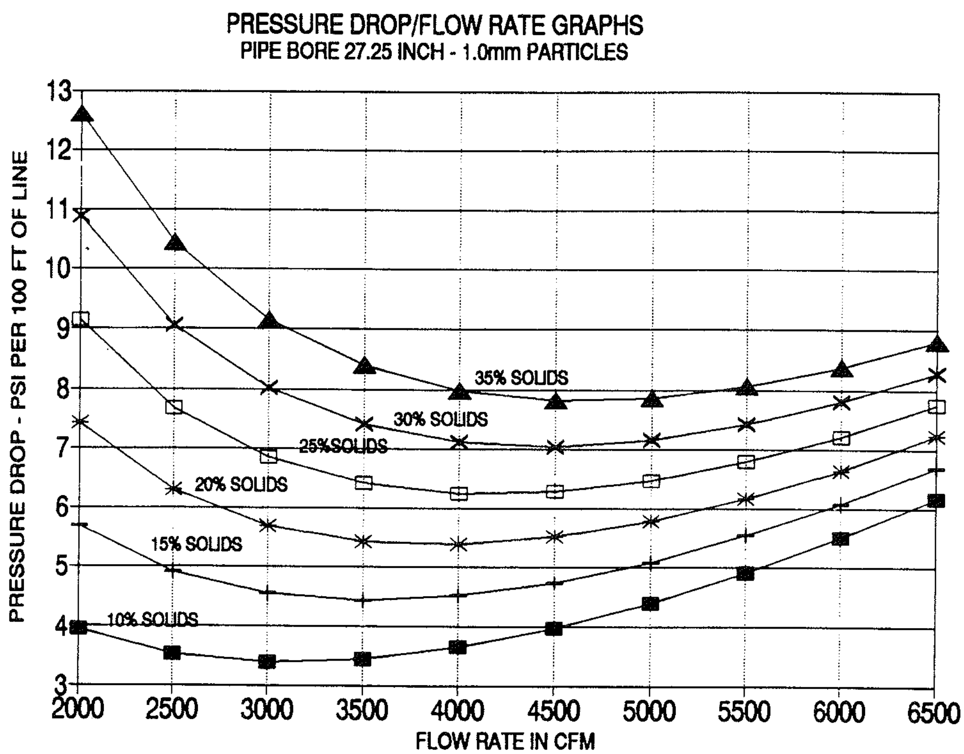
PRESSURE DROP/FLOW RATE GRAPHS
PIPE BORE 27.25 INCH - 0.2mm PARTICLES



PRESSURE DROP/FLOW RATE GRAPHS
PIPE BORE 27.25 INCH - 0.4mm PARTICLES




PRESSURE DROP/FLOW RATE GRAPHS
PIPE BORE 27.25 INCH - 0.8mm PARTICLES
PRESSURE DROP - PSI PER 100 FT OF LINE
13
12
11
10
9
8
7
6
5
4
3
35% SOLIDS
30% SOLIDS
25%SOLIDS
20% SOLIDS
15% SOLIDS
10% SOLIDS
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
FLOW RATE IN CFM


PRESSURE DROP/FLOW RATE GRAPHS
PIPE BORE 27.25 INCH - 1.0mm PARTICLES
PRESSURE DROP - PSI PER 100 FT OF LINE
13
12
11
10
9
8
7
6
5
4
3
35% SOLIDS
30% SOLIDS
25%SOLIDS
20% SOLIDS
15% SOLIDS
10% SOLIDS
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
FLOW RATE IN CFM

4 Example

Flow Rate = 4500 cfm
Particle size = 0.2 mm
Percent Solids = 25%
Hose Bore = 28 inches
Length of Hose 300 ft floating
100 ft submarine
Pipe Bore= 27.25 inches
Length of pipe = 1500 ft

Solution

Hose: 4.09 psi/100 ft * 400 ft = 16.36 psi
Pipe: 6.28 psi/100 ft * 1500 ft = 94.20 psi

Total: 110.56 psi

5 Program Listing

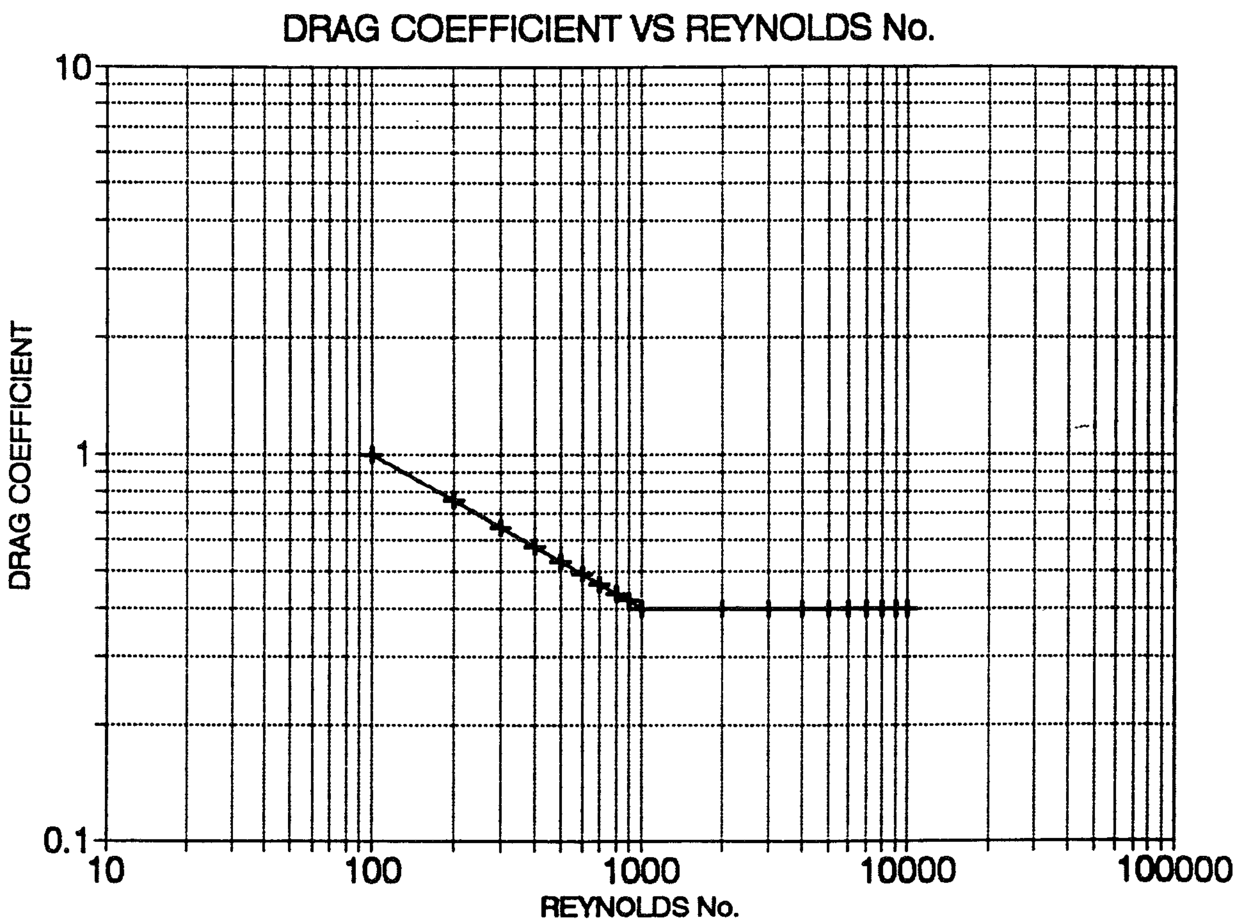
```
DECLARE FUNCTION Cd! (R!)
DECLARE FUNCTION Re! (V!, D!)
'
'This program is written for MicroSoft QuickBasic 4.0. Some modifications
'may be required to use other versions of BASIC.
'
'This program will compute pressure drops for a water / sand slurry. The
'results are written to a file named DROUT. The output is imported into
'a spreadsheet for graphical presentation.
'
'The formulas used are taken from pages 112 - 114 of APPLIED FLUID DYNAMICS
'HANDBOOK by Robert D. Belvins (Van Nostrand Reinhold Co. Inc., 1984) and
'from a publication from DUNLOP entitled PRESSURE DROP, CAPACITY / VELOCITY
'GRAPHS.
'
'The primary variables in this situation are :
'    D       hose or pipe diameter
'    PDIA    particle diameter
'    CON     volume fraction of the solid
'    FLOW    flowrate in cubic feet per minute
'    V       mean velocity -  determined by D and FLOW
'    e       absolute duct roughness
'
'The equations used are those formulated by Durand and Condolios.
'The range studied by Durand and Condolios is:
'    Line diameter from 1.5 to 23 inches
'    Particle diameter from 0.008 to 1.00 inches (0.2 to 25.4 mm)
'    Concentrations from 2% to 22.5% by volume
'
'A combination of line diameter and particle diameter will be selected for
'which the line losses in psi per 100 feet will be calculated for several
'values of solid concentration as the flow rate is varied.
'
'Input the physical constants, increment values etc.
'
SCREEN 0
COLOR 4, 7
CLS 0
REM INPUT "ENTER THE DIAMETER OF THE PIPE / HOSE ==> ", D
REM PRINT "ENTER THE ABSOLUTE ROUGHNESS OF THE PIPE / HOSE"
REM INPUT "(PIPE = 0.06 INCHES, HOSE = 0.010 INCHES) ==> ", e
REM INPUT "ENTER THE VISCOSITY OF THE LIQUID IN cp (WATER = 1.0 cp) ==>", VIS REM INPUT
"ENTER THE SPECIFIC GRAVITY OF THE LIQUID (SG) ==> ", SGL
```

```
REM INPUT "ENTER THE WEIGHT OF THE SOLID IN LB PER CUBIC FT ==>  ", DENSLD
INPUT "ENTER THE SMALLEST PARTICLE SIZE TO BE CONSIDERED (mm)==>",PDIAMIN
REM INPUT "ENTER THE LARGEST PARTICLE DIA TO BE CONSIDERED ==>",PDIAMAX
REM INPUT "ENTER THE INCREMENT VALUE FOR PARTICLE DIAMETER ==>",PDIAINCR
REM INPUT "ENTER THE LOWEST FLOW RATE TO BE CONSIDERED ==>", FLOWMIN
REM INPUT "ENTER THE HIGHEST FLOW RATE TO BE CONSIDERED ==>", FLOWMAX
REM INPUT "ENTER THE INCREMENT VALUE FOR FLOWRATE ==>", FLOWINCR
REM INPUT "ENTER THE MINIMUM CONCENTRATION OF SOLIDS BY VOLUME ==>",
                                                                  CONMIN
REM INPUT "ENTER THE MAXIMUM CONCENTRATION OF SOLIDS BY VOLUME ==>",
                                                                  CONMAX
REM INPUT "ENTER THE INCREMENT VALUE OF SOLIDS CONCENTRATION ==>",
                                                                  CONINCR
D = 27.25
e = .06 ' ==> median value for commercial steel, general rust
'       ==> value for hoses is 0.01 inch, as per Dunlop information.
'
' To generate graphs, interactive input disabled and values assigned below.
'
VIS = 1
SGL = 1!
DENSLD = 96             '==> lbs per cu. ft.
FLOWMIN = 2000            '==> flows in cfm
FLOWMAX = 6500
FLOWINCR = 500
CONMIN = .1
CONMAX = .4
CONINCR = .05
Pi = 3.14159
XAREA = Pi * D ^ 2 / 4 / 144 '==> Duct area in sq. ft.
SGSLD = DENSLD / 62.4 ' ==> s.g. of solid
CON = CONMIN
PDIA = PDIAMIN
OPEN "C:\123\DREDGE\DROUT" FOR OUTPUT AS #1 ' ==> table for input into
'                                              spreadsheet.
WRITE #1, PDIA
DO WHILE CON <= CONMAX
  WRITE #1, CON
  FLOW = FLOWMIN
  DO WHILE FLOW <= FLOWMAX
    V = FLOW / XAREA / 60     '==> flow velocity, fps
    Red = Re(V, PDIA / 25.4)  '==> particle Reynolds No.
    Cdd = Cd(Red)             '==> particle drag coeff.
    Ree = Re(V, D)            '==> pipe/hose Reynolds No.
    FI = (1.14 - 2 * .43438 * LOG(e / D + 26.25 / Ree ^ .9)) ^ -2
```

```
    Fs = 81 * Fl * CON * (32.2 * D / 12 / V ^ 2 / Cdd ^ .5 * (SGSLD - 1)) ^ 1.5
    DELP = 62.4 / 32.2 * SGL * V ^ 2 / 2 * 1200 / D * (Fl + Fs) / 144
    WRITE #1, FLOW, V, V / 3.2808, DELP, DELP * .0328 / 1.42168
    FLOW = FLOW + FLOWINCR
  LOOP
  CON = CON + CONINCR
LOOP
END

FUNCTION Cd (R)
  IF R < 1000 THEN
    Cd = 10 ^ (-.3979 * (LOG(R) / 2.3026 - 2))
  ELSE
    Cd = .4
  END IF
END FUNCTION

FUNCTION Re (V, D)
  SHARED SGL, VIS
  Re = V * SGL * 62.4 * 123.9 * D / VIS
END FUNCTION
```


DRAG COEFFICIENT VS REYNOLDS No.
10
1
0.1
DRAG COEFFICIENT
10
100
1000
10000
100000
REYNOLDS No.

DREDGE MOORING STUDY
Phase II Report

APPENDIX D
SYSTEM TIME/RESOURCE ANALYSIS
TRANSPORT, ASSEMBLY & INSTALLATION

July 15, 1991

SOFEC, Inc. - Houston, TX
Project No. 667

U.S. Army Corps of Engineers
Waterways Experiment Station

Contract No. DACW39-90-C-0075

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LIST OF FIGURES

1 DPO SPM Transportation Requirements.

1.1 The transportation analysis of the DPO SPM system is based on the use of over-the-road trucks. This method of transport provides the most extensive coverage of the geographical areas of the nation. The system has not been analyzed specifically for rail or barge transport on the premise that truck transport dictates a more stringent weight criteria and cube requirement.

1.2 To minimize overall system life cycle cost, it is assumed that the system will be primarily working on station or held in storage at a staging yard. The fleet of trucks required for shipping the system are required temporarily. Therefore, maximum utilization of rental trucks is envisioned. As part of the initial contract, each component shall be provided with the requisite support blocking/frame to facilitate truck shipment. In addition to the system components and their support blocking/frame, the material requiring transport includes the material handling system, i.e., slings, shackles, spreader bars, come-alongs, and assembly equipment, i.e., air compressor, air hose, air tools, drifts, assembly stands, etc. It is recommended the DPO SPM system and support equipment be configured to ship on the type of rental truck trailer most commonly available in the freight forwarding industry and referred to as a "40' Float".

1.3 The specification description of the "40' Float" trailer is a forty feet long, maximum fifty six inches high fixed bed, platform style, two axle, kingpin trailer with a gross capacity of forty tons and an actual usable payload capacity of approximately twenty five tons (50 kips).

1.4 The vehicle requirements, both number and type, for transport of the DPO SPM system is controlled by the following factors: Total component weight and weight distribution per vehicle, total component cube per vehicle with specific limitations on overall height and width, and contingency planning constraints. The first two items are self explanatory; however, contingency planning constraints will be further explained. Contingency planning constraints encompass the possibility of a vehicle breakdown or delay, space limitation at the assembly staging area, limited rental fleet availability in a particular geographic area, or overall system transport costs.

1.5 The following scenario presents an example of contingency planning constraint. Assume for a specific deployment that the DPO SPM system was configured and shipped using the minimum transportation cost, i.e., minimum number of rental trucks, as the primary constraint. Enroute to the staging area the truck carrying the majority of the load handling equipment and assembly tools has mechanical problems and is delayed. At the staging area, the deployment of the system is halted with the concurrent cost of an idle crew, crane, and loaded rental trucks. Per the example, it is recommended that the trucks be loaded, as much as possible, with complete component subassemblies and supporting material handling and assembly equipment.

1.6 To meet highway height restrictions the buoy hull will require a "low boy" style trailer, as depicted in Method 1, Drawing 667-P2-7, Figure 1.1. "Low boy" trailers with sufficient length and capacity are not normally readily available in the majority of truck rental fleets. Two alternative solutions for this problem are available. A "low boy" style trailer can be purchased as part of the Contract and dedicated to the transport of the buoy hull, i.e., Method 1. Conversely, the buoy could incorporate in its design the attachment rails for a tandem axle assembly and a fifth wheel kingpost assembly, with the additional purchase of the tandem axle assembly. This configuration is depicted as Method 2, Drawing 667-P2-8, Figure 1.2. A cost-benefit analysis and life cycle analysis should be conducted to indicate the optimum solution for transport of the buoy hull.

1.7 The following shipping configuration, listed in the desired order of arrival at the assembly/deployment staging area and encompassing shipping segregation of SPM components into complete subsystems and requisite support equipment, is presented:

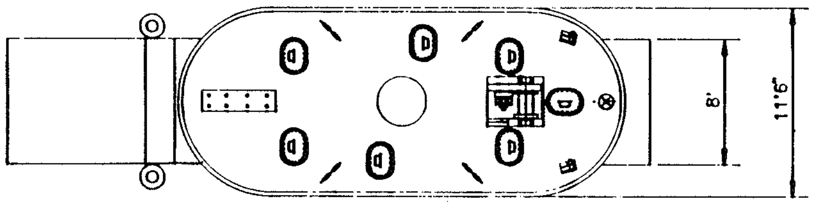
TRUCK	LOAD	WEIGHT	HEIGHT/WIDTH
1	Three underbuoy hoses (35') Hose handling frame Two leg chain sling Three nylon slings Buoy piping assembly Four shots of anchor chain Hose hardware, Air compressor Assembly tools-impact wrenches, standard tool kit, Two spar buoys	45 kips	14 / 8 feet
2	Two marine anchors w/pins Seven shots of anchor chain Two half shots of anchor chain One short shot of anchor chain Anchor chain connecting links Four anchor pendant buoys Assembly tools-hammers, pliers, come-along	46 kips	10 / 8 feet
3	Two marine anchors w/pins Seven shots of anchor chain Two half shots of anchor chain One short shot of anchor chain	46 kips	10 / 8 feet

	Anchor chain connecting links Four anchor pendant buoys Assembly tools-hammers, pliers, come-along		
4 *	4-part heavy lift sling ass'y Towing bridle, Two buoy stands Mooring table, Buoy lift frame Air compressor, Assembly tools -impact wrenches, standard tool kit Buoy rigging and blocks Anchor tensioner w/ rigging Four half shots of anchor chain Two short shots of anchor chain	46 kips	10 / 12 feet
5 *	Buoy hull	44 kips	12 / 12 feet
6	Four floating hoses (35') Three shots of anchor chain Hose hardware	40 kips	13 / 8 feet
7	Three floating hoses (35') Three shots of anchor chain Mooring hawser assembly Chain stopper assemblies Hose hardware	35 kips	12 / 8 feet

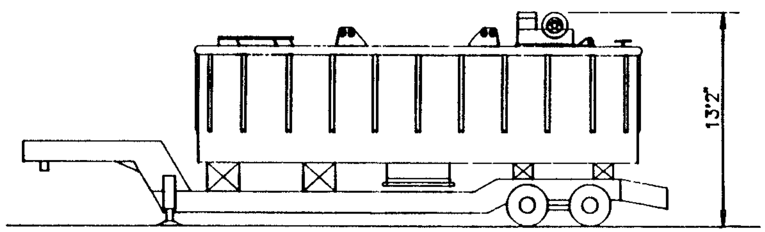
1.8 As depicted in the above shipping plan, only two vehicles of the seven, denoted by (*), will require a permit for transport. Both vehicles will require a wide load permit. All vehicles are within maximum weight limits.

1.9 A typical industry procedure in shipping heavy freight on trucks is for the truck supplier to supply the tie-down chains or nylon straps, normally per the customer's preference, upon request by the customer.

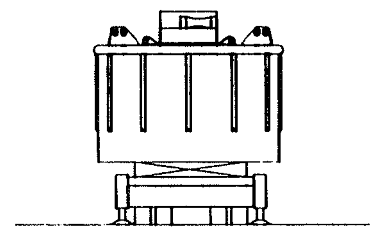
1.10 The truck tractors, driver, and, depending on trucking company or distance of shipment, assistant driver are provided by freight forwarding company.



PLAN



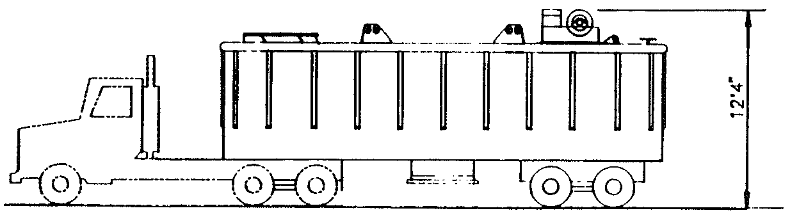
ELEVATION



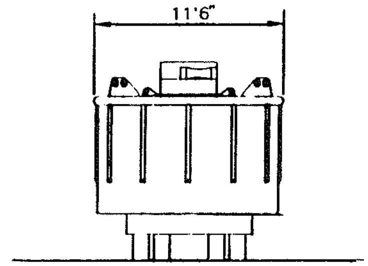
REAR VIEW

FIGURE 1.1

DREDGE MOORING STUDY TRUCK TRANSPORT METHOD 1			
CAD FILE:TRL	DWN. BY: D.Mc.	DWG. NO. 667-P2-7	
PLOT DATE:7/12/91	DATE: 2/20/91	REV. 0	SHEET 1
PLOT SCALE: 1:48			



ELEVATION



REAR VIEW

FIGURE 1.2

DREDGE MOORING STUDY TRUCK TRANSPORT METHOD 2			
CAD FILE: TRL2	DWN. BY: D.Mc.	DWG. NO. 667-P2-8	
PLOT DATE: 7/12/91	DATE: 7/10/91	REV. 0	SHEET 1
PLOT SCALE: 1:48			

2 DPO SPM Assembly and Marine Installation

2.1 Staging Area: The DPO SPM assembly and marine deployment staging area shall be located along a dock or similar structure that can support the use of heavy equipment and has a channel with a minimum depth of twelve (12) feet for marine deployment and tow of the SPM buoy. The staging area should encompass an obstacle free, well drained, flat area capable of supporting heavy trucks. Approximate dimensions of the staging area would be not less than 300 feet by 250 feet. A frontage of 300 feet on the water is desired.

