NATIONAL STEEL AND SHIPBUILDING COMPANY

FIBERGLASS REINFORCED PIPING
FOR SHIPBOARD SYSTEMS

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Background

This is a preliminary submittal of some findings from the study of plastics and reinforced plastics-which is one of the many research projects being managed and cost shared by Todd Shipyards Corporation, a participant in the National Shipbuilding Research Program. The Program is a cooperative effort by the Maritime Administrations Office of Advanced Ship Development and the U.S. shipbuilding industry. The objective for the basic study, as conceived by the Ship Production Committee of the Society of Naval Architects and Marine Engineers, is to determine the cost effectiveness of plastics in the shipbuilding industry.

An initial report by the research subcontractor, DeBell & Richardsor an authority in the evaluation of new plastic products, indicated that although plastic pipe had been introduced, its usage in shipbuilding was limited compared to its potential for much greater improvements in productivity. It was apparent that such limited usage was due to limited knowledge possessed by designers owners, regulators and shipbuilders regarding the use of specific plastic materials in specific marine applications. This view was corroborated by a coincident and professional marine marketing survey comissioned by a manufacturer of fiberglass reinforced pipe. Thus, National Steel and Shipbuiiding Co. undertook, on a cost sharing basis, to determine the design feasibility and potential cost benefits of fiberglass reinforced pipe installed in a modern U.S. tanker. The resulting report is contained herein.

And, from the outset of this project liaison has been maintained with the researchers who have similar objectives regarding the use of plastics in ships of the U.S. Navy. A discussion of the results of their pertinent investigations are also contained herein. It contributes significantly to the knowledge prerequisite for the greater and safe use of fiberglass reinforced pipe in commercial ships.

Mr. G. A. Uberti, Chief of Development Engineering, National Steel and Shipbuilding Company managed the feasibility study for fiberglass reinforced piping in a tanker.

Mr. G. F. Wilhelmi, Project Engineer, David Taylor Naval R&D Center Annapolis was the principal Navy investigator with whom research results were exchanged.

Mr. R. F. Heady was the R&D Project Manager who provided technical direction and Mr. L. D. Chirillo was the R&D Program Manager having cognizance. Both performed in behalf of the Seattle Division of Todd Shipyards Corporation.

Since a shipbuilder and a fiberglass piping supplier were planning to meet on mutually unfamiliar ground in undertaking this project, a short technology exchange program preceded the actual performance of the study. The shipbuilder's sonnel were taught the rudiments of fiberglass piping application at the fiberglass factory, and the suppliers personnel were exposed to ship design and production procedure at the shipyard. The knowledge gained through the exchange prevented many false starts as the work proceeded.

The study was performed by the Engineering and Estimating Departments of National Steel and Shipbuilding Co. (Nassco) in San Diego, Technical consultation on fiberglass design was furnished by Ciba-Geigy Corp., Pipe Systems Department of Houston and Burkburnett, Texas. Ciba-Geigy supplied background information and technical data on fiberglass reinforced epoxy piping contained in this report. The first draft of the report was reviewed by other departments at Nassco, as well as by Ciba. Geigy and Todd.

Principals involved in the study were C. Grant, R. Monastero, and G. A. Uberti of Nassco, and D. Abbott, J. Biro, and J. Carter of Ciba-Geigy Corp.

G. A. Uberti

July 1, 1976

Foreword

Fiberglass reinforced technology was initially advanced after World War II by Defense Department programs, through Hercules and Aerojet General, to produce rocket casings for solid propellant rockets. Fiberglass reinforced piping was introduced initially into the chemical industries as process piping in the mid-1950's This was *a* logical application, since these composites offer excellent resistance to corrosion.

Since then, fiberglass reinforced piping systems have found general acceptance in such diverse industries as oil field production, coal. mining, petroleum product piping, and power plant utility piping. Widespread uses in troublesome services such as steam condensate return piping, oil field down-hole tubing, and military jet-fuel transport are now common. Approximately 50 million feet of fiberglass reinforced pipe is produced each year. The industry grows at a rate of 8-10% per year.

Fiberglass reinforced piping has been used aboard ship to a limited degree, and with varying *success, in cargo lines,* ballast lines, condult, service lines, and the like. Previous attempts to introduce fiberglass piping systems into shipboard services have faced four major obstacles:

1. Absence of adequate piping engineering data to enable a designer to translate the effects of ship movement into stress and strain on fiberglass piping; and consequently, lack of acceptable testing criteria permitting evaluation of suitability and predictability of long term performance.

2. Lack of essential design practices for such ship-building details as bulk penetrations, anchoring, supports, and pipe hangers.

3. Unavailability of data necessary to design and test a fiberglass pipe joining system, adequate to the marine environment.

4. Finally, lack of a sound basis for the regulatory bodies and classification societies on which to evaluate the general acceptability of fiberglass piping for various marine services.

Resolution of these impediments is in progress in concurrent programs. J.J. Henry Company of New York has been retained by Ciba-Geigy Corporation to address the problem of specifying marine testing criteria, and then to conduct appropriate test programs. This will provide the necessary engineering data to measure performance of fiberglass piping in shipboard service. Also, the proprietary mechanical joining system developed by Ciba-Geigy and used extensively in non-marine industries is currently under test in the J.J. Henry program.

This study examines the design and installation problems and the comparative economics in substituting fiberglass for steel in actual designs of shipboard piping system. Successful outcome of the above-mentioned tests and approval by the U.S. Coast Guard for material application and design details is presumed. The study uses piping system components ordinarily furnished by Ciba-Geigy for other markets. It should be noted that Ciba-Geigy currently produces PiPing and fittigs in sizes up to 16" . The 18" and 30" piping used in the cargo oil system are still under development at Ciba-Geigy. This report does not survey piping systems furnished by competing suppliers.

In making the cost comparison, fiberglass materials costs were quoted by Ciba-Geigy, and installation labor costs were estimated by Nassco. In estimating the labor costs, Nassco consulted FMC Corporation in Portland, Oregon, and took into account their experience in installing 10 ballast suction lines to a ring-main on a handy size double-hull tanker. No account was taken of operating experiences in the few scattered marine installations since this is a first-cost study and does not include life-cycle factors.

Fiberglass piping has a special appeal. to the shipowner in corrosive fluids systems. It was considered that the best shipboard application would be the cargo oil system and the salt water clean ballast system. These distributive systems of the 90,000 DWT San Clemente class tanker were studied in their entirety, except for the portions contained in tine pump-room. This exclusion was deemed advisable due to the high congestion in this area on a modern tanker.

Application of fiberglass piping is limited to U.S. Coast Guard Class II service. This corresponds to a maximum pressure of 225 psig and a temperature range for cargo oil of 0° *to* 150°F.

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PART I - SUMMARY

1 OBJECTIVES

1.1 The primary objective of this study was preliminary investigation into the possibility of a cost advantage to the shipbuilder by substituting fiberglass reinforced epoxy piping in place of steel for certain systems in an oil tanker.

1.2 If the results had shown that the fiberglass system did not indicate a cost advantage to the shipbuilder, a secondary objective was to identify the *items* of higher cost.

1.3 Since the fiberglass system did result in a cost advantage, the secondary objective was to recommend further steps that might be taken to introduce fiberglass piping systems for general use in merchant ships.

2 FINDINGS

2.1 Minimum saving to the shipbuilder by installing fiberglass cargo oil piping throughout the ship, exclusive of the pumproom, is 15% of the cost of installing steel piping. This percentage saving is conservative because it includes a high labor contingency allowance. Saving will increase as the shipyard gains experience, permitting *a* reduction in *this* contingency allowance to a lower actual level. The percentage will increase further by improved fiberglass system design techniques which maximize the amount of factory pre-fabrication.

2.2 Corresponding saving for a fiberglass clean ballast system is in the order of 20% of the cost of installing *steel* piping.

2.3 There are no design or installation problems that would prohibit the application of fiberglass piping to selected fluid systems in merchant ships. (This presumes a successful outcome of the on-going tests and eventual general. acceptance by the U.S. Coast Guard, rather than acceptance on a case basis.)

2.4 No capital outlay is required for fiberglass piping installation. No specially skilled craftsmen are needed.

3 RECOMMENDATIONS

3.1 Design

3.1.1 Complete the study in two areas unresolved in this project. These are:

a. Investigate the stresses in fiberglass flange connections at bulkhead and deck penetrations resulting from "working" of the ship. If these stresses are low, or if a flange can be designed for low stress, the special adaptor used at each penetration could be eliminated.

b. Review all details of fiberglass piping system design that require field fit-up. Investigate piping system installation procedures that will allow maximum use of fiberglass piping sub-assemblies completely prefabricated and tested at vendor's factory.

3.1.2 Perform life-cycle cost study to determine the savings to the shipowner by using fiberglass in Class II fluids systems where piping is replaced at least once in the life of the ship.

3.2 State of the Art

3.2.1 Study past and current fiberglass experience to see what lessons can be learned in the areas of design, operation, and maintenance applicable to marine systems. Potential fields of investigation are:

a. Selected n-on-marine fiberglass systems in service.

b. Few merchant ships containing some fiberglass piping.

c. Naval vessels containing fiberglass piping.

d. Current ballast piping installation in Chevron tankers by FMC in Portland, Oregon.

3.2.2 Study the fiberglass reinforced piping systems of suppliers competing with Ciba-Geigy Corporation in order to broaden the field of vendor selection.

3.3 New Construction

3.3.1 Perform an in-service evaluation of one or more selected piping systems. Return costs and performance should be monitored for:

a. Engineering analysis and system design.

b. System installation and testing, incliding rework.

c. Operation and maintenance experience over a specified period of time.

Since this study indicates that fiberglass piping will yield a first-cost saving to the shipbuilder, and does not rely solely on a life-cycle cost saving to the shipowner, any Class II piping system may be selected.

3.3.2 Work out details of guarantee among fiberglass vendor, shipbuilder, and shipowner. Define extent of participation by the Maritime Administration.

3.3.3 When a shipyard decides to install fiberglass piping, arrange to have design and production personnel undergo a short indoctrination in fiberglass technology, preferably at the vendor’s manufacturing plant.

PART II - COMPARISON OF FIBERGLASS AND STEEL

4 DESCRIPTION OF MATERIAL SYSTEMS COMPARED

4.1 Steel System (Ballast Piping)

4.1.1 Material. The *steel* ballast piping consists of ASTM A-53 pipe supplied in double random lengths, 34' to 36' long. Fittings are ANSI standard: B16 .9 for elbows, and B16.5 far flanges. Piping is galvanized. Thickness corresponds to standard weight. Diameters are 8" and 10”.

4.1.2 Joining. The piping system is welded wherever possible,including at bulkhead penetrations. Elbows are buttwelded. Flanged connections are made at valves.

4.1.3 Expansion. The ballast system under consideration is the version that uses pipe bends to allow for expansion. Bends are made with a pipe bender at a radius of 5D. Where space is *critical,* standard elbows are used in place of bends.

4.1.4 Supports. Pipe hangers are made of U-bolts through angle iron supports welded directly to the ship structure. The bulkhead penetration serves as an anchor point for the ballast piping, where necessary.

4.2 Steel System (Cargo Oil Pining)

4.2.1 Material. The steel cargo oil piping consists of ASTM A-53 pipe supplied in double random lengths, 34' to 36' long. Fittings are ANSI standard: elbows, and B16.5 for flanges. Piping is coated with epoxy on the outside, which is the same as the cargo tank coating. All piping is 1/2 thick. Diameters are 8", 18”, and 30" .

4.2.2 Joining. The piping system is welded wherever possible, including at bulkhead penetrations. Spuds are welded into the pipe to form tee connections. Elbows are buttwelded. Flanged connections are made at valves. Lengths of piping comprising the mains and the branches are joined by Dresser couplings.

4.2.3 Expansion. The Dresser couplings take up thermal expansion and "working" of the ship. See Appendix A for a detailed explanation of the operation of Dresser couplings.

4.2.4 Supports. Bulkhead penetrations, with the bulkhead plating and brackets welded directly to the pipe, serve as anchors Other anchors are formed by short *risers* of large diameter pipe welded directly to the cargo pipe and to the tank top. These supports have cut-outs to avoid pockets of liquid or vapor. Pipe hangers are made of U-bolts and angle iron pedestals.

4.3 Fiberglass System

4.3.1 Material. Fiberglass reinforced epoxy piping used in is study is a composite of fiberglass filaments wound into epoxy resin, and manufactured to ASTM D-2310. See Anpendix B. Piping is furnished in lengths up to 40', and can be supplied plain-ended or with "built-in" fittings, as described in paragraph 4.3.5. Common practice for large piping is to furnish lengths of pipe with both ends ready for rapid assembly. Piping is left uncoated. Wall thickness varies from 1/4" for 16" pipe to 1/2" for 30" pipe. Diameters range from 8" to 30".

4.3.2 Joining. Fiberglass piping system joints are made by adhesive bonding or by mechanical coupling with an elastomeric seal. (Other techniques are available, but are not considered in this study.) Although adhesive bonding is generally employed for relatively small size pipe (up to 6"), this method is used on larger sizes when it is necessary to attach a flange to a pipe. It results in a permanent joint that is as strong as the pipe itself. See Appendix C for a discussion of the adhesive bonded joint.

4.3.3 Expansion. The principal type of joint used in this study is the patented Pronto-Lock mechanical joint manufactured by Ciba-Geigy. See Appendix D for a detailed description. This is a leak-tight joint which permits a certain degree of axial and angular movement, and provides restraint against pulling apart. The fiberglass system is designed such that thermal expansion and "working" of the ship is accommodated in this type of joint.

4.3.4 Supports. Split-ring hangers are used for piping supports. These are lined with rubber or Buns-N and bolted together with a slight clearance. At least 120° of support is required for fiberglass pipe. Anchors are formed by building positive stops that connect to a flange.

4.3.5 Pre-fabricated Piping Sub-assemblies. Sections of piping assemblies may be made at the vendor's factory and delivered to the shipyard for direct installation into the ship. The most common example of this practice is the case of a section of pipe cut to required length, and shipped complete with the male-end and female-end Pronto-Lock joint, as described in Appendix D. More complex arrangements are made in the factory by the "hand lay-up" method. This method is used to produce special tees and crosses, and the like.

5 BASIS FOR COMPARISON

5.1 Definition of Systems Compared

5.1.1 Ballast System. The complete ballast system is described briefly in Appendix E. A large part of the piping consists of individual suction lines for the ballast tanks. The portion of the ballast system defined for comparison with steel consists of two 8" suction lines and four 10" suction lines, complete with suction bellmouths. All of these lines are located within the double bottom. The piping in the pumproom is not recommended for comparison in this early study, due to the congestion in the pumproom and the relative complexity of the piping arrangement.

5.1.2 Cargo Oil System. The complete cargo oil system is described briefly in Appendix F. The physical arrangement of the system may be considered in three separate parts: in-tank piping, pumproom piping, and deck piping. The portion of the cargo oil system defined for comparison with steel consists of the in-tank suction piping and the deck discharge piping. Two 30" suction mains, eighteen 18" suction branches, and eighteen 8" stripping spuds, all installed above the inner bottom, comprise the in-tank piping. The deck piping consists of two 24" discharge mains, terminating in 24" manifolds with 16" nozzles, and two 8" branches for fueling at sea. The study includes the two 24" drop lines from the deck piping to the suction lines. For the same reasons mentioned in Paragraph 5.1.1, the pumproom piping is not recommended for comparison.

5.2 Selection of Control Areas

5.2.1 To facilitate the comparisons defined above, representative control areas of the systems were selected as described below.

5.2.2 Ballast Piping. The control area selected for the ballast piping is Tank No. 5, whose arrangement in steel is shown in Figure 1. The replacement study investigated design details for an equivalent arrangement in fiberglass, and uses this as a basis for estimating the comparative cost of fiberglass.

5.2.3 Cargo In-tank Piping. The control area selected for the cargo in-tank piping is Tank No. 4. As seen in Figure 2, it includes the drop lines as well as suction mains and branches.

5.2.4 Cargo Deck Piping. The entire run of deck piping from the pumproom to the midship cargo manifold and the fueling-at-sea stations was studied for replacement In fiberglass. Figures 3 and 4 are reproductions of working drawings in steel with the deck piping highlighted.

6 MATERIAL AND PRODUCTION CONTROL

6.1 Material Control

6.1.1 The many items of material that ultimately comprise a ship are procured and delivered to the workshops such that the right materials in the right quantities are available to support the shipbuilding schedule. Because of the quantity of material procured, the diversity of types, the schedule of material requirements, and the possible limitations of warehouse capacity, a computer-based material control system is employed in many shipyards.

6.1.2 Material requirements are determined by the Engineering Department as the drawings are developed. The material control system maintains material status through purchasing, receipt, inspection, warehousing, and issue to the production shops.

6.1.3 A standard catalog of repetitive materials used at the shipyard is compiled, and a standard method of assigning material codes is used. Non-repetitive or special purpose items are given psuedo-codes and are not included in the catalog.

6.2 Material Procurement

6.2.1 The information on the List of Materials (L/M) on an engineering drawing is carried over to a Bill of Materials (B/M) which begins the procurement process. The materials involved (in this comparison study) are standard lengths of pipe, standard flanges and couplings, and standard materials for anchors and supports. All of this material is carried in the catalog mentioned above.

6.2.2 For fiberglass reinforced epoxy piping, each element except anchors and supports will probably be unique. Thus, a section of pipe would be purchased to a specific predetermined length, with end fittings attached as required. Pipes may have branch stubs assembled in the factory. Standard fittings may be procured from the fiberglass vendor's catalog, or special fittings may be made to suit the shipbuilder's design.

6.2.3 As an alternate procedure, a shipyard using fiberglass piping may decide to order only standard pipe and fittings from the vendor's catalog. This approach would be similar to the material ordering procedure for steel described in Paragraph 6.2.1. The shipbuilders catalog would then be expanded to include these items. This method would necessitate a new expertise in fiberglass piping assembly techniques to be established in the shipyard. This approach was not investigated in this study,. since it appears that a significant advantage to the shipbuilder will be realized by having as much fabrication as possible performed by the vendor's specialists. Also, a greater degree of freedom in design is afforded if the designer is not limited to the standard line of fiberglass pipe fittings.

6.3 Production Control

6.3.1 All production operations are scheduled and monitored so that pre-fabrication is performed as required to support the erection schedule for the building ways or graving dock. It may be noted that a modern shipyard tends to do as much shop fabrication and pre-erection outfitting as practicable so as to minimize the length of time a hull spends *on* the ways or in the dock.

6.3.2 After the piping system is designed, the Production Department decides on the size and extent of individual piping spools, location of field welds, and the composition of the various piping subassemblies and packages. This infomation is then incorporated in the engineering drawings. Production breakdown and production control identification may be seen on Figure 1.

6.3.3 The production control system keeps track of material from the *time* of original issue from the warehouse until its final transportation to the ship. For steel piping systems, the intermediate steps are:

- transport to pipe shop
- fabricate into sub-assembly
- transport to galvanizing shop or to sandblast area
- galvanize, or sandblast and paint
- transport to storage area
- store and inventory as a fabricated part
- issue to ship *upon* request

6.3.4 For fiberglass piping, shop fabrication and protective coating is *not* required. Unique pieces ordered from the vendor, as described in Paragraph 6.2.2, will *be* given package identification for convenience. However, all of the intermediate production steps listed in Paragraph 6.3.3 will. not be necessary. Material will be issued from the warehouse and transported directly to the ship, *or* to the hull subassembly, for final erection.

7 DESCRIPTION OF FIBERGLASS DESIGN

7.1 Double Bottom Piping

7.1.1 The steel ballast system is welded from bulkhead to bulkhead with expansion bends in between, *as* shown in Figure 1. The limited access through lightening holes in the structural floors requires that certain sections of 10" and 8" pre-fabricated piping be shipped loose with the hull subassemblies. Final fit-up and welding will be done on the ways. Figure 1 snows three erectable piping packages: p2-1, P2-3, and P2-5. These are associated with specific hull sub-assemblies as shown.

7.1.2 The fiberglass replacement of this piping is shown in plan view in Figure 5. These PiPing runs are straight and are connected to flanged steel bulkhead penetrations. (No attenpt is made to run fiberglass piping through tine bulkhead.) Each run consists of three lengths of pipe with factory-fitted Pronto-Lock end fittings, and. two flange-by-Pronto-Lock adaptors. The steel penetration sleeve through the forward bulkhead is left loose. After the five fiberglass sections are made up, the bulkhead penetration sleeve is positioned, bolted to the flange adaptor, and welded to the bulkhead.

7.1.3 The technique of leaving a bulkhead penetration sleeve loose avoids completely the need for field measurement and shop fabrication of fiberglass piping. If the sleeve were not left loose, the design would have to include a short flanged make-up piece, perhaps 3' long. This would be made in the shop by adhesive bonding to the exact dimension lifted from the ship.

7.1.4 The flange-by-Pronto-Lock adaptors at the bulkhead penetrations provide an added degree of flexibility. This feature is intended to avoid the possibility of stress concentration in rigid fiberglass flanges due to working of the ship.

7.1.5 If it becomes.necessary to disassemble the piping to replace an O-ring in a Pronto-Lock joint, the following method may be used:

a. Break the flange at one. bulkhead penetration.
b. Loosen the hangers in the adjacent pipe length.
c. Unscrew the locking ring in the adaptor.
d. Lift end of pipe to clear bulkhead penetration sleeve, and remove adaptor.

This will provide the clearance necessary to disassemble any other Pronto-Lock joint in the piping run.

7.1.6 Bulkhead Penetrations. A typical bulkhead penetration for ballast piping is shown in Figure 6. This consists of a short length of pipe with a slip-on flange welded at each end. The mating fiberglass connection is a two-piece Van Stone flange, with either steel or fiberglass ring. The fiberglass stub end is attached to the fiberglass pipe by adhesive bonding. Figure 7 shows a similar penetration used as an anchor at the end of a suction line adjacent to a suction bell-mouth. Note the added stiffening.

7.1.7 Pipe Supports. The standard U-bolt and flat support commonly used with steel piping are not adequate for use with fiberglass piping. An arc of bottom support of 120° is needed, and the circumference of the pipe must be *protected* from abrasion. Figure **8** shows a split-ring hanger that satisfies these needs. The hanger is lined with rubber and the lower half is welded to an angle attached to the ship structure. The halves are bolted together with sufficient shim stock to provide l/32" diametral clearance.

7.1.8 Figure 9 illustrates an alternate design which is an adaptation of the familiar U-bolt *arrangement. A* curved steel wear plate is bonded to the bottom of the fiberglass pipe to carry the load and permit sliding. The pipe is held down by a rubber-lined strep terminating in threaded studs. Nuts are adjusted to set the diametral clearance. This design is considered to be less desirable than that described in Paragraph 7.1.7, since it affords a *lesser* degree of lateral. restraint of the fiberglass pipe.

7.1.9 Suction bellmouths. Each ballast suction line terminates in a suction bellmouth located near the center of the ship. In some tanks, this positioning results in a horizontal offset from bulkhead penetration to the suction point. Figures 10 and 11 show the arrangement of bellmouths, one direct and the other offset. The bellmouth is connected to an elbow by means of a Van Stone flange. This flange provides a ready means for attaching an anchor as illustrated in Figure 12. Alternatively, the elbow and bellmouth could be procured as one fabricated assembly, in which case another means of anchoring would have to be devised.

7.2 In-Tank Piping

7.2.1 The steel cargo suction piping shown in Figure 2 runs along the bottom of the cargo oil tanks and consists of 30”, 18”, and 8" piping. Many Dresser couplings are used in the mains and In the branches and, therefore, relatively little field welding needs to be done.

Most of the pipe welds are made in the shop. Assembly on the ship is facilitated by the smooth and flat working area presented by the inner bottom surface. Piping is welded where it passes through a bulkhead and at other anchor points as indicated.

7.2.2 The fiberglass replacement of this piping is shown in plan view in Figure 13. The layout is very similar to the steel piping arrangement in Figure 2. The 30″ mains are assembled in the same manner as described in Paragraph 7.1.2 *for* the ballast lines. The notable difference, other than larger size, is that the mains contain crosses and tees for branch line connections. Also, in Tanks No. 4 only, there are tee connections for drop lines.

7.2.3 The inboard 30″ main has a flange-by-Pronto-Lock adaptor at each end. Assembly starts at the aft end with the flanged connection to the bulkhead penetration. The 30″ x 18″ 4-way Pronto-Lock cross is then set in place and made up to the adaptor. The first length of pipe to be installed is Pronto-Lock-by-flange so as to maintain rigidity with the 30" x 24" tee that follows. (Possibly, this 30″ pipe might be furnished with a 24″ stub pre-fabricated at the factory in *order* to avoid the flanged joint.) After setting the tee, three Pronto-Lock joints are made up. The penetration sleeve in the forward bulkhead is then positioned, bolted to the adaptor, and welded to the bulkhead.

7.2.4 The outboard 30" main has a flange-by-Pronto-Lock adaptor at the forward bulkhead only. The tee for the branch line is close to the after bulkhead, and is bolted directly to the bulkhead penetration. The rest of the main is assembled as described in Paragraph 7.2.3.

7.2.5 With the mains in place, the longitudinal bulkheads are targeted from the *cross* and the branches, and installation of the transverse piping may proceed. The procedure is similar to that for the 30″ piping. Joints are Pronto-Lock and flanged. Each 18" branch line has an 8" stub pre-fabricated at the factory. Figure 14 shows another view of the branch suction lines.

7.2.6 Pipe Supports. Figure 15 shows a split-ring hanger used for the 30″ pipe, and is similar to the 10″ split ring hanger described in Paragraph 7.1.7. The lower half is welded to ship structure as shown, and shim stock is used between the two halves for pipe clearance. Unlike the smaller size, the 30″ hanger uses a rigid liner bonded to the pipe.

7.2.7 Figure 16 illustrates an alternate type of support corresponding to that described in Paragraph 7.1.8 for 10″ pipe. Here too, it is not preferred to the split ring hanger for the same reason cited.

7.2.8 Valve SupPorts. While the steel piping is strong enough to support the 18″ and 8" cargo valves, external supports to ship structure must be provided for valves in a fiberglass piping system. In this application simple flat plate supports depicted in Figure 17 will suffice because the piping is low in the tank. The supports are bolted *to* the flanged joint as shown.

7.3 Drop Line Piping

7.3.1 As explained in Appendix F, cargo is loaded through the cargo drop lines, which connect the deck mains to the suction mains. The physical arrangement is such that each of the two 24″ cargo drop lines lies completely in a single transverse plane, connecting a flange in the deck main to a flange in the cargo suction main. Figure 18 shows the lower ends of these piping runs. The lines continue through sections of vertical piping leading to the deck penetration overhead, shown in Figure 19.

7.3.2 Assembly begins at the 30″ x 24" tees in the suction mains shown in Figure 13. The outboard 24" branch connection is a Pronto-Lock for flexibility. The inboard 24" branch is a flange connection. Two Pronto-Lock-by-flange 30° elbows are arranged as shown in Figure 18 to offset one transverse line, allowing it to cross over the 30″ main.

7.3.3 Flanged 90° elbows turn the pipe, and flange-by-Pronto-Lock adaptors form the base for the vertical lengths of Pronto-Lock piping rising the height of the cargo tank. The drop line in the tank is finished by positioning the deck penetration sleeve, bolting it to a flange-by-Pronto-Lock adaptor, and welding the sleeve to the deck, as shown in Figure 19.

