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PLANT SYSTEMS/COMPONENTS MODULARIZATION STUDY

Final Report

July 1977

Work Performed Under Contract No. EY-76-C-02-4039

Stone & Webster Engineering Corporation
Boston, Massachusetts

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FINAL REPORT

PLANT SYSTEMS/COMPONENTS MODULARIZATION STUDY

Prepared for the

U. S. ENERGY RESEARCH

AND DEVELOPMENT ADMINISTRATION

Contract EY-76-C-02-4039

July 1977

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MASSACHUSETTS

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1. PURPOSE

The purpose of this report is to summarize the final results of a Plant Systems/Components Modularization Study based on Stone & Webster's Pressurized Water Reactor Reference Design and performed for the U.S. Energy Research and Development Administration (ERDA) under contract No. EY-76-C-02-4039.

To fully evaluate the practicability and desirability of the identified preassembly modules and recommend a basis for application to a new nuclear power plant, Stone & Webster has identified the Sundesert Nuclear Plant presently planned for southern California for possible implementation of modular construction techniques. The program has been modified to include evaluation of the most promising areas for modular consideration based on the level of the Sundesert Project engineering design completion and the feasibility of their incorporation into the plant construction effort. A final report supplement will be prepared for the Sundesert evaluation.

The specific objectives of the overall study are:

1. Development of criteria against which to judge the viability or the application of modularization concepts to systems and components. These criteria address such areas as construction installation time, size, total cost, vendor availability and capability for shop modularization, operability, and maintainability, shipment size limitations, etc, that are needed to distinguish promising candidates for modularization.

2. Detailed review of the Stone & Webster Reference Nuclear Power Plant (RNPP) general arrangement drawings and piping and instrumentation drawings (P&IDs) to determine which systems and/or subsystems have potential for fabrication by either shop or site modularization or possibly a combination of both. Associated with this task is defining the need for development of more detailed designs e.g., piping arrangements.

3. Having determined that the preassembly of a grouping of components is feasible, an evaluation is being made as to the practicality and desirability of such methods. This will be accomplished by utilizing the criteria developed in the initial task for each eligible grouping of components. The results include, as appropriate, the quantification of the anticipated economic incentives and/or construction schedule advantages of modularization, with the supporting bases.

   This evaluation will develop for the Sundesert Nuclear Plant drawings, erection sequences, and models for the modular construction of the mat reinforcing and liners in the Containment/Annulus Building. The evaluation will also identify and summarize cost savings in labor and material, and time savings in the construction schedule for the mat reinforcing and liners including factors such as module size limitations, shop construction capability, erection sequencing and time scheduling, installation fit-up time, transport costs, welding techniques, and cost benefit analysis comparison to past methods. Conclusions regarding the feasibility and application of mat reinforcing and liners, recommended subsequent phases for implementation in the Sundesert Plant and a generic application of these modules to other plant designs including those by other architect/engineers will be developed.

Appendix A, which is a reproduction of portions of a previous report, provides preliminary criteria and savings for the RNPP to meet objectives 1 and 3. The same appendix reports completion of objective 2 by providing a review of the general arrangement drawings and P&IDs.

This report, which utilizes a functional approach, provide revised criteria and detailed analyses of modularization concepts which were previously identified on a building-by-building or system-by-system basis in Appendix A.

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2. SUMMARY

Appendix A contains portions of a previous report which described the development of preliminary criteria against which modularization concepts could be evaluated and the preliminary review of P&IDs and general arrangement drawings from Stone & Webster's Pressurized Water Reactor Reference Nuclear Power Plant Safety Analysis Report (SWESSAR-P1). Reactor Reference Nuclear Power Plant Safety Analysis Report (SWESSAR-P1).

That report contained copies of the P&IDs and general arrangement drawings which are not reproduced in Appendix A of this report.

Final criteria (Section 3.1) developed included road, rail, and barge size and weight limitations for establishing a basis for and savings required for module recommendation for implementation.

The following modularization concepts are recommended for industry implementation since potential cost and schedule savings far exceed the established criteria:

Reinforcing steel
Structural steel
Polar crane supports
Pipe modules
Pipe racks

The following modularization concepts are recommended although the cost and schedule benefits can vary and may not substantially exceed the established criteria.

Liners (containment and fuel related)
Skid-mounted modules (sumps, demineralizers, and filters)
Condenser
Tanks
Cable installation
Cable trays

The following modularization concept should be considered following appropriate regulatory review since it substantially exceeds both cost and schedule savings criteria.

Precast concrete

The following modularization concept is not recommended since neither cost or schedule criteria are met.

Skid-mounted modules (moisture separator/reheater, feedwater pump/turbine package, compressed air system, and condensate polishing components)

3. ANALYSIS

3.1 Final Criteria for Evaluating Modules

3.1.1 Savings Criteria

To establish a basis for evaluating various modularization concepts, the following savings criteria were established.

Savings of 5 percent (minimum) of material or labor costs based on previous jobs, with a minimum of $75,000. All cost savings were based on March 1, 1976 dollars (present day).

Savings of one day on the critical path. Savings of one day on the critical path is defined as any module of systems, components, or structures known or assumed to be on the critical path that could decrease the in-place erection time by one day; or any module of systems, components, or structures which would delay the start of in-place construction by one day and allow some other critical path activity to be performed, or the area used for some other critical purpose.

3.1.2 Weight and Size Limitations

The following weight and size limitations were developed for determining whether module fabrication could take place in the shop or in the field. Shop fabrication guidelines have both weight and size limitations. Field fabrication guidelines have only weight limitations.

Envelope A includes shop fabricated assemblies that meet the weight and size limitations for road and rail. These are described in Table 3.1-1. Two road limitations are given. The second is for oversize loads and requires a permit. Two or more of these shop assemblies could be combined in the field before installation.

Envelope B includes shop fabricated assemblies that meet the weight and size limitations of barges used on most inland waterways. These are also described in Table 3.1-1. Note that not all sites have navigable water access.

Envelope C includes shop fabricated assemblies that fall within the envelope required for the movement of the reactor pressure vessel and reactor vessel support structure. This is described in Table 3.1-1. Special provisions and plans are required for these types of moves. Assemblies falling within this envelope were carefully reviewed because of the problems involved.

Envelope D includes field-fabricated assemblies that can be moved and installed with normal construction equipment. This is described in Table 3.1-1.

The weight and size limitations described are a general guide only and are the same as those provided in the previous report. Exceptions could be taken to these limitations for any given modularization concept investigated if warranted.

3.1.3 Crane and Site Transportation Requirements

For the purposes of this study, major cranes required to erect modules recommended for implementation should not exceed, in capacity and number, those currently contemplated for conventional construction. These requirements are affected by site conditions, equipment availability, and utility preferences.

It was assumed that two 350-ton class crawler cranes, each equipped with a 600 ton lift attachment, would be available to place large structural modules in the containment and annulus buildings. Each of these cranes has typical capacities ranging from 240 tons at an effective radius of 105 feet to 150 tons at an effective radius of 165 feet. These cranes have the capacity either individually, or in tandem, to lift and place all the major modules identified in this study. Other types of large construction cranes currently in use such as stationary or mobile ringer cranes and stiff-legged derricks of comparable capacity could also be used.

Both standard truck-mounted and hydraulic cranes are available with capacities ranging between 5 to 140 tons. Hydraulic cranes have telescoping booms which enable them to enter into confined areas, not accessible to conventional cranes equipped with standard type booms. Either type can be utilized for installation of smaller modules and for materials handling in the preassembly areas, and were assumed to be available.

For modules exceeding 100 tons, special crawler and hydraulic multiwheeled transporters would be considered for module movement. Crawler transporters are self-propelled and can operate under varying ground conditions with an ability to turn within their own radius. Single unit crawlers are available that are capable of carrying 1,600 ton payloads.

Where specific requirements for large capacity cranes or transports have been identified, they are discussed in the section for that modularization concept. In many instances, however, smaller weight modules could be handled in any number of ways and requires an individual assessment for each site.

3.1.4 Modularization Fabrication Shop

A decision to locate the modularization fabrication shop either offsite or onsite is directly dependent on the following variables:

1. Barge, rail, or roadway access to the site.
2. Geographical location of the site.
3. Area jurisdictional labor contracts.
4. Temporary or permanent stop facility consideration.
5. Force account or subcontracted job.
6. Structural integrity during transport.

3.1.4.1 Offsite Considerations

Advantages are:

1. Independent craft jurisdiction.
2. Greater utilization of lower wage crafts.
3. Possible use of existing contractors facilities (if modularization fabrication is subcontracted to a local vendor).

Disadvantages are:

1. Greater distance from installation area resulting in increased shipping costs and potential schedule delays.
2. Adequate shop facilities not always available locally.
3. Possible land use problem in transporting completed modules if in close proximity to site area, or highway use problem if distant from site.

3.1.4.2 Onsite Considerations

Advantages are:

1. Crafts jurisdictional contracts same as site.
2. Use of shop facility in future by owner.
3. Close proximity to installation area.
4. Easier material traceability and control of documentation.
5. Better control of material delivery from offsite vendors.
6. Site rigging equipment already available.

Disadvantages are:

1. Craft disputes may affect shop progress.
2. Possible restricted craft types usable in site shop due to labor contract.
3. Possible site construction layout and space limitations.

3.1.4.3 Conclusions

In general, the location of the fabrication shop whether it be onsite or offsite necessitates the transportation of modules to the installation area. The distance a module is transported from the modularization shop to the installation area is not a strong governing factor once rigging equipment is available for loading and unloading if other than highway use is required. In any case, control of material and equipment must adhere to government regulations and procedures. For the purposes of this study, an onsite module fabrication shop has generally been assumed since it would be applicable to a larger number of sites.

TABLE 3.1-1

SHOP AND FIELD LIMITATIONS

Envelope A

Road

	No Permit	Permit
Height of Load (Using "Lowboy")	10'-6"	11'-6"
Width of Load	8'-0"	10'-0" (may go to 16 ft in some states)
Length of Load	50'-0"	50'-0"
Net Weight	20 Tons	30 Tons

Note: These limitations vary between states and between interstate and state highways.

Rail

	Normal	Special
Height of Load	11'-0"	13'-0"
Width of Load	10'-8"	12'-0"
Length of Load	60'-0"	60'-0"
Net Weight	125-200 tons	300 tons

Envelope B

Barge - Inland Waterway

Width	30'-0"
Length	180'-0"
Net Weight	1,000 tons

Envelope C

Height	21'-6"
Width	21'-0"
Length	100'-0"
Net Weight	500 tons

Envelope D - Field Fabrication	
Inside Containment Structure	500 tons (polar crane capacity)
Other Structures	
Group 1 - using one or two crawler cranes as guyed derricks	240 tons/crane
Group 2 - using crawler transporters and jacks	1,000 tons

3.2 Structural Modules

3.2.1 Reinforcing Steel

3.2.1.1 Current Construction Methods

The most prevalent method of assembling the reinforcing steel used in nuclear power plant structures is to place and tie individual bars in specified positions within walls or floors. Forms are constructed before or after reinforcing is installed and concrete is placed within the form, creating an integral structure.

3.2.1.2 Proposed Module Description

3.2.1.2.1 General

To reduce the length of time required to place and tie the individual bars, preassembled reinforcing steel modules may be used to facilitate construction of structures. The wall or slab reinforcing is placed and tied in a horizontal position at an onsite preassembly area. Wooden templates are used to control the placement of the reinforcing and to ensure that the reinforcing of one module interfaces properly with that of another. Some additional or stronger ties are required, as well as bracing, to prevent racking of the module as it is moved and lifted. In the light modules, reinforcing bars are used to provide module bracing. Structural steel members are used to brace the heavier modules. Reinforcing steel modules are adaptable for use in mats, walls, and floors as delineated below.

3.2.1.2.2 Mats

The top and bottom faces of reinforcing are placed separately and the structural steel lifting support framework is designed to be reusable to optimize placement of the modules consistent with rigging and crane requirements. Placement of both top and bottom faces of reinforcing in a module was determined to be more costly and difficult than placing each face separately.

3.2.1.2.3 Walls

The modules are assembled and hauled in the horizontal position and are then upended just prior to installation in the structure. Some of the lighter modules are held in place with a crane while the lower ends of the vertical bars are tied to the reinforcing extending up from the concrete below. The heavier modules have structural steel support framing which provides support and rigidity to the reinforcing. When lifted into place, these modules are supported on structural steel columns which extend down from the bottom of the module. Additional reinforcing bars are placed in areas where one module is spliced to another, forms are set, and concrete is placed up to an elevation sufficiently below the top of the module to allow for splicing to the module above.

3.2.1.2.4 Floor and Roof Slabs

Floor and roof slab module assembly is similar to that for walls. Slab modules are assembled, hauled, and installed in the horizontal position. Structural steel support members are required only for the heaviest modules. In general, these structural steel support members, unlike those for most of the walls, are removed prior to concrete placement. The slab module is placed on conventional reinforcing supports.

3.2.1.2.5 Assembly and Weight Considerations

In assessing the use of reinforcing steel modules, the following factors were considered:

1. The maximum weight of any one module would not exceed 150 tons based on assumed available crane capacity.

2. Individual reinforcing steel modules would be assembled onsite and would be available prior to the scheduled time for their inclusion in the permanent structure.

3. An effort would be made to standardize the modularization construction technique by selecting repetitive types of reinforcing steel modules.

3.2.1.3 Specific Modules

A summary of each module type is provided in Table 3.2.1-1. Information provided includes the size and maximum weight of each module type, the total weight for all modules of the same type, and cost savings for modular versus conventional construction.

3.2.1.3.1 Containment

Mat

Fifty-four reinforcing steel modules can be used to facilitate construction of the mat. The first module to be installed is a circular module placed at the center of the mat, containing two layers of bottom reinforcing. Additional modules are placed around the first module forming two overlapping circular rings. A similar placing sequence is used for other modules as shown in Figure 3.2.1-1, each consisting of two layers of reinforcing. The modules are lifted into place, by large capacity cranes, with structural steel support framing attached. The structural steel support framing is then detached from the reinforcing and is removed. The reinforcing is attached to the bottom flanges of the structural steel support members by means of J-bolts. The reinforcing steel modules are joined to each other with cadwelds placed loose before setting module. The reinforcing bars of the last module are individually installed and field cut to assure proper fit.

Upper layer reinforcing steel modules are placed in a manner similar to the lower reinforcing steel modules described above. Vertical and/or shear reinforcing steel between the upper and lower modules are placed in a conventional manner. Embedments are also placed in a conventional manner due to the high tolerances required.

Exterior Wall

Forty-five reinforcing steel modules can be used to facilitate construction of the exterior wall. The inner modules include all the circular and vertical bars on that face. The outer modules include two vertical layers and a circular layer. The remaining four diagonal layers and one circular layer cannot be reasonably installed in modular units because adjacent layers cannot be broken into the same geometric shapes without adding cadwelds.

Structural steel support framing is attached to the reinforcing steel module with J-bolts to give the module rigidity. The support framing consists of vertical columns with baseplates attached and curved horizontal members to which the reinforcing is connected. A typical module is shown in Figure 3.2.1-2. Anchor bolts are embedded in the wall concrete beneath the final location of each reinforcing steel module or concrete footing below the mat. Leveling plates, approximately the same size as those attached to the columns, are placed over the anchor bolts and are grouted to predetermined elevations. The modules, with structural steel support framing attached, are lifted with large capacity cranes and the columns with baseplates are set onto the grouted leveling plates. The anchor bolt nuts are tightened to provide support for the structural steel framing. The reinforcing is attached to the structural steel framing in such a way that, when the columns are set, the reinforcing will be properly aligned for cadwelding. Cadweld sleeves are placed loose before setting the module. Cadwelds are staggered approximately 4 ft, as this is the customary practice for individual placement of reinforcing.

After a module is set and the cadwelds have been installed, the J-bolts which attach the reinforcing to the structural steel support framing and the anchor bolt nuts are removed. The structural steel support framing is then removed with a crane.

The structural steel support framing is reused for the installation of other similar modules.

Primary Shield Wall

The primary shield wall reinforcing can be installed in two modules: the inner and outer face reinforcing. Structural steel support framing systems are attached to the reinforcing as shown in Figure 3.2.1-3. The structural steel support framing systems are composed of wide flange columns and curved channel sections. The support framing system remains attached to the reinforcing after installation and is buried in the wall when the concrete is placed. The structural steel support framing system is designed to facilitate lifting with a large capacity crane and to help maintain the shape of the module.

Unlike the installation of the containment wall reinforcing steel modules, the ends of the vertical bars in the primary shield wall modules are set directly into B-series cadweld sleeves attached to plates embedded in the mat. The module is self-supporting and does not require the structural steel columns for vertical stability. This difference in installation technique results because each of the primary shield wall modules consists of a complete circular reinforcing segment, whereas each containment wall module covers only a section of the much larger circumference of the containment. Therefore it requires more precise alignment to ensure proper fit-up.

Cubicle Walls

The cubicle walls within the containment which form a continuous octagonal arrangement, adjacent to the steam generators, can be constructed using four reinforcing steel modules and four sections of conventionally placed reinforcing, joining the modules. Steam generator installation is completed prior to cubicle wall completion. However, steam generator replacement can be made following full power operations if required. Each module is composed of both the inner and outer reinforcing with interconnecting ties attached. The structural steel support framing system is composed of wide flange columns and transverse channel sections attached to the columns extending to both the inner and outer reinforcing. Reinforcing is attached to longitudinal channel sections at each end of the transverse channels. The arrangement is shown in Figure 3.2.1-4.

The structural steel columns are set on baseplates embedded in the concrete below in a fashion similar to that used for the containment wall reinforcing modules. After the modules are set with a large capacity crane, they are joined directly to the reinforcing below with cadwelds and are joined horizontally with field-cut lengths of reinforcing and cadwelds. The support framing system remains attached to the reinforcing after installation and is buried in the wall when the concrete is placed.

3.2.1.3.2 Annulus Building

Exterior Wall

Most of the annulus building exterior wall is potentially composed of precast concrete panels; however, that portion between the mat and the level of the first precast panels, approximately 25 ft, consists of reinforcing steel modules and cast-in-place concrete. Eight reinforcing steel modules, composed of both faces of wall reinforcing and the mat edge reinforcing, are placed around the circumference of the mat. These wall modules are placed prior to the placement of the exterior top face mat reinforcing modules, simplifying their installation.

The structural steel support framing system is shown in Figure 3.2.1-5, and is composed of wide flange columns and transverse and curved longitudinal channel sections. The transverse sections attach to the columns and extend to both inner and outer wall reinforcing. The curved longitudinal channel sections are located at each end of the transverse channels, and the reinforcing is attached to them. The columns are set on leveling plates, embedded in concrete column support pads, in a fashion similar to that used for the containment wall reinforcing. The concrete column support pads are provided exclusively for modular construction. After the modules are set, they are joined to each other horizontally by lap splicing reinforcing bars. The support framing system remains attached to the reinforcing after installation and is buried in the wall when the concrete is placed.

Interior Walls

Most of the annulus building interior walls are potentially composed of precast concrete panels; however, where it is not feasible to use precast panels, reinforcing steel modules are used if there is a sufficient quantity of reinforcing to justify such modules. (Average module weight estimated to be 2 tons.) These reinforcing steel modules consist of two faces of reinforcing and are fabricated in the horizontal position. They are braced with a small amount of additional reinforcing bars. No internal structural steel support frame is used. The modules are placed within the structure and are lap spliced and tied to the adjacent reinforcing. No cadwelds are used in these modules as none of the bars are larger than No. 11. Most bars in these modules are No. 8 or smaller.

Similar modules are fabricated and used in precast wall panel modules described in Section 3.2.2. If precast concrete is not used, additional wall modules could be constructed with rebar.

Floor Slabs

Floor slab reinforcing steel modules are used where at least 1 ton of floor reinforcing steel can be assembled into a single unit. The modules consist of two faces of reinforcing and are fabricated in the horizontal position without any internal structural steel support framing. A module is placed on standard reinforcing supports set on the concrete form within the structure and is joined to adjacent reinforcing by means of lap splices as all bars are No. 11 or smaller.

Similar modules are fabricated and used in precast floor slab modules as described in Section 3.2.2. If precast concrete is not used, additional floor slabs could be constructed with rebar modules.

3.2.1.3.3 Turbine Building

Ground Floor Slab

For the concrete floor slab at grade level, reinforcing steel modules of approximately 600 sq ft in plan area are recommended due to smaller sizes of reinforcing steel and inherent flexibility of the lighter modules. Each module consists of only one face of the slab reinforcing. It is estimated that the slab reinforcing for 75 percent of the gross floor area of the turbine building, excluding the area of the turbine pedestal, can be assembled into modules. (The turbine pedestal is currently constructed using preassembled reinforcing steel and, as such, was excluded from this study.) Each module weighs less than 1 ton. Reinforcing bar development is accomplished by means of lap splices between modules.

Spread Footings and Grade Beams

The reinforcing steel for grade beams and spread footings can also be preassembled. Each module is given rigidity by additional reinforcing bars tied within the module. Structural steel support framework should not be required for any of the modules. The spread footing modules are placed in their final locations and forms installed around them. Concrete is then placed, forms are removed, and the area is backfilled. The grade beam reinforcing modules are then placed and forms are constructed. All bar development is accomplished by means of lap splices. Each module weighs less than 3 tons, and no special hauling or lifting equipment is required for module installation.

Condensate Polishing Shield Walls

If precast concrete is not used, reinforcing steel modules could be used for the shield walls. Savings associated with these modules are not included in Table 3.2.1-1.

3.2.1.3.4 Control Building

Walls and Floor Slabs

If precast concrete is not used, walls can be broken up into reinforcing steel modules similar to those described for the annulus building. Savings associated with these modules are not included in Table 3.2.1-1.

3.2.1.4 Site Requirements/Assumptions

An adequate laydown area must be available on the site to set up the preassembly operation.

Major modules are assembled adjacent to the structures in which they will be used to facilitate placement by crane without hauling. Design of the structural steel support framework and rigging is performed by field construction forces.

3.2.1.5 Engineering Impact

Preassembly operations can begin earlier than with individual bar placement. Reinforcing steel must be delivered two months earlier. Specifications and drawings must be available two months earlier. This should not have any significant adverse effect on engineering activities. In addition to the reinforcing drawings, structural steel drawings related to the installation support framework will be required in sufficient time to have the structural steel delivered to the jobsite at least one month before the reinforcing installation start date.

Additional design drawings must be prepared indicating installation sequence and module connection details. These drawings must be prepared in conjunction with and at the same time as the normal design drawings.

This will require additional engineering and design man-hours over that required for conventional construction and is taken into consideration when establishing total savings in Table 3.2.1-1.

3.2.1.6 Cost Savings

The estimated differential costs for modular construction compared to conventional construction are shown in Table 3.2.1-1.

3.2.1.7 Schedule Savings

Structural schedule savings attributable to reinforcing modularization are listed below for each applicable building:

Building	Savings
Containment Building	
Mat	10 weeks
Primary Shield Wall	7 weeks
Cubicle Walls	4 weeks
Annulus Building	
Exterior Wall	2 weeks
Interior Walls & Slabs	3 weeks

Expected plant critical path savings of 21 weeks occurs in the containment.

Deferring construction of the containment exterior wall may result in additional critical path savings which cannot be readily identified without a detailed schedule analysis.

Other modules do not result in critical path schedule savings.

3.2.1.8 Savings Criteria

Reinforcing steel modules meet both the cost and schedule savings criteria.

3.2.1.9 Recommendations

The modules identified in Table 3.2.1-1 should be utilized for future construction. If precast concrete is not used in the annulus and control buildings, reinforcing steel modules should be evaluated for all wall and slab systems in these structures. Potential savings for these modules have not been considered in this report.

3.2.2 Precast Concrete

3.2.2.1 Current Construction Method

Currently, reinforced concrete structures are cast-in-place. Cast-in-place concrete provides complete structural continuity between slabs and walls throughout the entire structure. Cast-in-place concrete is placed in forms in the exact location where concrete elements are required in the structure.

3.2.2.2 Proposed Module Description

3.2.2.2.1 General

Structural integrity of concrete structures may be obtained by using a combination of precast concrete panels and cast-in-place closure pours. This technique requires the reinforcing to extend beyond the limits of the precast concrete so closure pours can be utilized to tie the precast panels together and ensure structural integrity. This technique is acceptable for both walls and slabs. The reinforcing used in these modules will be modules in themselves and follow the method described in Section 3.2.1.

During the precasting phase, wall modules are formed with reinforcing bars extending beyond the edges of the concrete. During the construction phase, the precast module is erected into place such that the protruding reinforcing bars lap with similar protruding reinforcing bars in the surrounding structure to form the necessary splice length. The structure is completed by placing additional cast-in-place concrete in the lap spliced regions forming one continuously reinforced concrete structure. During erection and placement of concrete in the closure pour, wide flange shapes embedded in the precast module and affixed to wide flanges in the existing structure serve as a temporary support mechanism for the precast concrete module. This vertical support system is shown in Figure 3.2.2-1. Precast walls require two vertical supports per panel. Depending on the size of the concrete module, additional support may be required to add to the lateral stability of wall modules until the surrounding closure pours have had an opportunity to set.

Similar to the wall modules, the precast slab modules have reinforcing bars extending beyond the face of the concrete to provide a continuous connection with the existing structure. During erection of the precast module, the concrete slab is supported at the intersection points with walls by wide flanges, similar to the wall panels; however, four are required for each module.

In assessing the various structures for sizing precast panels, the following were considered:

1. The maximum weight of any one module would not exceed 300 tons based on assumed available crane capacity.

2. Individual reinforced concrete precast modules would be built onsite and would be available prior to the scheduled time for inclusion in the permanent structure.

3. An effort has been made to standardize the modularization construction technique where possible by:

   a. Selecting a module size which may be used many times over,

or

b. Selecting modules from a range of sizes, each one of which may be easily built, using a single versatile form arrangement easily adjustable for width.

Precast panels are poured in a designated precast and storage area. This area is close to the batch plant and approximately 1/4 mile from the major plant structures. The precast operation would start at the same time as the containment - annulus building mat pour. This will allow one month for precasting the interior walls required at the mat elevation for the annulus building, the first precast structure to be started.

Using high early strength cement, the concrete panels will have reached sufficient strength to be moved to storage in three days. Considering two reusable forms for each module type, a sufficient number of panels can be precast and stored to keep the precasting operation off the critical path.

The precast and storage area is set up to minimize the required movement of the precast panels. Storage will be directly opposite the precasting location. Sufficient storage area is provided to hold one-third of the total number of panels at any one time.

As precast panels are needed in the construction sequence, cranes at the storage area will place each panel on three crawler transporters. These will take the panels to the structure where erection cranes will lift each panel into place. The erection crew will then secure the panel. When a group of panels has been erected, closure pours will be made completing the construction operation.

3.2.2.3 Specific Modules

A summary of each module group is provided in Table 3.2.2-1, giving the total yardage and number of similar modules, maximum weight, and dimensions as well as associated cost savings.

3.2.2.3.1 Annulus Building

The structural elements in the annulus building which can be precast are shown in Figure 3.2.2-2 (10 sheets). These consist of the exterior wall, the interior circumferential walls, selected radial and cubicle walls, and floor and roof slabs. Structural elements with numerous penetrations will not be precast to prevent erection problems in the field.

The exterior wall is divided into three different module groups, with 12 modules in each group. The dimensions and weights are shown in Figure 3.2.2-3 representing a rollout of the exterior wall. These panels are poured in the horizontal position. The circular shape of the precast panels is established by using special precasting beds and screeds. The reinforcing and structural steel sections extend beyond the confines of the concrete in all directions as previously described.

During the erection of the structure, the precast modules are lifted into place by cranes. Connections are then made between the structural steel shapes embedded in the modules. Lateral support is provided by structural steel knee braces and struts. The remainder of the reinforcing for the closure pour area is installed, forms erected, and the closure pour made, completing the module erection. The erection sequence is shown in Figure 3.2.2-4.

The interior circumferential wall modules are similar to those in the exterior wall; the precasting and erection sequence is the same. The radial wall panels are precast in a horizontal position. Erection sequence is integrated with the exterior and other interior circumferential walls.

Use of precast slabs is restricted to large cubicles. This avoids supporting the slab at locations other than the edge, thus simplifying the closure pours. Erection support, consisting of embedded structural steel, attaches to the two interior circumferential walls rather than the radial walls, thus allowing flexibility in the width of the slab panel. This allows a certain amount of standardization in form requirements. Each slab would have the same length; the width could be adjusted by moving the two radial forms to the desired angle.

Embedded plates, pipe sleeves, and/or blockouts are cast with the slabs during the precasting operation. These plates are used for the attachment of pipe supports, restraints, and cable trays.

After a series of precast elements are erected, closure pours are made to tie the structure together and maintain structural continuity. Figure 3.2.2-5 shows a typical closure pour in the annulus building interior. These are located on the truck aisle and pipe or electrical tunnel floor slab at each floor elevation. Before placing the truck aisle closure pour, a minimum of five precast panels are erected.

3.2.2.3.2 Control Building and Diesel Generator Building

Precast panels in the control building and diesel generator building are similar to those previously discussed in the annulus building. Figures 3.2.2-6 (3 sheets) and 7 show the location of the various panels in these two structures. The upper floor and roof of the control building are erected from structural steel modules, not precast concrete, and are discussed in Section 3.2.3. The large spans and extensive use of steel columns at these elevations preclude the use of precast slabs.

Precast panels are temporarily supported with embedded structural steel. Closure pours are then made to join the panels and ensure structural continuity. The number of panels in the control building and diesel generator building as well as a summary of the cost information and potential savings are described in Table 3.2.2-1.

3.2.2.3.3 Turbine Building

The shield walls in the condensate polishing area are readily broken up into 17 similarly sized panels. These modules and their cost advantages are summarized in Table 3.2.2-1. Closure pours are similar to those previously discussed.

3.2.2.4 Site Requirements/Assumptions

1. One additional large capacity crane will be required at the precast area to move panels from the casting bed to storage and from storage to the transporters. No additional cranes will be required at the site. Panels will be erected using cranes normally required for this job.

2. Two precast panels can be erected per day.

3. The precast area is located approximately 1/4 mile from the site in the vicinity of the batch plant. Panel storage is adjacent to the precast bed.

4. Two sets of three transporters and one prime mover are available to move the panels from storage to the site.

3.2.2.5 Engineering Impact

The precasting operation would begin while the large mat is poured. Design drawings of precast elements at the lower elevations must be completed early enough in the schedule to allow the necessary reinforcing steel to be fabricated and delivered to the jobsite.

With the use of precast concrete, an engineering and design effort will be required to evaluate rebar lap splices in conjunction with closure pour locations, determine shear capability of the concrete at closure pours and design shear lugs to withstand these loads, develop closure pour details, erection details, and erection sequences. Additional engineering and design man-hours are required to resolve these concerns. This has been taken into consideration in establishing total cost savings in Table 3.2.2-1.

Nuclear Regulatory Commission (NRC) approval of this modularization concept would be required prior to implementation.

3.2.2.6 Cost Savings

After developing schemes for breaking up each structure into acceptable precast modules as previously described, costs associated with the precasting operation were determined. Consideration was given to developing a semipermanent precast area with room for panel storage. Costs associated with moving the panel from precast form to storage and from storage to the erection location have been included.

Man-hour rates for fabrication of panels in the precast area were determined by breaking down the man-hour rates for similar items in a cast-in-place operation and attributing savings for the ability to do work at grade rather than at the elevation of installation. Man-hour rates for closure pours were substantially increased due to the difficulty and lack of continuity.

In the annulus building there is a substantial amount of concrete which is cast-in-place but is not considered as closure pours. The volume of cast-in-place concrete is distributed among the precast panels as shown in Figure 3.2.2-2. The difficulty in placing this concrete is greater than if the entire structure was cast-in-place. Forms, equipment, etc, have to be removed from the structure and then re-setup in "leap frog" fashion. If the structure were entirely cast-in-place, concrete placement would be a continuous uninterrupted operation as in the conventional manner. Where precast concrete and closure pours are mixed with cast-in-place concrete, this process is broken up. Taking this into consideration, man-hours required for pours in the range of 100 to 400 cu yd were, in general, penalized approximately 10 percent. Pours smaller than 100 cu yd were considered the same as closure pours and were penalized approximately 40 percent. Table 3.2.2-1 summarizes the cost data developed through the above analysis.

3.2.2.7 Schedule Savings

Structural schedule savings attributable to the precasting of concrete panels is itemized below:

Structure	Savings
Annulus Building	36 weeks
Control Building	13 weeks
Diesel Generator Building	6 weeks
Turbine Building	6 weeks

Critical path savings are limited to two weeks for the annulus building.

Deferring construction of other structures may result in additional critical path savings which cannot be readily identified without a detailed schedule analysis.

3.2.2.8 Savings Criteria

Precast concrete modules meet both savings criteria.

3.2.2.9 Remarks

Means of preventing plastic flow of concrete as circular panels continue to cure in storage must be resolved. Lifting heavy panels such as those in the exterior wall of the annulus building will require a detailed evaluation of the load transfer mechanism in the panel. Shear pullout must be considered in conjunction with the strength of concrete at the time of the first lift. This may even limit the maximum weight of panel that can be successfully precast. As the structure is analyzed, consideration must be given to shear transfer between precast panels and closure pours. In areas of high shear load, shear lugs will be required to effect this transfer.

The precast concrete modules discussed in this section have been sized for the maximum lift capacity of commercially available cranes. This makes some of the modules extremely heavy and large and was intentionally done so that potential cost savings would be maximized. Man-hours used in determining savings from precasting concrete were based on judgment whereas material costs were based on actual experience. Precasting of power plant structures is relatively new and actual cost data is difficult to find.

3.2.2.10 Recommendations

Although these modules meet the savings criteria, further investigation should be made into the problems discussed in Section 3.2.2.9.

This modularization concept should be considered following NRC approval for this technique.

3.2.3 Structural Steel

3.2.3.1 Current Construction Method

The current method of structural steel erection consists of placing individual beams and columns and attaching them to other steel members with bolted or welded connections. Beams are attached to columns or other beams, typically, with double angles on the webs of the beams. Column sections are joined with web and flange splice plates. Roof trusses are preassembled and are installed as single structural elements.

3.2.3.2 Proposed Module Description

3.2.3.2.1 General

Preassembled structural steel modules may be used to facilitate construction of the structures. The structural steel modules are fabricated at an onsite preassembly area assumed to be approximately 1/4 mile from the structures in which the modules will be located. After the structural steel of a floor or roof module is assembled at grade in the preassembly area, the metal deck or grating is attached to the top of the steel. The steel modules which support concrete floors or roofs have reinforcing placed on supports attached to the metal deck. After a module is assembled, it is hauled to the appropriate structure and set into place with a crane. Modules are attached to previously installed columns as depicted in Figure 3.2.3-1.

In addition to the typical modules described above, roof support trusses, where used, may be shop fabricated to the maximum extent possible and may be preassembled in the field. The fully assembled trusses may then be installed in their final locations. This technique is currently used to facilitate construction.

The majority of structural steel modules, with appurtenant items attached, will weigh between 50 and 80 tons with a few modules weighing as much as 120 tons. The modules will be hauled from the preassembly area approximately 1/4 mile to the appropriate structures on flat-bed trailer trucks.

3.2.3.2.2 Specific Modules

Turbine Building

Forty-six modules will be used for the construction of the mezzanine floor level and the condensate polishing area roof.

Columns, where used, are installed in the conventional manner. Modules are then lowered between the columns and the webs of the module header beams are attached to column flanges as shown in Figure 3.2.3-1. Shim plates are used between column flanges and beam webs as excess clearance is provided to facilitate installation.

In the condensate polishing area, where columns are not used, modules are set directly into beam seat pockets in the concrete walls.

After the modules are installed, grating or metal deck and reinforcing is placed between the modules to provide continuity. Edge forms are installed as required for concrete floors and the condensate polishing area roof and concrete is placed and finished.

Thirty-seven modules in the operating floor are placed above the mezzanine floor modules. Installation is similar to that described above for the mezzanine floor and condensate polishing roof level.

A typical example of the steel framing as it currently exists in the turbine building is shown in Figure 3.2.3-2. Structural steel modules for the same area are as shown in Figure 3.2.3-3.

The remainder of the steel framing in the turbine building is placed in the conventional manner. The turbine bay roof trusses are preassembled and installed as single structural elements as is the current practice.

Annulus Building

As described in Section 3.2.2, floor and roof slabs over large cubicles could be precast. Structural steel floor framing which remains does not appear amenable to modularization. If precast floor and roof slabs are not used in the annulus building, structural steel modules with metal deck and reinforcing attached can be used to facilitate construction. The structural steel modules are assembled in a fashion similar to those of the turbine building. The modules are supported in beam pockets in the concrete walls, are attached to columns, or are attached to plates embedded in the walls.

After modules are installed, metal deck and reinforcing is placed between the modules to join them. A typical example of the steel framing as it currently exists in the annulus building is shown in Figure 3.2.3-4. Structural steel modules for the same area are shown in Figure 3.2.3-5. Floor or roof concrete is placed in a fashion similar to that for the turbine building.

Control Building

The majority of the control building roof and floor framing can be modularized with some modifications to the present framing scheme. In order to facilitate modularization, the number of interface points between a structural steel module and other similar modules or concrete walls must be minimized. To minimize the interface points and to ensure structural integrity when using structural steel modules, concrete haunches are provided on which module header beams are supported. The haunches are similar to those currently used in the control building to support the roof girders. Additional haunches are required at the roof level to support the header beams required when using the structural steel module concept. A typical example of the steel framing as it currently exists in the control room floor is shown in Figure 3.2.3-6. Structural steel modules for the same area are shown in Figure 3.2.3-7. The modules are joined to columns as shown in Figure 3.2.3-1. At the exterior concrete walls the modules are supported on concrete haunches; at the interior concrete walls the modules are supported in beam pockets. After the modules are installed, metal deck and reinforcing is placed between the modules to structurally join them. Floor and roof concrete is then placed in a fashion similar to that for the turbine building. If precast concrete is not used, an additional floor can be constructed out of steel modules. This has not been included in the savings of Table 3.2.3-1.

3.2.3.3 Site Requirements/Assumptions

Adequate laydown area is available on the site to set up the preassembly operation.

Sufficient hauling equipment is available to haul the modules from the preassembly area to the structures in which they will be installed. Hauling costs are included in the data presented in Table 3.2.3-1.

Rigging design will be performed by field construction forces or the structural steel erector.

3.2.3.4 Engineering Impact

Construction of both the control building and turbine building can be delayed in order to facilitate construction of the annulus building. Therefore, engineering information and structural material deliveries for those structures will not be required any earlier than required for conventional construction.

Modularization of the structural steel in the annulus building will require that engineering information and structural material be available approximately two months earlier than in the conventional construction situation.

Additional design drawings will have to be prepared indicating erection sequence, erection details, and module connection details. These drawings will have to be prepared in conjunction with and at the same time as the normal design drawings. Engineering and design man-hours over those required for conventional construction are included in the savings shown on Table 3.2.3-1.

3.2.3.5 Cost Savings

The estimated total construction differential costs for modular construction compared to conventional construction are shown in Table 3.2.3-1. Additionally, this table sets forth the numbers, sizes, and weights of each type of module considered. For all modules there is a relative cost saving compared to conventional construction techniques.

3.2.3.6 Schedule Savings

Schedule savings for activities in each applicable building is summarized below.

Building	Savings
Turbine Building	18 weeks
Control Building	2 weeks

No critical path schedule savings were identified.

3.2.3.7 Savings Criteria

Structural steel modules meet the cost savings criterion.

3.2.3.8 Recommendations

Structural steel modularization should be utilized wherever possible. Additional engineering and design analysis to maximize this technique is required.

3.2.4 Liners

3.2.4.1 Containment Liner

3.2.4.1.1 Current Construction/Fabrication Method

The current practice of fabricating and erecting a containment liner is to fabricate the following:

1/4 in. bottom mat liner plates
3/8 in. rolled shell plates
1/2 in. and 1 in. spherically dished dome plates
Personnel access locks
Equipment hatch
Piping and electrical penetrations (individual as well as grouped in common 1 in. plate)
Shell base assembly with anchoring reinforcing bars
Bottom mat liner reinforcing steel penetration assemblies

All these items are shipped to the construction site in the sequence required by the erection schedule.

At the construction site, the shell base assembly and all of the bottom mat liner reinforcing bar penetration assemblies are positioned and leveled with the greatest possible accuracy, and then the bottom reinforced concrete mat is poured.

After the concrete has set up adequately, the 1/4 inch thick bottom mat liner plates are welded to the bottom mat liner reinforcing bar penetration assemblies and to the shell base assembly, forming an uninterrupted bottom mat liner. All of these welds are dye-penetrant examined.

Concurrent with the above, the shell is constructed by fastening shop-rolled shell plates to the shell base assembly and to each other by means of erection strong-backs to form a complete shell ring. After making all necessary adjustments to bring the ring to specified roundness and girth seam levelness, a wind girder is attached to the inside diameter of the ring, and the vertical seams are welded. Following completion of vertical seam welding, the girth seam joining this first ring to the shell base assembly is welded.

Because the vertical reinforcing bars of the concrete containment have staggered cadwelded joints in a prescribed pattern, it is necessary to erect approximately 30 ft of vertical reinforcing bar at the time that the bottom mat is poured. The presence of these reinforcing bars physically prevents double-butt welding of all shell ring welded joints located within the first 30 ft of the shell base. These joints are then, of necessity, welded against a backing strip and are magnetic-particle examined.

All shell rings up to the dome springline are erected in a similar manner with the exception that all joints located greater than 30 ft above the mat are double-butt welded and random radiographed. All girth seams located above the first 30 ft of the shell are automatically welded.

The hemispherical dome is constructed by double-butt welding together two or more spherically dished plates on the ground, and then fastening this subassembly to the shell or previously completed spherical zone and to adjacent plates or subassemblies in the zone being fabricated, by means of erection strong-backs to form a complete spherical zone. All piping and electrical penetrations are installed at the time that the shell ring in which they are located is erected.

When the liner shell has been completed (end of Phase I), the erection effort ceases for a period of eight to twelve months to allow completion of the erection of all the reinforced concrete structures located within the containment, and to allow completion of the erection of the containment polar crane and its support.

The personnel access locks, and the equipment hatch, are installed during the Phase I effort.

At the completion of the above construction activities, erection of the containment liner resumes (Phase II) and continues to completion.

3.2.4.1.2 Proposed Module Description

Four cylindrical shell liner assemblies, consisting of four rings each, and three dome liner spherical zone assemblies complete with spray piping, are constructed on an assembly foundation located within crane operating radius of the containment. Upon completion, each assembly is lifted into place by two ringer-mounted cranes.

Approximately ten weeks prior to the scheduled start of containment liner erection, the erector begins construction of a four ring high shell liner on the foundation. A center point is established, and a line scribed in the bearing plate embedded in the foundation to indicate the inside diameter of the shell liner. Permanent reference points are established inside of the theoretical diameter for the purpose of measuring "as-built" dimensions throughout construction.

The shop fabrication of all the components of the containment liner, and the construction of the mat liner and the first shell ring, are identical to that described under Section 3.2.4.1.1. The first ring of each four ring shell liner assembly is erected on the assembly foundation on the line scribed on the theoretical inside diameter, and secured to the bearing plate embedded in the foundation. It is fit-up and double-butt welded so that the top of the ring is level, and that the measured circumference is within tolerance. On completion of welding, a wind girder is erected to provide lateral stiffening and round out the circumference of the ring. The second, third, and fourth rings are each erected in a similar manner. All girth seams are automatically double-butt welded. All vertical seams are manually double-butt welded. All welds are random radiographed.

An additional stiffening member is added to the assembly at the lift point, and the assembly is lifted and set in place on the first shell liner ring that has been previously erected in the conventional manner. The girth seam at the juncture of the assembly, and the first shell liner ring, is hand welded against a backing strip, and is magnetic-particle examined.

The remaining three shell liner assemblies are each erected and welded to the preceding assembly with the exception that the juncture girth seam is automatically double-butt welded and random radiographed. All assembly lifts are made during weather periods when the wind velocity is less than 10 knots.

Piping and electrical penetrations are installed in the assembly in which they are located, as erection progresses on the foundation, whenever possible.

When the liner shell has been completed (end of Phase I), all work on the containment liner by the erector ceases for a period of eight to twelve months to allow completion of the construction of containment internal structures and to allow completion of the erection of the containment polar crane and its support.

During this period, the liner erector fabricates the three dome liner spherical zone assemblies on the foundation in a manner similar to that described above for the shell assemblies. Periodic frequent measurements are made, and appropriate actions taken, to assure that each dome liner spherical zone assembly is within tolerance, and fits its mating section and the completed shell properly.

At the completion of the above construction activities within the containment, erection of the containment liner resumes (Phase II). The dome liner spherical zone assemblies with containment spray piping attached are each lifted, hand double-butt welded into place, and ramdom radiographed. As with the shell ring assemblies, all lifts are made and during weather periods when the wind velocity is less than 10 knots.

The personnel access locks, and the equipment hatch, are installed during the Phase I effort.

Figures 3.2.4-1 and 3.2.4-2 illustrate the proposed method of fabricating and erecting a containment liner.

3.2.4.1.3 <u>Site Requirements/Assumptions</u>:

All equipment and facilities required for the fabrication, transportation, lifting, and assembling at the construction site, and testing are available. These include a fabrication area, automatic welding equipment, and large capacity cranes.

3.2.4.1.4 <u>Engineering Impact</u>

This modularization concept does not require any early purchasing or other engineering requirements beyond that required for the current fabrication and construction method.

3.2.4.1.5 <u>Cost Savings</u>

A review of this modularization concept with two leading containment liner erectors indicates that the total time at the construction site required to complete a containment liner could be reduced by as much as six months under the twenty months required for the current method. Although this time saving is substantial, additional work and material required for extensive stiffening of the shell rings and the dome spherical zones, additional personnel required at the construction site combine to make the prediction of a cost decrease difficult. However, because of increased efficiency, both on the part of the liner erector and the other construction activities occurring simultaneously at and within the containment, overall cost savings can be anticipated but must be evaluated on a site specific basis.