2.2 Staging Area Equipment: A mobile rental crane or a fixed crane with sufficient capacity and boom length is required on site during buoy and component unloading, assembly, deployment, recovery, disassembly, and loading for transport. Minimum crane capacity during buoy assembly and launch is 60 kips at 20 feet radius. The following cranes can meet this criteria: 60 ton wheeled rough terrain crane, 50 ton hydraulic truck crane, 50 ton lattice boom crawler crane, or port stevedoring cranes over 100 tons. Crane manpower requirements is two personnel, operator and rigger/oiler.

2.3 Assembly/Marine Deployment

DAY 1

@ Staging area: Unload Truck 1 at dock edge.

1. Rig two leg chain sling on crane.
2. Unload buoy piping assembly and set aside, out of the way.
3. Unload hose hardware and standard tool kit.
4. Rig three nylon slings on hose spreader beam and rig spreader beam to two leg chain sling on crane.
5. Unload three underbuoy hose sections and align along edge of dock, parallel to channel, and hand fit up flange connections during unloading process. Remove and stow hose spreader beam assembly.
6. Unload the air compressor, assembly tools-impact wrenches, blind flange, towing padeye assembly, and complete make up of underbuoy hose string to towing configuration.
7. Unload two spar pendant buoys and stow on tow vessel dedicated to the tow of the under buoy hose assembly.
8. Unload four shots of anchor chain and stow near dock edge.

9. Upon completion of the make up of the underbuoy hose assembly, the hose assembly is connected to the tow bridle of the tow vessel, and lowered into the water. The under buoy hose assembly is towed to the marine deployment site for connection to the submarine pipe line before it is lowered to the sea floor.

Crew = 5 personnel. Estimated elapsed time = 5 hours. Truck 1 is released.

@ Staging area: Unload Truck 2 at dock edge, opposite Truck 1 location.

1. Unload two marine anchors w/ pins using crane with two leg chain sling. Assemble anchor shank to fluke on both anchors by aligning pin holes and inserting pins. Note: Set anchor shank angle to correct angle per marine site soil condition requirements.

2. Load both anchors onto stern of anchor handling vessel.

3. Unload the following material from Truck 2 and load onto anchor handling vessel as vessel crew indicates: seven full shots, two half shots, and one short shot of anchor chain; anchor chain connecting links; four anchor pendant buoys and the assembly tools.

4. The remaining items on Truck 2 shall be unloaded after the truck is repositioned in the vicinity of the anchor chain unloaded from Truck 1.

@ Staging area: Unload Truck 3 at the position just vacated by Truck 2.

1. Unload the following material from Truck 3 and load onto anchor handling vessel as vessel crew indicates: three full shots, two half shots, and one short shot of anchor chain.

NOTE: At this point the anchor handling vessel is loaded with two complete chain leg assemblies and its crew is securing the load for sea transport, connecting the chain shots with baldt links and connecting the anchors to the initial chain shots with pearlinks.

2. Move Truck 3 and the crane to location of Truck 2 and complete the unloading of both trucks.

Crew = 5 personnel. Estimated elapsed time = 6 hours. Trucks 2 & 3 are released.

@ Marine Site: Underbuoy Hose Tow Vessel

1. The underbuoy hose is raised and aligned by the barge crane installing the submarine pipeline, the quick release blind flange is

removed and stowed on the tow vessel, and the pipeline to hose assembly joint is made up.

2. A spar pendant buoy is attached to the pipeline/hose joint; a spar pendant buoy is attached to the end of the underbuoy hose.

3. The tow padeye assembly and tow bridle are removed from the hose and stowed on the tow vessel.

4. The pipeline and hose are lowered to the seafloor.

Crew = 3 personnel. Estimated elapsed time = 1 hour. Tow vessel returns to dock and unloads blind flange, and tow padeye assembly to designated storage site.

NOTE: Travel time is not included in elapsed time estimates.

@ Dock: Anchor Handling Vessel

1. Crew continues securing the load for sea transport, connecting the chain shots with baldt links and connecting the anchors to the initial chain shot with a pearlink.

NOTE: The anchor handling vessel is equipped with a minimum of two independent winch drums for the controlled pay out, under tension, of the anchor chains during deployment.

Crew = 4 personnel. Estimated elapsed time = 2 hours.

DAY 2

@ Staging area: Position Truck 4 near existing anchor storage area.

1. Unload anchor chain tensioner with rigging and load onto anchor handling vessel.

NOTE: Anchor handling vessel departs to deploy two opposing anchor legs at the marine site.

2. Unload the following items from Truck 4 and place in vicinity of anchors: four half shots and two short shots of anchor chain.

3. Unload the buoy lift frame from truck 4 and place in the vicinity of the buoy piping assembly.

4. Move Truck 4 and the crane to the center of the dock frontage approximately 30 feet from the edge of the water.

5. Unload the air compressor, assembly tools-impact wrenches, buoy rigging and blocks, towing bridle, and remove the two leg chain sling from the crane.

6. Rig the crane with the four part heavy lift sling assembly.

7. Survey site to position crane and buoy assembly site in proper position for buoy launch. Without moving crane, the crane should be capable of:

    1. Unloading mooring table and buoy hull from trucks to the designated buoy assembly site.

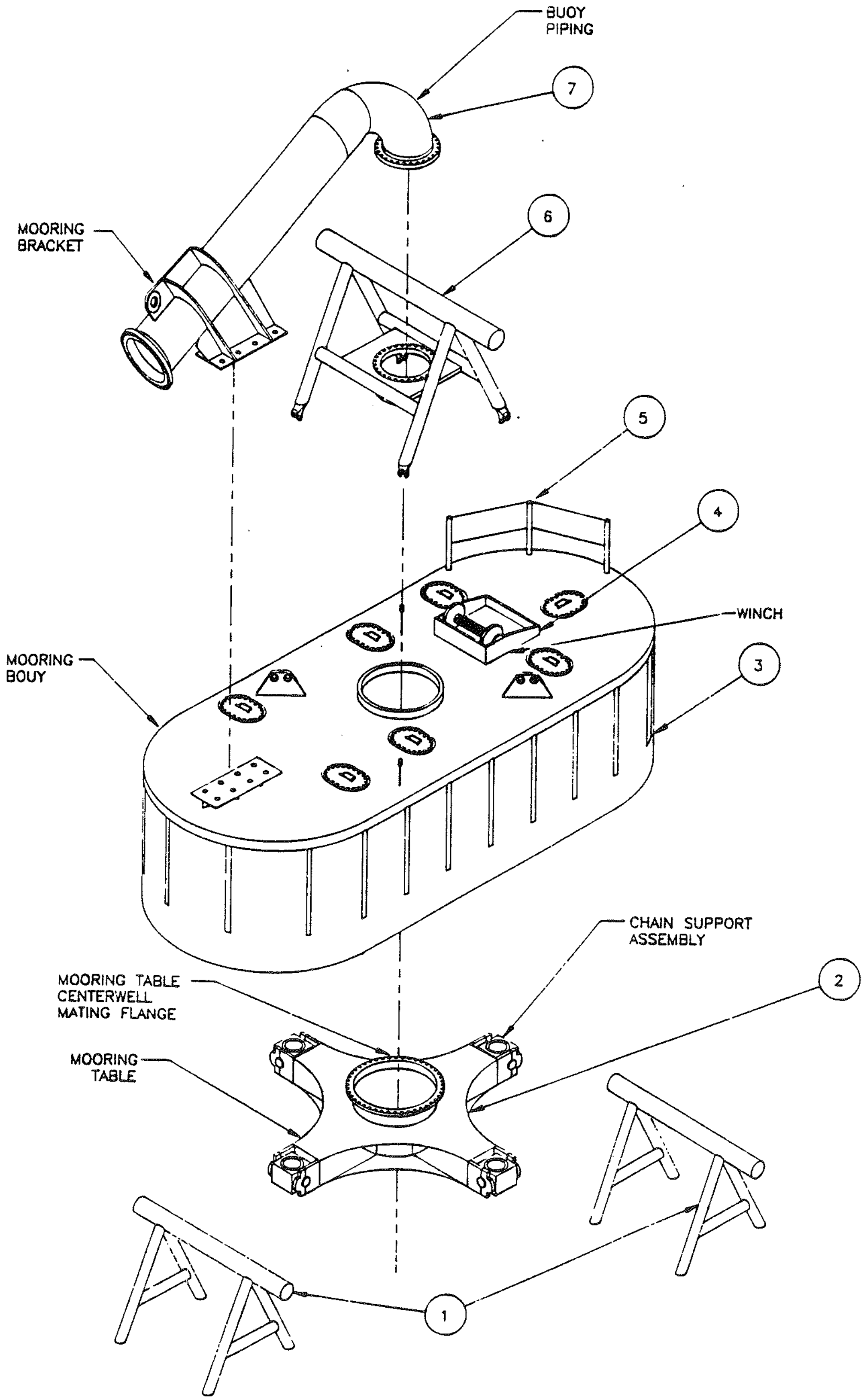
    2. Lift buoy hull/mooring table assembly, swing unit over the water, and lower/launch unit without exceeding the load-radius capacity of the crane and without encountering obstructions.

    3. Anticipated radius for lifts is 20 feet.

NOTE: Refer to Figure 2.1 for identification of components involved in the buoy assembly:

1. Buoy stands.
2. Mooring table complete with chain support assemblies.
3. Buoy hull.
4. Onboard winch.
5. Portable handrails.
6. Buoy lift frame assembly.

FIGURE 2.1


BUOY
PIPING
7
MOORING
BRACKET
6
5
4
WINCH
MOORING
BOUY
3
CHAIN SUPPORT
ASSEMBLY
MOORING TABLE
CENTERWELL
MATING FLANGE
2
MOORING
TABLE
1

7. Buoy piping assembly.

8. Unload the mooring table and locate it on firm level ground approximately 12 feet from the edge of the water.

9. Unload the two tubular buoy stands and locate them on firm ground on either side of the mooring table, approximately 4 feet and 26 feet, respectively from the edge of the water.

Crew = 5 personnel. Estimated elapsed time = 4 hours. Truck 4 is released.

@ Staging area: Position Truck 5 at location exited by Truck 4

1. Rig the heavy lift sling assembly to the buoy hull and support the majority of the buoy hull weight with the crane. Release the fifth wheel and tandem axle assembly. Lift the buoy hull free and have the truck tractor move out of the way.

2. Swing the buoy hull into alignment over the mooring table. While manually maintaining joint alignment, lower the buoy hull onto the buoy stands.

3. Make up the mooring table to buoy hull joint.

4. Raise the buoy assembly, remove the outboard buoy stand, swing the buoy assembly 90° and launch the buoy.

5. Secure the buoy to the dock and remove the heavy lift slings.

6. Truck 5 moves the tandem axle assembly to a designated storage area and is released.

Crew = 5 personnel. Estimated elapsed time = 2 hours. Truck 5 is released.

@ Staging area: Move crane to locations as required.

1. Move crane to designated storage area and remove heavy lift sling assembly.

2. Rerig crane with two leg chain sling.

3. Move the buoy stands to the designated storage area.

4. Position the crane at the marine anchors.

5. Assemble anchor shank to fluke on both anchors by aligning pin holes and inserting pins. Note: Set anchor shank angle to correct angle per marine site soil condition requirements.

Crew = 5 personnel. Estimated elapsed time = 1.5 hours.

@ Staging area: Move Trucks 6 & 7, in turn, to the anchor area.

1. Unload three full shots of anchor chain from Truck 6.

2. Unload three full shots of anchor chain from Truck 7.

3. Rig three nylon slings on hose spreader beam and rig spreader beam to two leg chain sling on crane.

4. Move crane and both trucks to a designated area free of material along the dock at the edge of the water and offload the seven surface hose sections and hose hardware.

5. Remove the hose handling rigging from the crane.

6. Unload the mooring hawser assembly.

Crew = 5 personnel. Estimated elapsed time = 4 hours. Trucks 6 & 7 are released.

@ Marine Site: Anchor Handling Vessel

1. In route to marine site, crew completes installation of all anchor connecting links and installs anchor pendant buoys on both anchors and on chain leg Number 1.

2. On station at the anchor set down point for chain leg Number 1 the anchor is deployed by alternately feeding out anchor chain under tension with the two hoists as the vessel steers to the pipeline spar buoy. See Figure 2.2 for typical anchor leg arrangement.

3. The vessel continues on its present course until all the anchor chain in chain leg Number 1 is expended and the attached anchor pendant buoy is deployed.

4. The vessel now takes up a reverse course from on station at the anchor set down point for chain leg Number 3. The chain leg opposite chain leg Number 1. The anchor is deployed by alternately

FIGURE 2.2

TYPICAL ANCHOR LEG ARRANGEMENT

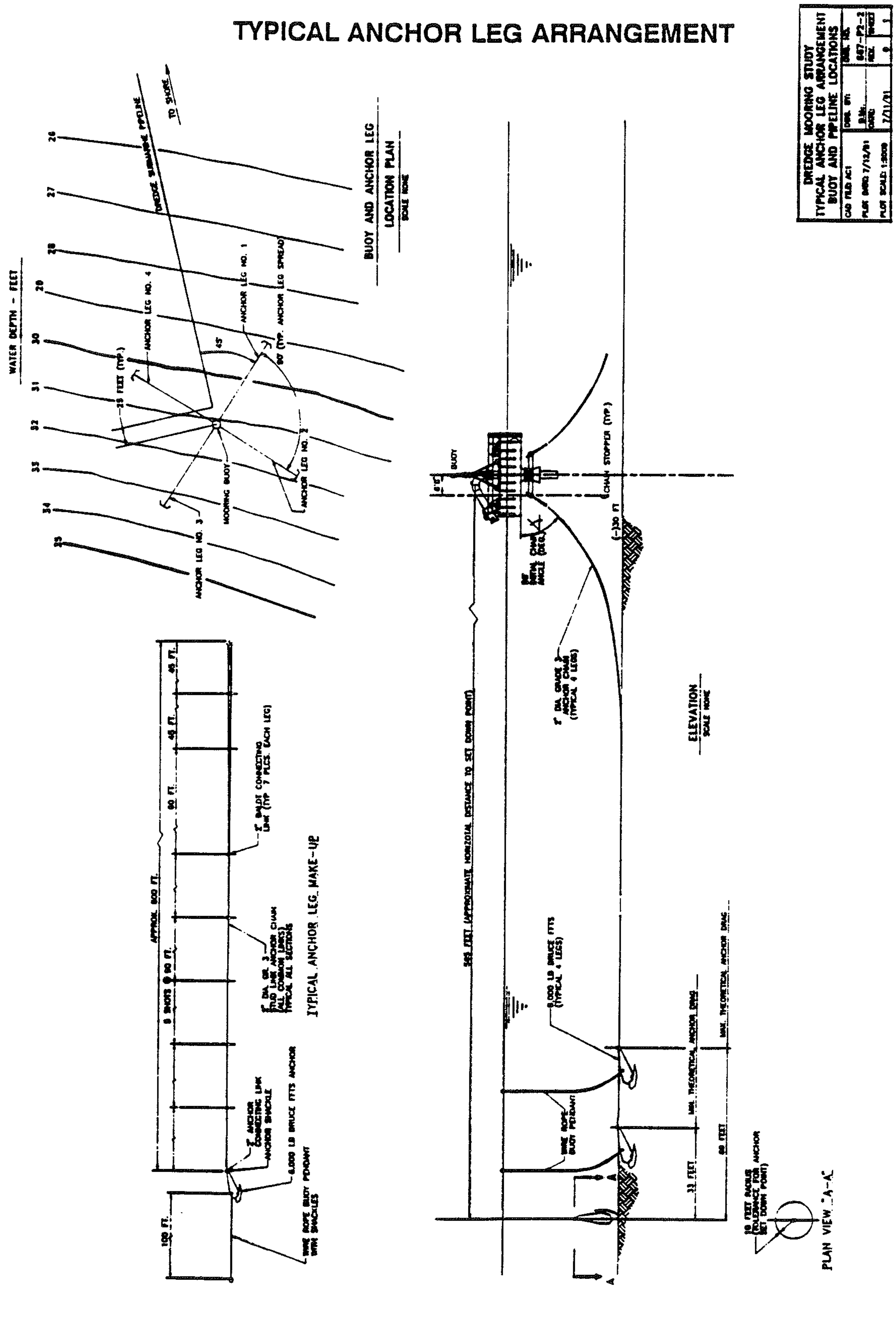
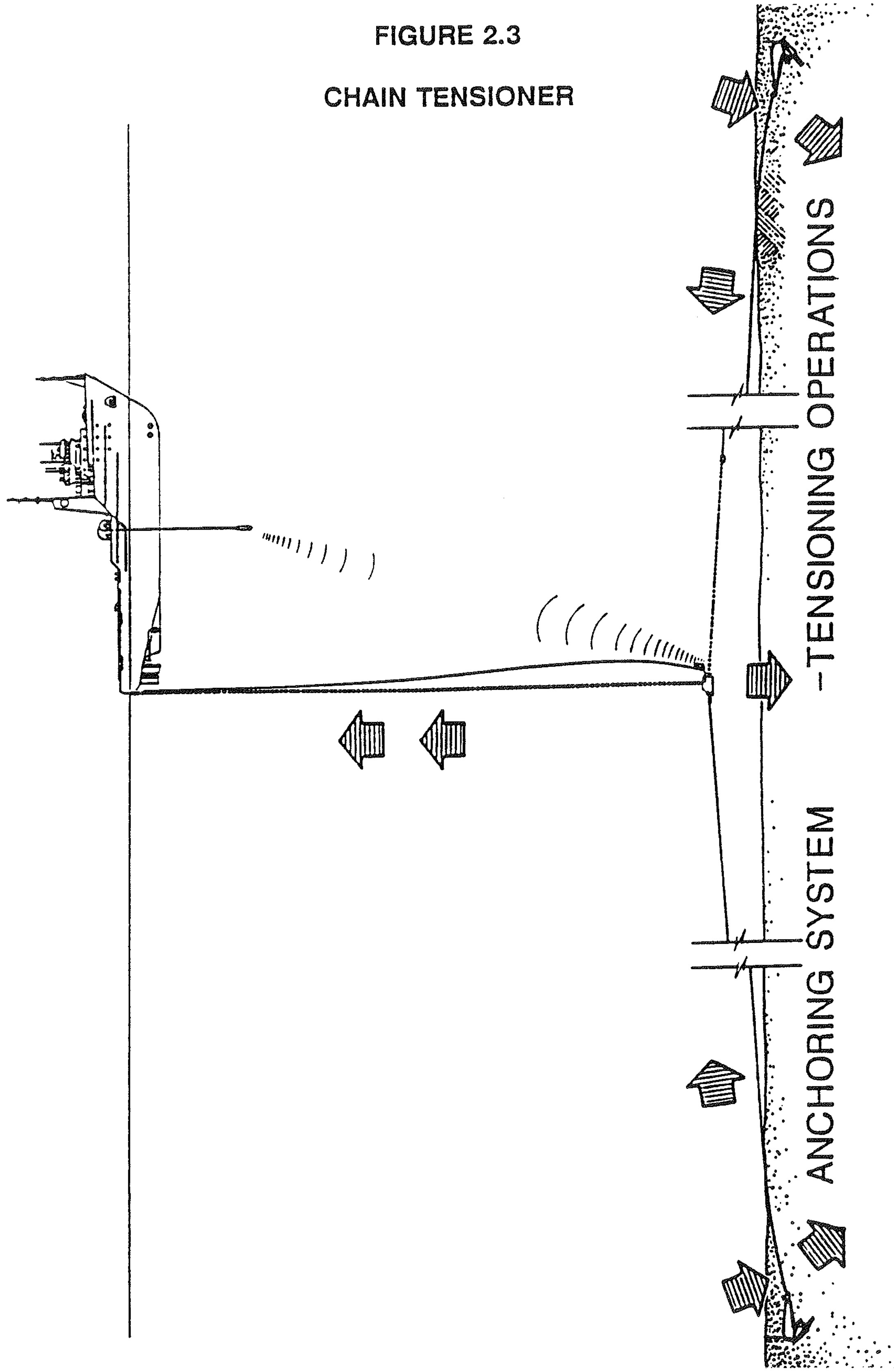


FIGURE 2.3

CHAIN TENSIONER



feeding out anchor chain under tension with the two hoists as the vessel steers to the pipeline spar buoy.

5. Enroute back to the pipeline spar buoy location, the pendant buoy deployed at the end of chain leg Number 1 is recovered and the end half shot of chain leg Number 1 is recovered on the vessel deck.

6. The pendant buoy is removed from anchor leg Number 1 and both anchor leg Number 1 and 3 are rigged in the chain tension device. The device and its operation is depicted in Figure 2.3.