7.3.4 The remaining section of the drop line piping illustrated in Figure 19 is fitted and installed on deck and is discussed in Paragraph 7.4.9.

7.3.5 Supports. The straight vertical runs of drop line piping are supported at the base by a built-up weldment attaching to a flange as shown in Figure 20. Split-ring hangers *for* each length of pipe, with stand-offs from the bulkhead, are not shown. Figure 21 shows the method of anchoring the two 30° elbows described in Paragraph 7.3.2.

7.4 Deck Piping

7.4.1 The steel cargo discharge piping on deck is high-lighted in Figures 3 and 4, which are portions of the deck piping composite drawings. There are two straight runs of 24" pipe extending from the pumproom access trunk (left end of Figure 3) to the 24" transverse lines terminating at the port and starboard midship loading and discharge stations. Each 24" line is divided into two 16 valved branches.. The entire athwartships assembly, consisting of terminal valves, manifolds, and transverse pipe with 24" center stub, is shop fabricated and shipped to the *ways as a* unit.

7.4.2 There are three fore-and-aft points in each deck main that are fixed by virtue of the system design and the consequent constraints in the assembly procedure. These are: the bulkhead penetration at the house front, the location of the branches to the drop lines, and the connection to the transverse lines amidships. With steel piping, excess material is allowed at the Dresser coupling. The pipe is trimmed on deck before making up the coupling. With fiberglass, it will be necessary to trim excess at a flange connection. An adhesive bond joint would be then made in the field.

7.4.3 Figures 22 and 23 show the general layout of the fiberglass replacement of the deck piping. Assembly may start at either the aft end or forward end, *or* at both ends simultaneously.

7.4.4 Manifold assembly. Erection of the transverse piping and manifold assembly begins with the placement of the 24" tee and 45° elbow detailed in Figure 24. The connections are Pronto-Lock on the runs and flange on the branch. Elbow ends *are* both Flanged. (Possibly, the flange joint could be eliminated and a single ell-tee piece could be pre-fabricated at the factory.) The fittings are anchored as illustrated.

7.4.5 Having set two tees in place, the manifold assembly is completed by installing four 24″ lines running outboard, each terminating in two 16" flanged connections for valves. Figure 25 shows the design to accomplish this. It consists of a length of 24" pipe with a 16″ pre-fabricated branch, a 16″ flanged elbow, a 16" flanged spool piece, and a 24″ x 16″ flanged reducer. The reason for the many flanges is to allow fitting up to manifold valves installed in advance. Figure 26 illustrates an alternate manifold with a lesser capacity for field adjustment of the piping. Pipe supports are shown in Figure 27. Hanger arrangements for the 16″ valves are not shown, since they are the same as for the steel piping system.

7.4.6 There appears to be, however, a much better solution for the manifold assembly design not illustrated herein. Each assembly from the 24″ tee to the two 16″ branches might be supplied as a single pre-fabricated part from the vendor's factory. This would be installed with a single 24″ Pronto-Lock connection at the tee. This arrangement would avoid field fit-up as well as the need to make adhesive bonded joints and flange connections. The four 16″ valves, port and starboard, would then be assembled and their supports welded to the to the ship. A further development of this idea would be to supply the entire transverse assembly as a pre-fabricated unit. This would include four 16" flanged branches, a 24″ line connecting them, with a 24″ stub having a 45° bend and *a* flanged connection taken from the center. There might be some limitations in shipping, since this pre-fabricated assembly would be about 65' long.

7.4.7 Deck Mains. The 24″ mains running from the house front to the transverse piping are installed as shown in Figures 22 and 23. Starting from the aft end, each main consists of a flange-by-Pronto-Lock adaptor, a straight section with Pronto-Lock ends, a Pronto-Lock section with an 8" stub, another straight Pronto-Lock section, a Pronto-Lock-by-flange section, a 24" valve, and a flanged section with a 24" flanged stub. The foremost pipe length must be set so that the 24″ stub is in line with the 24″ deck penetration for the drop line. The forward end is then cut to fit, a flange is attached by adhesive bonding, and the flange is bolted to the 45° elbow.

7.4.8 The 24" valve is bolted to the pipe flange and the valve support is welded to the deck. A detail of the valve support is not shown, but is similar to that in Figure 28. Assembly of the main may proceed from the house front in the forward direction. The Pronto-Lock-by-flange section is used as a make-up piece. Required length is measured in the field. A flange is attached to the pipe by adhesive bonding and bolted to 24" valve. This completes the assembly of the fore-and-aft mains.

7.4.9 Drop Line Connections. Figure 19 shows the connection from the 24" stub in each main to its corresponding 24" deck penetration. The fit-up must take account of variation in athwartships spacing between these fittings, together with the varying length of the penetration sleeve protruding above deck after closing the drop line piping inside the tank. (See Paragraph 7.3.3.) The connection is made with a special flanged 45° elbow with one long leg, a gate valve, a standard flanged 90° elbow, and a flange on the steel deck sleeve. The deck sleeve is scribed for correct height and a slip-on flange is welded on the end. The long leg of the fiberglass 45° elbow is scribed for correct length. A flange is attached by adhesive bonding and bolted to the 24" valve. The valve support is as shown in Figure 28. This completes the drop line connection.

7.4.10 Fueling-At-Sea Branches. The 8" piping for fueling at *sea* shown in Figure 22 is depicted in greater detail in the section view of Figure 29. This consists of 8" sections of pipe, 30° elbows, and Van Stone flanges. Each of the port and starboard lines includes one gate valve and terminates with a blind flange at another valve outboard. Since precise placement of the valves Is not required, all of the piping can be pre-fabricated at the factory, with only one field joint to be made at the main by adhesive bonding. Pipe supports are shown in Figure 27. Valve supports are not shown, but will be similar *in* design to those illustrated in Figure 28.

8 METHOD OF COST COMPARISON

8.1 Approach

8.1.1 The estimate of comparative costs is determined by making a material take-off of line items comprising each system to the extent delineated in the selected control areas. (See Section 5.2.) The source for the steel system material take-off is Nassco's Piping Department spool sheets. Fiberglass system material was determined from the arrangements and details shown In Figures 5 to 29.

8.1.2 Each line item is priced for labor and material. The items and their costs are grouped into discrete packages, which are recognizable Portions of the piping systems. These packages and their associated costs are listed in Table 1 for both steel and fiberglass systems.

8.1.3 Material costs for the steel system were taken at Nassco's buying level through quotations from current suppliers. Fiberglass costs are from quotation from Ciba-Geigy. All prices are f.o.b. Nassco yard.

8.1.4 Piping labor pricing for steel has two component parts: shop fabrication and ship installation. In the case of fiberglass piping, no labor cost is added for shop fabrication. Assemblies are made in the vendor's factory, and his shop costs are included in the material cost Fiberglass piping assemblies are transported directly to the ship, and all piping labor costs are for. ship installation. However, both steel and fiberglass systems contain shop and ship costs for steel support assemblies.

8.1.5 Material handling cost is a percentage of direct labor, and is included in the cost of direct labor. Fiberglass piping 10" and below will be handled manually. Forklift trucks and slings will be used for larger sizes. Because of the lighter weight of fiberglass piping, handling costs are reduced by more than 50% as compared to steel.

8.1.6 Miscellaneous material and labor pricing is included for nuts, bolts, gaskets, and welding rod as applicable for steel and fiberglass systems. The fiberglass system miscellaneous labor includes 24 hours per valve in tanks and 8 hours Per valve on deck due to added installation and handling-on ship. The fiberglass system labor also includes a 30% contingency on the piping labor for unknown assembly problems.

TABLE 1

COMPARATIVE COSTS OF STEEL AND FIBERGLASS SYSTEMS
(as of May 1976)

SYSTEM	PACKAGE	DESCRIPTION	STEEL SYSTEM PIPING MATL $	STEEL SYSTEM PIPING LABOR $	STEEL SYSTEM SUPPORTS MATL $	STEEL SYSTEM SUPPORTS LABOR $	STEEL SYSTEM MISC M & L	STEEL SYSTEM TOTAL M & L	FIBERGLASS SYSTEM PIPING MATL $	FIBERGLASS SYSTEM PIPING LABOR $	FIBERGLASS SYSTEM SUPPORTS MATL $	FIBERGLASS SYSTEM SUPPORTS LABOR $	FIBERGLASS SYSTEM MISC M & L	FIBERGLASS SYSTEM TOT[AL] M [& L]
BALLAST IN D.B. TK #5	A	10" PORT BALLAST LINE	2006	4201	34	459	33	6733	1527	1250	65	565	636	40
	B	10" PORT BALLAST LINE	2118	4430	34	459	33	7074	1527	1250	65	565	636	40
	C.	10" PORT BALLAST LINE	2188	3925	34	459	33	6637	1527	1250	65	565	636	40
	D	10" STBD BALLAST LINE	2006	4201	34	459	33	6733	1527	1250	65	565	636	40
	E	8" TANK SUCTION	330	184	9	30	6	559	457	376	35	134	181	11
		SUBTOTAL	8646	16941	145	1866	138	27730	6565	5376	295	2394	2725	17
CARGO OIL IN #4 P, S, C TKS	A	30" PORT C.O. MAIN #4 TKS	5679	7149	295	5361	55	18539	8045	3387	309	1344	966	14
	B	18" & 8" CO/STRIP PORT SUCT.	1587	1955	105	687	55	4389	1095	1304	42	323	1255	49
	C	18" & 8" CO/STRIP STBD SUCT.	1838	2566	106	687	55	5252	2229	1385	73	470	1282	54
	D	30" STBD CO SUCTION MAIN	5679	7332	295	1588	55	14949	7246	2289	309	1344	946	12
	E	18" #4 CTR CO TK SUCTION	2002	2932	111	871	55	5971	2565	1198	55	403	1221	54
	F	24" AFT DROP LINE	4792	5743	324	1482	55	12396	7255	2772	311	1331	1069	12
	G	24" FWD DROP LINE	2780	3299	98	306	38	6521	3587	1492	142	658	682	65
		SUBTOTAL	24357	30976	1334	10982	368	68017	32942	13835	1241	5873	7441	61
CARGO OIL ON DECK	A	24" C.O. MANIFOLDS	8514	10020	832	2520	110	21996	13918	3009	270	3589	1724	22
	B	24" C.O. MAINS ON DECK	20629	27617	2029	8968	220	59461	22344	6455	2291	8535	2330	41
	C	24" DROP LINES	2378	244	0	----	5	2627	1298	188	83	376	58	20
	D	8" P. & S. F.A.S. LINES	627	2001	55	626	33	3342	1443	336	20	188	344	23
		SUBTOTAL	32148	39882	2916	12112	368	87426	39001	9988	2664	12688	4456	68
		GRAND TOTALS	65151	87799	4395	24960	874	183179	78508	29199	4200	20955	14622	14

NOTE: Differences shown in parentheses ( ) indicate higher cost for steel syst

8.1.7 The following additional notes pertain to the estimating approach:

a. No attempt is made in the cost estimate to reduce the number of fiberglass flanges and other fittings beyond those included in the arrangement and detail drawings. It is evident, however, that such reduction can be made, which will further reduce the cost of the fiberglass system.

b. The cost of a portable power taper tool for fiberglass adhesive bonded joints is not included. This is a one-time cost and is expected to be in the order of $5000. This would be spread over the entire fiberglass system, rather than limited to the control *areas* listed.

C. Steel plates and shapes used for anchors, supports, and hangers are mild steel.

d. Material and labor cost for painting the outside of the steel cargo piping is not included.

e. Piping quantities used in the steel material costs include 5% to 8% allowance for waste. Except for the small excess length margin for the few bonded field fit-up joints, no general waste allowance is made for fiberglass, inasmuch as the piping spools are received ready for assembly.

f. Initial costs for familiarization with fiberglass assembly practices are not included.

8.2 Cost Comparison

8.2.1 Ballast Piping. The ballast system shows a 37% cost saving in fiberglass. Examination of the piping columns in Table-l reveals a significant reduction in piping material cost and an even greater reduction in piping labor cost for packages A,B,C, and D.

Note: This saving may be misleading. The fiberglass system was not a direct replacement for the steel piping as originally designed. The steel piping has expansion bends, while the fiberglass piping was set in straight runs. A more appropriate comparison would be with straight steel piping containing Dresser couplings. See Paragraph 8.2.4d.

The 8" suction bellmouth assembly, Package E, costs more than twice as much in fiberglass compared to *steel.*

8.2.2 Cargo In-Tank Piping. The cargo in-tank piping shows a 10%m cost saving in fiberglass. Inspection of Table 1 shows the following:

a. Fiberglass piping material costs are higher for all packages.

b. Fiberglass piping labor costs are *lower* for all packages.

c. Comparative material and labor costs for supports *vary* considerably among the seven packages. The total result is a small material saving and a large labor saving for supports with the fiberglass system.

d. Total miscellaneous material and labor costs for fiberglass are about 20 times the *costs* for steel. This is *largely* due to the 30% piping labor contingency mentioned in Paragraph 8.1.6

e. The largest overall fiberglass savings, both *in* dollars-and in percentage are realized in the 30" mains, packages A and D. The percentages are 24% and 19%, respectively, and are occasioned by the considerable differences in piping labor as compared to steel.

8.2.3 Cargo Deck Piping. The cargo deck piping shows a 21% cost saving in fiberglass. While fiberglass material costs are still higher than steel, the labor savings more than offsets this increase. The complex design of the fiberglass manifolds, Package A, is reflected in a cost which is 2% greater than steel.

8.2.4 Overall. The overall saving of 19% appearing in the *lower* right column will have to be tempered *as* follows:

a. For the reason presented in Paragraph 8.2.1, the 37% saving in fiberglass should be removed *from* the totals and considered separately because of the apples-to-oranges comparison* of fiberglass and steel ballast systems (See sub-paragraph d below.) Subtracting the ballast sub-totals, total

*Straight fiberglass piping was compared with bent steel piping.

costs for steel and fiberglass become $155,443 and $130,129, respectively, representing a fiberglass saving of about 16%.

b. To consider the overall savings for fiberglass replacement of the entire cargo system, exclusive of the pumproom, five more sets of cargo tanks must be added. However, these are added at a savings rate greater than 10% each, since they will not be burdened by the more expensive cargo drop lines, packages F and G. Removing these packages, the subtotals for in-tank piping for *a* set of port, starboard, and center tanks in steel and fiberglass became $49,100 and $42,033, respectively, representing *a* fiberglass *saving* of about 14%. Not having the 24" tee connections in the 30" mains would further increase the savings in fiberglass.

c. Considering the above, an approximation of the savings in total cost for the *cargo* system piping in fiberglass is about 15%, exclusive of pump*room* piping.

d. The ballast system piping saving would be more than 15%, but less than 37% in an apples-to-apples comparison. Because the design consists of straight piping runs with little complexity in design, a conservative estimate of fiberglass savings is about 20%.

PART III - RESULTS AND ANALYSIS

9 RELATIVE COSTS

9.1 Cargo Piping

9.1.1 The overall cost savings for a fiberglass system replacement for all of the cargo oil system piping, exclusive of pumproom piping, is about 15%.

9.1.2 The savings percentage will increase if the fiberglass replacement design is refined to reduce the number of flanges and fittings, relying on a higher proportion of prefabrication in the vendor's factory.

9.1.3 The savings percentage will increase further if the 30% contingency factor on fiberglass system shipyard installation labor is either reduced or eliminated as the shipyard gains experience with this piping material.

9.2 Ballast Piping

9.2.1 The overall cost savings for a fiberglass system replacement for the ballast system, exclusive of the pumproom piping, is about 20%.

9.2.2 If, concurrent with the substitution of fiberglass for steel, there is an opportunity to redesign the steel system eliminating piping bends, greater savings up to 37% may be realized through additional savings in material.

10 Advantages OF FIBERGLASS -

10.1 **Design**

10.1.1 Due to the non corrosive nature of fiberglass reinforced epoxy, systems subject to corrosion can be designed for longer life, probably the life of the ship .

10.1.2 Fiberglass reinforced epoxy piping has *lower* frictional resistance to fluid flow than metallic piping. Since there is no rust build-up, as can occur in ferrous piping, the flow factor stays constant.

10.1.3 Due to the lower modulus of elasticity of fiberglass reinforced epoxy, a lower piping stress will result from a given strain, such as working of the ship.

10.2 Construction

10.2.1 Light weight of fiberglass piping simplifies handling during construction.

10.2.2 Non-corrosiveness of material permits open air stowage.

10.2.3 Pronto-Lock joining system allows rapid assembly of joints.

10.2.4 Piping can be pre-fabricated at factory, eliminating shop fabrication at shipyard.

11 DISADVANTAGES OF FIBERGLASS

11.1 Design

11.1.1 Since piping cannot be bent, small bends and offsets desired for piping layout would have to be "designed around", or made by hand lay-up in the vendor's factory.

11.1.2 Since heavy valves cannot be supported by the adjacent fiberglass piping as is the case with steel, there is less freedom in placement of valves. due to the special supports that must be built.

11.1.3 Split-ring pipe hanger design for fiberglass piping is more complex than for steel, since simple conventional U-bolt hangers cannot be used.

11.2 Construction

11.2.1 Installation of pipe anchors in a fiberglass system is usually more difficult. Positive attachment is made *at* fiberglass piping flanges, while steel piping has anchor points welded to pipe.

11.2.2 Some degree of pipe protection will be required during construction.

11.2.3 If a joint leak occurs during hydrostatic testing it will be more difficult, depending on the joint location, to effect a repair. If an O-ring must be replaced, its Pronto-Lock joint will have to be disassembled.

12 UNRESOLVED DESIGN PROBLEMS

12.1 Certain mechanical properties of fiberglass reinforced epoxy piping were not taken into account in this study. These are impact resistance, fire resistance, and resistance to shock and vibration. Marine service requirements are being defined in the J.J. Henry Co. project mentioned in the foreword of this report. Testing and evaluation will be conducted in conjunction with an overall program to obtain general approval of the U.S. Coast Guard.

12.2 Resistance to erosion and cavitation, such as may occur at high fluid velocities; was not considered. This, too, is included in the J.J. Henry Co. project.

12.3 Stress concentration in rigid pipe flanges at bulkhead and deck penetrations were not investigated. The problem was avoided by adding a Pronto-Lock joint close to the flange.

12.4 The possibility of anchoring fiberglass piping by adhesive bonding to the outer surface was not explored thoroughly. Pipe anchors were built-up by steel members to the pipe flanges.

12.5 A second-time-around design *review* to reduce flanged joints and maximize vendor pre-fabrication was not done.

13 CONCLUSIONS

13.1 Significant cost savings can be realized by the shipbuilder by substituting fiberglass reinforced epoxy piping in place of carbon steel. Substitution is contingent on:

a. General approval by the U.S. Coast Guard of piping material and joint design.* In the meantime, special request for approval may be made for a particular application.

*U.S.C.G. approval for fiberglass piping systems is presently granted on a case basis. A current example is the Chevron double hull tankers being built at FMC.

b. Availability of piping materials in sizes required.

c. Acceptance by the shipowner of such substitution.

13.2 Greater savings can be realized through improved design methods resulting in a greater degree of factory pre-fabrication.

13.3 A shipyard may go into the business of fiberglass piping installation without the need for capital outlay or acquiring specially skilled craftsmen.

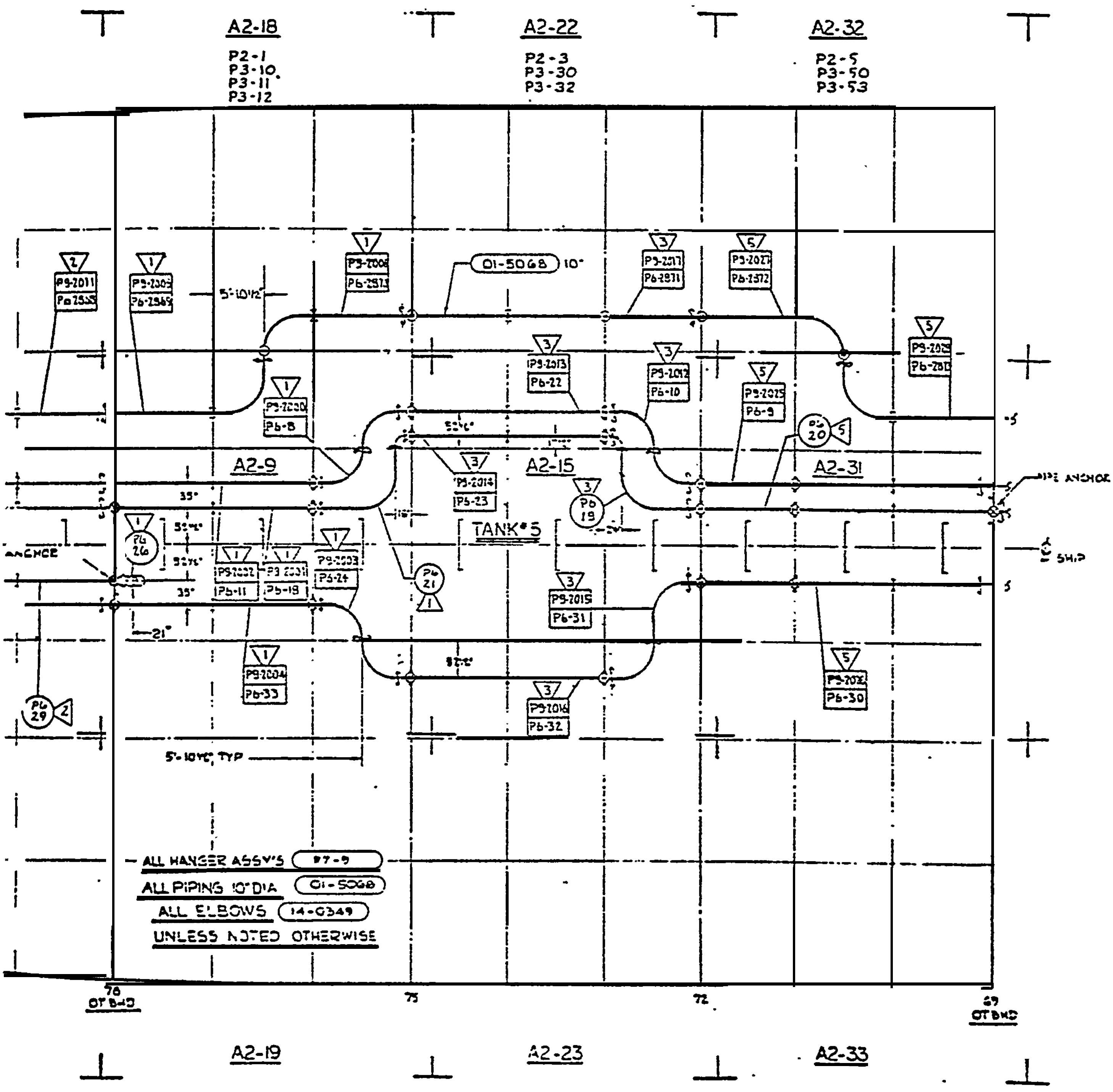


Figure 1 - Arrangement of Steel Ballast Piping

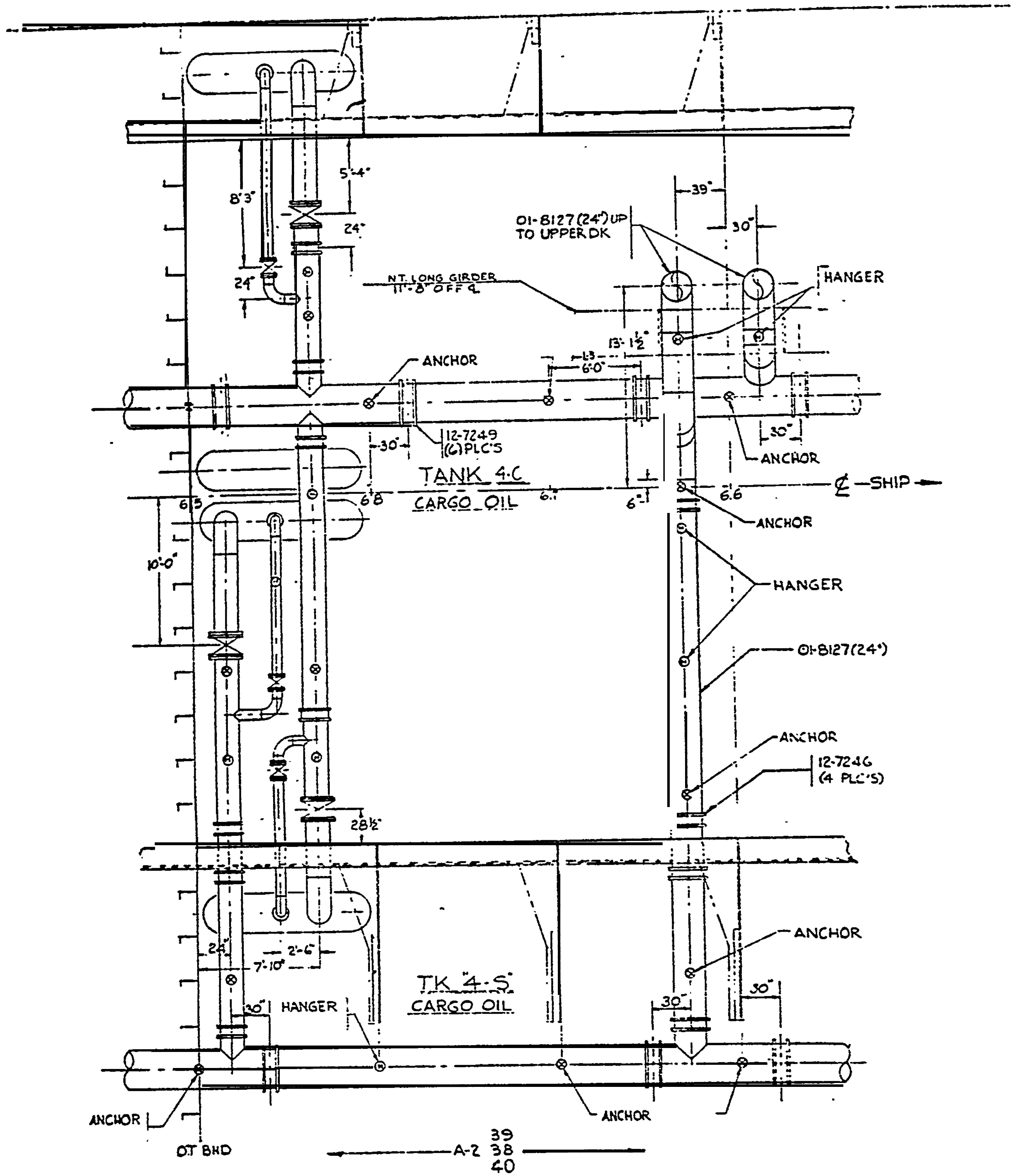


Figure 2 - Arrangement of Steel Cargo In-Tank Piping

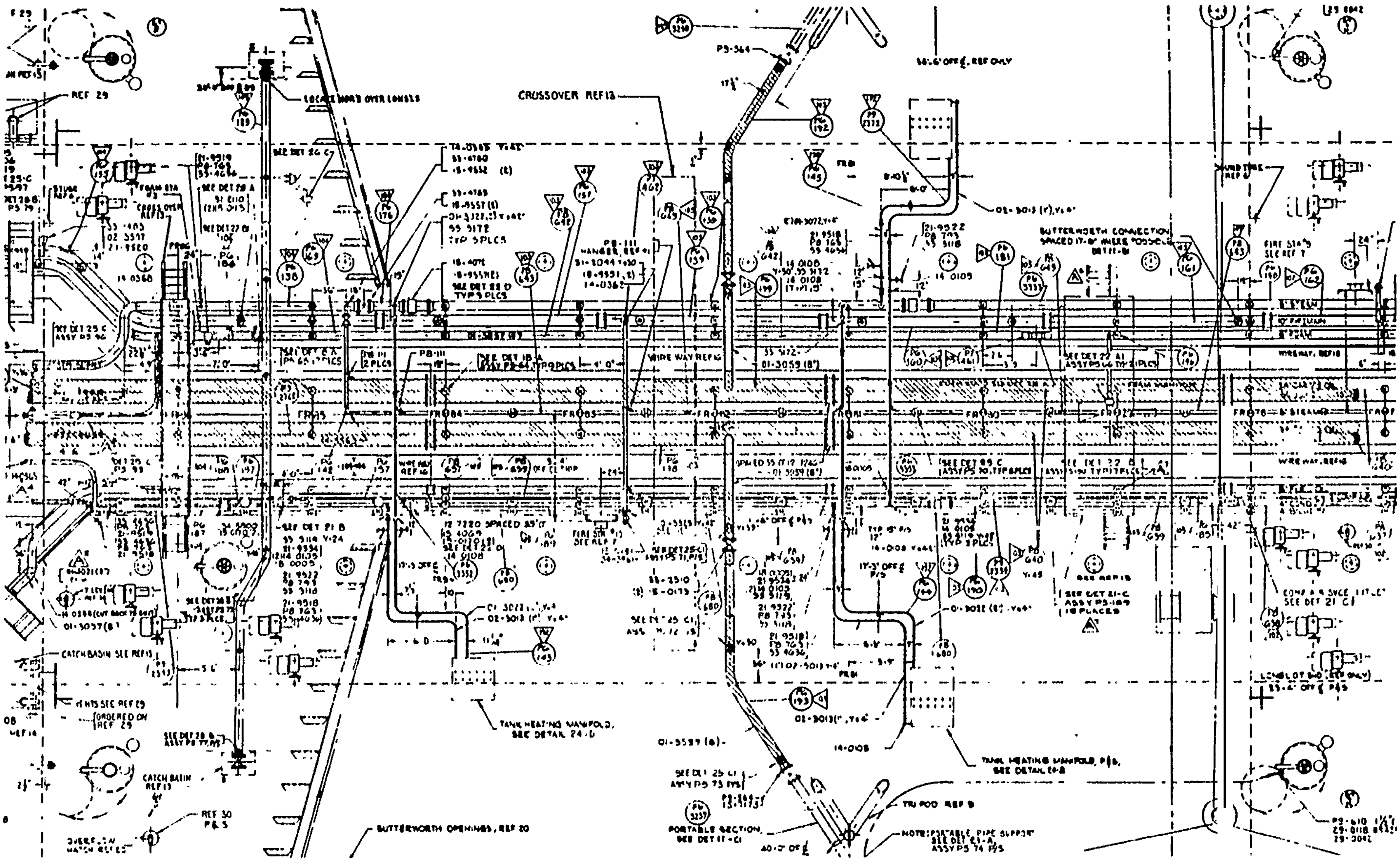


Figure 3 - Arrangement of Steel Cargo Deck Piping (Aft)