3.2.4.1.6 Schedule Savings

The containment liner itself does not occupy a position of importance on the critical path. However, the six months reduction in the time required for completion will result in increased efficiency in the construction of other critical path activities, such as the containment wall, the shield and cubicle walls, and other major reinforced concrete internal structures, the polar crane supporting structure and ring girder, and installation of the polar crane. A decrease in the in-place erection time of one or more of these activities by at least one day may reasonably be anticipated, thus meeting the schedule savings criterion established for this study. Additional critical path savings due to reduced congestion could result but requires a detailed schedule analysis.

3.2.4.1.7 Savings Criteria

Containment liner modularization meets the schedule savings criteria.

3.2.4.1.8 Recommendations

It is recommended that the techniques described be utilized as the basis of design, fabrication, and erection of all subsequent containment liners.

3.2.4.2 Liners for Spent Fuel Pit, Fuel Transfer Canal, and Refueling Cavity

3.2.4.2.1 Current Construction Method

The current practice of procuring liners for the spent fuel pit, fuel transfer canal, and refueling cavity is to have the liners fabricated and assembled in the shop, then disassembled and shipped to the construction site in the largest sized subassemblies possible. At the construction site, all equipment mounting pads are cast into a concrete floor and then the liner floor is installed as an overlay, fitted and welded to the mounting pads. The subassemblies are then hand-welded to each other and to the floor plates, forming a complete free-standing liner. The complete liner assembly is then braced and used as a form for the surrounding building concrete. The major construction site fabrication difficulty lies in the area of fit-up. Because of the inherent flexibility of the subassemblies resulting from their great size, coupled with the distortion resulting from fillet welding structural section stiffeners to the plates, it has proven difficult and time-consuming to fit-up the mating edges of the subassemblies for adequate welding.

3.2.4.2.2 Proposed Module Description

The following is a tabulation of sketches made part of this study illustrating the proposed modular method of fabricating and erecting liners:

Transfer canal liner	Figure 3.2.4-3
Transfer canal liner	Figure 3.2.4-4
Transfer canal liner	Figure 3.2.4-5
Transfer canal liner	Figure 3.2.4-6
Transfer canal liner	Figure 3.2.4-7
Transfer canal liner	Figure 3.2.4-8
Transfer canal liner	Figure 3.2.4-9
Transfer canal liner	Figure 3.2.4-10
Transfer canal liner	Figure 3.2.4-11
Spent fuel pit liner	Figure 3.2.4-12
Spent fuel pit liner	Figure 3.2.4-13
Spent fuel pit liner	Figure 3.2.4-14
Spent fuel pit liner	Figure 3.2.4-15
Spent fuel pit liner	Figure 3.2.4-16
Spent fuel pit liner	Figure 3.2.4-17
Field erection inside corner brace	Figure 3.2.4-18
Field erection braces	Figure 3.2.4-19
Field erection module braces	Figure 3.2.4-20
Field erection module braces	Figure 3.2.4-21
Field erection module braces	Figure 3.2.4-22

Although specific sketches were not prepared for the refueling cavity line modules, they are similar to the sketches for the spent fuel pit liner. Savings are reflected in Sections 3.2.4.2.5 and 3.2.4.2.6 for the refueling cavity liner.

All bottom plates (modules 1, 3, 5, 7, and 17)) are 1 inch thick consisting of 3/4 inch carbon steel plate with 1/4 inch stainless steel cladding to eliminate the necessity of field fitting 1/4 inch plate to the numerous bottom mounting inserts as is presently required. The plates are stiffened on the concrete side with structural tee sections of a size and spacing sufficient to maintain the plate in a minimum distorted condition both during handling and welding. The tee sections also function to anchor the bottom plates to the concrete. Grout openings are furnished between each row of stiffeners for proper placement of concrete. The bottom plates are fabricated of the largest possible sections and are butt welded at the construction site by the automatic submerged arc process for minimum distortion. The tee stiffeners are all shop welded to the bottom plates employing gas metal arc flux core semi-automatic welding (GMAW). All panels are stiffened for their full length with flanged stiffeners formed from plate of the same thickness and specification as the panel. These stiffeners are welded to the panels in the shop. Resistance spot pulsation welding is employed to provide distortion free panels. (See Figures 3.2.4-7 and 3.2.4-8.) The large amount of welding required to assemble the liners at the construction site dictates that, if time and money are to be saved, automatic welding must be used to the maximum possible extent. All vertical seams are welded using pulsed gas tungsten arc welding (GTAW) and all horizontal seams are welding using gas metal arc weld flux core welding (GMAW). Automatic welding is employed both in the shop in the fabrication of the modules, and at the construction site in the assembly of the modules.

The automatic welding at the construction site is performed with automatic welding machines which can deposit weld metal at 425 amperes at a travel speed of up to 11 inches per minute (at least 5 times faster than manual welding) for 1/4 inch butt welds and at 450 amperes at a travel speed of 8 inches per minute (at least 30 times faster than manual welding) for 1 inch full penetration welding.

This high rate of travel coupled with the high arc ampage, insures minimum welding distortion. Figure 3.2.4-3 illustrates a transfer canal liner assembly. Figures 3.2.4-4 to 11 inclusive illustrate the details of the transfer canal modules. Modules 1, 2, 3, 4, 5, 6, and 12 are rigidly braced for shipping and handling at the construction site. The braces are not removed until the entire assembly has been fit-up and clamped together, as illustrated in Figures 3.2.4-18 to 22 inclusive, in preparation for welding.

All corners, except those formed at the juncture of panels to the 1 inch thick bottom plate, are prepared by bending the plate as illustrated in Figures 3.2.4-7 and 8. This allows the use of automatic welding machines described above. Figure 3.2.4-12 illustrates a spent fuel pit liner assembly. Figures 3.2.4-13 to 17 inclusive illustrate the details of the spent fuel pit modules. Modules 13, 14, and 15 are rigidly braced for shipping and handling at the construction site. The braces are not removed until the entire assembly has been fit-up and clamped together, as illustrated in Figures 3.4.2-18 to 22 inclusive, in preparation for welding.

These modules can be assembled and welded into complete pool liners in place or in an onsite assembly area and lifted in place using large capacity cranes.

All welds are vacuum box tested to assure freedom of leaks before concrete is poured. During the concrete placing operation, each panel stiffener is tied to the outer concrete form-work on 60 inch centers. This allows the concrete to be poured in 5 foot lifts without endangering the liner.

3.2.4.2.3 Site Requirements/Assumptions

All equipment and facilities required for the fabrication, transportation, assembly at the construction site, and testing are available.

3.2.4.2.4 Engineering Impact

This modularization concept does not require any early purchasing or other engineering requirements beyond that required for the current fabrication and construction method.

3.2.4.2.5 Cost Savings

It is estimated that the liners can be completely assembled and welded at the construction site cost at an estimated total cost savings of $470,000 thus meeting the cost savings criterion.

3.2.4.2.6 Schedule Savings

Although liner erection can be completed in approximately one-tenth of the time presently required, no plant critical path savings were identified.

3.2.4.2.7 Recommendations

It is recommended that the techniques in Figures 3.2.4-3 to 22 inclusive, be utilized as the basis of design, fabrication, and erection of all subsequent liners.

3.2.5 Polar Crane and Supports

3.2.5.1 Current Construction Method

After installation of interior concrete walls and structural steel to the operating floor, erection is started of the polar crane support steel from the operating floor to the box girder. Support steel is erected piece-by-piece, using conventional structural steel erection techniques. The curved box girder is shop-fabricated in the largest sections that can be shipped to the site via railroad. Therefore, a total of nine box girder sections, with the largest section weighing approximately 60 tons and having an arc length of 60 ft, are shop-fabricated and shipped to the construction site. Each girder section is lifted by crane over the containment liner at the bendline and placed atop the support columns. After all sections are set in place, they are accurately aligned and then permanently welded to each other and bolted to the support column cap plates. As shown in Figure 3.2.5-2, openings are provided at one end of each section to allow access for welding of girder sections. Following erection of the box girder, the crane rail is set, aligned, and fastened to the top of the girder. The support structure is now ready to receive the polar crane.

3.2.5.2 Proposed Module Description

Prior to the scheduled erection of the polar crane support steel, modules consisting of three columns and two bays of support steel with cap plates attached are preassembled in a horizontal position at a preassembly station remote from the containment area. The preassembly station consists of a slab on grade with steel support framing on which one module is constructed at a time. After a module has been assembled, it is transported to a storage area until required and assembly of the next module is begun.

A total of five modules are required, as shown in Figure 3.2.5-1, with the largest being approximately 70 ft long and 85 ft high and weighing 136 tons.

Preassembled modules will be transported from storage to the containment using four crawler transporters. Once at the containment, a module is upended, lifted over the liner at the bendline using large capacity cranes, and set and bolted to preset baseplates. Anchor bolt nuts are tightened to provide support for the structural steel module. After two adjacent modules are in place, the horizontal and diagonal bracing members tying the modules together are erected piece-piece.

Nine curved box girder sections will be shop-manufactured and shipped to the site, as described in Section 3.2.5.1. Three of these sections will be welded together to form a module on a preassembly pad located adjacent to the containment mat. There will be a total of three modules (see Figure 3.2.5-2) with the largest one having an arc length of 125 ft and weighing approximately 147 tons. Each module will have the crane rail installed on top of the box girder with rail clips prior to the installation of the module. A large capacity crane will lift each module from the preassembly area over the liner and set it atop the support columns. After all three modules are set in place, they are aligned so that the ends of the modules can be welded together and bolting of the box girder to the column cap plates can begin. See Figure 3.2.5-2. As in Section 3.2.5.1, openings are provided at one end of each section to allow access for welding. The crane rail is adjusted into final position and permanently fastened to the girder with steel rail clips. See Figure 3.2.5-3.

The polar crane is then erected atop the support structure.

3.2.5.3 Site Requirements/Assumptions

Adequate areas are available onsite for preassembly and storage of modules.

3.2.5.4 Engineering Impact

The preassembly of support steel modules and box girder modules is required to begin earlier than would be required using current construction methods. Therefore, design drawings for the support steel and box girder will have to be completed early enough to allow fabrication and delivery for preassembly. In order to begin erection of the support steel modules on the start date for conventional construction, the steel must be delivered one to two months earlier than otherwise would be required. In general, this will require that specifications and drawings be available one to two months earlier than required for current construction methods.

Engineering and design man-hours will increase only a minor amount.

3.2.5.5 Cost Data

The estimated differential total construction costs for modular construction methods compared to current construction methods showed no significant cost savings.

This does not meet the cost saving criteria.

3.2.5.6 Schedule Data

This modularization method meets the schedule savings criterion since five weeks critical path savings are expected primarily due to preassembly of the box girder.

3.2.5.7 Savings Criteria

Polar crane modularization meets the schedule savings criteria.

3.2.5.8 Recommendations

The size and number of modules have been selected such that no one module will exceed 150 tons in weight. The principal difficulty expected is the precise alignment and interface required to ensure proper closure and roundness of the polar crane box girder.

The techniques described should be utilized as the basis of design, fabrication, and erection of the polar crane supporting structures and box girder.

TABLE 3.2.1-1

PREASSEMBLY OF REINFORCING STEEL

Module Description	No. of Modules	Module Weight, Tons	Module Dimension, Ft	Total Weight of Modules, Tons	Module Cost Savings[1]
Containment					
Exterior wall	45	97 (max)	61 x 68	3,378	$540,000
Mat	54	145 (max)	162 x 62	5,781	191,000
Cubicle walls	4	108 (max)	64 x 50	432	162,000
Primary shield wall	2	95 (max)	34 diam x 50	190	38,000
Annulus Building					
Exterior wall	8	143 (max)	120 x 35	1,016	76,000
Interior wall	132	2 (avg)	12 x 26	246	32,000[2]
Floor and roof slabs	110	4 (avg)	12 x 30	624	75,000[2]
Turbine Building					
Ground floor slab	179	1 (avg)	20 x 30	179	-
Spread footings	80	1.5 (avg)	12 x 12	120	21,000
Grade beams	50	2.1 (avg)	4 x 29.4	104	34,000
					$1,169,000
Additional Engineering and Design Requirements					(70,000)
				Total	$1,099,000

[1]These are total construction cost savings with present day at 3/1/76.

[2]Savings would increase if precast concrete is not used.

TABLE 3.2.2-1

PRECAST CONCRETE

Module Description	Total Yardage in Structure (yd)	Total Yardage Similar Module (yd)	Maximum Module Weight (tons)	Number of Similar Modules	Maximum Dimensions	Precast-1 Total Cost Savings	Remarks
Annulus Building							
1. Exterior Circum-ferential Wall	9,200	4,400	285	36	62' x 31'	$660,000	
2. Interior Circum-ferential Walls	7,500	4,800	225	91	58' x 23'	780,000	Savings for interior circumferential, radial, and cubicle walls are based on total yardage in structure. (Penalty placed on cast-in-place concrete when mixed with precast.) All other savings are based on total yardage of similar modules.
3. Radial and Cubicle Walls	13,800	6,900	240	113	68' x 23'	1,408,000	
4. Cubicle Slabs	9,900	3,100 (41,850 SF)	290	38	45' x 48'	(209,000)	Cast-in-place construction is less expensive than precast.
Control Building							
1. Walls	6,800	3,500	170	56	20' x 56'	300,000	
2. Slabs	4,800	1,100 (14,800 SF)	130	16	25' x 35'	-	No cost difference
Diesel Generator Building							
1. Walls	1,100	600	215	6	27' x 52'	51,000	
2. Slabs	700	500 (6,800 SF)	200	6	33' x 40'	-	No cost difference
Turbine Building							
1. Shield Walls	1,900	1,500	200	17	28' x 48'	360,000	Large savings are due to high man-hour rates for construction in-place. This area of the turbine building is very congested.

TABLE 3.2.2-1 (CONT)

Additional Engineering and Design Requirements	(250,000)
Total	$3,100,000

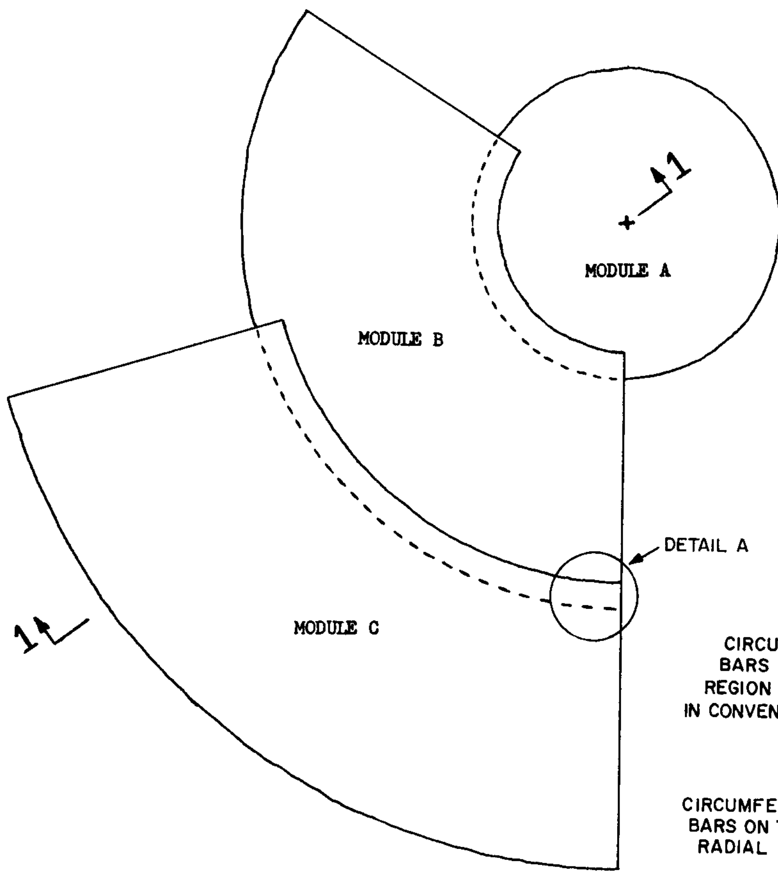
[1]Dollars represent total construction costs with present day at March 1, 1976

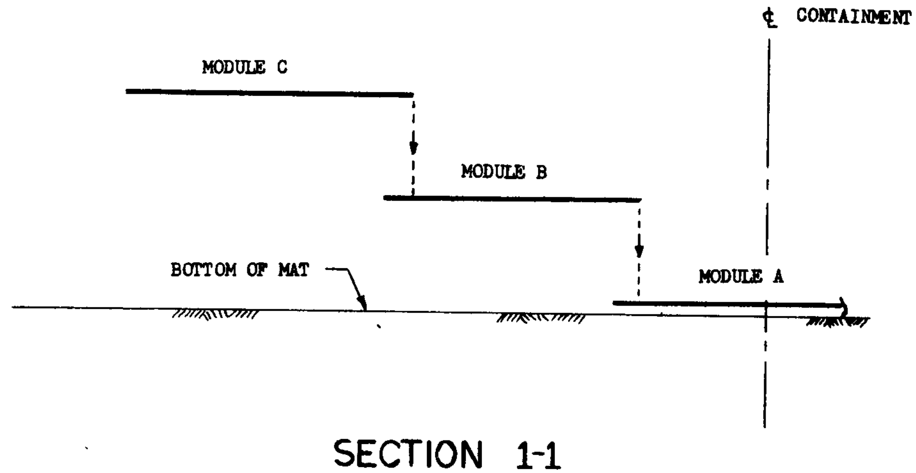
TABLE 3.2.3-1

PREASSEMBLY OF STRUCTURAL STEEL

Module Description	No. of Modules	Module Weight (Avg tons)	Module Dimensions	Module - Total[1] Cost Savings	Remarks
Turbine Building:					
Mezzanine Level	46	47	30' x 36'	$174,000	
Operating Level	37	53	30' x 36'	$167,000	
Annulus Building:					
Floors and Roof	68	12	27' x 43'	$170,000	Floor and roof slabs have been considered as precast concrete as described in Section 3.2.2. Therefore, this cost saving is not included in the total.
Control Building:					
Floor and Roof (Edge Module)	24	25	26' x 36'	$117,000	
Floor and Roof (Interior Module)	10	25	26' x 36'	$ 24,000	
Additional Engineering and Design Requirements				($ 78,000)	
Total				$574,000	

[1]Dollars represent total construction costs with present day at March 1, 1976.





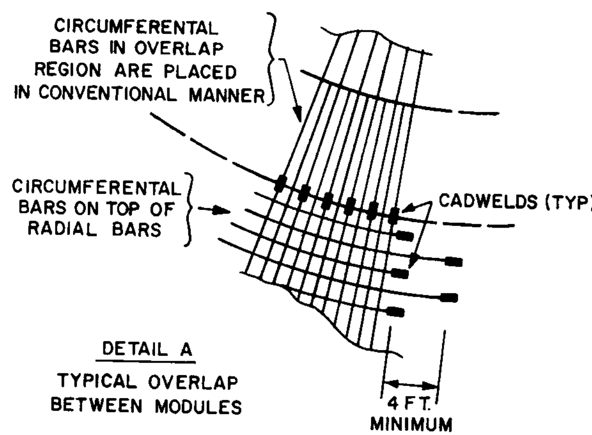
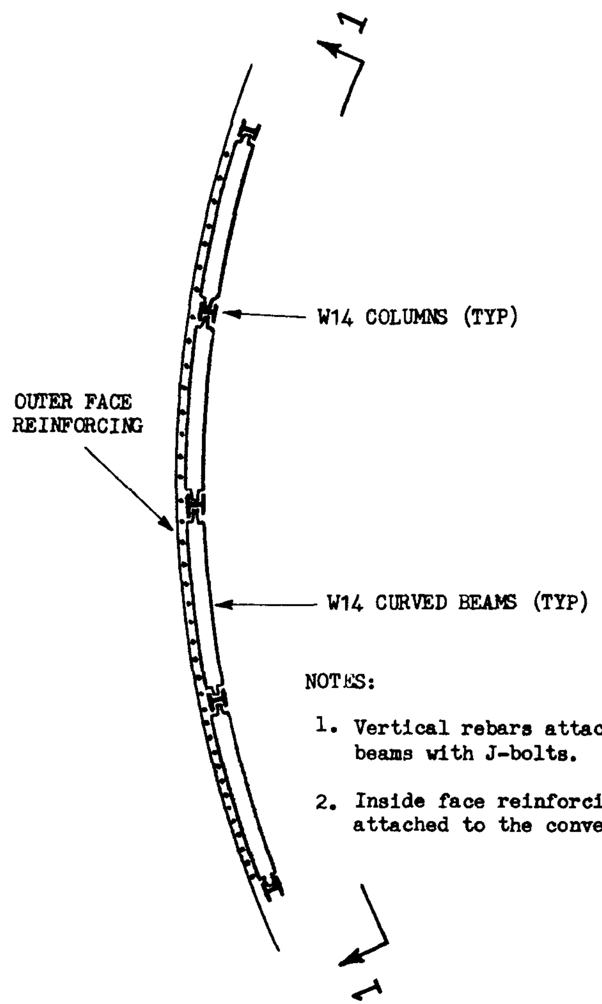


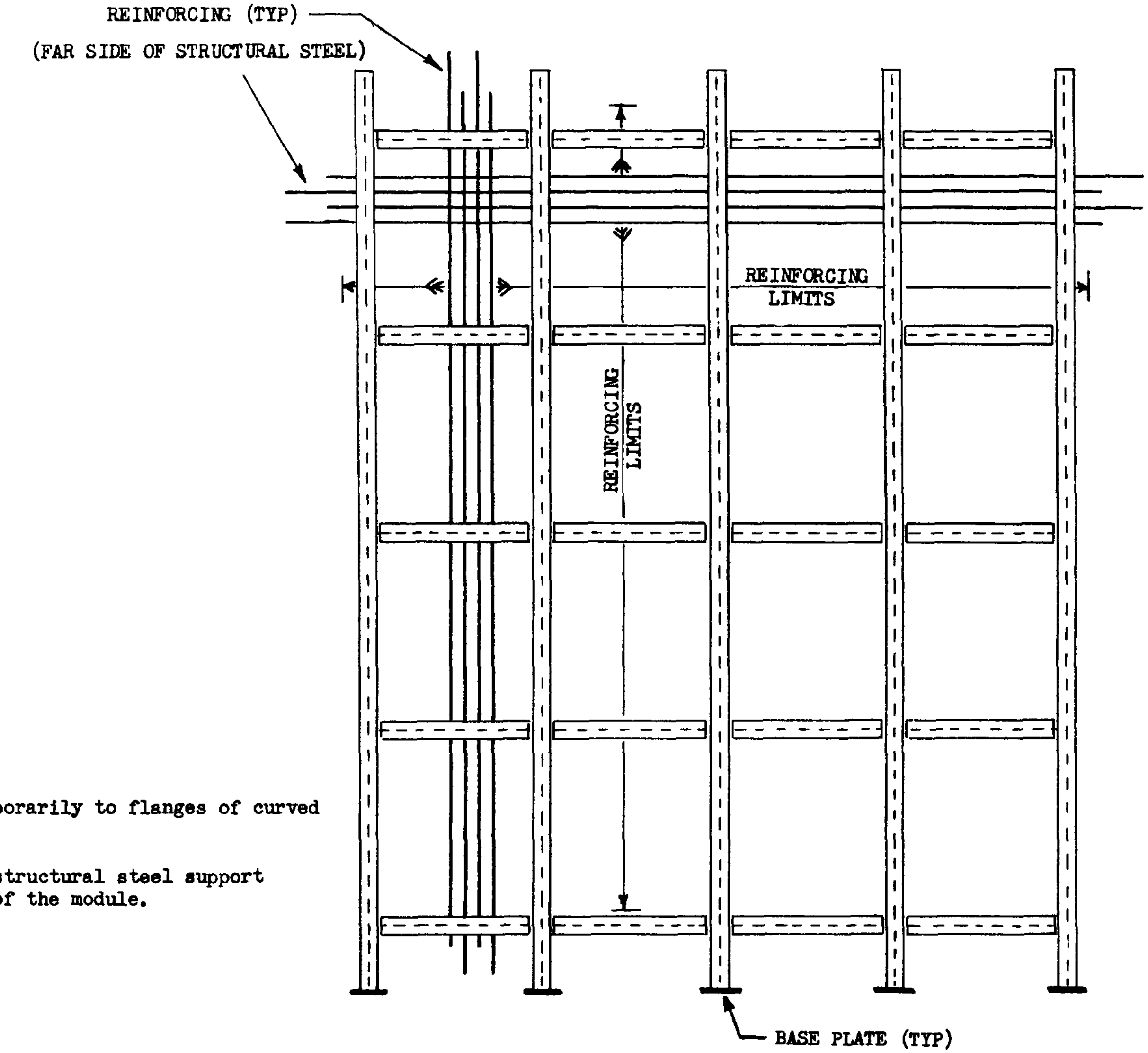
FIGURE 3.2.1-1
CONTAINMENT MAT
REINFORCING MODULES



NOTES:

1. Vertical rebars attached temporarily to flanges of curved beams with J-bolts.
2. Inside face reinforcing has structural steel support attached to the convex side of the module.

PLAN (OUTSIDE FACE REINFORCING)



SECTION 1-1

FIGURE 3.2.1-2
CONTAINMENT WALL
REINFORCING MODULES

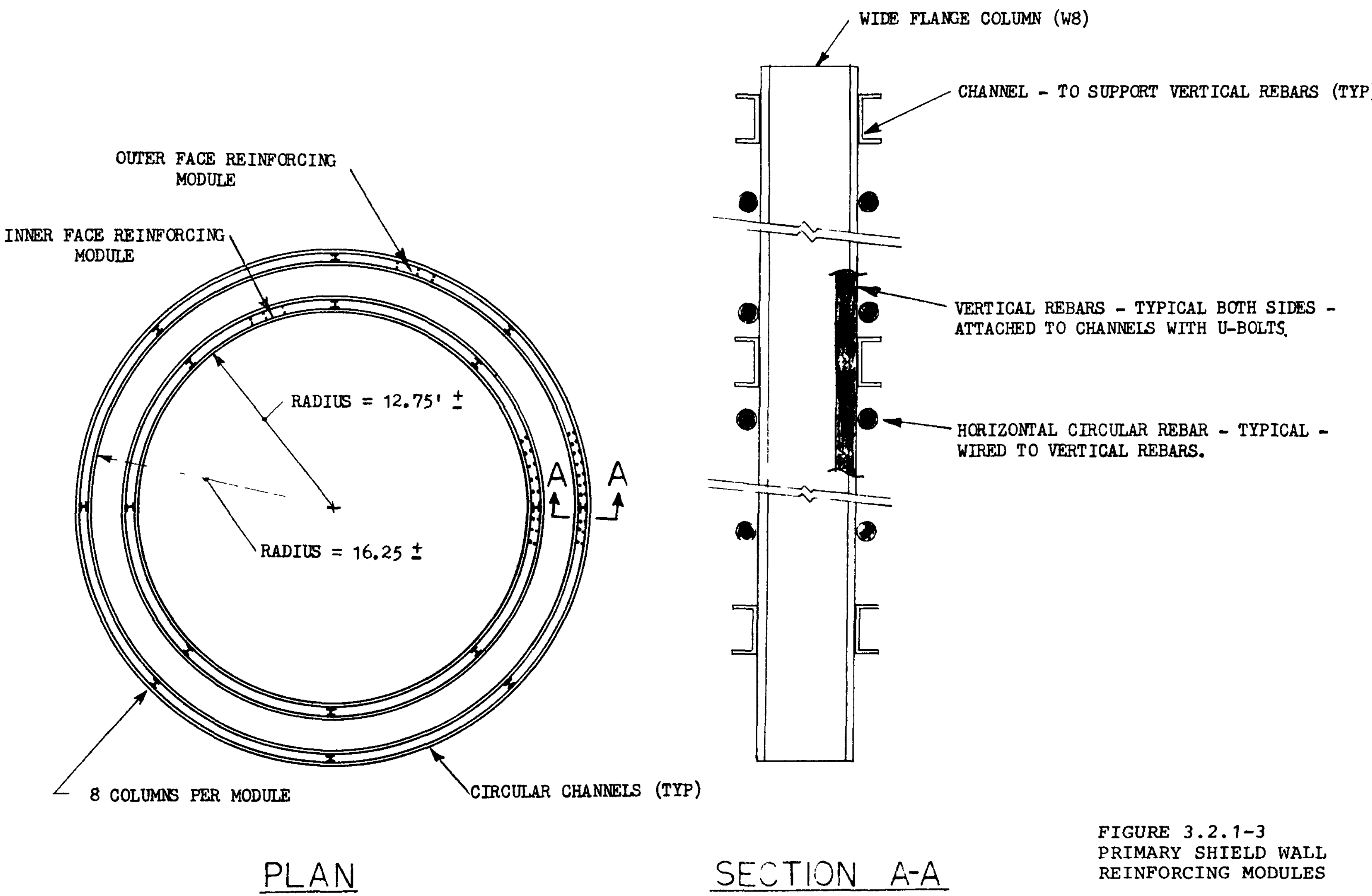


FIGURE 3.2.1-3
PRIMARY SHIELD WALL
REINFORCING MODULES

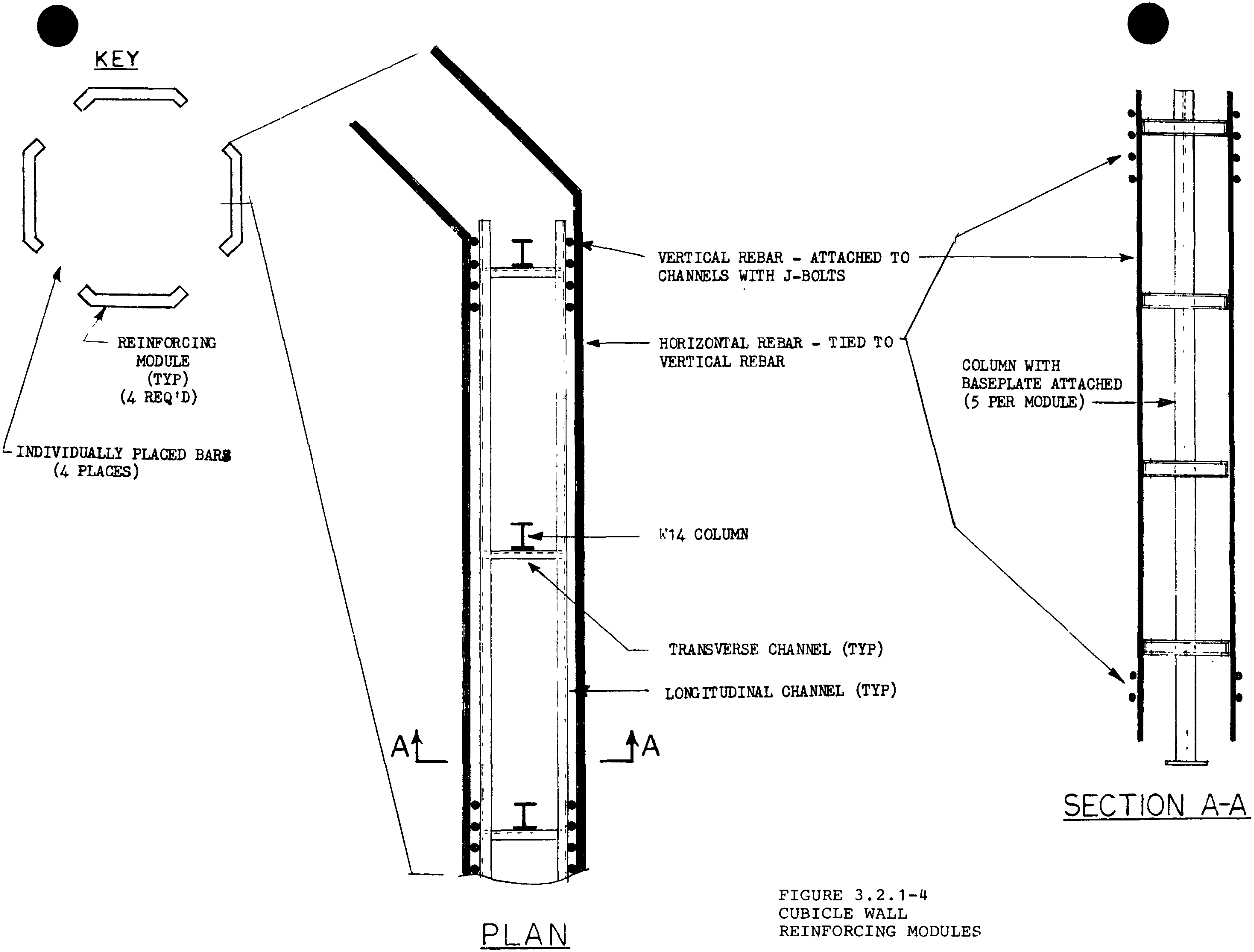


FIGURE 3.2.1-4
CUBICLE WALL
REINFORCING MODULES

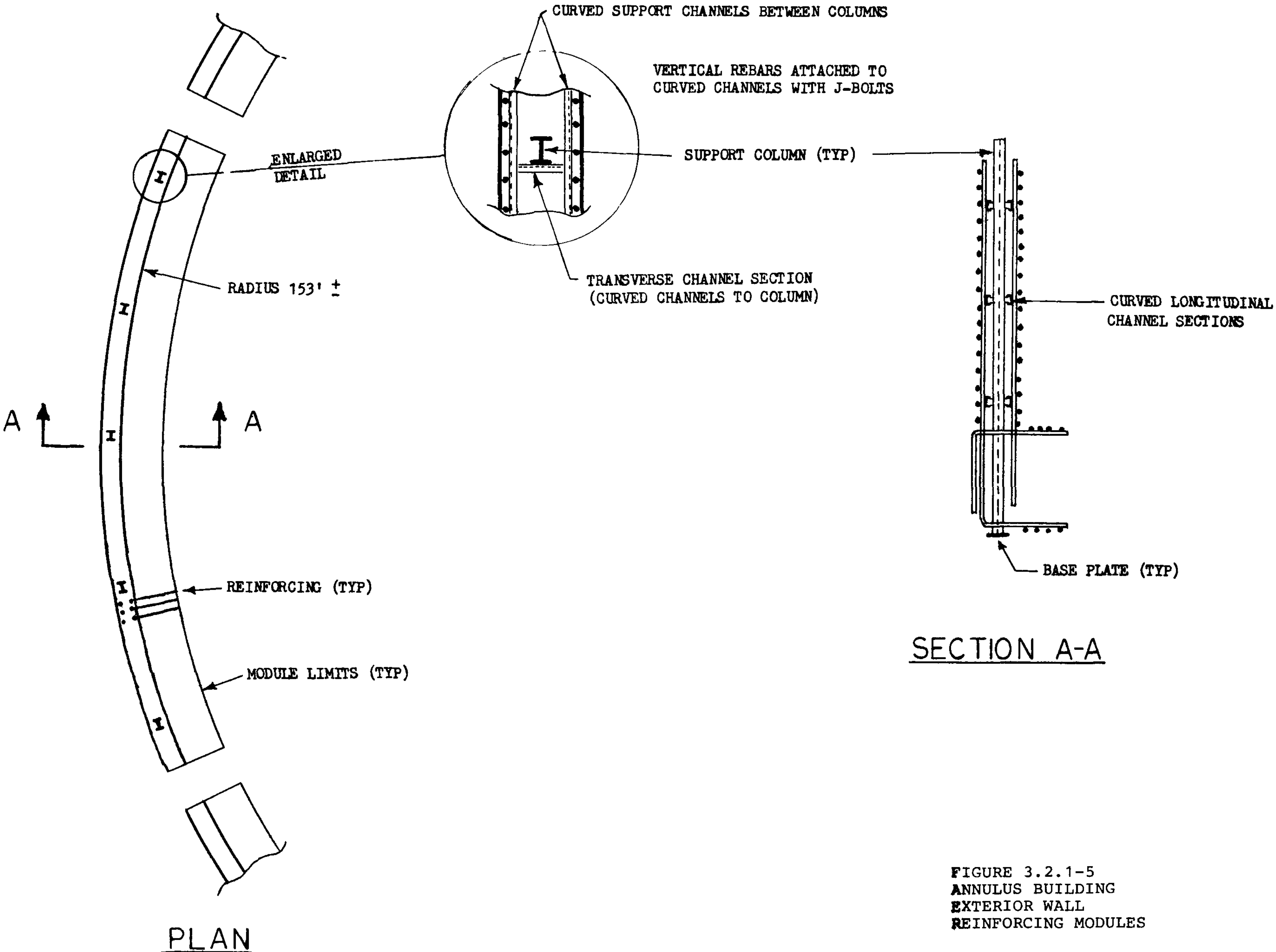


FIGURE 3.2.1-5
ANNULUS BUILDING
EXTERIOR WALL
REINFORCING MODULES

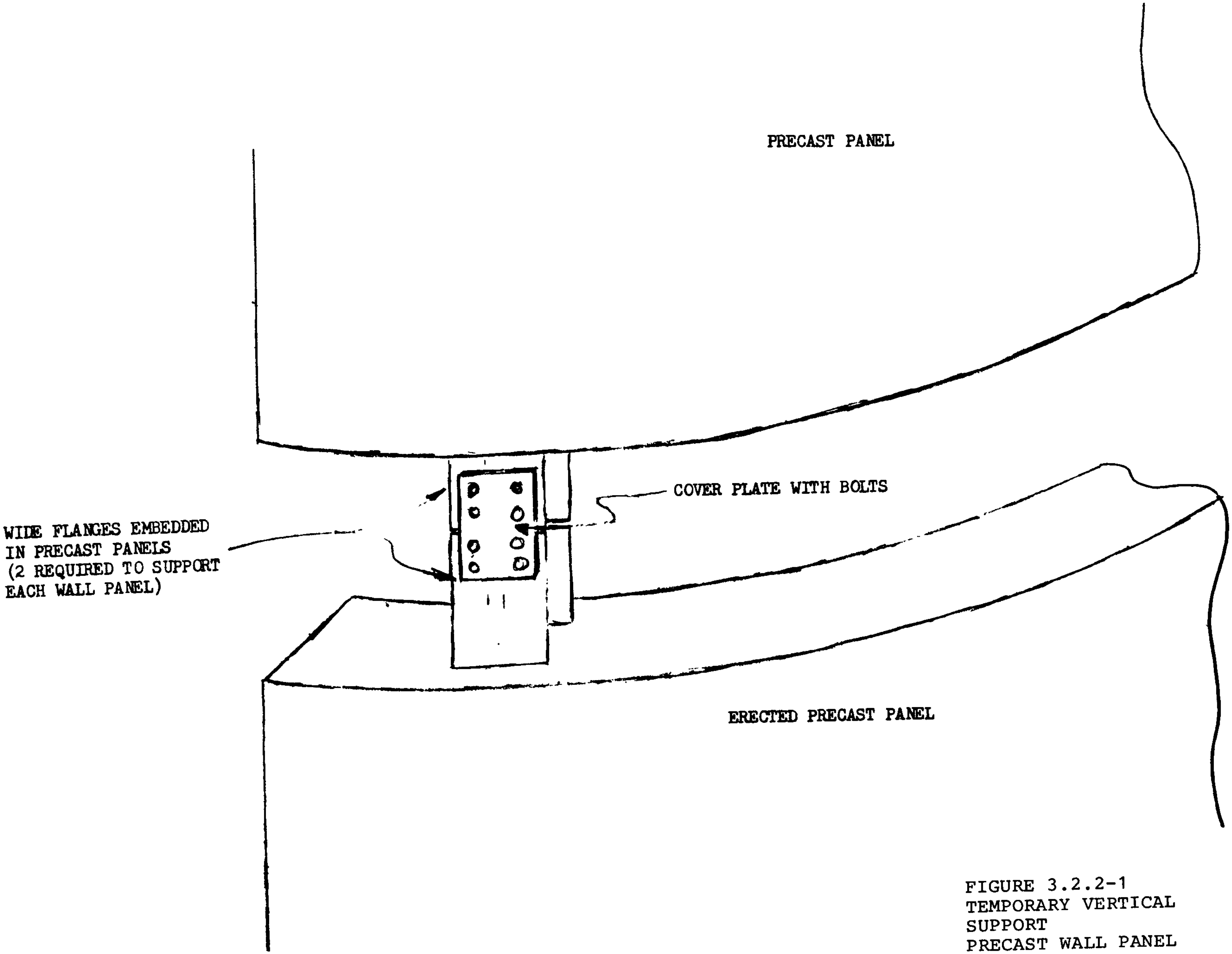
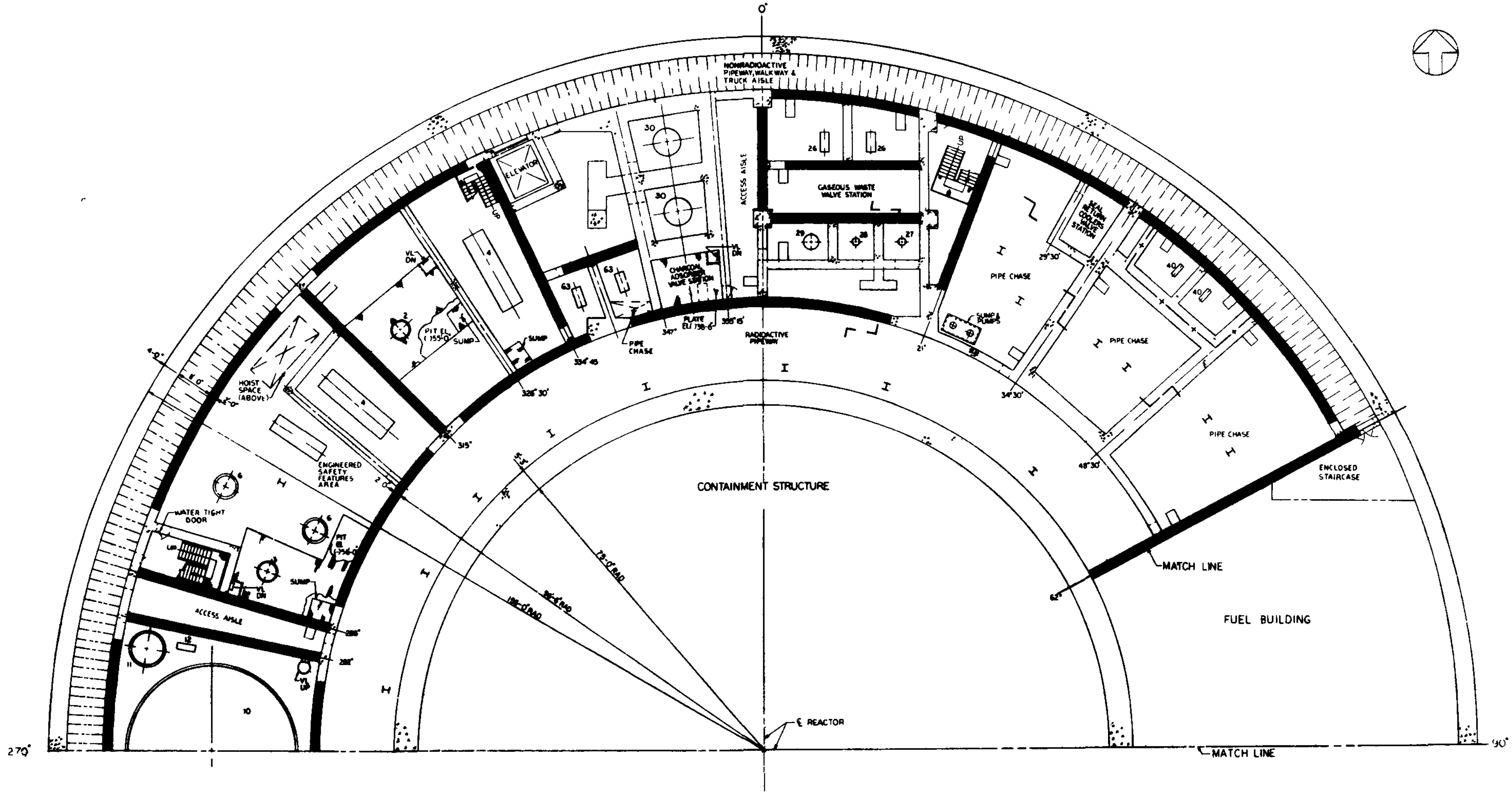