7. The anchor handling vessel will then pretension both anchors utilizing the chain tensioner.

8. The chain tensioner is recovered, both anchor chain ends will be marked with the buoy pendants and lowered overboard at approximately 50 feet from the pipeline spar buoy.

9. The anchor handling vessel will then return to the dock/staging area.

Crew = 4 personnel. Estimated elapsed time = 6.0 hours.

DAY 3

@ Dock: Anchor Handling Vessel

1. Load both anchors onto stern of anchor handling vessel.

2. Load the following material onto the anchor handling vessel as vessel crew indicates: ten full shots, four half shots, and two short shot of anchor chain; anchor chain connecting links; and four anchor pendant buoys.

NOTE: At this point the anchor handling vessel is loaded with two complete chain leg assemblies and its crew is securing the load for sea transport, connecting the chain shots with baldt links and connecting the anchors to the initial chain shots with pearlinks.

3. Anchor handling vessel departs dock to buoy installation site.

Crew = 5 personnel. Estimated elapsed time = 4 hours.

@ Staging Area:

1. The buoy lift frame is positioned on and pinned to the buoy.

2. The buoy piping assembly is positioned in alignment at the hose swivel and deck attachment points and the joints are made up.

3. The chain tensioning rigging is installed on the buoy, the air winch operation verified and the components secured to the buoy.

4. The mooring hawser assembly is installed on the buoy and secured to the deck.

5. The navigational and safety equipment is installed and their correct operation verified.

6. The buoy tow bridle is installed and secured.

Crew = 5 personnel. Estimated elapsed time = 4 hours.

@ Marine Site: Anchor Handling Vessel

1. Enroute to the marine site, the crew completes installation of all anchor connecting links and installs anchor pendant buoys on both anchors and on chain leg Number 2.

2. On station at the anchor set down point for chain leg Number 2 the anchor is deployed by alternately feeding out anchor chain under tension with the two hoists as the vessel steers to the pipeline spar buoy.

3. The vessel continues on its present course until all the anchor chain in chain leg Number 2 is expended and the attached anchor pendant buoy is deployed.

4. The vessel now takes up a reverse course from on station at the anchor set down point for chain leg Number 4. The chain leg opposite chain leg Number 2. The anchor is deployed by alternately feeding out anchor chain under tension with the two hoists as the vessel steers to the pipeline spar buoy.

5. Enroute back to the pipeline spar buoy location, the pendant buoy deployed at the end of chain leg Number 2 is recovered and the end half shot of chain leg Number 2 is recovered on the vessel deck.

6. The pendant buoy is removed from anchor leg Number 2 and both anchor leg Number 2 and 4 are rigged in the chain tension device.

7. The anchor handling vessel will then pretension both anchors utilizing the chain tensioner.

8. The chain tensioner will be recovered, both anchor chain ends will be marked with the buoy pendants and lowered overboard at approximately 50 feet from the pipeline spar buoy.

9. The anchor handling vessel will then return to the dock/staging area and return the chain tensioner with rigging, the assembly tools, and the chain bundle slings to the designated storage area.

Crew = 4 personnel. Estimated elapsed time = 6.0 hours.

DAY 4

@ Dock: Buoy Tow Vessel

1. The chain stopper assemblies are stowed on the towing vessel and the buoy is towed to the marine installation site.

2. The mooring table is positioned to allow use of the chain tensioning rigging. The air winch air supply line is installed.

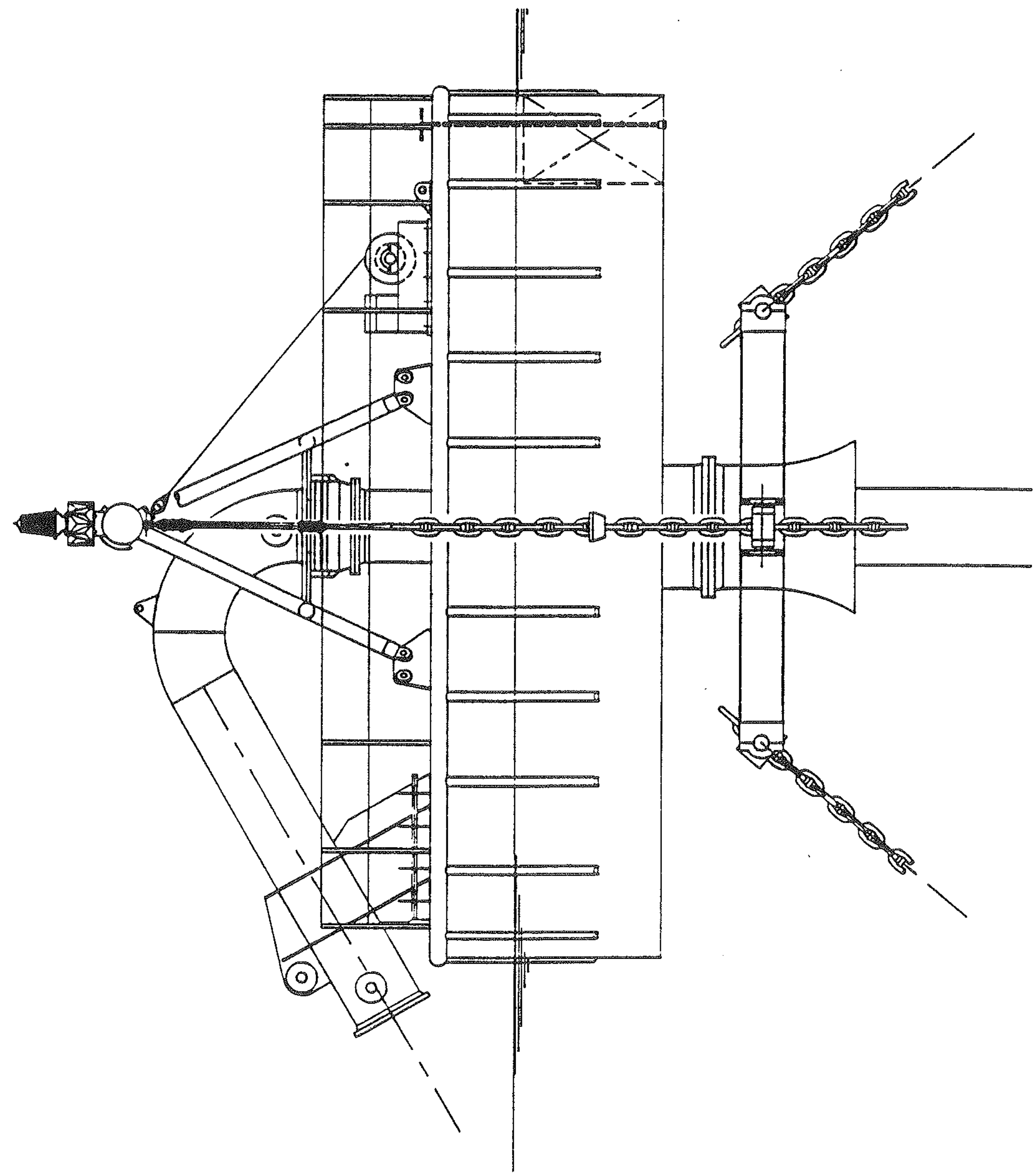
3. The up current chain leg pendant buoy is secured and the pendant is threaded through the appropriate mooring table chain support stopper. This operation can be accomplished easily by a diver and, if desired, with a little more difficulty, from the surface of the buoy deck. The pendant is hoisted in using the chain tensioning rigging and choker slings until the chain is obtained. The pendant buoy is then removed from the chain, reassembled and stowed on the tow vessel.

4. The chain is tugged in by the chain tensioning winch until there is approximately ten excess chain links. See Figure 2.4 for an illustration of the chain tensioning rigging and procedure. The chain is secured at the top of the buoy lift frame by a stationary choker sling so the block can be cycled for the next pull.

5. A chain stopper assembly is installed and the chain is lowered into the chain support assembly.

FIGURE 2.4

CHAIN TENSIONING RIGGING ARRANGEMENT



6. The process is repeated until all the chain legs are installed.

7. A measurement of the relative chain angles by a diver for each chain leg and a measurement of the buoys actual location relative to its design location will provide the data required to determine the correct chain link adjustment to place the buoy in its design location with each chain leg at its proper chain angle.

8. Each chain leg is readjusted utilizing the chain tensioning rigging as previously described to adjust the amount of chain links as determined in Step 7.

9. The diver remeasures the chain angles to verify the adjustment in Step 8. The new location of the buoy is checked against the design location.

10. The chain tensioning rigging is secured on the buoy. The tow bridle is recovered onto the tow vessel and the vessel returns to the dock/staging area.

Crew = 4 personnel. Estimated elapsed time = 8.0 hours.

@ Staging area:

1. The crane is rigged with the hose lifting frame.

2. The seven surface hose sections are lifted, in turn, and moved to the edge of the dock. The hose sections are located, in a single line, parallel to the edge of the water. The crane positions the hose sections so the hose flanges can be aligned and manually made up during the move.

3. The tow padeye assembly is installed.

4. The installation and tightening of the fasteners at all the flange joints are completed.

5. The floating hose assembly is lowered into the water and secured to the dock.

6. The remaining tools, equipment, shipping frames/blocking, etc. at the staging area is consolidated, maintained as required, cleaned, inventoried and placed at a designated holding point at the staging area for on site storage or later transport to an alternative storage site.

Crew = 4 personnel. Estimated elapsed time = 8.0 hours. The crane can be released at this time depending upon future lift requirements in the staging area.

DAY 5

@ Dock Floating Hose Tow Vessel

1. The hose connection hardware and tools are loaded onto the tow vessel. The tow line is rigged and the hose assembly is towed to the buoy.

Crew = 4 personnel. Estimated elapsed time = 1.0 hour.

@ Marine site Floating Hose Tow Vessel

1. The floating hose assembly is rigged to the buoy piping assembly and the tow line is removed and stowed on the tow vessel.

2. The buoy winch is rigged to seat the floating hose assembly flange onto the buoy piping flange. See Figure 2.5 for an illustration of the procedure. The air supply line is attached to the winch and the hose flange is seated to the buoy piping flange.

3. The joint is made up and the rigging is repositioned to tug in the under buoy hose. See Figure 2.5 for an illustration of the procedure.

4. The underbuoy hose spar pendant is secured and a line is attached to pull the hose into the centerwell. This procedure can be completed by a diver or from the buoy deck.

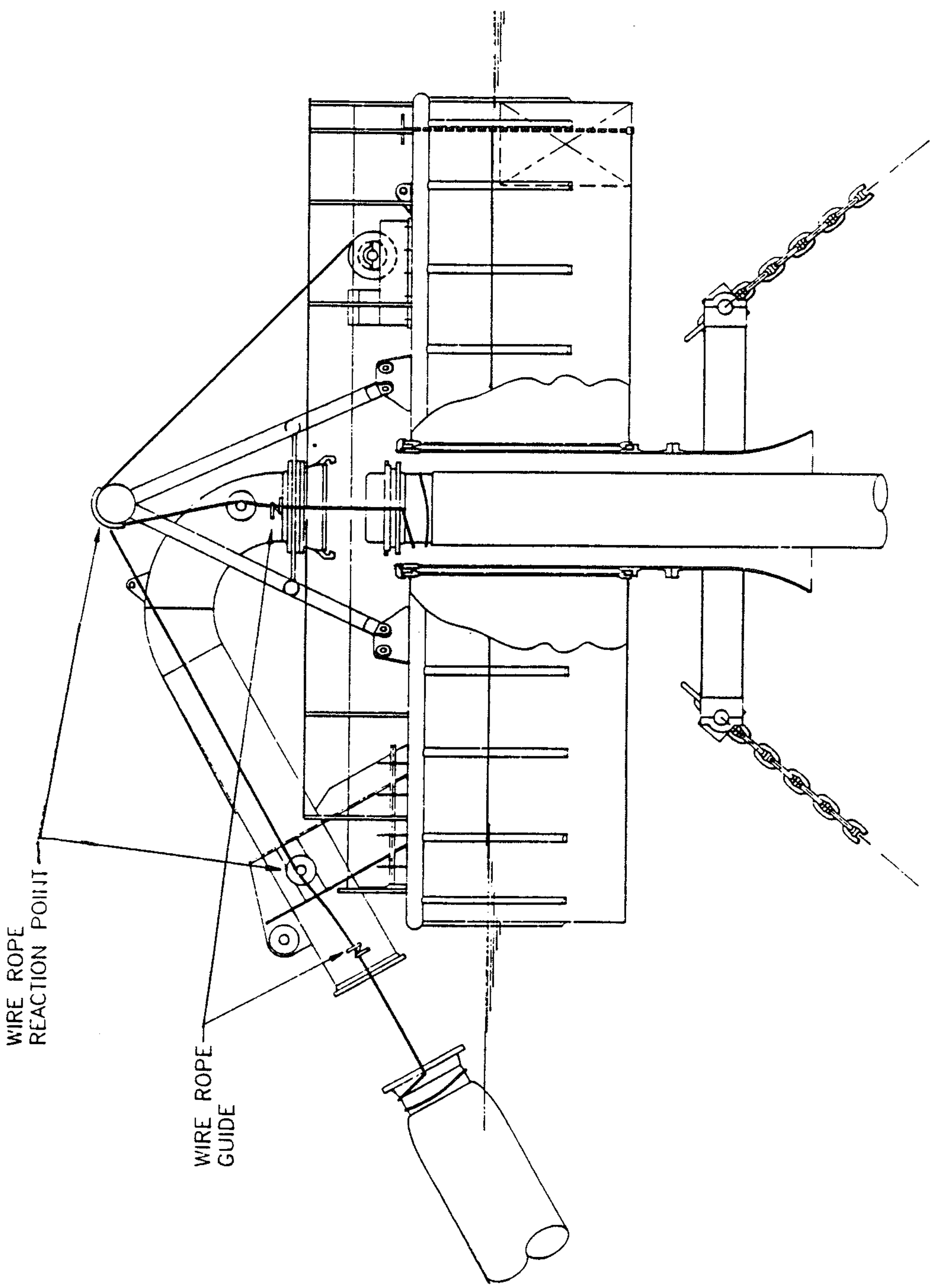
5. The under buoy hose is pulled into the buoy centerwell and secured at the buoy deck. The hose is rerigged to insure alignment of the hose swivel connection and tugged into position.

6. The locking ring is hammered into position on the locking fingers of the hose swivel and the retaining pins are installed.

7. The chain leg chain angles are reverified and corrected as required. The spar buoy located at the end of the submarine pipe line is recovered.

FIGURE 2.5

HOSE RIGGING ARRANGEMENT



8. The rigging, tools, buoy pendants, etc. are secured on the tow vessel.

9. The buoy trim is adjust by flooding the buoyancy tank. The valve is closed when desired trim is achieved.

10. The operation of the navigation aids are verified. The handrails are stowed. The mooring hawser is deployed.

11. The tow vessel returns to the dock/staging area and offloads equipment.

NOTE: The DPO SPM is ready for operational use.

Crew = 4 personnel. Estimated elapsed time = 5.0 hours.

DAY 6 Weather hold, marine travel time to site, equipment delay or other contingency time reserve.

DAY 7 Weather hold, marine travel time to site, equipment delay or other contingency time reserve.

2.3 Resource Summary: The following table lists the minimum equipment and personnel required to assembly and deploy the DPO SPM system in a marine environment in the specified time period:

Equipment:	**Personnel:**
7 Trucks	7 Drivers, 7 Co-drivers (Optional)
1 Crane	1 Operator, 1 Oiler/Rigger
Staging Area Crew	5 Personnel
Buoy Crew	4 Personnel (including Diver)
1 Tow Vessel	3 Personnel
1 Anchor Handling Vessel	4 Personnel

Total elapsed time: 1 Week or less.

EVENT SUMMARY

DESCRIPTION	RESOURCE	TIME
Day 1		
Unload buoy piping, air compressor, tools, marker buoy, underbuoy hose, and hose hardware. Assemble underbuoy hose for tow.	Staging Area Crew + Crane	5 Hours
Tow underbuoy hose to marine site	Tow Vessel	Travel
Connect underbuoy hose to end of pipeline, mark, and drop.	Tow Vessel + Pipeline Constructors	1 Hours
Transfer two complete anchor leg assemblies with marking buoys to Anchor Handling Vessel and preposition remaining anchor components at staging area site.	Crane + Staging Area Crew + Anchor Handling Vessel	6 Hours
Assemble shots of anchor chain into anchor leg assemblies.	Anchor Handling Vessel	2 Hours
Day 2		
Transfer chain tensioner assembly to Anchor Handling Vessel. Unload anchor chain to staging area site. Set up mooring table and buoy stands for buoy assembly. Unload air compressor, tools, slings, marking buoys, towing bridle, and hardware. Erect buoy on mooring table, make up joint and launch buoy. Unload remaining anchor chain. Assemble remaining anchors. Unload seven floating hose sections and mooring hawser assembly.	Staging Area Crew + Crane	10.5 Hours
Anchor Handling Vessel sails to marine site.	Anchor Handling Vessel	Travel
Install two opposing anchor legs.	Anchor Handling Vessel	6 Hours

Day 3

Load two anchor leg assemblies onto the Anchor Handling Vessel and assemble the anchor legs.	Staging Area Crew + Crane + Anchor Handling Vessel	4 Hours
Anchor Handling Vessel sails to marine site.	Anchor Handling Vessel	Travel
Install two opposing anchor legs.	Anchor Handling Vessel	6 Hours
Complete assembly of the buoy components on the floating buoy. Test and confirm the function of the safety, navigation, and rigging equipment on the buoy.	Staging Area Crew + Crane + Buoy Crew	4 Hours

Day 4

Tow buoy to marine site.	Tow Vessel + Buoy Crew	Travel
Install buoy at marine site.	Tow Vessel + Buoy Crew	8 Hours
Assemble floating hose string for tow. Consolidate equipment in the staging area for inventory and storage/transport.	Staging Area Crew + Crane	8 Hours

Day 5

Tow floating hose string to marine site.	Tow Vessel + Buoy Crew	Travel
Install floating hose string. Install underbuoy hose string. Trim buoy. Adjust chain angles as required. Deploy mooring hawser. Insure proper operation of buoy equipment. Recover and stow marker buoys and installation equipment.	Tow Vessel + Buoy Crew	5 Hours

Complete staging area clean-up and equipment accountability/storage.	Staging Area Crew + Crane	4 Hours

Day 6 & 7

Contingency days for equipment failure/delay, extensive travel times to the marine site or weather delay.

Note: Primary constraint at the staging area is material handling capacity. Therefore, the addition of another, lesser capacity, "cherry picker" type crane with an additional rigging and assembly crew would accelerate offload and assembly. Recommend the staging area water access frontage be increased to 400 feet minimum. The staging area job consists of offloading the trucks, assembling the four major components, i.e., four anchor leg assemblies, the buoy assembly, the underbuoy hose assembly, and the floating hose assembly, and loading them for marine shipment. Primary constraint at the marine site is the installation of the anchor legs. To benefit from a gain at the staging area, employ a second anchor handling vessel to emplace the second opposing anchor leg system in a staged schedule with the first anchor handling vessel. Estimated time saved: 1 to 2 days.

3 DPO SPM Recovery

3.1 The DPO SPM recovery operation is essentially the reverse of the deployment operation. More time will be required to carry out the operation due to the requirement to:

1. Perform maintenance on the system components, tools and equipment.

2. Account for components, fasteners, tools, etc. and replace lost items.

3. Bundle the numerous shots of anchor chain.

4. Remove the individual hose sections from the water.

5. Sort the system components, tools, equipment, and shipping frames/blocking into the shipping configuration.

6. Load the trucks.

3.2 The sequence of marine recovery is:

1. Recover the floating hose string.

2. Release the underbuoy hose and four anchor chain legs. Tow the buoy to the dock.

3. Recover the underbuoy hose string.

4. Recover the four marine anchors and anchor chain legs.

Anticipated elapsed time for marine recovery = 5 days.

3.3 The dock/staging area activity will include removal of the system from the water, disassembly, accountability, maintenance/replacement, packing and preparation for shipment. Anticipated elapsed time for dock/staging area activity is 7 to 10 days.

3.4 The loading of the system onto trucks for transport is anticipated to require 4 days assuming the use of one crane.

3.5 Crew complement for the recovery operation is equivalent to the assembly and installation operation.

4 DPO SPM Emergency Buoy Recovery

4.1 The towing bridle is recovered from the support vessel and each leg of the dual leg towing bracket is attached to its respective buoy towing bracket. The support vessel utilizes the towing bridle as its primary mooring line during the remainder of the emergency buoy recovery operation. Total estimated elapsed time = .25 hours

4.2 The buoy handrail system is deployed as desired. The winch air supply hose is rigged from the support vessel to the onboard buoy winch. The chain tensioning blocks are transferred to the buoy and rigged. A pelican hook is attached to the hook block. Four short choker slings and four anchor pendant buoys with shackles are transferred to the buoy. Total estimated elapsed time = .50 hours

4.3 The underbuoy hose string is released from the buoy hose swivel by:

4.3.1 Removing the quick lock pins.

4.3.2 Rotating the rotating bar socket by hammering on the hammering lug provided, causing the five locking lugs to disengage, and releasing the lower swivel assembly and underbuoy hose to drop through the buoy hull centerwell to the sea floor.