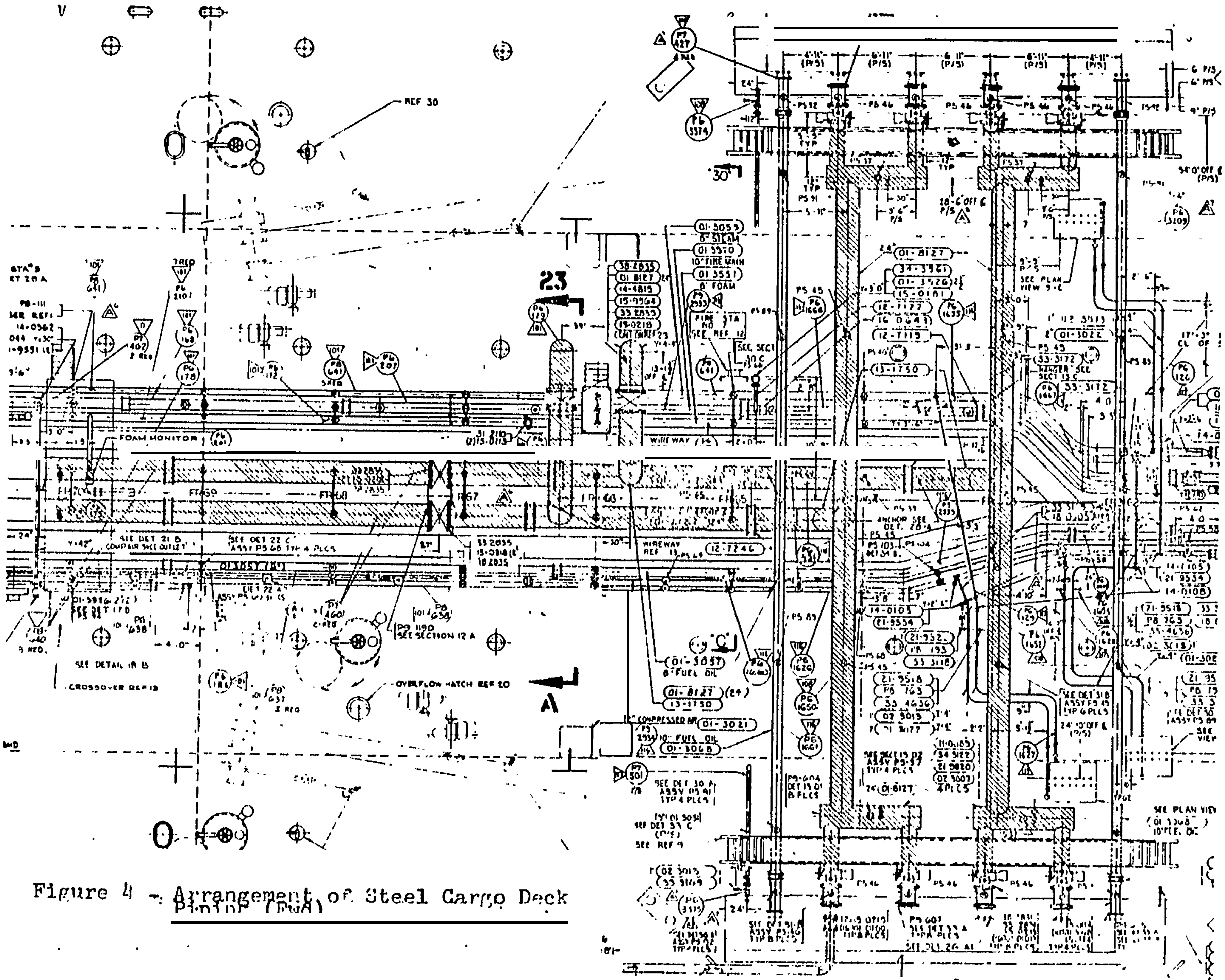
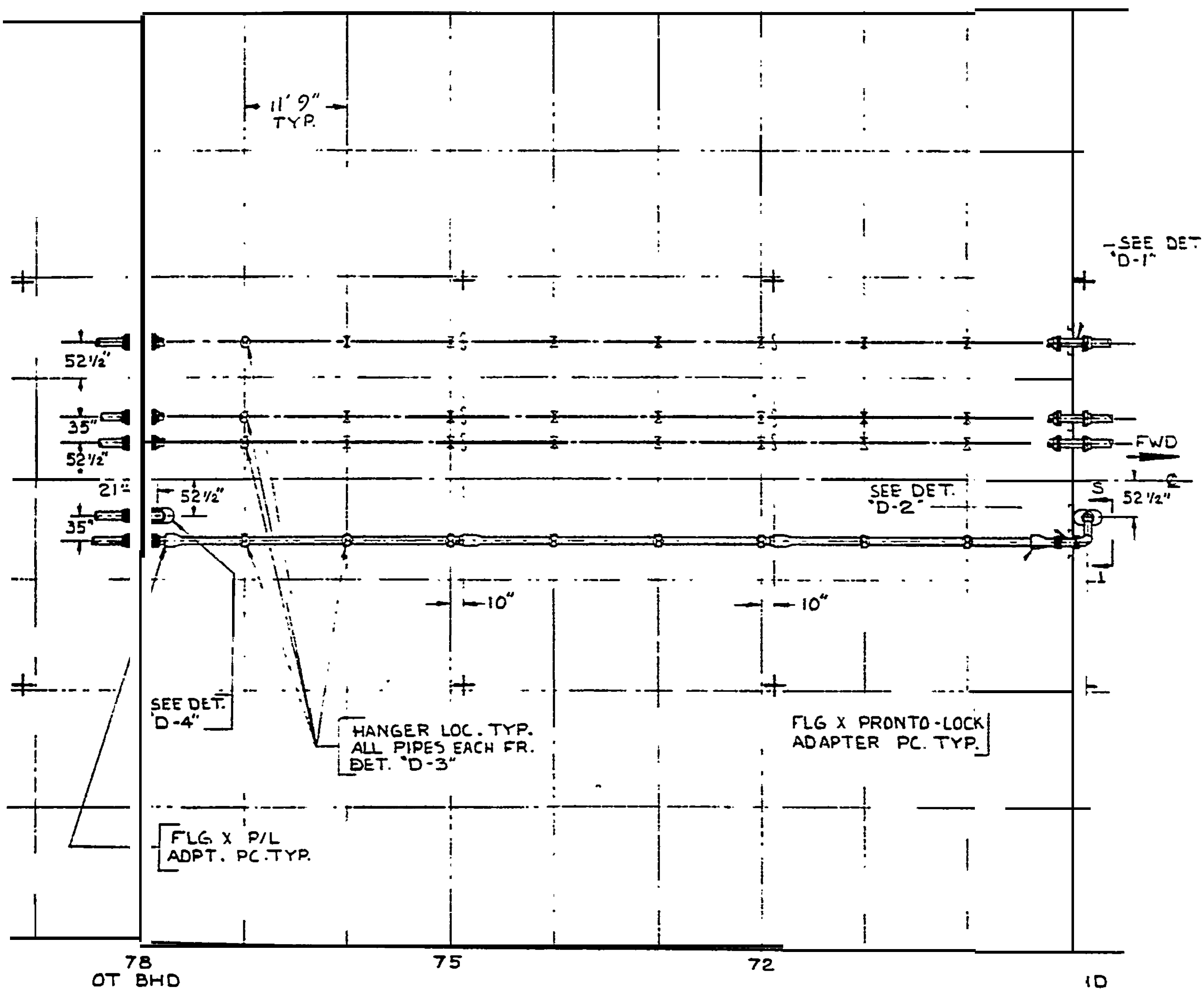


Figure 4 - Arrangement of Steel Cargo Deck Piping (Fwd)



PLAN INNER BOTTOM BALLAST TANK *5

Figure 5 - Arrangement of Fiberglass Ballast Piping

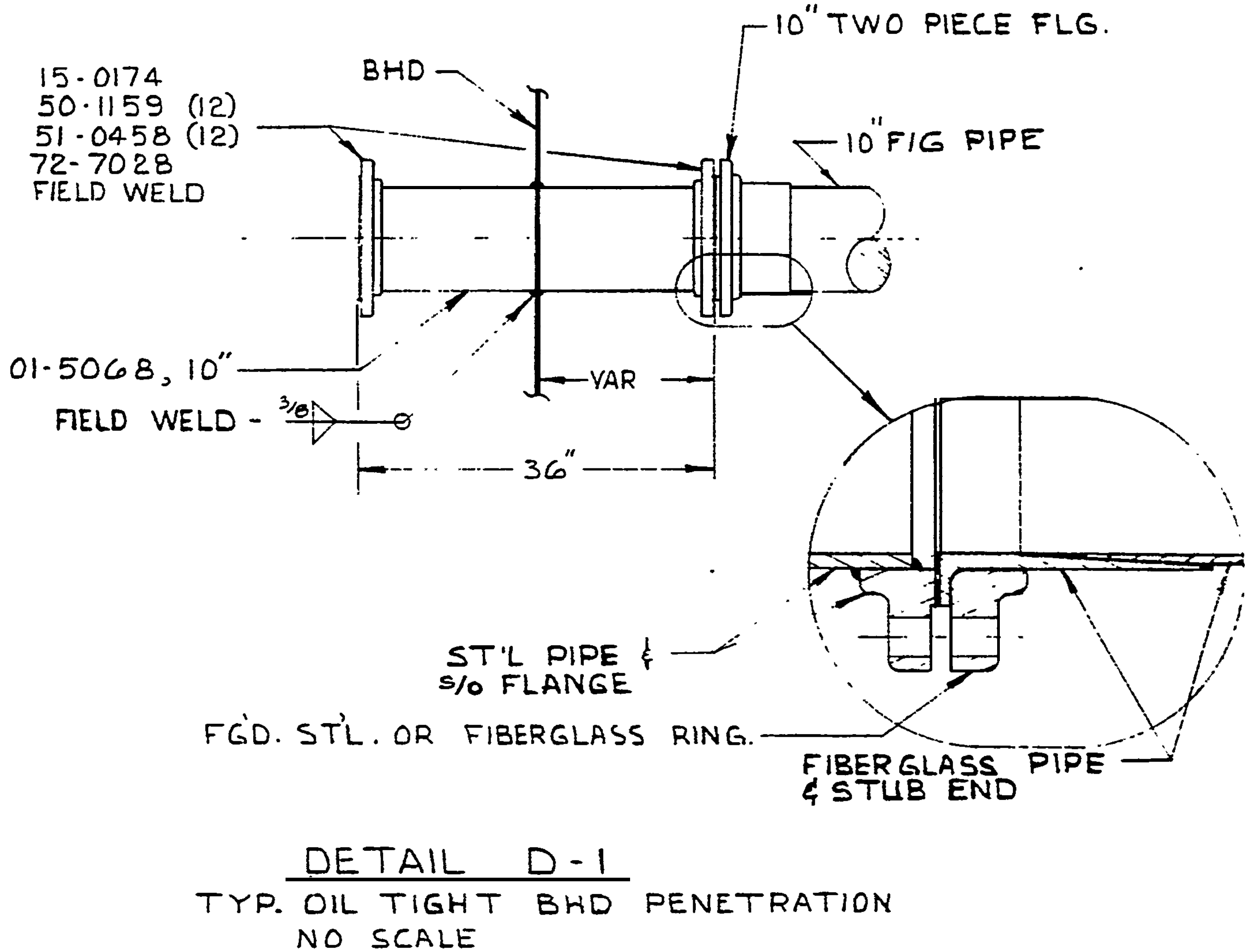


Figure 6 - Detail of Bulkhead Penetration and Fiberglass Flanged End

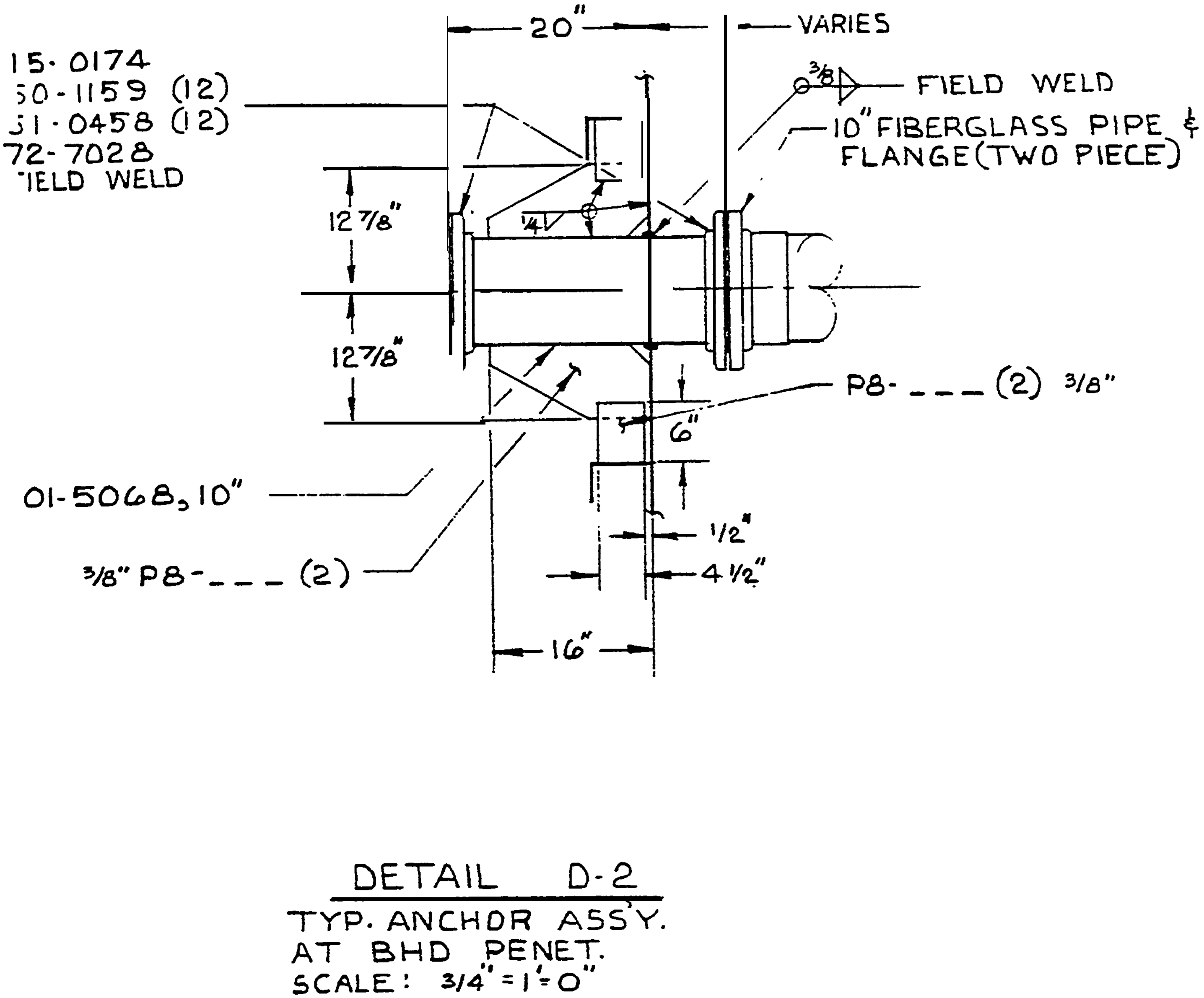
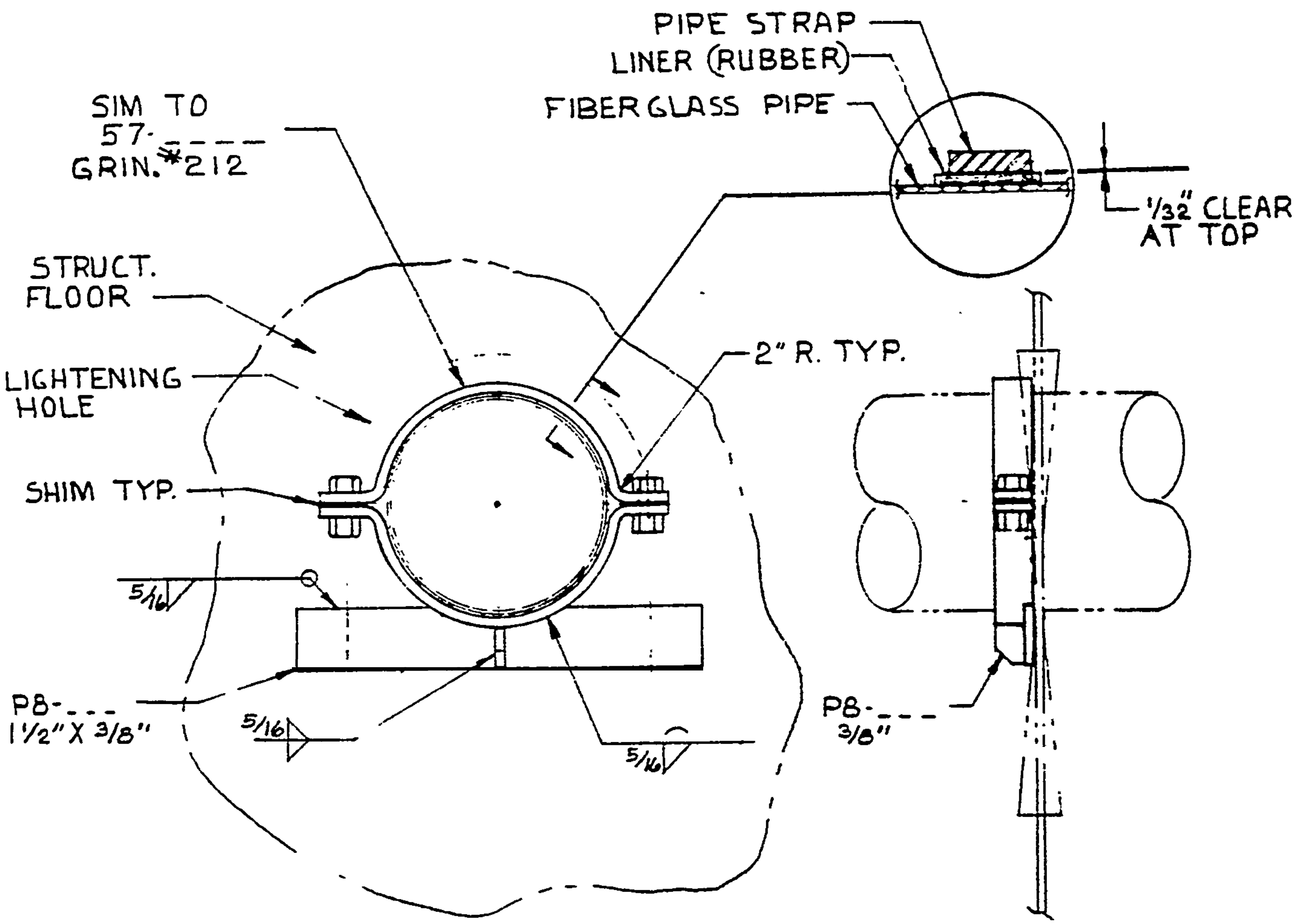


Figure 7 - Detail of Bulkhead Penetration and Anchor

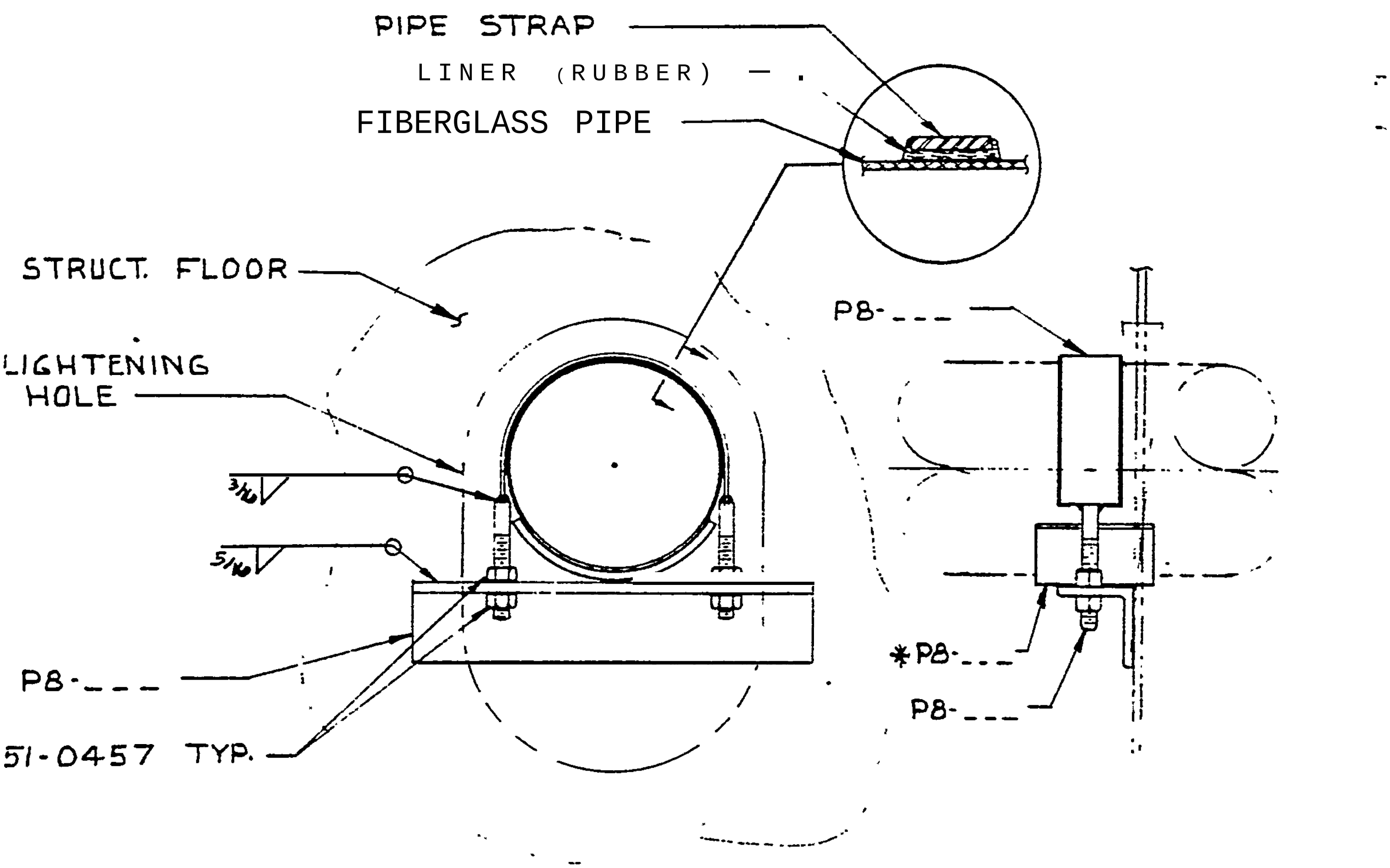


DETAIL D-3

TYPICAL HANGER ASSY (P7-___)
NO SCALE

NOTE:
SHIM BETWEEN HGR. TABS FOR 1/32" CLEAR
FROM TOP OF LINER TO INSIDE OF HANGER

Figure 8 - Detail of 10" Split-Ring Pipe Hanger



DETAIL D-3 (ALTERNATE)
TYPICAL HANGER ASS.Y. (P7-___)
NO SCALE

NOTE:
* 6" X 11½" x ½" WEAR PLATE ST'L. EPOXY BONDED TO PIPE.