FIGURE 3.2.2-1
TEMPORARY VERTICAL
SUPPORT
PRECAST WALL PANEL



EQUIPMENT LIST

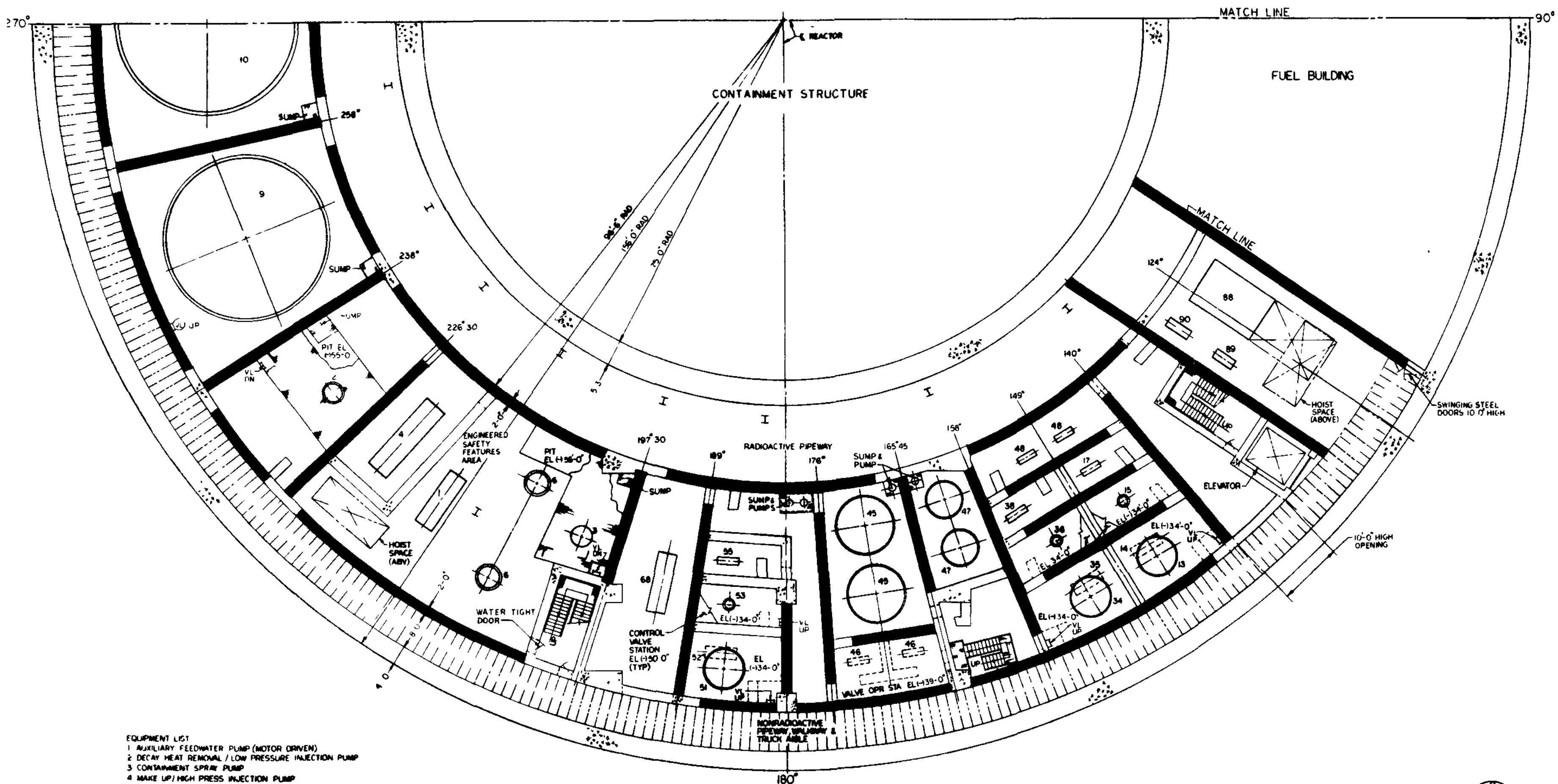
1 AUXILIARY FEEDWATER PUMP (MOTOR DRIVEN)
2 DECAY HEAT REMOVAL/LOW PRESSURE INJECTION PUMP
3 CONTAINMENT SPRAY PUMP
4 MAKE UP/HIGH PRESSURE INJECTION PUMP
6 COMPONENT COOLING WATER HEAT EXCHANGER
10 BORATED WATER STORAGE TANK
11 CHEMICAL ADDITION TANK
12 CHEMICAL ADDITION TANK PUMP
26 DEGASIFIER RECIRCULATION PUMP
27 DEGASIFIER RECOVERY EXCHANGER
28 DEGASIFIER FEED PREHEATER
29 TRIM COOLER
30 PROCESS GAS CHARCOAL BED ADSORBER
63 BORIC ACID PUMP

40 ANNULUS BUILDING WASHDOWN HOLD TANK PUMP; NOTE 4

PLAN EL (-)150-0"

PRECAST WALL PANELS
PRECAST SLABS
TRUCK AISLE

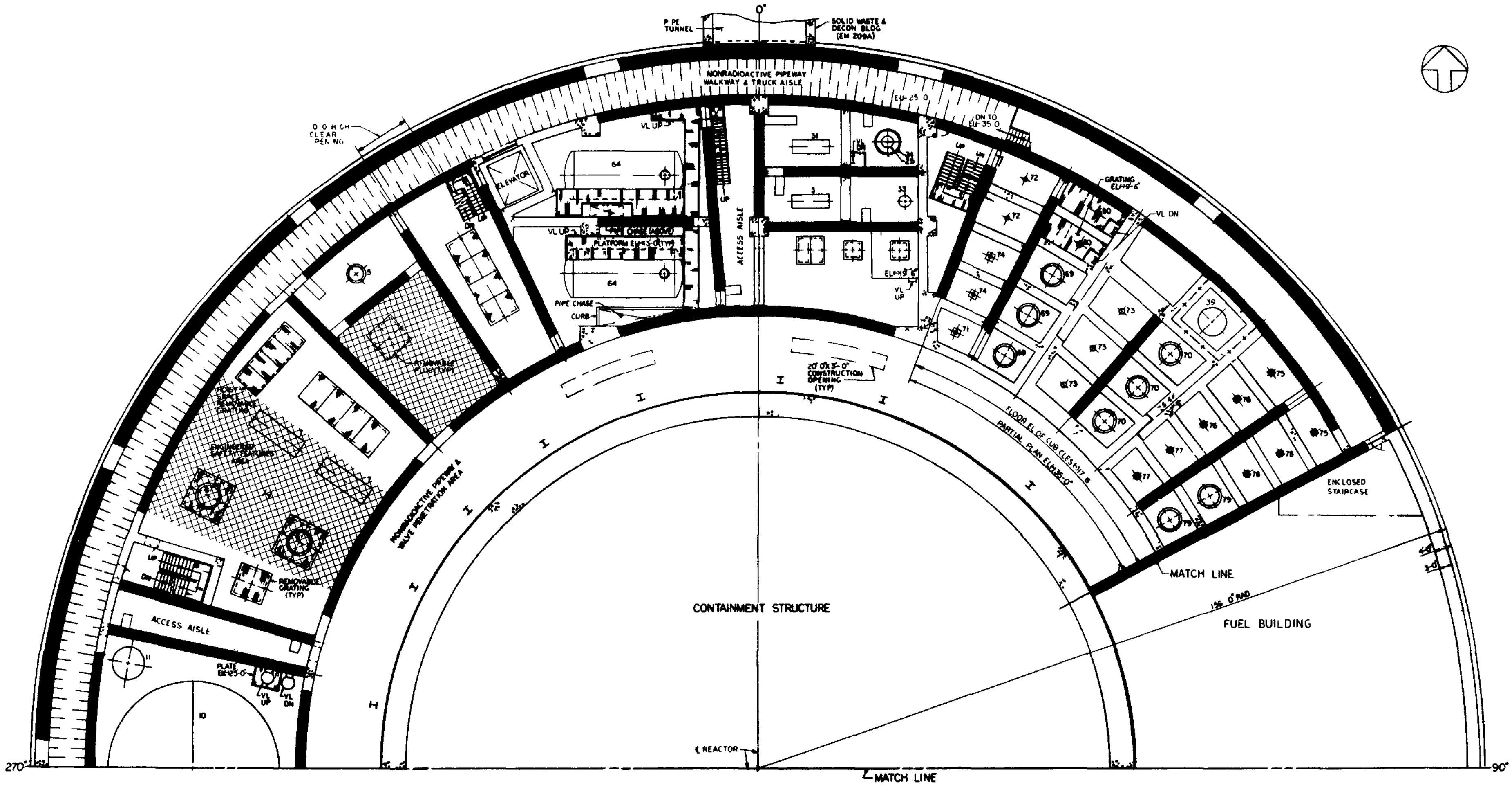
FIGURE 3.2.2-2 (SH 1 OF 10)
ANNULUS BUILDING
PRECAST PANELS



EQUIPMENT LIST
1 AUXILIARY FEEDWATER PUMP (MOTOR DRIVEN)
2 DECAY HEAT REMOVAL / LOW PRESSURE INJECTION PUMP
3 CONTAINMENT SPRAY PUMP
4 MAKE UP/HIGH PRESS INJECTION PUMP
6 COMPONENT COOLING WATER HEAT EXCHANGER
9 AUXILIARY FEEDWATER STORAGE TANK
10 BORATED WATER STORAGE TANK
13 BORON EVAPORATOR
14 BORON EVAPORATOR REBOILER PUMP
15 BORON EVAPORATOR REBOILER
17 BORON EVAPORATOR BOTTOMS PUMP
34 WASTE EVAPORATOR
35 WASTE EVAPORATOR REBOILER PUMP
36 WASTE EVAPORATOR REBOILER
38 WASTE EVAPORATOR BOTTOMS PUMP
45 HIGH LEVEL WASTE DRAIN TANK
46 WASTE EVAPORATOR FEED PUMP
47 LOW LEVEL WASTE DRAIN TANK
48 LOW LEVEL WASTE DRAIN PUMP
51 REGENERANT CHEMICAL EVAPORATOR
52 REGENERANT CHEMICAL EVAPORATOR REBOILER PUMP
53 REGENERANT CHEMICAL EVAPORATOR REBOILER
55 REGENERANT CHEMICAL EVAPORATOR BOTTOMS PUMP
68 AUXILIARY FEEDWATER PUMP (TURBINE DRIVEN)
88 CONTAINMENT
89 CHILLER WATER PUMP
90 RECIRCULATING CONDENSING WATER PUMP

PLAN EL (-)50'-0"

FIGURE 3.2.2-2 (SH. 2 OF 10)
ANNULUS BUILDING
PRECAST PANELS



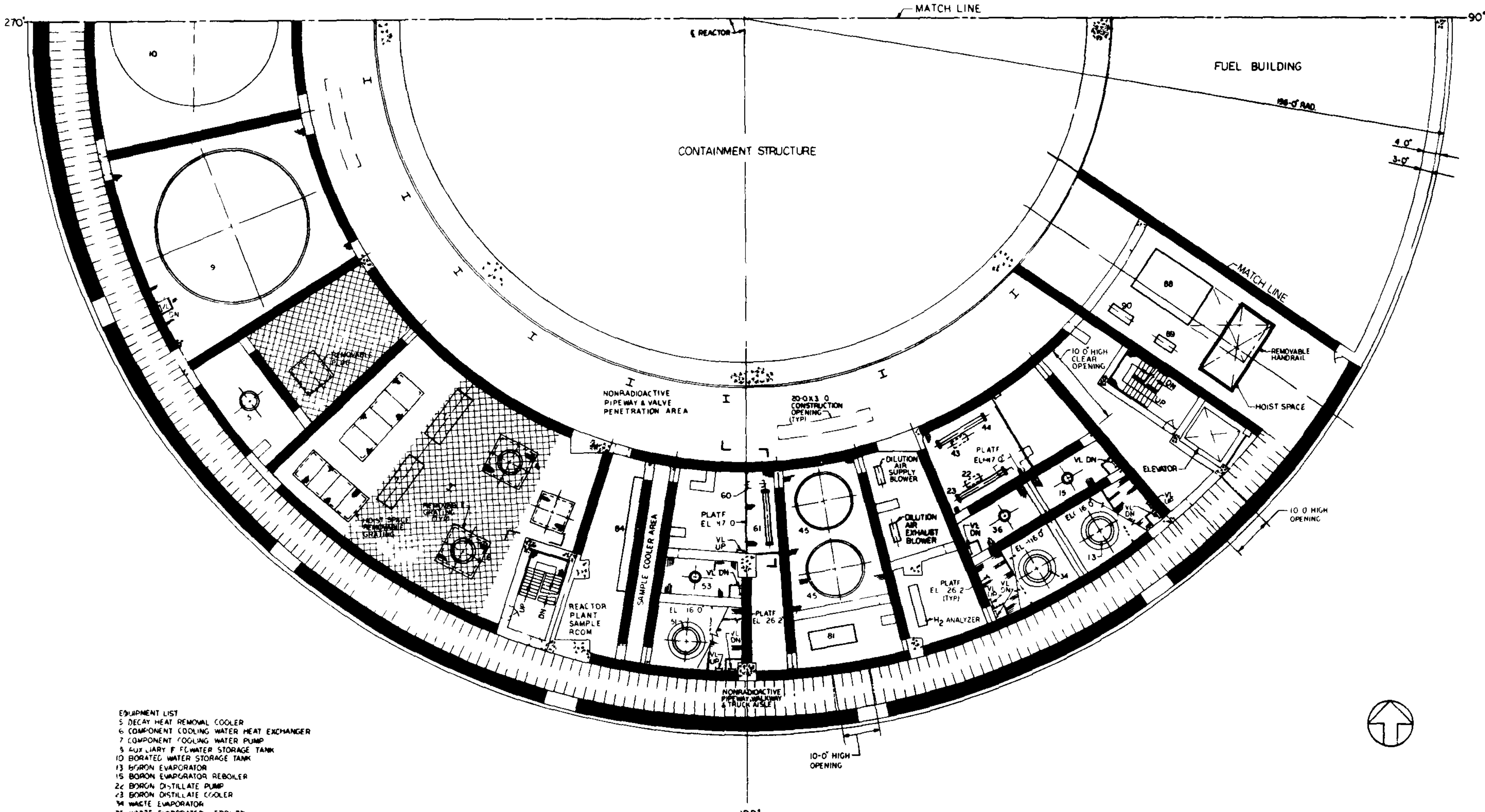
PLAN EL (−) 25-0'
(EXCEPT AS NOTED)

EQUIPMENT LIST

5 DECAY HEAT REMOVAL COOLER
6 COMPONENT COOLING WATER HEAT EXCHANGER
7 COMPONENT COOLING WATER PUMP
10 BORATED WATER STORAGE TANK
11 CHEMICAL ADDITION TANK
24 DEGASIFIER
25 DEGASIFIER CONDENSER
31 PROCESS GAS COMPRESSOR PREFILTER AFTERCOOLER
33 PROCESS GAS RECEIVER TANK
64 CONCENTRATED BORIC ACID STORAGE TANK
69 PURIFICATION DEMINERALIZER
70 DEBORATING DEMINERALIZER
71 DEMINERALIZER PREFILTER
72 SEAL INJECTION FILTER
73 DEBORATING DEMINERALIZER FILTER
74 PURIFICATION FILTER
75 LOW LEVEL WASTE EFFLUENT FILTER
76 BORIC ACID FILTER
77 BORON EVAPORATOR BOTTOM FILTER
78 BORON RECOVERY FILTER
79 CESIUM REMOVAL ION EXCHANGER
80 SEAL RETURN COOLER

39 ANNULUS BUILDING BACKWASH HOLD TANK}- NOTE 4

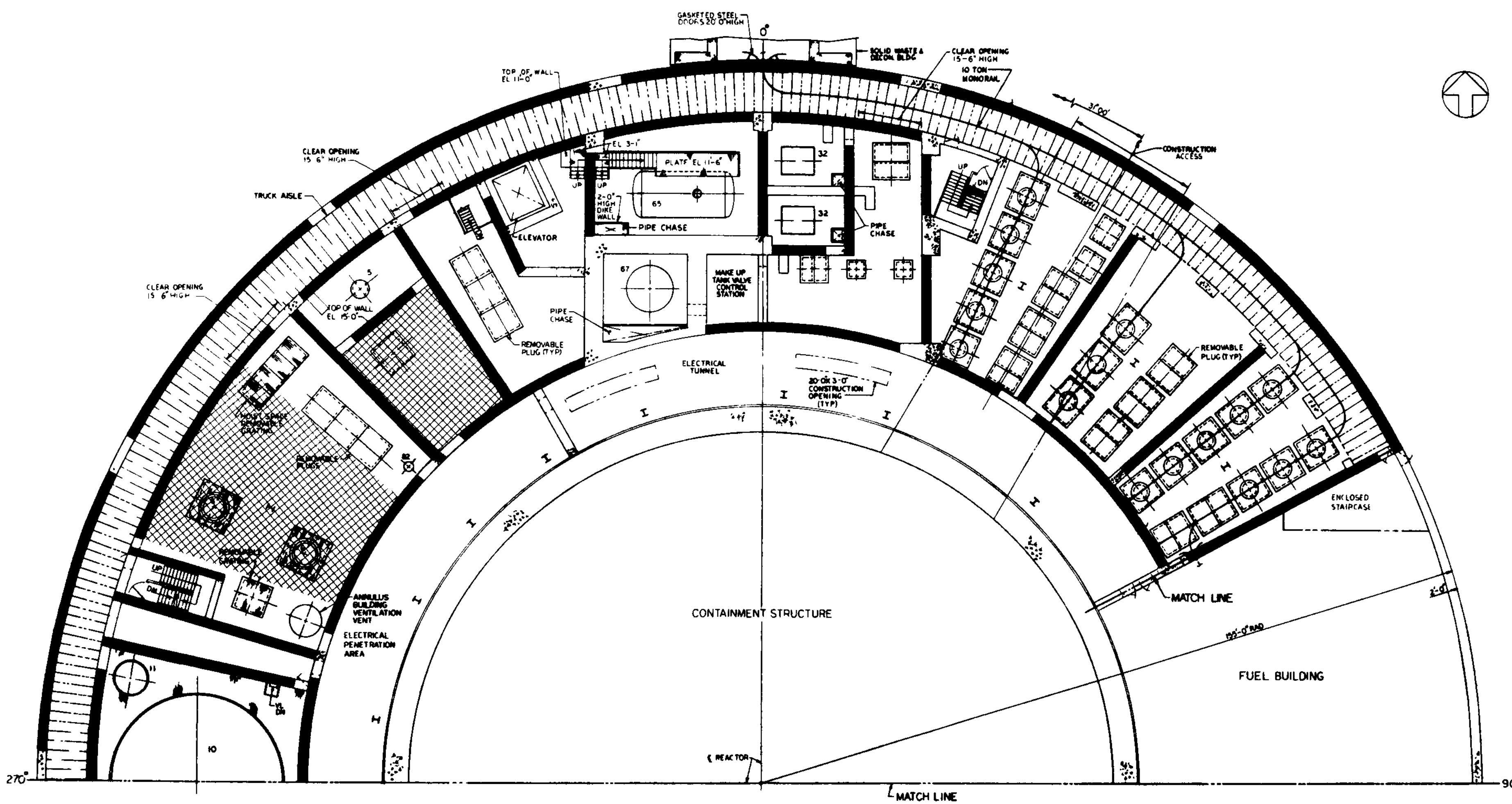
FIGURE 3 2 2-2 (SH 3 OF 10)
ANNULUS BUILDING
PRECAST PANELS



EQUIPMENT LIST
5 DECAY HEAT REMOVAL COOLER
6 COMPONENT COOLING WATER HEAT EXCHANGER
7 COMPONENT COOLING WATER PUMP
9 AUXILIARY FEEDWATER STORAGE TANK
10 BORATED WATER STORAGE TANK
13 BORON EVAPORATOR
15 BORON EVAPORATOR REBOILER
22 BORON DISTILLATE PUMP
23 BORON DISTILLATE COOLER
34 WASTE EVAPORATOR
36 WASTE EVAPORATOR REBOILER
43 WASTE DISTILLATE PUMP
44 WASTE DISTILLATE COOLER
45 HIGH LEVEL WASTE DRAIN TANK
5 REGENERANT CHEMICAL EVAPORATOR
53 REGENERANT CHEMICAL EVAPORATOR REBOILER
60 REGENERANT CHEMICAL DISTILLATE PUMP
61 REGENERANT CHEMICAL DISTILLATE COOLER
81 HYDROGEN RECOMBINER
84 REACTOR PLANT SAMPLE SINK
88 CONTAINMENT
89 CHILLER WATER PUMP
90 RECIRCULATING CONDENSING WATER PUMP

PLAN EL (-)25'-0"

FIGURE 3.2.2-2 (SH 4 OF 10)
ANNULUS BUILDING
PRECAST PANELS

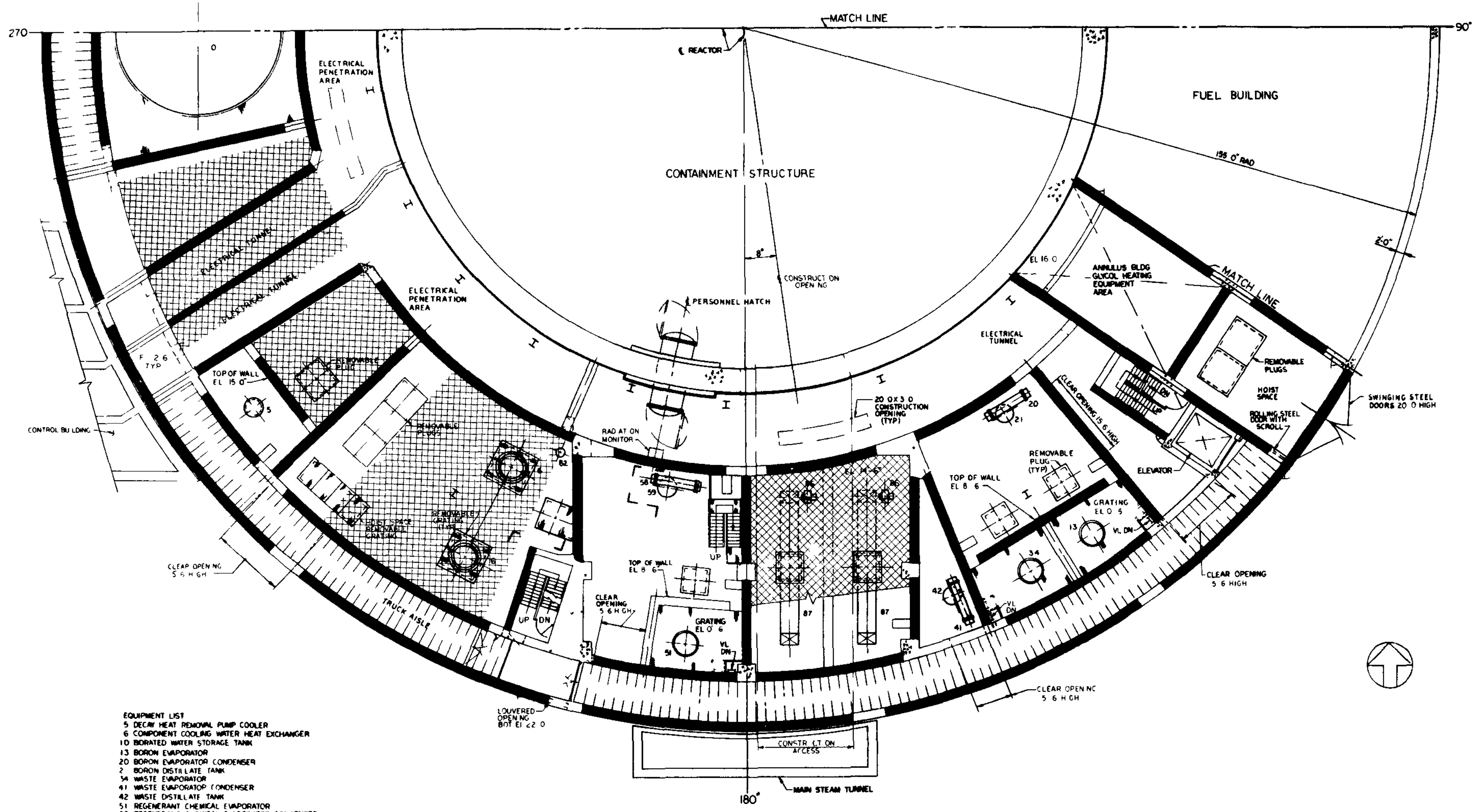


PLAN EL 0'-6"

EQUIPMENT LIST

5 DECAY HEAT REMOVAL COOLER
6 COMPONENT COOLING WATER HEAT EXCHANGER
10 BORATED WATER STORAGE TANK
11 CHEMICAL ADDITION TANK
32 PROCESS GAS REFRIGERANT DRYER
65 BORIC ACID ADDITION TANK
67 MAKEUP TANK
82 COMPONENT COOLING WATER CHEMICAL ADDITION TANK

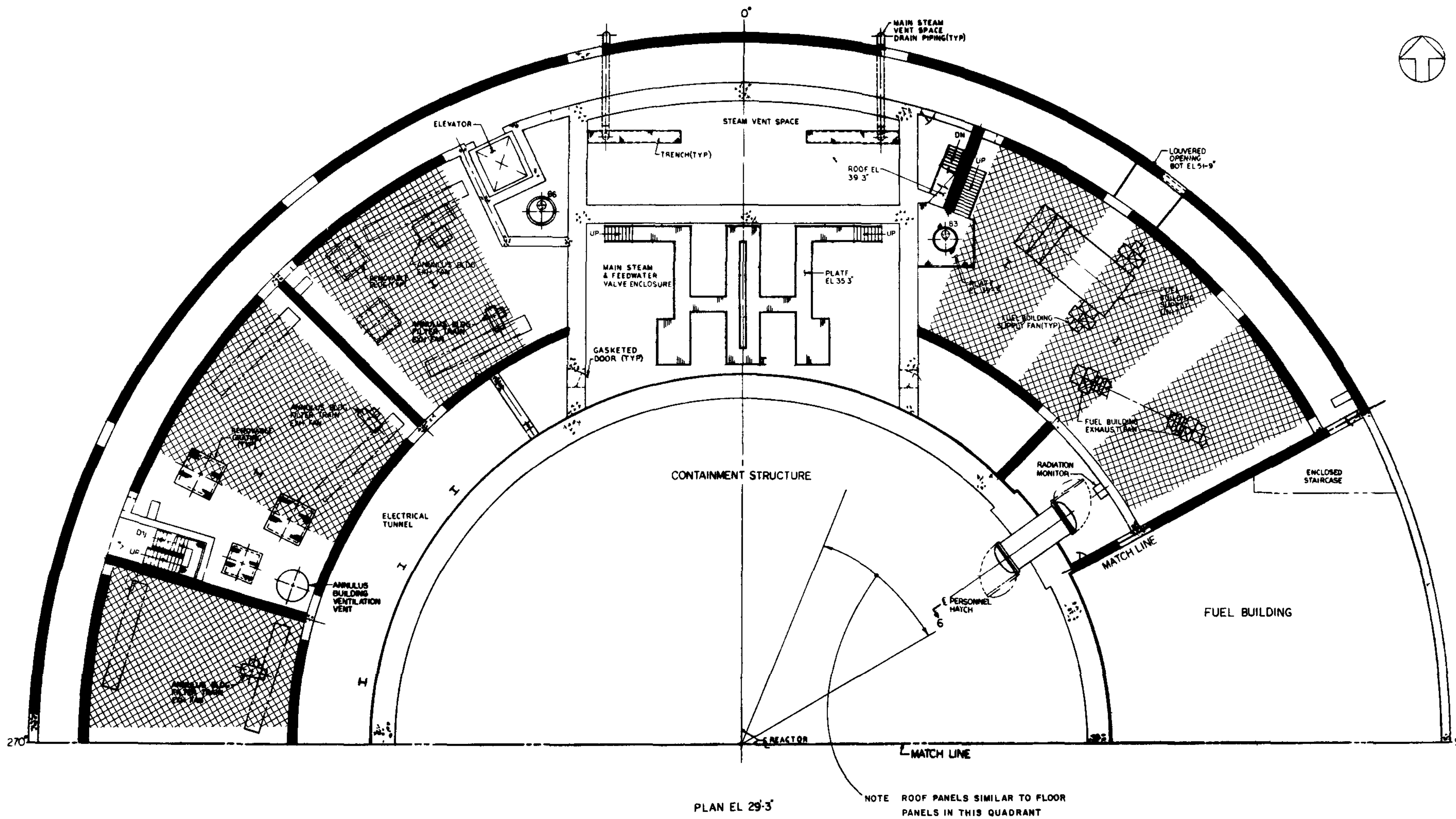
FIGURE 3.2.2-2 (SH. 5 OF 10)
ANNULUS BUILDING
PRECAST PANELS



EQUIPMENT LIST
- 5 DECAY HEAT REMOVAL PUMP COOLER
- 6 COMPONENT COOLING WATER HEAT EXCHANGER
- 10 BORATED WATER STORAGE TANK
- 13 BORON EVAPORATOR
- 20 BORON EVAPORATOR CONDENSER
- 2 BORON DISTILLATE TANK
- 34 WASTE EVAPORATOR
- 41 WASTE EVAPORATOR CONDENSER
- 42 WASTE DISTILLATE TANK
- 51 REGENERANT CHEMICAL EVAPORATOR
- 58 REGENERANT CHEMICAL EVAPORATOR CONDENSER
- 59 REGENERANT CHEMICAL DISTILLATE TANK
- 82 COMPONENT COOLING WATER CHEMICAL ADDITION TANK
- 86 PROCESS VENT BLOWER
- 87 PROCESS VENT FILTER ASSEMBLY

PLAN EL 0 6"
EXCEPT AS NOTED

FIGURE 3 2 2-2 (SH 6 OF 10)
ANNULUS BUILDING
PRECAST PANELS



EQUIPMENT LIST
66 BORIC ACID MIX TANK
83 LITHIUM HYDROXIDE MIX TANK

FIGURE 3.2.2-2 (SH. 7 OF 10)
ANNULUS BUILDING
PRECAST PANELS

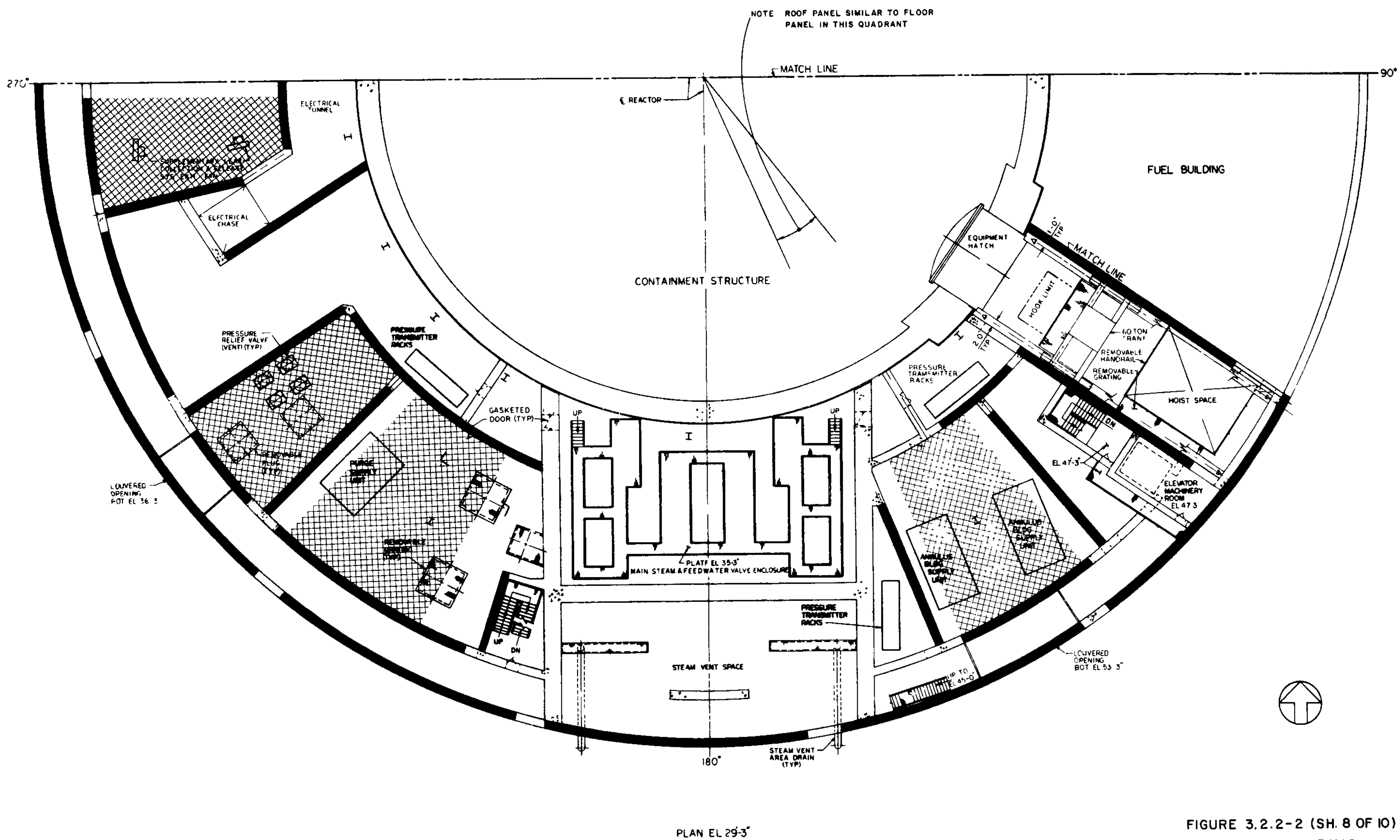


FIGURE 3.2.2-2 (SH. 8 OF 10)
ANNULUS BUILDING
PRECAST PANELS

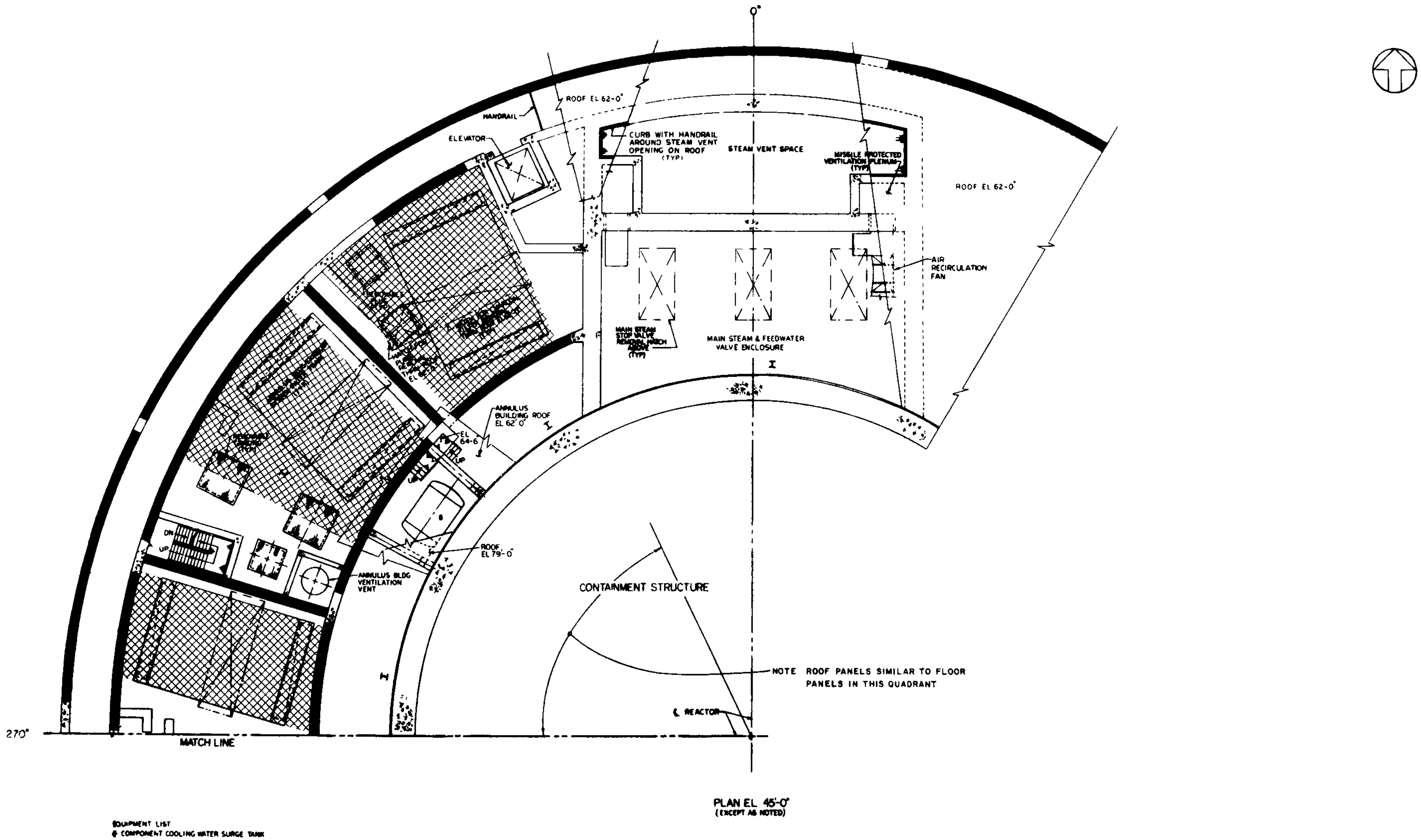
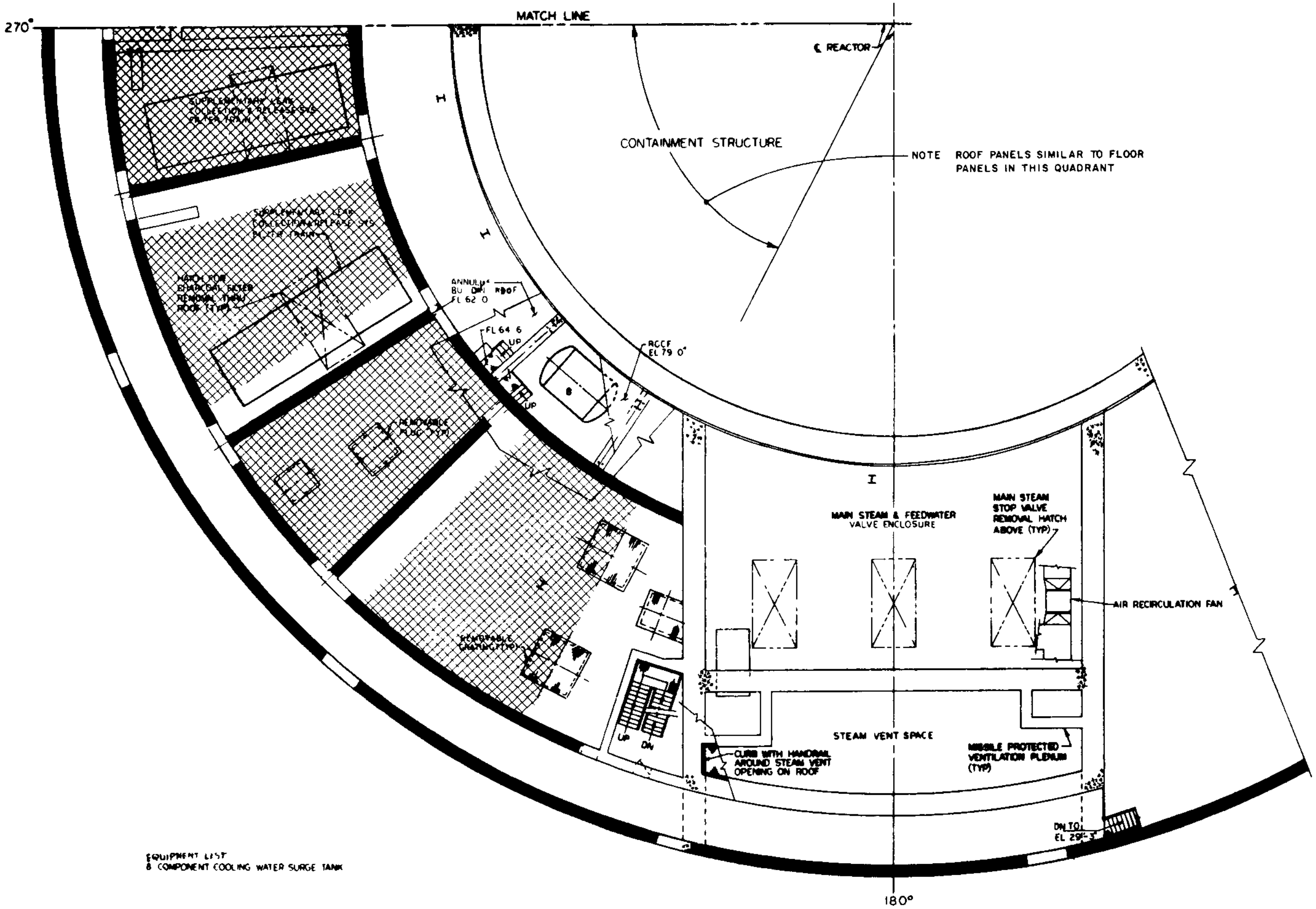


FIGURE 3.2.2-2 (SH 9 OF 10)
ANNULUS BUILDING
PRECAST PANELS



PLAN EL 45-0"

FIGURE 3.2.2-2 (SH. 10 OF 10)
ANNULUS BUILDING
PRECAST PANELS

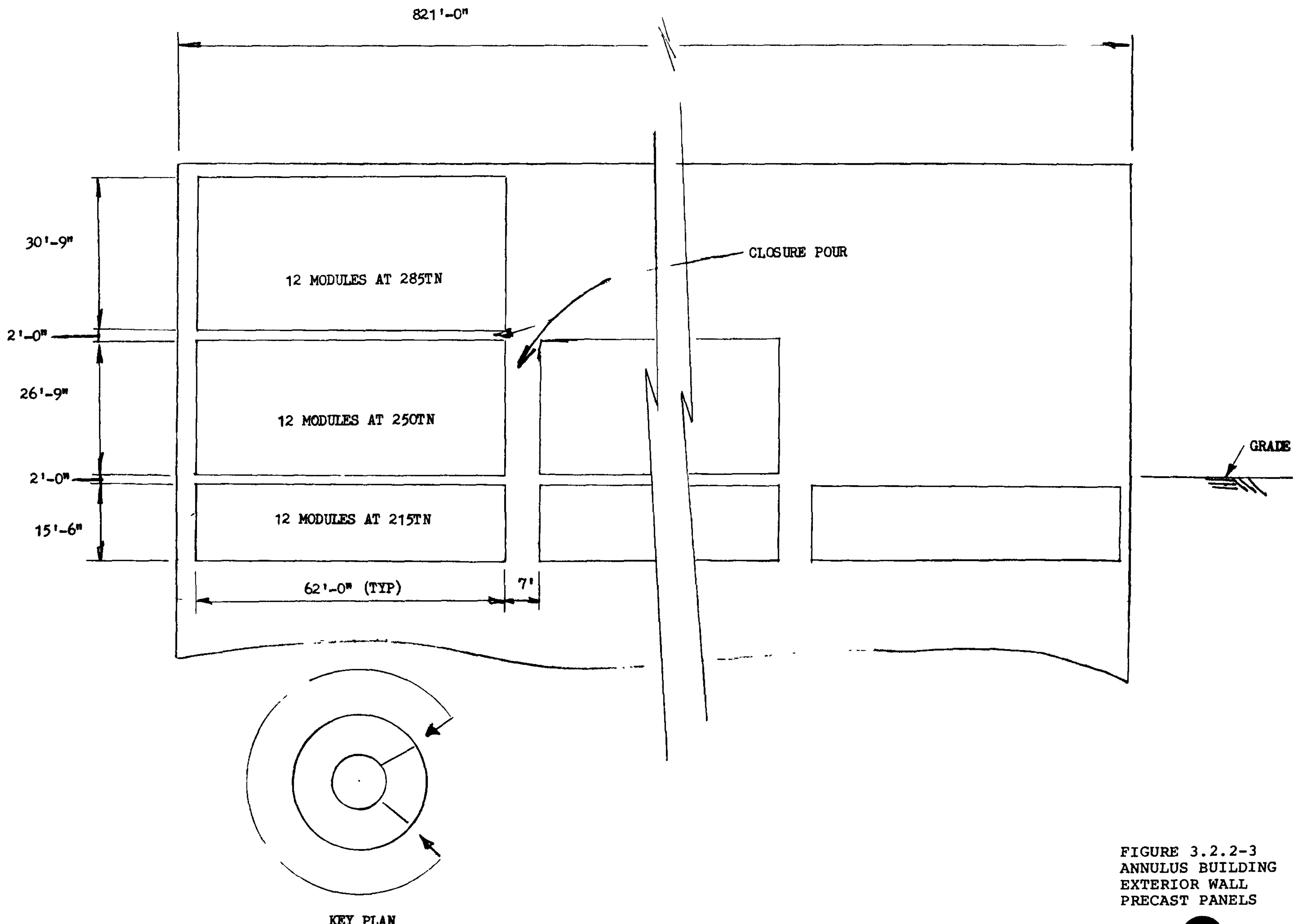
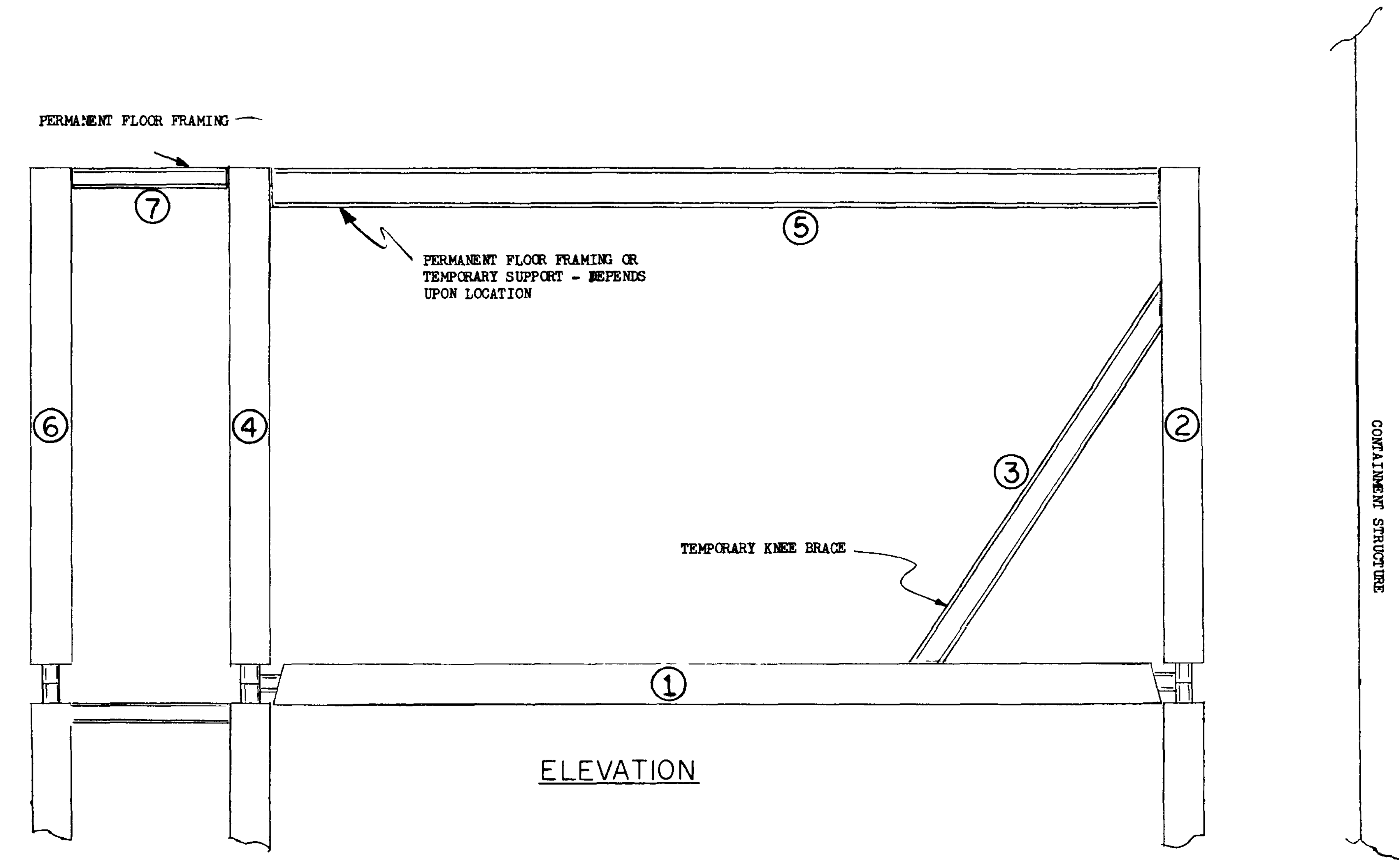