Total estimated elapsed time = .25 hours

4.4 The mooring hawser assembly is pulled, hand over hand, onto the buoy hull deck and secured. Alternatively, the mooring hawser assembly could be released from the buoy and secured on the support vessel. Total estimated elapsed time = .25 hours

4.5 The support vessel will maneuver the buoy hull into position over each individual chain support assembly to align the chain tensioning tackle for chain release. The support vessel captain should plan his method of maneuver to arrange to have the up current chain leg be the last chain to be released. The first chain support assembly is selected and the support vessel holds the buoy on station.

4.6 The chain legs will be released in turn. The sequence of events are:

4.6.1 The diver locates the short sling at a chain link slightly above the chain stopper and attaches the pelican hook.

4.6.2 The buoy crew raises the anchor chain to gain access to the chain stopper halves and removes the chain stopper halves to the support vessel.

4.6.3 The diver threads the anchor pendant buoy up through the chain support assembly and attaches it to the end link of the anchor chain.

4.6.4 The diver clears the area. The buoy crew deploys the anchor pendant buoy assembly clear of the buoy.

4.6.5 The buoy crew trips the pelican hook and releases the anchor chain leg.

4.6.6 The buoy hull is maneuvered into position over the next chain support assembly and the process is repeated until all four anchor chains are marked and released.

Total estimated elapsed time to release all four anchor chains = 1 hour.

4.7 The buoy crew secures the chain tensioning rigging, the winch air hose, and the buoy handrails. Estimated elapsed time = .50 hours.

4.8 The buoy is ready for tow to shore. Total estimated elapsed time on site is 2.5 hours. Buoy crew consists of four personnel, one of which is the diver. Support vessel crew as required by vessel; but, a minimum of three personnel.

DREDGE MOORING STUDY
Phase II Report

APPENDIX E
BID PROPOSAL SPECIFICATION

July 15, 1991

SOFEC, Inc. - Houston, TX
Project No. 667

U.S. Army Corps of Engineers
Waterways Experiment Station

Contract No. DACW39-90-C-0075

TABLE OF CONTENTS

1 GENERAL

1.1 Scope

This specification defines the minimum standards of performance, quality and acceptability governing the design, supply, inspection, supervision, and testing of the Direct Pump Out (DPO) Dredge Buoy Single Point Mooring (SPM) for the Army Corp of Engineers (CE). This specification is not intended to be all inclusive and the use of guidelines contained herein shall not relieve the Contractor of his responsibility to design and supply a SPM system fully capable of meeting the design criteria, operating parameters and intended service as required by the applicable codes and standards. In addition to the SPM system the Contractor shall supply recommended procedures for the shipping of the system on over-the-road trucks, component rigging and assembly, ocean tow and site assembly, operation, maintenance, and recovery. In addition, a one and five year recommended list of spare parts will be provided.

1.2 Definitions

The following definitions shall apply:

Company or Company Representative - Army Corp of Engineers employees, engineers, engineer's assistants, inspectors, and other authorized representatives designated by written notice to the contractor.

Contractor - SPM designer and supplier.

Standards - Industry codes, standards, and recommended practices referenced herein.

1.3 Responsibilities

For any requirement in question by the Contractor, it shall be the Contractor's responsibility to obtain clarification from the Company's Representative, which shall be final and binding. Contractor shall obtain the Company's written authorization to deviate from the requirements of this Specification, referenced codes and standards, drawings, or contract. All documents submitted for approval shall be signed by the Contractor.

1.4 Document Precedence

In the event of conflict between documents, the priority shall be as follows:

a. Contract
b. This Specification
c. Referenced Drawings
d. Referenced Codes and Standards

However, conflicts shall be reviewed and resolved with the Company's Representative prior to initiation and/or continuance of the work.

1.5 SPM Design, Materials and Equipment

All designs, materials, and equipment fabricated, manufactured and/or supplied under this Specification shall be new and of best quality, of proven design and in accordance with sound engineering, fabrication and engineering practices. Prototypes, new designs, or extensive modification of standard designs shall be unacceptable without written consent of the Company.

1.6 Direct Pump Out Dredge Buoy System Description

The Direct Pump Out (DPO) Dredge Buoy System is a modular component, single point mooring (SPM) system utilizing a catenary anchor leg mooring (CALM) concept to moor a dredge vessel in an open sea environment. The SPM provides a piping system for transfer of material from the dredge hopper through a floating hose, buoy swivel, submarine hose, submarine pipeline to the designated beach refurbishment/deposit site. The buoy and piping swivels allow the vessel to "weathervane" about the mooring due to forces imposed by the prevailing environmental conditions; thereby, reducing loads on the vessel and the SPM. The DPO dredge buoy system is truck transportable for rapid displacement to a designated work area.

1.7 SPM Description

The DPO Dredge Buoy SPM shall be a catenary anchor leg mooring system and shall consist of, but not limited to, the following components:

- Rotating Capsule-shaped Buoy Hull
- Navigation Aids
- Rigging System
- Chain Support Mooring Table
- Anchor Chain Pendants
- Seafloor Anchors
- Floating Hose System
- Hose Swivel System

- Underbuoy Hose System
- Mooring Hawser Assembly

These components are further described in this specification.

1.8 Scope of Work

1.8.1 Design

Contractor shall be responsible for the detailed design of the SPM system. Sufficient design details of the SPM system shall be included in the bid proposal so that a complete evaluation of the SPM system design can be performed. Contractor shall identify and designate all materials, equipment and manufactured items for the SPM system.

Within 45 calendar days of the contract award Contractor shall furnish complete design data and calculations for the SPM system. Contractor shall also submit a complete set of design drawings including all mechanical and structural details. All drawings are to be dimensioned and detailed in English units. Company reserves the right to request additional information that is not shown on the design drawings, calculations, specifications or presented in the design data.

The design drawings shall be supplemented by specifications necessary to convey the intent of the design. Standard specifications for material and fabrication shall be referenced on the appropriate drawings.

The drawings and detailed procedures shall include the weights and centers of gravity of all subassemblies, shall depict the location of lifting padeyes and provide suggested lifting sling arrangements and shall show the suggested installation aids for the marine anchors, anchor chain, hose systems and hawser assembly.

1.8.2 Fabrication and Manufacturing

Contractor shall be responsible for preparing and submitting to Company for review and approval all fabrication, erection, assembly and test procedures, as well as, material specifications. The procedures shall be in strict accordance with the codes and standards referenced herein.

Contractor shall also be responsible for procurement of all manufactured items including preparation of specifications, purchase orders/contracts, quality control/plant inspections, and material/equipment documentation. All specifications, quality control procedures and material control procedures shall be submitted to Company for review and approval prior to issuing the purchase orders/contracts for procurement of the respective materials or equipment. Contractor shall be responsible for expediting procurement of material/equipment as required to maintain schedule.

All procured materials, equipment and systems shall be manufactured in accordance with the applicable codes, standards and specifications referenced herein.

1.8.3 Delivery

Contractor shall be responsible for all costs of inland and/or marine freight, packing, loading and shipping of the SPM system components from the various fabrication sites and manufacturing plants to the designated receiving point.

Contractor shall develop a method of material control and material control reports to coordinate the procurement, expediting and receiving of all SPM system materials and manufactured items that will be incorporated in the SPM system, and to control the delivery of all SPM subassemblies and ancillaries.

The material control report for stock material and manufactured items shall include an unpriced copy of all Contractor purchase orders with their scheduled delivery dates and specifications of purchased material or components. The report shall include delivery schedules for all other materials and components, and shall be correlated to the Contractor's fabrication and assembly schedule to indicate the impact of material and component deliveries on the SPM system's fabrication and delivery.

The material control report for SPM subassemblies and ancillaries shall include a details description of each subassembly and ancillary and a schedule showing dates for loadout and delivery to the final destination. The name and type of carrier shall also be indicated.

Unpriced copies of purchase orders and copies of the specifications that accompany purchase orders shall be submitted for Company review prior to the placing of the orders for all materials and equipment purchased by the Contractor for use in the SPM system.

1.8.4 Test Installation

The Bid Proposal shall contain sufficient information to permit an accurate description of the installation equipment required and the work to be performed during the SPM prototype installation acceptance testing. Contractor shall submit 45 calendar days after contract award a complete installation procedure specification to include complete installation drawings showing the make-up of the SPM sub-assemblies and indicating the assembly sequence. These drawings shall be supplemented by detailed transportation, assembly and installation specifications, procedures, and special instructions, as required, to complete the field installation acceptance trials.

The procedure/drawings shall give assembly and installation tolerances. The acceptance test shall include a detailed pre-installation and post-installation acceptance test check list of the SPM system.

The system shall be judged acceptable if the following two milestones are successfully accomplished:

1. Phase I. The system is transported a minimum of ten (10) miles in its over-the-road truck configuration to a Company designated shore based staging area. The system is then deployed to an offshore site designated by the Company which is located a minimum of three (3) nautical miles from the shore based staging area and assembled into an operational system. The submarine pipeline to the beach will have been installed by the Company prior to test initiation. The Contractor is allowed a maximum continuous time period for this phase of the test of 168 hours (7 - 24 hour days). The system is deemed acceptable if it is undamaged and ready for operation at the end of the allowed time period.

2. Phase II. At dawn on the eighth day the Company shall begin immediate operational use of the SPM system and shall continue its operational testing of the SPM system for a minimum of 72 continuous hours (3 - 24 hour days). The system is deemed acceptable if it maintains its operational readiness during the designated time period.

Contractor shall provide qualified manufacturer's representatives to monitor and assist during the final assembly and installation of the hose and hawser systems. The manufacturer's representative's qualification will be submitted to and approved by the Company. Contractor shall be responsible for the mobilization of the manufacturer's representatives. The cost associated with Contractor and manufacturer representatives shall be included in the lump sum price, but shall also be indicated as a separate day rate.

No compensation shall be paid by the Company for any delay in the installation and testing of the SPM system.

1.8.5 Classification

Contractor shall obtain certification of the system as detailed in the contract. The cost for certification shall be included in the lump sum price.

1.8.6 Loadout and Tie Down

As detailed in his installation procedures, the Contractor shall be responsible for preparing the SPM buoy for towing to the installation site, including any required ballasting. The Contractor shall be responsible for placing the buoy into the water at a site accessible to the marine towing vessel, and providing the towing bridle. The Contractor is responsible for the loadout and tie down of all other system components and equipment required for the recommended installation of the SPM.

1.8.7 Installation Aids

Contractor shall be responsible for the design and fabrication of installation aids required for the offshore installation of the SPM buoy and hose systems, including, but not limited to the following:

a. Minimum of two chain angle indicators.

b. 10% spare hose bolts.

c. 10% spare hose gaskets.

d. blind flanges for hydrotesting of pressurized hoses and piping.

e. 5 gallon buoy touch up paint

f. Other specialized rigging/tools/items specific to the installation of the SPM system.

2 DESIGN CRITERIA AND OPERATING PARAMETERS

2.1 Codes and Standards

All materials and equipment supplied and work performed herein shall conform to the latest edition of the applicable industry codes, standards, references and recommended practices. Should there be any contradiction or inconsistency between standards or codes, then the one with higher quality shall govern.

2.1.1 American Bureau of Shipping (ABS)

"Guide for the Certification of Offshore Mooring Chain"

"Non-Destructive Inspection of Hull Welds"

"Rules for Building and Classing Single Point Moorings"

"Rules for Building and Classing Steel Vessels"

2.1.2 American Institute of Steel Construction (AISC)

"Steel Construction Manual - WSD"

2.1.3 American National Standards Institute (ANSI)

B31.3 "Petroleum Refinery Piping"

2.1.4 American Petroleum Institute (API)

RP 2A "Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms"

RP 2B "Specification for Fabricated Structural Steel Pipe"

Spec 2F "Specification for Mooring Chain"

Spec 5L "Specification for Line Pipe"

Std 1104 "Standard for Welding Pipelines and Related Facilities"

2.1.5 American Society of Mechanical Engineers (ASME)

Section V	"Non-Destructive Examination"
Section III	"Pressure Vessels"
Section IX	"Welding and Brazing Qualifications"

2.1.6 American Society for Testing and Materials (ASTM)

2.1.7 American Welding Society (AWS)

D1.1	"Structural Welding Code"

2.1.8 Manufacturer Standardization Society (MSS)

SP-44	"Steel Pipe Line Flanges"
SP-53	"Quality Standard for Steel Castings - Dry Particle Magnetic Inspection Method"
SP-54	"Quality Standard for Steel Castings - Radiographic Inspection Method"

2.1.9 National Association of Corrosion Engineers (NACE)

RP-06	"Recommended Practice for Control of Corrosion on Offshore Steel Pipelines"
RP-0387-87	"Metallurgical and Inspection Requirements for Cast Sacrificial Anodes for Offshore Applications"

2.1.10 National Fire Protection Association (NFPA)

"National Electrical Code No. 70-1978"

2.1.11 Oil Companies International Marine Forum (OCIMF)

"Buoy Mooring Forum SPM Hose System Design Commentary"

"Buoy Mooring Forum SPM Hose Ancillary Equipment Guide"

"Standards for Equipment Employed in the Mooring of Ships and Single Point Moorings"

2.1.12 Steel Structures Painting Council (SSPC)

"Steel Structures Painting Manual"

2.1.13 U. S. Coast Guard (USCG)

33 CRF 149 "Deep Water Ports - Design, Construction and Equipment"

2.1.14 National Association of Pipe Coating Application (NAPCA)

2.1.15 Minerals Management Service (MMS)

2.1.16 Cordage Institute Standard Test Methods (CISTM)

Related clauses included in the above codes and standards, but not explicitly listed shall be followed if applicable.

2.2 Location

The SPM system will be designed for operational deployment in any inland waterway or along any coast of the United States of America as the Company mission dictates.

2.3 Water Depth

The SPM System will normally be deployed in an operational water depth of 30 to 40 feet.

2.4 Survival Conditions

Significant Wave Height	10.0 ft
Significant Wave Period	Pierson-Moskowitz Spectrum
Swell Height	20.0 ft

2.5 Operating Conditions

Significant Wave Height	6.0 ft @ 60 degree from shoreline
Wave Velocity	30.0 knots @ 90 degree from shoreline
Current Velocity	2.0 knots @ 0 degree from shoreline

2.6 Operating Swell Conditions

Swell Height	6.0 ft @ 60 degree from shoreline
Wave Velocity	30.0 knots @ 90 degree from shoreline
Current Velocity	2.0 knots @ 0 degree from shoreline

2.7 Seawater Temperature

Annual Range at Surface	0 - 90 degree F

2.8 Geotechnical Data

The SPM system by definition is a highly portable DPO SPM system with the capability to be installed at diverse sites with a variety of soil types and conditions. For design purposes the Contractor shall use the following soil descriptions to define the limits of expected conditions:

2.8.1 Sand:

2.8.2 Medium Clay:

2.9 Nominal Dredge Vessel Characteristics

	Maximum	Minimum
Displacement (DWT)	19,366	11,966
LOA (ft)	408	300
LBP (ft)	384	288
Beam (ft)	78	68
Molded Depth (ft)	39	33
Loaded Draft (ft)	29.5	26
Loaded Freeboard (ft)	9.6	6.5

2.10 Dredge Slurry Characteristics

	Maximum	Average	Minimum
Material			
Specific Gravity			
Viscosity			

2.11 Throughput Rate

	Maximum	Average	Minimum
Rate (GPM)			

2.12 Maximum Pressures

Design	225 psig
Operating	100 psig

3 BUOY HULL

3.1 The mooring buoy hull shall consist of a capsule shaped, welded steel structure with a symmetrically located circular centerwell. The buoy shall be designed and fabricated in accordance with the codes, standards, design criteria and operating parameters specified in Section 2. The mooring buoy shall be not less than 28 feet long. The mooring buoy shall be not more than 11.5 feet wide and 7.5 feet in height (from top of the buoy circumferential fender at the deck to the bottom of the mooring table bolted joint).

3.2 The buoy hull shall be divided by bulkheads into watertight compartments. The number and placement of the watertight compartments shall be so designed as to insure positive buoyancy of the buoy in the event that two adjacent compartments become flooded or damaged. A mounting plate for a manually operated bilge pump complete with mounting brackets, as required, shall be provided at a centralized location on the buoy deck. A water ballasting compartment shall be provided on the buoy end opposite the surface hose attachment point to provide for leveling of the buoy. The water ballast compartment will be equipped with a valve to allow and control flooding of the compartment from the deck of the buoy. A method to remove the ballast water from the compartment while on site and controlled from the deck of the buoy shall be provided.

3.3 All watertight compartments shall be equipped with:

- A hull deck manway access consisting of a watertight bolted hatch/cover complete with a neoprene gasket. All manway cover fastenings shall be corrosion resistant and the manway cover shall be as flush as possible with the hull deck.

- A vertical steel constructed ladder extending from the hull deck to the hull bottom plate shall be located/attached beneath each manway access cover.

- A vent and sounding pipe for detection of water within a compartment. The sounding pipe shall extend to within one inch of the buoy bottom plate. The vent and sounding pipes shall have an outlet at the hull deck sealed with a watertight screw-on cap.

- A mounting plate for a manually operated bilge pump complete with mounting brackets, as required, shall be provided at eighteen inches above the buoy bottom plate.

3.4 The central cylindrical centerwell shall be open to the sea at the lower end for connection of the underbuoy hose to the hose swivel above the buoy deck level. The buoy hull adjacent to the centerwell shall be fitted with a reinforced structural steel foundation adequately machined for mounting and installation of a central rotating mechanical swivel assembly. The mechanical swivel shall allow continuous 360 degree rotation of the buoy about the mooring table. The wear surfaces of the mechanical swivel shall be constructed of corrosion resistant materials suitable for long term exposure to salt spray and sea water. The bushings utilized in the mechanical swivel shall be of the self lubricating type and shall be suitable for submerged use in sea water. A method to provide supplemental grease lubrication of the wear surfaces of the mechanical swivel from the buoy deck shall be provided. The mechanical swivel shall be designed to facilitate passage of the underbuoy hose for connection to the hose swivel. The mechanical swivel shall be designed to accommodate the axial and radial loads and overturning moments induced by the buoy hull, surface and underbuoy hose strings and mooring hawser. The lower structure of the mechanical swivel shall attach to the mooring table with a bolted joint. The bolted joint shall be a machined connection designed with adequate bearing area and a sufficient number of fasteners to transfer the forces generated by the axial and radial loads and overturning moments induced by the buoy hull, surface and underbuoy hose strings and mooring hawser to the mooring table.

3.5 The buoy hull shall be fitted with a rolled and welded steel pipe fender around the top circumference of the buoy hull, and shall be fitted at one yard intervals with either and/or half round steel pipe welded vertically to the hull exterior plate or replaceable elastomeric fenders extending from the top of the buoy hull to one foot below the design waterline.

3.6 The buoy hull shall be fitted with draft marks consisting of six (6) sets of welded steel plate numerals indicating hull draft in six inch increments and extending over the full height of the buoy hull. The numerals shall be equally spaced around the circumference of the buoy, with one set mounted on the longitudinal centerline at the bow and another set located on the longitudinal centerline at the stern.

3.7 The Contractor shall provide a portable handrail system for temporary erection on the perimeter of the buoy deck as dictated by safety requirements when personnel are aboard the buoy. The buoy hull shall be designed to support the portable handrail system. Preferred storage of the handrail system is on the buoy.

3.8 The buoy hull shall be equipped with a minimum of four lifting lugs/padeyes located on the deck of the buoy and in alignment with the interior bulkheads for the lifting of the complete hull and mooring table assembly as a single unit. The Contractor shall supply the complete rigging, i.e., the shackles, wire rope slings, and spreader bar, if required, to lift the complete hull and mooring table assembly as a single unit. The buoy hall shall be equipped with two towing brackets/padeyes located on the deck of the buoy and in alignment with the interior bulkheads at the bow of the buoy. The Contractor shall supply the complete rigging, i.e., shackles, tow bridle and ancillary equipment required, to tow the buoy hull, mooring table, piping, and surface hose string as a single unit.

3.9 The buoy deck shall be equipped/fitted with a minimum of four (4) mooring bitts/points for use by small service vessels and mooring launches. The mooring points shall be located on the perimeter of the buoy, aligned with interior bulkheads and symmetrically arrayed around the center of the buoy.

3.10 The buoy deck shall be fitted with brackets/padeyes to allow the pinned attachment of the tubular steel lifting frame. The lifting frame will incorporate sufficient rigging connection points to facilitate tensioning of the anchor chain on either side of the buoy hull and installation of the floating and underbuoy hose strings. The lifting frame shall incorporate mounting points for ancillary equipment including radar reflector, fog horn, navigation aid light, and safety equipment. A mounting foundation for a winch shall be provided on the buoy deck opposite the buoy piping assembly. The ancillary equipment is described in Section 9. The tubular steel lifting frame shall also incorporate the mounting structure for the buoy piping assembly and underbuoy hose swivel assembly at the centerwell of the buoy. A buoy piping assembly attachment point shall be provided on the longitudinal centerline of the buoy deck opposite the towing brackets and winch foundation.

3.11 A single padeye, suitably reinforced, shall be provided at the vertical centerline of the buoy piping assembly in the vicinity of the floating hose connection. This padeye shall be the connection point for the mooring hawser assembly. The padeye support structure shall support the end of the buoy pipe assembly and shall transfer the mooring loads around the pipe and into the buoy hull.

3.12 A means shall be provided for locking the rotating buoy hull to the stationary mooring table during installation/maintenance/repair operations. The locking mechanism shall be designed to lock the longitudinal centerline of the buoy hull in alignment with the centerline of each of the mooring table chain support arms.