Figure 9 - Detail of Alternate 10" Pipe Hanger

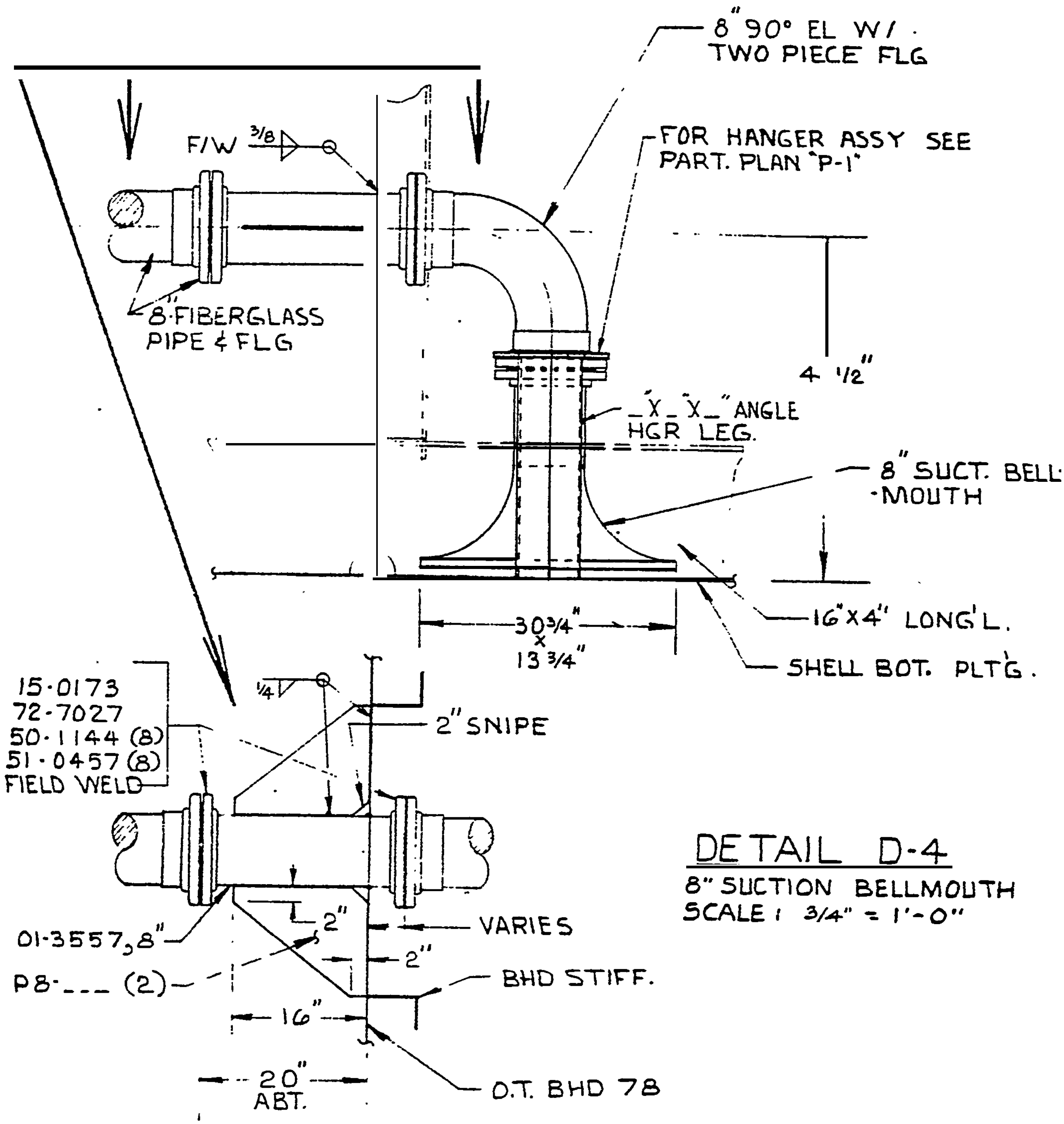
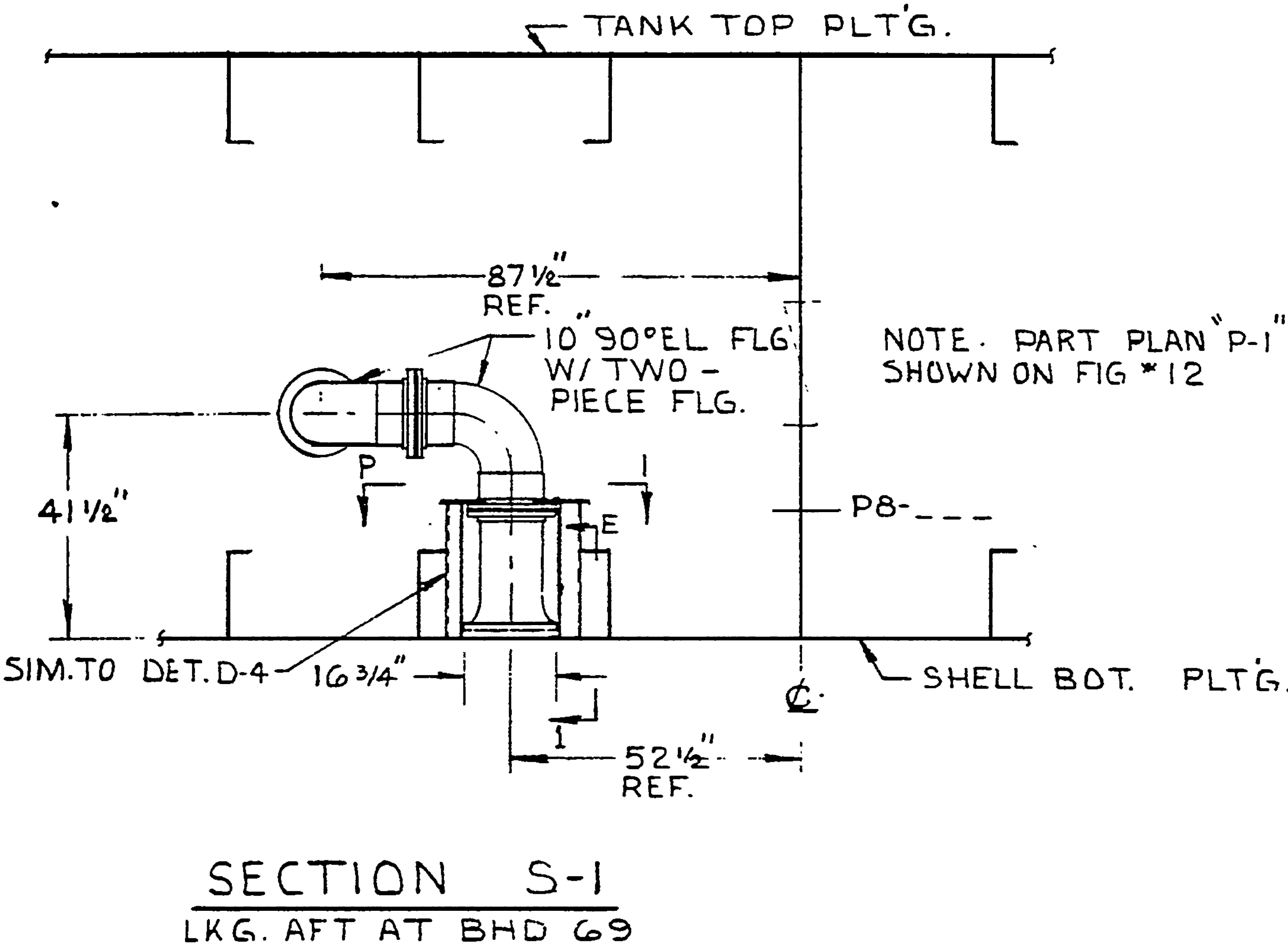


Figure 10 - Arrangement of Suction Bellmouth



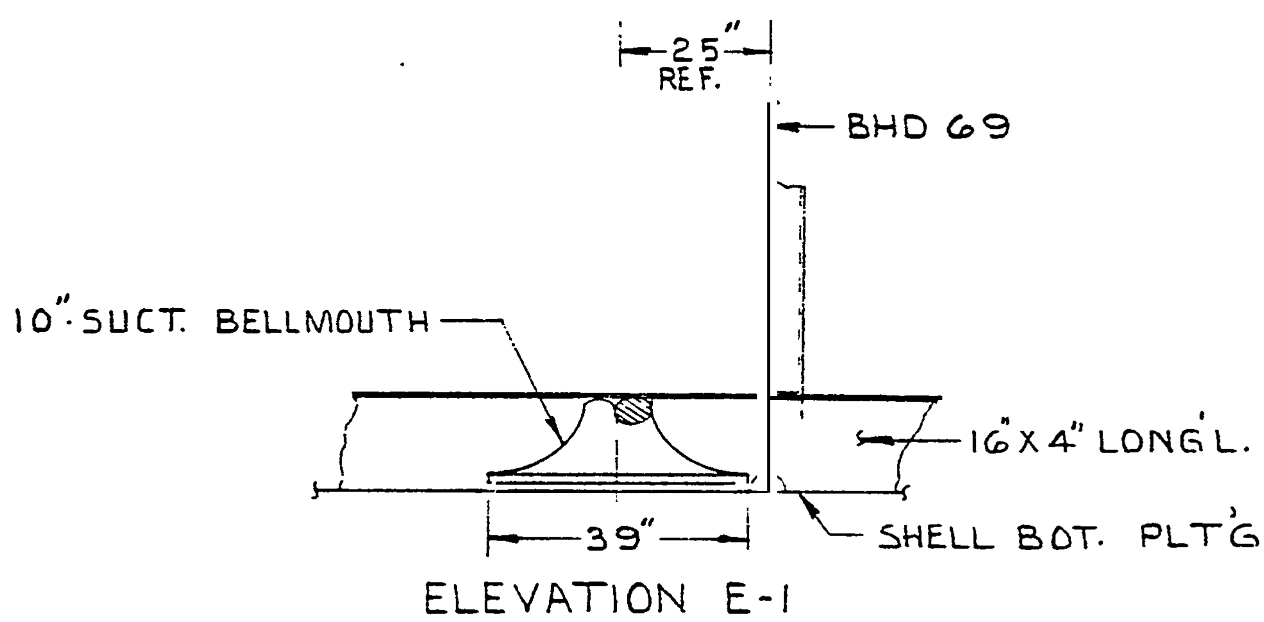


Figure 11 - Arrangement of Offset Suction Bellmouth

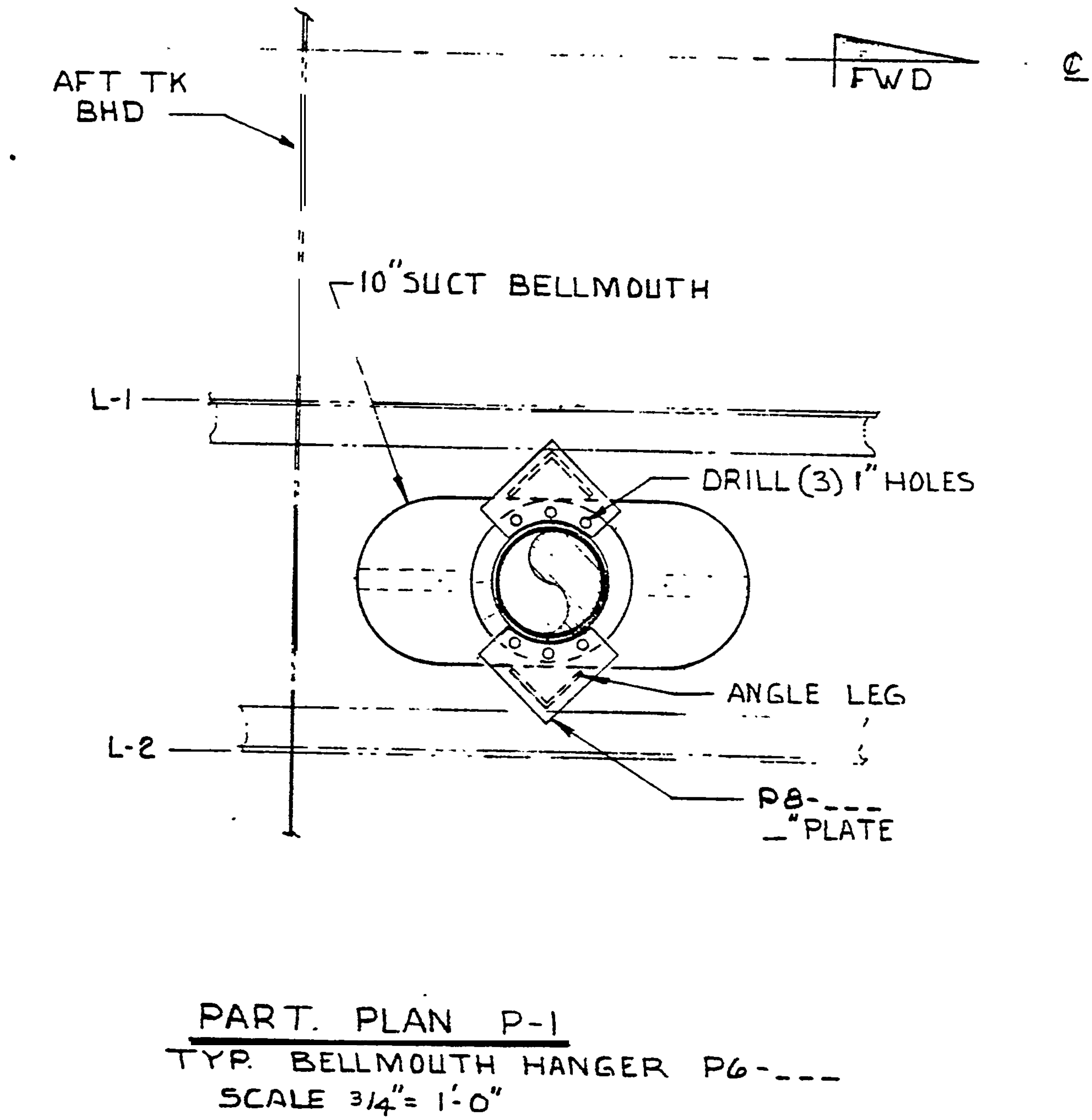
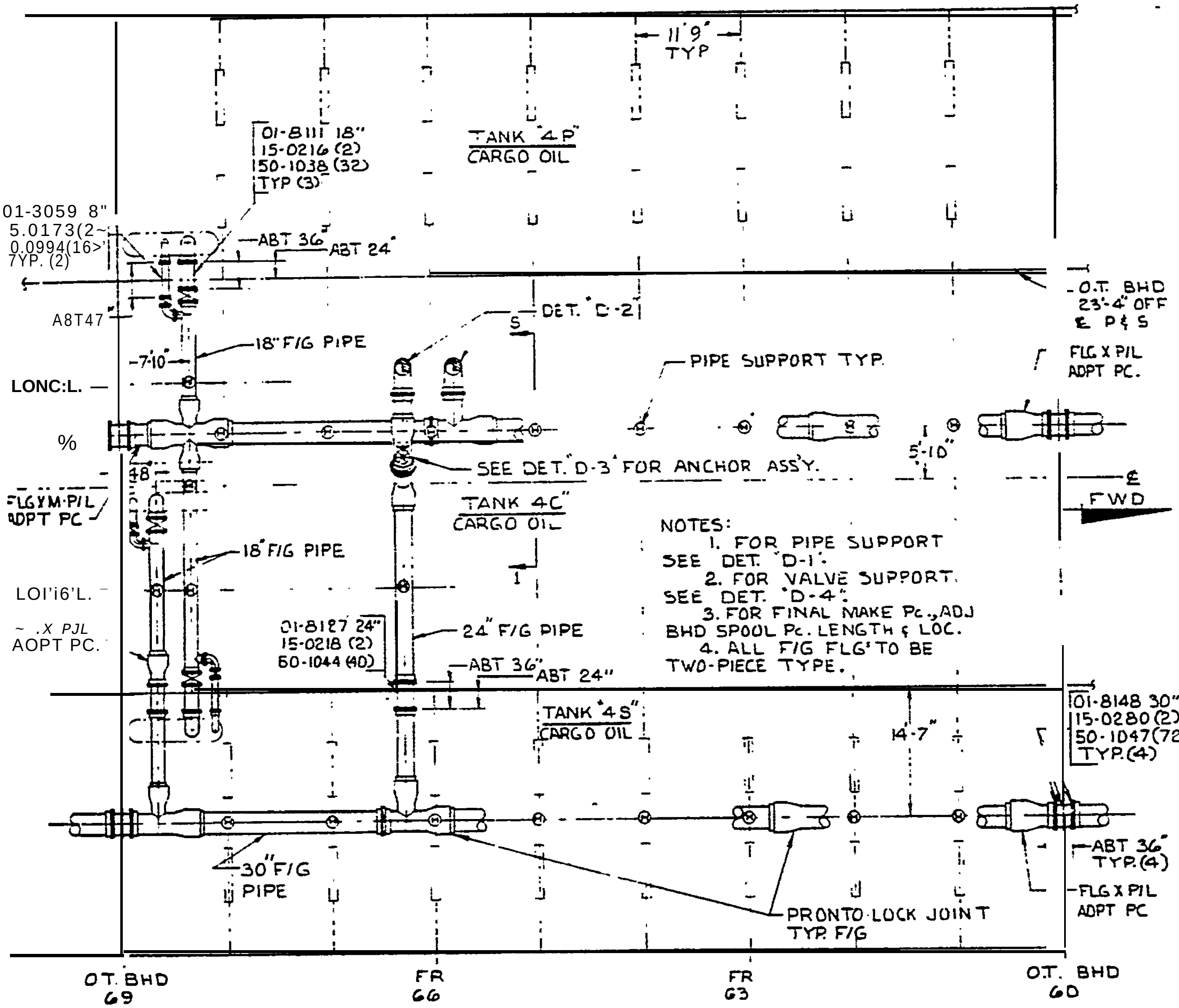


Figure 12 - Detail of Suction Bellmouth Anchor



PLAN CARGO OIL TANKS 4P, 4C & 4S

Figure 13 - Arrangement of Fiberglass Cargo Suction Piping

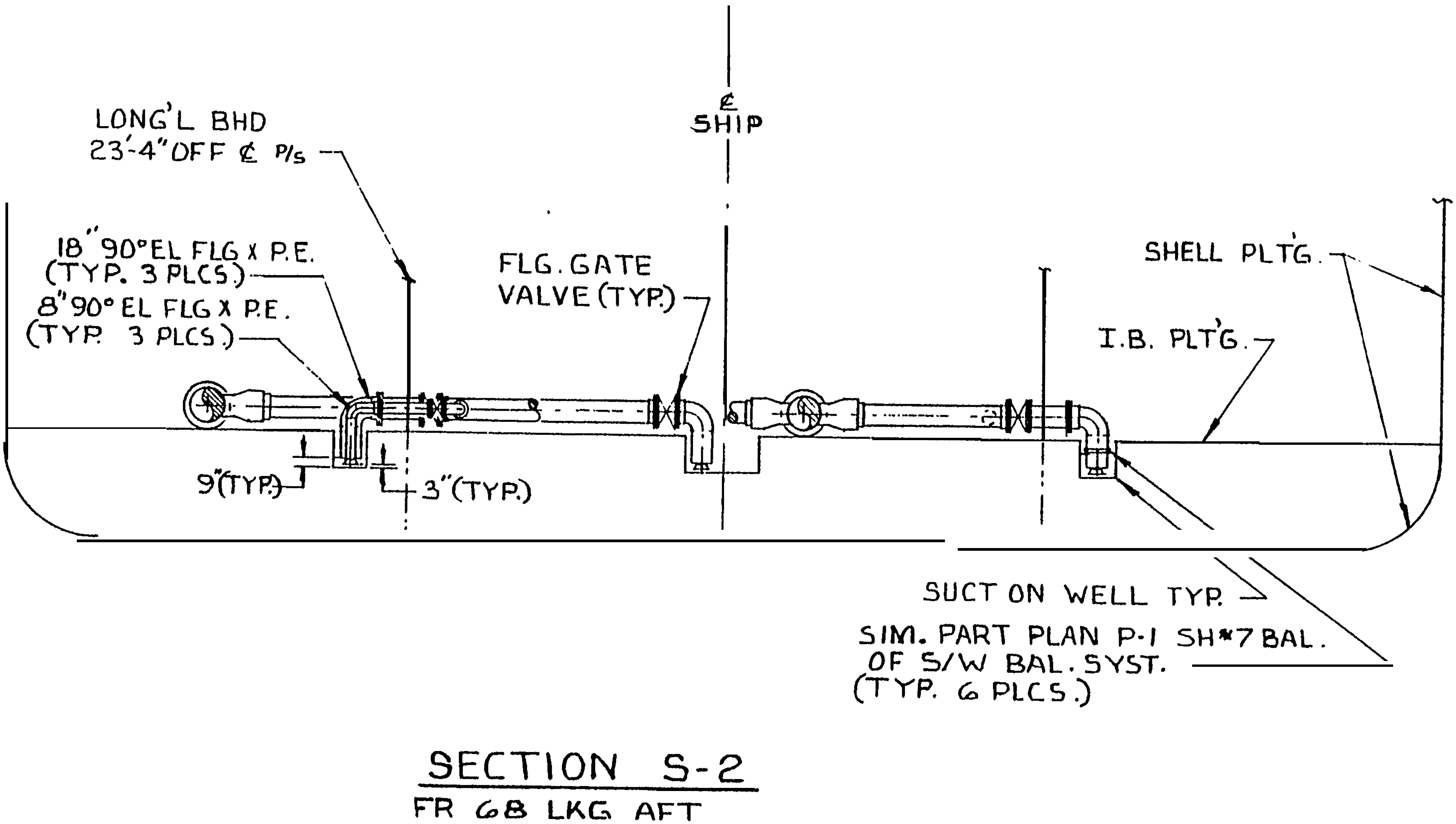
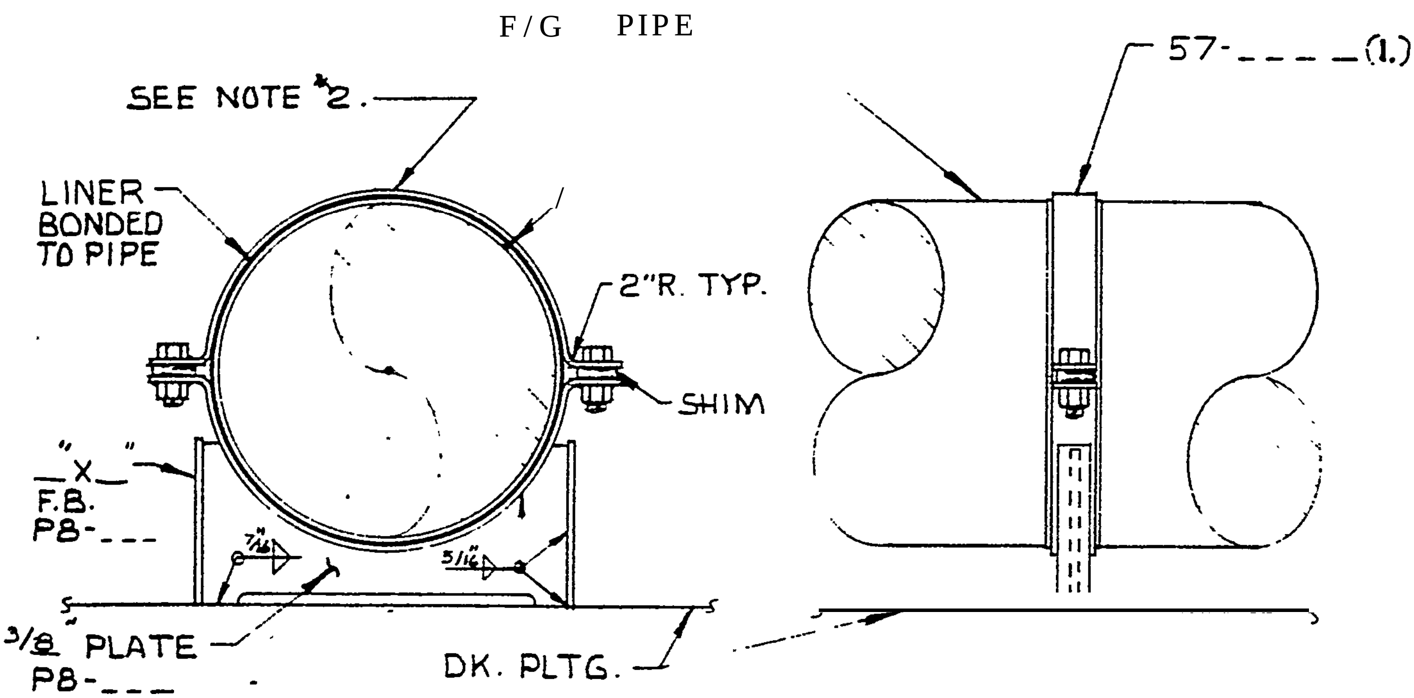


Figure 14 – Section View of Fiberglass Cargo Suction Piping

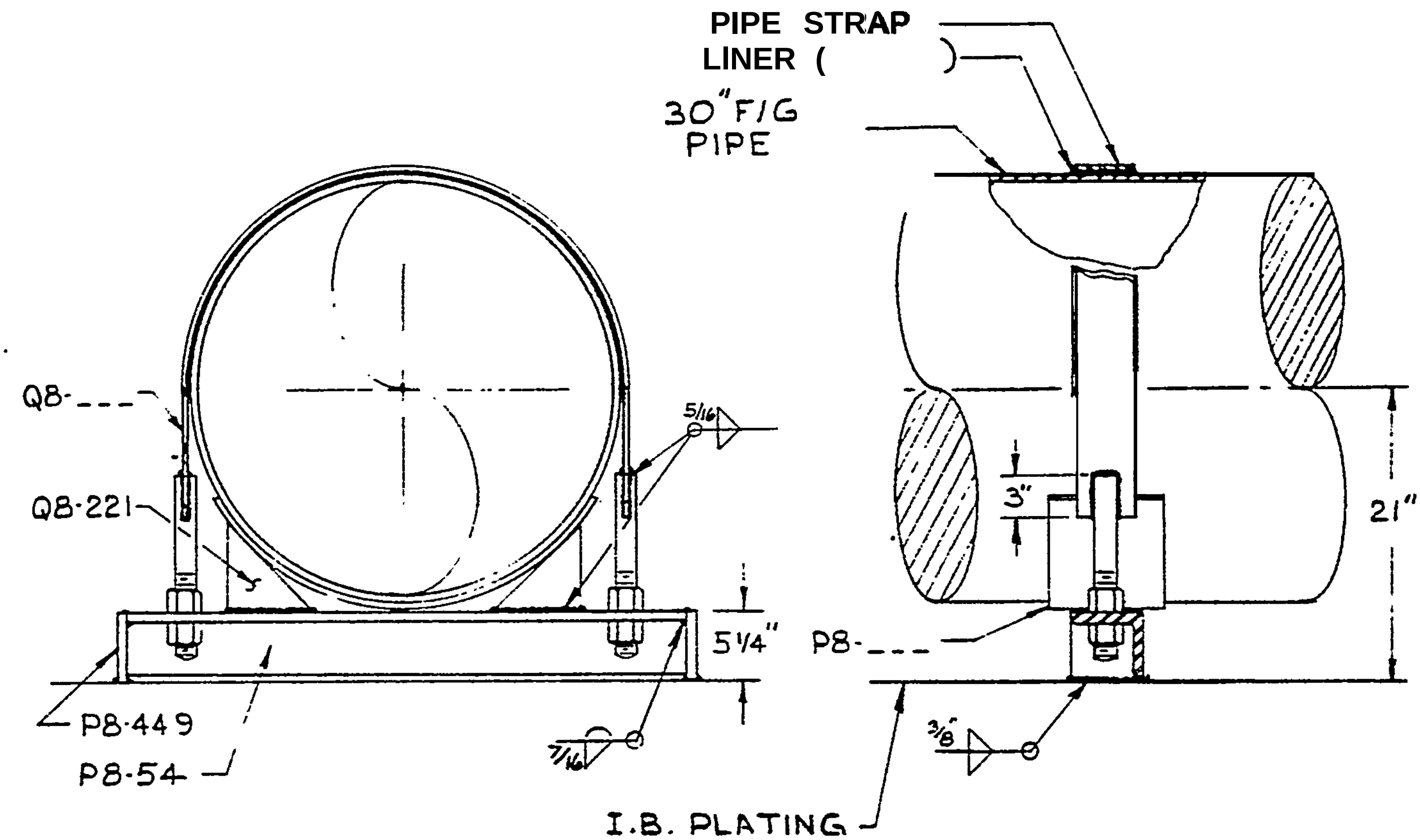


DETAIL D-1

TYP. HANGER ASSY FOR
18", 24" & 30" F/G PIPE
P7-___
SCALE: 3/4" = 1'-0"
(30" SHOWN)

* NOTE:
57-____ SIM. TO GRINNELL FIG. *212
2. SHIM BETWEEN HGR. TABS FOR 1/32" CLEAR FROM TOP OF LINER TO INSIDE OF HANGER

Figure 15 - Detail of 30" Split-Ring Hanger



DETAIL D-1' (ALTERNATE)

TYP. HANGER ASSY. 30" PIPE
NO SCALE

INOTE :

HANGER STRAP MADE FROM 4" x 1/2 x 31 1/2 F.B. & 1 1/2" DIA. ROD (2) THREAD ONE END 6" WITH (2) 1 1/2" HEAVEY NUTS.