FIGURE 3.2.2-3
ANNULUS BUILDING
EXTERIOR WALL
PRECAST PANELS



NOTES:

NUMBERS INDICATE ERECTION SEQUENCE OF PRECAST PANELS & TEMPORARY SUPPORT STEEL

FIGURE 3.2.2-4
TYPICAL PRECAST PANEL ERECTION SEQUENCE,
ANNULUS BUILDING

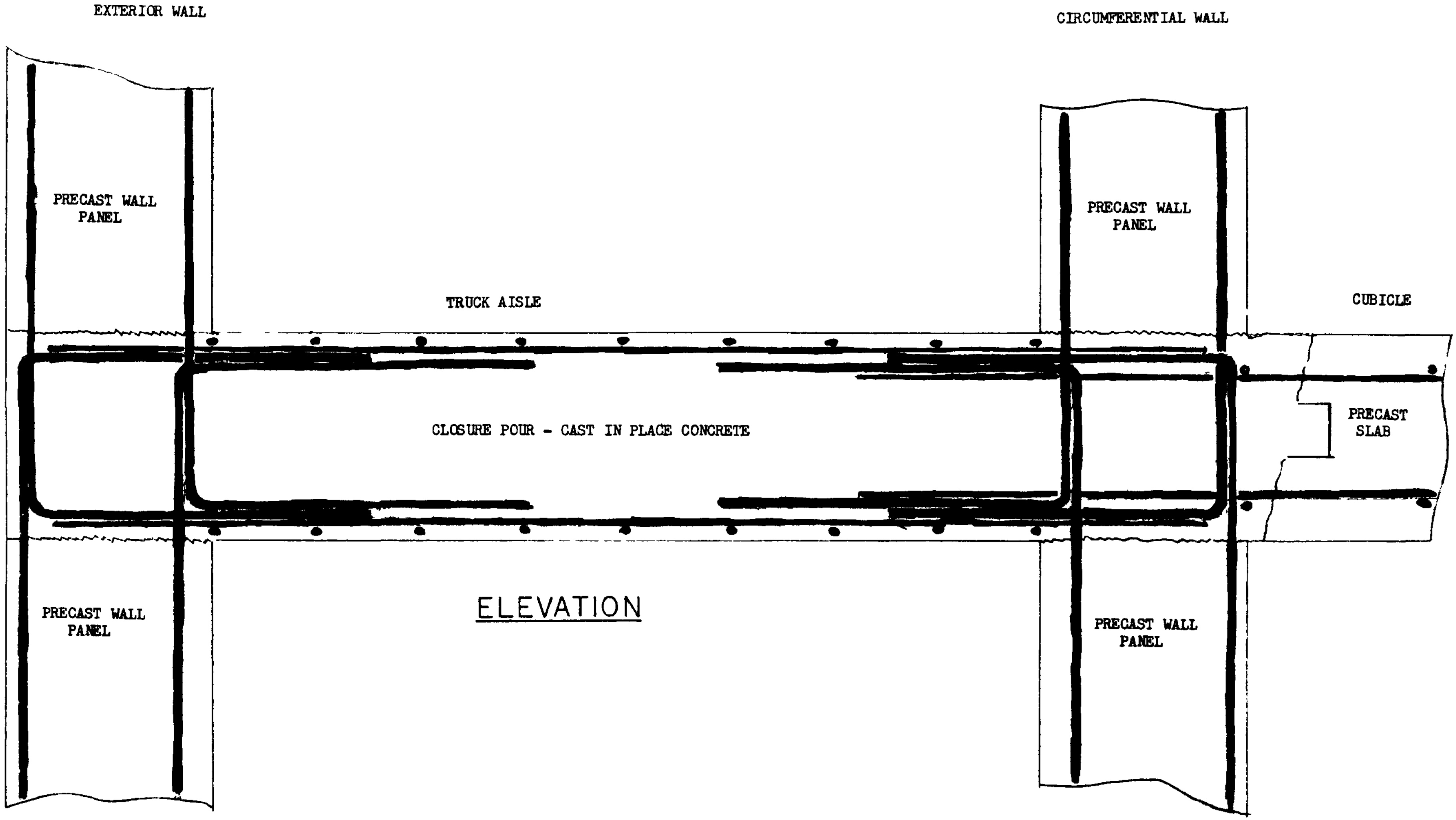
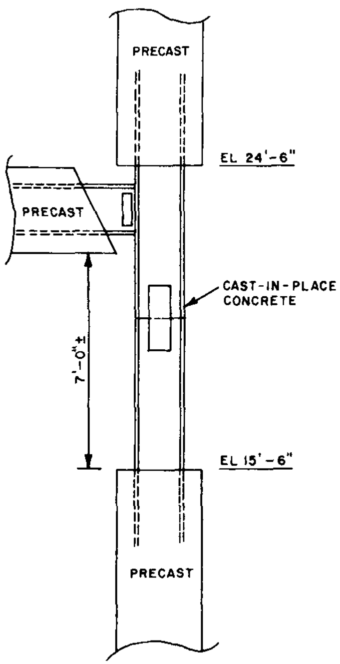


FIGURE 3.2.2-5
ANNULUS BUILDING
TYPICAL CLOSURE POUR

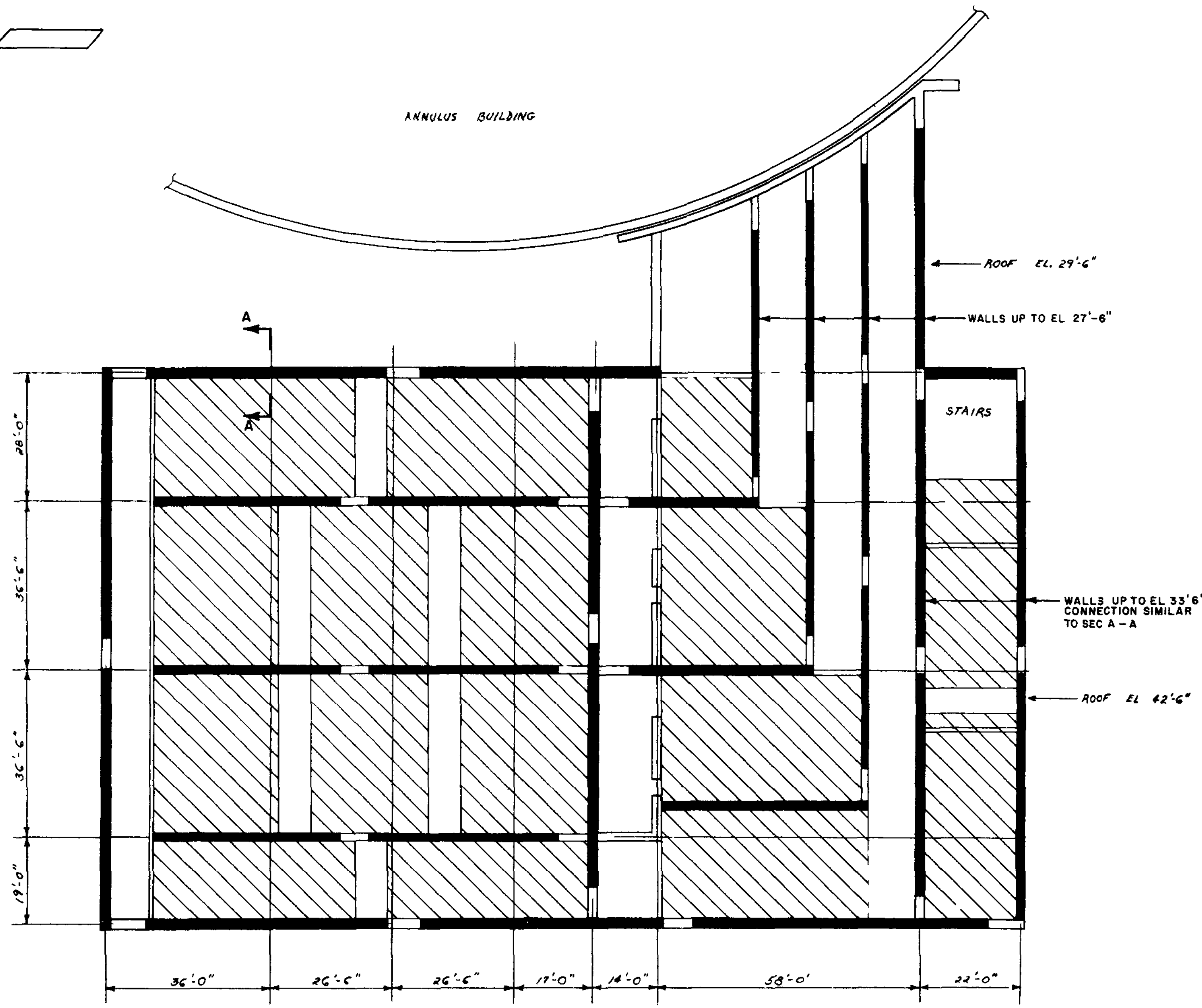


SECTION A—A

SCALE ½"=1'-0"

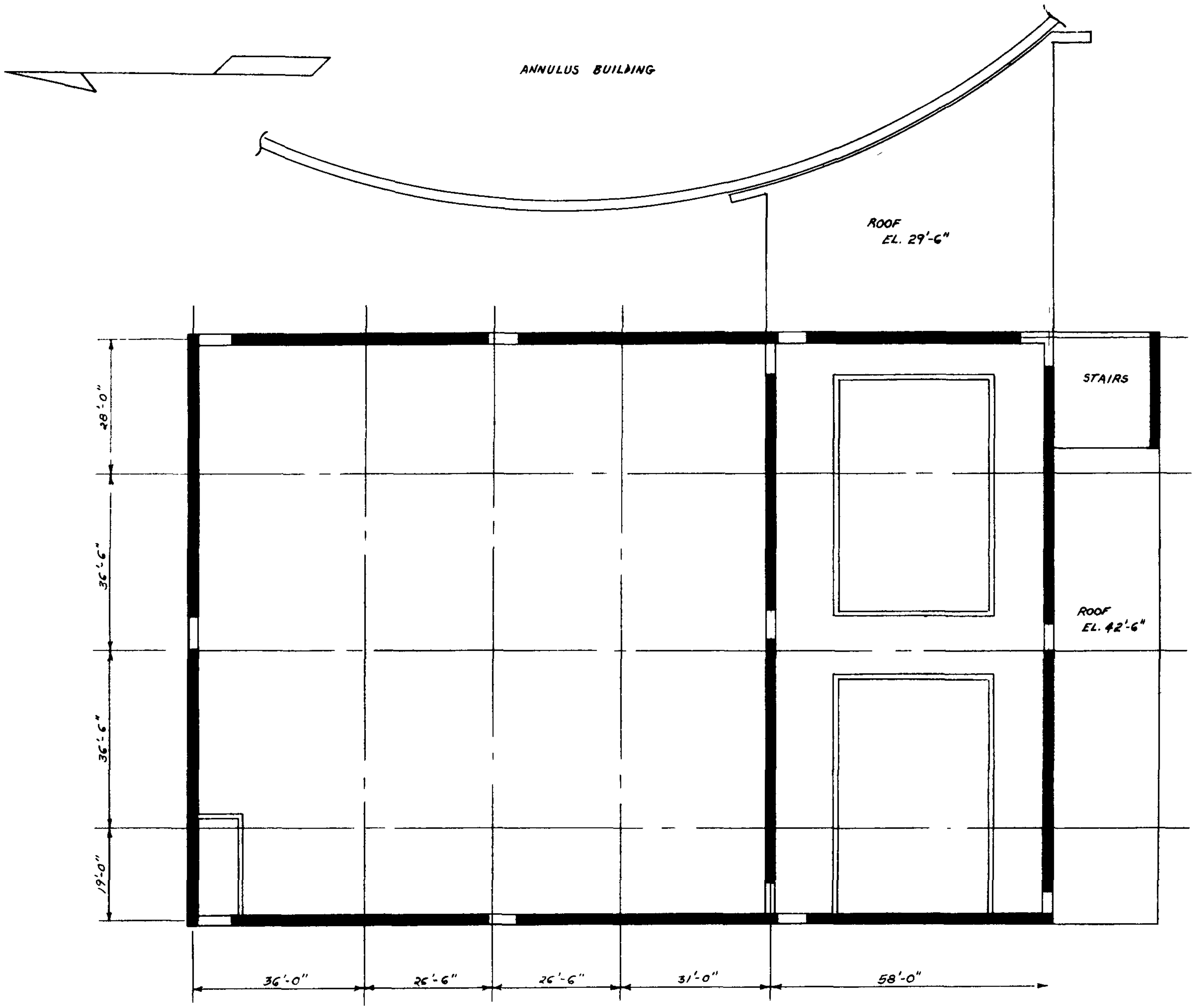
TYPICAL DETAIL FOR FLOOR AND WALL SUPPORT PRIOR TO PLACEMENT OF CAST-IN-PLACE CONCRETE

WALLS WITH CAST-IN-PLACE CONCRETE SLABS ON ONE OR BOTH SIDES EXTEND UP TO EL 22'-6".



EL. 24'-6"

FIGURE 3.2.2-6 SH. 1 of 3
CONTROL BUILDING
PRECAST PANELS



EL. 48'-6"

FIGURE 3.2.2-6 SH. 2 of 3
CONTROL BUILDING
PRECAST PANELS

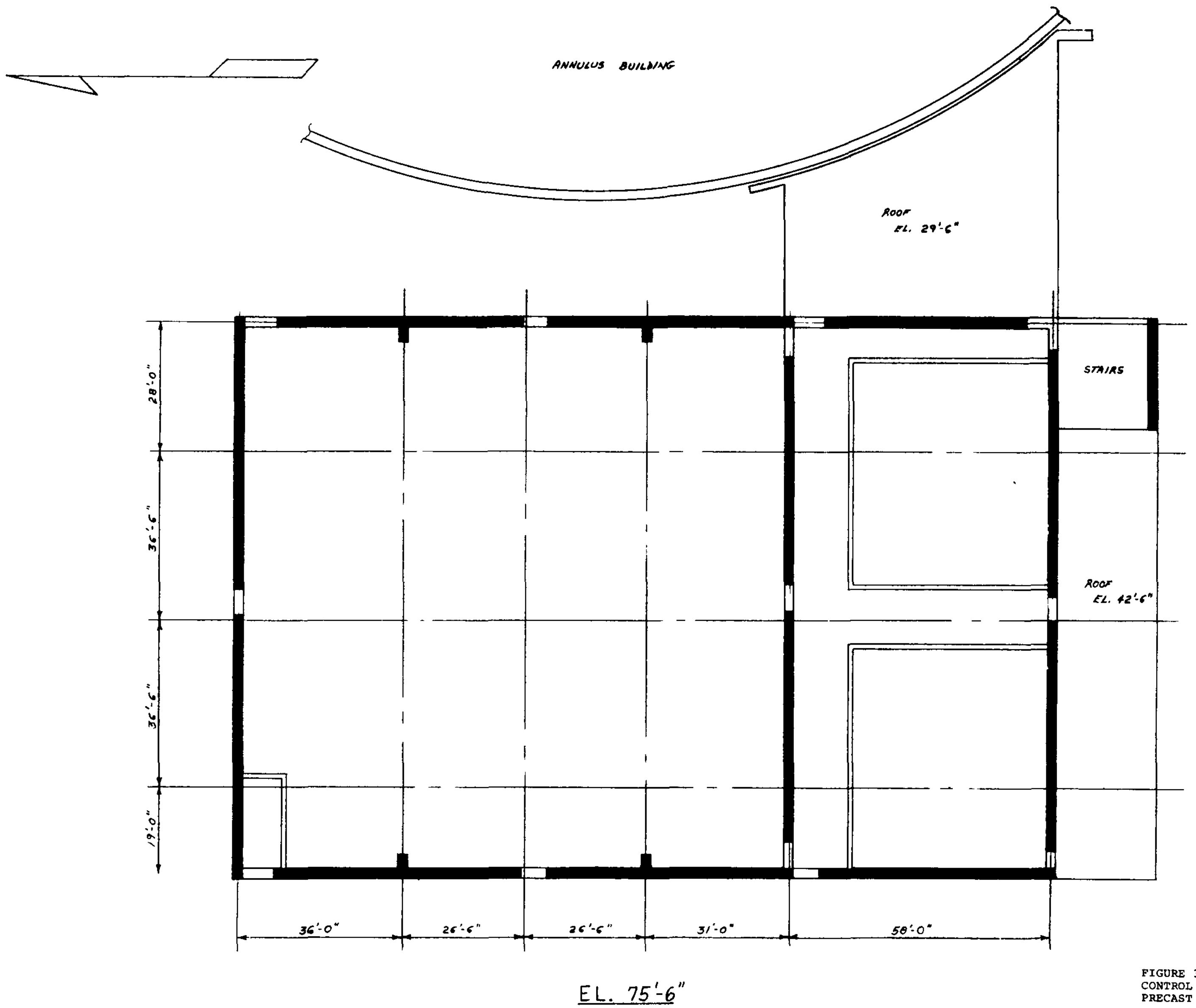
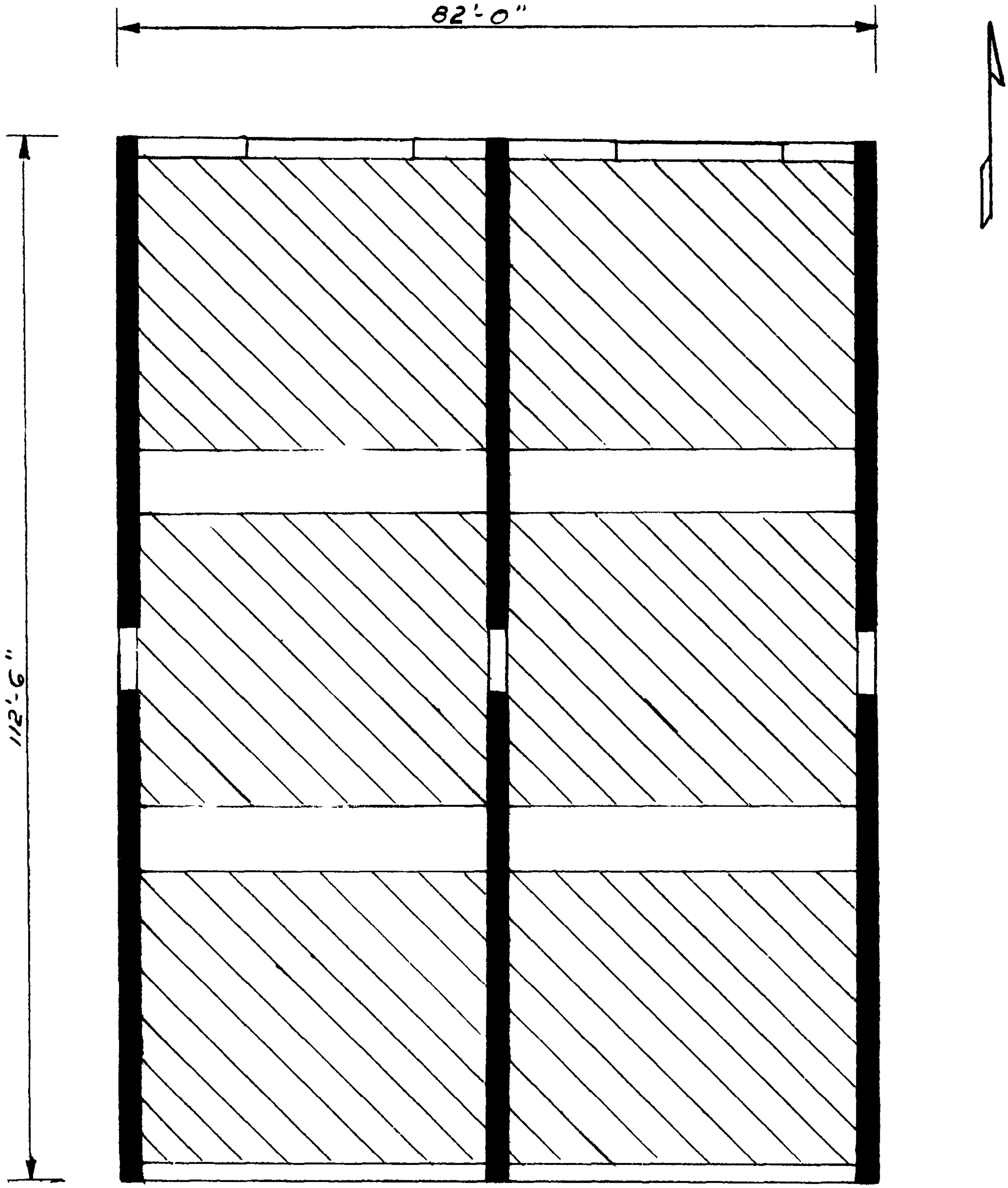
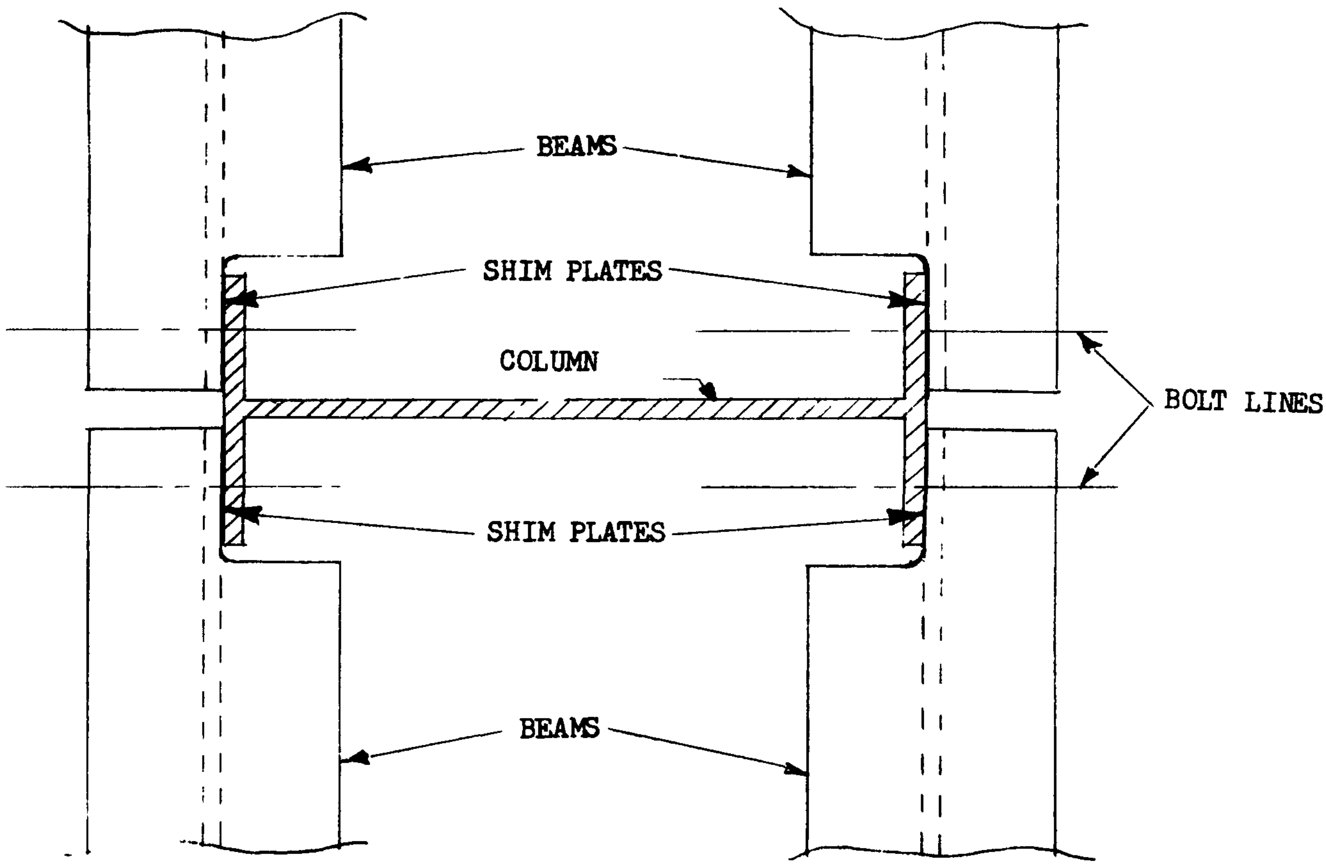


FIGURE 3.2.2-6 SH. 3 of 3
CONTROL BUILDING
PRECAST PANELS



PRECAST WALLS - EL. 0'-6" TO EL. 27'-6"
PRECAST ROOF SLABS AT EL. 36'-6" (TOP).

FIGURE 3.2.2-7
DIESEL GENERATOR BUILDING
PRECAST PANELS



PLAN

NOTE:

Beam flanges are coped as required to allow direct connection between column flanges and beam webs. Shim plates are used between the webs of module beams and the columns in order to provide erection clearance.

Beam webs are bolted to column flanges.

Columns are erected in the conventional manner prior to module installation.

FIGURE 3.2.3-1
STEEL MODULE TO
COLUMN CONNECTION
DETAIL

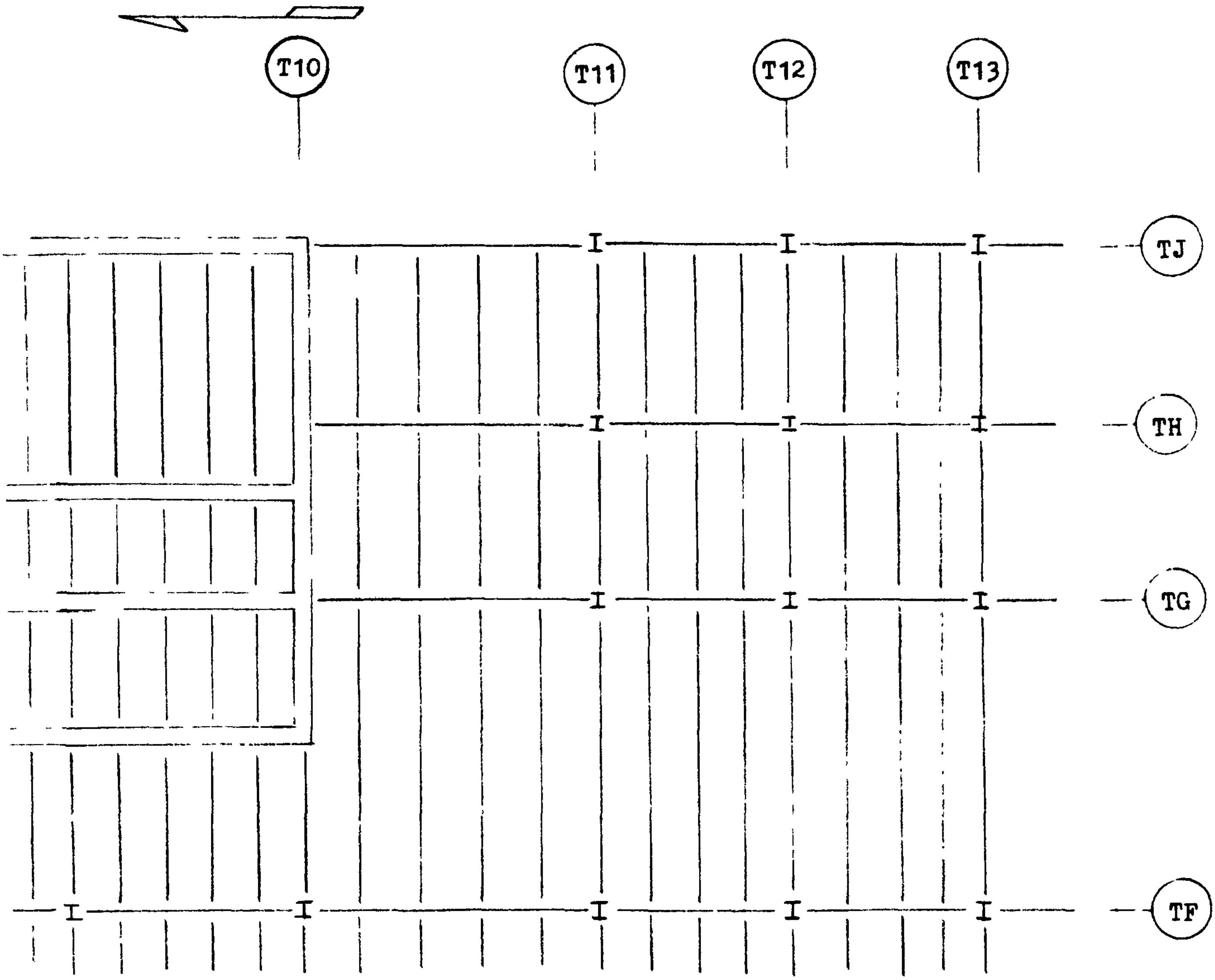


FIGURE 3.2.3-2
TURBINE BUILDING, EXISTING
FLOOR STEEL ARRANGEMENT

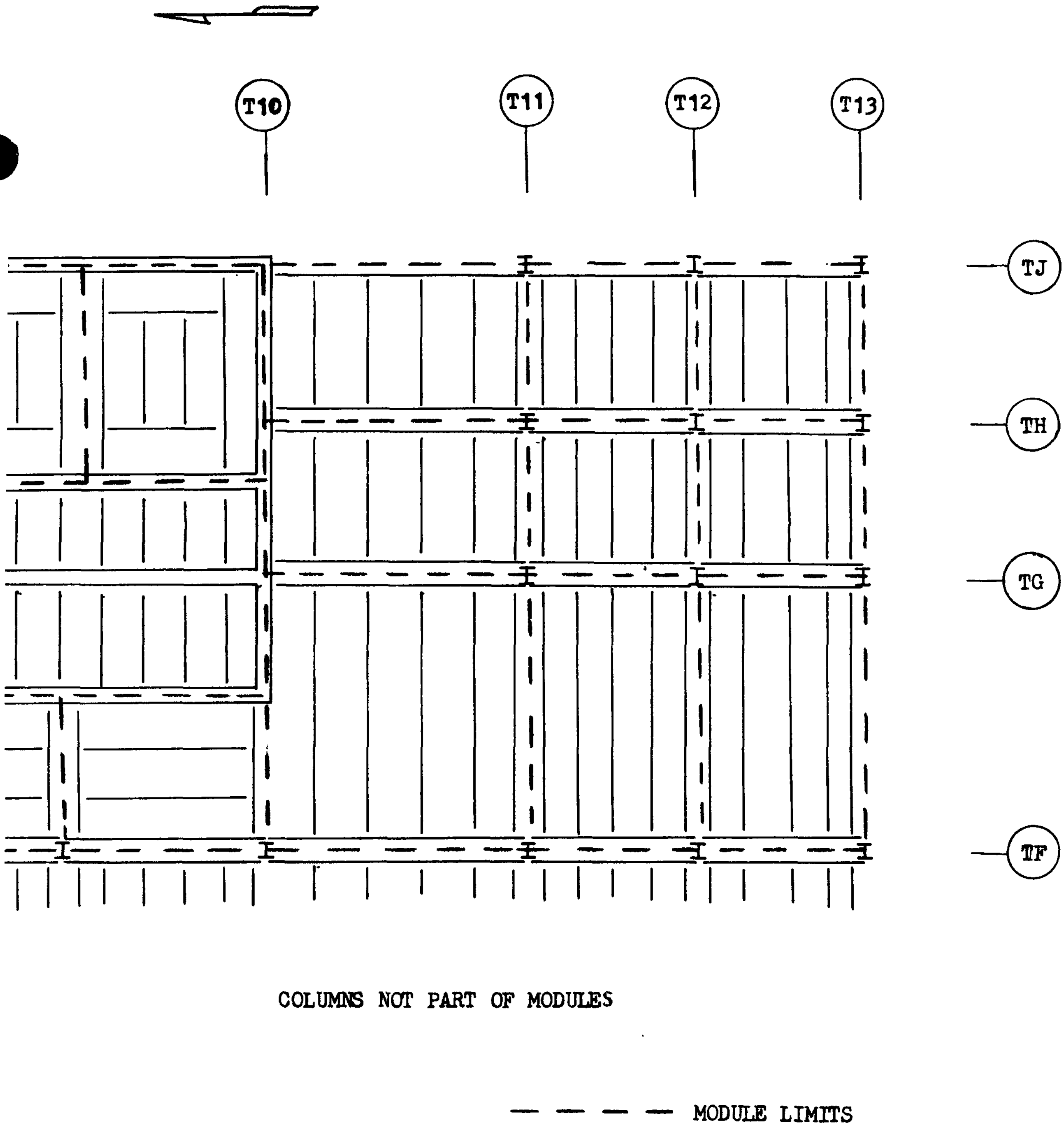
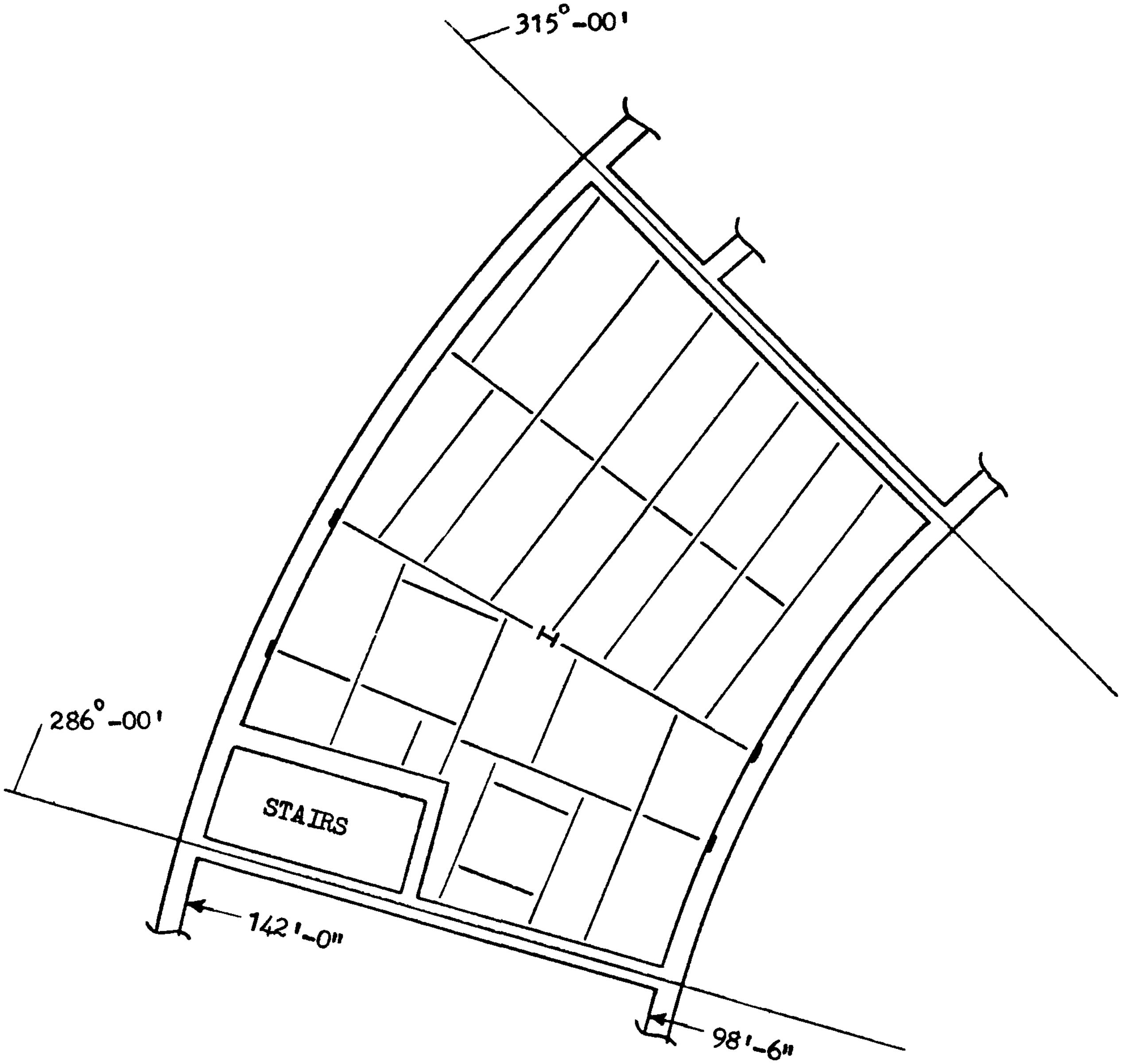


FIGURE 3.2.3-3
TURBINE BUILDING, PROPOSED
FLOOR STEEL MODULES



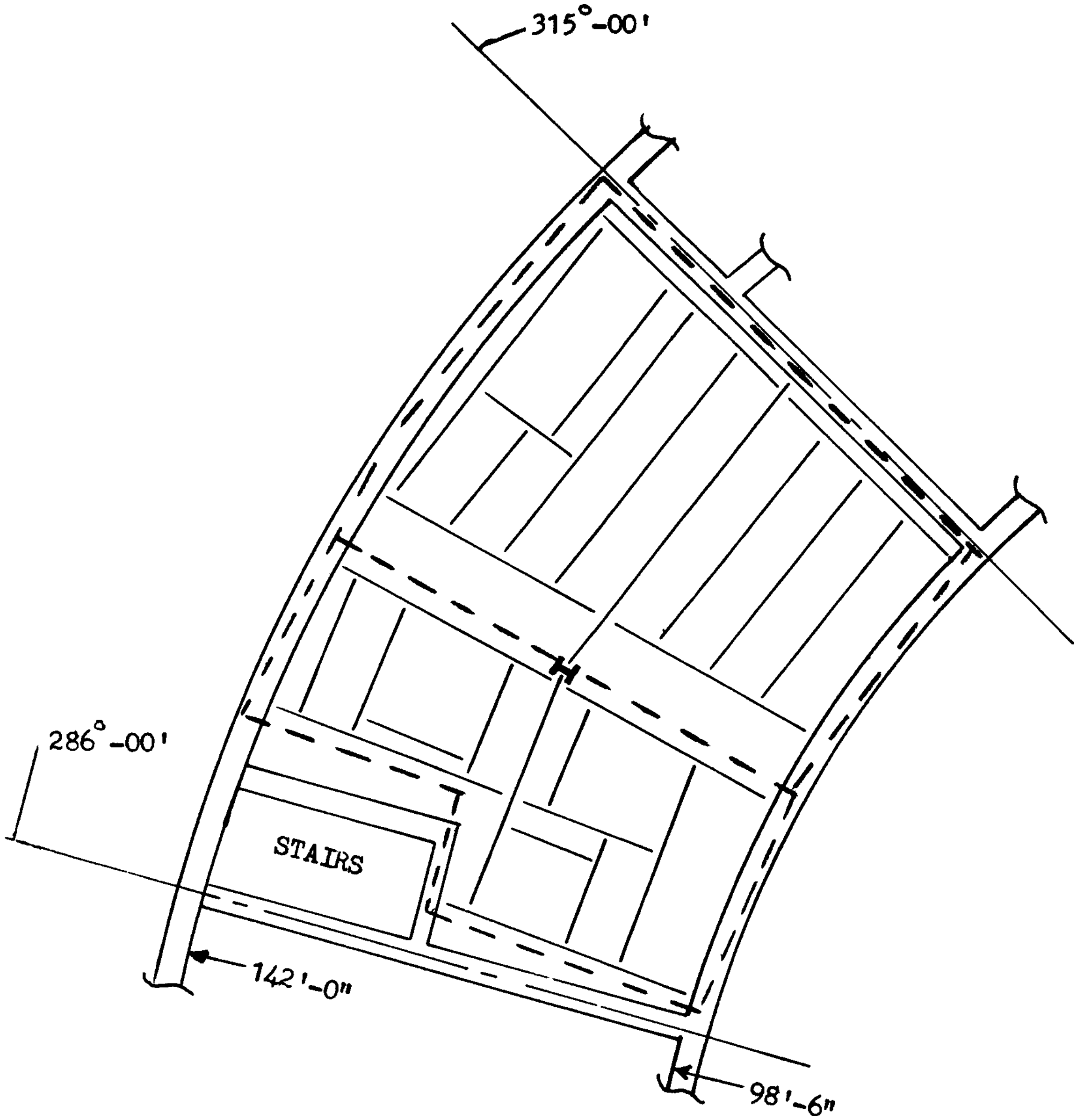
NOTE:

Beams set in wall pockets unless otherwise noted.

— Embedded plate for beam support

Primary members W36 x ___.