3.13 The submerged portion of the buoy hull shall be fitted with a cathodic protection system consisting of sacrificial zinc and/or aluminum anodes. The design life of the cathodic protection anode system shall be a minimum of five (5) years. The current density for uncoated surfaces including stud link chain pendants and anchor points shall be 120 mAmps/sqm, and 50 Mamps/sqm for coated surfaces. The anodes shall be bolted to the mounting brackets in such a manner as to insure positive grounding of the anodes to the buoy hull plate. Electrical continuity between the anode and the mounting bracket shall be tested with an ohm-meter. The anode shall be manufactured and tested in accordance with applicable industry codes and standards. The cathodic characteristics and manufacturer data sheets shall be submitted with the bid proposal. Design data shall include service life, current density, sea water resistivity, anode type and material, anode output, crude utilization factor, number of anodes, anode net weight, and attachment details.

3.14 The buoy hull shall be fabricated, coated and tested in accordance with the requirements contained in Sections 10, 12, and 13.

4 MOORING TABLE ASSEMBLY

4.1 The mooring table assembly shall consist of a one-piece steel fabricated structure consisting of a central tubular component with four equally spaced box beam arms radiating from it. The upper end of the tubular incorporates a bolted joint to facilitate attachment to the buoy mechanical swivel assembly at the buoy centerwell. The lower end of the tubular incorporates a bell fairing. The mouth of the bell faring shall be fitted with a rolled and welded steel pipe circumferential fender to facilitate the passage and protect the integrity of the underbuoy hose string. The four radial arms support the anchor chain support assemblies.

4.2 The mooring table assembly shall be equipped/fitted with four (4) locking type chain support assemblies for securing the stud link chain pendants. The chain support assemblies shall be designed to permit adjustment of the chain pretension from the hull deck, and shall not cause chain wear. In addition, the chain support assemblies and chain stoppers shall be fitted with lifting lugs.

4.3 Each chain support assembly shall:

- be of a swiveling type that allows free rotation about the horizontal axis.

- swivel on a bearing surface of corrosion resistant material suitable for long term exposure to sea water.

- utilize self lubricating material in the design of the bushings and thrust washers.

- provide a chain passage hole in the body of the support assembly of sufficient size to allow the passage of anchor chain connecting links.

- incorporate a chain support stopper that is positively retained by the chain support assembly and allows free rotation of the anchor chain when not under load.

- have provisions for storing or suspending a maximum of twelve links of excess/spare chain.

4.4 The mooring table shall be fitted with a cathodic protection system consisting of sacrificial zinc and/or aluminum anodes. The design life of the cathodic protection anode system shall be a minimum of five (5) years. The current density for uncoated surfaces including stud link chain pendants and anchor points shall be 120 mAmps/sqm, and 50 mAmps/sqm for coated surfaces. The anodes shall be bolted to the mounting brackets in such a manner as to insure positive grounding of the anodes to the buoy hull plate.

Electrical continuity between the anode and the mounting bracket shall be tested with an ohm-meter. The anode shall be manufactured and tested in accordance with applicable industry codes and standards. The cathodic characteristics and manufacturer data sheets shall be submitted with the bid proposal. Design data shall include service life, current density, sea water resistivity, anode type and material, anode output, crude utilization factor, number of anodes, anode net weight, and attachment details.

4.5 The mooring table shall be fabricated, coated and tested in accordance with the requirements contained in Sections 10, 12, and 13.

5 BUOY PIPING ASSEMBLY AND HOSE SWIVEL

5.1 Buoy Piping Assembly

5.1.1 The buoy piping assembly, located above the aft deck of the buoy, provides a hard pipe product passage from the floating hose string, with the connection located outboard of the buoy, through the hose swivel, with the connection located above deck at the centerwell of the buoy, to the underbuoy hose string.

5.1.2 The buoy piping assembly shall be designed for ease of removal from the buoy to facilitate over-the-road truck transport of the system and rapid assembly of the system during installation/deployment. The buoy piping assembly shall be support by the mooring hawser padeye structure on the aft deck of the buoy and by the hose swivel at the centerwell of the buoy. Refer to Section 3 for additional information on the buoy piping supports.

5.1.3 The buoy piping assembly shall consists of a 28 inch diameter pipe and shall transition from approximately 20 degrees above horizontal orientation at approximately sea level outboard of the buoy deck to a vertical orientation opening downward at the centerwell of the buoy. End flanges shall be ASTM A105/ANSI B16.5 Class 150, Tube Turns or equal, weld neck flat face flanges.

5.1.4 All cable guides, reaction points, pipe supports and/or appendages attached to the pipe shall be designed and fabricated in strict accordance with the applicable codes and standards, i.e., doublers, reinforcement plates (full or partial encirclement).

5.1.5 The buoy piping assembly shall be fabricated, coated and tested in accordance with the requirements contained in Sections 11, 12, and 13.

5.2 Hose Swivel

5.2.1 The hose swivel shall be a commercially available device with a history of successful performance in dredging operations with a design specifically tailored for continuous service in a sea water and/or marine environment

5.2.2 The hose swivel shall be securely mounted above the deck of the buoy hull at the centerwell and connected to the buoy piping assembly.

5.2.3 The hose swivel shall be fitted with a means to lubricate the sliding bearing surfaces and lip seal from the buoy deck.

5.2.4 The hose swivel shall be coated and tested in accordance with the requirements contained in Sections 11, 12 and 13.

6 ANCHORING SYSTEM

6.1 The SPM anchoring system shall consist of four (4) flash butt welded stud link chain pendants extending from the chain support assemblies located in the buoy mooring table to four (4) seafloor anchor points consisting of high efficiency fabricated steel marine anchors.

6.2 Contractor shall establish the operational and survival loads by computational analysis and/or by model testing based on the design criteria and geotechnical data provided.

6.3 The chain pendant length and diameter and marine anchor type and capacity shall be determined based on operational and survival loads, buoy hull excursions and motions during operational and survival conditions as determined by the Contractor.

6.4 The anchoring system capacity shall be defined by the ultimate strength of the weakest component in the system. For this purpose, the system is defined as the chain, anchor and joining shackles at both ends. The ultimate strength of the components shall be the specified break strength provided by the component manufacturers. Failure of any component in the anchoring system shall not result in damage to the buoy hull or result in buoy instability.

6.5 The anchoring system design safety factor against component breakage shall be a minimum of 3 for all loading conditions. Under the maximum design load, a minimum of one full shot of anchor chain (90 feet) shall remain on the seafloor. Marine anchor design loads shall not include any reduction for chain/seafloor friction.

6.6 Each chain pendant shall be of approximately equal length and shall include sufficient chain length to allow for setting of anchors and obtaining required pretensions during installation.

6.7 The anchoring system shall be oriented so that the submarine pipeline will bisect the angle between two adjacent chain pendants.

6.8 Each marine anchor shall be equipped with a wire rope buoy pendant designed to allow surface recovery of the anchor.

6.9 Each stud link chain leg or pendant (from the anchor end to the chain stopper end) shall consist of one anchor shackle, a detachable anchor connecting link (pearlink), and the required number of individual common link chain shots each joined together with the required number of detachable chain connecting (baldt) links, except for the last shot which shall consist of two (2) half shots joined together with a detachable chain connecting (baldt) link which will allow the upper portion of the chain pendant to be removed due to excessive length or replaced due to abnormal or excessive wear (chain link diameter reduction or stud damage).

6.10 All stud link chain and chain fittings shall comply with material, manufacturing and testing requirements for Grade 3 stud link chain and fittings as specified by international classification societies (ABS, API, or equal) and shall be furnished with classification society certificates indicating that all testing requirements have been satisfied. After manufacturing and testing have been successfully completed, each chain stud weld shall be subject to ultrasonic and magnetic particle inspection, and each link shall be subject to dimensional checks.

6.11 After final inspection, the chain fittings shall be coated with coal tar epoxy to a minimum dry film thickness of 8 mils (200 microns). Each chain shot shall be bundled and bound with wire ripe slings ending in woven eyes to permit easy handling of chain bundles during shipment and assembling at the installation site. Connecting links shall be bundled or strapped to shipping pallets by type and shall be marked with metal identification tags attached by wire twists. All connecting links shall be placed atop or aside from all chain shots to permit easy access to the connecting links during assembly of the chain pendants at the installation site.

6.12 For marine anchors, the rated anchor holding capacity shall be in accordance with ABS Rules for Building and Classing Single Point Moorings. Drag anchor design data with support anchor test data shall be submitted to Company for approval.

7 HOSE SYSTEM

7.1 The DPO SPM shall be equipped with a single, twenty eight inch inside diameter smooth bore rubber hose system consisting of two basic sections. One section is referred to as the underbuoy or submarine hose system. The underbuoy hose system extends from the end of the submarine pipeline located on the seafloor upward to the buoy hull centerwell and ends at the hose swivel. The second section, referred to as the floating hose section, extends from the end of the buoy piping assembly to the dredge manifold.

7.2 The CONTRACTOR shall be responsible for determining the optimum underbuoy hose configuration and shall determine the optimum position of the buoy centerwell relative to the end of the submarine pipeline to maintain the recommended hose configuration. The overall length of the underbuoy hose section will be dependent on the actual hose configuration recommended by the CONTRACTOR. The underbuoy hose sections selected by the CONTRACTOR for use in the underbuoy hose system shall have a history of successful use in continuous service in dredge applications.

7.3 The overall length of the surface hose section shall be 245 feet, composed of seven hose sections of 35 feet each. The CONTRACTOR shall be responsible for verifying the suitability of this surface hose configuration relative to his overall system design. The individual hose sections selected by the CONTRACTOR in the surface hose system shall have a history of successful use in continuous service in dredge applications.

7.4 Performance Requirements

7.4.1 Pressure Rating

The maximum required working pressure shall be specified by the purchaser. Common rating "classes" are 145 psig, 250 psig and 290 psig. The pressure rating should consider the pump shut off head as well as the maximum operating pressure. Increased pressure due to possible hydraulic transients shall also be considered.

7.4.2 Operating Pressure

The operating pressure range of the hoses shall be from the pressure rating as identified in 7.3.1 above to a momentary vacuum of 10 inches of mercury.

7.4.3 Minimum Burst Pressure

The minimum burst pressure shall be three times the pressure rating of the hose.

7.4.4 Flow Velocity

The inner tube or lining shall be suitable for continuous operation at a flow velocity of 18 feet per minute.

7.5 Length

7.5.1 Nominal Length

The hose sections shall be provided in standard lengths of 35 feet. The hose length shall be as measured from face of flange to face of flange.

7.5.2 Tolerances

The actual length of the hose sections shall not vary more than plus or minus 2 percent from the specified nominal length.

7.5.3 Permanent and Temporary Elongation Values

The permanent elongation shall not exceed 0.7 percent of the specified nominal length. The temporary elongation shall not exceed 2.5 percent of the specified nominal length.

7.6 Flexibility

The hoses shall be capable of being bent to a minimum radius of 4.5 times the nominal diameter. After bending, the hose body shall show no permanent deformation such as kinking or ovaling. The integral flotation of floating hoses shall show no permanent damage such as creasing or cracking.

7.7 Construction

7.7.1 Hose Lining

The inner tube or lining shall be a composite of natural and synthetic rubber formulated to obtain high abrasion resistance. The lining shall include open weave fabric or some other means of providing resistance to laceration, gouging and cut propagation. The lining thickness shall be a minimum of 0.50 inches.

7.7.2 Hose Body

The hose body shall be constructed from high tensile strength cords encapsulated in rubber, helically applied in a number of layers. In the shoulder area there shall be additional plies tapered into the body of the hose to increase the stiffness and strength in the transition zone between the end fittings and hose body. The reinforcement shall be both mechanically and chemically bonded to the end fittings.

7.7.3 Special Reinforced Ends

Hoses with special reinforced ends shall have additional built-in reinforcement extending over a minimum of one third of the hose length from the reinforced end(s). The reinforcement shall be a maximum at the nipple end decreasing to zero extra reinforcement at a distance of one third of the hose length.

7.7.4 Floatation (Floating Hoses Only)

Floating hoses shall have integrally built floatation over the basic hose consisting of layers of closed-cell expanded foam. The floatation material shall be firmly adhered to all sides and facings of the hose, as well as to the hose body and cover so that there is no movement or tendency to unravel in service. Should the floating hose become submerged for a sufficient time and depth to collapse the foam, the foam shall be capable of recovering its initial shape and hence its initial buoyancy.

The amount of floatation shall be sufficient so that the hose has a reserve buoyancy of 20 percent when filled with a water and solid suspension which has an effective specific gravity of 2.0.

Full floating hoses shall have floatation along the full length of the hose. Half floating hoses shall have flotation along one half of the hose length. At the ends of the hoses (and at the mid-body of a half float hose) the flotation material shall taper down to the hose body smoothly to the hose body.

7.7.5 Outer Cover

The outer cover shall be constructed of a neoprene based black rubber compound which is resistant to weathering, sea water, oil and abrasion. The outer cover thickness shall be a minimum of 0.25

inches. The cover shall be smooth. Any changes in contours shall not be sharp and shall be no more than 0.125 inches high or deep at locations of indentations and ridges.

7.8 Nipples

Hoses shall be supplied with built-in nipples. The nipples shall be standard weight, seamless or double submerged-arc welded steel pipe conforming to ASTM A-106 Gr. A or Gr. B or API-5L Gr. A or Gr. B with restriction on carbon content to 0.23 percent in all cases.

7.9 Flanges

Steel flanges with full penetration welds shall be supplied on all hoses. Flange material shall be ASTM A-105. Unless specified otherwise, flanges shall match ANSI Class 150 lb flanges (bolt hole drilling, outside diameter etc.) as specified in ANSI B16.5 and shall be flat face.

7.10 Markings

7.10.1 Floating Hoses

Floating hoses shall have a bright orange spiral along the full length of the hose.

7.10.2 Submarine Hoses

Submarine hoses shall have a straight white stripe of minimum thickness of two inches along the length of the hose.

7.10.3 All Hoses

All hoses shall be permanently and legibly marked with labels comprising of characters of at least 0.375 inches in height and in non-fading contrasting colors. The labels shall be located at diametrically opposed positions at each end of the hose. The labels shall provide the following information:

1. Manufacturer's name or trademark
2. Nominal inside diameter
3. Pressure rating
4. Month and year of manufacture
5. Manufacturer's serial number
6. Type of hose

8 MOORING HAWSER ASSEMBLY

8.1 The DPO SPM system shall be equipped with a single mooring hawser assembly supplied in accordance with the Oil Companies International Marine Forum (OCIMF) Standards for Equipment Employed in the Mooring Of Ships at Single Point Moorings, OCIMF Procedures for Quality Control and Inspection during Production of Hawsers, OCIMF Guide to Purchasing Hawsers and applicable sections of the US Department of Transportation Guidelines for Deep Water Single Point Mooring Design.

8.2 The mooring hawser assembly shall consist of the following components:

- Crosby 55 ton, bolt type, polytetrafluoroethylene (PTFE) coated, chain shackle, or equal.

- Suggested length of 100 feet of 3.2 inch diameter, 10 inch circumference, polypropylene sheath/polypropylene core, "2 in 1 Viking Braidline" , or equal, with soft eyes at both ends and a PTFE coated thimble at the buoy attachment end.

- Contractor shall recommend and provide chafe protection at the buoy attachment point to safeguard the buoy piping assembly coating system and hawser assembly.

Contractor shall verify suitability of suggested components.

Contractor shall submit, with the bid proposal, mooring hawser design loads, safety factors and manufacturer data sheets and drawings for each component and the overall mooring hawser assembly.

8.3 The rated tensile breaking strength of a new, dry, eye-spliced specimen of the mooring hawser shall meet or exceed the manufacturer's published rating. Breaking strength determination shall be conducted using an eye-spliced specimen in accordance with Section 5 of the Cordage Institute Standard Test Methods, or realization test methods in accordance with British Standards.

8.4 The elongation of the rope shall not exceed 35 percent at the rated breaking strength of the rope.

9 ANCILLARY EQUIPMENT

9.1 Chain Tensioning and Lifting Equipment

9.1.1 An air driven winch consisting of a pneumatic drive motor, speed reducing gear, clutch gear, brake gear, winch drum, frame and base shall be located on the buoy deck for retensioning the anchor chain pendants. The winch/line pull capacity, drum wire rope spooling capacity and wire rope diameter shall be designed for the maximum chain tensioning arrangements based on a safety factor of 3. The air motor characteristics including power rating, effective air pressure, and air consumption shall be compatible with the chain retensioning winch capacity. The winch system shall also include all blocks, sheaves, fairleads, reaction points and ancillary rigging to perform the required tensioning functions.

9.1.2 A davit, tripod, lift frame, or derrick including wire rope sheaves, pulleys, and/or guides shall be mounted on the buoy deck in a position directly above the buoy centerwell and extending over the sides of the buoy hull. The davit/tripod and associated rigging shall be designed for retensioning the anchor chain pendants, and lifting and positioning the underbuoy hose system during installation or maintenance. Reaction points shall be designed and provided on the buoy piping assembly for lifting and positioning the floating hose system during installation and maintenance. All blocks, sheaves, fairleads, reaction points and ancillary rigging to perform hose system installation and maintenance shall be provided.

9.1.3 All lifting equipment shall have a minimum load safety factor of 3, and shall be designed for continuous service in an offshore marine environment including exposure to salt water spray. Therefore, the equipment shall be of welded steel fabricated construction and attached in accordance with Section 10 and shall be coated in accordance with Section 12.

9.2 Navigation Aids

The single point mooring shall be equipped with the following navigational aids:

9.2.1 Marine Signal Light

A battery-powered signal light shall be permanently mounted at the highest point on the buoy. The light shall have a 155 mm diameter red acrylic lens designed for 360° horizontal operation and capable of emitting a red light visible at a range of 5 miles (8.3 km), with an atmospheric transmissivity factor of 0.85.

The marine signal light shall have an automatic sun switch to operate the light only during hours of darkness and an automatic lamp changer, holding six (6) lamps, to position a new lamp at the lens focal center when a lamp fails.

An automatic timer shall repeatedly flash a Morse Code "A" signal characteristic. The housing shall have a molded bird spike located at the center of the lens top surface and shall be designed to mount on the radar reflector.

Twelve (12) volt disposable primary cell batteries shall provide sufficient ampere/hour capacity for a minimum of 180 days of unattended operation. The batteries for the marine signal light shall be located in a ventilated battery box designed for use in a salt water marine environment.

9.2.2 Fog Horn

A battery-powered fog horn shall be mounted on the buoy. The fog horn shall be automatically operated and shall be suitable for salt water marine operating conditions with an acoustic range of one half (.5) nautical miles, based on an audio level of 55 phons at the observer's ear under still air conditions. An automatic timer shall provide a repeating Morse Code "C" signal at 30 second intervals.

9.2.3 Radar Reflector

A 20-inch (o.5 m) diameter ANSI 316L stainless steel octahedral radar reflector shall be provided on the buoy. The reflector shall be mounted in a location which is unobstructed and visible from all approach directions. The reflector shall be designed to support the marine signal light.

9.3 Safety Equipment

9.3.1 Life Buoys

Two 30-inch diameter ring-type life buoys with approved water lights and with 100 feet of self floating polypropylene line shall be mounted in accessible locations on the buoy. Life buoy mountings shall prevent the life buoy from being washed away during storm conditions.

9.3.2 Fire Extinguisher

One 15 pound dry chemical fire extinguisher shall be furnished in readily accessible watertight storage containers located on the buoy.

10 STRUCTURAL FABRICATION

10.1 General Requirements

10.1.1 All structural materials and fabrication shall be in accordance with the codes, standards, and references contained in Section 2 and the Contractor's Specification. Structural components shall be fabricated and assembled in the Fabrication Contractor's shop or yard to the maximum extent possible. Work shall not be performed when the weather does not permit satisfactory workmanship or conditions prevent adequate inspection.

10.1.2 All workmanship shall be of the highest quality. All labor shall be performed by men skilled and experienced in their particular line of work. All structural materials shall be installed without springing, forcing or wedging.

10.1.3 Any deviation from this specification shall require approval in writing by Company before starting fabrication. Responsibility for obtaining such written approval shall rest solely with the Contractor.

10.1.4 Shop drawings shall be furnished to Company Representative by the Contractor for information, review and approval prior to fabrication.

10.1.5 As-built drawings which show all field modifications and weld locations, with a numbering system corresponding to the Non-Destructive test reports, shall be furnished to Company Representative by the Contractor no later than 30 days after completion of fabrication. This shall constitute a portion of the inspection records to be prepared and submitted by the Contractor.

10.2 Welded Connections

10.2.1 Welding Procedures

10.2.1.1 All structural welding shall conform to the Contractor's welding procedures approved by the Company. The Contractor shall maintain copies of the procedures in each fabrication area and provide adequate supervision to ensure adherence to the procedures.

10.2.1.2 Welding procedures, complete with repair procedures, shall be prepared in accordance with AWS D1.1, and shall be transmitted to the Company Representative for approval.

10.2.1.3 The procedures shall be approved prior to beginning fabrication.

10.2.1.4 The approved procedures shall be adhered to during construction and any change must be resubmitted for Company's approval.

10.2.2 Welder's Qualifications

10.2.2.1 All welders and welding operators shall be qualified in accordance with ABS Rules for Building and Classing Steel Vessels or AWS D1.1.

10.2.2.2 Welder and welding operator performance certificates shall be maintained on file and available for review by the Company Representative during fabrication.

10.2.2.3 All costs and materials required for the qualification of welders shall be for the account of the Contractor.

10.2.3 Dimensions

10.2.3.1 All welding shall conform to the types, sizes and extent detailed on the Contractor's shop drawings. In the absence of specific instructions, all welding shall conform to ABS Rules for Building and Classing Steel Vessels or AWS D1.1.