Figure 16 - Detail of Alternate 30" Pipe Hanger

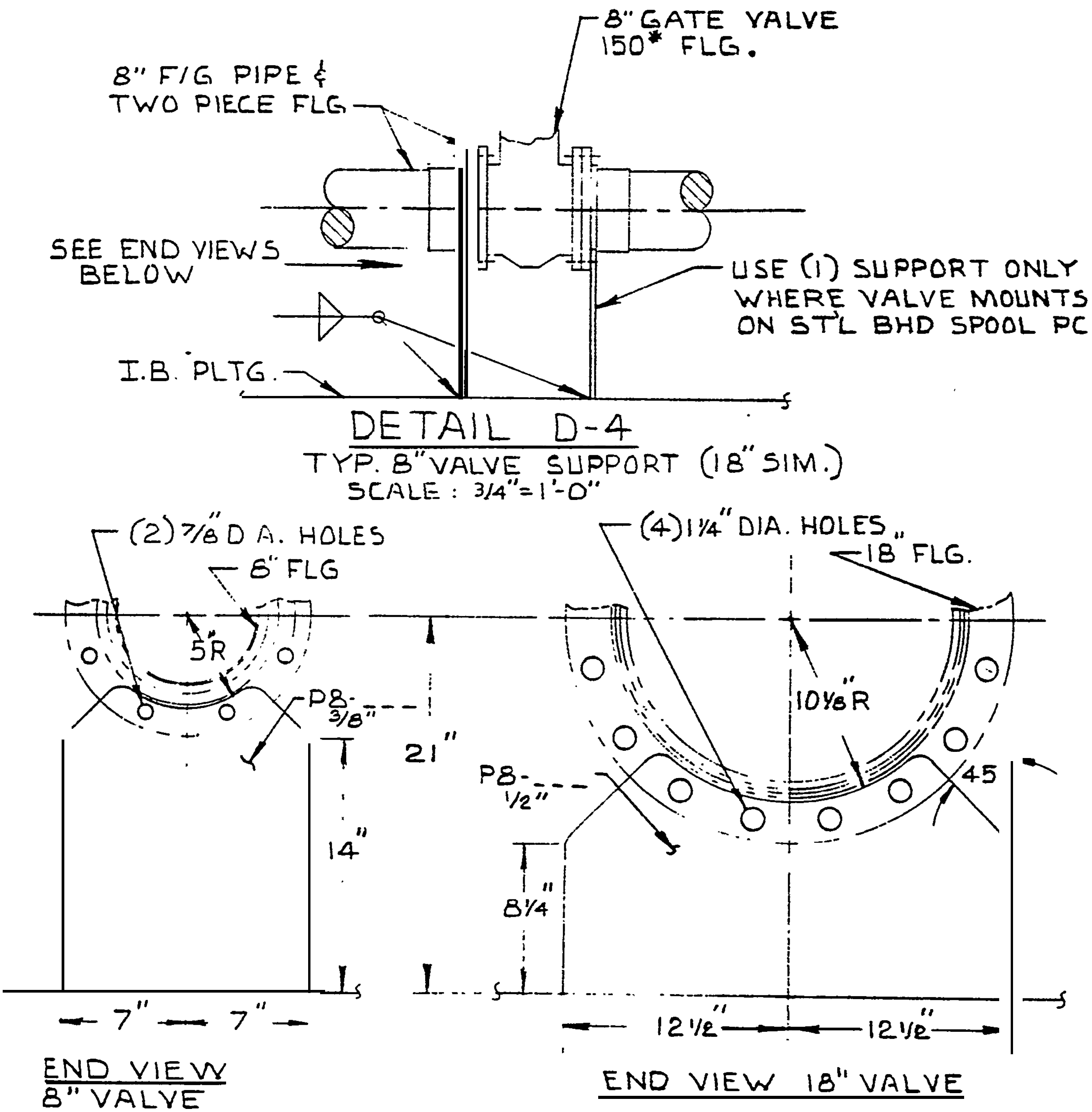
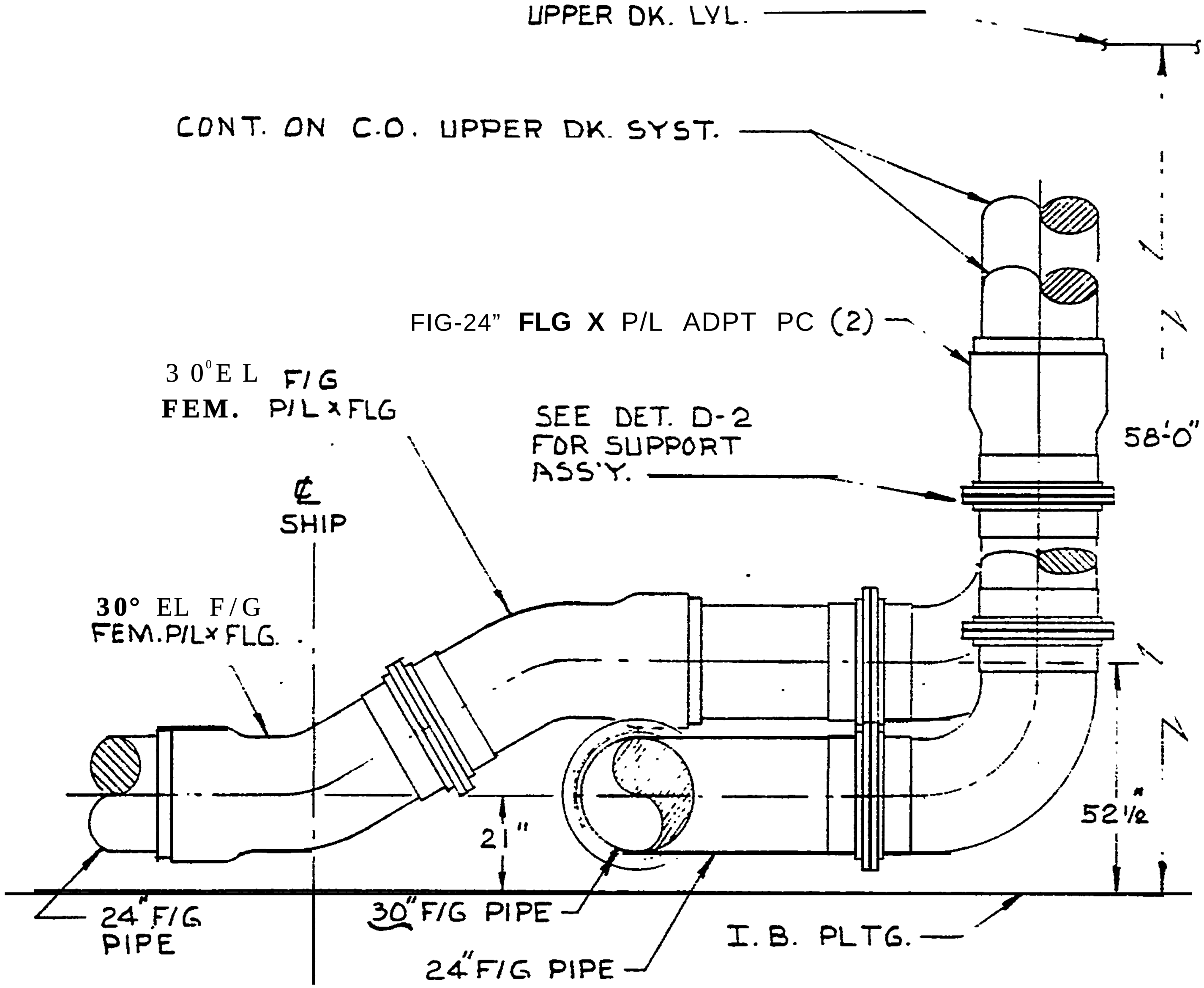


Figure 17 - Detail of Valve Supports



SECTION S-1

FRAME 65 LOOKING AFT

SCALE : 3/8"= 1"- 0"

Figure 18 - Arrangement of Fiberglass Drop Lines in Tank

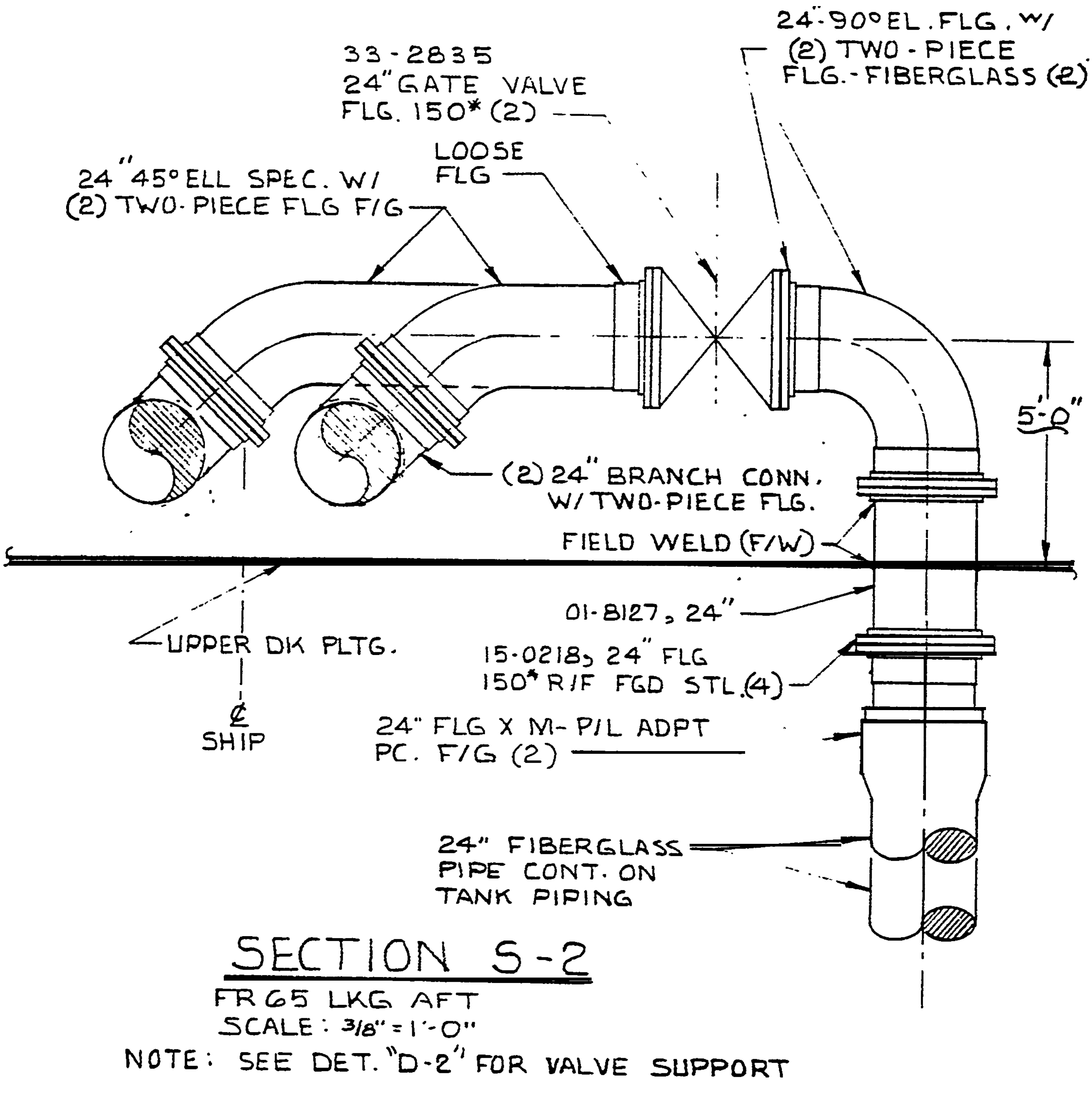
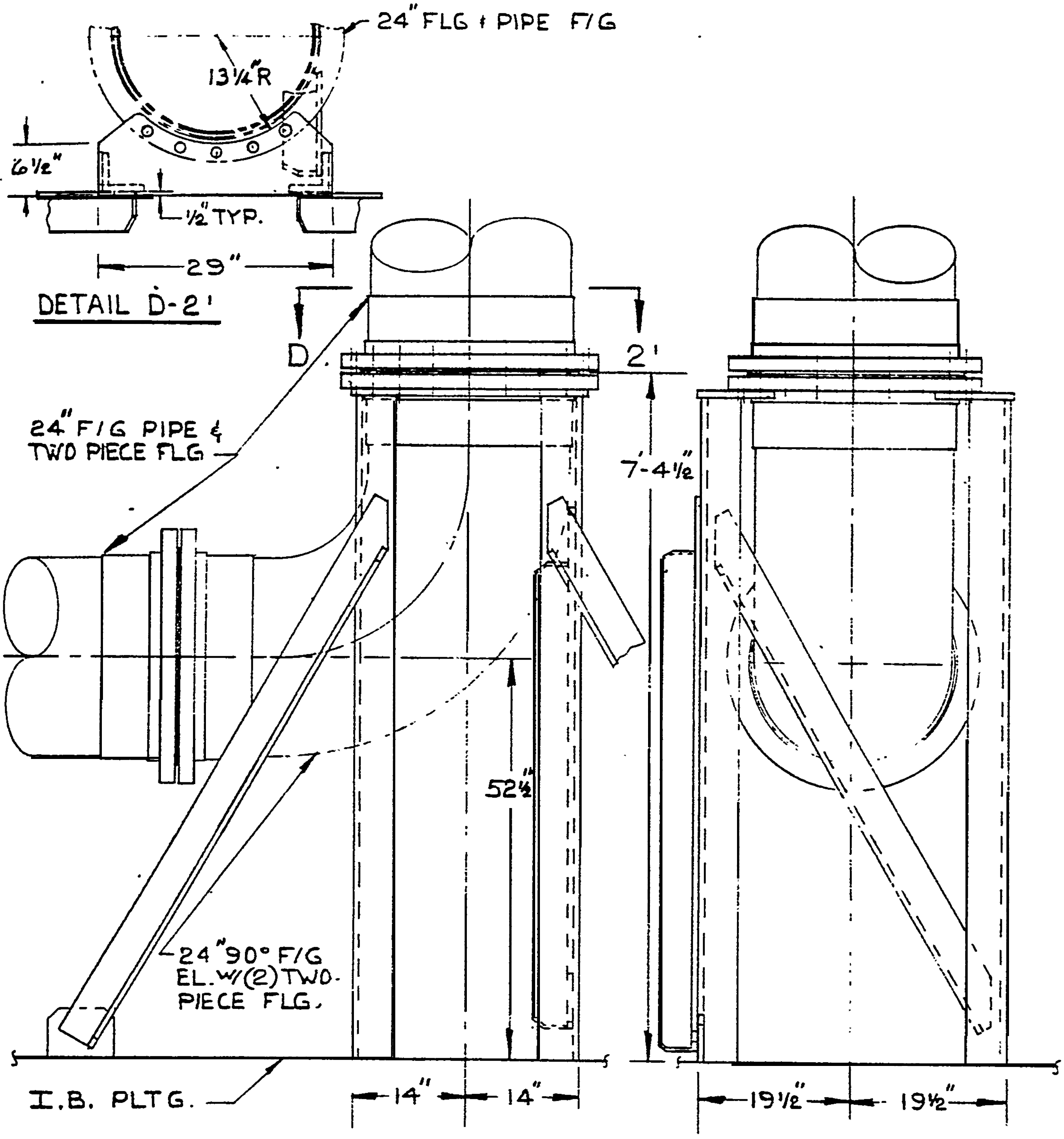


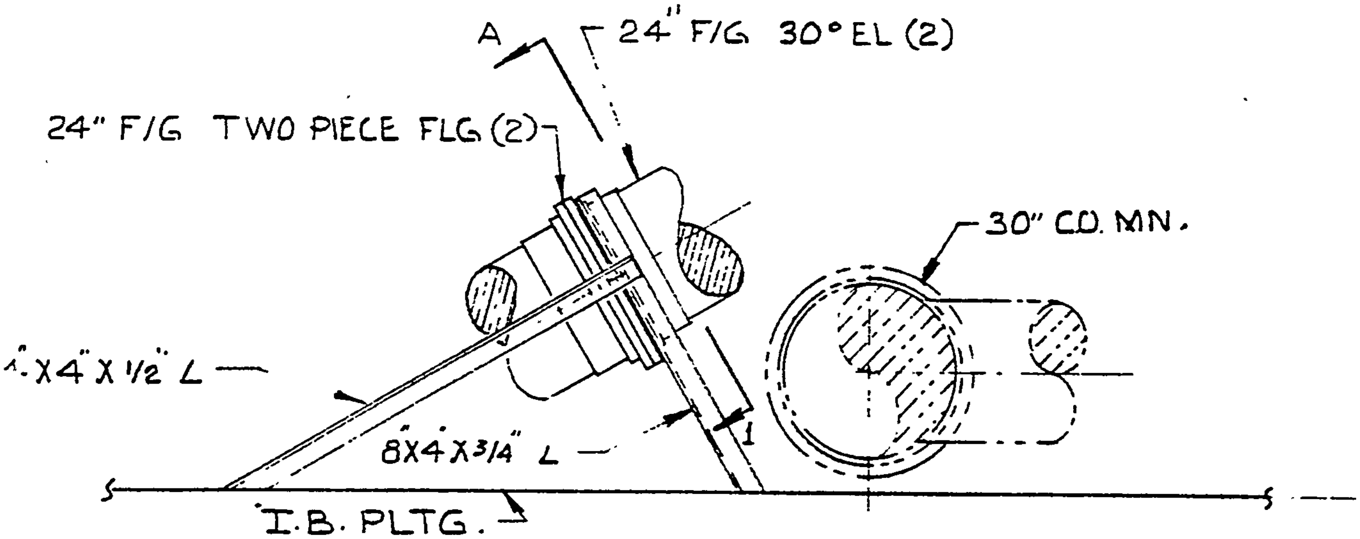
Figure 19 - Arrangement of Fiberglass Drop Lines on Deck



DETAIL D-2

SUPPORT DETAIL FOR (2) 24" 90° EL AT LOWER END OF CARGO OIL DROP LINES. AFT LINE SHOWN, FWD LINE SIM.

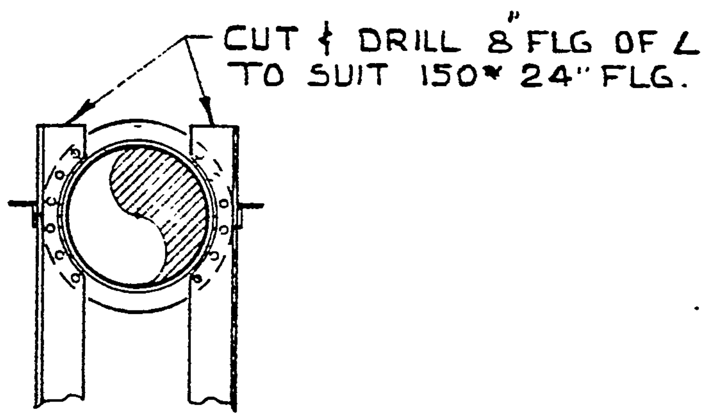
Figure 20 - Detail of Drop Line Support at Elbow



DETAIL D-3

ANCHOR ASSY P7___

SCALE: 3/8" = 1'-0"



DET. A-1

Figure 21 - Detail of Drop Line Anchor at Flange

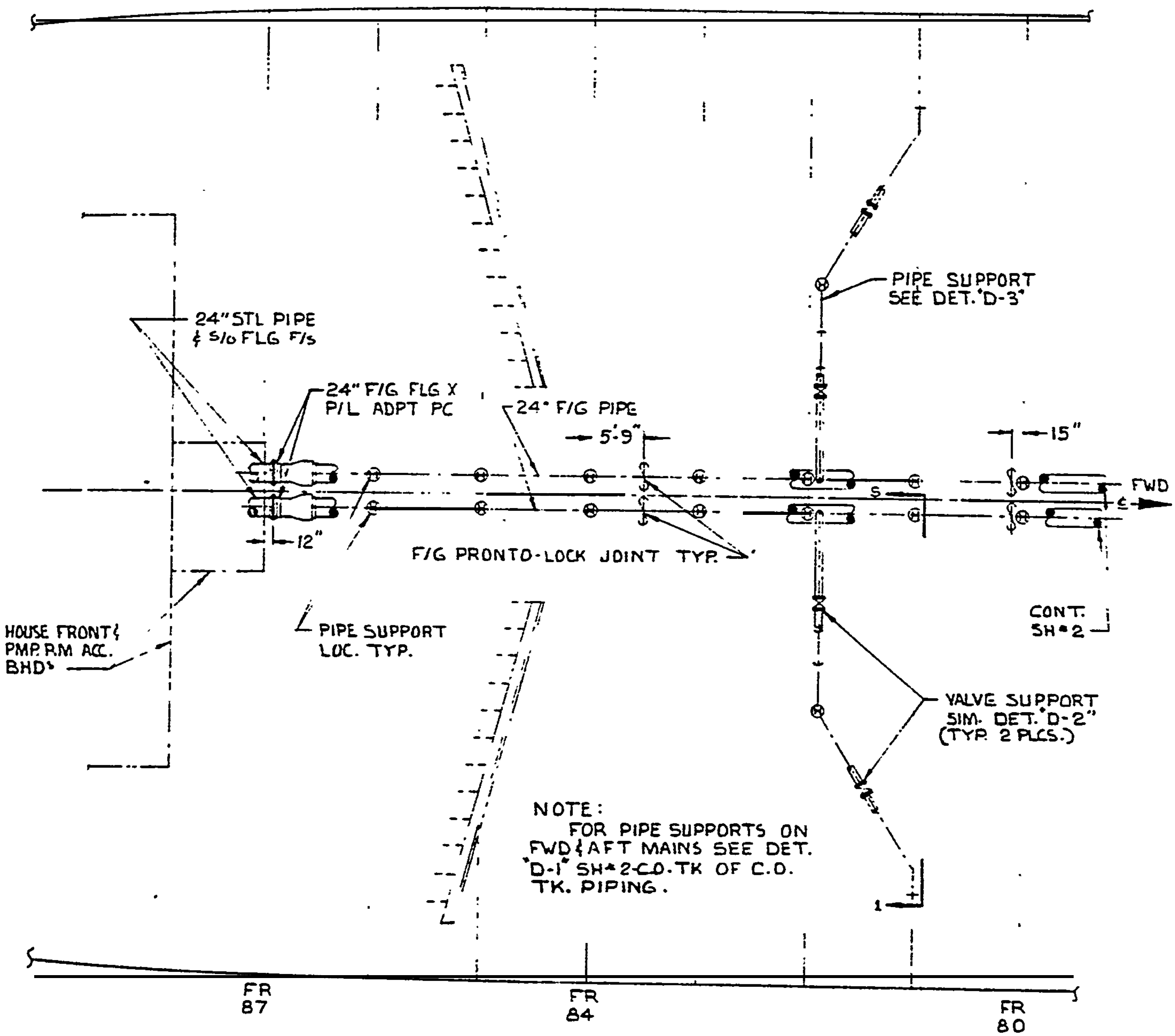


Figure 22 - Arrangement of Fiberglass Cargo Deck Piping (Aft).