FIGURE 3.2.3-4
ANNULUS BUILDING, EXISTING
FLOOR STEEL ARRANGEMENT



NOTE:

Beams set in wall pockets

Column not part of either module

— — — Module limits

FIGURE 3.2.3-5
ANNULUS BUILDING, PROPOSED
FLOOR STEEL MODULES

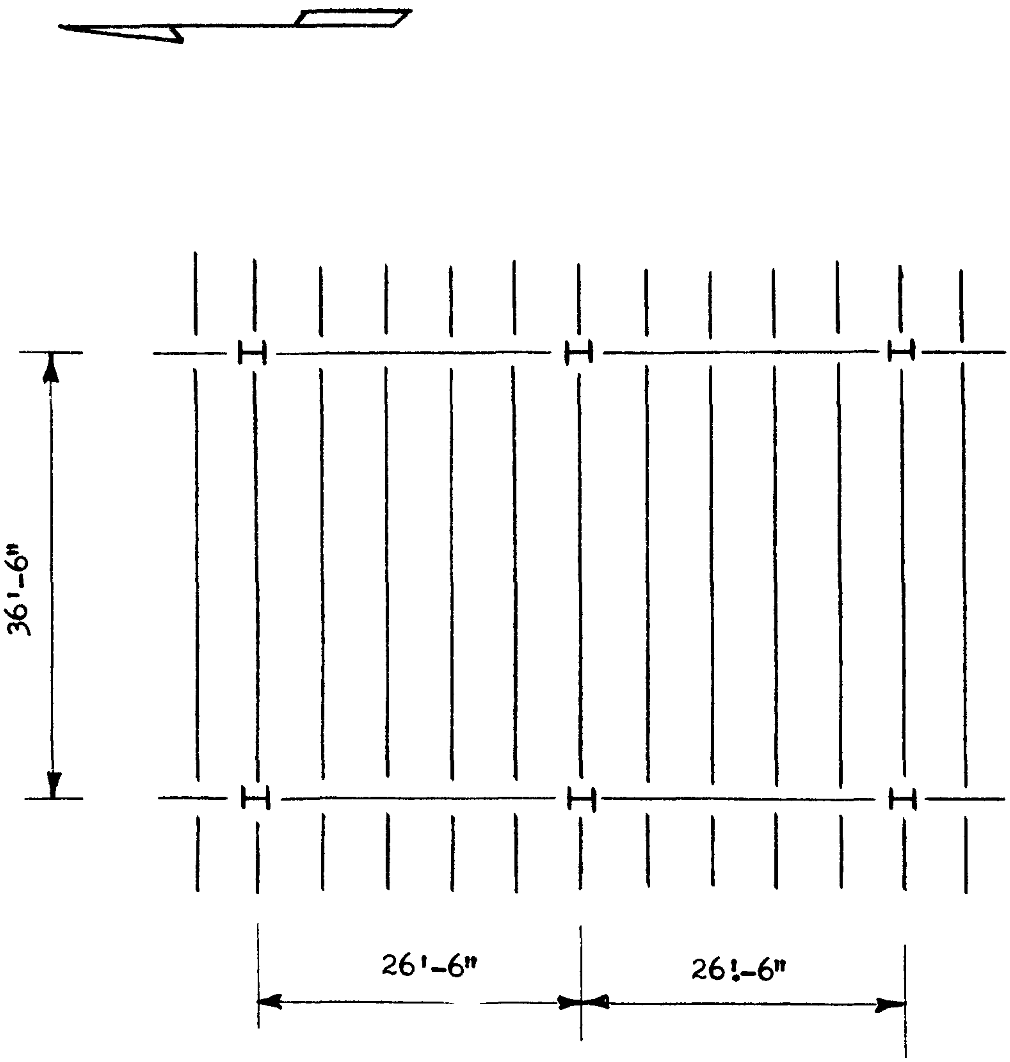


FIGURE 3.2.3-6
CONTROL BUILDING, EXISTING
FLOOR STEEL ARRANGEMENT

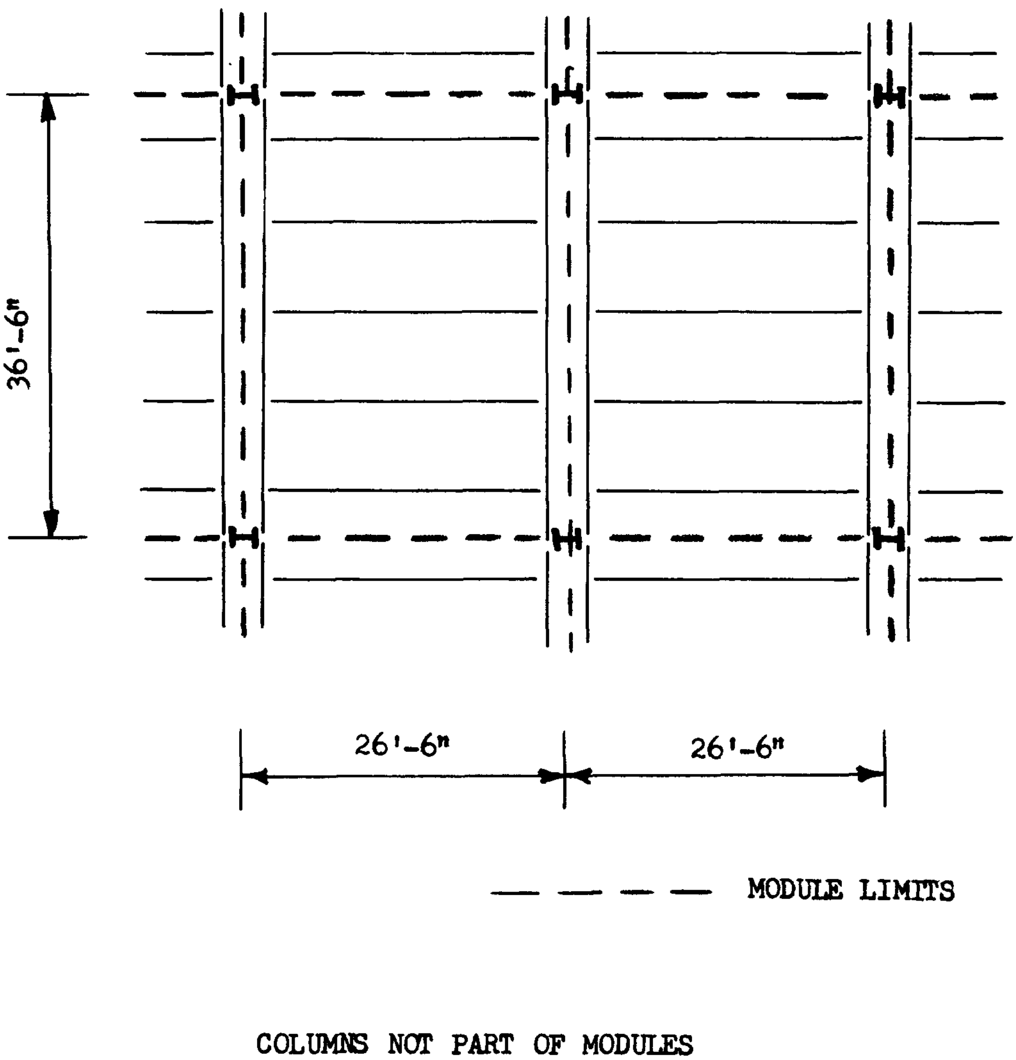
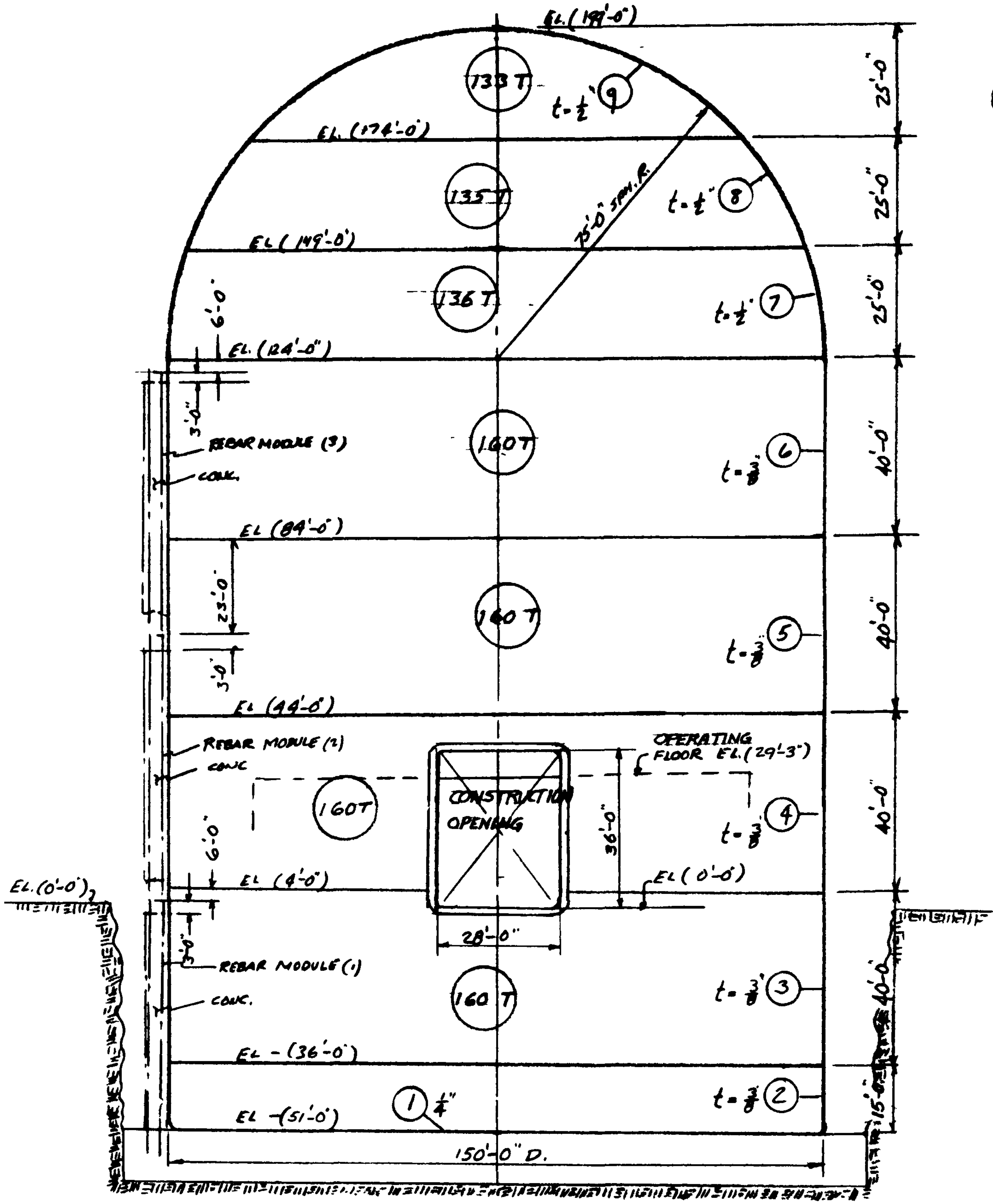


FIGURE 3.2.3-7
CONTROL BUILDING, PROPOSED
FLOOR STEEL MODULES



Note: See legend, Figure 3.2.4-2

FIGURE 3.2.4-1
CONTAINMENT LINER MODULES

LEGEND

(160 T) Weight of modules in tons i.e. modules 3, 4, 5 & 6 = 160 tons

(3) Liner shell ring No. 3 each ring has a height of 40'-0" and a thickness of 3/8".

EL (0'-0") Elevation of grade

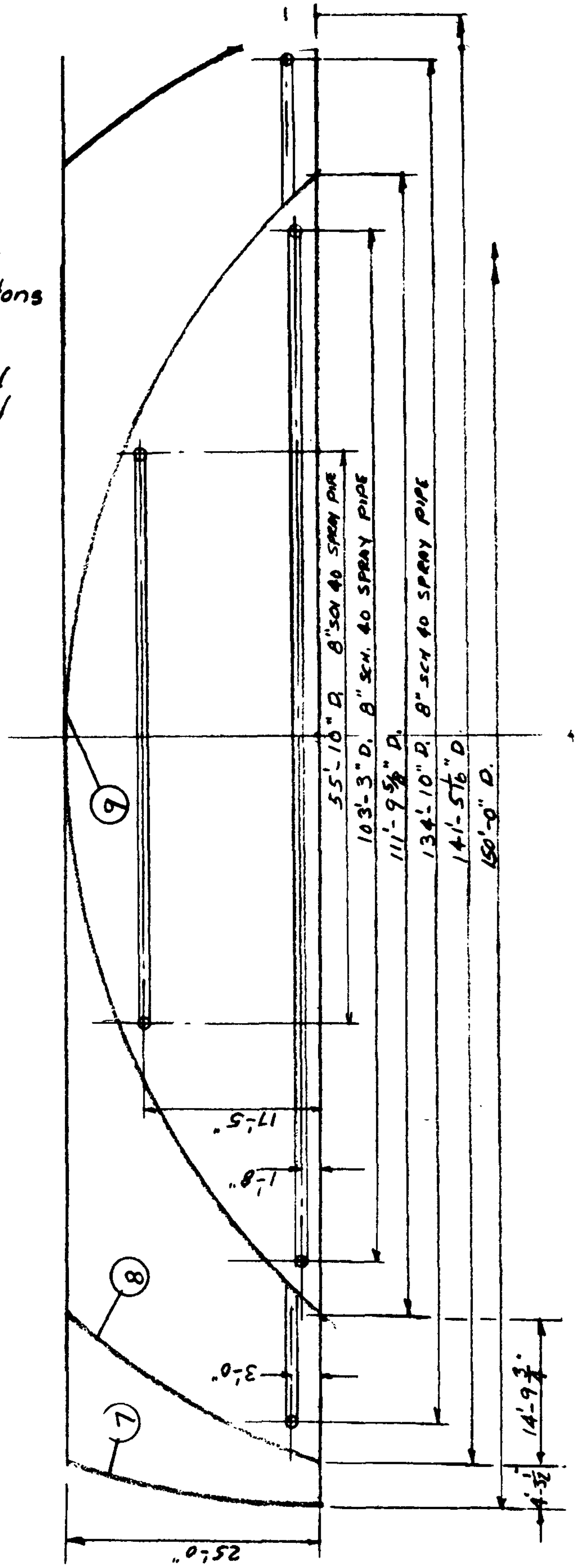


FIGURE 3.2.4-2
CONTAINMENT LINER
MODULES

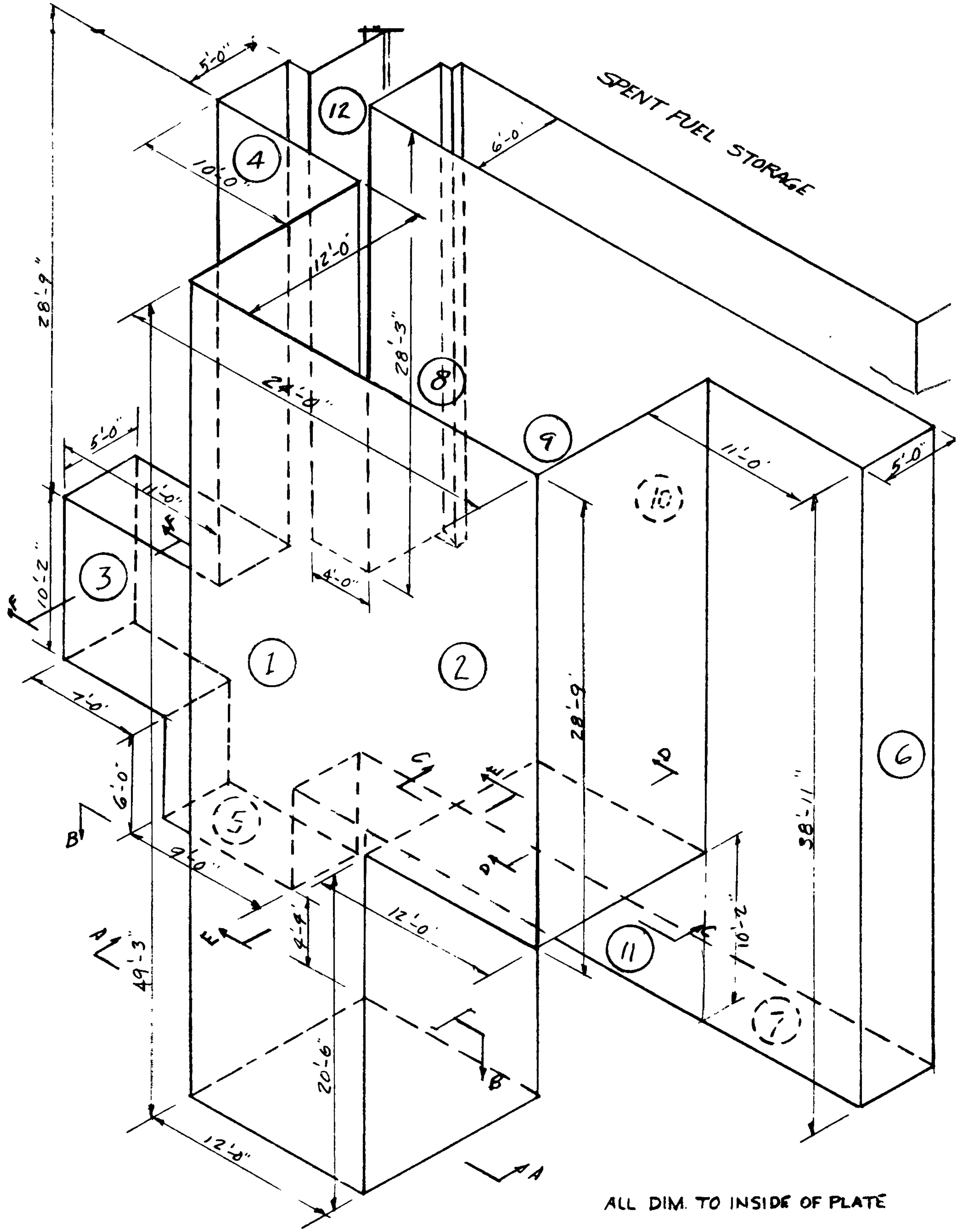
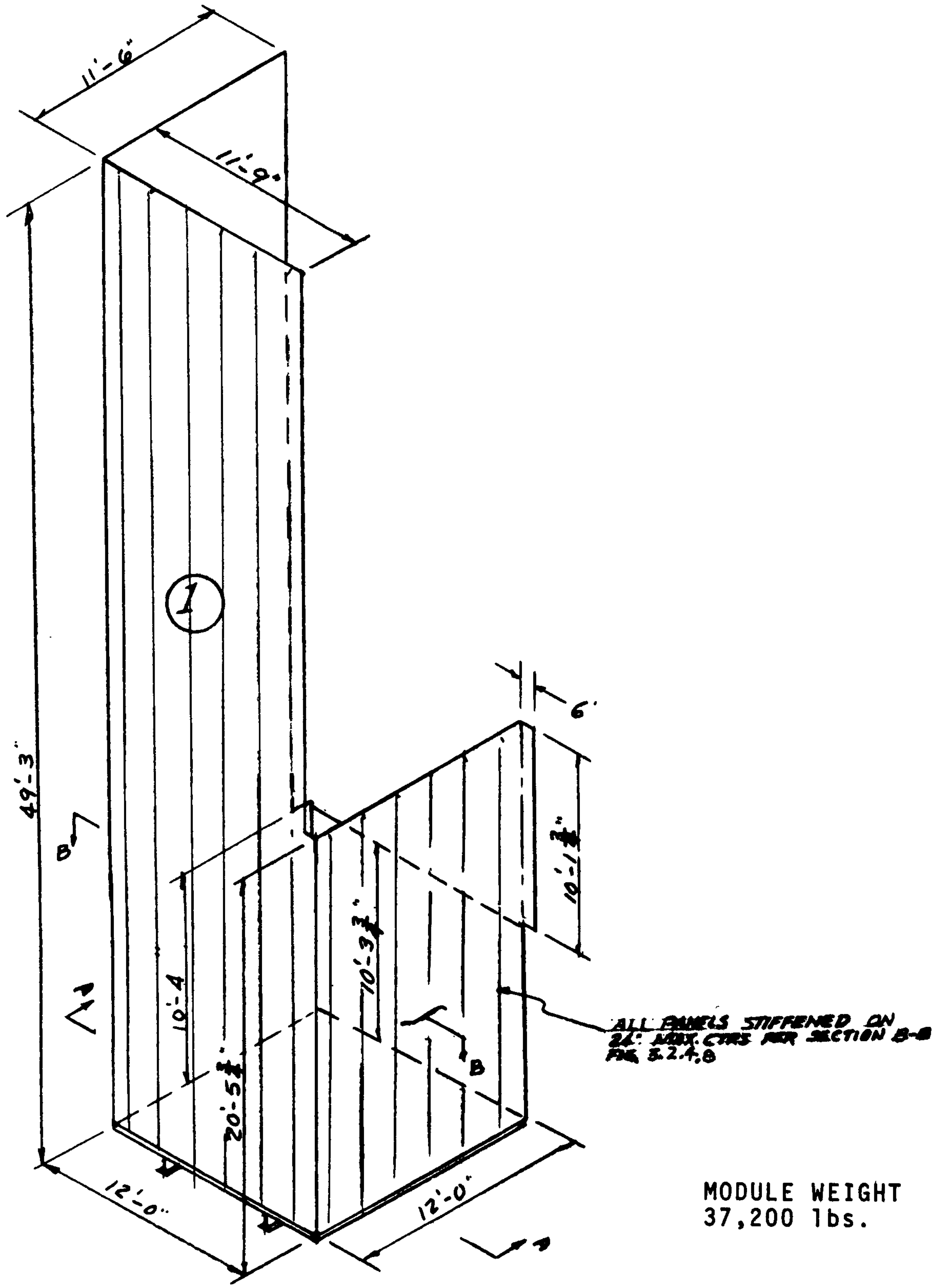
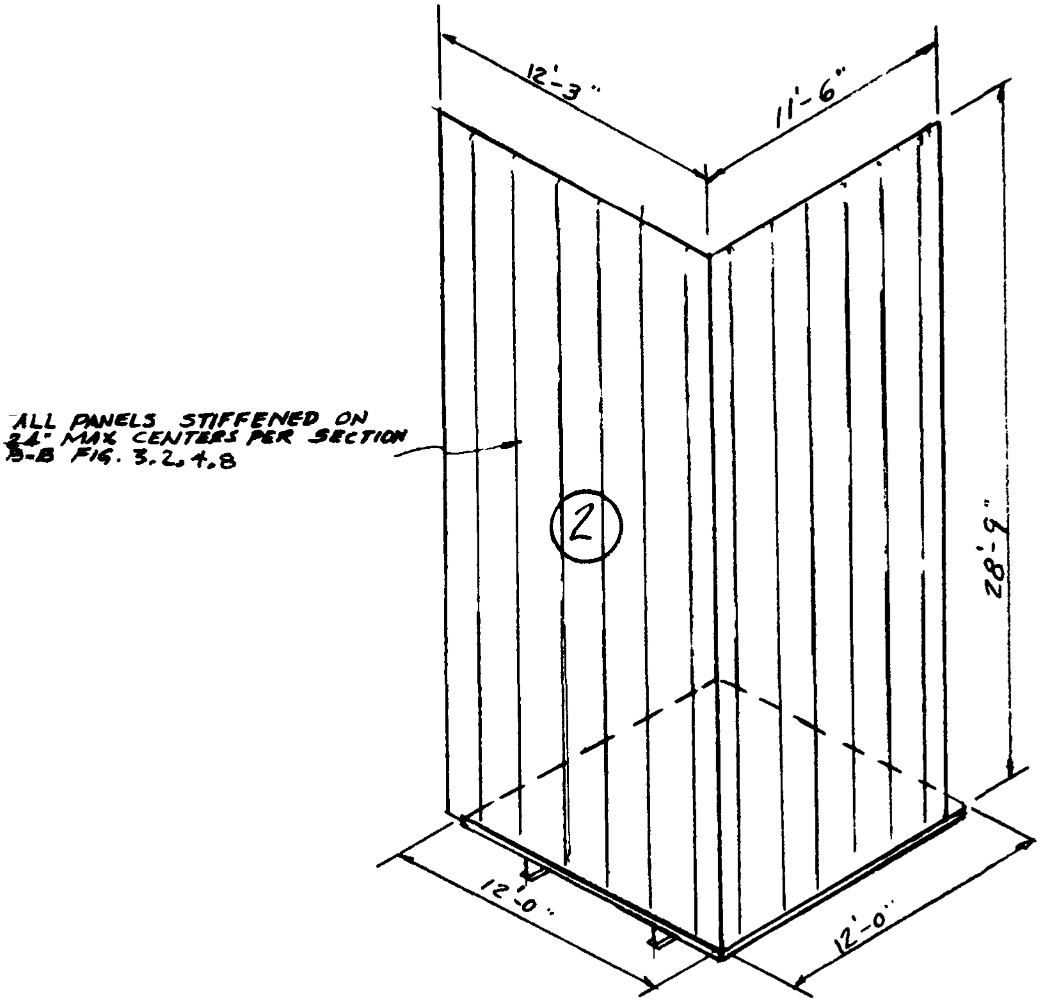


FIGURE 3.2.4-3
TRANSFER CANAL LINER



MODULE WEIGHT
37,200 lbs.

FIGURE 3.2.4-4
TRANSFER CANAL LINER



MODULE WEIGHT
20,100 lbs.

FIGURE 3.2.4-5
TRANSFER CANAL LINER

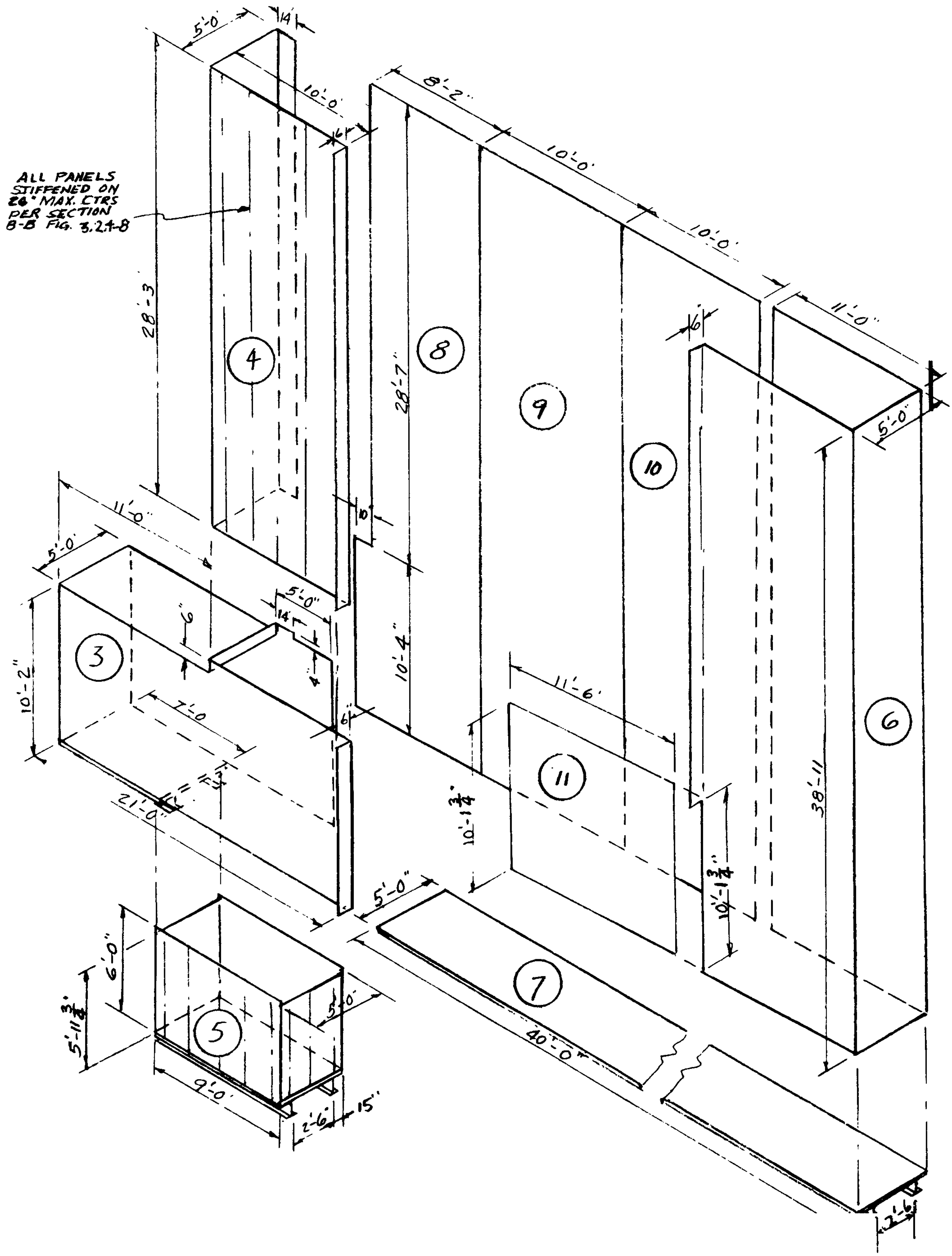
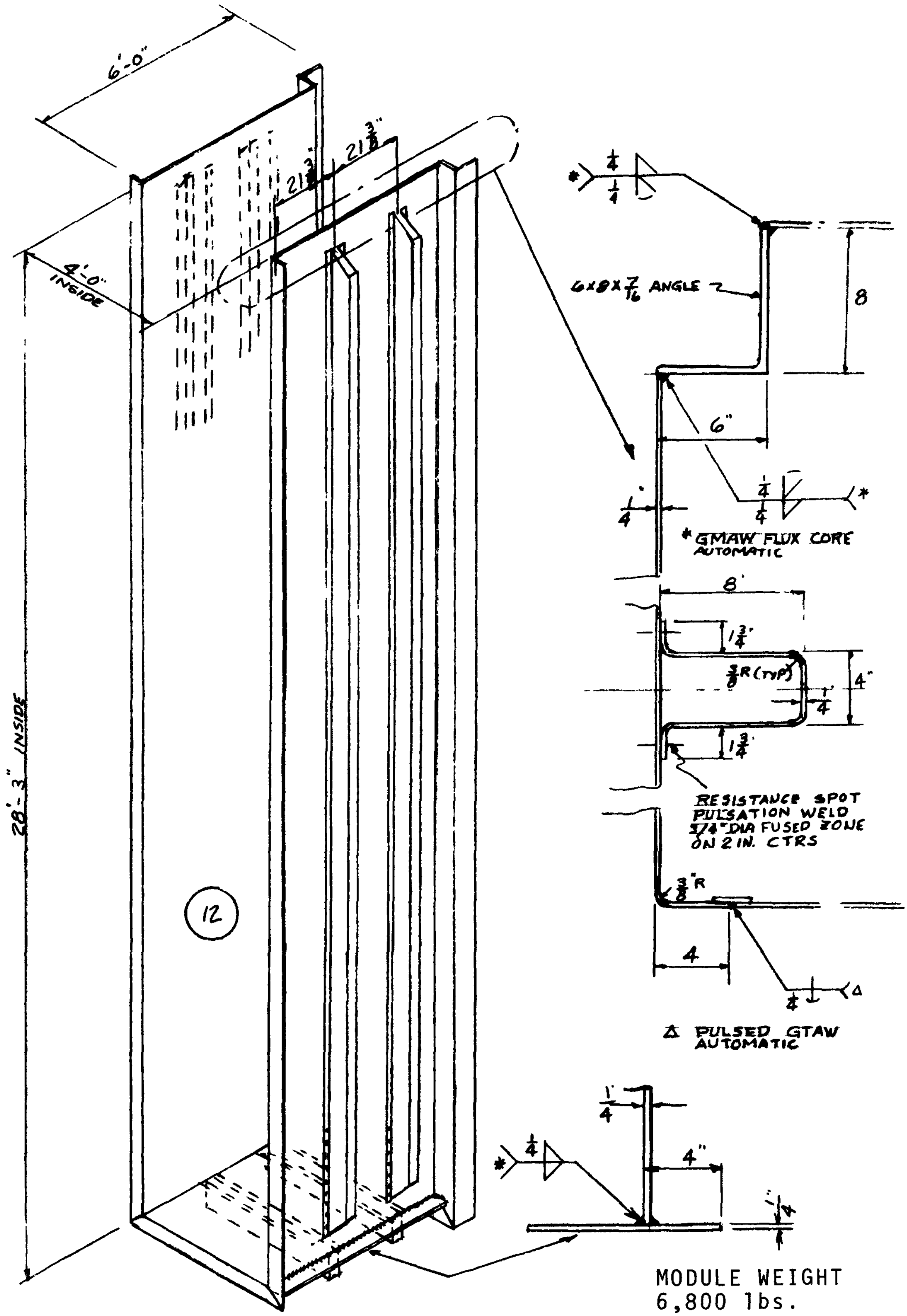


FIGURE 3.2.4-6
TRANSFER CANAL LINER



MODULE WEIGHT
6,800 lbs.

FIGURE 3.2.4-7
TRANSFER CANAL LINER

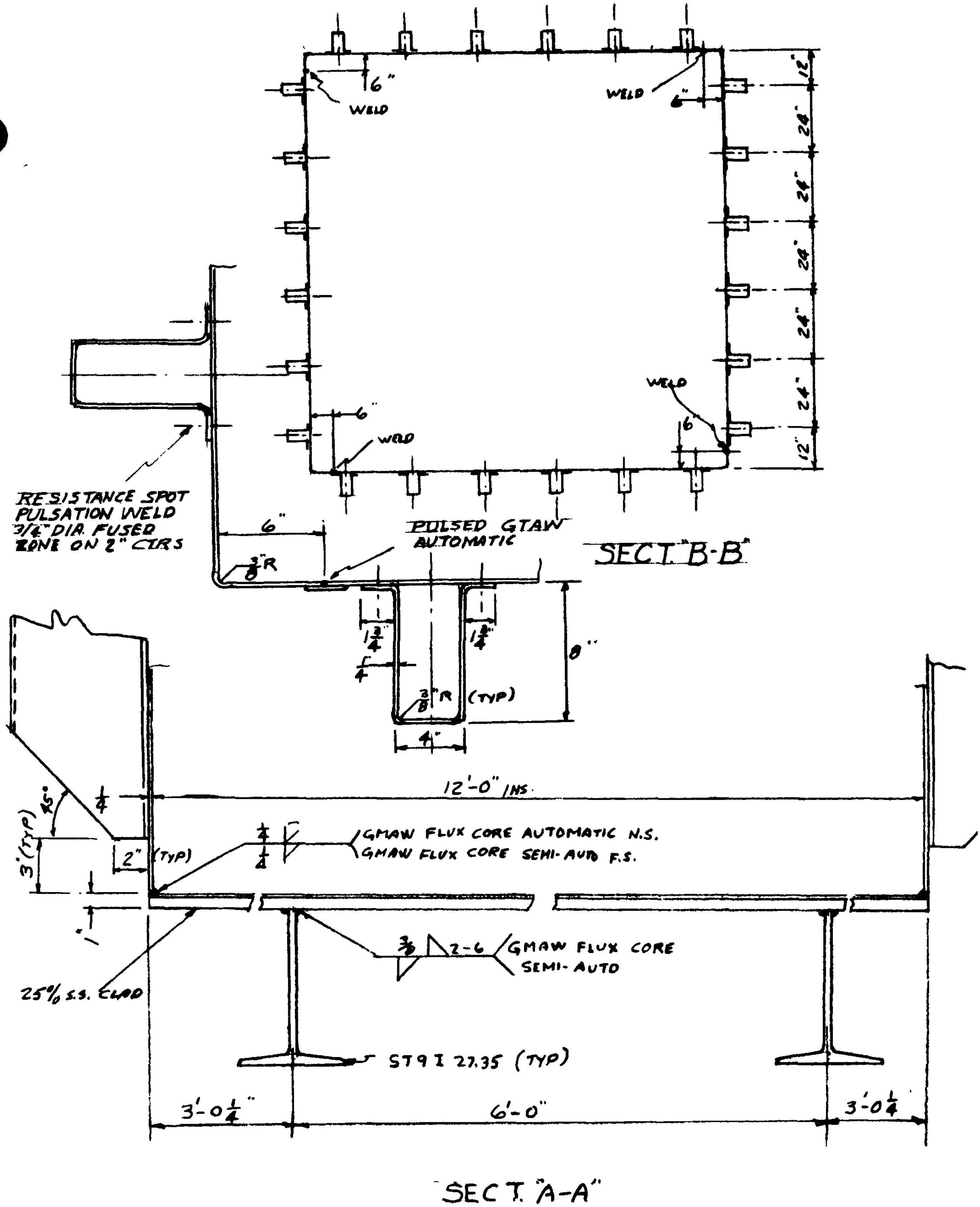


FIGURE 3.2.4-8
TRANSFER CANAL LINER

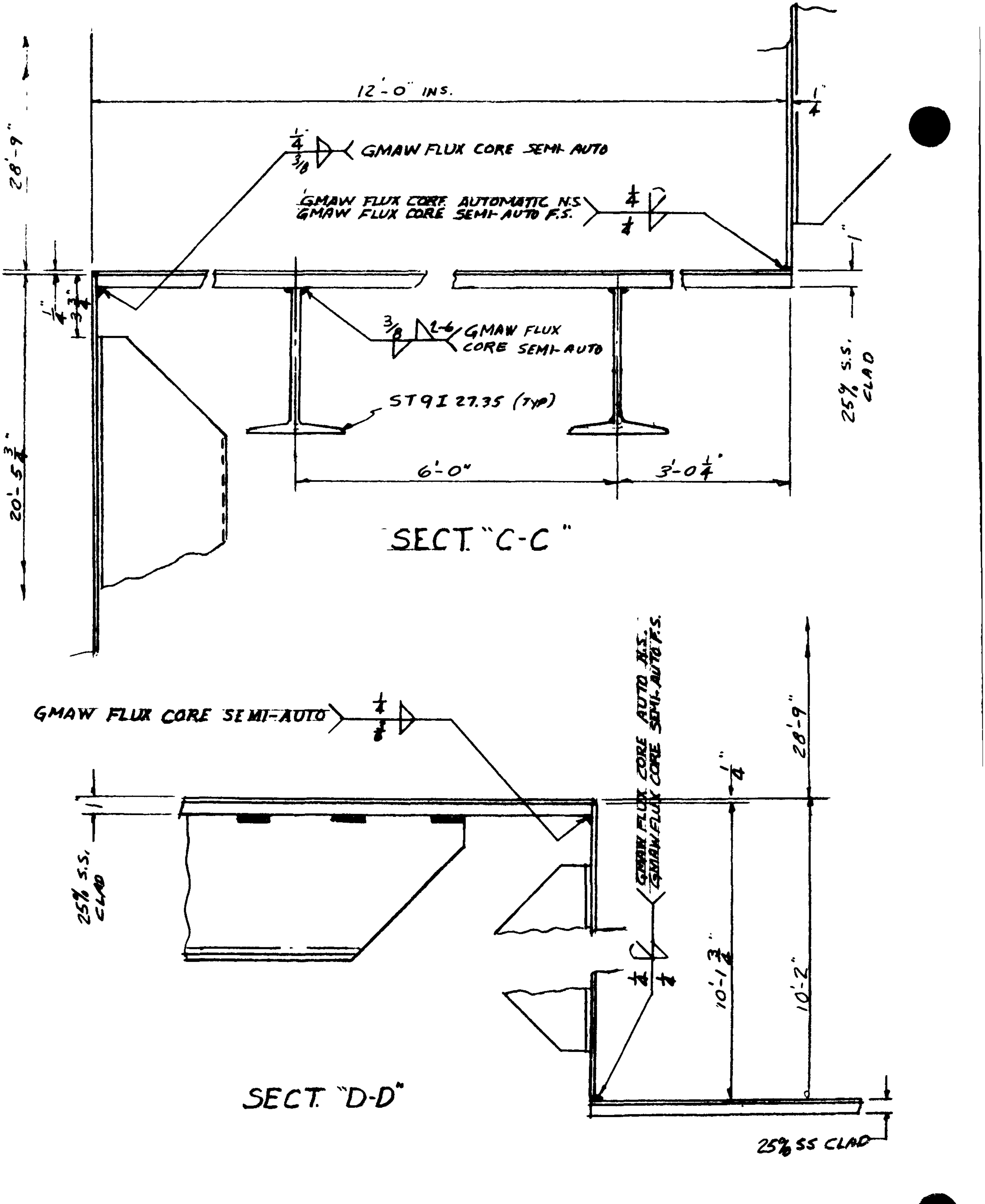


FIGURE 3.2.4-9
TRANSFER CANAL LINER

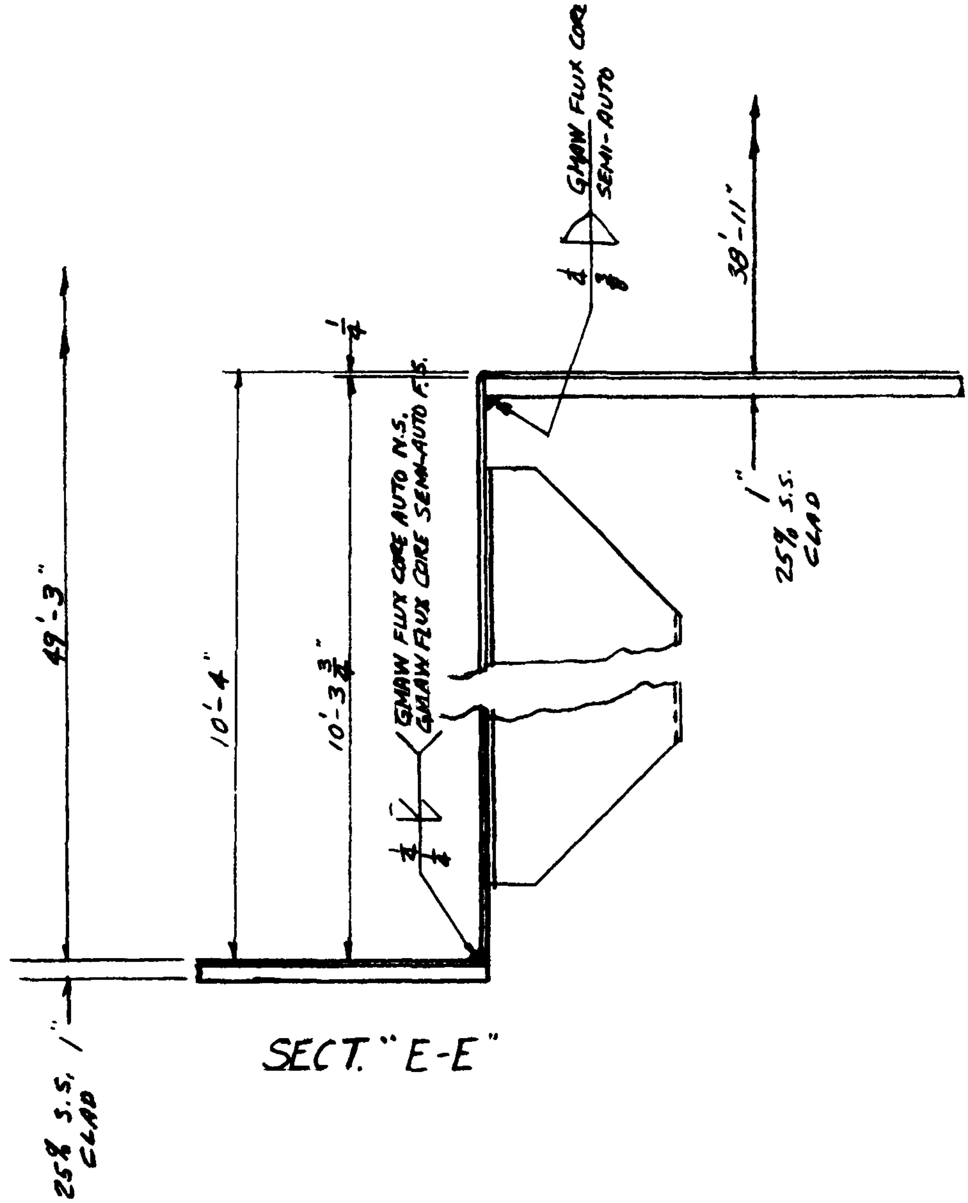


FIGURE 3.2.4-10
TRANSFER CANAL LINER

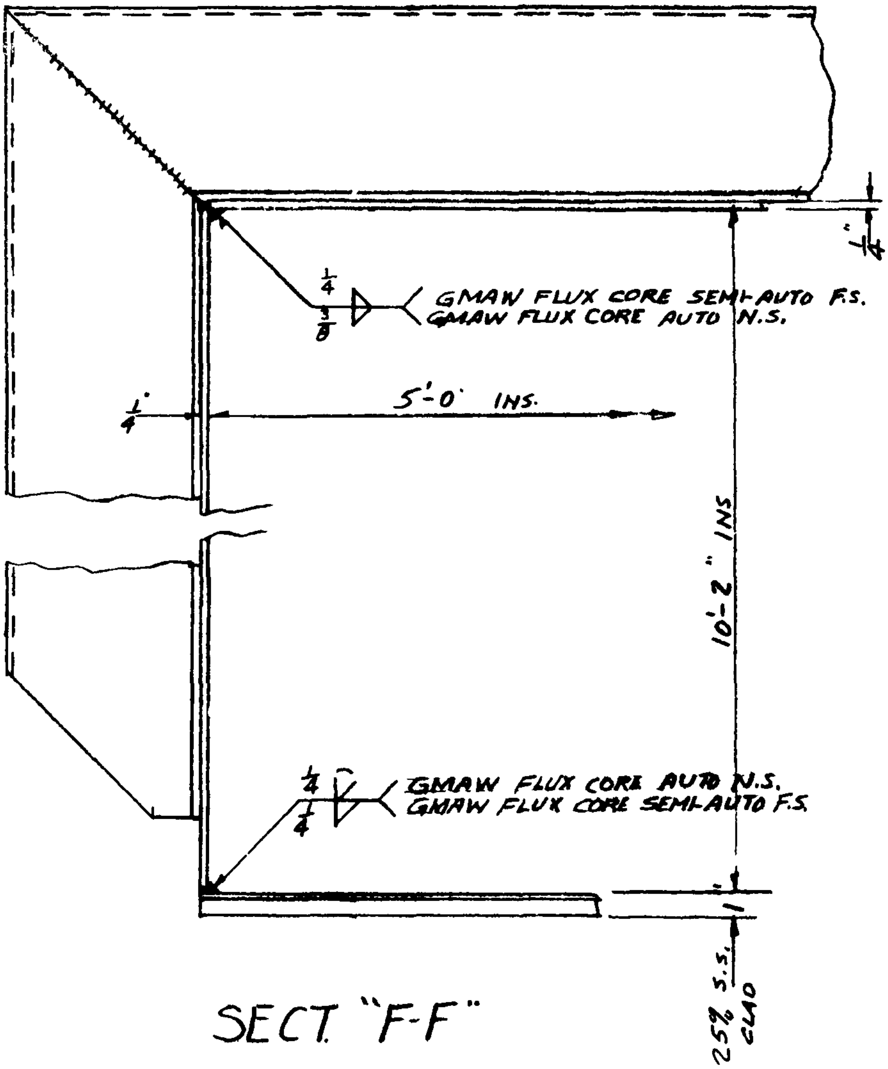


FIGURE 3.2.4-11
TRANSFER CANAL LINER

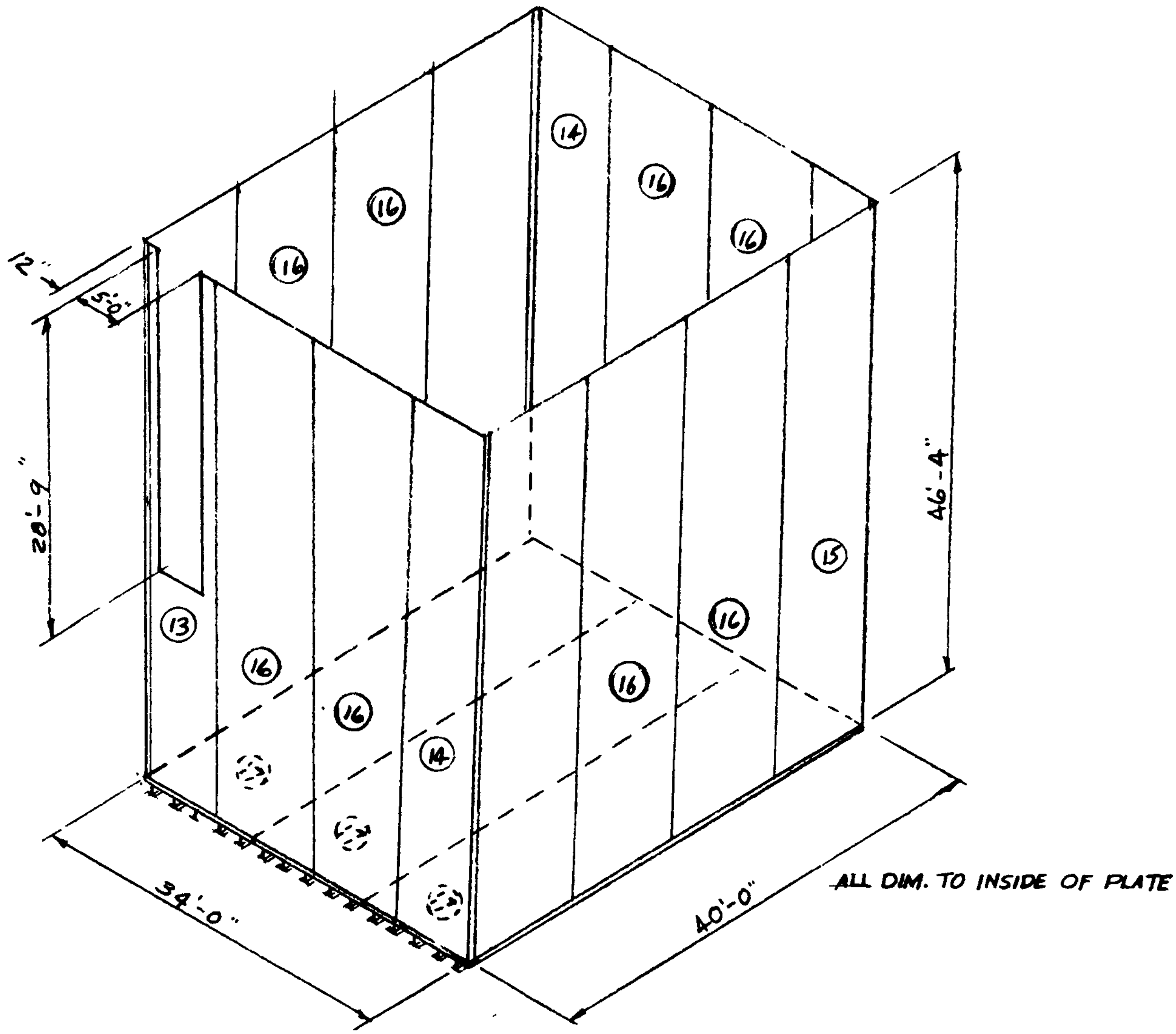
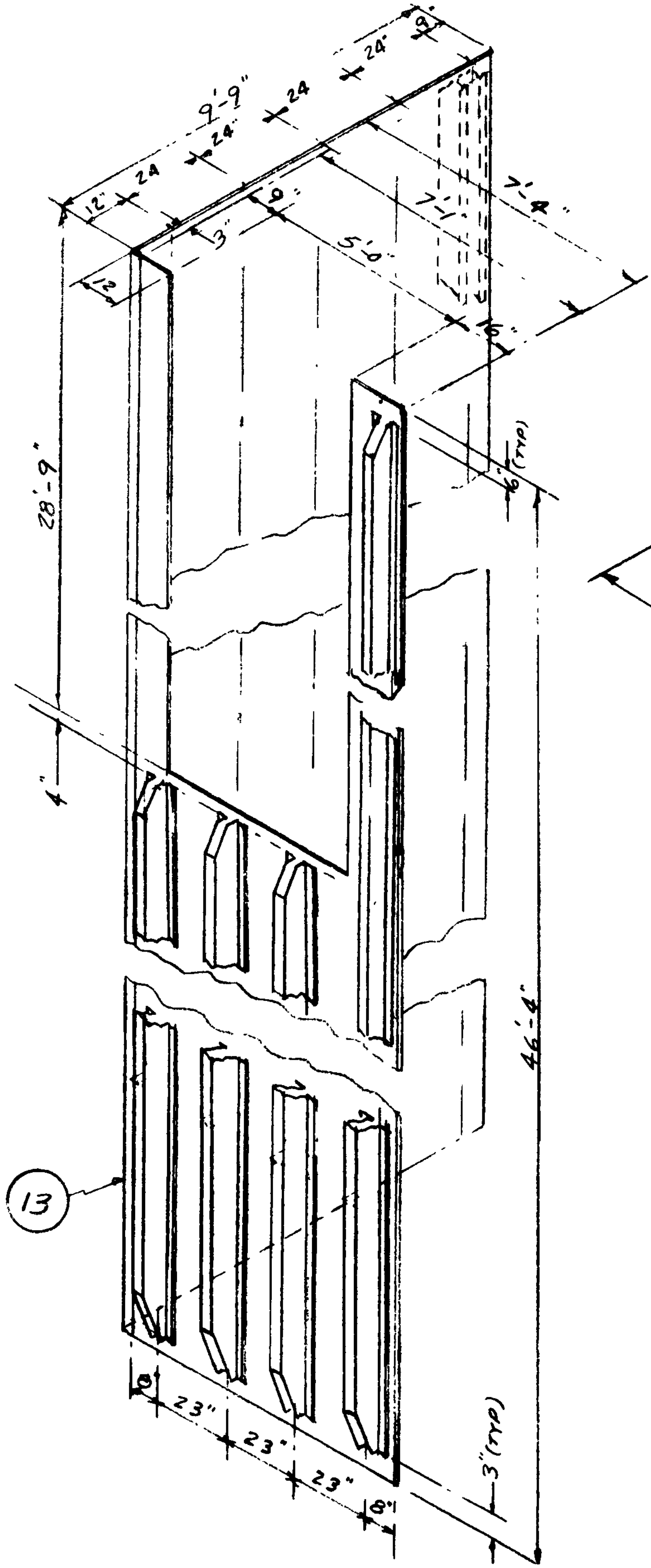
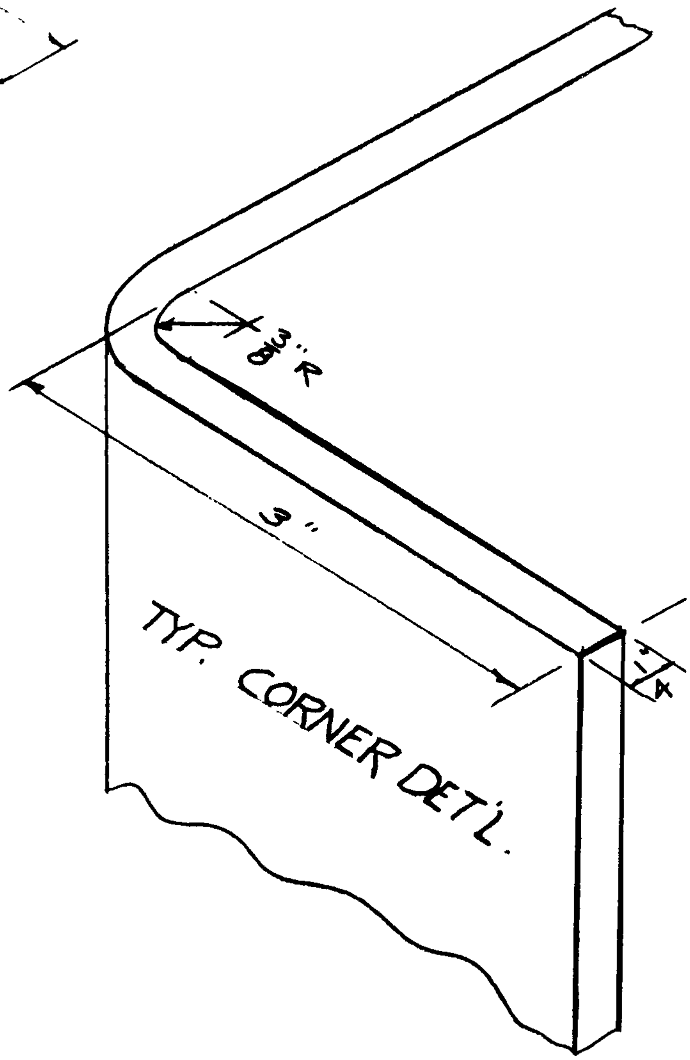