10.2.3.2 All welds shall be visually inspected by the Contractor as to size, configuration, appearance, undercut and other surface flaws to insure that all welds conform with the applicable codes.

10.2.4 Primary Connections

10.2.4.1 All welded connections shall be full penetration unless otherwise specified on the Contractor's shop drawings and all welds shall be continuous seal welds to protect the members against corrosion.

10.2.4.2 Edge preparation for beams and shapes shall be in accordance with AWS D1.1, Section 2.

10.2.4.3 Joint details for welding, as shown in AWS D1.1 for plates, pipes and structural shapes, shall be used wherever practical. When a transition from one basic groove detail to another, or to a fillet weld, is required in an otherwise continuous welded connection, the Contractor's shop drawing shall describe the boundaries and changing contour to be developed in the transition zone.

10.2.4.4 All structural welds shall be continuous and properly sized to develop the full strength of the smaller of the two members being joined. All splices shall be V-butt joints, single or double, depending on the size of the member, continuous and of sufficient size to develop the full strength of the member being spliced.

10.2.4.5 All members of the structure shall be properly aligned and spaced to result in a joint configuration conforming to the requirements of AWS D1.1, latest revision, and Contractor's qualified welding procedure. Any bevelled edge that has been damaged shall be restored to the minimum tolerances.

10.2.4.6 All surfaces to be welded shall be free of loose scale, oil or other foreign material. Cleaning shall be performed by grinding, power wire brushing or sand-blasting.

10.2.4.7 Materials may be cut and shaped by machining grinding, chipping, flame or plasma-arc cutting or shearing. Mechanically guided equipment must be used where applicable. Sheared edges not subject to welding shall be trimmed by grinding or machining to a minimum depth of 1/8 inch (3 mm) to ensure complete removal of cracked or cold work metal.

10.2.4.8 All plate edges or pipe ends to be welded shall be examined for lamination before welding. The materials shall be tested for laminations by ultrasonic inspection of the area of the welds, refer to AWS D1.1, Section 10.5.4, for recommended procedure.

10.2.4.9 When the ambient temperature is below 32°F (0°C) the entire area to be welded shall be warmed before welding is started to minimum temperature of 70°F (21°C). Pre-heat and interpass temperatures shall conform to those given in AWS D1.1 Table 2, or Contractor's qualified welding procedure.

10.2.4.10 Welding shall not be done when the quality of the completed weld would be impaired by the prevailing weather conditions; including, without limitation, airborne moisture, blowing soils, or high winds. Windshields may be used when practical. Company's Representative shall decide if weather conditions are suitable for welding.

10.2.4.11 No welding shall be performed in any area when the base metal temperature is above 500°F (260°C).

10.2.4.12 Arc-air gouging shall be an acceptable method for random metal removal and back gouging. The temperature and weather limitations specified above for welding shall apply to all arc-air gouging.

10.2.4.13 In general, all low hydrogen flux-coated electrodes shall be heated before use by holding in a drying oven for a minimum period of 24 hours at a temperature of 300°F (150°C) minimum to 400°F (205°C) maximum; however, the supplier's instructions shall be adhered to.

10.2.4.14 Weld detail, for fillet weld contour and reinforcement of butt welded joints shall conform to the requirements given in AWS D1.1. Full or partial penetration groove-welded Tee joints shall be contoured smoothly into the upstanding member by building up a filler reinforcement in the inner corner with a minimum transition radius equal to 1/2 the thickness of thinner member jointed, but not more than 3/16 inches (4.5 mm) unless otherwise specified for joint strength.

10.2.4.15 Root openings in the welding joint wider than permitted by AWS D1.1, but not greater than the thickness of the thinner member shall be built up by welding to the specified grooved dimensions before the parts are joined.

10.2.4.16 Root openings in the welding joint less wide than permitted by AWS D1.1 shall be chipped or gouged in a manner as to maintain the specified groove dimensions.

10.2.4.17 Care shall be exercised to keep "arc-strikes" and "weld scars" at a minimum. Temporary fit-up and erection attachments shall be welded with the same care and procedures as for the structural connections, If "arc-strikes" occur, dye penetrant examination will be requested.

10.2.5 Seal Welds

10.2.5.1 All tubular members, structural shapes, connection, stiffeners, gussets, and miscellaneous plate materials shall be seal welded in place to minimize corrosion.

10.2.5.2 All attachments to the buoy deck such as pipe supports, packaged equipment, etc. shall be seal welded in place to minimize corrosion.

10.2.5.3 Non-structural seal welds shall be fillet welds or partial penetration groove welds and shall not be larger than 1/8 inch (3 mm).

10.2.5.4 Strength welds and full penetration welds shall be as specified on the Contractor's shop drawings.

10.2.6 Temporary Welds and Repairs

10.2.6.1 When temporary welding is deemed necessary, the welding shall be performed with the same care, materials, electrodes, minimum preheat, and procedures as permanent weld installations.

10.2.6.2 Temporary welds shall be removed in such a manner as to prevent damage to the parent materials. All damage (gouges, tears, etc.) unacceptable under the governing codes shall be repaired in accordance with these codes. Temporary welding shall not be removed by arc-air gouging.

10.2.6.3 Defects in weld deposits shall only be repaired after authorization by Company Representative. Removal of defects for repair may be by any method which produces a clean uncontaminated surface for installation of the repair weld.

10.2.6.4 Weld repairs shall be accomplished in accordance with the original, approved weld repair procedure. This procedure may be developed to encompass multiple types of defect repair, but shall provide for maximum adherence to the essential requirements of the Qualified Welding Procedure.

10.2.7 Quality Control

10.2.7.1 Thirty (30) days prior to beginning work, Contractor shall furnish the Company Representative for approval Contractor's Quality Assurance and Quality Control Procedures. Welding inspection shall be in accordance with the requirements of the applicable codes and specifications and shall include but not be limited to visual inspection, ultrasonic testing, radiographic testing, magnetic particle testing and dye penetrant testing. The Contractor shall furnish all equipment necessary to conduct these tests and shall submit to the Company Representative complete descriptions of the procedures required for each type of test performed.

10.2.7.2 Regardless of any other method of inspection used, all welding shall be subject to visual inspection. Visual inspection shall include checking the fit-up of joints to be welded to see that they are in proper alignment and conform to the requirements of the welding procedure in respect to groove angle, root face, root opening and undercut. Before any inspection, all welds should be cleaned of weld spatter.

10.2.7.3 The procedure for care and storage of electrodes shall include the storage conditions prior to opening containers, the holding temperature after opening, and the reconditioning procedure for electrodes which have been exposed to atmospheric conditions for periods in excess of manufactures's recommendations. A positive means of identification of wire and electrodes shall be established.

10.2.7.4 The flux condition procedure shall detail methods of assuring dryness before use, recovery of flux after use, screening of foreign materials and flux, and the storage of flux to prevent contamination.

10.2.7.5 Definite methods shall be established for all operations involving preheat, interpass temperature, post heat or stress relief temperature control.

10.2.7.6 A Procedure whereby each welder shall be assigned a unique identifying number that he shall use to identify all welding performed by him.

10.2.7.7 A Procedure for color coding each grade of steel is to be used. Marking shall be applied with paint. Lumber crayon or wax sticks are unacceptable. Paint may be used on unprimed material. If materials are primed a paint compatible with final coating system shall be used.

10.2.7.8 The welder and weld area shall be provided with protection during periods of inclement weather and/or excessive wind conditions. The procedures shall include means of protecting electrodes, wire, fluxes, etc.

10.2.7.9 The Contractor shall include in quality control procedures a brief description of precautions to be taken to prevent warpage in accordance with AWS D1.1, Section 3.

10.2.8 Inspection

10.2.8.1 All circumferential butt welds on primary structural members shall be 100 percent radiographed in accordance with AWS D1.1 Section 6 unless this is impractical because of weld location. Film interpretation shall be in accordance with AWS D1.1, Section 10.

10.2.8.2 All butt welds which cannot be radiographed shall be ultrasonically examined in accordance with AWS D1.1, Sections 6 and 8.

10.2.8.3 In accordance with standard offshore industry practices and AWS requirements, it is not recommended that ultrasonic examination generally replace 100 percent radiography of primary structural members.

10.2.8.4 Flange welds in all primary structural shapes shall be 100 percent inspected with radiographic or ultrasonic techniques in accordance with AWS D1.1, Sections 6 and 8.

10.2.8.5 Padeyes and lifting devices welded to the structure shall be 100 percent inspected using ultrasonic techniques where practical. Fillet welds shall be inspected using magnetic particle or dye-penetrant methods.

10.2.8.6 Prior to framing a branch member into a mating member where the loading is directed perpendicular to the surface of the mating member, the mating member shall be examined for the presence of laminations. The area shall be examined 100 percent along the plane of the weld fusion and for a distance equal to twice the branch member thickness on either side of the plane of the weld.

10.2.8.7 Full penetration welds on secondary members such as pipe supports, mud mats and ancillary structures shall be ultrasonically or radiographically inspected by a 10 percent random method. The amount of inspection may be increased by the Company Representative if the examinations indicate unacceptable defects. The inspection shall be in accordance with AWS D1.1, Section 6, 8 and 10.

10.2.8.8 The root (or second) side of all joints shall be back gouged to clean sound metal. The back gouged weld root shall be subject to inspection (for porous or unfused metal and cracks) by magnetic particle methods, until the gouging operating has been demonstrated capable of consistently producing a sound weld surface for subsequent weld passes.

10.2.8.9 The root pass of all partial penetration groove welds shall be visually inspected for adequate penetration into the joint before welding is continued.

10.2.8.10 All inspection operations shall be maintained concurrent with weld completions. All general clean up and surface repairs shall be completed before final inspection.

10.2.8.11 Welding on primary strength members shall not be permitted on any galvanized surface or any surface coated with a lead or zinc bearing paint, unless otherwise specified.

10.2.8.12 As fabrication of various items or portions of a structure is completed, the Contractor shall grind welds and remove all burrs, tack welds and gouges made by scaffolding of temporary bracing used in the fabrication procedure. Random arc strikes shall be removed by grinding and/or weld repair.

10.2.8.13 All rough and/or sharp edges and welds shall be ground smooth.

10.3 Bolted Connections

10.3.1 All bolted connections shall conform to the requirements of AISC manual of Steel Construction, Part 5, unless otherwise specified.

10.3.2 All holes for bolted connections shown on the Contract Drawings shall be of a diameter of 1/16 inch larger than the bolts used.

10.3.3 Bolts shall be inserted accurately into the holes without driving or damaging the threads. Bolt heads and nuts shall rest squarely against metal.

10.3.4 Bolts transmitting shear shall be threaded to assure that no more than one thread will be within the grip of the structural members.

10.3.5 The bolts shall be of a length that will extend entirely through but no more than approximately 1/4 inch (6 mm) beyond the nuts. Bolt heads and nuts shall be drawn tight against the work.

10.3.6 All holes shall be drilled at right angles to the surface of the metal as shown on the shop drawings and shall not be enlarged by burning. Enlarging of holes shall be by reaming only, and with approval from the Company. All holes shall be drilled and reamed as necessary prior to application of protective coating.

10.3.7 Unfinished bolts and nuts may not be used permanently in main members. They may only be used temporarily during construction or permanently in secondary members.

10.3.8 Finished bolts and nuts shall be either cadmium plated or galvanized except where shown otherwise on the Contract Drawings. They shall be designed and installed in accordance with the AISC "Manual of Steel Construction."

10.3.9 Provision shall be made to prevent loosening of nuts due to vibration of the structure. A lock nut system using either two nuts or a nut and a lock washer shall be used to join any components of the structure which may be removed later for maintenance or operation. Tack welding of the nut to the bolt may be used on permanently installed bolts and submerged bolts.

10.4 Dimensional Control

10.4.1 To effectively control fabrication tolerances of vital structural dimensions, the Contractor shall submit every two weeks a dimensional control report to Company Representative giving at least the overall structure dimensions.

10.4.2 Any other available dimensional control data and report shall also be made available to Company Representative upon requested.

11 PRESSURIZED PIPING FABRICATION

11.1 General Requirements

11.1.1 Fabrication under this specification shall include all components of the piping system, or part thereof connecting fabricated assemblies including testing and fit-up of complete fabricated assemblies to ensure correct fit and alignment, including all in-line valves, gaskets, bolts and flanged fittings to ensure the integrity and proper functioning of all components.

11.1.2 The Contractor shall furnish shop drawings to the Company Representative for review and approval prior to start of fabrication.

11.1.3 Prior to the start of fabrication and/or installation, the Contractor shall submit his Welding Procedure Specification (WPS) and Welding Procedure Qualification Record (PQR) to the Company for approval.

11.1.4 Qualified personnel only shall be employed by the Contractor for the fabrication and installation of all phases of the work involved for the pressurized piping fabrication.

11.2 Material Requirements

11.2.1 Material Inspection

11.2.2 Each length of pipe shall be thoroughly examined for evidence of damage to pipe wall or end bevel. Damaged portions of pipe shall be removed and damaged or improper bevels shall be re-ground to applicable specifications.

11.2.3 Each imperfection or damage that impairs the serviceability of the piping or pipe fittings must be repaired or removed. If repair is made by grinding, the remaining wall thickness must be at least equal to the minimum thickness required by the tolerance in API Specification 5L.

11.2.4 Any of the following pipe defects or damages shall be considered as unacceptable defects and shall be cut from the pipe and the fitting shall be replaced.

a. A dent with a stress concentration.

b. A dent affecting a longitudinal weld or circumferential weld.

c. A dent or scratch that has a depth of more than 2 percent of the nominal pipe diameter on 14 inch (356 mm) or larger pipe.

11.2.5 For any component pipe material supplied by the Contractor, four (4) certified copies of mill test reports shall be provided.

11.2.6 For any component material other than pipe, such as flanges and welded fittings supplied by the Contractor, for which mill test reports are not available, the Contractor shall provide certified statements that the material meets all requirements of the designated ASTM specification.

11.2.7 Legible mill test reports and/or certified statements shall be available to the Company Representative.

11.2.8 Material Preparation

11.2.9 Internal and external surfaces to be welded shall be free from paint, oil, rust, scale or other material that would be detrimental to either the weld or the base metal under welding conditions.

11.2.10 All pipe and fittings shall be examined internally and cleaned where necessary to ensure that they are free from dirt and other contamination. Prior to line-up of a pipe for welding, it shall be reexamined to ensure that it is clean and free of all extraneous matter.

11.2.11 Pipe bevels, when repaired, shall be ground to a bright metal finish for a distance of 1/2 inch on the inside and outside of the pipe. Bevelling by a hand held cutting flame is not permitted.

11.2.12 All piping, where possible, shall be lined up for welding by use of an internal line-up clamp, and no tack welds shall be permitted when aligning the pipe for position welding. For all other pipe work where use of an internal line up clamp is impossible, an external line-up clamp shall be used.

11.2.13 Tack welding of pipes aligned by an external clamp shall be avoided as far as possible and only undertaken when essential. Tack welding may be performed with the approval of the Company Representative.

11.2.14 If a tack weld is to be incorporated in the completed weld, it shall be ensured that the tack penetrates to the bottom of the welding groove being of same quality as the finished weld and is made by a qualified welder. Otherwise, the tack shall be removed by grinding or chipping it out to the base metal, but it shall be ensured that the original joint design is maintained. Tack welds lacking penetration are not acceptable.

11.2.15 The minimum tack length shall be 1.5 inch (38 mm) for pipe 12 inch (305 mm) diameter and larger, and 1 inch (25.4 mm) for pipe smaller than 12 inch (305 mm) in diameter. The tacks shall be equally spaced around the pipe and there shall be at least two tacks on smaller diameter pipe. When conditions so warrant, more than two tacks may be required on the smaller diameter pipe. Large tack welds, which almost fill the welding groove, are not acceptable.

11.2.16 Stud bolts and nuts used in the installation of flanged joints shall be PTFE coated and shall conform to ASTM A193-B7 and ASTM A194-2H, respectively.

11.2.17 All bolts are to extend through the nuts by a minimum of two (2) threads. Bolt lengths to be as quoted in drilling and template tables of ANSI B16.5.

11.3 Welded Connections

11.3.1 All production welding, inspection, preparation and matters related thereto shall be governed by ANSI B31.3 and ASME Section IX. However, where any clause in this Specification calls for stricter or additional requirements to those included in ANSI B31.3, such clauses shall be deemed to supplement, add to or replace the relevant clause in ANSI B31.3. In addition, the requirements of all jurisdictional codes within which the piping systems are to be installed shall also be satisfied.

11.3.2 Prior to the start of welding, welding procedures shall be prepared in detail by the Contractor and submitted to the Company for approval a minimum of 30 days prior to commencement of work.

A copy of all approved welding procedures required to perform the work shall be maintained at the job site.

11.3.3 A weld map or table or fabrication drawing specifying the welding procedure to be used for each weld is required.

11.3.4 A welding procedure shall be considered qualified under this Specification only after all the following items are complete and the procedure has been submitted and approved in accordance with the following:

a. The Contractor shall prepare a written Weld Procedure Specification (WPS).

b. The Contractor shall prepare weld test coupons in accordance with the WPS.

c. The Contractor shall have a qualified materials testing laboratory (approved by the Company) prepare and test the specimens in accordance with this Specification and the relevant governing code.

d. The Contractor shall have the testing laboratory record and certify the test results of the procedure qualification on, or attached to a Welding Procedure Qualification Record (PQR).

e. The Contractor shall certify that the WPS and the results of testing, as reported in the PQR meet the requirements of this Specification and the relevant governing code.

11.3.5 The Contractor shall submit the WPS, PQR, and Request Forms to the Company through the Company Representative. Welding may not commence until written approval from the Company has been obtained.

11.3.6 In addition to the essential variables listed in the various codes, the following are also to be considered essential variables for this Specification:

a. An increase of more than 10 percent over the current used in the qualification test for SMAW or GMAW vertical-down welding.

b. An increase of more than 1/32 inch (0.8 mm) in diameter over the electrode size used in the qualification test for SMAW or GMAW vertical-down welding.

c. Welding procedure qualification on carbon steels which use controls other than stress relieving to control the hardness of the weldment shall also include a hardness traverse test across the heat affected zone (HAZ) and base metal to ensure a hardness of less than HRC 22.

11.3.7 Qualification of Welders

11.3.7.1 The Contractor shall only use competent and skilled welders. No welding shall be done on any pipes, fittings or any other equipment by welders who have not demonstrated their competence by tests as required herein.

11.3.7.2 The qualification tests of welders shall be as described in ASME, Section IX or API 1104. Tests shall be performed under the supervision of a Company Representative. A set of welder qualification records shall be maintained at the job site for examination by the Company Representative.

11.3.7.3 Welder qualification by radiography only is not acceptable.

11.3.7.4 The only two codes used to qualify welders are as follows:

a. ASME, Section IX (latest issue at time of qualification).

b. API 1104 (latest issue at time of qualification) for piping work. This code may require more than one qualification per welder.

11.3.7.5 The Company reserves the right to monitor any and/or all phases of the contractor welder testing procedures, and to require retesting of any welder at any time.

11.3.8 Welding Electrodes

11.3.8.1 Heavy flux coated type electrodes, filler wires, and fluxes shall conform to the requirements of ASME Boiler and Pressure Vessel Code, Section II, Part C, or AWS A.5 specifications for welding carbon steel pipe and for welding stainless steel pipe, as indicated on the approved welding procedures.

11.3.8.2 Electrodes and filler metals, used in all welding processes, shall meet the additional requirements of Section IV of the ASME Boiler and Pressure Vessel Code.

11.3.8.3 Electrodes shall be supplied by the Contractor in airtight containers. These contained shall be kept sealed and be opened only as and when required. Electrodes which have been removed from their sealed containers shall be stored in ovens, in accordance with ASW D.1.1 Specification. Any welding electrode which shows evidence of moisture absorption in the flux, deterioration or damage shall be discarded.

11.3.9 Welding Processes

11.3.9.1 The following welding processes are acceptable under this Specification:

a. Shielded Metal Arc Welding (SMAW).

b. Gas Tungsten-Arc Welding (GTAW or TIG).

c. Gas Metal-Arc Welding (GMAW).

d. Submerged Arc Welding (SWA).

e. Combinations of the above processes.

11.3.9.2 Welding of pipe 2 inches (51 mm) and over nominal diameter shall be performed by one of the above electric arc welding methods. Butt welds in pipe diameters of less than 2 inches (51 mm) shall be made by the GTAW process.

11.3.9.3 For welding of stainless steel pipe, the GTAW process shall be used on the root pass of open butt joints welded from one side only.

11.3.9.4 All welds greater than 0.125 inch (3 mm) thick shall be made in at least two passes.

11.3.9.5 Welded branch or tee connections shall be made by full penetration weld only.

11.3.9.6 No active flux or fluxes which produce a manganese build up in multi run welds should be used in the SAW process which would create unacceptable hardness values.

11.3.9.7 Pipe shall not be welded when its temperature is less than 32 degrees Fahrenheit (0°C).

11.3.10 Preheat and Postheat Treatment

11.3.10.1 Heat treatment will be required where specified before, during, and/or after welding. This Specification shall be used to determine such requirements including equipment, heating methods, and inspection. Preheat temperature and practices shall be specified in the welding procedure and approved by the Company Representative.

11.3.10.2 All welding shall be performed utilizing interpass and preheat (when required) temperature sufficient in magnitude to eliminate the initiation of cracks or unacceptable hardness valves. Preheat and interpass requirements are normally stated as minimums. The preheats listed in the applicable code, either required or recommended, shall be mandatory.