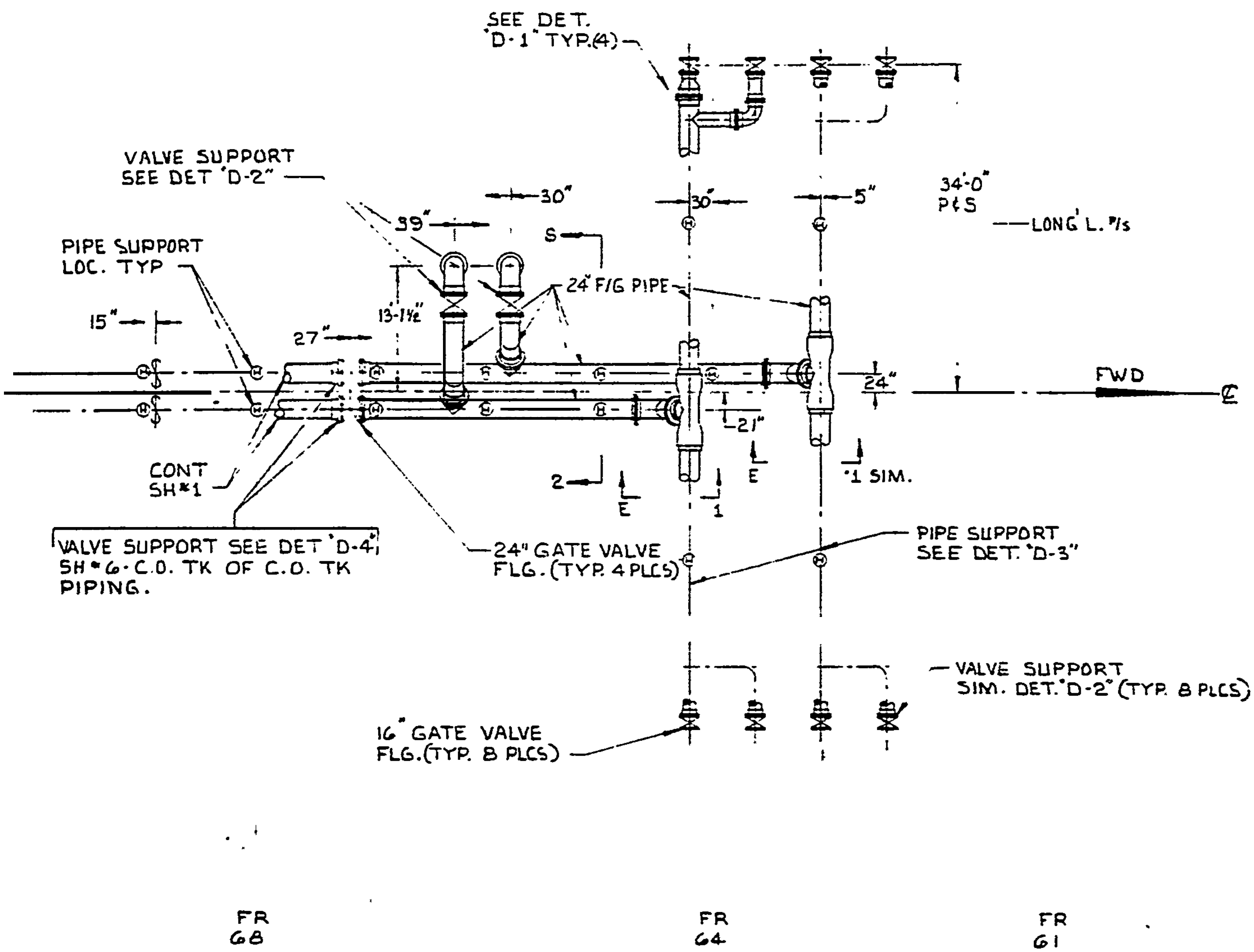
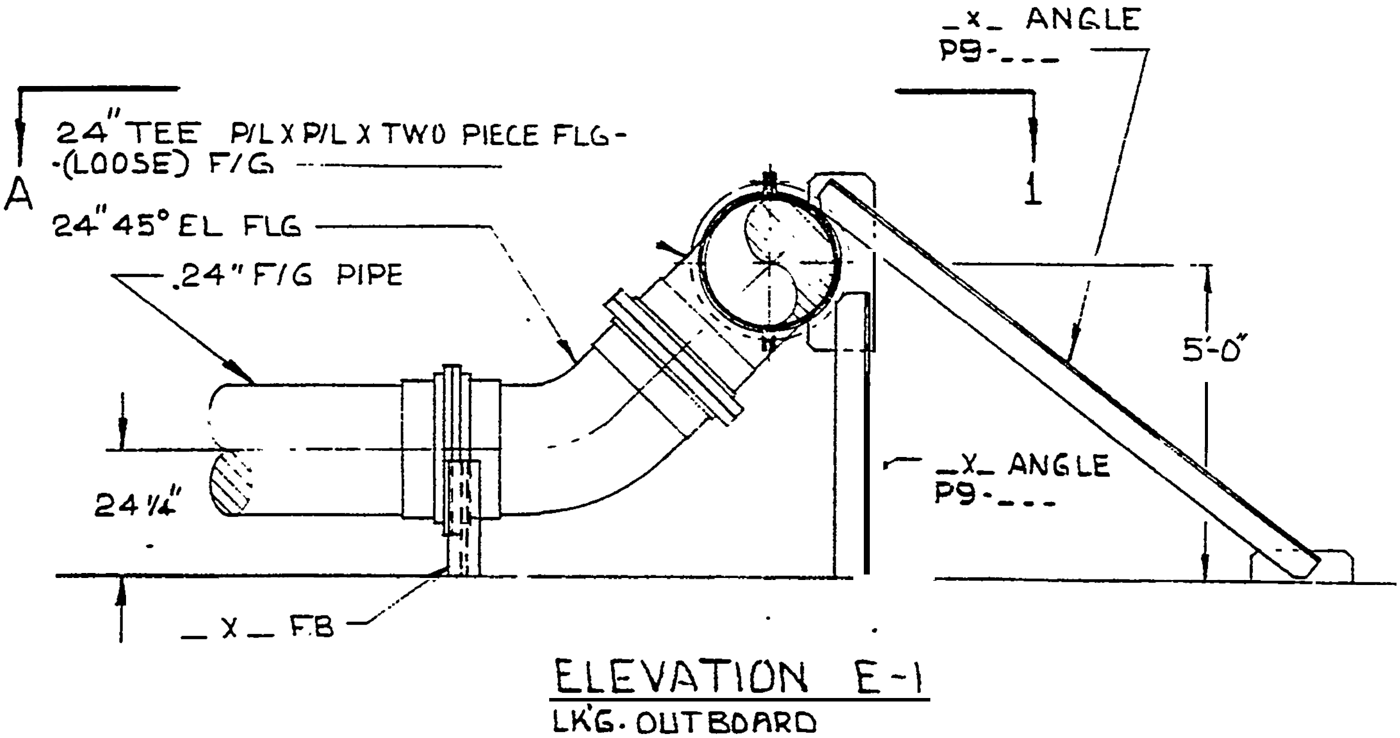


Figure 23 - Arrangement of Fiberglass Cargo Deck Piping (Fwd)



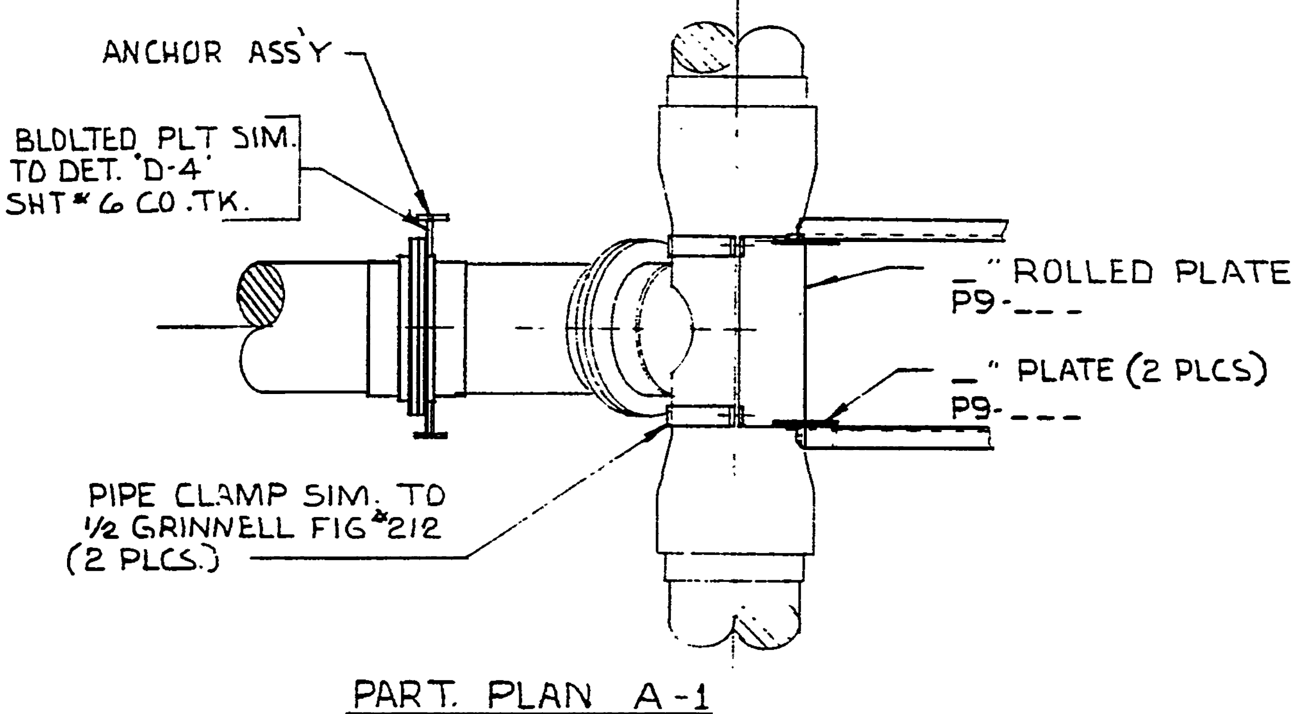
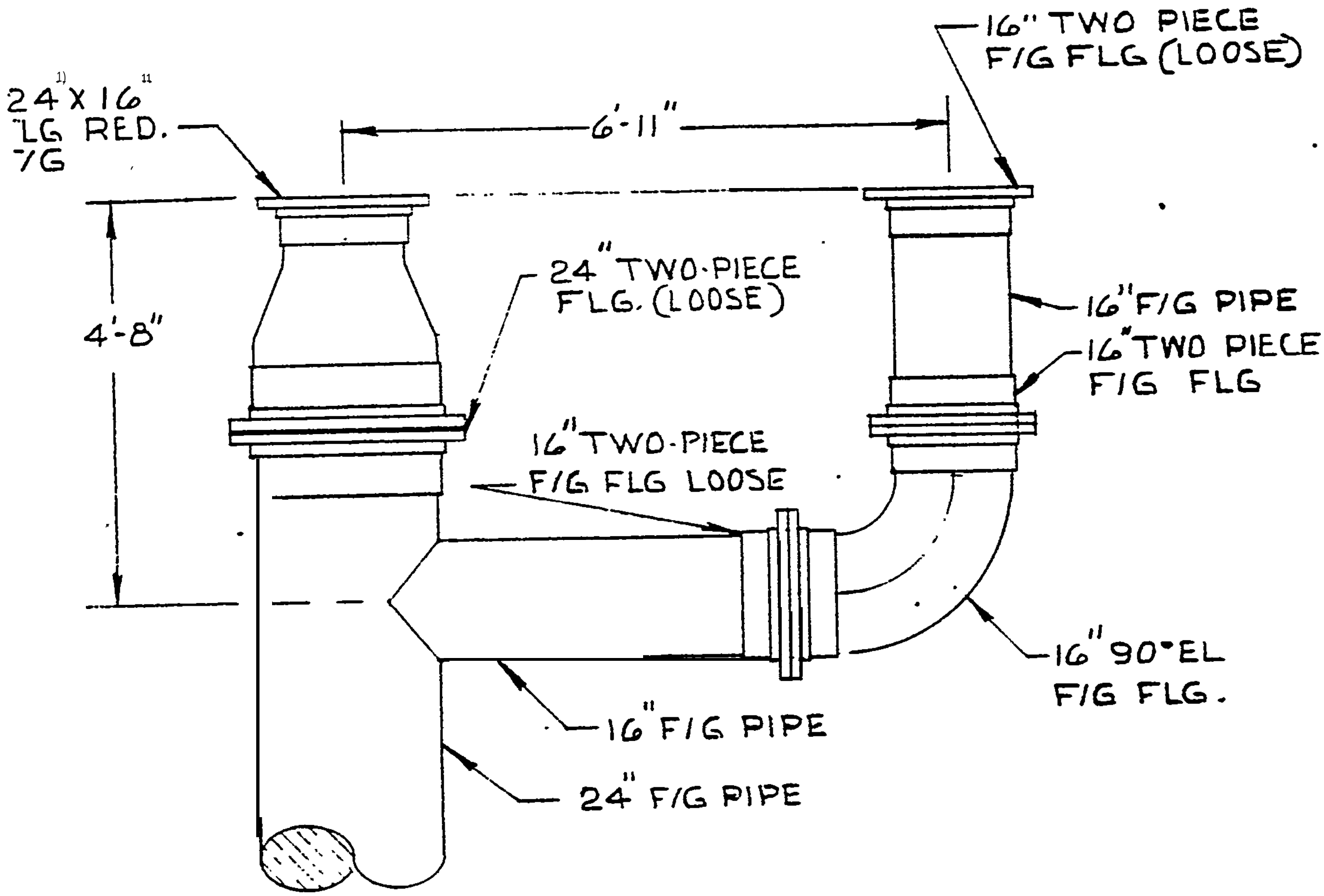


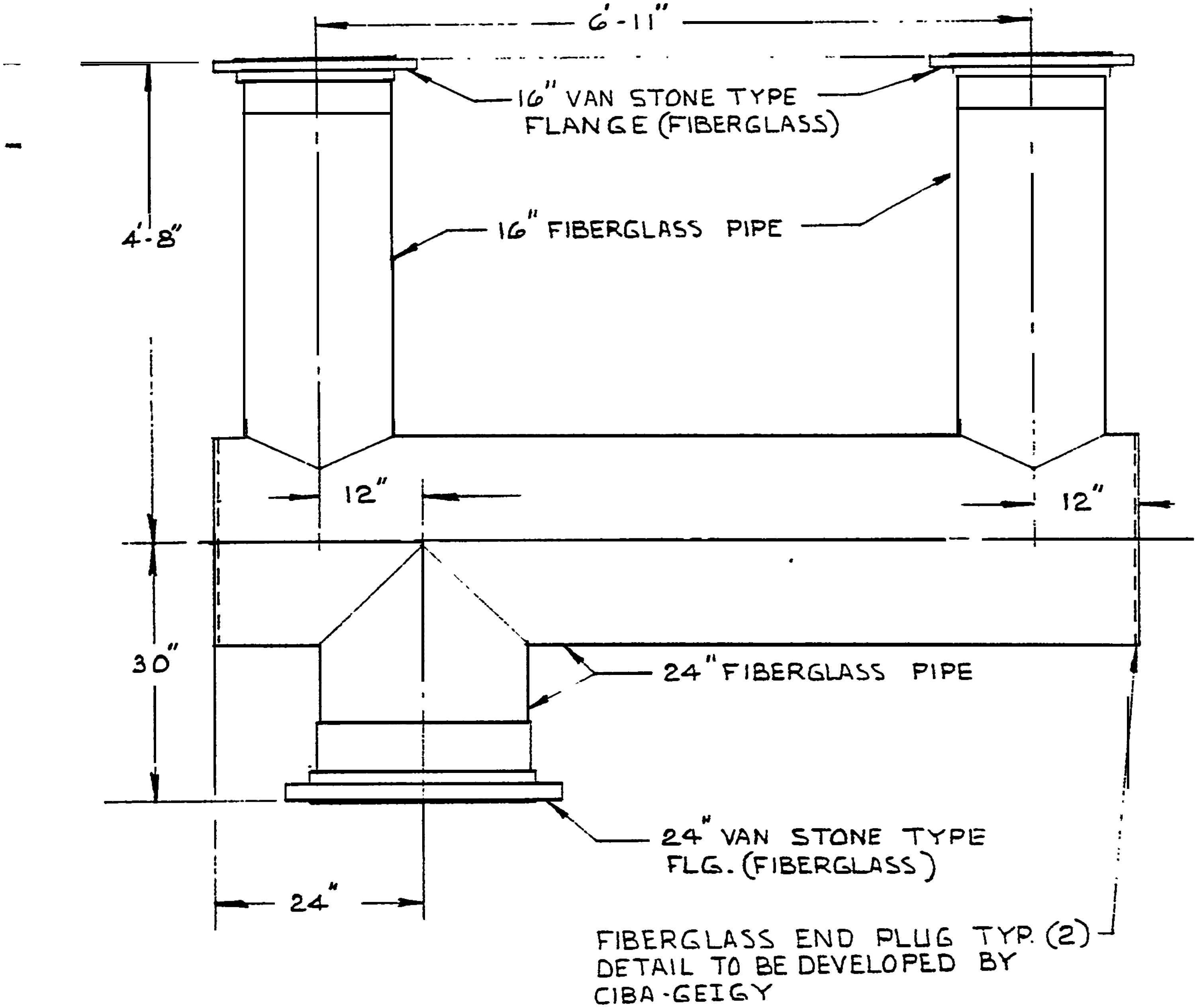
Figure 24 - Detail of 24" Tee in Transverse Deck Line



DETAIL D-1

TYP. F/G DISCHARGE / RECEIVING MANIFOLD (4)
SCALE: 1/2" = 1'-0"

Figure 25 - Detail of 24" x 16" x 16" Manifold Terminal



DETAIL D-3 ALTERNATE
TYP. DISCHARGE / RECEIVING MANIFOLD (4)
SCALE: 3/4" = 1'-0"

Figure 26 - Detail of Alternate 24" x 16" x 16" Manifold Terminal

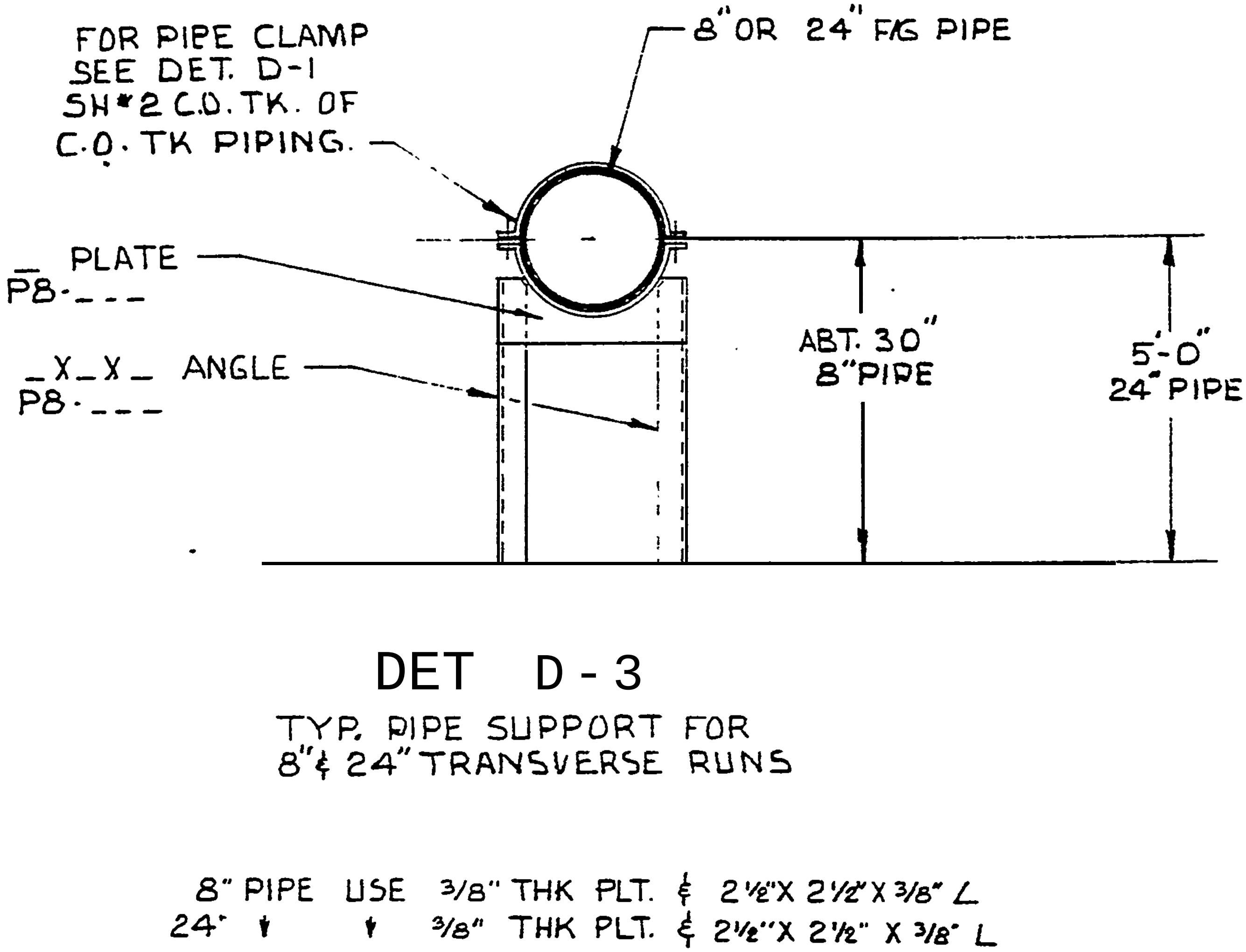
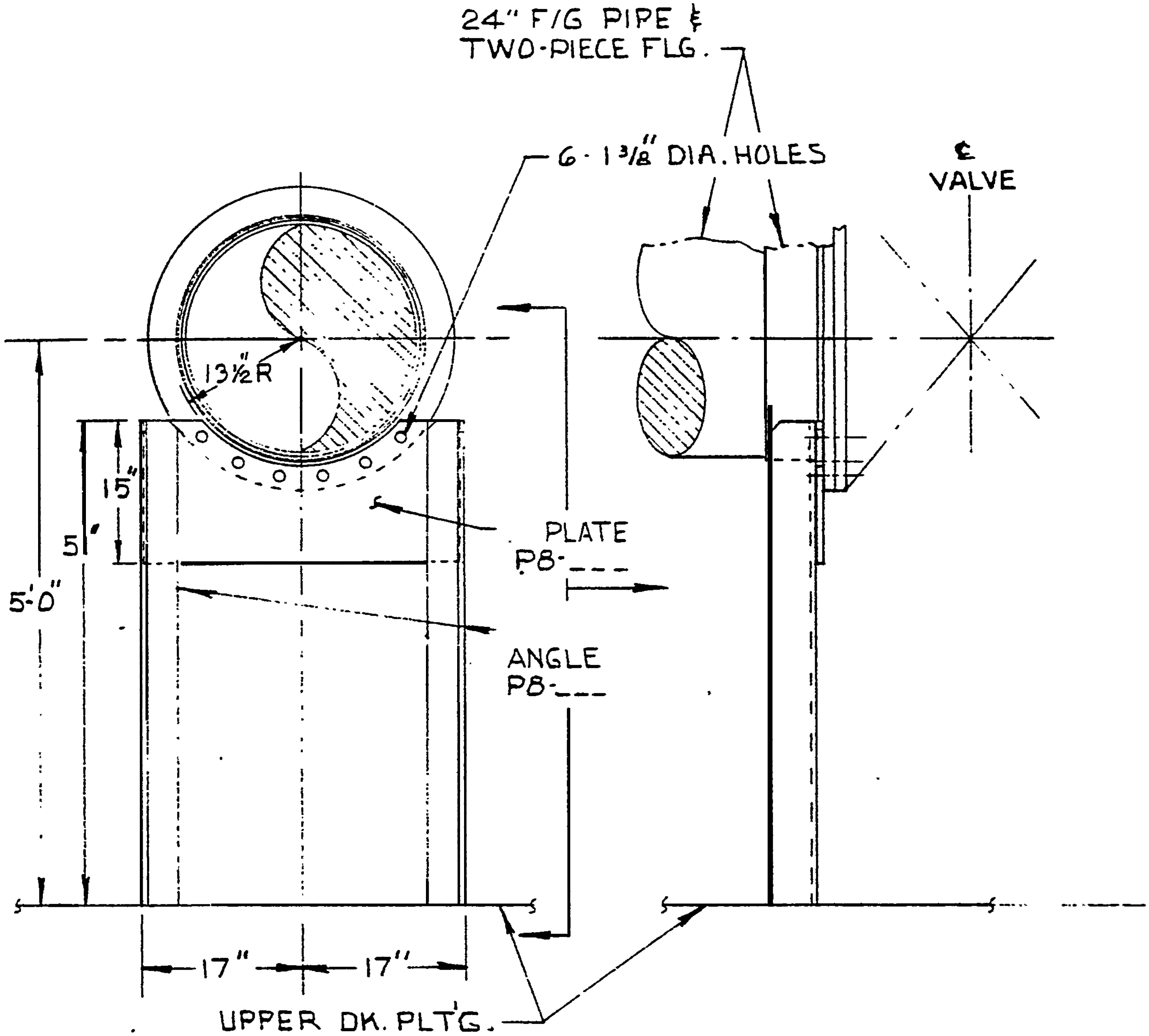


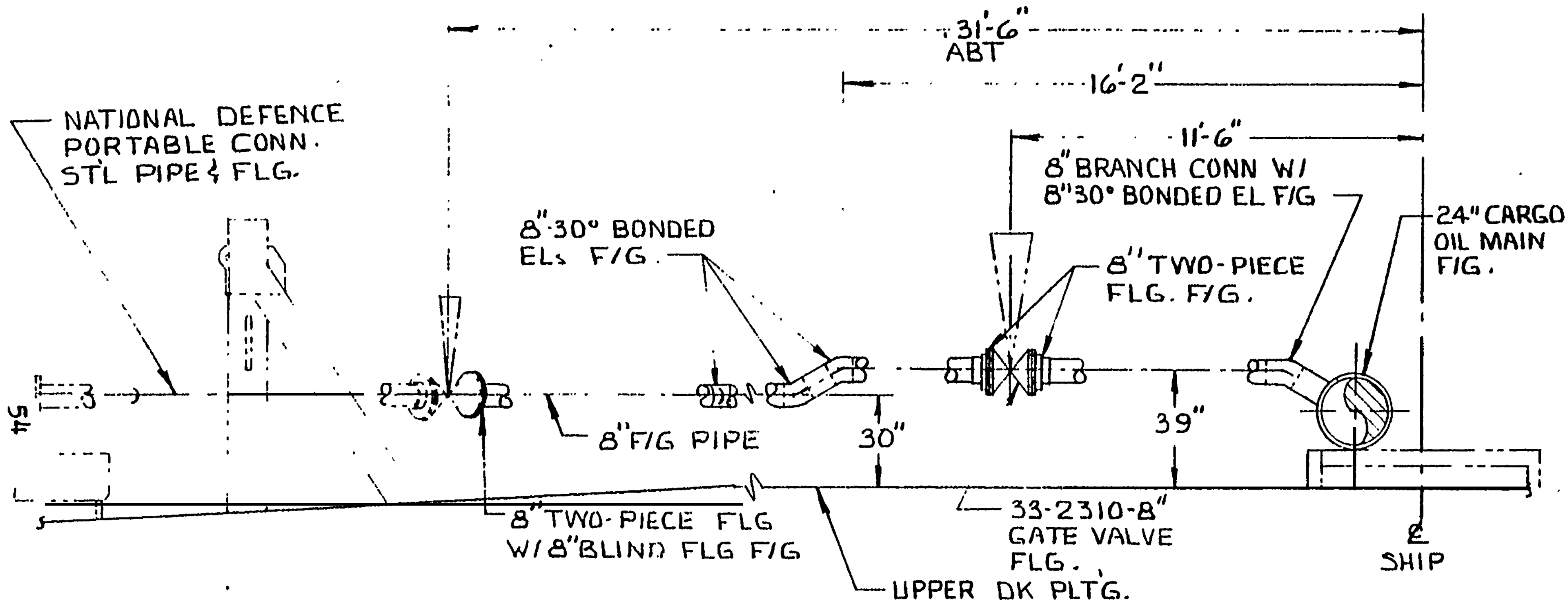
Figure 27 - Typical Pipe Support for 8" and 24" Pipe



DETAIL D-2

VALVE SUPPORT FOR 24" GATE VALVE
TYP. BOTH ENDS.
SCALE: 3/4" = 1'-0"

Figure 28 - Detail of Support for 24" Gate Valves



SECTION S-1

FR 81 LKG AFT STBD
SHOWN PORT SIM. & OPP.

Figure 29 - Section View of Fiberglass Fueling-At-Sea Piping

APPENDIX A

DRESSER COUPLING

The Dresser coupling is a common fitting in tanker steel piping systems. While it is used primarily to join *two* pipes together, it has the capacity for a limited amount of expansion and can accommodate a small amount of angular displacement or misalignment. Figure A-1 is a cross-section of a typical Dresser coupling for cargo and ballast systems. It consists of.a pair of resilient gaskets contained between two steel followers and a steel middle ring. The assembly is held together by a series of long bolts. The gasket is held on the outside of the pipe by friction, and is constrained within the gasket recess of the follower.