FIGURE 3.2.4-12
SPENT FUEL PIT LINER

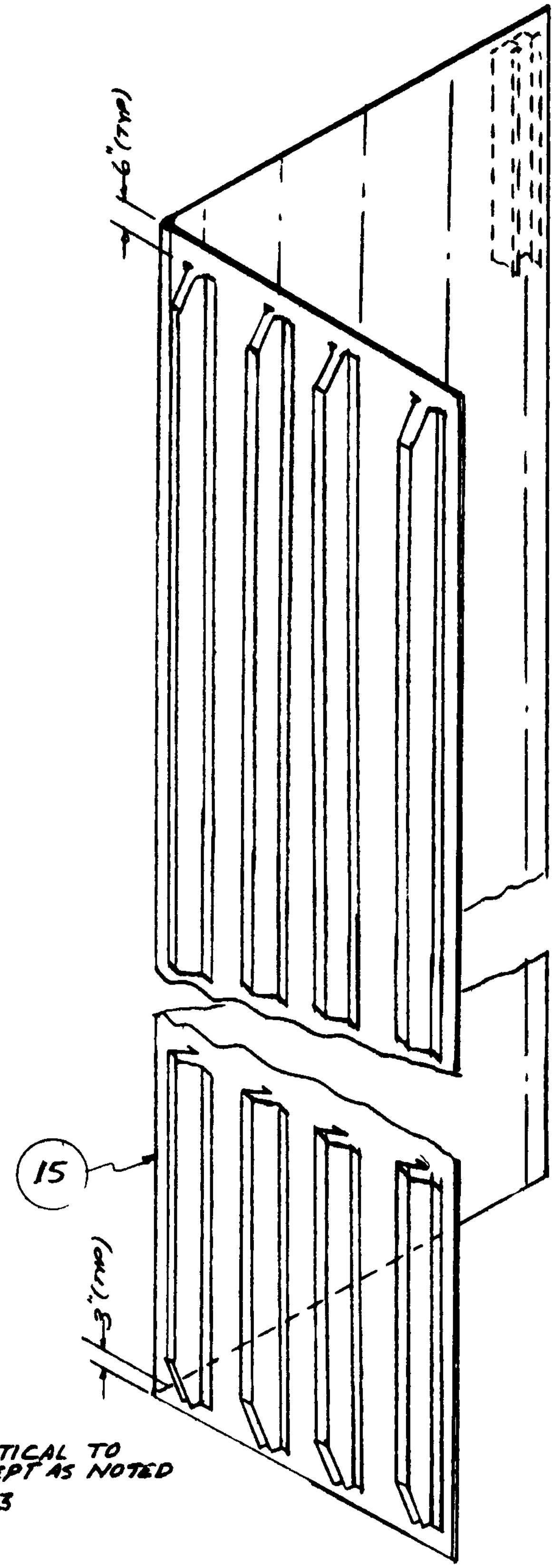




SEE SECT. B-B FIG 3.2.4-8 FOR DETAIL OF PANEL STIFFENERS

MODULE WEIGHT
13,000 lbs.

FIGURE 3.2.4-13
SPENT FUEL PIT LINER



MODULE 15 IDENTICAL TO MODULE 13 EXCEPT AS NOTED SEE FIG. 3.2.4-13

MODULE WEIGHT
16,200 lbs.

FIGURE 3.2.4-14
SPENT FUEL PIT LINER

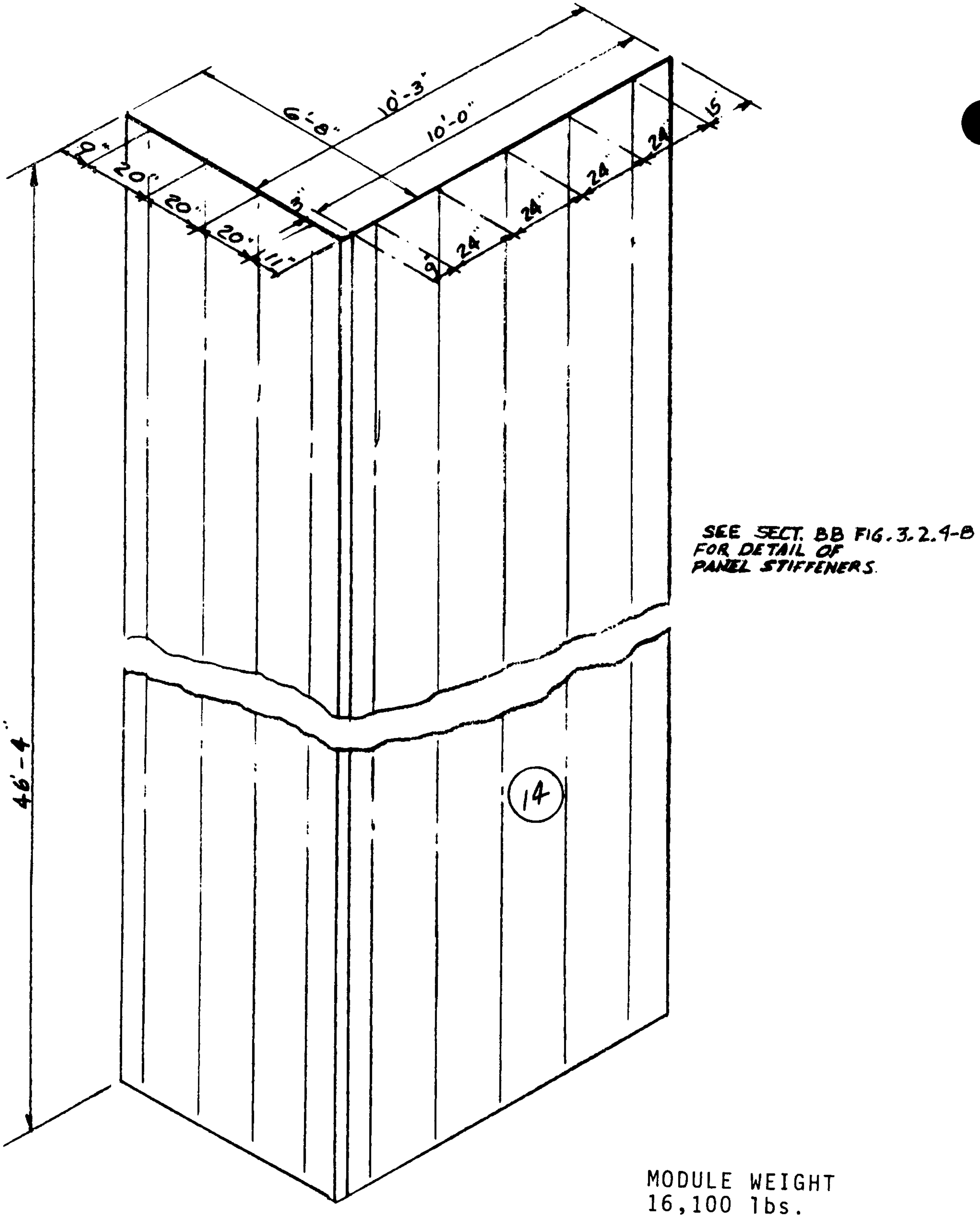
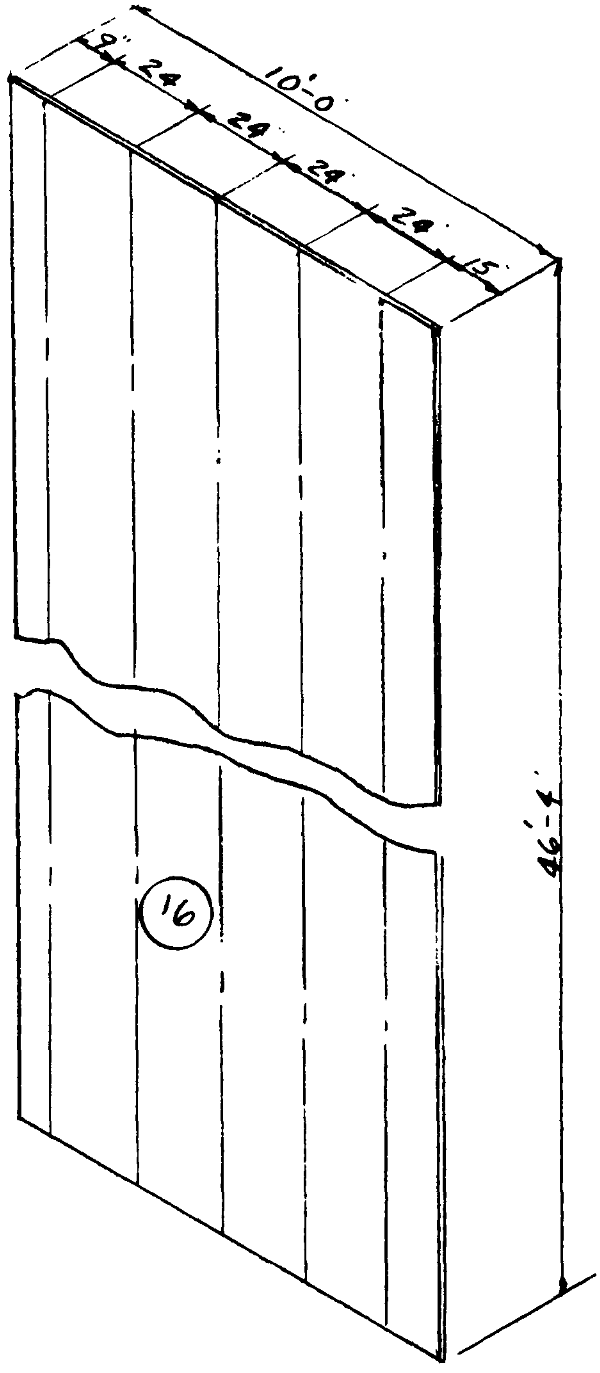


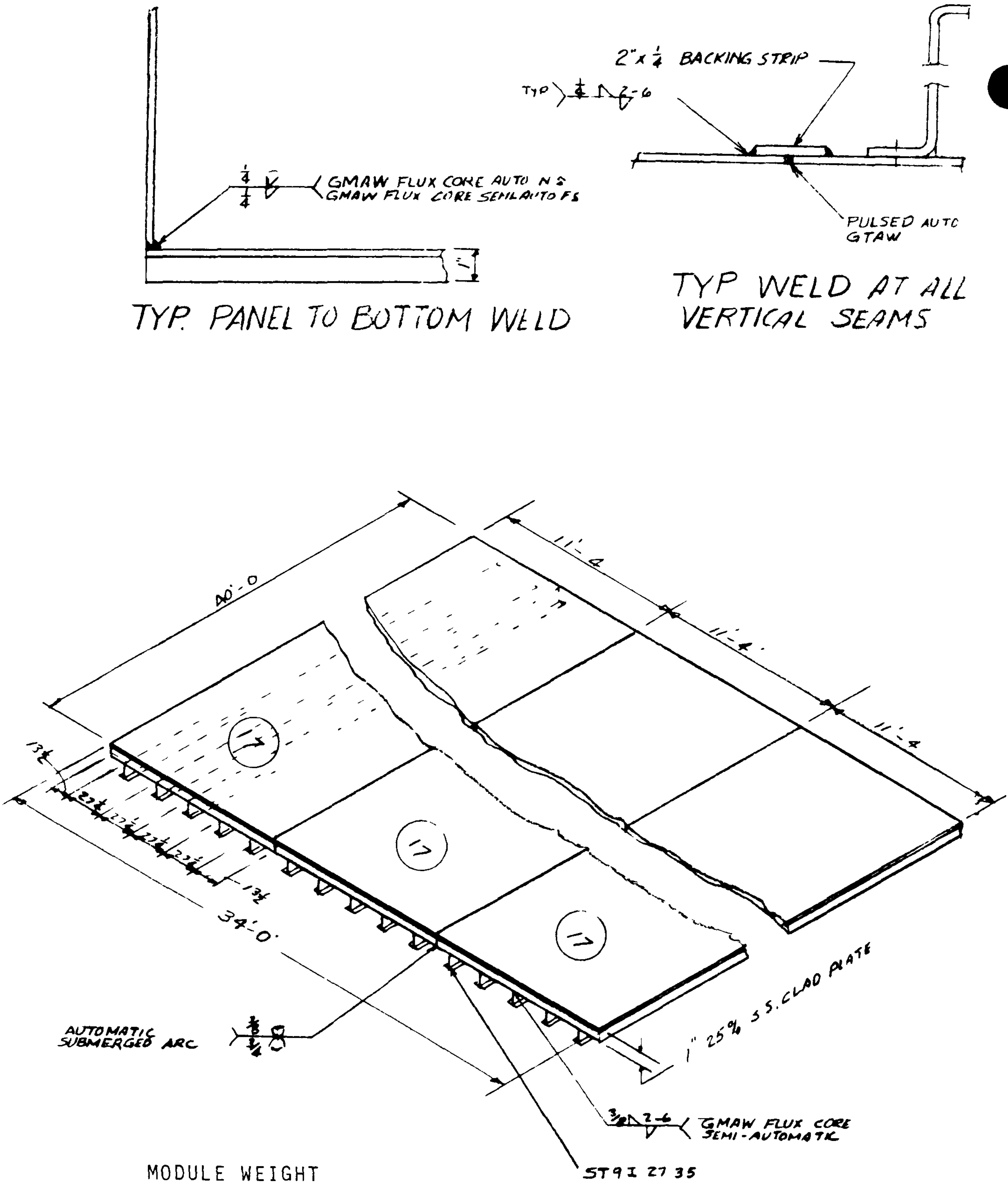
FIGURE 3.2.4-15
SPENT FUEL PIT LINER

SEE SECT. BB FIG. 3.2.4-8 FOR DETAIL OF PANEL STIFFENERS



MODULE WEIGHT
9,200 lbs.

FIGURE 3.2.4-16
SPENT FUEL PIT LINER



MODULE WEIGHT
71,900 lbs.

FIGURE 3.2.4-17
SPENT FUEL PIT LINER

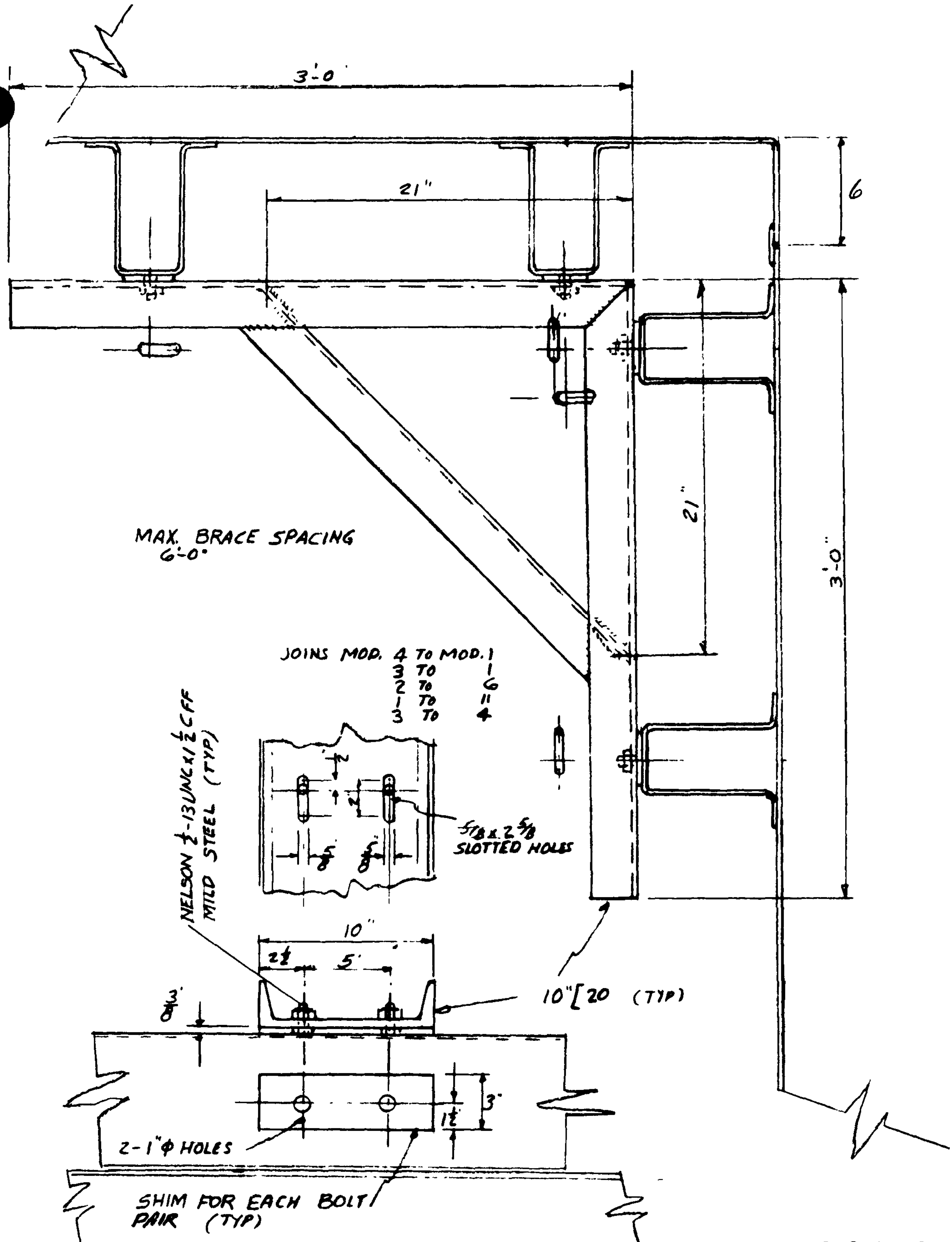


FIGURE 3.2.4-18
FIELD ERECTION
INSIDE CORNER BRACE

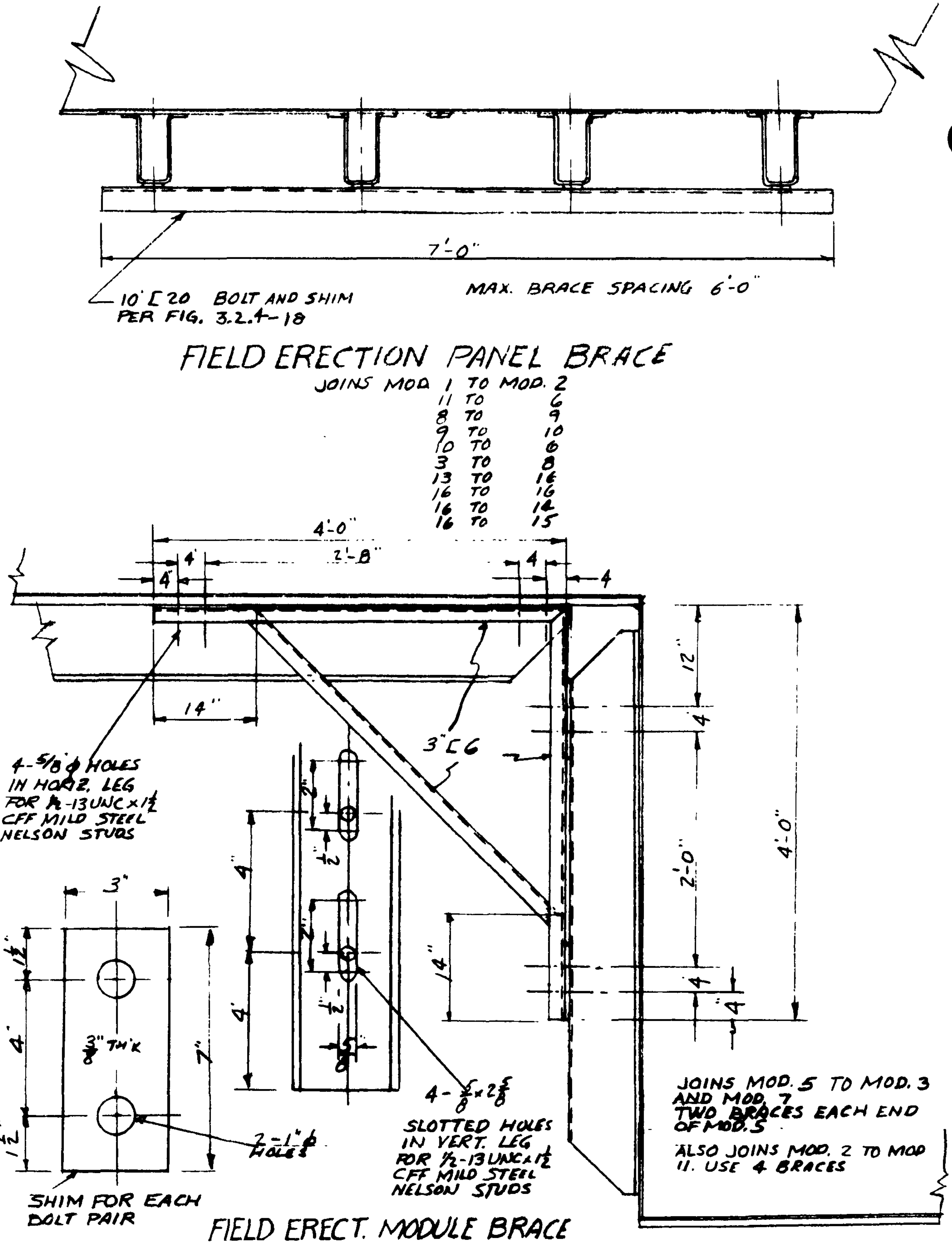


FIGURE 3.2.4-19
FIELD ERECTION BRACES

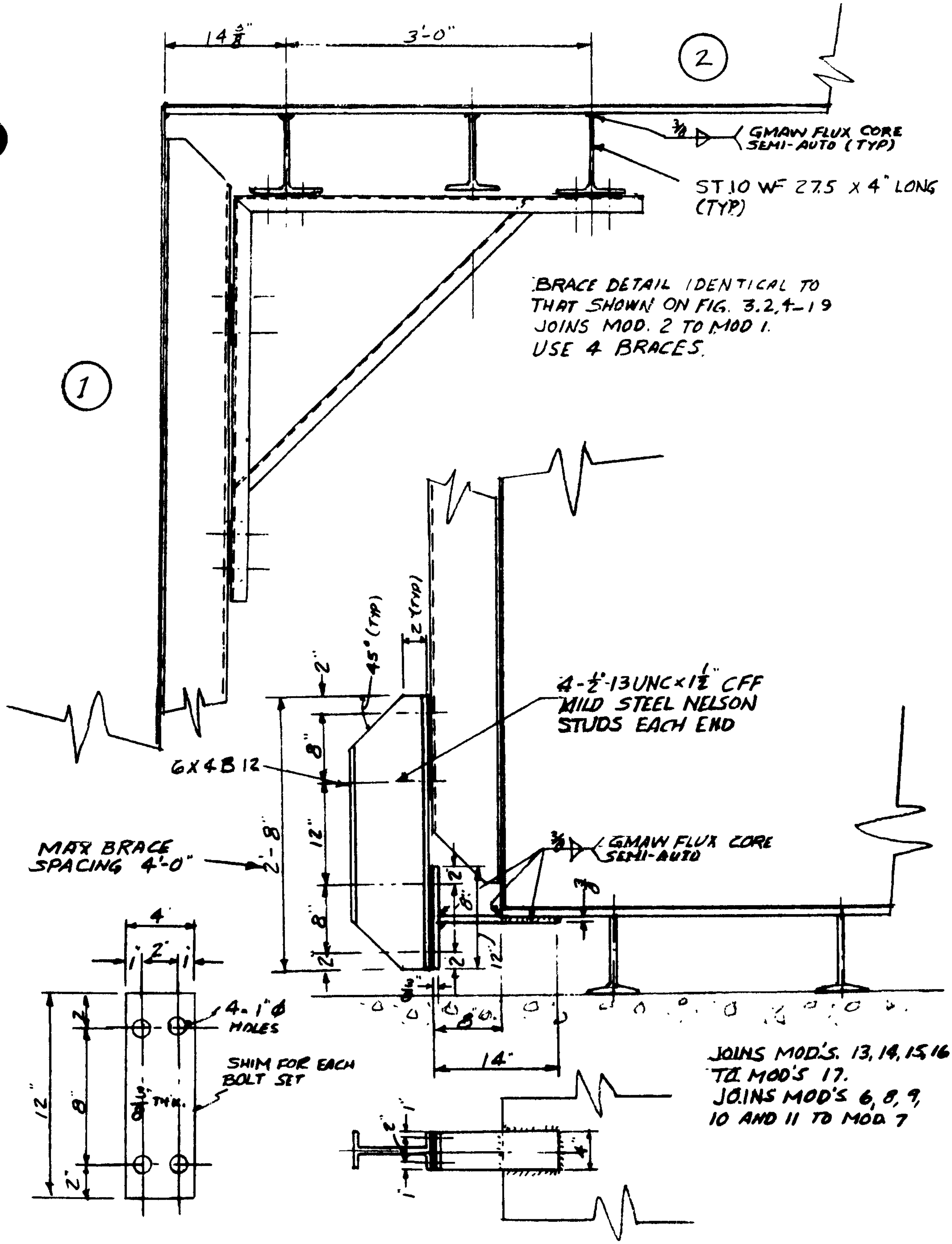


FIGURE 3.2.4-20
FIELD ERECTION
MODULE BRACES

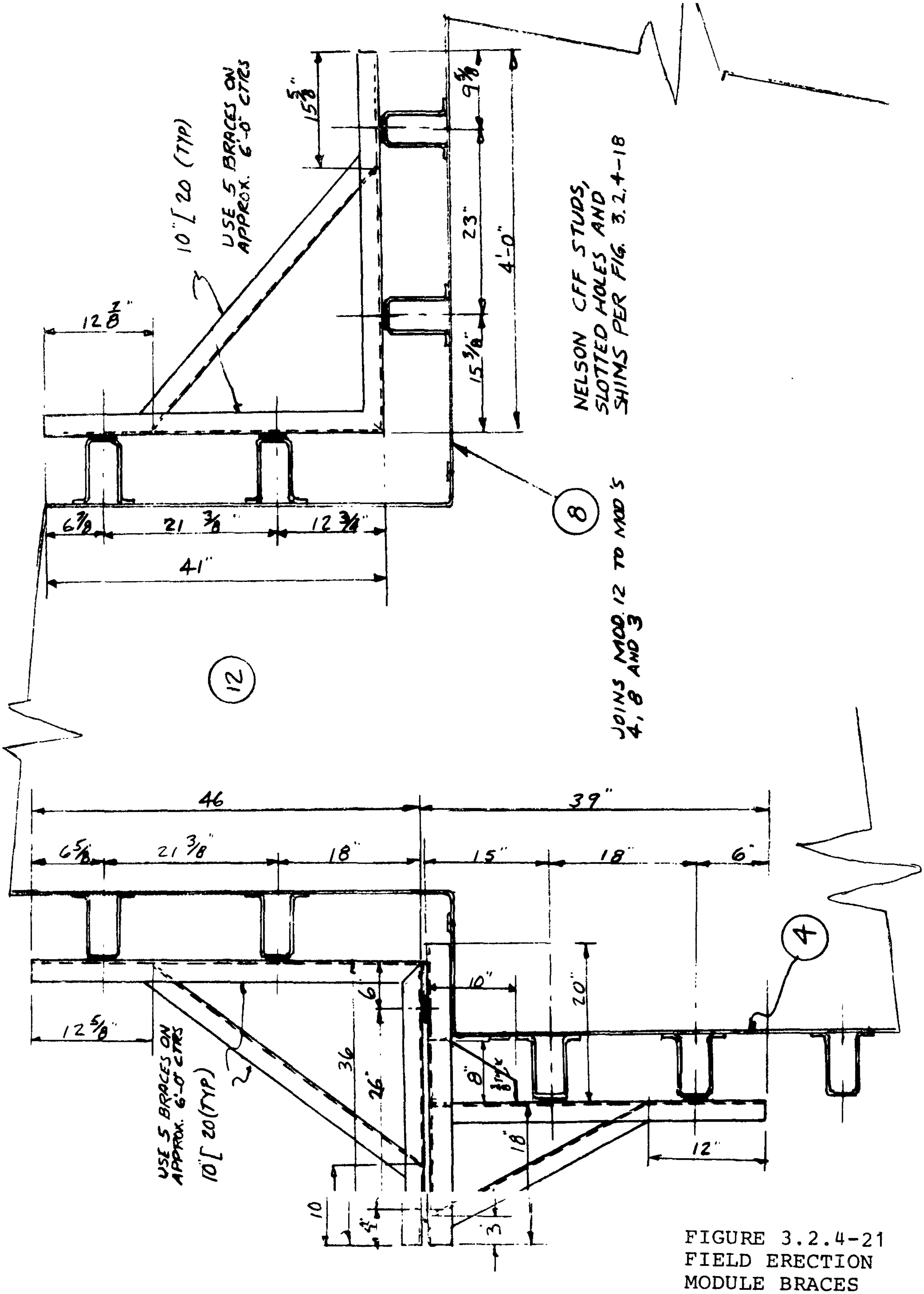


FIGURE 3.2.4-21
FIELD ERECTION
MODULE BRACES

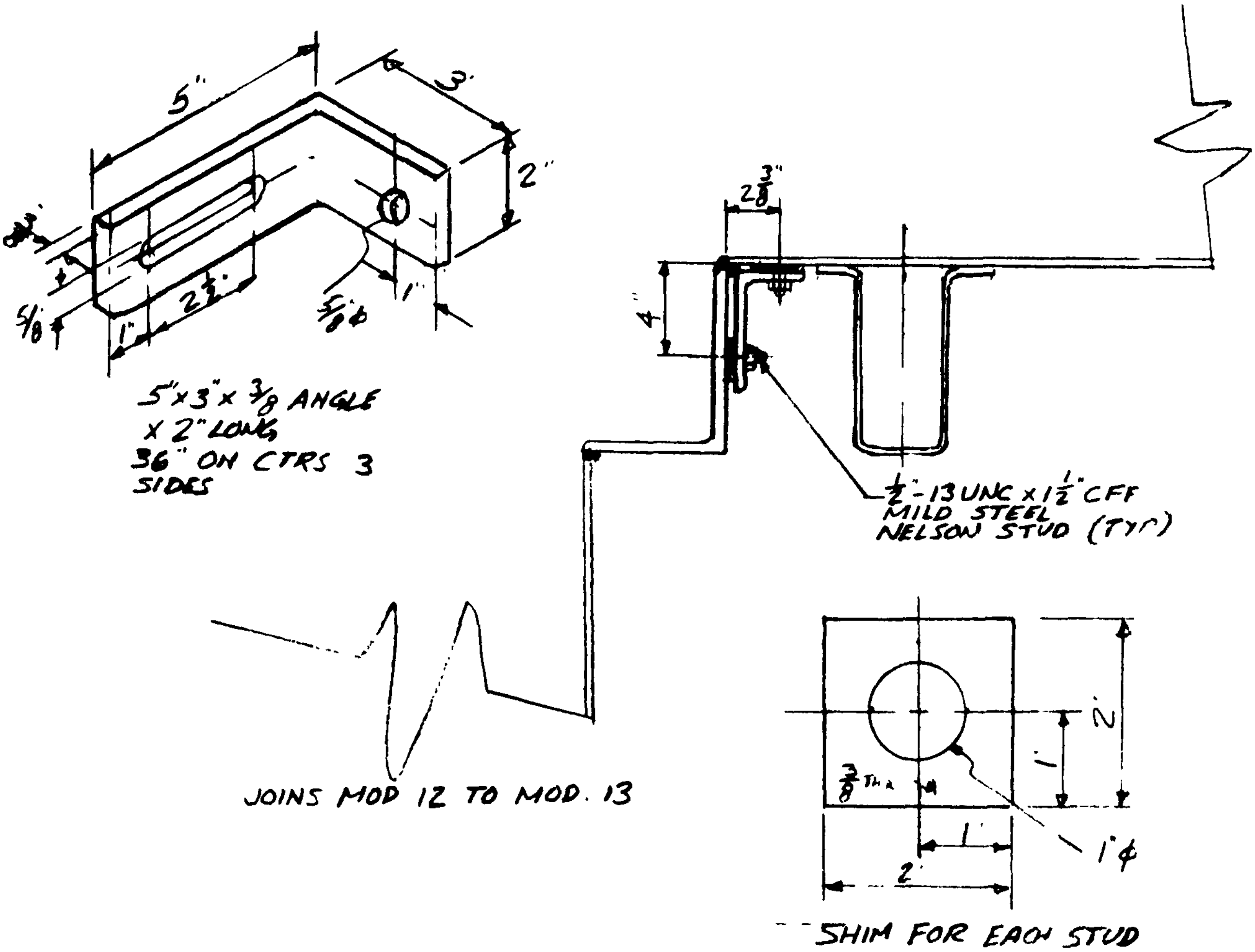
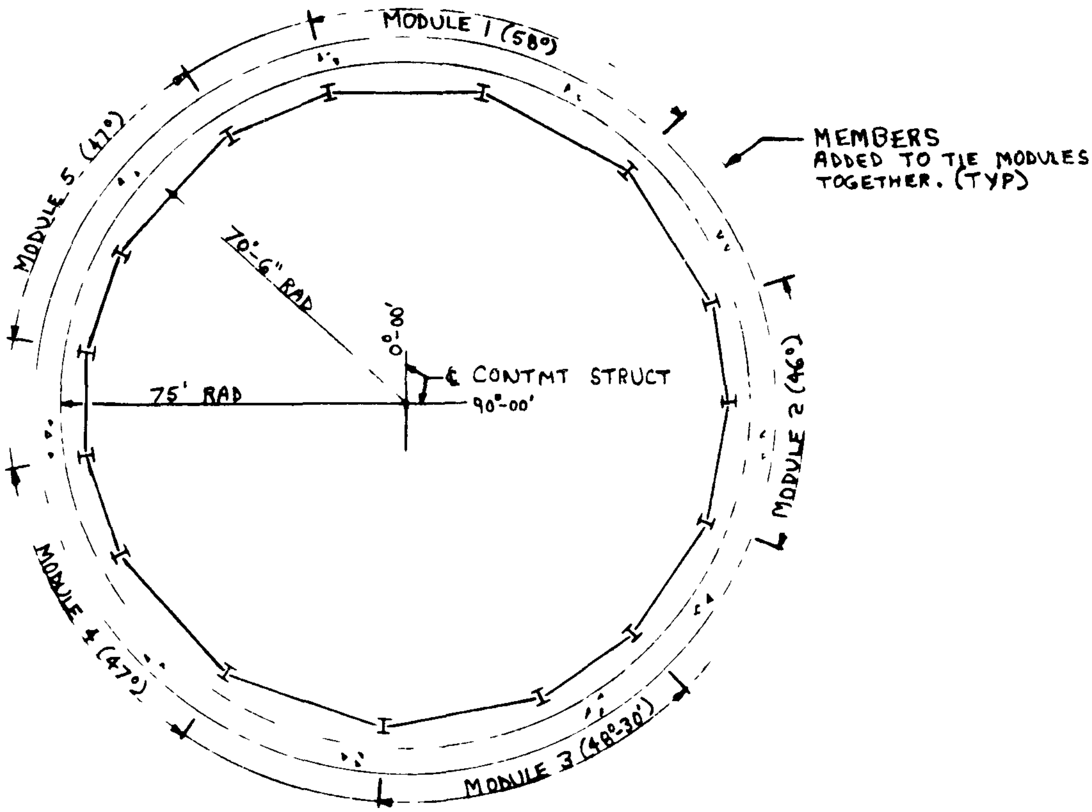


FIGURE 3.2.4-22
FIELD ERECTION
MODULE BRACES



MODULE 1

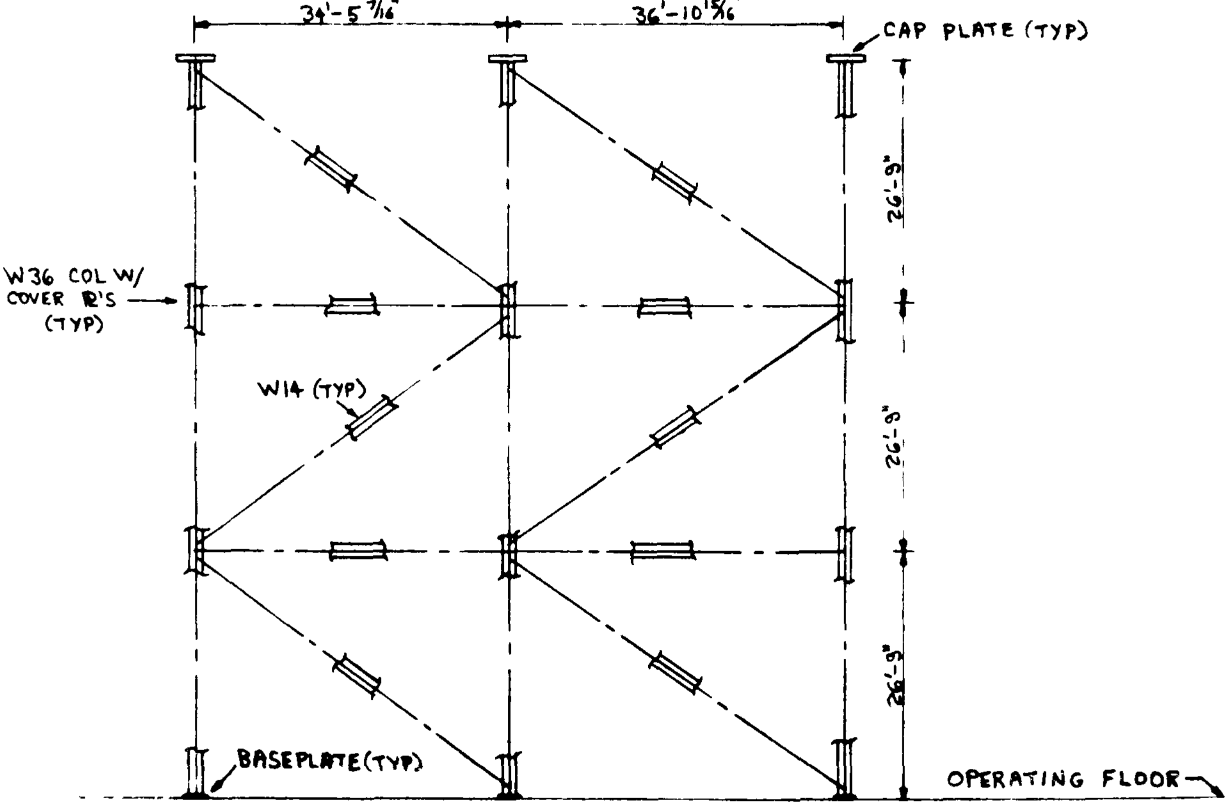


FIGURE 3.2.5-1
CONTAINMENT POLAR
CRANE SUPPORT
STEEL MODULES

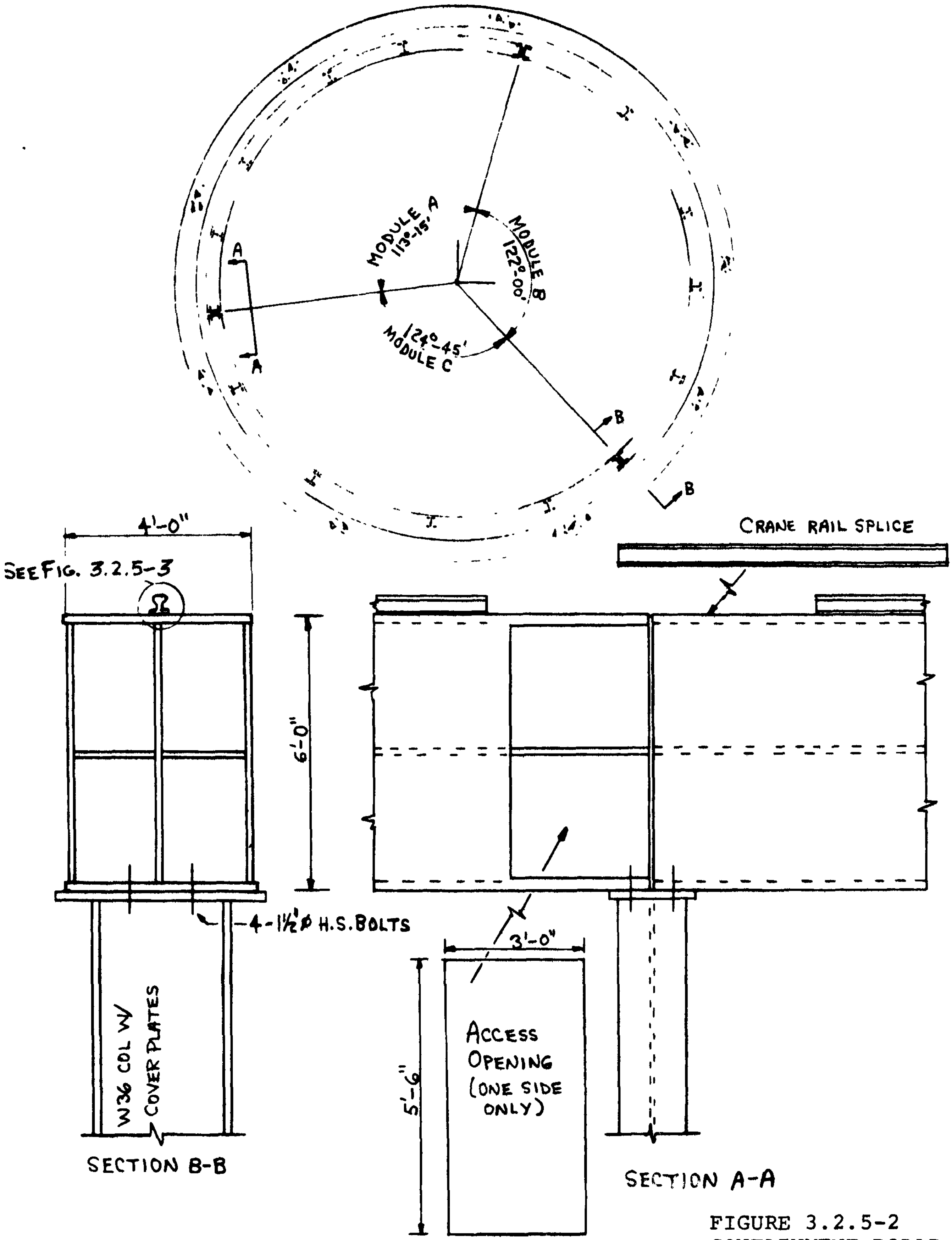
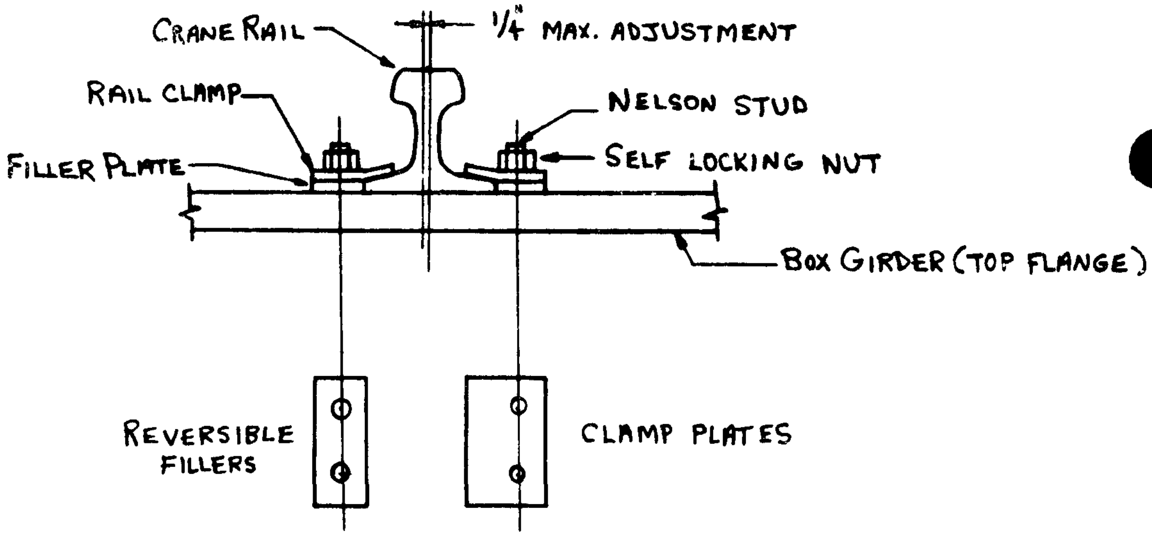
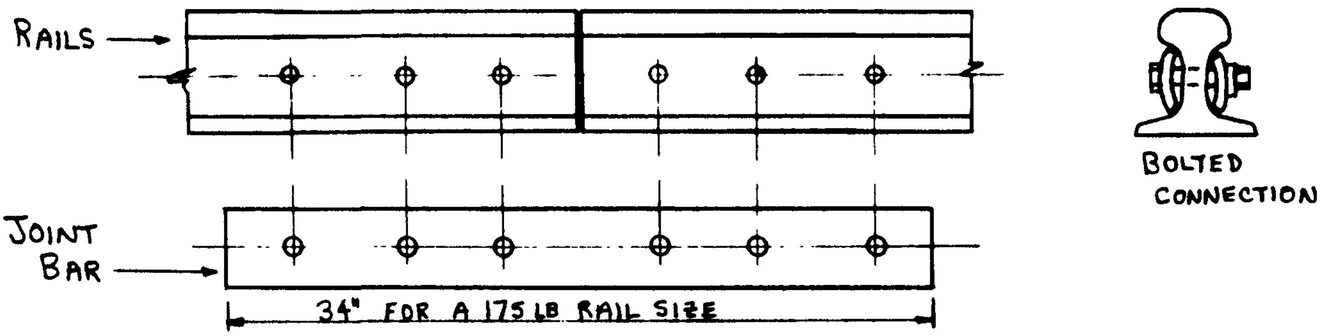


FIGURE 3.2.5-2
CONTAINMENT POLAR
CRANE BOX GIRDER
MODULES



TIGHT RAIL CLAMP (MINIMUM SPACING OF 3 FT.)