11.3.10.3 Preheat and interpass temperatures shall not be exceeded if stated as a maximum. This requirement is for materials such as quenched and tempered steels, which will be adversely affected if heated to temperature above the specified.

11.3.10.4 If a weld is not completed and a preheat is specified, then the weld must be preheated again before recommencing welding.

11.3.10.5 Preheating shall be carried out by approved methods such as by gas burners or electrical resistance heaters.

11.3.10.6 When an interpass temperature is specified, it must be achieved before the next pass is started. Some, but not all, materials may require a continuous minimum interpass temperature maintenance until the weld is completed.

11.3.10.7 The areas to be welded shall be preheated equally so that the maximum preheat difference between the two pieces being welded shall not exceed 100°F (55°C) at the time of welding.

11.3.10.8 Temperature indicating crayons or contact pyrometers shall be used to control and measure preheat and interpass temperatures.

11.3.10.9 The preheat temperature applies to the entire thickness of the weld and at least 2 inches (50 mm) on each side of the weldment. Whenever possible, heating shall be done on the opposite side of the work from where the welding will be performed.

11.3.11 Postweld Heat Treatment

11.3.11.1 Postweld heat treatment is not required for Carbon Steel material if nominal wall thickness is 0.75 inches (19 mm) or less.

11.3.11.2 Postweld heat treatment is required for all Carbon Steel material if nominal wall thickness is greater than 0.75 inches (19 mm).

11.3.11.3 Postheat requirements shall be in accordance with the applicable code. Unless specified otherwise by the applicable code or standard, heating and cooling rates shall conform to ASME, Section VIII.

11.3.11.4 Postweld heat treatment times and temperatures shall be applied over an area extending at least 3t or 1 inch (25 mm), whichever is greater, from each edge of the weld (t = wall thickness of the thickest part being welded).

11.3.11.5 Postweld heat treatment for chromium alloy steels up through 13 percent chrome shall be performed according to one of the two time schedules below. No other heat treatment schedule is allowable:

a. Preferred Method: Postweld heat treatment is applied immediately after welding is completed. The temperature of the weldment shall not fall below the specified minimum preheat temperature before the postweld heat treatment is applied.

b. Interrupted Heat Treatment: For cases when the postweld heat treatment is not applied immediately after welding, but will be applied after initial cooling, the specified minimum preheat temperature shall be maintained after welding for at least one hour per inch of thickness before the weldment is allowed to cool. (This procedure minimizes the danger of delayed hydrogen cracking.) Subsequent postweld heat treatment shall be applied in accordance with the applicable code.

11.3.11.6 Postweld heat treatments may be carried out using one or more of the following types of heat sources:

a. Permanent or semipermanent furnaces (gas or electric).

b. Electrical resistance heaters.

c. Electrical induction heaters.

d. Gas burners (not to be used for piping or vessels less than 24-inch diameter).

Note: Exothermic kits for field welds may be used only when specifically designed for the particular application and with the prior written concurrence of the Company Representative.

11.3.11.7 The postheat temperature shall be within the range of 1100 to 1200°F. The heat rates shall not exceed 400°F per hour, after reaching 600°F. The cooling rates shall not exceed 500°F per hour down to 600°F, after which cooling is not critical.

11.3.11.8 Thermocouples and a temperature chart recorder shall be used to provide an accurate and legible record of all postweld heat treatments.

11.3.11.9 Thermocouples shall, if possible, be placed on the inside for objects being heated from the outside and vice-versa, if internally heated.

11.3.11.10 At least two thermocouples shall be used for circumferential welds on pipe diameters of 2 inches (51 mm) through 24 inches (610 mm). These should be placed at the top and bottom (6 and 12 o'clock) of the pipe. Pipes less than 2 inches (51 mm) diameter may have only one thermocouple. Pipes of diameter larger than 24 inches (610 mm) shall have at least four thermocouples equally spaced around the circumference.

11.3.11.11 Hardness testing if required, shall not be done until the vessel or pipe has reached ambient temperature, and shall be carried out on or as near to the weld heat affected zone as possible in addition to tests of the weldment.

11.3.11.12 Adherence to final hardness reading, where specified, is required in addition to meeting time and temperature requirements.

11.3.11.13 Pipe ends, flange faces and threaded joints shall be suitable protected against damage during heat treatment unless subsequent approved machining operations are employed to remove any damage caused.

11.3.11.14 Pipe bends shall be checked after heat treatment to assure proper alignment of flanges and correct dimensions. Cold bending will be permitted to correct deviations that are within acceptable tolerances from the true dimensions.

11.3.11.15 The postweld heat treatment procedure shall be reviewed and approved by the Company Representative.

11.3.11.16 All postweld heat treatment chart records shall be obtained and checked by the Company Representative and submitted as part of the equipment file for permanent record.

11.3.11.17 The Company Representative shall verify all temperature indicating and recording equipment prior to use for proper calibrations certification.

11.3.12 Fabrication

11.3.12.1 All weld preparation shall be in accordance with ANSI B31.3, and other applicable Company approved or specified details.

11.3.12.2 Spacers shall be used while tack welding pipe and fittings in position to ensure proper weld gap and full penetration in welding. The tack welds complying with the requirements of ANSI B31.3 may be allowed to become a part of the finished weld, whereas those not complying are not acceptable and must be chipped out before completing the weld.

11.3.12.3 Tacks which are to be incorporated in the completed weld shall be thoroughly cleaned and suitable prepared at each end by grinding to ensure complete root continuity.

11.3.12.4 Where pipe, fittings and flanges are to be joined by circumferential butt-welds, the corresponding parts shall be modelled and matched so that any misalignment at the inside of the piping shall not exceed 1/6 inch (1.5 mm) at any point of the circumference of the joint.

11.3.12.5 All flanged joints shall be made by the use of weld neck flanges only. The pipes shall be so aligned that the flange faces are paralleled.

11.3.12.6 Bolt holes of flanges shall straddle the vertical and horizontal center lines.

11.3.12.7 The use of permanent backing strips is not permitted.

11.3.12.8 Cold bending or local heating used to correct minor discrepancies in alignment and deviations from true dimensions may be performed only under the direction of the Company Representative, who shall approve the method used and the need and extent of heat treatment required.

11.3.12.9 Longitudinal seams in adjoining lengths of welded pipe shall be staggered and shall be located to clear openings and external attachments.

11.3.12.10 Branch connections and branch reinforcements should not be positioned over girth welds.

11.3.12.11 Adjacent circumferential welds shall not be spaced closer than 2 inches (50 mm) between the outside edges of adjoining bevels.

11.3.12.12 Pipe support attachments shall be centered over pipe supports in the ambient temperature position and welded to the pipe during shop fabrication prior to stress relieving and hydrostatic testing.

11.3.12.13 Reinforcement pads shall be fabricated and positioned in accordance with ANSI B31.3 or ASME, Section VIII. Basic material shall be the same as the pipe material unless otherwise approved by the Company Representative. Pad sizes and shape may be altered provided that the equivalent cross sectional area is maintained and ANSI B31.3 code requirements are met. Each pad or pad section shall have a 3 mm vent hole positioned away from the crotch area. When two or more sections are used to fabricate reinforcement pads, the welded joints shall be circumferential and not longitudinal.

11.3.12.14 Threadolets and sockolet may be substituted for screwed or socket weld couplings whenever such substitutions do not result in an increased cost.

11.3.12.15 All couplings welded into pipes are to be carefully shaped to suit the contour of the pipe, and the bore of the coupling reamed out. A hand tap should be run into couplings after welding to clean out and true-up threads.

11.4 Non-Destructive Examination and Tests

11.4.1 General

11.4.1.1 Inspection shall include, but not necessarily be limited to, visual inspection for satisfactory workmanship, dimension checks, face defects, materials, welding, testing and compliance with the applicable Specifications.

11.4.1.2 Ample notice in writing as to when fabrication will start and testing will be carried out shall be given to the Company Representative so that the Representative may witness any particular parts of the fabrication process and testing.

11.4.1.3 All materials, welding and all other aspects of fabrication shall be subject to inspection and approval by the Company Representative at any time.

11.4.1.4 All tests and inspections shall be performed at the place of fabrication.

11.4.1.5 Evidence or discovery of materials which are not furnished in accordance with the relevant specifications shall be cause for rejection of the components material involved.

11.4.1.6 All welds shall be subject to the visual examination requirements of ANSI B31.3 by the Contractor.

11.4.1.7 The Contractor shall perform one hundred (100) percent radiographic examinations for all the following welds. Fittings containing longitudinal welds shall also be radiographed at the junction of welds.

11.4.1.8 Radiograph examinations shall be in accordance with ANSI B31.3 Code. The radiographic film shall be developed and interpreted by the Contractor and receive approval by the Company Representative before the weld in accepted.

Note: Radiographic examination shall be made before installation of separate components which may make radiographic examination impractical.

11.4.1.9 Radiographic technique and sensitivity requirements shall be according to the ASME Code for Unfired Pressure Vessels, Section VIII, Paragraph UW-51.

11.4.1.10 Should visual inspection by the Company Representative indicate questionable workmanship, or the radiograph reports show inadmissible defects, then the Company Representative may request additional 100 percent radiography, which may not be limited to only those welds in question.

11.4.1.11 Welding defects are not permissible. Welding imperfection limitations, as defined in ANSI B31.3, are allowable subject to correct repair procedures being performed and the following additional requirements:

a. No crack at the region of the weldment, regardless of cause, size or location will be acceptable and repairs will not be permitted. A weldment showing evidence of a crack shall be cut out of the line and the adjoining components prepared for re-welding.

b. Where an acceptable imperfection in a completed weld has undergone a repair, but radiographic examination following the repair indicates the repaired area is still unacceptable, secondary repairs at the same location may only be permitted at the discretion of the Company Representative.

c. All repairs made to welded joints shall be re-radio-graphed to establish that the repair is sound and the welded joint is acceptable.

11.4.1.12 Radiographic examination of a welded joint may be supplemented by ultrasonic and/or dye penetrant inspection, if this assists in the evaluation of a defect, or for welds in difficult positions.

11.4.1.13 Welding processes employing inert gas welding techniques shall exhibit the following radiographic standards of acceptability and additional requirements:

a. The root of the weld shall exhibit a smooth contour and complete freedom from evidence of non-fused land at the edges of the base metal.

b. Sink or depression of the root pass shall not result in a total thickness, including weld reinforcement, which is less than the original wall thickness of the material being welded. The total length of depression of the root pass shall not exceed 20 percent of the circumference of the pipe.

11.4.2 Hardness Tests

11.4.2.1 Hardness testing shall be performed in accordance with ANSI B31.3 when the component part is at ambient temperature.

11.4.2.2 Hardness tests shall be made on a minimum of 10 percent of all welds and 100 percent of those which are locally heat treated.

11.4.2.3 Hardness tests or weld metal and heat affected zones shall also be made on a minimum of 10 percent of production welds when approved controls other than stress relieving are used to control material hardness.

11.4.2.4 The hardness of the weld metal and heat affected zone in carbon steels shall not exceed HRC 22. In any instance where hardness tests indicate an unacceptable value, stress relieving and/or re-welding shall be mandatory to reduce the hardness to within acceptable limits.

11.4.2.5 The Company Representative shall be permitted to call for additional hardness testing on all production welds if test results are determined unsatisfactory. Hardness retesting shall be mandatory for stress relieved and/or re-welded materials.

11.4.2.6 The hardness tests shall be conducted on metallic surfaces affected by bending or welding operations. For stress relieved weldments, the hardness values stated in ANSI B31.3 shall not be exceeded. For annealed bends, the hardness values shall not exceed 180 Brinell.

11.4.2.7 Hardness traverse tests, if requested by the Company Representative, shall be conducted on ground and polished cross sections of the weld. The traverse shall extend from the weld, through the heat affected zone (HAZ) and into the parent metal.

11.4.3 Hydrostatic Pressure Tests

11.4.3.1 Fabricated spool assemblies and/or installed piping systems, where all openings are flanged or threaded, shall be hydrostatic tested to 340 psig and held for six (6) hours.

11.4.3.2 Test records shall be prepared and maintained for all piping systems. Test records shall include date of test, ambient temperature, identification of piping system tested, test pressure, test fluid with its temperature, approval signatures of the Contractor and the witnessing Company Representative.

11.4.3.3 All tests, satisfactory or not, shall be recorded and all test forms shall be made part of the permanent job records.

11.5 Dimensional Control

11.5.1 Prior to preparation for shipment, all parts and dimensions of the fabricated buoy piping assembly shall be checked to ensure the final fabrication meets all the requirements according to the drawings and specifications.

11.5.2 The release of the fabricated buoy piping assembly by the Contractor shall not relieve the Contractor of his responsibilities. Details at any time may be subject to inspection by the Company Representative and any rejections made by his authority shall be considered as final.

12 PROTECTIVE COATING SYSTEM

12.1 Surface Preparation

12.1.1 All welded areas, weld spatter and residual flux shall be given particular attention during abrasive blasting. Special care is required to remove corrosion products from pits and cracks. Rough welds, sharp edges, cutoffs, slag, spatter and all burned, scarred or scored areas shall be removed by chipping or grinding prior to abrasive blasting. Power tool cleaning shall be in accordance with SSPC SP 3 "Power Tool Cleaning."

12.1.2 Abrasive blasting shall be permitted only when the steel surface is 5°F (3°C) or more above the dew point. Contractor shall have available and use at the coating site a hygrometer, a surface pyrometer and a dew point calculator to verify compliance. In no case shall blasting be done when the temperature is below 40°F.

12.1.3 Abrasive blasting shall be allowed only if the relative humidity is 85 percent and falling and if other weather conditions will permit the surface to remain dry for several hours after blasting and coating. All blasting operations shall cease if the relative humidity is 85 percent and rising.

12.1.4 Prior to blasting, all deposits of grease or oil shall be removed by chemical cleaning.

12.1.5 The blast cleaning operation shall be scheduled such that no more surface is cleaned than can be given the base coating during the same working day. Any surface which shows indication of rust after blast cleaning shall be re-blasted to a near white metal surface prior to the application of any coatings. In no case shall blast cleaning be carried out during periods of rainfall or foggy weather, or when condensation is present on the steel surfaces, or when the temperature is below 50°F (10°C). All blasted areas remaining overnight or for more than an eight hour period without being primed shall be re-blasted before application of the primer.

12.1.6 Steel surfaces shall be prepared for coating by abrasive blasting to a minimum cleanliness of Near White Metal SSPC-SP-10-67/SIS-SA 2.5. The minimum/maximum acceptable surface profile after blasting is 35 to 65 μM (1.5 to 2.5 mils).

The height of the profile shall not exceed 1.5 mils and the anchor pattern shall be uniform throughout the area covered.

Note: SA 2.5 is defined as follows:

SA 2.5, Near-white Metal Blast: A surface where at least 95 percent of each element of area is in the white metal condition. All oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint, or other foreign matter shall be completely removed from the surface except for very light shadows, very slight streaks, or slight discolorations caused by rust stain, mill scale oxides, or slight, tight residues of paint or coating that may remain. At least 95 percent of each square inch of surface area shall be free of all visible residues, and the remainder shall be limited to the light discoloration mentioned above. Photographic or other visual standards of surface preparation may be used as provided in the Appendix of Steel Structures Painting Manual Volume 2 "Systems and Specifications" to modify or further define the surface if specified in the contract.

12.1.7 The blasting media shall be manufactured or a by-product abrasive such as steel grit, aluminum or mineral slag. It shall be contaminant free, dry, angular, and of sufficient particle size, hardness and density to provide the specified surface profile. The abrasive shall be approved by the Company in writing prior to commencing the blasting. Use of reclaimed grit or sand is prohibited. Blasting shall be performed by experienced operators with approved equipment.

12.1.8 The compressed air used for nozzle blasting shall be free of contamination. First and second stage moisture and oil separators and driers shall be provided and these shall be kept emptied of contaminants.

12.1.9 The nozzle size shall be 3/8-inch (9.5 mm) minimum to 1/2-inch (12.7 mm) maximum inside diameter. The nozzle shall be held 6-inches (152 mm) to 12-inches (305 mm) from the surface with a minimum abrasive discharge pressure of 90 psig.

12.1.10 Abrasive blasting shall not be done within 300 feet (91 m) of coating operations or wet paint areas which are susceptible to contamination. Precautions shall be taken to ensure that the residual abrasive material dust does not enter any bearing assemblies or the sealing surfaces. Surfaces which cannot be blast cleaned shall be cleaned with a disc sander or grinder to a grey metal SSPC-SP10-67/SIS-ST 2.5 surface.

12.1.11 All preparation and blasting operations shall be stopped each day to allow sufficient time to complete priming before the end of daylight hours.

12.1.12 All valve and equipment manufacturer's identification plates shall be masked for protection during blasting and painting operations.

12.2 Coating Systems

12.2.1 Preparation and Construction Primer

12.2.1.1 Immediately after blast cleaning, apply one coat of Dimetcoat 205 Inorganic Zinc shop primer to a dry film thickness of 0.5 to 1 mil (12.5 to 25 microns). This coating shall be applied to all steel plate and sections prior to fabrication and be allowed to dry 10 minutes prior to handling and 24 hours prior to applying any top coats. After fabrication all <u>exterior surfaces</u> are required to be blasted removing shop primer and immediately coated as stated below.

12.2.1.2 Interior surfaces will require either mechanical cleaning or blasting of areas where primer was damaged or soiled during fabrication and coated as stated below.

12.2.2 Coating Areas

12.2.2.1 For coating purposes, the SPM system surfaces are divided into three areas:

a. Emerged intermittent wet and dry or splash zone surface areas of the buoy hull and rotating turntable assembly exterior extending from 1.64 feet (0.5 meters) above the design water line to the top structure.

b. Submerged surface areas of the buoy hull exterior extending from the bottom of the buoy hull to approximately 1.64 feet (0.5 meters) above the design water line.

c. Interior surface areas of the buoy hull.

12.2.3 Coating Systems

a. Emerged Surfaces

Coating System	Dry Film Thickness
1 coat of Inorganic Zinc (Dimetcote 9 or equal)	3.0 mils (75 microns)
1 coat of Polyamide Epoxy Red Oxide (Amercoat 385A or equal)	5.0 mils (125 microns)
1 coat of Polyamide Epoxy Orange (Amercoat 385 or equal)	5.0 mils (125 microns)
1 coat of Modified Acrylic White (Amercoat 234 or equal)	2.5 mils (63 microns)

b. Submerged Surfaces

Coating System	Dry Film Thickness
1 coat of Amercoat 385A Epoxy Red Oxide	6.0 mils (150 microns)
1 coat Amercoat 385 Epoxy White	6.0 mils (150 microns)
1 coat Amercoat 698 HS Antifouling Gray	3.0 mils (75 microns)
1 coat Amercoat 698 HS Antifouling Red	3.0 mils (75 microns)

c. Interior Surfaces (ALL)

Coating System	Dry Film Thickness
1 coat Dimetcote 205 Primer	0.6 mils

	(15 microns)
1 coat Amerlock 400 HS Epoxy Pearl Gray	5.0 mils (125 microns)
1 coat Amerlock 400 HS Epoxy White	5.0 mils (125 microns)

12.3 Coating Application

12.3.1 The application of coatings shall be in strict accordance with the manufacturer's recommendations. A complete set of application procedures shall be provided to Company at least seven (7) days prior to coating applications.

12.3.2 Coatings shall only be applied when the relative humidity is within the limits shown below unless a deviation is specifically authorized in writing by Company.

Coating	Relative Humidity Minimum	Preferred	Maximum
Inorganic Zinc	20%	above 50%	95%
Epoxy	20%	below 80%	85%

12.3.3 All coatings shall be applied only to surfaces that are thoroughly dry and only under such combination of humidity and temperature that will cause evaporation of moisture from the surfaces rather than condensation. In no case shall any paint be applied to surfaces upon which there is frost, moisture, or during foggy or misty weather, or when the temperature is below 50°F (10°C) or the relative humidity is above 85 percent.

12.3.4 Coatings shall not be applied when there is a likelihood of a deterioration in weather conditions within two (2) hours after application. The Company will suspend application of coating when, in Company's opinion, damage to the coating may result from actual or impending weather conditions.

12.3.5 All materials should be applied to clean surfaces by spraying in such a manner as to produce smooth, even coatings of uniform thickness completely covering all corners and crevices.

12.3.6 Spraying shall be done in areas free of sparks, flames, unusually hot surfaces, strong winds, and operating electrical equipment that is not explosion proof. All coating should be applied to clean surfaces by spraying in such a manner as to produce smooth, even coatings of uniform thickness completely covering all corners and crevices. Surfaces which have been painted shall not be worked on or otherwise disturbed until the last paint applied is completely dry and hard.

12.3.7 When spraying is done in enclosed areas, adequate ventilation must be provided during the application and curing period.

12.3.8 Spray guns shall be immersed in solvents for cleaning. Caustic solutions shall not be used for cleaning the spray gun.

12.3.9 All coating materials shall be thoroughly mixed with a power mixer and strained (if necessary) before pouring into a pressure pot for conventional spraying. Mixing shall be done in a well-ventilated area free of sparks and open flames.

12.3.10 If a film has formed over the surface of paint, it shall be carefully cut loose and discarded.

12.3.11 After proper mixing, some two-component materials may be required to stand or "sweat in" for approximately 30 minutes.

12.3.12 When the pot life limit is reached, the spray pot shall be emptied and the remaining material discarded.

12.3.13 All surfaces, which will be difficult to paint or inspect properly after fabrication and/or installation must be blasted and coated prior to assembly.

12.3.14 Each coat shall be applied uniformly over the entire surface. Skips, runs, sags and drips shall not be allowed. When these occur, they shall be brushed out or the material shall be removed and the surface recoated.