The action of the Dresser coupling is very simple. Relative axial movement between the two installed pipes causes distortion of the gaskets within the design limit of the coupling. Dresser couplings operating in this mode can absorb a certain amount of axial, movement without experiencing slip between pipe and gasket.

The installation shown in Figure A-1 is the normal set-up when there is no relative axial movement of the pipe. When the piping system is subjected to thermal expansion or “working" of the ship, a small amount of slippage may occur within the coupling. In order to insure against cumulative creep, the U.S.

Coast Guard requires some provision to avoid the possibility of the coupling eventually working off one end of the joint. A satisfactory method is to install a simple centering pin as illustrated in Figure A-2. This is effective only if the locations of pipe anchors and supports are such that the pipe ends are restrained from excessive movement which may result in blow-out of the coupling.

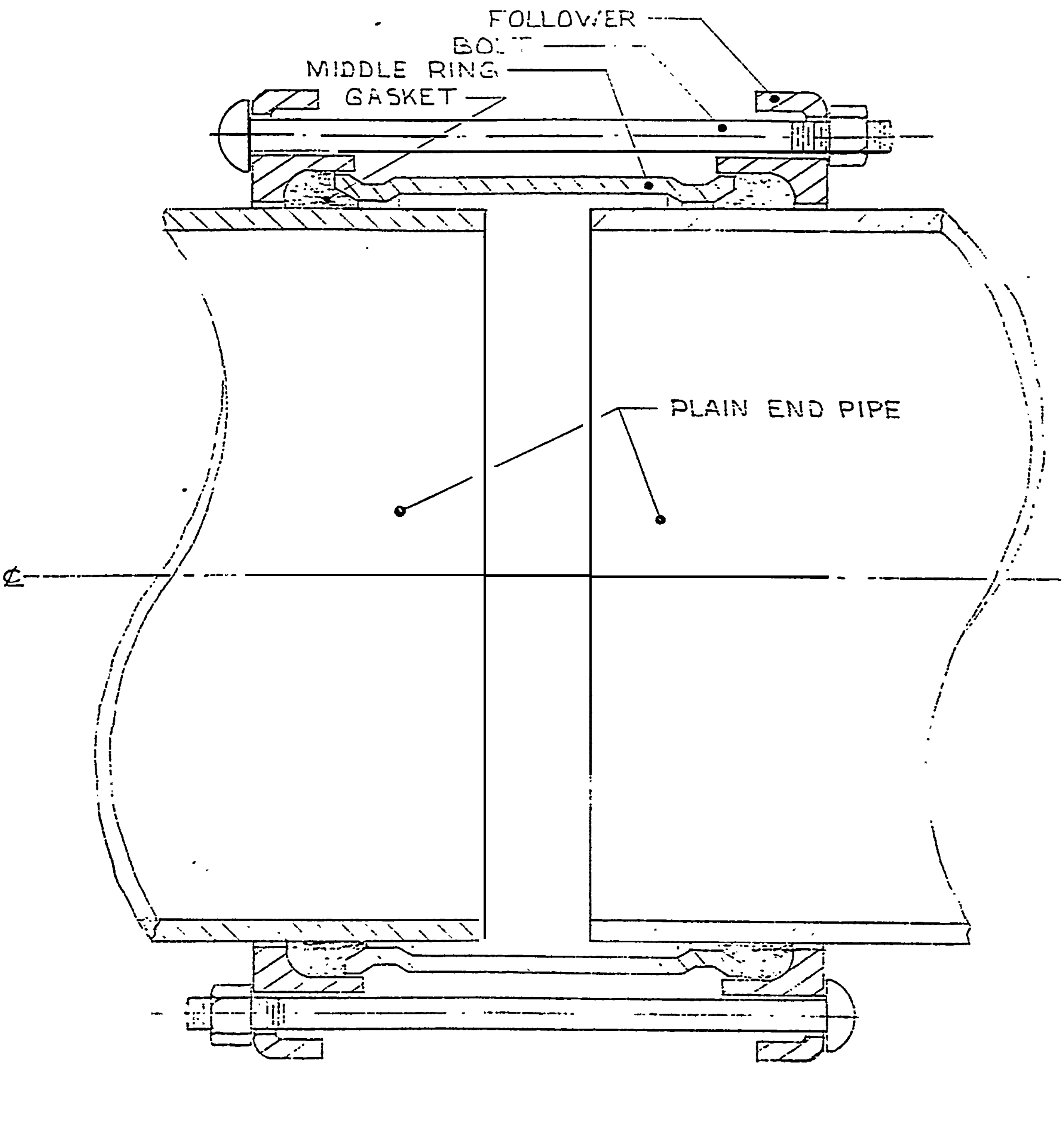
Where sufficient pipe restraint against blow-out is not provided, an external harness may be arranged in such a manner that separation of the pipe ends within the coupling is limited to a pre-determined amount. A number of schemes may be devised for this purpose, but it appears that none would.be more productive than the centering pin mentioned above used in conjunction with proper anchors and supports.

Unlike packed sliding joints, Dresser couplings will not wear if the locations of anchors and supports limit relative movement of the pipe ends to the design limit of the gaskets. Therefore, regular tightening should not be necessary. Occasional weeping can be stopped by tightening the coupling bolts. If larger leaks develop in the joint for any reason, the gaskets should be renewed.

Dresser couplings are used where a leak in one system would not contaminate mother. For this reason, they are installed in deck piping where leaks would be conspicuous. They are used also in cargo lines running through cargo tanks, and ballast lines through ballast tanks. In single-bottom tankers, where ballast lines pass through cargo tanks, either expansion bends or bellows-type expansion joints must be used.

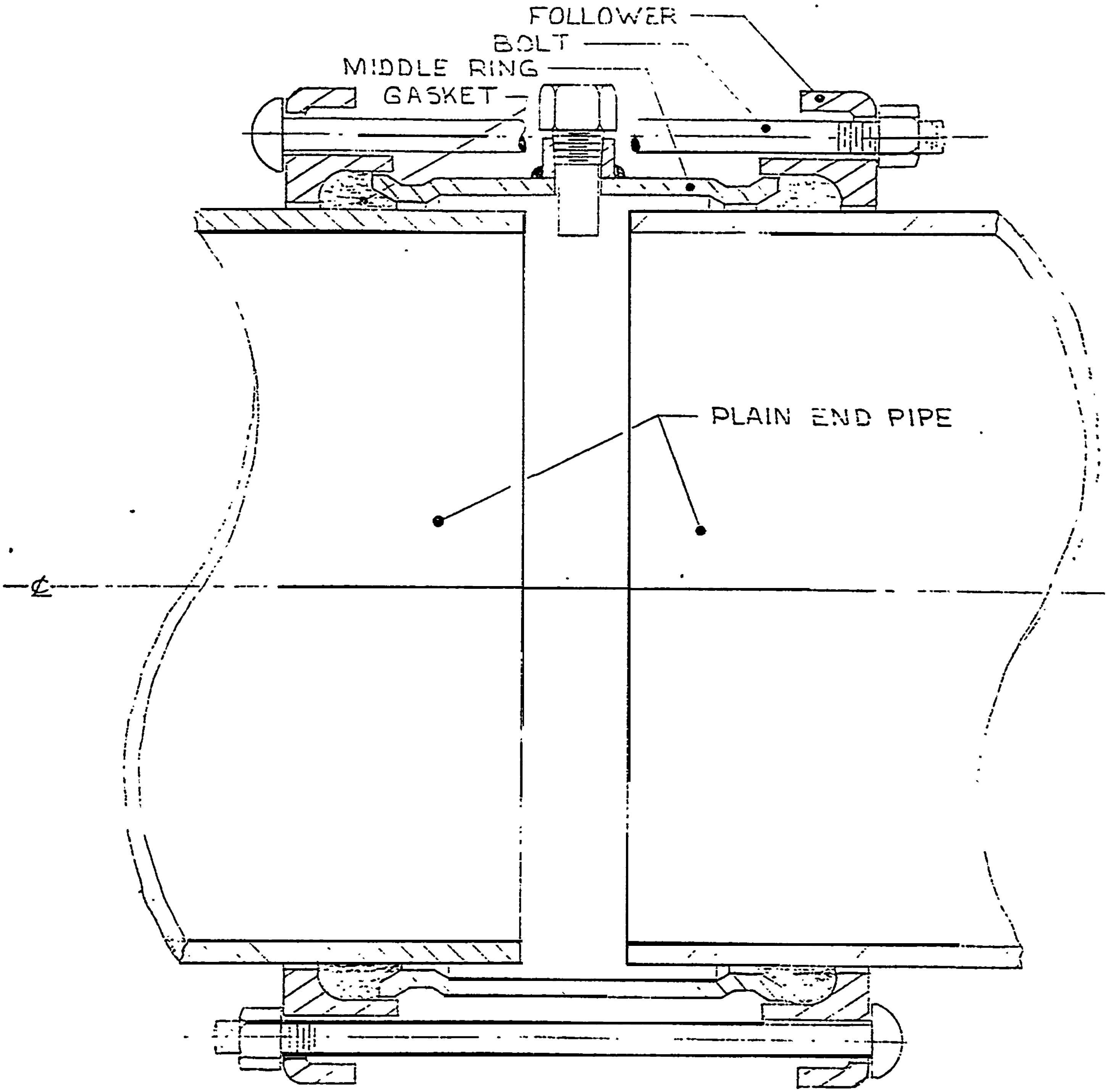
The capacity for total axial movement in a Dresser coupling is 3/8", for pipe sizes 10" and above.

An inherent design advantage of the Dresser coupling is that the middle ring can slide completely over one end of the pipe, facilitating field fit-up and disassembly. Potential application of this advantage to the fiberglass systems was not explored. Investigation must include availability of coupling diameter sizes to match the fiberglass piping outer diameter, and the compatibility of the gaskets with the surface finish of the fiberglass pipe.



LONGITUDINAL SECTION THROUGH STYLE 38 CPLG.
NO SCALE

Figure A-1 - Detail of Dresser-type Coupling



LONGITUDINAL SECTION THROUGH STYLE 38 CPLG.
NO SCALE

Figure A.2 **Dresser-type Coupling with Centering Pin**

APPENDIX B

FIBERGLASS REINFORCED PIPING

Fiberglass *reinforced* epoxy piping is a composite material that is engineered to combine the high strength-to-weight ratio of fiberglass filaments and the excellent corrosion resistance of epoxy resin. The strength of the composite is dependent on the amount of reinforcement and its orientation relative to the direction of principal stress.

In the pipe manufacturing process, continuous fiberglass filaments are impregnated with epoxy resin and then wound on a cylindrical mandrel. The reinforcement is oriented to provide twice the strength in the hoop direction as in the axial direction. This coincides with the stress distribution under internal pressure.

Ciba-Geigy pipe obtains this strength pattern by alternately applying two hoop *layers* and one axial layer of reinforcement. This results in a product having an ultimate strength about the same as standard steel, approximately one-tenth of the modulus of elasticity of standard steel, and about one-tenth of the weight of Schedule 40 steel pipe.

Other manufacturers elect to achieve the 2:1 hoop/axial strength ratio by a single winding angle for the fiberglass filament. The necessary angle is calculated to be 55° to the axis of the pipe. (See Figure B-1.) This reinforcement pattern results in a product with lower tensile strength (about 1:3), lower modulus of elasticity (about 1:2), and higher co-efficient of thermal expansion (about 2:1) as compared with dual angle winding. Comparative values of certain properties of fiberglass reinforced epoxy and steel are listed in Table B-1 .

The U.S. standard covering fiberglass reinforced epoxy pipe is ASTM D2310 “Standard Classification for Machine-Made Reinforced Thermoset Resin Pipe”. This standard describes the materials used in construction of pipe, the manufacturing method used in producing the pipe, the internal liner system (if any), and the long-term hydrostatic design basis (hoop stress) value.

TABLE B-1

COMPARATIVE PROPERTIES OF STEEL AND FRP

			Steel	FRP		
Density	(lb/in^3)		0.281	0.065		
Coeff. of expansion	($10^{-6} in/in/^{0}F$)		6.07	6.9 to 9.7		
Hazen-Williams flow factor			*120	150		
				single angle	dual angle	
Tensile strength	(psi)	GR. A	48,000	10,000	30,000	(axial)
		GR. B	60,000	40,000	70,000	hoop)
Modulus of elasticity(106psi)			27.9	1.4	3.0	axial)
				2.7	4.6	(hoop)

*H-W flow factor for new steel pipe is 120.
Value drops to about 100 after-ifiternal scale build-up

Single Angle

Dual Angle

Figure B-1 - Filament Winding patterns

APPENDIX C

FIBERGLASS ADHESIVE BONDED JOINT

Epoxy resin is one of the best industrial adhesives known today. When used to join two surfaces made of epoxy resin themselves, the resultant joint is excellent. Required conditions are that the matrix surfaces must not be contaminated by grease, dirt, or moisture, and that the resultant bond-line must be kept very thin, usually under 0.005" in thickness.

The best results have been obtained with matching tapered bonding surfaces, since this design is self-centering. More importantly, the joint assures a minimal bond-line thickness. The taper angle is 1-3/4° If straight non-tapered surfaces are used, tolerances become very critical.

The strength of a bonded epoxy joint is In shear, i.e. in axial tension or compression of the pipe, even combined with *torsion* of the pipe. The joint is considerably weaker under a "peeling" load, where external. forces act to pull the two surfaces apart, rather than causing one to slide over the other. Pipe joints exploit the strength advantage, since forces on the joint result in shear loading only. See Figure 6 for an illustration of an adhesive bonded joint.

Tapering of the pipe can be done on location with the aid of a portable tapering tool. This tool is pre-set and indexed for tapering to the correct angle and the required length. Also, piping can be procured from the supplier with one or both ends tapered.

Joining is performed by applying epoxy adhesive to both matrix surfaces and then forcing the surfaces together. The adhesive is usually furnished in pre-measured kit form. The joint cures in a specified time, which varies with ambient temperature. Curing time is between 1-1/2 and 8 hours. Heat assist devices can shorten this to 1 hour or less. However, heat assist must be used below 60°F, since the adhesive will not cure by itself below this temperature.

Adhesive joints are used generally in pipe sizes of 6" *or less. In* larger sizes alignment is more difficult. Also, in larger sizes, holding the two ends together against a hydraulic force created by the liquid adhesive requires more effort than a usual pipe installing crew can be expected to exert without mechanical. assistance. Thus, *a* mechanical joint such as Prontolock (see Appendix D) is more desirable for these sizes.

APPENDIX D

CIBA-GEIGY PRONTO-LOCK JOINING SYSTEM

Like the Dresser coupling described in Appendix A, the Pronto-Lock joining *system is* used primarily to join two pipes together. It functions also as an expansion joint and as an accommodation for small angular deflections or misalignment. The Pronto-Lock joint consists of a female end containing an O-ring, a tapered male end with a bearing ring, and a free-turning lock ring. These parts are shown in Figure D-l(a) before assembly.

Eigure D-l(b) shows the joint after insertion, at which point an effective seal is created. The two ends are joined in a leak-tight assembly, but they will be free to separate if the piping remains unrestrained axially. *Figure D-1(c) shows* Pronto-Lock completely made-up, including axial securing of the joint. The threaded lock-ring assures that the two ends cannot pull apart. The lock ring threads into the female end and seats against the bearing *ring* to provide axial restraint.

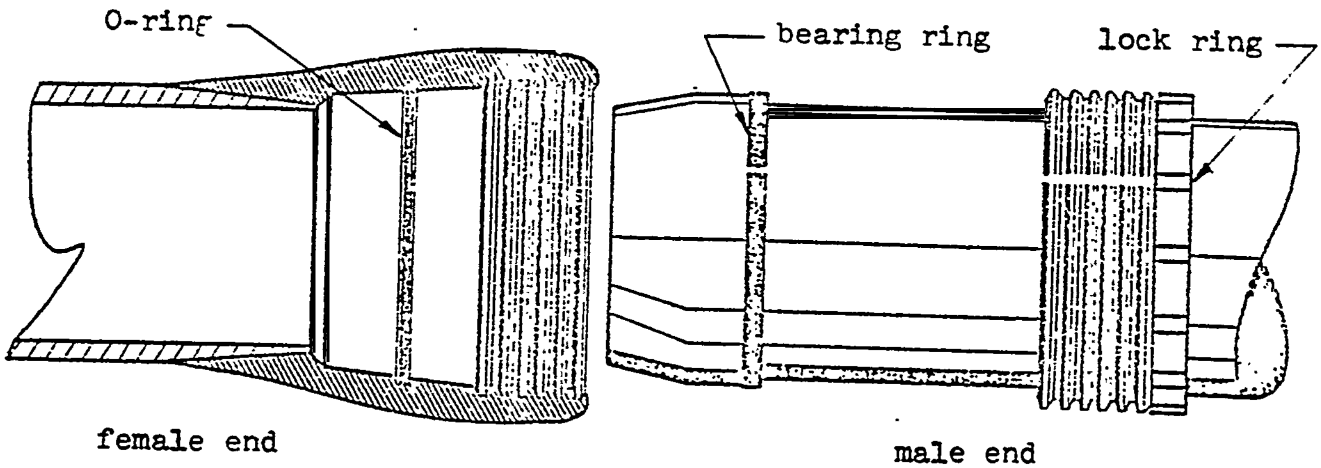
The Pronto-Lock joint can accommodate up to 2 degrees angular deflection off the center-line (4°total) during service, or can be installed with up to the same amount of angular mis-alignment. Figure D-2(a) shows the relative positions of mating surfaces in the straight (0° misalignment) condition. Figure D-2(b) shows the same cross-section at the maximum 2° deflected *con*-dition. Note that at 0° deflection there is a small angular clearance on both sides of the O-ring. At maximum 2° mis-alignment, this clearance disappears on one side as the gap is closed, and it widens on the other side.

Pronto-Lock behavior under axial movement is shown in Figure D-3. Figure D-3(a) shows the joint as installed with no axial loading. Point of contact is inside the joint and just to the left of the O-ring. There is a free annular space between the bearing ring and the female end. Also, there is axial clearance at the extreme left between the male end and the internal shoulder of the female end. Under tensile load, the two ends can move, as shown in Figure D-3(b). Such move-ment is limited to the extent that the free space between the bearing ring and the lock ring is taken up as the bearing ring compresses under load. During this movement, the O-ring Con-tinues to maintain the leak-tight integrity of the joint. The joint cannot pull out due to the restraint of the lock ring.

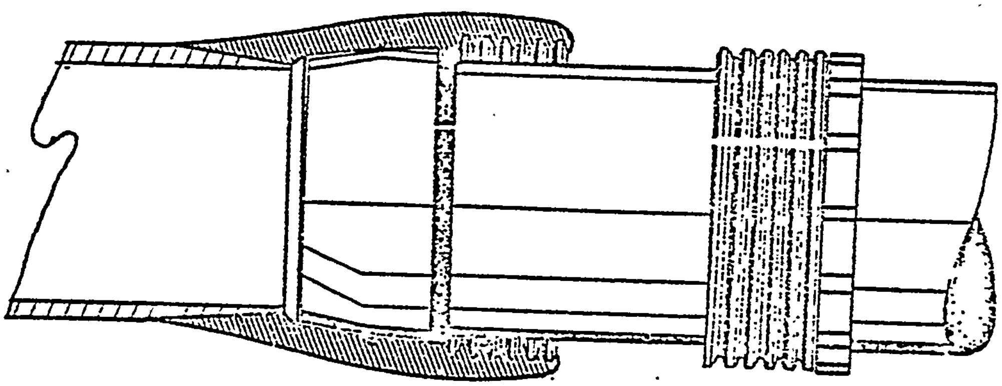
Under compressive load, the joint slides together until the male end hits the shoulder inside the female end, as shown in Figure D-3(c). The total capacity for axial move is about 3/8". While the neutral (no-load) position cannot be determined exactly in an assembled joint, it has been found that the no-load position is generally half-way between the two extreme positions. It should be noted that the lock ring is assembled with only a light torque. There is *a* mechanical *stop* between the lock ring and the external shoulder of female end (not illustrated), and overtorquing will not advance the threads to compress the bearing ring. In the unloaded joint, there is some clearance on both sides of the bearing ring.

Since there are mechanical stops at both ends of the axial travel, cumulative creep cannot occur and cause the joint to separate, as in case of Dresser couplings. Therefore, no special external restraints *are* necessay. Pronto-Lock operates with standard size O-rings. No tightening is necessary after the joint is put into operation. The joint can be disassembled if necessary, and the O-ring can be replaced. However, in order to open a Pronto-Lock joint, about 10″ of axial clearance is required to separate the two ends.

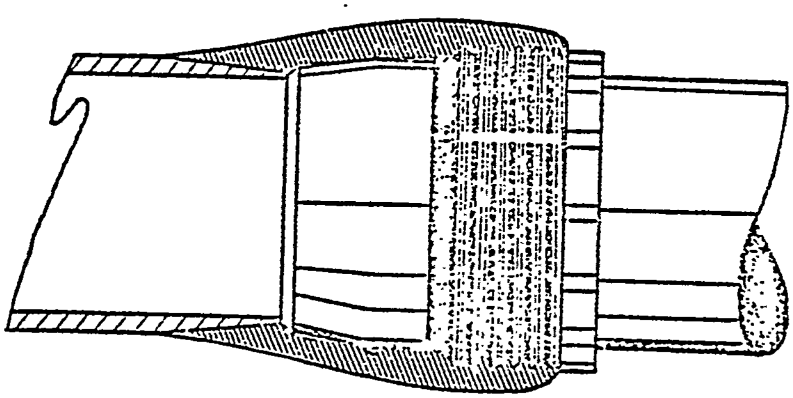
The female end of the Pronto-Lock joint is fiberglass *re*-inforced epoxy and is filament-wound onto a length of pipe in the factory. The male end is machined and attached in the factory by adhesive bonding. The male end and the lock ring are centrifugally cast chopped fiberglass reinforced epoxy. The resilient bearing ring is Buna-N. O-ring material *is* selected to be compatible with system fluid, e.g., Buns-N for cargo oil or ballast. Assembly of the joint in the field does not require any special skills.



a. Joint before assembly

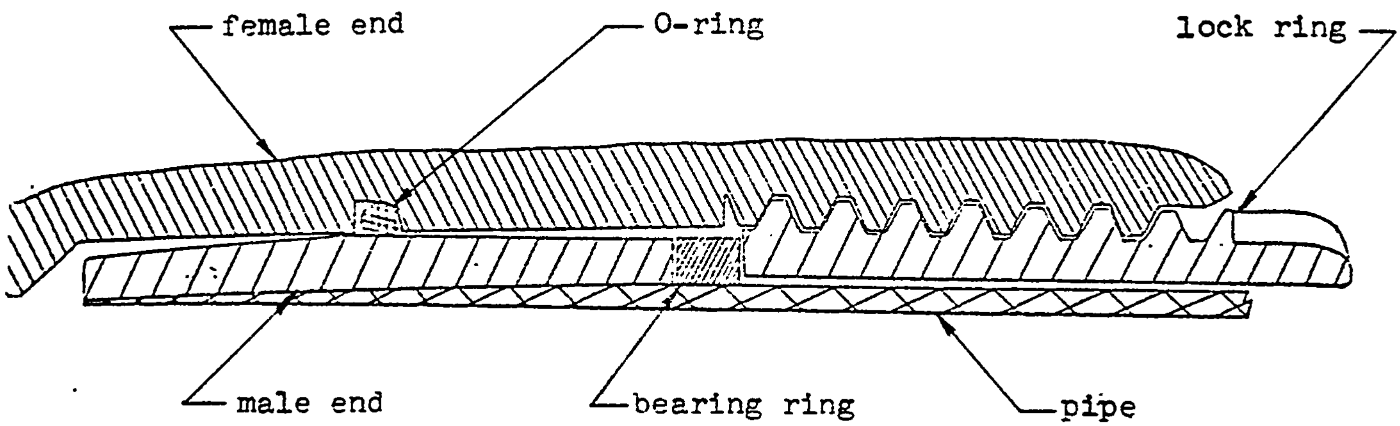


b. Joint after insertion

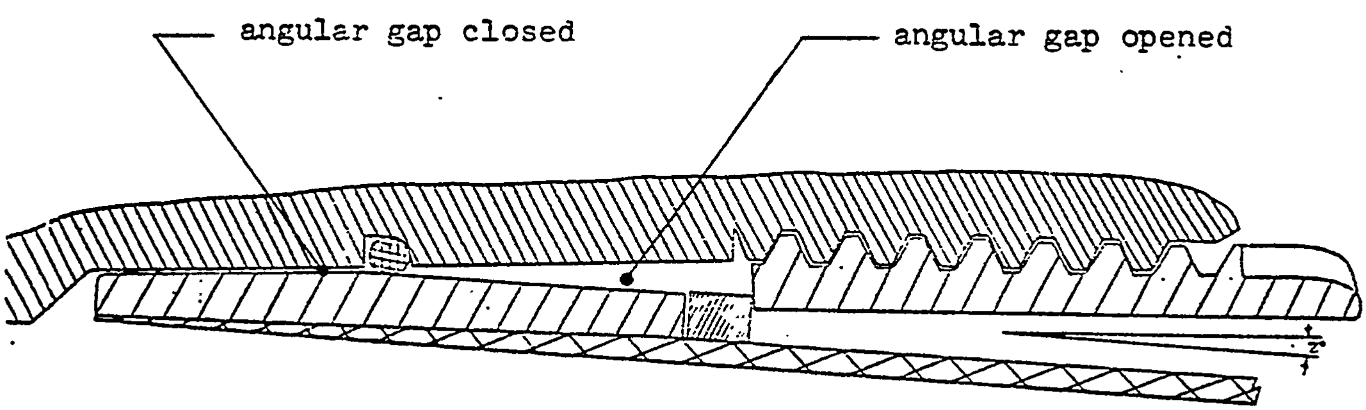


c. Joint completely assembled

Figure D-1 - Ciba-Geigy Pronto-Lock Joint

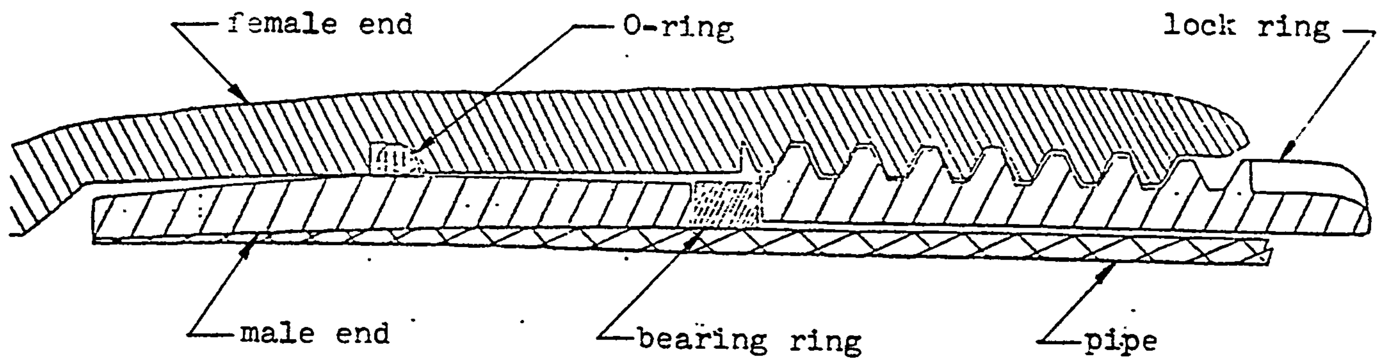


a. <u>Assembled joint - 0° deflection</u>

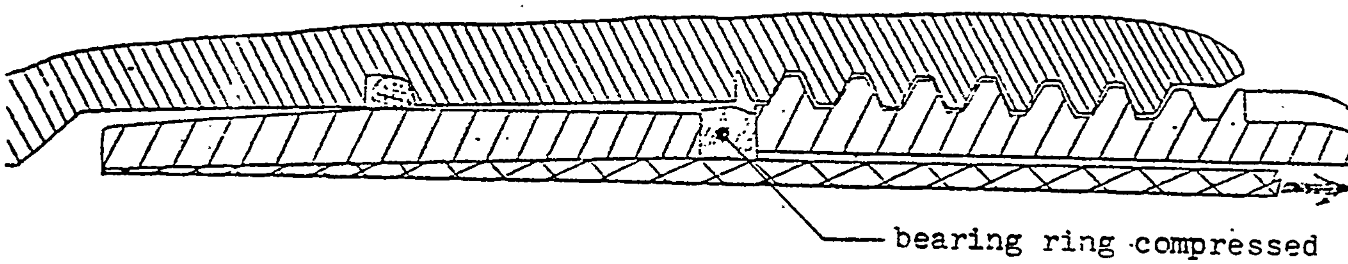


b. <u>Assembled joint - 2° deflection</u>

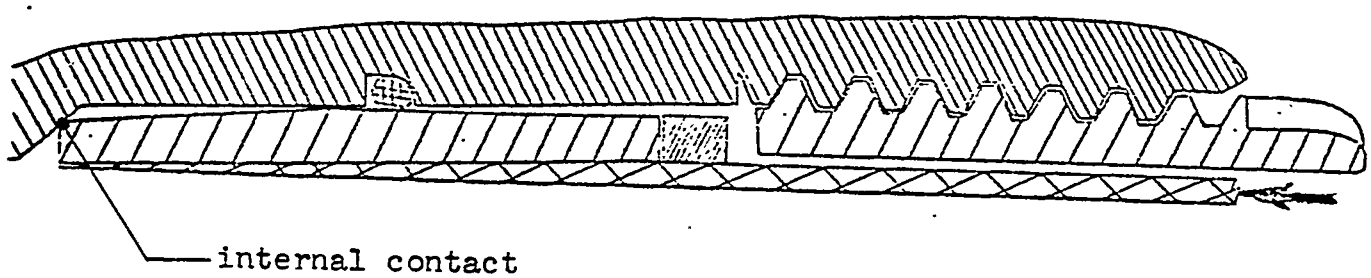
Figure D-2 - <u>Angular Deflection in Pronto-Lock Joint</u>



a. Assembled joint, unloaded



b. Assembled joint in tension



c. Assembled joint in compression

Figure D-3 - Axial Movement in Pronto-Lock Joint

APPENDIX E

CLEAN BALLAST SYSTEM

The San Clemente Class tanker has a segregated ballast system, illustrated in Figure E-1, which allows clean sea water to be carried in six double-bottom tanks. A diagrammatic arrangement of the in-tank piping is shown, together with a schematic diagram of the portion of the system located in the pumproom. The system consists of 10" and 8" suction lines from the individual ballast tanks to a valved manifold located in the pumproom. From this manifold, the tanks can be filled or emptied using equipment and piping in the pumproom.