CRANE RAIL SPLICE

FIGURE 3.2.5-3
CONTAINMENT POLAR
CRANE BOX GIRDER
MODULES

3.3 Mechanical Modules

3.3.1 Skid Mounted

3.3.1.1 Sumps

Building sumps collect equipment drainage and leakage. Each sump consists of two pumps mounted on a baseplate and located over a rectangular depression in the floor.

3.3.1.1.1 Current Construction Method

The sumps, pumps, and piping are presently assembled in place. Assembly procedures include attaching a baseplate over a portion of the sump, mounting the sump pumps on the baseplate, and installing and welding the piping.

3.3.1.1.2 Proposed Module Description

The proposed module (Fig. 3.3.1-1) consists of two sump pumps, piping, and valves, mounted on a common baseplate and fabricated as a single unit in an onsite fabrication shop. Sump depth varies from 2 to 7 ft and is accommodated by varying the length of each pump column. The same size baseplate is provided for all modules. Table 3.3.1-1 lists the space envelope and weight of the proposed module.

3.3.1.1.3 Site Requirements/Assumtpions

Handling time associated with the modular concept is no greater than that associated with the current method of construction. An onsite fabrication shop is available.

3.3.1.1.4 Engineering Impact

Standardization of the baseplate size for all sumps can be accommodated in the present building designs with a minimum of engineering effort and design changes.

Purchasing and engineering of sump components is required earlier than for current construction methods because of the following schedule requirements:

1. Depending on each module's location and the congestion due to surrounding equipment, placement of the module is required prior to the installation of nearby components and piping.

2. Placement of the sump modules must occur prior to placement of concrete for the floor above.

3.3.1.1.5 Cost Savings

Cost savings result from the man-hour differential between shop and field welding. All piping and valves in the module are 2 inch, 150 lb, stainless steel with 14 nonnuclear safety socket welds per module. Table 3.3.1-2 lists the cost savings of the sump modules in each building.

3.3.1.1.6 Schedule Savings

Use of the proposed module does not affect the plant critical path construction schedule.

3.3.1.1.7 Savings Criteria

The sump modularization concept does not meet the schedule or manpower savings criteria established for implementation.

3.3.1.1.8 Recommendations

Although cost and schedule savings do not meet the criteria for implementation, modularization of the sumps is recommended for fabrication convenience on a case-by-case basis.

3.3.1.2 Demineralizers and Filters with Associated Piping and Valves

Demineralizers and filters in the annulus building are located in separate cubicles with piping extending through floors to valve areas and pipe tunnels on successive levels below. The filter and demineralizer cubicles in the fuel building and the solid waste and decontamination building are served by a common valve and piping area on the level below.

3.3.1.2.1 Current Construction Method

The demineralizer/filter vessels are installed in their cubicles, and the associated piping and valving are welded in place.

3.3.1.2.2 Proposed Module Description

It is proposed that separate subassemblies be fabricated for each level of the demineralizer and filter configurations. Three levels in the annulus building contain subassemblies:

Level I - Demineralizer/filter vessel with associated piping piping in the cubicle (two subassemblies)

Level II - Piping and valves in the valve area (six piping modules)

Level III - Piping in the pipe tunnel (five piping modules)

For the fuel building and solid waste and decontamination building, two levels contain subassemblies:

Level I - Demineralizer/filter vessel with associated piping in the cubicle (two subassemblies)

Level II - Associated piping and valves on the level below the cubicles (five piping modules)

The subassemblies are constructed in an onsite fabrication shop and installed with a crane. Final welds between subassemblies are performed at their building locations. Figures 3.3.1-2 and 3.3.1.3 show typical subassemblies and Table 3.3.1-3 lists their weight and space envelope.

3.3.1.2.3 Site Requirements/Assumptions

An onsite fabrication shop is available.

Each subassembly is installed prior to placing concrete for the floor above. Intermediate floors are constructed prior to placement of the subassemblies above.

3.3.1.2.4 Engineering Impact

The construction schedule must be revised to reflect installation of piping modules prior to placement of concrete for the floor above. Therefore, purchasing and engineering analysis of these modules must occur earlier than for current construction methods.

3.3.1.2.5 Cost Savings

The current installation methods for the demineralizers and filters require extensive welding of piping in compact cubicles, valve areas, and pipe tunnels. The proposed modularization concept allows a majority of these welds to be performed in an onsite fabrication shop. Cost savings result from the reduced man-hours associated with shop versus field welding and inspection and are dependent on the weld size and required safety class designation. Each demineralizer is identified in Table 3.3.1-4; each filter is identified in Table 3.3.1-5. Analyses of the cost savings for a module of two purification demineralizers, including piping, and various filter modules are presented in Tables 3.3.1-6 and 3.3.1-7. Similar analyses of all modularized demineralizers and filters result in total plant cost savings of $120,000-$210,000 for demineralizers and $75,000-$85,000 for filters, dependent on the NSSS vendor.

3.3.1.2.6 Schedule Savings

Revision of the construction schedule to allow installation of piping modules prior to placement of the floor above does not result in any savings since installation of these modules is not on the critical path.

3.3.1.2.7 Savings Criteria

The total estimated cost savings associated with the modularization of the demineralizers and filters and associated piping meet the cost savings criteria.

3.3.1.2.8 Recommendations

Use of the proposed modularization concept is recommended.

3.3.1.3 Moisture Separator/Reheater

Large nuclear plant steam turbines have either two or four moisture separator/reheaters (MSR), depending on turbine manufacturer. The MSRs are located on the turbine building operating floor on either side of the turbine. A drain tank is provided for each moisture separator shell and each reheater tube bundle. Drain piping connects to the moisture separator and reheater drain tanks and large bore steam piping to the high and low pressure turbines.

3.3.1.3.1 Current Construction Method

Current construction methods include separate operations to mount the MSRs on the operating floor and to hang the drain tanks below the MSRs. Interconnecting piping is then installed and welded.

3.3.1.3.2 Proposed Module Description

The proposed module can be utilized only for the MSRs of a 4-MSR plant design. The MSR size in a 2-MSR plant design results in excessive module weights and dimensions.

The MSR is mounted on a large structural steel skid using conventional MSR supports. The reheater drain tank is located above the skid beneath the MSR and the moisture separator drain tank is hung below the skid. Both drain tank locations are dictated by the required elevation differentials for proper drainage from the MSR. Steam and drain piping are supported on or hung from the skid.

The module, shown in Figure 3.3.1-4, is approximately 65 long by 25 wide by 25 ft high (14 ft above the skid and 11 ft below) and weighs in excess of 200 tons.

The largest crane identified in Section 3.1.2 of the Phase I report lifts the module onto the turbine building operating floor at the south end of the building. The module is then transferred to the turbine building traveling crane for placement on the operating floor.

3.3.1.3.3 <u>Site Requirements/Assumptions</u>

A crane of the required capacity is available when required. Sections of piping are purchased as spools or welded into spools in an onsite fabrication shop, regardless of module implementation.

3.3.1.3.4 <u>Engineering Impact</u>

The major impacts are in the structural design since portions of the operating floor must be redesigned to accommodate the proposed module since a large opening is required in the operating floor for placement of the structural steel skid. Components of the module extend above and below the skid.

3.3.1.3.5 <u>Cost Savings</u>

Cost savings result from the man-hour differential between shop and in-place field welding. The present construction method maximizes shop welding of piping spools.

Therefore, use of the module will result in only 10 additional shop welds, most of which are pipe-to-vessel welds. The total cost savings due to this additional shop welding is estimated as approximately $4,400 (present day, March 1976) per module. However, this savings is outweighed by the increased costs associated with the redesign of the operating floor, design, and fabrication of the skid, and the more complex hauling procedures and rigging necessitated by a larger and heavier lift.

3.3.1.3.6 <u>Schedule Savings</u>

Since the turbine building is not on the plant critical path and because the increased costs associated with the implementation of the module will outweigh any schedule savings, the impact on the turbine buildng construction schedule was not evaluated.

3.3.1.3.7 <u>Savings Criteria</u>

The MSR modularization concept does not meet the savings criteria.

3.3.1.3.8 <u>Recommendations</u>

Use of the proposed module is not recommended.

3.3.1.4 Feedwater Pump and Turbine

Modularization of the main feedwater pumps, turbine drives, and associated equipment has been evaluated.

3.3.1.4.1 Current Construction Method

Varying degrees of preassembly are presently used in the shipping and installation of large feedwater pumps, turbine drives, and associated equipment. The degree of preassembly ranges from individual shipments of pump, turbine drive, and auxiliary systems, requiring complete assembly in the field, to complete manufacturer packaged units, shipped and installed in one piece.

All pump and turbine manufacturers have the capability of providing the completely "broken-down" option. In addition, the major turbine manufacturers can provide the turbine and its accessories as a preassembled unit. However, only one manufacturer has the capability to offer a single preassembled package of the pump, turbine, and auxiliary equipments.

3.3.1.4.2 Proposed Module Description

The turbine and its auxiliary systems are purchased, shipped, and installed as one package. This turbine package consists of the following:

1. Turbine with baseplate
2. High and low pressure stop valves
3. Lubricating oil system, including tank, piping, and pumps
4. Turbine protection equipment
5. Turbine supervisory equipment
6. Instrument console

The turbine package is assembled, aligned, flushed, and shop-tested prior to shipment.

Placement of the package is accomplished with the turbine building overhead crane. Field work to be performed after placement of the turbine package and the pump consists of:

1. Connection, leveling, and alignment of pump and turbine
2. Wiring of electric power supplies
3. Connection of remote instrumentation and controls

4. Connection of steam seal piping with the main turbine generator, oil piping with the oil conditioning system, and steam inlet and exhaust piping.

The turbine package is approximately 30 long by 12 1/2 wide by 12 1/2 ft high. Weight of the package is approximately 50 tons.

3.3.1.4.3 Site Requirements/Assumptions

Special permits, allowing road or rail transportation of oversized loads, allow travel of the module load. (See Envelope C, Table 3.1-1.)

3.3.1.4.4 Engineering Impact

There is no engineering impact involved with this modularization concept, since all techniques are currently used by industry. No early scheduling of engineering is required.

3.3.1.4.5 Cost Savings

Cost estimates from turbine manufacturers indicate that a packaged turbine costs approximately $20,000 more than a completely "broken-down" unit due to the increased work performed in the manufacturer's shop. However, increased shop work results in a decrease in field assembly work. Therefore, use of a packaged turbine results in a cost savings of $27,500 per turbine package.

3.3.1.4.6 Schedule Savings

Use of a packaged turbine shortens field installation time by approximately 10 days, but does not achieve critical path time savings.

3.3.1.4.7 Savings Criteria

Based on three feedwater pumps and turbine drives per plant, use of the proposed modularization concept results in a total cost savings of approximately $82,500, which meets the cost savings criteria.

3.3.1.4.8 Recommendations

The turbine drives for all main feedwater pumps should be purchased, shipped, and installed as packaged units. These packaged units have been supplied by turbine manufacturers for a large percentage of feedwater pump drives purchased in the past few years.

Preassembly of the pump and turbine as one package is not recommended for the following reasons:

1. Only one manufacturer currently offers a pump/turbine package.

2. A pump/turbine package results in negligible cost savings over the recommended package, since field labor savings resulting from shop mounting and alignment of the pump are offset by the increased cost of the larger skid.

3. A single skid for the pump and turbine does not have the required rigidity and stiffness to prevent costly misalignment of the pump/turbine package resulting from piping forces and moments.

3.3.1.5 Modularization of Compressed Air System Components

Two compressed air systems are provided: one located in the containment structure and one in the turbine building. Each system consists of compressors, air receivers, aftercoolers, dryers, and filters, grouped together in their respective buildings.

3.3.1.5.1 Current Construction Method

The components of the compressed air system are presently purchased separately and assembled at their building location.

3.3.1.5.2 Proposed Module Description

Packaged units, each consisting of a compressor and associated equipment with the exception of the dryers, are currently available from several manufacturers. These units are installed by a forklift truck and require a minimum of field piping and instrumentation connections. The dryers are not included in the package since these are usually purchased from a separate manufacturer.

3.3.1.5.3 Site Requirements/Assumptions

It was assumed that the cost savings associated with the turbine building compressed air system were typical for both systems.

3.3.1.5.4 Engineering Impact

There is no engineering impact involved with the purchase, shipping, and installation of packaged compressors, since the packages are currently used for other applications. However, packaged compressors historically require more complex maintenance procedures.

3.3.1.5.5 Cost Savings

Modularization of the compressed air system results in field labor cost savings due to the relative ease of installing a packaged unit. However, these savings are outweighed by the increased cost of a packaged unit. Table 3.3.1-8 compares typical purchase and installation costs of a packaged versus component compressed air system.

3.3.1.5.6 Schedule Savings

There is no critical path schedule savings for the proposed module.

3.3.1.5.7 Savings Criteria

Neither cost nor schedule savings are achieved with this concept.

3.3.1.5.8 Recommendations

The compressed air system modularization concept is not recommended.

3.3.1.6 Condensate Polishing Components

The condensate polishing system, located in the turbine building, consists of tanks, pumps, filters, demineralizers, and blowers.

3.3.1.6.1 Current Construction Method

The condensate polishing system is presently constructed utilizing several modules of regeneration components, which are preassembled in the manufacturer's shop and installed as individual packages. The remainder of the condensate polishing equipment and associated instrumentation and piping is individually installed.

3.3.1.6.2 Proposed Module Description

Modularization of the condensate polishing system consists only of those modules currently available from the equipment manufacturers and presently utilized in plant construction. Those modules include preassemblies of tanks and connecting piping, pumps with valves and piping, and other closely related components. Extent of the modularization is based on arrangement. The modules are individually placed and the interconnecting piping is installed after module placement. Table 3.3.1-9 lists the proposed modules, all of which are currently available from manufacturers.

The remaining system components are individually installed in the field.

3.3.1.6.3 Site Requirements/Assumptions

No special site requirements or engineering assumptions were used in evaluating the proposed concept.

3.3.1.6.4 Engineering Impact

Since the extent of the proposed modularization is limited to that implemented on previous plants, there is no additional engineering impact.

3.3.1.6.5 Cost Savings

No changes are proposed to the current purchasing, shipping, and installation methods for the condensate polishing system components. Therefore, there are no cost savings evaluated.

3.3.1.6.6 Schedule Savings

No changes are proposed to the current purchasing, shipping, and installation methods for the condensate polishing system components. Therefore, there are no schedule savings.

3.3.1.6.7 Savings Criteria

No savings are met.

3.3.1.6.8 Recommendations

The degree of modularization implemented on previous plants should be continued.

Further modularization of the system is not recommended since there are no cost savings associated with the fabrication of larger modules than those described in Table 3.3.1-9. Larger modules would require increased support and more complex handling operations. In addition, the equipment is presently arranged in cubicles and the consolidation of equipment from several cubicles onto one skid would require the addition of shielding between components.

Implementation of a modular concept for piping would not significantly affect cost of manpower expenditures since the majority of piping is Saran-lined steel with screwed and flanged connections.

3.3.2 Condenser Modularization

3.3.2.1 Current Construction Method

Steam surface condensers for large present-day power generating plants are too large to consider complete shop fabrication and one-piece shipment to the jobsite. They must be fabricated in pieces small enough to transport.

Various manufacturers have different philosophies regarding the extent to which condensers should be shop fabricated, and the size of the shop fabricated pieces. Some prefer to ship condensers completely "broken down." Others prefer to maximize shop assembly, and to ship assembled condenser sections as large as can be shipped to the jobsite.

Condensers are bought and shipped both ways. Condenser specifications currently invite bids for both total field fabrication and various degrees of shop fabrication. Bids are evaluated on the basis of installed costs.

3.3.2.2 Proposed Module Description

The condenser should be designed from the start with shop fabrication in mind. The condenser would be fabricated in sections that could be accommodated by transportation modes available to the specific jobsite under consideration.

3.3.2.2.1 Transverse Condenser - Barge Shipment

The condenser is a transversely tubed condenser of the conventional triple shell, single pass, divided water box design. Each condenser shell can be conveniently shop fabricated in the following modules:

Two tube bundles with hotwell sections, tube sheets, tube support plates, and shell sides

One steam inlet assembly

Four water boxes

Each tube bundle module will be approximately 16 wide by 36 ft high and will not exceed 60 ft in length. The steam inlet assembly would be approximately 32 wide by 24 ft high and will not exceed 60 ft in length. Each water box will be approximately 9 by 12 by 21 ft high.

3.3.2.2.2 Transverse Condenser - Truck or Rail Shipment

Design changes to obtain modules of lesser width and height necessary to accommodate truck or rail transport can be accomplished by two different methods.

Method 1: Each condenser shell retains its basic form. However, to reduce module size, the sides of the shell must be shipped separately, and tube sheets and tube support plates must be cut vertically and horizontally. The shell, tube sheets, and tube support plates would then be welded or otherwise joined in the field. As an alternate to welding, the tube support plates can be installed with spacers connecting sections together and to the shell. In addition, the steam inlet assembly must be fabricated in four smaller pieces for transport.

Method 2: Each condenser shell would be designed with a multiplicity of smaller tube bundles and header-like water boxes. Each tube bundle would be considerably smaller than those of a conventionally designed condenser, and would be easily transportable by either truck or rail. Similarly, the steam inlet assembly would be fabricated in smaller transportable pieces.

With either method, the condenser sides and hotwell sections can be assembled in a site assembly area adjacent to the turbine building, thus minimizing the amount of work that must be performed in close proximity to the turbine pedestal legs. These sections would then be installed prior to in-place assembly of the rest of the condenser.

3.3.2.2.3 Longitudinal Condenser

A longitudinally tubed condenser could be designed for either barge or rail transport. However, because of the excessive length of the longitudinal condenser, approximately 120 ft long, shop fabrication might necessitate intermediate water boxes depending on site-related, access clearance limitations.

3.3.2.2.4 Condenser Installation

For any of the above condenser configurations, the modules can be installed directly into place between the turbine pedestal legs using the turbine building traveling crane. If for any reason it becomes necessary to place major turbine components before the condenser, modules can be installed either by skidding into place or by using yard cranes.

3.3.2.3 Site Requirements/Assumptions

Shop fabrication and shop tubing of condensers are currently within the capabilities of all domestic large steam surface condenser manufacturers.

For modules that are larger and/or heavier than normal road and rail limitations, but still within the actual clearances and load limits associated with the specific transit route, special permits allowing transportation can be obtained.

3.3.2.4 Engineering Impact

A shop tubed condenser would require delivery of the tubes approximately six to nine months earlier than a field tubed condenser, assuming the completion date for the installed condenser remains the same. This would require an earlier engineering effort for the bid specification for the condenser tubes.

For all shop tubed condensers, and especially for a condenser design with tube sheets and tube support plates cut vertically and/or horizontally, field welding or joining is required in proximity to the tube bundles. Tube sheets form barriers between circulating water and steam/condensate, and must be welded continuously across each end of the condenser shell. Tube support plates are surrounded by steam/condensate and need not be continuous; but can be installed using spacers to connect the tube support plates to the shell. The spacers would be welded both to the shell and to the support plates to ensure tube alignment and to minimize the possibility of tube vibration. These tube sheet-to-tube sheet and support plate-to-spacer welds must be performed with great care to protect the tube bundles both from weld spatter and from distortion.

For condenser design with a multiplicity of small tube bundles, extensive analyses must be performed to ensure effectiveness of the innovative design. In addition, scale model testing would be required to ensure proper flow distribution through the circulating water piping and the water boxes.

3.3.2.5 Cost Savings

When barge shipment is available from the manufacturer's shop to the site, the shop tubed, shop fabricated condenser, even though its purchase price will be greater, will frequently have an installed cost lower than that of a field erected condenser. For some sites this cost differential may be as great as a few hundred thousand dollars in favor of shop fabrication, thus meeting the cost savings criterion.

When barge shipment is not possible, the cost comparison is reversed and the totally field fabricated condenser may be found to save considerable dollars when compared with the partially shop fabricated condenser.

Actual cost savings associated with one method or the other cannot be evaluated without knowledge of cooling system configuration and available modes of transportation.

3.3.2.6 Schedule Savings

Because of the extensive analyses and/or scale model testing that would be required for an innovative condenser design, the condenser bid evaluation and purchase should remain scheduled at the very beginning of the plant schedule. To allow shop tubing, the condenser tube specification must be scheduled earlier than at present.

The possibility of significantly delaying the start of turbine building construction due to various modularization techniques has been identified. This possibility is facilitated since the turbine building construction need not be dependent on condenser installation. As discussed above, whether the condenser is entirely shop fabricated and shop tubed or field assembled, placement of the condenser between the turbine pedestal legs can occur at any time during building construction.

If a condenser is of the conventional design described above, either shop or field fabricated, there would be no impact on design or engineering activity scheduling. However, if a longitudinal condenser or a transverse condenser of innovative design is provided, the additional design and engineering activities discussed above must be factored into the overall plant schedule.

Although some building schedule savings can be achieved, no overall plant critical path savings were identified.

3.3.2.7 Recommendations

No change should be made in the way the condenser is currently purchased. Both shop and field fabrication are evaluated on an installed cost basis, and consideration is given to the site-related influence of the modes of transporation available to the site.

When barge shipment capability does exist, total shop fabrication and shop tubing are recommended; otherwise, an evaluation on a case-by-case basis is necessary before a recommendation can be made.

3.3.3 Tanks

3.3.3.1 Current Construction Method

Current and past construction practice is, and has been, to build most field fabricated tanks on their permanent foundations. In a few instances, however, small to moderate size field-fabricated tanks have been erected on temporary foundations and then moved to their permanent locations. This has been made necessary by space restrictions in permanent foundation areas. Predicted interference between construction disciplines would have caused schedule delays.

Some large tanks that have been constructed and moved thus far have been 30 ft–0 in. OD by 41 ft–7 in. high, weighing about 30 tons. None of the tanks have required temporary bracing. The tanks were lifted by crawler crane and moved across the yard. Lifts were made using four temporary lifting lugs per tank, welded to the top of the cylindrical sides. An orthogonal arrangement of spreader beams ensured that the lifting forces on the tank remained essentially vertical. Moving was accomplished by site construction personnel. The manufacturer's warranty was not prejudiced.

3.3.3.2 Proposed Module Description

Tanks larger than about 12 feet in diameter are usually fabricated at the power plant site due to the difficulties of transporting shop-fabricated units. Of the 12 RNPP tanks in this category, 10 may be erected on their permanent foundations since none of the 12 tanks are on the critical path. However, in the case of the auxiliary feedwater storage and the refueling (borated) water storage tanks, their large size and the restricted space around them in their annulus building cubicles suggests that a possible savings could be made by building them outside the building and then moving into place.

The proposed module consists of a completed tank, except for any protruding nozzles, constructed on a temporary foundation adjacent to the annulus building. Each tank bottom would be temporarily braced to prevent overstressing during moving. Each tank would be lifted by a construction crane under the supervision of the tank manufacturer. The tanks would be lifted over the annulus building walls and lowered to their permanent foundations at an elevation of approximately –50 ft. Lifting would be via a cable slingspreader beam arrangement and temporary lifting lugs at the top of the side walls.

Dimensions and estimated weights of the two tanks proposed for modularization are as follows:

	Auxiliary Feedwater	Refueling Water Storage
Diameter, ft	35	37
Tank height, ft	44	78
Overall height, including rigging, ft	85	120

Estimated weight, including rigging, tons	50	110

Both tanks would be erected on temporary foundations adjacent to the outer wall of the annulus building. The temporary foundations would be located far enough away from the outer wall to provide easy access for all erecting operations (including automatic welding of seams), but also near enough that each tank could be swung into final position without walking the crane.

Schedule estimates show that the tanks could be erected in the area to be provided for prefabrication of the containment dome.

Lifting tanks of this diameter would entail reinforcement of their flat bottoms to prevent overstressing the peripheral welds and possibly collapsing the side walls. The reinforcement would consist of a number of radial beams tack welded or bolted to the bottom plates on the inside of the tank. In one scheme, an appreciable percentage of the bottom weight would be taken by a simple central vertical cable up through the tank top, with the lifting force distributed equally to each radial bottom beam through a conical sling arrangement. Side wall and roof weight would be taken through several equally spaced lifting lugs, welded to the tank outer walls at the bendline (intersection of walls and roof). Vertical cables would lead up to the periphery of a ring shaped spreader beam. A wire configuration would then connect with the crane hook. A representative lifting arrangement is shown in Figure 3.3.3-1. The tank manufacturer would be responsible for the engineering calculations and sketches for reinforcement.

The water-fill leak test would be performed after the tanks have been moved and are installed on their permanent foundations.

3.3.3.3 <u>Site Requirements/Assumptions</u>

It is assumed that the erecting area provided for fabrication of the containment dome can be scheduled for tank erection also. The tanks would be erected on wood cribbing.

Scheduling of tank erection can be coordinated with the annulus building construction. In general, the auxiliary feedwater storage tank would have to be ready for moving before the annulus building walls are up to ground grade and the floor slabs poured. The refueling water storage tank would have to be ready before the building walls are up to the 29 ft-3 in. elevation and the floor slabs poured.

It is also assumed that the crane and operator would be furnished by site construction forces. Moving the tanks would require the crane services for part of a day for each tank. The entire moving operation would be under the direct supervision of the tank manufacturer and would be covered under the tank manufacturer's guarantee.

Engineering Impact

The fabrication and erection specification must include a section on the procedure and requirements of modularization in sufficient detail to ensure compliance by the erector.

3.3.3.4 Cost Savings

Detailed cost data are displayed and summarized in Table 3.3.3-1 for one unit. Results of the three budget estimates received from the tank manufacturers contacted indicate that savings range from $25,000 to $109,000 for the two tanks in the annulus building.

It should be noted that figures presented in budget estimates are developed from a generalized basis and are therefore not conclusive. Results from actual bids may well be different.

All estimates are based on Section III, Division 1, Class 2 tanks constructed of carbon steel, but with no painting or linings. The tank manufacturers state that there will be no significant difference in cost savings due to modularization whether the tanks are built of carbon steel, stainless steel, or aluminium.

3.3.3.5 Schedule Savings

The tanks are not on the critical path. Schedule estimates show 6 weeks of slack time if the tanks are built on their permanent foundations in the annulus building and 17 weeks if built on a temporary foundation and then moved to their permanent foundations.

The schedule indicates that there is sufficient time to erect the tanks in the area adjacent to the annulus building that will be provided for prefabrication of the containment dome.

3.3.3.6 Savings Criteria

The schedule savings criterion is not met.

Savings under the cost criterion are doubtful. Only one of the estimates received showed a definite cost saving by modularizing; two indicated savings less than $75,000.

3.3.3.7 Recommendations

Modularization of the two tanks cannot be recommended at this time since they do not meet either criteria unequivocally.

It is recommended, however, that more accurate data be obtained on possible cost savings on a case-by-case basis before any final decision is made.

3.3.4 Piping

3.3.4.1 Current Construction Method

The current practice of fabricating and erecting large-bore piping systems is to fabricate lengths of pipe, up to 40 ft long, in a pipe fabricating shop, and to erect the complete piping system at the construction site by manually welding each pipe length in place. These pipe lengths are designated as "spools," and include all bends, elbows, flanges, etc as specified.

The spools are unloaded and stored in a laydown area at the construction site until required. They are then picked up and transported to their installation area in a specific sequence, fit-up and manually welded to adjacent spool pieces, valves, tank nozzles, pump nozzles, etc to form a completed piping system.

It is difficult, at best, to minimize the total elapsed time and the total man-hour effort required to fabricate and erect a piping system to current practice because of the repetitious handling, scaffolding, shoring, aligning, and clamping of each spool and component, all under congested working conditions, in the installation area at the construction site. Further, it is often difficult to employ welders, fitters, supervisory, and inspection personnel in an efficient manner because of these congested working conditions.

Small-bore piping modularization concepts are already utilized in the construction of many nuclear power plants.

3.3.4.2 Proposed Module Description

In order to reduce the total elapsed time and man-hour effort and cost, the following modular approach is proposed for the fabrication and erection of piping systems.

A fabrication shop/area for piping modularization is erected at the construction site. Spools are delivered to the construction site by the fabricator according to a pre-scheduled sequence, and are unloaded and stored in a laydown area until required. They are then picked up and transported to the fabrication shop/area, along with valves and other components, where assembly and automatic welding occur, and the module is completed.

Fit-up tolerances for large bore butt welded piping limit both mismatch and gap to 1/32 in. To maintain these tolerances, equipment will be located and accurate measurements taken before the module is fabricated. In order to achieve proper pump alignment, the modules will be fabricated with provisions for adjustment, so that in this instance, the fit-up will be exact. Modules that are to be welded or flange bolted to equipment other than pumps, will be allowed the above 1/32 in. tolerance.

All modules will be supported on their permanent hangers wherever possible. Where permanent hangers cannot be used, temporary bottom supports made of timber or structural shapes will be employed. After the permanent hangers or supports have been installed, the temporary supports will be removed.

Welded anchor attachments will be installed on the modules in the fabrication shop/area, requiring that all anchor locations be established at the time that the piping drawings are completed.

While the module is being processed through the fabrication shop/area, it will be supported on layout tables, jigs, fixtures, and other supports made of rolled structural shapes and/or plate as required.

A module is assembled by bringing the required pipe spools from the laydown area to the fabrication shop/area by means of mobile crane or flat-bed truck. The spools are brought into the fit-up bay, along with the required valves taken from the valve storage area in the shop, and the module is assembled by tack welding all components in position. After verification of all dimensions, the module is welded and all required nondestructive tests are performed.

The completed module is then either held in an outside storage area or transported to its building to be installed.

In the building, at installation, the module is set in position on its temporary bottom supports. Wherever possible, permanent hangers are installed and the module is tack-welded or flange-bolted where provided. When all modules comprising a particular system or system segment are thus positioned, all module locations are given a dimensional check, followed by welding. As welding progresses, frequent dimensional checks are made to assure that welding distortions have not violated the tolerances.

Generally, floor slabs must be constructed later so that piping modules may be lowered into place without hinderance. Wall sections may have to be left open at specifically designated areas for placement of modules.

In some instances equipment will have to be scheduled for installation after a particular module, because of late delivery.

Total elapsed time, man-hour effort, and cost can be reduced by this modular approach because in the fabrication shop/area, positioners, automatic welding equipment, and other production type tooling lend themselves to a closely regulated production atmosphere.

Figures 3.3.4-1 through 3.3.4-12 illustrate a few of the more complex piping modules. These modules are located in the annulus building with the exception of Fig. 3.3.4-8 and 3.3.4-12 which are located in the containment.

Each piping module figure tabulates the total linear footage of piping required, the total number of field welded joints that would be required if the module were fabricated to current practice, the total number of field welded joints required by the module, the total number of spools required to assemble the module, the approximate weight of the module, the approximate weight of the module lifting rig, and the maximum lift.

3.3.4.3 Site Requirements/Assumptions

The module fabrication shop/area that is required at the construction site consists of a 40,000 sq ft structure equipped to handle structural components, large pipe modules, small bore piping fabrications, and cable tray subassemblies. In order to effect the greatest economy, the building is designed such that it can be used by the owner as a warehouse and/or maintenance facility once construction is completed. In addition, the 30 ton overhead crane that will be used in the solid waste decontamination building is installed and used in the module fabrication shop/area for the duration of module assembly.

3.3.4.4 Engineering Impact

In order that the full advantages of piping modularization be realized, it is necessary that every engineering effort be exerted to assure that all valves, piping, and fittings, as well as all module terminal equipment such as pumps, tanks, heat exchangers, etc be at the construction site in time to coordinate with their respective modules. In many instances, this will require engineering activity at least 18 months earlier than in the conventional method. Planning networks require revision to reflect the impact of the modularization of piping systems.

In addition, coordination between construction and engineering is required to establish the extent of, and to identify, each module so that module drawings, including specifications for lifting and transporting for assured freedom of any damage, are prepared and are at the construction site in ample time to comply with the construction schedule. Additional costs for this effort are reflected in Section 3.3.4.5.

A priority list must be prepared so that the pipe fabricator can furnish the spools in the proper sequence. Finally, all anchor locations and hanger designs are required at the construction site before any work is initiated on a module.

3.3.4.5 Cost Savings

The estimated cost differential to fabricate, transport, and erect each module is as noted below:

Module	Differential Cost
151	$45,000
254	19,000
258	19,000
262	63,000
264	50,000
294	27,000
342	61,000
370 (Primary loop)	146,000
390A & C	25,000
390B	15,000
391	67,000
410	55,000

These estimates illustrate differential costs only for the more complex modules. These estimates do not include material and commercial shop fabrication of spool pieces.

There are an estimated 539 modules in the reactor building, annulus building, and turbine building of the Reference Nuclear Power Plant (RNPP).

On the basis of a field fabrication shop equipped with automatic welding machines and utilizing assembly line methods, the estimated construction cost savings would be approximately $1,500,000. The automatic welders would be positioned on the joint and deposit weld material as it rotates around the pipe and the spool piece which would be held in a fixed position. An additional $2,000,000 saving would be realized in erection operations for a total construction labor cost savings as of March 1, 1976, of $3,500,000.

It is believed an additional savings of $2,000,000 to $3,500,000 is attainable; however, this would require a detailed review of the field shop operations involved for the proposed 539 modules.

The comparative construction costs for a field piping fabrication shop, fully equipped for fabricating pipe modules, compared to current practice, are as follows:

	Difference
Building	$300,000
Equipment	100,000
Total Construction Cost	$400,000

Additional engineering, design, and construction non-manual costs would be approximately $100,000.

Net savings of at least $3,000,000 is, therefore, anticipated. Possible net savings could exceed $6,000,000.

3.3.4.6 Schedule Savings

Since the Critical Path is "floating," it is not possible to determine decreases with assurance that the Critical Path will not "jump" to another activity, resulting in a "no-gain" situation.

It has been determined, however, that there is a possible 16 week decrease of the Critical Path resulting from piping modularization with the reactor building and the annulus building complex. Of equal importance is the total combined activity duration reductions which do not always follow Critical Path but can result in man-hour savings. The following is a breakdown, by building, of possible activity duration reductions:

Reactor Building	36 weeks
Annulus Building	28 weeks
Control Building	8 weeks
Turbine Building	42 weeks
Service Building	10 weeks
Miscellaneous Structures	12 weeks

A detailed schedule analysis for a specific project is desirable for a better evaluation of schedule savings.

There is a possible 16 week decrease of the Critical Path resulting from piping modularization within the containment and annulus building complex.

3.3.4.7 Recommendations

It is recommended that the modularization techniques described be utilized as the basis of design, fabrication, and installation of all RNPP piping systems provided all engineering schedule requirements can be met.

3.3.5 Pipe Racks

3.3.5.1 Current Construction Method

The current construction method of installing pipe racks and piping in the pipe tunnels of the annulus building consists of the following.

Install pipe rack vertical steel and building columns piece by piece. Install pipe rack horizontal steel beams that are needed to support piping, leaving out members that may interfere with the installation of piping spools. Beams are attached to columns typically with double angles on the webs of the beams. Piping is fabricated in spools of up to 40 ft in length in a pipe fabricating shop. The spools are shipped to the site, unloaded and stored at a laydown area on the construction site until required. They are then picked up and transported to the annulus building and placed on the racks. Next, the remaining horizontal support steel is installed. Pipe spools are fitted up and manually welded together and fastened to the rack by U-bolts.

3.3.5.2 Proposed Module Description

In order to reduce the total elapsed time, man-hour effort, cost, and to minimize congestion in the annulus building, modularization is proposed for the fabrication and erection of pipe racks with piping in the nonradioactive and radioactive pipe tunnels. Two such modules are shown in Figs. 3.3.5-1 and -2.

Prior to the scheduled installation of pipe racks and piping, modules consisting of piping supported on the pipe rack horizontal beams will be preassembled on a foundation which encircles the preassembly area for modularization of the containment liner. The preassembly foundation consists of a circular slab on grade, approximately 14 ft wide and having an arc length of 480 ft, with steel support columns on which modules are constructed. Each elevation of pipe rack consists of a maximum of five modules, having an arc length of approximately 90 ft and weighing up to 35 tons including lifting beam and rigging.

Pipe rack horizontal members are placed on the support columns on the preassembly slab. As in Section 3.3.5.1, piping is fabricated in spools, shipped to the site, and stored. Spool pieces are transported to the preassembly slab, set on the horizontal rack members and are automatically welded together and fastened to the rack with U-bolts. All modules for a rack elevation are preassembled on the preassembly slab at the same time to ensure proper fit-up and alignment of modules when placed in the pipe tunnel. Concurrently with preassembly of modules, pipe rack vertical steel, and building columns are erected piece by piece. Pipe rack modules are lifted by crane, using the rack horizontal members as part of the lifting rig, from the preassembly area to the annulus building pipe tunnel. The module cross beams are set on and bolted to beam seats preattached to the rack vertical steel and building columns. Next, the pipes are manually welded to adjacent modules. All modules at the lowest elevation in the tunnel are completed before moving on to the next elevation.

3.3.5.3 Site Requirements/Assumptions

Adequate area around the preassembly slab for modularization of the containment liner is available for a preassembly slab for pipe rack modules. Preassembly of pipe racks and containment liner will not interfere.

3.3.5.4 Engineering Impact

The preassembly of pipe racks with piping is required to begin earlier than would be required using current construction methods. Therefore, design drawings for pipe racks and piping will have to be completed early enough to allow fabrication and delivery for preassembly. In order to begin erection of the pipe racks on the start date for conventional construction, the rack steel and piping must be delivered one to two months earlier than otherwise would be required.

In addition, coordination between construction and engineering is required to establish the extent of, and to identify, each module. Lifting points and sequence of erection of modules must also be established. Such activities are reflected in a cost penalty described in Section 3.3.5-5.

3.3.5.5 Cost Savings

The estimated total construction cost savings based on fabricating, transporting, and erecting each module is as noted below:

Module	Location	Total Construction Cost Savings
A	Radioactive pipe tunnel	$17,000
B	Radioactive pipe tunnel	26,000
C	Non-radioactive pipe tunnel	18,000
D	Non-radioactive pipe tunnel	38,000

*Modules are representative for cost analysis only.

There are an estimated 39 pipe rack modules in the annulus building pipe tunnels. An estimated $700,000 to $1,000,000 can be saved by modularization of pipe racks and piping. These savings are offset by additional engineering, design, and construction non-manual activities of approximately $25,000. Therefore, net savings of $675,000 to $975,000 are expected with the modularization technique.

3.3.5.6 Schedule Savings

Since the Critical Path is "floating," it is not possible to determine decreases with assurance that the Critical Path will not jump to another activity, resulting in a "no-gain" situation. It is estimated that modularization of pipe racks and piping i the annulus building could result in a schedule time savings 28 weeks. This savings does not always follow the Critical Path but could result in up to 16 weeks Critical Path savings concurrently with piping modularization schedule savings. A detailed schedule analysis for a specific project is necessary to fully evaluate schedule savings.

3.3.5.7 Savings Criteria

Pipe rack modules in conjunction with piping modules meet both savings criteria.

3.3.5.8 Recommendations

It is recommended that the modularization techniques be utilized as the basis of design, fabrication, and installation of pipe racks with piping in the pipe tunnels of the annulus building subject to a more detailed scheduled analysis for a specific project.

TABLE 3.3.1-1

SUMP MODULE DESIGN CHARACTERISTICS

Maximum space envelope, ft	3 W x 4 L x 9.5H*
Module weight, lb	
Pumps (2)	750*
Motors (2)	100
Baseplate	300
Piping and valves	50
Total	1,200

*Assuming a 7 ft pump column.

TABLE 3.3.1-2

TYPICAL COST SAVINGS - SUMP MODULARIZATION

Building	No. of Modules	Total Number of Welds	Total Cost Savings[1]
Annulus Building	6	84	$4,200
Containment Structure	2	28	1,400
Fuel Building	1	14	700
Solid Waste and Decontamination Building	1	14	700
Turbine Building	3	42	2,100
Total			$9,100

[1]Dollars represent total construction costs with present day at March 1, 1976.

1 of 1

TABLE 3.3.1-3

DEMINERALIZER/FILTER MODULES
TYPICAL DESIGN CHARACTERISTICS

Module (Number)	Maximum Weight Per Module, Ton	Maximum Space Envelope
Annulus Building Demineralizers		
Level I (1)	2	10' W x 8' L x 25' H
Level II (3)	1	10' W x 20' L x 10' H
Level III (5)	3/4	10' W x 48' L x 10' H
Fuel Building/Solid Waste and Decontamination Building Demineralizers		
Level I (1)	2	8' W x 8' L x 20' H
Level II (4)	1	15' W x 20' L x 10' H
Annulus Building Filters		
Level I (2)	1/2	8' W x 7' L x 10' H
Level II (3)	1/2	8' W x 15' L x 15' H
Level III (5)	1/2	8' W x 48' L x 10' H
Fuel Building/Solid Waste and Decontamination Building Filters		
Level I (2)	1/2	8' W x 7' L x 10' H
Level II (4)	1	8' W x 7' L x 20' H

(1) Based on a 3,800 lb demineralizer vessel.