12.3.15 Each coat shall be allowed to dry for the time specified by the manufacturer before succeeding coats are applied. Where painting has commenced, the complete painting operations, including priming and top coats, shall be completed as soon as possible. In no event, except delay due to weather conditions, shall more time elapse between successive coats than is necessary for the coats to thoroughly dry. The final coat of paint will be considered dry when it is sufficiently hard to permit maximum pressure to be exerted against the film by the thumb rotated through 90 degrees without wrinkling or otherwise disturbing the film, in no case should this be less than twenty-four (24) hours.

12.3.16 Inorganic zinc silicate primer shall be checked for surface zinc oxide formation immediately prior to applying the first epoxy top coat. Any oxide formation shall be removed by high pressure fresh water cleaning, or by fresh water hosing followed by scrubbing with stiff brushes to remove zinc salts. Excessive Zinc build up causing "mud cracking" will be sweep blasted and recoated using Amercoat Zinc rich Epoxy Primer 68A or equal. The surface shall be allowed to dry thoroughly prior to applying the topcoat.

12.3.17 Primer, intermediate coat, and topcoats shall be of contrasting colors.

12.3.18 The inorganic zinc silicate must be fully cured before the epoxy coating sequence commences.

12.3.19 The surface of the inorganic zinc must be free of zinc salts, dry spray, dirt, grease, oil and other contaminants. Surface contaminants must be removed by Company approved means before application of the epoxy intermediate coat.

12.3.20 Weld seams, fillets, edges, bolts and other similar features shall be given an extra intermediate coat (so called "stripe coat") of epoxy. Preferably, this should be applied by brush and before the epoxy coating sequence commences.

12.3.21 To avoid pinholes and bubbles occurring in the full intermediate coat of epoxy, a mist-coat thinned 10 to 20 percent shall first be applied to the inorganic zinc primer.

12.3.22 Only thinners specified by the manufacturer shall be used. Manufacturer's latest printed instructions and the requirements of the applicable product specifications shall be followed. Thinning in excess of manufacturer's specification is not allowed. Contractor shall provide the Company with a copy of the manufacturer's recommended thinning procedures at least seven (7) days prior to fabrication and assure that all paint craftsmen are instructed in following the procedures.

12.3.23 Excessive thinning of an inherently viscous coating system to improve ease of application shall not be allowed due to detrimental effects on the coating service performance.

12.4 Quality Control

12.4.1 Contractor shall notify Company in writing not less than five (5) days in advance of the start of each coating application and shall provide a detailed time schedule to permit Company, if desired, to witness all or part of the surface preparation, coating application, drying time, and testing.

12.4.2 Contractor shall establish and maintain such quality assurance systems as are necessary to assure that the coating complies in all respects with the requirements of this Specification.

12.4.3 Company will assess such systems and undertake such surveys as are necessary to assure that the Quality Assurance (QA) systems are satisfactory.

12.4.4 Company shall be given the right to undertake inspection during any stage of the coating application and to check the validity of the certificate of equivalency acceptance provided by the coating manufacturer.

12.4.5 The Quality Assurance System shall include, as a minimum, the following:

a. Checking acceptability of storage conditions.

Note: All coating materials shall be stored and mixed in accordance with manufacturer's recommended practices.

b. Checking substrate for cleanliness immediately prior to blasting, including removal of weld splatter and sharp protrusions.

c. Checking dew point of the surface just before blasting and coating operations.

d. Checking ambient temperature and relative humidity.

e. Monitoring size, shape, dryness and cleanliness of the abrasive.

f. Monitoring air pressure and nozzle size of blasting equipment.

g. Checking the surface visually in good light for metal defects, dust, and surface debris after blasting, including removal of weld splatter and sharp protrusions.

h. Checking surface blast profile with an approved surface comparator.

i. Checking coating thickness and standard of adhesion with approved and appropriate equipment. Checking surface cleanliness of inorganic zinc before top coating.

j. Checking for missed spots, holidays, poor adhesion, or other defects.

k. Checking that adequate and proper repair of all defects has been undertaken.

l. Checking of coating color, appearances and uniformity.

12.4.6 Each coating application and surface shall be checked for thickness in accordance with Steel Structures Painting Council SSPC-PA2-73T, Measurement of Paint Thickness with Magnetic Gages.

12.4.7 Wet film thickness shall be checked regularly during each coating application.

12.4.8 Company may at any time require Contractor to prepare a set of test panels and average tests of the panels at a laboratory agreeable to Company.

12.5 Repair of Damaged Coatings

12.5.1 Damaged areas with loss of adhesion to the metal substrate, butt welds, shims, and bolts:

a. The surface shall be thoroughly solvent or detergent cleaned to remove all contaminants such as oil, grease, and dirt.

b. All edges of the existing sound coating shall be feathered.

c. The surface shall be blasted in accordance with the original specification, excepting that the blasting medium shall be a manufactured product or a natural product completely free of all deleterious salts, soluble sulfates, and chlorides. Areas of over blast shall be rubbed down.

d. The surface shall be re-primed in accordance with the original specification, excepting that the primer shall be organic zinc-rich epoxy, in place of the standard inorganic zinc primer, applied by spray or brush to a dry film thickness of 1.5 to 2.0 mils (38 to 50 microns). The zinc-rich epoxy primer shall be from the same manufacturer and compatible with the scheduled topcoat.

e. The surface shall be coated with an intermediate coat and a topcoat in accordance with the original specification.

12.5.2 Damaged areas with loss of topcoat adhesion to sound inorganic zinc primer:

a. The surface shall be sweep blasted or cleaned with a power tool to remove defective topcoats.

b. The surface shall be thoroughly cleaned to remove all contaminants such as oil, grease, and dirt.

c. All edges of the existing sound coating shall be feathered.

d. Organic zinc-rich primer shall be applied as in Paragraph 12.5.1 above.

e. Intermediate and topcoats shall be applied as in Paragraph 12.5.1 above.

12.5.3 Small damaged areas:

a. The surface shall be thoroughly cleaned to remove all contaminants such as oil, grease, and dirt.

b. Power or hand tool clean in accordance with SSPC-SP3.

c. All edges of the existing sound coating shall be feathered.

d. One coat of rust inhibitive straight epoxy primer shall be applied by spray or brush. The primer shall be from the same manufacturer and compatible with the scheduled topcoat.

e. The intermediate coat and topcoat in accordance with the original specification shall be spray or brush applied to the required dry film thickness.

12.6 Handling of Coated Steel

Care shall be exercised when handling coated steel. Suitable slings and hooks designed to minimize damage at the points of support shall be used. Suitable supports shall be provided to receive the coated steel when stacked prior to construction. Attention is called to the fact that subsequent retouching and repair of coating is inevitably inferior to the original application. Therefore, every possible precaution shall be taken to minimize the necessity for such repairs.

12.7 Company Approved Coating Products

Contractor may select any of the products qualified and approved by Company, but shall use primer, intermediate coat, and topcoats from the same manufacturer. Contractor may submit alternate products for written approval by Company. This shall be accomplished prior to the commencement of work.

13 TESTING REQUIREMENTS AND PROCEDURES

13.1 Testing Requirements

13.1.1 Buoy Hull

Prior to hull sandblasting and coating, all buoy hull compartments shall be sealed and air tested at a pressure of 3 psig and visually inspected at all weld seams, hatches, covers and plate penetrations by the use of a soap and water solution. All welds, penetrations and joints shall be free of any slag, grease or other debris that would possibly interfere with the testing and visual examination. No air leaks shall be acceptable.

13.1.2 Sounding and Vent Piping System

The sounding and vent piping system that forms an integral part of the buoy body shall be subjected to the same tests and criteria as the buoy internal compartments.

13.1.3 Mechanical Swivel Rotational Test

Upon test assembly of the buoy hull to the chain mooring table and prior to shipping the completed SPM buoy, the buoy hull shall be supported and the mooring table shall be rotated clockwise and counterclockwise. The rotational test of the well lubricated mechanical swivel assembly shall be carried out to verify the smooth rotation of this assembly. Both break-out and running torques shall be measured and recorded. Any further testing or measurements needed to confirm proper rotation or repairs necessary to cause the turntable assembly to rotate smoothly and uniformly shall be carried out by the fabricator at no additional cost.

13.1.4 Product Piping System

Upon final assembly of the buoy piping system and hose swivel and prior to shipping the completed SPM buoy, the entire piping system from the underbuoy hose connection flange to the floating hose connection flange shall be hydrostatically tested. During this test, the hose swivel assembly shall be rotated 360° clockwise and counter-clockwise. The torque required to breakout or start the rotation and the running or continuous torque shall be recorded and provided to the Company Representative. The breakout and running torque shall be tested at the following pressures: 0, 60, 100, and 225 psig. Each test pressure shall be held for a minimum of one (1) hour, in accordance with the hydrostatic NDE procedures contained herein.

The buoy piping assembly shall be hydrostatically tested at 340 psig for six (6) hours in accordance with the hydrostatic NDE procedures contained in this Specification.

13.1.5 Chain Tensioning Equipment and Rigging

Winches and other lifting equipment located on the rotating turntable shall be load tested to 125 percent of the design capacity. A load cell or tensionometer shall be used to measure the applied loads. The test shall be witnessed by the Company Representative and a test report will be submitted to Company for signature.

13.1.6 Ancillary, Navigation and Safety Equipment

All ancillary equipment located on the buoy shall be functionally tested after mounting in accordance with the manufacturer's recommended procedures. Tests shall be witnessed and verified by the Company Representative.

13.1.7 Transport Configuration

Contractor shall demonstrate the transportability of the DPO SPM system by loading the System components onto over-the-road trucks in compliance with the Contractor's recommended procedure and utilizing only the recommended rigging and equipment and transporting the System a minimum of ten (10) miles.

13.1.8 Marine Deployment

Contractor shall demonstrate the capability to deploy the DPO SPM system to an operational configuration at a marine site located a minimum of three (3) nautical miles from the staging area in a time period consisting of 168 continuous hours. Contractor shall follow his recommended procedure and utilize only the recommended rigging and equipment. Successful completion of the marine deployment demonstration within the allotted time frame shall meet the acceptance criteria of the Company.

13.2 Non-Destructive Examination/Testing (NDE) Procedures

13.2.1 Radiographic

The Contractor shall perform radiographic examination in accordance with the applicable code for all the following welds:

One hundred (100) percent radiographic testing is mandatory for the following welds:

a. All pressurized piping full penetration butt and longitudinal weld joints.

b. All full penetration butt welds in the support structure of the chain support assemblies.

c. All full penetration butt welds in the buoy piping assembly and hose swivel supporting structures.

d. All full penetration butt welds in the buoy mechanical swivel supporting structure.

e. All full penetration butt welds attaching padeyes/lifting lugs to the buoy structure.

Ten (10) percent radiographic testing is mandatory for the following welds:

a. All buoy hull plate and structural shape full penetration butt welds.

b. All mooring table plate and structural shape full penetration butt welds.

Fittings containing longitudinal welds shall also be radiographed at the junction of the welds. All radiographs shall be identified by the weld and welder identification. All butt welds which are 10% radiographed will be 10% of each welder's work and this percentage will increase if defects are found until the Company Representative is satisfied with the weld quality.

13.2.2 Ultrasonic

Ultrasonic testing shall be performed on all welds designated for radiographic (NDE) but deemed to be impractical for radiographic inspection with the concurrence of the Company Representative.

13.2.3 Magnetic Particle

One hundred (100%) percent magnetic particle testing is mandatory on the following welds:

a. All full penetration tee and corner joints welded in the buoy hull, deck, bulkheads and bottom plating bounding the watertight compartments within the buoy.

b. All full penetration tee and corner joints welded from both sides in the structural framing in the mooring buoy.

13.2.4 Dye Penetrant

Dye penetrant testing shall be performed on all welds designated for magnetic particle NDE but deemed to be impractical for magnetic particle inspection with the concurrence of the Company Representative.

13.2.5 Visual

All welds shall receive a 100% visual examination and any weld deemed questionable by the Company Representative shall be inspected to code by any or all of the previously identified NDE methods to verify the integrity of the weld.

13.2.6 Hydrostatic

13.2.6.1 Water use for the pressure test shall be free of substances which could settle out in the piping system, coat the interior of the pipe or pipe swivel joint, cause corrosion of, or be injurious to the pipe, swivel, seal or other such equipment used in fluid piping system. All hydrostatic testing shall be made with water containing a rust inhibitor approved by the Company Representative. The rust inhibitor shall be applied in a quantity as recommended by the inhibitor's manufacturer.

13.2.6.2 A pressure recording instrument and a temperature recorder, both equipped with eight (8) hour recording charts, shall be used to record time, pressure, and ambient and test water temperatures during the pressuring and testing operations. Pressure measuring equipment shall have an accuracy and repeatability of ±0.1 percent. The accuracy of temperature testing equipment shall be 0.5°F. Possible effect of temperature on pressure shall be evaluated by a qualified person, and shall be taken into account in determining the correct pressure.

13.2.6.3 The pressure recording instrument shall be tested and calibrated with a deadweight tester before the pressure test begins. Deadweight tester shall be capable of measuring in increments of 1.5 psi.

13.2.6.4 The pressure recorder, dial pressure gauge, and the deadweight gauge (or tester) shall be manifold in parallel, with adequate valving and venting for each device. Contractor shall have evidence that recorders and deadweight gauge have been calibrated by an independent laboratory within the last 60 days prior to use. The use of a pressure surge snubber is recommended.

13.2.6.5 The pressurizing pump shall be installed such that the suction port is flooded at all times and shall have a minimum suction head of 5 feet (1.5 m). The discharge shall be connected to the system through a check valve and leak proof injection block valve. The pump discharge shall be easily separable from the system to be tested. This shall be done after the test pressure is achieved.

13.2.6.6 Fabricated piping assemblies of components, which are separately hydrostatic tested in the shop, shall be subjected to the specified hydrostatic test pressure for not less than six (6) hours.

13.2.6.7 When the test pressure is reached, the pump shall be shutdown, the inlet block valve shall be closed and the injection line shall be vented between the two injection block valves. A period of observation shall be made to verify that the test pressure is being maintained and that the test water temperature has stabilized. A continuous chart recording of pressure during the specified test period shall be maintained. The chart record shall be substantiated by deadweight pressure gauge checks as follows:

One made at the beginning, one every half hour for the full test period, and one at the end of the test period. The pressure and temperature charts shall be ink marked and noted at the point in time on the scribed gradients each time a deadweight pressure gauge reading is made. The time, temperature of test water, and the deadweight pressure gauge readings made during the specified test period shall be entered in the table provided on the certification form.

13.2.6.8 The cause of any pressure-temperature changes occurring during the hold period shall be noted. A pressure increase due to temperature increase during the hold period shall be limited to the maximum permissible test pressure by a slow bleed-off. The time and amount of pressure bled off as measured by dead weighing and the volume and temperature of the liquid bled off shall be measured and recorded.

13.2.6.9 If there is a loss of pressure, Contractor shall evaluate how much loss of pressure can be attributed to change in temperature and to free air dissolving into the water. If the pressure drop can be explained to the complete satisfaction of Company, the test may be accepted.

13.2.6.10 If Contractor's explanation for pressure drop during the test period is not found satisfactory by Company, Contractor shall, upon the request of company, extend the test period until completely satisfactory results are obtained.

13.2.6.11 Results of the hydrostatic test shall be witnessed and certified by Company and Contractor as a condition of acceptance of the test.

13.2.6.12 Immediately after each test is accepted by Company as successful, Contractor shall relieve the test pressure on the completed section.

13.2.6.13 Should a failure occur, the test shall be repeated after repairs have been made until a continuous test for the specified test period has been maintained without unacceptable deviations in the specified test pressure. All pressure readings noted for record shall be deadweight pressure gauge readings.

13.2.6.14 Should it be determined that the leak or break occurred as the result of Contractor's workmanship, material furnished by Contractor, or Contractor's negligence, the line shall be repaired and retested by Contractor, all at no extra cost to Company.

13.2.6.15 Failures, if any, shall be located and a detailed program shall be developed and approved by Company for effecting the repair. Such program shall include methods and procedures for depressurizing, removing and disposing of test media, repairing the pipe, refilling with test media, venting and repressurizing.

13.2.6.16 Repairable weld defects shall be cut out and repaired in accordance with an approved welding procedure. Pipe containing non-repairable weld defects, splits, ruptures, cracks or other defects shall be removed as a cylinder and replaced by a length of sound pipe from the parent pipe order of the same grade and wall thickness. Welding of the replacement section into the line shall be in accordance with an approved welding procedure.

13.2.6.17 A complete record of failures occurring during the test shall be maintained. The record shall include the exact location, type and cause of failure, method of repair, etc. Pipe, fittings, or valves which fail and are replaced because of inherent mechanical or metallurgical deficiencies shall be reported as to the location and pressure at which they failed.

13.2.6.18 Contractor shall furnish all testing equipment, eight (8) hour recording instruments, all necessary supplies and shall maintain accurate and permanent records. The testing and recording equipment shall be subject to Company approval. The pressure recording shall serve only as information data and may not be used to determine pressure drop. Tests shall not be accepted until the applicable full test period can be recorded without pressure loss unless due to temperature change or removal of test medium documented by Contractor and verified by Company.

13.2.6.19 A time-pressure plot shall be made during the test to indicate the progress of the pressure test. This record shall be made using the deadweight pressure measurement and shall be used to determine if the test is satisfactory.

13.2.6.20 All records shall comply with the requirements of the Minerals Management Service (MMS) for accuracy, quality and identification.

13.2.6.21 The originals of all records, data and charts shall be clearly marked with the following information and shall be furnished to Company.

a. Company's name and name of Company's authorized representative.

b. Testing Contractor's name and name of Contractor's authorized representative.

c. Description of facilities tested.

d. Date and time of test (start and completion).

e. Test pressure and duration.

f. Description of test medium used.

g. Total volume of chemical additives and water injected.

h. Explanation of any pressure discontinuities that appear on any chart.

i. A full explanation of any failures during the test operation.

j. Signature of Company's and Testing Contractor's authorized representatives.

13.2.7 Pneumatic

13.2.7.1 The work covered consists of furnishing all plant, labor, equipment, supervision and materials required for testing, and in performing all operations in connection with pneumatic testing of the separate buoy compartments and sounding and vent piping systems to verify water tight construction.

13.2.7.2 The Contractor shall furnish all instruments, compressors, valving, hose connections, etc. necessary to complete the work. Pressure gauges for air testing shall be graduated in the zero to twenty-five (25) pound range and shall be of the mercury type. Pressure gauges must be calibrated within 60 days prior to testing.

13.2.7.3 The Contractor shall submit to the Company Representative for approval a complete description of his proposed testing sequence and method including detailed descriptions or catalogue cuts of all testing equipment.

13.2.7.4 The air tests shall be performed prior to the application of protective coatings, and after the completion of all outfitting including the installation of all piping components.

13.2.7.5 All slag or spatter shall be removed by power driven wire brushes or other Company approved means from all welds affecting the watertight integrity of the mooring buoy compartments.

13.2.7.6 The Contractor shall clean all compartments of debris and erection aids to the satisfaction of the Company Representative before commencing testing.

13.2.7.7 All tests shall be conducted in the presence of the Company Representative. More than one test may be carried out at the same time. The Contractor shall record the results of inspection and tests and he shall submit copies of all such reports to the Company Representative.

13.2.7.8 All areas subject to testing shall be individually pressurized to a test pressure of 3 psig. The test pressure shall be maintained for a minimum period of three (3) hours without a drop in pressure and shall be held as long as required for the inspectors to perform the examination specified below. These tests shall be performed on a cloudy day, at night or indoors to avoid pressure increases or decreases due to thermal expansion caused by solar radiation. The compartment being pressurized shall be allowed to cool to ambient air temperature before timing the three hour test period. If necessary, the test pressure shall be adjusted to the specified pressure prior to timing the test.

WARNING: The Contractor is solely responsible for monitoring and regulating the pressure to a maximum value of 3 psig. The test procedure shall be designed to allow emergency venting should an undesirable and potentially dangerous/destructive pressure spike develop.

13.2.7.9 Each compartment shall be closed and air shall be applied to the specific pressure. All seams and joints of bulkheads, decks, plating, manholes and pipes bounding each compartment shall be coated with a soapy water solution and then examined for leaks which may be detected by feel or by sound or by appearance of air bubbles. If leaks are discovered, the pressure shall be released, the leaks shall be repaired and the air shall be re-applied to the required pressure for the original specified time.

13.2.7.10 All leaks or other defects disclosed by the inspection or tests shall be remedied by the Contractor at his own expense. Seams and joints that leak or have defective welds shall be wholly or partially cut out as directed by the Company Representative and shall be repaired to code. Where leaks are found around manholes, or other fittings that are required to be watertight, the defective parts shall be tightened or shall be replaced by new fittings.

13.2.7.11 All temporary instruments required for testing purposes shall be removed after the tests are completed. All openings required for the fittings shall be made watertight in a manner approved by the Company Representative.

13.3 Defects and Repairs

If testing and inspection result in the rejection of any or all of the affected work in progress, such defective material shall be removed and corrective measures taken immediately to insure that the provisions of these Specifications shall be adhered to. Repaired areas shall be reinspected by the same inspection method used to reveal the defect originally. Where random non-destructive examination/testing procedures are employed and defective materials are detected, additional testing shall be performed in order to establish the extent of such non-compliance. The Company Representative may require that a particular weld be repaired before other welds are made, or may require that additional work be performed prior to the completion of a particular repair. The Contractor shall be responsible for all repairs, the retesting of such and the associated costs.

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