The piping in Tank No. 5 is taken as typical of the suction piping The four lines running fore-and-aft through the tank are anchored at the penetrations through transverse bulkheads. Provision for expansion must be made, and this was done in the form of pipe bends. Figure 1 shows the pipe bend arrangement used for comparison in this study. Later versions of the ballast system used Dresser couplings instead of pipe bends.

A design arrangement feature of the tank piping is that the suction bellmouth for each tank is required to be located near the centerline and at the aft end of that tank.

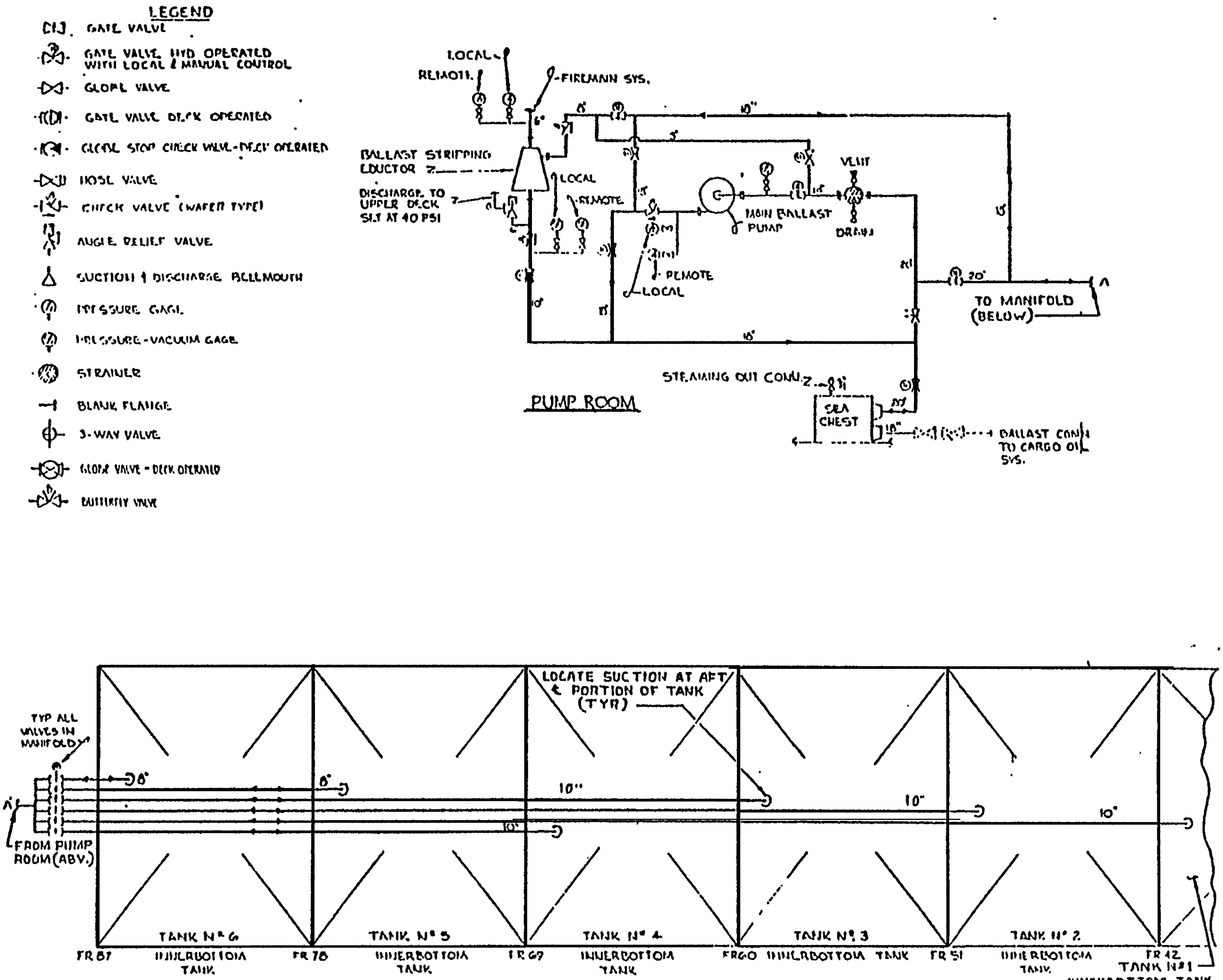


Figure E-1 - Clean Ballast System

APPENDIX F

CARGO OIL SYSTEM

The San Clemente Class tanker has a two-group cargo oil system which allows cargo to be loaded and discharged through a midship cargo station on deck. Figure F-1 is a diagrammatic arrangement of the in-tank piping and the deck piping. The rest of the system is located in the pumproom and is illustrated in Figure F-2. Cargo is drawn through the in-tank suction network by the pumps in the pumproom and discharged through the deck mains to the midship cargo station. Cargo is loaded in reverse manner, except that the pumproorn is bypassed by drop lines from the deck mains to the suction mains

The piping in Tanks No. 4 is taken as typical of the suction piping. Both suction mains are 30”, with 18" branch lines to each tank (port, starboard, and center). Each tank has an 8" stripping spud. The 30" main serving the wing tanks runs fore-and-aft through the center tanks. The main for the center tanks runs through the starboard wing tanks. The reason for this arrangement is to avoid having branch lines cross over or under a main, and thus be able to install all suction piping as low as possible. Figure 2 shows the actual arrangement of this piping. Bulkhead penetrations are anchor points. Dresser couplings are used throughout, and each section of piping has an anchor.

Deck piping consists of two 24" discharge mains, one for each group, discharging to port and starboard stations located amidships. The actual arrangement of the cargo piping is high-lighted in Figures 3 and 4, which are composite drawings of all piping on deck.

On deck also are two 8" branches, one from each discharge main. These are led outboard to fueling-at-sea stations, a requirement for national defense. This piping,, which is normally blanlked off, is shown in Figure F-2.

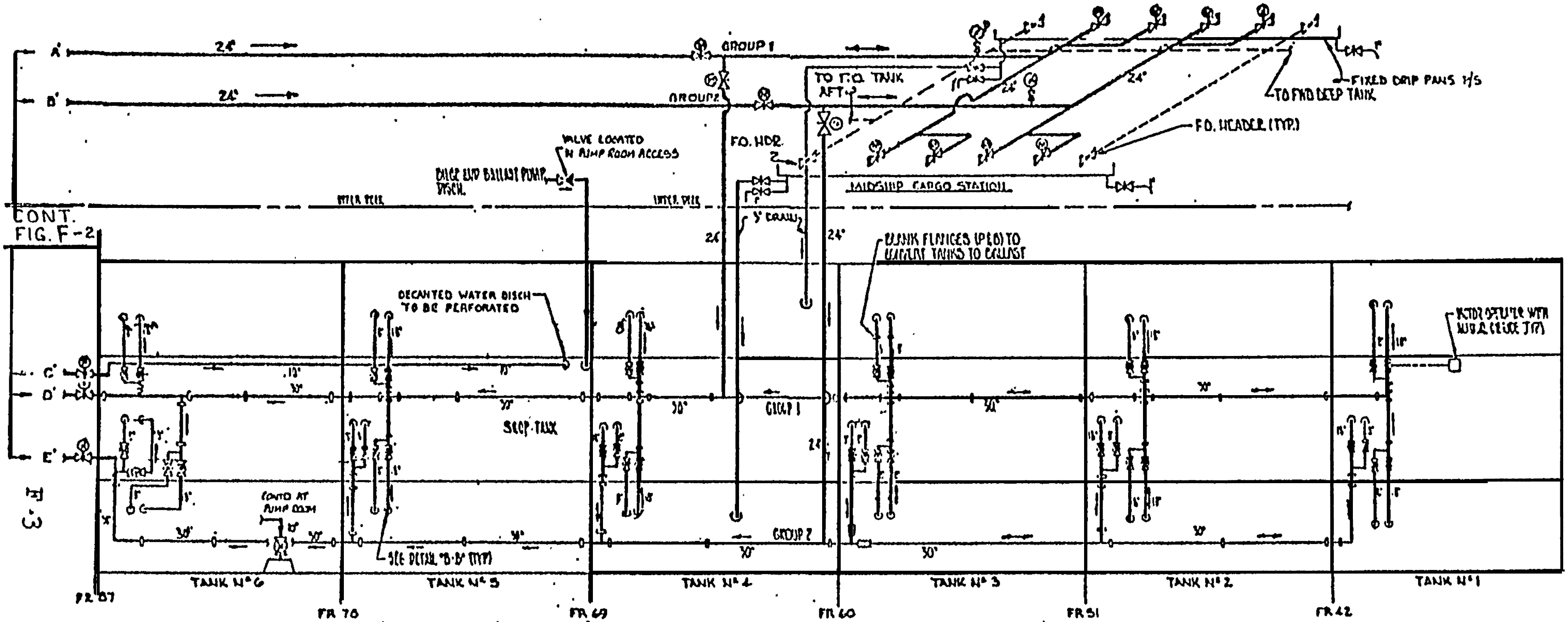


Figure F-1 - Cargo Oil System Piping in Tanks and on Deck

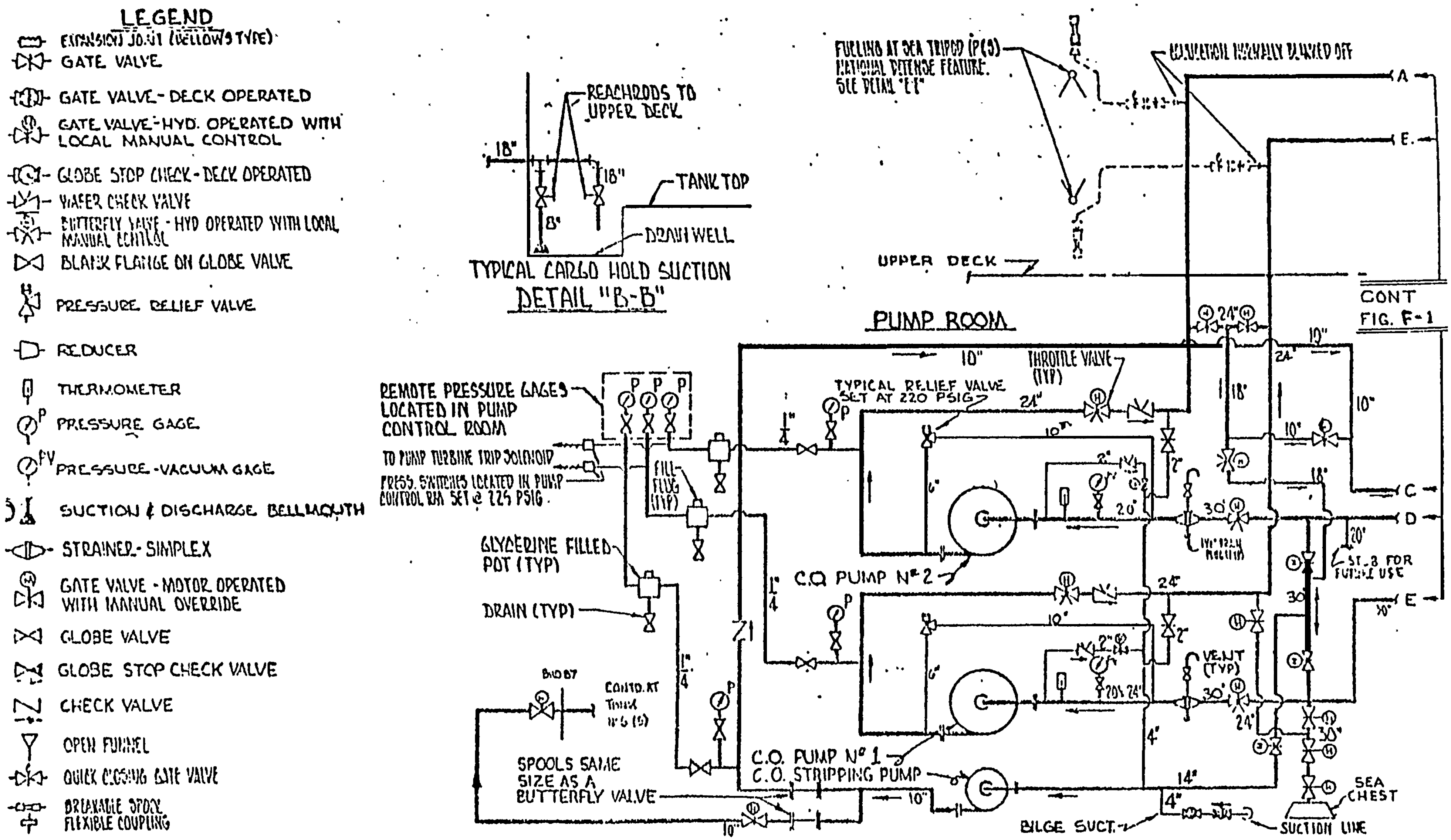


Figure F-2 - Cargo Oil System in Pumproom

DISCUSSION OF RESULTS FROM THE NAVY'S INVESTIGATION OF FILAMENT-WOUND FIBERGLASS PIPE

16 July 1976

Discussion of Results from the Navy's Investigation of Filament-wound Fiberglass Pipe*

1.0 Introduction:

1.1 This general discussion is intended to sketch the fire and mechanical performance expected from glass reinforced plastic pipe of the filament-wound epoxy type. Potential variations in properties are probably greater for filament-wound fiberglass than for any other pipe material. Therefore, in no case should these general results be applied to a particular brand of pipe. Further, most of the tests were made with only relatively small 2" and 3" diameter pipe and the fiberglass was compared only to aluminum and copper-nickel.

1.2 The tested pipe was manufactured by winding resin-soaked or preimpregnated filaments or tape on a rotating mandrel at a helical angle of about 35°. Epoxy resin made up a little over 30%, by weight, of the pipe wall. Glass filaments formed the remainder. The interior had a chemically resistant liner and the exterior was chemically protected by a rich resin coating.

1.3 Joints were tapered and adhesive-bonded. The tolerances maintained assured uniform adhesive distribution and a thin cement line. The latter makes the strength of the joint more dependent on the fiberglass than on the relatively weaker cement.

*written 1 December 1975 by R. F. Heady, R&D Project Manager, Todd Shipyards Corporation, Seattle Division and based upon an interchange of investigation results with G. F. Wilhelmi, Project Engineer (Code 2745.8), David Taylor Naval Ship R&D Center, Annapolis, Maryland. Revised 16 July 1976.

2.0 Navy's In-service Experience:

2.1 In 1969, three sections of plastic piping material were installed for evaluation in the seawater system in the hydrofoil HIGHPOINT. These sections consisted of fiber-glass and PVC piping and ball valves which were exposed to conditions of relatively high temperature and flow rate, constant salt water contact, and throttled flow. After nearly two years of service, the inner surfaces of the piping and valves were in excellent condition with no organic growth, scale, or deposits. On the basis of these results, the entire saltwater system in HIGHPOINT was constructed of fiberglass piping-during major modifications in 1973. After approximately two years crew members reported very satisfactory service. In 1973, the potable water system in the hydrofoil FLAGSTAFF was replaced with fiberglass and plastic components due to extensive corrosion of the original aluminum alloy system. No problems have been reported to date. The aluminum alloy saltwater and freshwater systems in the hydrofoil PLAINVIEW are currently being replaced with fiberglass pipe. The first extensive installation of fiberglass piping in a combatant ship was made in the NATO patrol hydrofoil (PHM) constructed by The Boeing Company. Fiberglass piping is being employed in the PHM's fresh, sea, waste, chilled, bilge, and sewage water systems.

3.0 Fire Test Performance:

3.1 Under the ASTM E84 fire tunnel test, fiberglass pipe coated with a fire-retardant intumescent latex paint achieved a flame spread rating of about 15. This was less than one-third the rating for the uncoated pipe. The smoke density rating for the coated pipe was on the order of 25 compared with a rating almost 20 times as much for the uncoated pipe. The fuel contribution factor was zero in both coated and uncoated tests.

3.2 Under the radiant panel surface flammability tests (ASTM E162), 110° sections of unprotected fiberglass pipe had an average flame spread on the order of 80 which was reduced to 25 or less with the addition of intumescent paint or lightweight ceramic insulation.

3.3 Uncoated fiberglass pipe subjected to the National Bureau of Standards smoke chamber test showed an average maximum specific optical density on the order of 290 under flaming conditions. The addition of intumescent epoxy paint reduced the optical denisty below 215. This smoke level is below the limit of 250 specified for plastic foam materials now used for piping insulation aboard naval surface ships.

3.4 Analysis of potentially toxic gases generated under flaming conditions with unprotected pipe specimens showed no hazardous concentrations under the personnel exposure limits established by the Navy's BUMED Instruction 6270.3F. Further work is planned to evaluate the effect of protective coatings regarding toxic gas generation.

3.5 Fiberglass pipe was tested against aluminum pipe and copper-nickel pipe over a vat of flaming hexane which produced temperatures exceeding those of the ASTM E119 Standard Fire Test. With flowing water at 100 psi internal pressure, uncoated fiberglass pipe with molded fittings and bonded joints remained functional for more than one hour. With stagnant water at 150 psi internal pressure, uncoated fiberglass pipe, molded fittings and bonded joints remained functional for the full half-hour fire test and out-performed both the aluminum pipe with welded joints and the silver-brazed joints in the copper-nickel system. However, the wall thickness of the filament-wound fiberglass fittings tested, proved too thin to provide enough thermal insulation to the bonded joints. In the dry pipe test, both the aluminum and fiberglass piping systems ‘failed within about two minutes. The aluminum tended to fail catastrophically while the fiberglass exhibited a much safer, gradual mode of failure (the epoxy resin burned away leaving layers of glass-fiber windings). The silver-brazed copper-nickel system failed within about four minutes. Extremely light-weight protective measures including intumescent paints and aluminized ceramic insulation added from one to ten minutes of protection to the dry fiberglass pipe (see peragraph 4.0, Fire Insulation).

3.6 An interesting ancillary result was the failure mode in the stagnant water condition of the fiberglass versus aluminum and silver-brazed copper-nickel pipe systems. Aluminum failed catastrophically within nine minutes-after fire ignition. Copper-nickel piping showed leakage from a silver-brazed joint after 15.5 minutes and physical separation from the coupling at 18 minutes. During the fiberglass test many small leaks occurred as some of the pipe wall burned out, but the pipe continued to hold pressure through-out the test. Unlike during the aluminum and copper-nickel tests, water temperature inside the fiberglass pipe remained below the boiling point because of the insulating nature of the composite fiberglass wall and because of the many small leaks which cooled the wall. In one test the 2" diameter Fiberglass pipe assembly reached a quasi-steady state condition after approximately ten minutes. After the half hour fire exposure, the assembly was repressurized to 160 psi and the total leakage rate measured only one gallon per minute. There were minor leaks at two of the bonded joints and at a molded seam in one of the elbows, but there were no signs of separation or back-out in any of the seven bonded joints in the assembly (in subsequent tests relatively thin-walled filament-wound fiberglass fittings caused failures only a few minutes after fire ignition probably because of their insufficient insulating properties for protection of the bond material).

4.0 Fire Insulation:

4.1 An application of mastic coating compound (approximately 1/16" thick) did not significantly improve performance in the dry pipe state. These coatings act more as flame barriers than insulators and consequently did not effectively retard resin burn out. The fiberglass pipe spirally wound with a composite tape lasted approximately 1/2 to 1 minute longer than unprotected specimens. The application of an aluminized felt cover with and without a l-inch gap provialed 2 to 21/2 minutes of additional protection. The application of intumescent epoxy and latex coating system (approximately 10 roils thick) provided an additional 1 to 3 minutes of air tight integrity in the dry pipe and a large reduction in structural damage. The most effective protective measure was ceramic felt insulation in the form of a felt batting. In 1/4, 1/2, and 1 inch thicknesses, it provided from four to ten minutes of additional protection and was itself unaffected by fire exposure.

5.0 Mechanical and Physical Tests:

5.1 A fatigue test was run on a l" 3" and 6" diameter fiberglass piping assembly incorporating molded fiberglass flanges, filament-wound sleeve couplings and molded fiberglass 90° elbows. In all cases except one, joint and fitting performance exceeded pipe performance. The one fitting failure was due to improper taper of a joint. Failures occurred in the fiberglass as small cracks, usually parallel to the fiber winding angle, which leaked when the assembly was at or close to maximum deflection. Normally when the assembly was returned to its neutral position, the leak would stop completely even when the assembly was fully pressurized (200 psi). In mcst cases, leakage amounted to only a few drops and all assemblies maintained internal pressure. This is a safe failure mechanism compared to fracture or joint separation.

5.2 Axial tension and cyclic fatigue tests conducted with notched and scarred fiberglass pipe and fittings showed that the material exhibited good resistance to external damage.

5.3 According GO an engineering analysis, fiberglass pipe can be expected to perform as well as or better than schedule 10 aluminum under water-hammer conditions. .Although the fatigue limit is less in fiberglass than aluminum, the fiberglass pipe has lower water-hammer pressure due to its lower modulus of elasticity.

5.4 The particular fiberglass pipe performed almost perfectly under a splash resistance test that immersed specimens for a period of 75 days in JP-5, diesel and navy distillate fuels and hydraulic fluid. However, chemical resistance may be very different for different resin formulations.

5.5 No quantitative results of the mechanical tests will be discussed because they would apply only to the pipe tested. Mechanical properties are very sensitive to the properties of the glass and resin, to the wall thickness and to the helical angle of the windings for a particular species of fiberglass pipe. This variability notwithstanding, the following "Minimum Performance Requirements for Fiberglass Piping Materials" describes the region of performance results expected for the pipe genus:

6.0 Minimum Performance Requirements for Fiberglass Piping Materials:

PHYSICAL PROPERTIES

PROPERTY	TEST METHOD	RECOMMENDED MAXIMUM REQUIREMENT AT 75°F
Thermal expansion, linear	ASTM-D-696	1.30×10^{-5} in/in-°F
Thermal conductivity	ASTM-D-177	3.0 Btu/hr/ft^2/°F/in
Flow factor	Hazen-Williams coefficient	150

MECHANICAL PROPERTIES

PROPERTY	TEST METHOD	RECOMMENDED MINIMUM REQUIREMENT AT 75°F
Long term cyclic pressur	ASTM -D-2992-71 Proedure A	6000 lbs/in^2 hoop stress at 150 x 10^6 cycles
Long term static pressur strength	ASTM D-2992-71 Procedure B	15,000 lbs/in^2 hoop stress at 100,000 hrs.
Ultimate hoop tensile strength at burst	ASTM D-1599-69	35,000 lbs/in^2
Long term cyclic fatigue strength in fully-reversed bending	NSRDC low and high frequency fatigue tests or equivalent	3,000 $1bs/in^2$
Ultimate axial tensile strength	ASTM D-2105-67	9,000 lbs/in^2
Axial modulus of elasticity .	ASTM D-2105-67	1.0 x 10^6 lbs/in^2
Hoop modulus of elasticity	static pressure test	2.0 x 10^6 lbs/in^2
Hydrostatic collapse strength, minimum "K" factor	ASTM D-2924-70	5.8
Impact resistance	Ball impact test	No damage, as verified by hydrostatic pressure test at twice rated pressure, after impact by 1.2-lb steel ball 2-in in diameter, from 6-ft drop height

FLAMMABILITY CHARACTERISTICS

CHARACTERISTIC	TEST METHOD	RECOMMENDED REQUIRMENT
Surface Flammability	ASTN-E-84 or ASTH-E-162	Max. flame spread index = 25
Smoke Density	NBS Smoke Chamber	Max. specific optical density= 250 (MIL-p-0015280F (Ships))
Smoke Toxicity	Calorimetric indicators, mass spectrometric analysis, gas chromatography or infrared analysis	"Personnel exposure limit for health hazardous air contaminants", BUMED INST. No. 6270.3F;