(2) Based on a 700 lb filter vessel.

(3) Based on piping modules serving two demineralizer or filter cubicles.

(4) Based on piping modules serving one demineralizer or filter cubicle.

(5) Piping modules consist of piping for all demineralizers/filters served by the pipe tunnel.

3.3-29

TABLE 3.3.1-4

MODULARIZED DEMINERALIZERS

Demineralizer	System	Building	Number of Demineralizers W-41	W-3S	CE	B&W
Mixed Bed	CVCS	Annulus	2	2	-	3
Purification	CVCS	Annulus	-	-	2	-
Cation Bed	CVCS	Annulus	2	1	-	-
Deborating	CVCS	Annulus	-	-	1	3
Boron Thermal Regeneration	CVCS	Annulus	5	5	-	-
Fuel Pool	FPS	Fuel	1	1	1	1
Cesium Removal	BRS	Annulus	2	2	2	2
Boron	BRS	Solid Waste and Decontamination	1	1	1	1
Waste	LWS	Solid Waste and Decontamination	1	1	1	1
Total			14	13	8	11

Notes

System Designations: CVCS - Chemical and Volume Control System (Makeup and Purification System - B&W)
FPS - Fuel Pool Cooling and Purification System
BRS - Boron Recovery System
LWS - Radioactive Liquid Waste System

3.3-30

TABLE 3.3.1-5

MODULARIZED FILTERS

Filter	System	Building	Number of Filters W-41	W-3S	CE	B&W
Reactor Coolant	CVCS	Annulus	2	2	2	2
Boric Acid	CVCS	Annulus	1	1	1	2
Seal Water Injection	CVCS	Annulus	2	2	2	2
Demineralizer Prefilter	CVCS	Annulus	-	-	-	1
Fuel Pool Prefilter	FPS	Fuel	2	2	2	2
Fuel Pool Post Filter	FPS	Fuel	1	1	1	1
Boron Recovery	BRS	Annulus	2	2	2	2
Boron Demineralizer Filter	BRS	Solid Waste and Decontamination	1	1	1	1
Waste Demineralizer Filter	LWS	Solid Waste and Decontamination	1	1	1	1
Waste Effluent	LWS	Annulus	2	2	2	2
Spent Resin	WSS	Solid Waste and Decontamination	1	1	1	1
Total			15	15	15	17

Notes

System Designations:

CVCS - Chemical and Volume Control System (Makeup and Purification System - B&W)
FPS - Fuel Pool Cooling and Purification System
BRS - Boron Recovery System
LWS - Radioactive Liquid Waste System
WSS - Radioactive Solid Waste System

TABLE 3.3.1-6

TYPICAL COST SAVINGS - DEMINERALIZER MODULARIZATION

Demineralizer(1)	Pipe Size, In.	Pipe Safety Class	Number of Welds Performed in Shop Rather than in Field	Estimated Cost Savings(2)
Deborating	2	3	34	$ 8,670
	3	3	18	5,400
	4	3	31	10,540
	2 1/2	NNS	114	5,130
Total Savings				$29,740

Notes

1. All demineralizers in the plant are standardized as to the arrangement and size of the associated piping and valves.

2. Total savings stated above are present day March 1, 1976, and are for 14 assemblies of a typical set of two demineralizers.

TABLE 3.3.1-7

TYPICAL COST SAVINGS - FILTER MODULARIZATION

Filter	Pipe Size, In.	Pipe Safety Class	Number of Welds Performed in Shop Rather than in Field	Estimated Cost Savings[1]
Reactor Coolant Filters	4	2	56	$23,240
	2	2	4	1,320
Total Module Savings				24,560
Boric Acid Filters	4	3	56	19,040
	2	3	4	1,020
Total Module Savings				20,060
Fuel Pool Prefilters	4	NNS	56	3,080
	2	NNS	4	200
Total Module Savings				$3,280

1. Total savings stated above are present day March 1, 1976 and are for 8 subassemblies of a typical set of two filters.

TABLE 3.3.1-8

TYPICAL COST COMPARISON - PACKAGED VERSUS COMPONENT COMPRESSED AIR SYSTEM

EQUIPMENT DATA

Number of compressors per system	3
Capacity, scfm	725
Discharge pressure, psig	125
Motor, hp	150

EQUIPMENT COSTS

	Packaged(1)(4)	Component(2)(4)
Equipment Price	$104,000	$88,000
Installation Cost(3)	37,200	49,600
Total Cost	141,200	137,600

Notes

(1) Includes three compressor packages.

(2) Includes three compressors, each with motor, inlet filter, aftercooler, intercooler, starter, controls, and receiver.

(3) Installation man-hours for three compressors:

packaged - 1,800 hr
component - 2,400 hr

(4) Dollars represent total construction costs with present day at March 1, 1976.

1 of 1

TABLE 3.3.1-9

TYPICAL CONDENSATE POLISHING EQUIPMENT MODULES

Module	Components (See Note 1)	Size	Shipping Weight, Lb
1	Cation Regeneration Tank	9'-5" x 9'-1" x 17'-4 1/2"	21,000
2	Anion Regeneration Tank	6'-10" x 6'-8" x 16'-9"	14,000
3	Resin Mix and Storage Tank	8'-11" x 8'-0" x 14'-11"	19,000
4	Acid Measuring Tank - Acid Regeneration Feed Pumps	8'-8" x 5'-0" x 7'-7 1/2"	2,600
5	Caustic Measuring Tank Caustic Regenerant Feed Pump Recovered Caustic Pumps	11'-8" x 5'-0" x 7'-7 1/2"	3,100
6	Recycle Pump	8'-5" x 3'-4" x 11'-5"	5,000
7	Lime Slurry Tank Lime Dissolving Tank Lime Solution Filter Lime Slurry Pumps	7'-9" x 7'-8" x 9'-0"	3,600
8	Sluicing Water Pumps	10'-0" x 5'-0" x 4'-8"	3,200
9	Rotary Air Blower	6'-0" x 6'-0" x 5'-0"	2,950

Note 1: Modules also include associated piping, valves, and instrumentation.

TABLE 3.3.3-1

TANK COST AND TIME COMPARISON
CONSTRUCTION IN ANNULUS BUILDING VS TEMPORARY
FOUNDATION AND MOVING

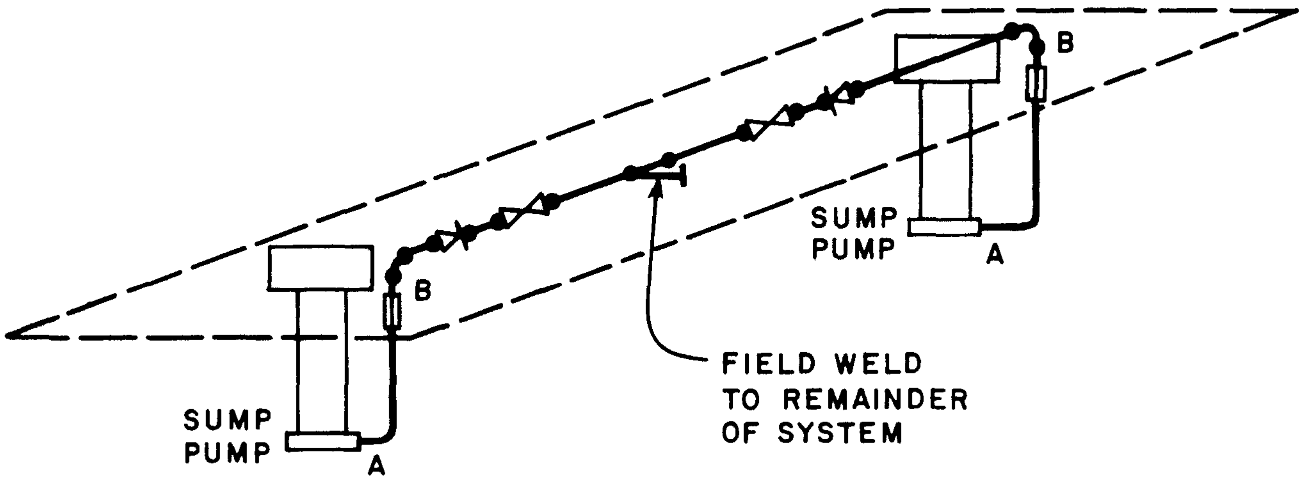
	Vendor A	Vendor B	Vendor C
Total construction cost savings (2 tanks) as of March 1, 1976	$25,000	$109,000	$44,000

Notes:

1. Tanks erected on temporary foundations adjacent to annulus building.

2. Crane cost considered a distributable expense.

3. Rigging personnel moving cost for the two tanks, approximately $6,000, is included in the cost to erect on a temporary foundation and move.



LEGEND:

BASEPLATE

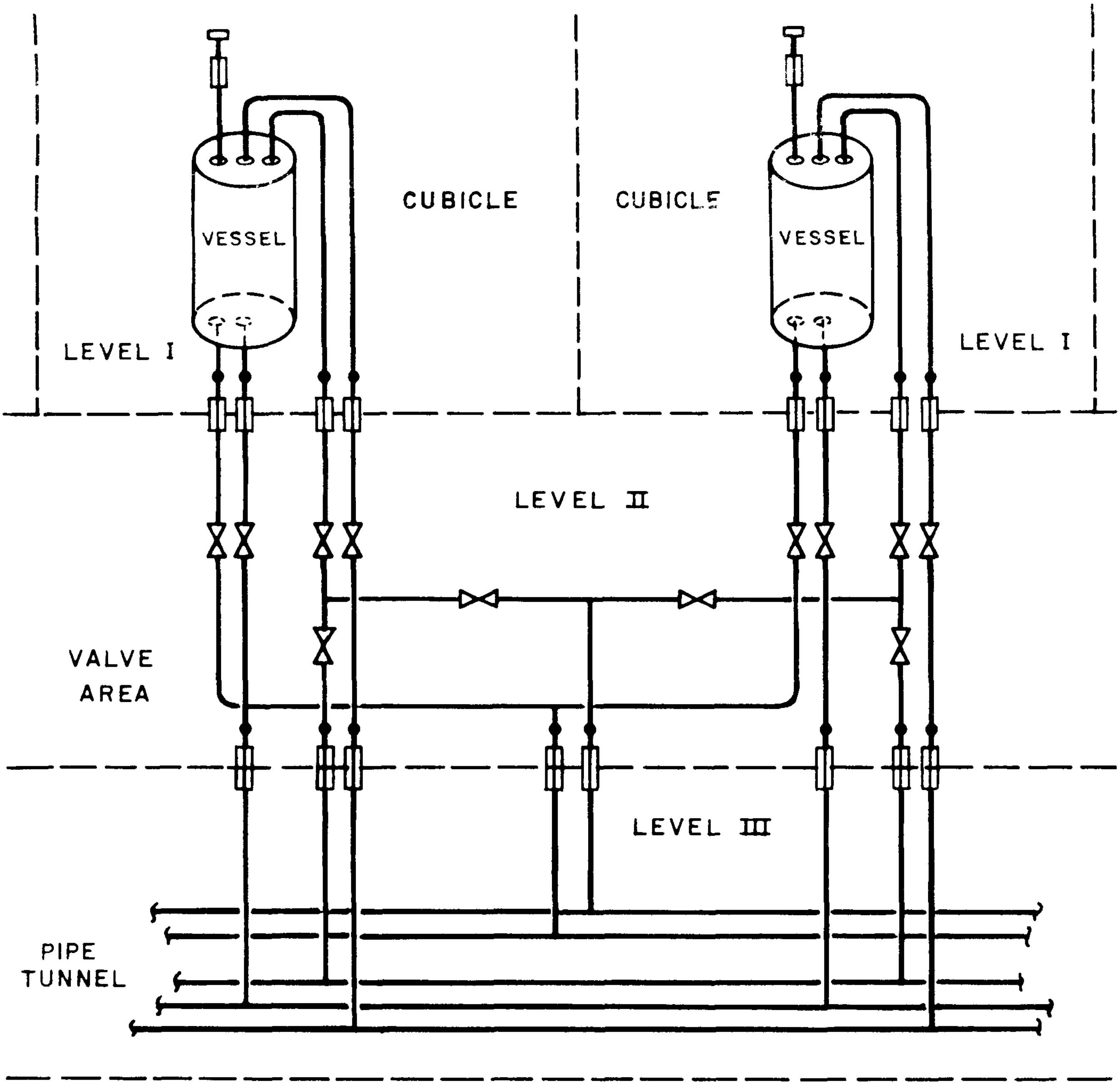
BASEPLATE PENETRATION

SHOP WELD

NOTES:

1. ALL PIPING IS 2 IN.
2. PIPING FROM PUMP DISCHARGE AT A TO WELD AT B IS SUPPLIED WITH PUMP.

FIGURE 3.3.1-1
SUMP MODULARIZATION



LEGEND:

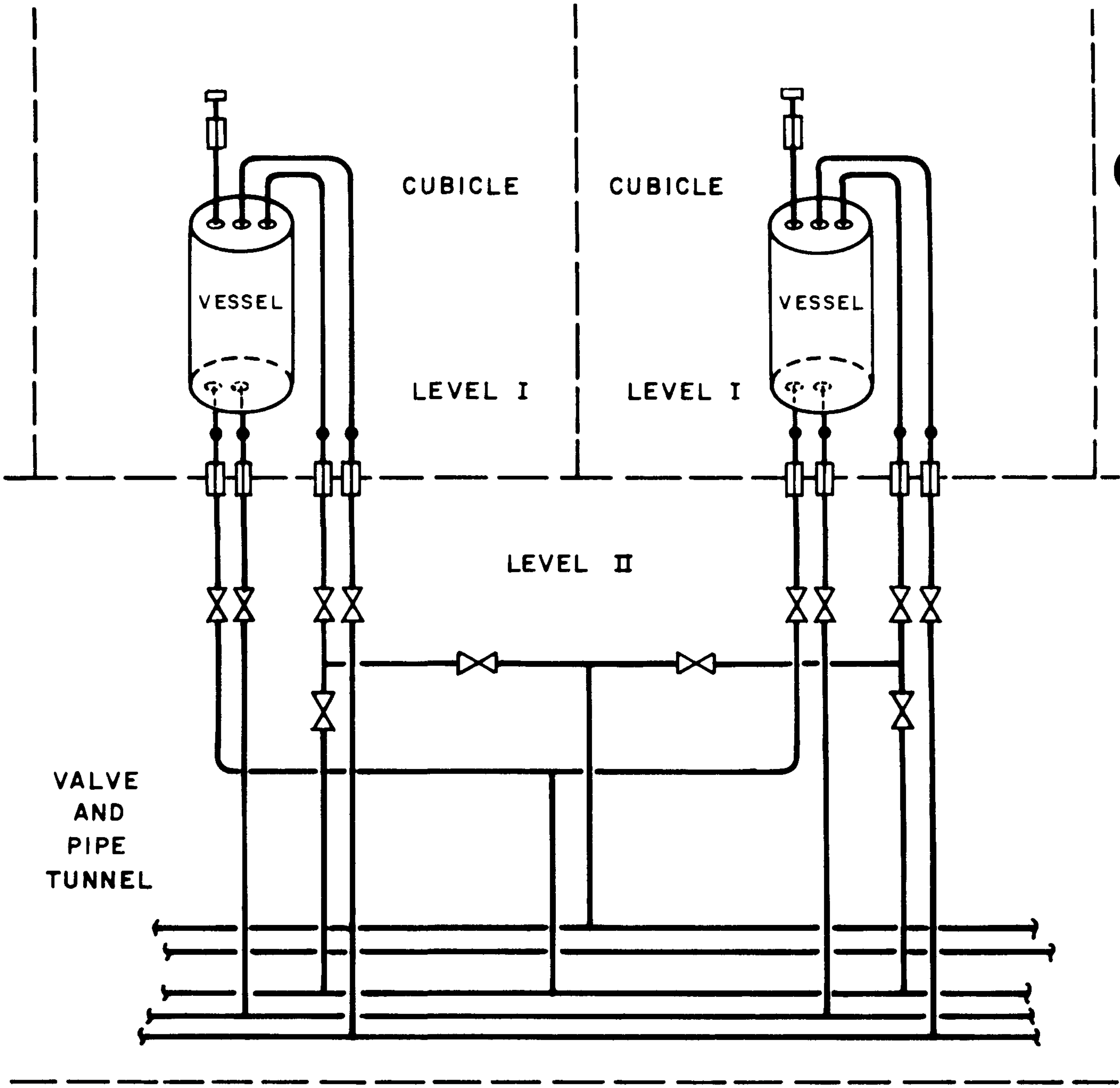
FLOOR PENETRATION
WALLS, FLOORS, CEILINGS
FIELD WELD

NOTES:

1. PIPING LAYOUT IS APPROXIMATE.
2. LEVEL III EXTENDS .
   IN EITHER DIRECTION OVER THE
   LENGTH OF THE PIPE TUNNEL.

FIGURE 3.3.1-2

ANNULUS BUILDING DEMINERALIZER FILTER SUBASSEMBLIES



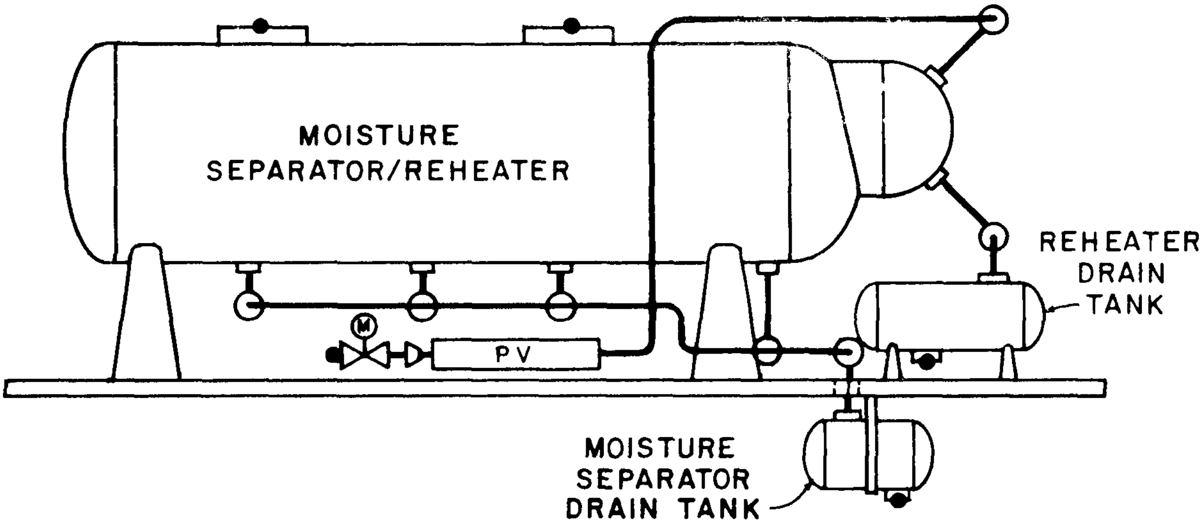
LEGEND:

- FLOOR PENETRATION
- WALLS, FLOORS, CEILINGS
- FIELD WELD

NOTES:

1. PIPING LAYOUT IS APPROXIMATE.
2. LEVEL II EXTENDS IN EITHER DIRECTION OVER THE LENGTH OF THE PIPE TUNNEL.

FIGURE 3.3.1-3
FUEL BUILDING AND
SOLID WASTE AND
DECONTAMINATION BUILDING
DEMINERALIZER/
FILTER SUBASSEMBLIES



● = FIELD WELD

FIGURE 3.3.1-4

MOISTURE SEPARATOR/ REHEATER MODULE

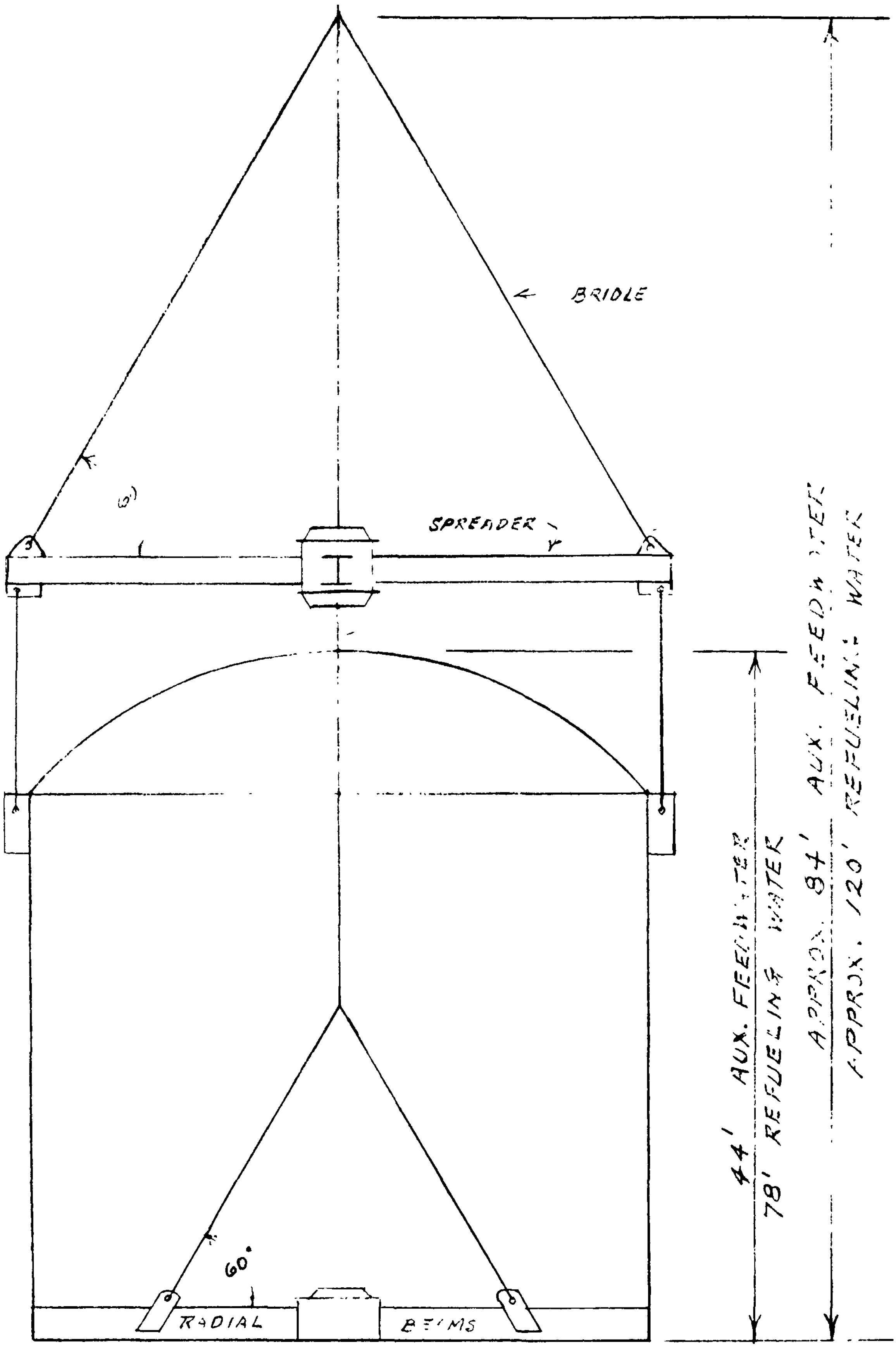


FIGURE 3.3.3-1
TYPICAL TANK LIFTING
ARRANGEMENT

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE
FIELD JOINT THIS MODULE

TOTAL LINEAR FOOTAGE IN MODULE = 52 FT.
TOTAL NUMBER OF FIELD WELDED JOINTS
WHEN FABRICATED TO CURRENT PRACTICE = 10
TOTAL NUMBER OF FIELD WELDED JOINTS
THIS MODULE = 3
TOTAL NUMBER OF FLANGE JOINTS = 11
TOTAL NUMBER OF SPOOLS = 10
APPROXIMATE WEIGHT OF MODULE = 48,600 LB
APPROXIMATE WEIGHT OF LIFTING RIG = 3,500 LB
MAX LIFT = 52,100 LB

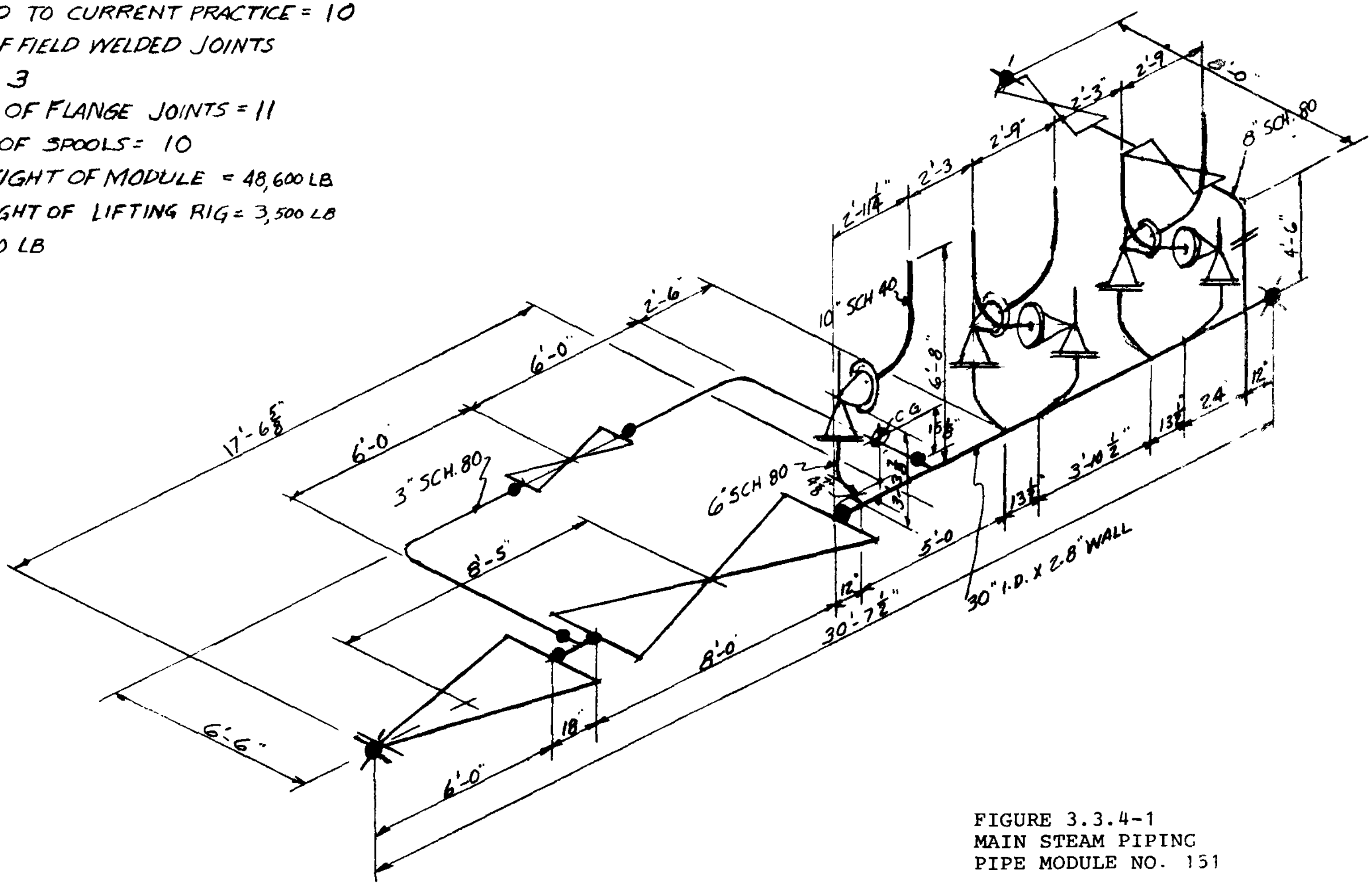


FIGURE 3.3.4-1
MAIN STEAM PIPING
PIPE MODULE NO. 151

TOTAL LINEAR FOOTAGE IN MODULE	112 (FT)
TOTAL NUMBER OF FIELD WELDED JOINTS WHEN FABRICATED TO CURRENT PRACTICE :	6
TOTAL NUMBER OF FIELD WELDED JOINTS THIS MODULE :	1
TOTAL NUMBER OF FLANGED JOINTS :	6
TOTAL NUMBER OF SPOOLS :	10
APPROXIMATE WEIGHT OF MODULE :	10,540 (LB)
APPROXIMATE WEIGHT OF LIFTING RIG :	1500 (LB)
MAX LIFT:	12000 (LB)

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE.

FIELD JOINT THIS MODULE.

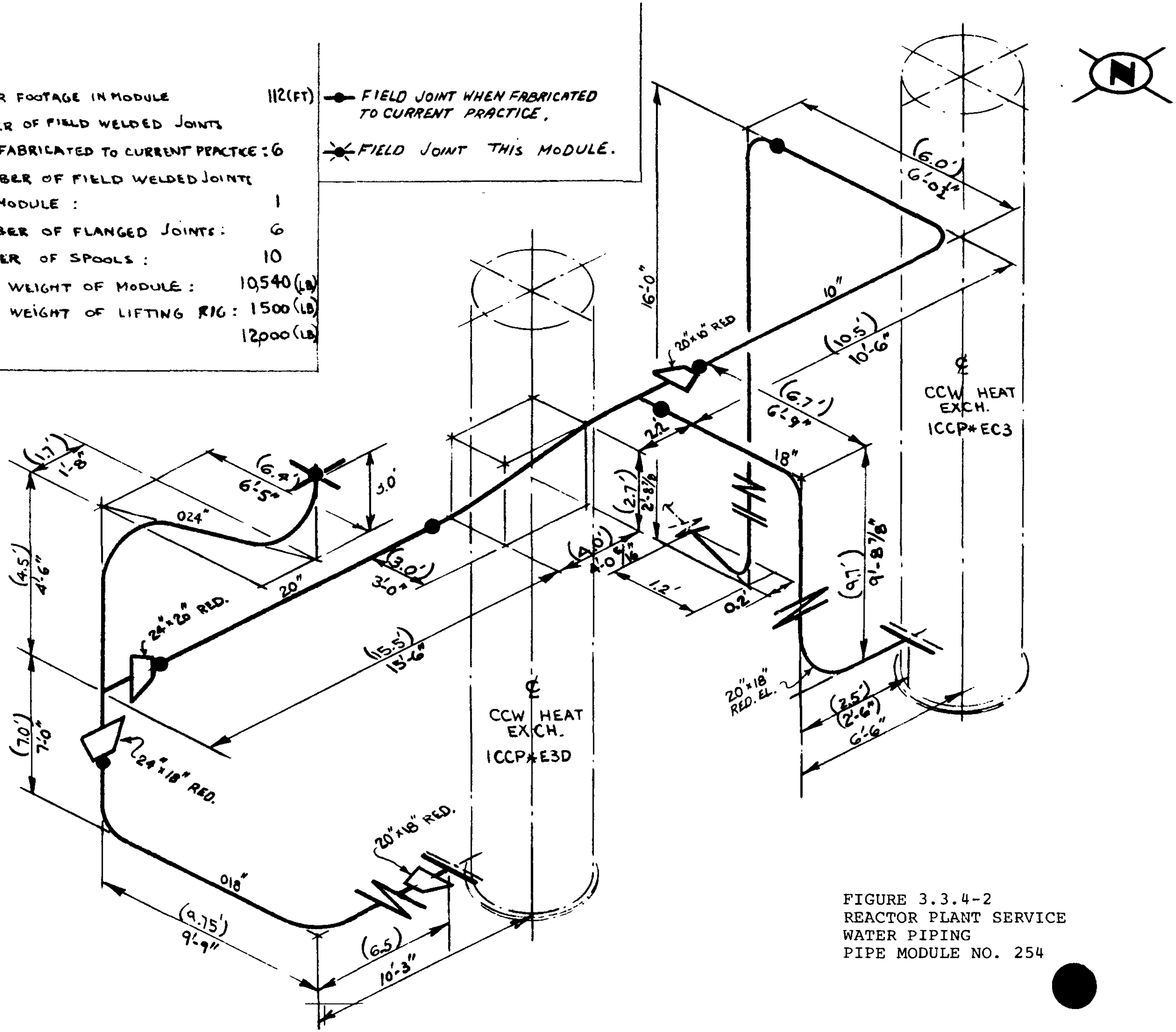


FIGURE 3.3.4-2
REACTOR PLANT SERVICE
WATER PIPING
PIPE MODULE NO. 254

TOTAL LINEAR FOOTAGE IN MODULE:	63 (FT)
TOTAL NUMBER OF FIELD WELDED JOINTS:	
WHEN FABRICATED TO CURRENT PRACTICE:	9
TOTAL NUMBER OF FIELD WELDED JOINTS THIS MODULE:	1
TOTAL NUMBER OF FLANGED JOINTS:	8
TOTAL NUMBER OF SPOOLS:	11
APPROXIMATE WEIGHT OF MODULE:	11,952. (LB)
APPROXIMATE WEIGHT OF LIFTING RIG:	3,015. (LB)
MAXIMUM LIFT:	15,000. (LB)

● FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE.

✕ FIELD JOINT THIS MODULE.

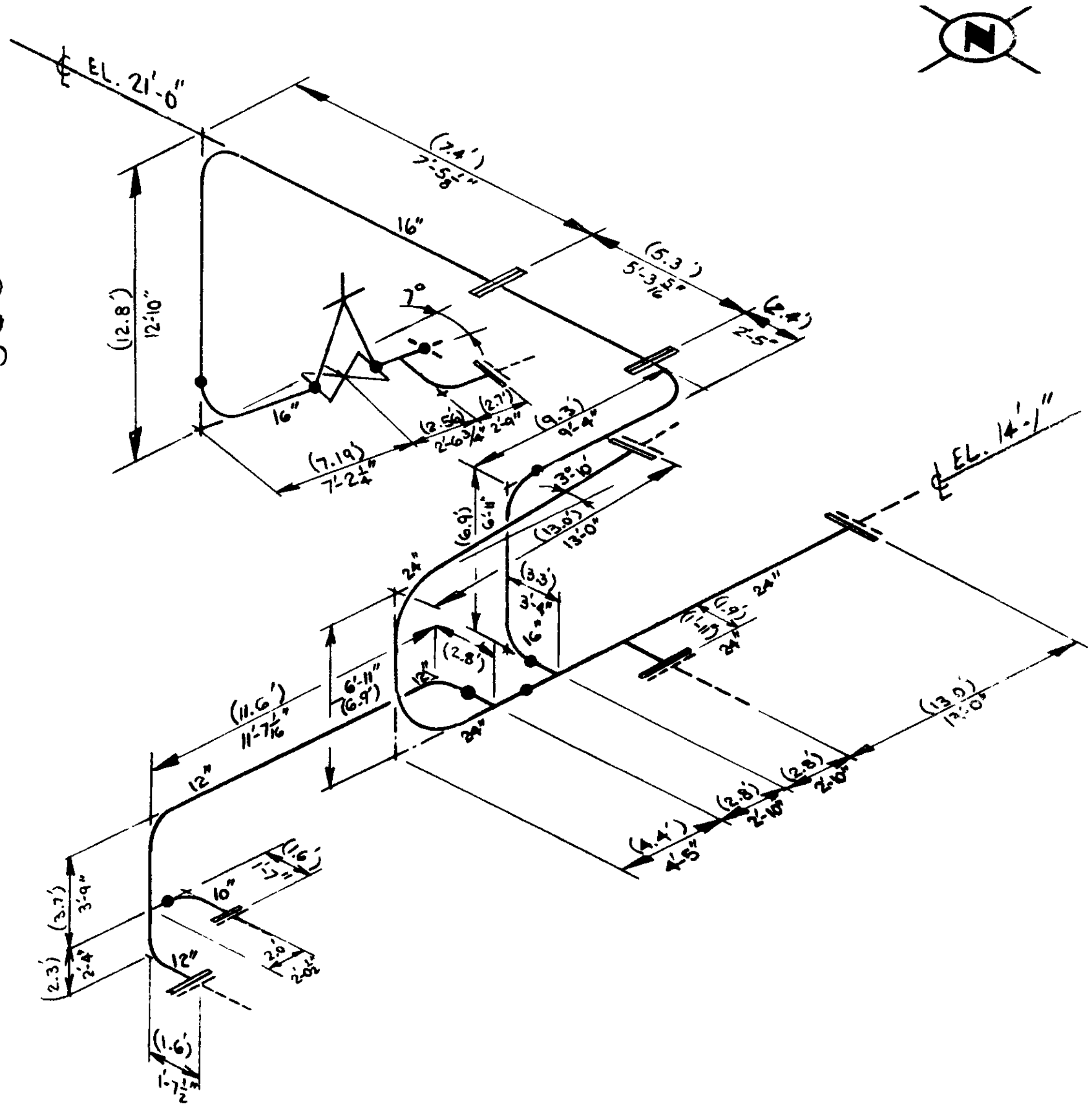
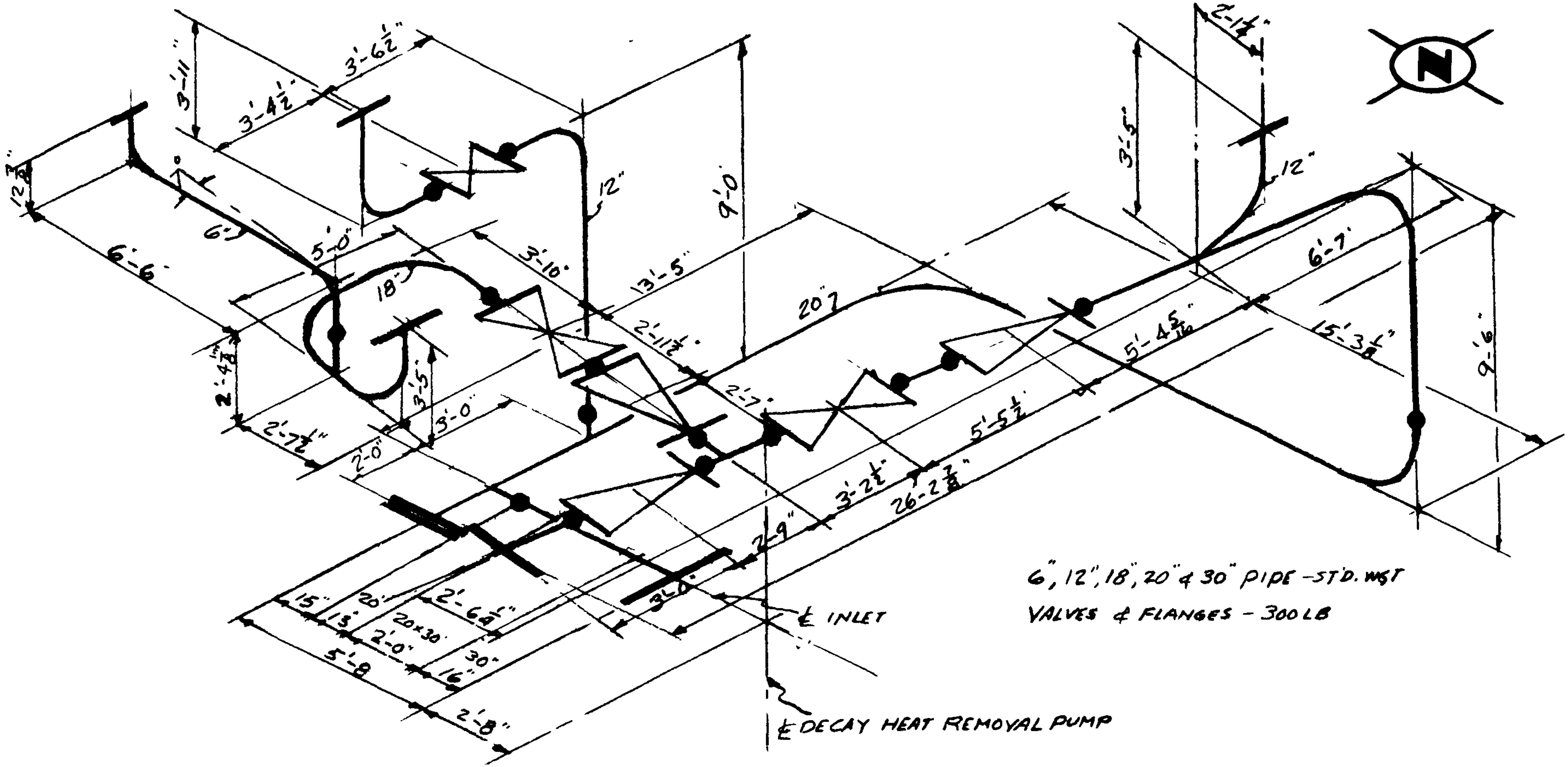


FIGURE 3.3.4-3
REACTOR PLANT COMPONENT
COOLING WATER PIPING
PIPE MODULE NO. 258



TOTAL LINEAR FOOTAGE IN MODULE = 58.5 FT
TOTAL NUMBER OF FIELD WELDED JOINTS WHEN FABRICATED TO CURRENT PRACTICE = 19"
TOTAL NUMBER OF FIELD WELDED JOINTS THIS MODULE = O
TOTAL NUMBER OF FLANGED JOINTS = 6
TOTAL NUMBER OF SPOOLS = 15
APPROXIMATE WEIGHT OF MODULE = 33,200 LB
APPROXIMATE WEIGHT OF LIFTING RIG = 3,300 LB
MAXIMUM LIFT = 36,500 LB

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE
FIELD JOINT THIS MODULE

FIGURE 3.3.4-4
REACTOR PLANT COMPONENT
COOLING WATER PIPING
PIPE MODULE NO. 262

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE.

FIELD JOINT THIS MODULE.

TOTAL LINEAR FOOTAGE IN MODULE : 90.25 (FT)

TOTAL NUMBER OF FIELD JOINTS WHEN FABRICATED TO CURRENT PRACTICE : 16

TOTAL NUMBER OF FIELD JOINTS THIS MODULE : 0

TOTAL NUMBER OF FLANGED JOINTS : 6

TOTAL NUMBER OF SPOOLS : 17

APPROXIMATE WEIGHT OF MODULE : 14,205.

APPROXIMATE WEIGHT OF LIFTING RIG :

MAXIMUM LIFT :

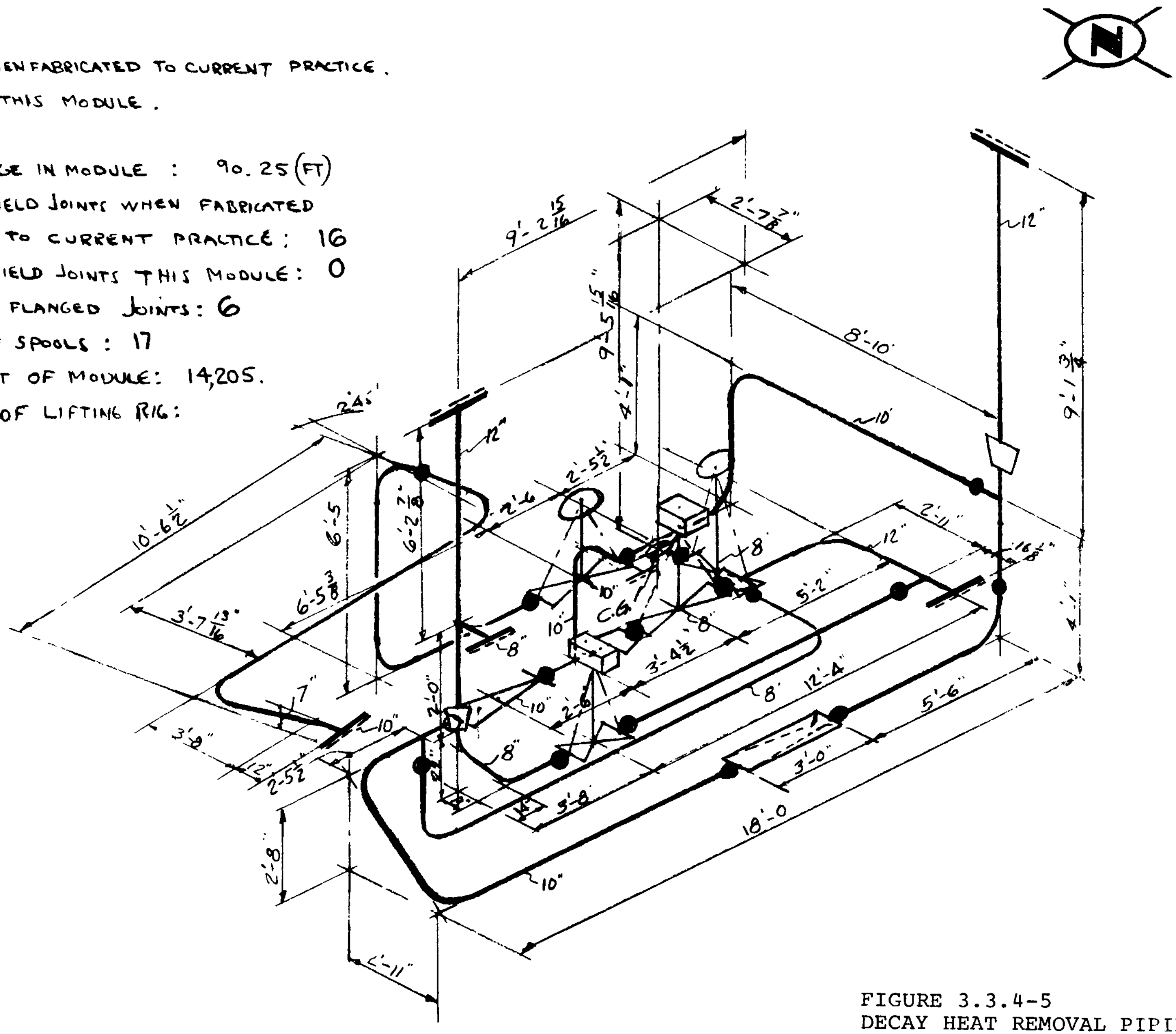
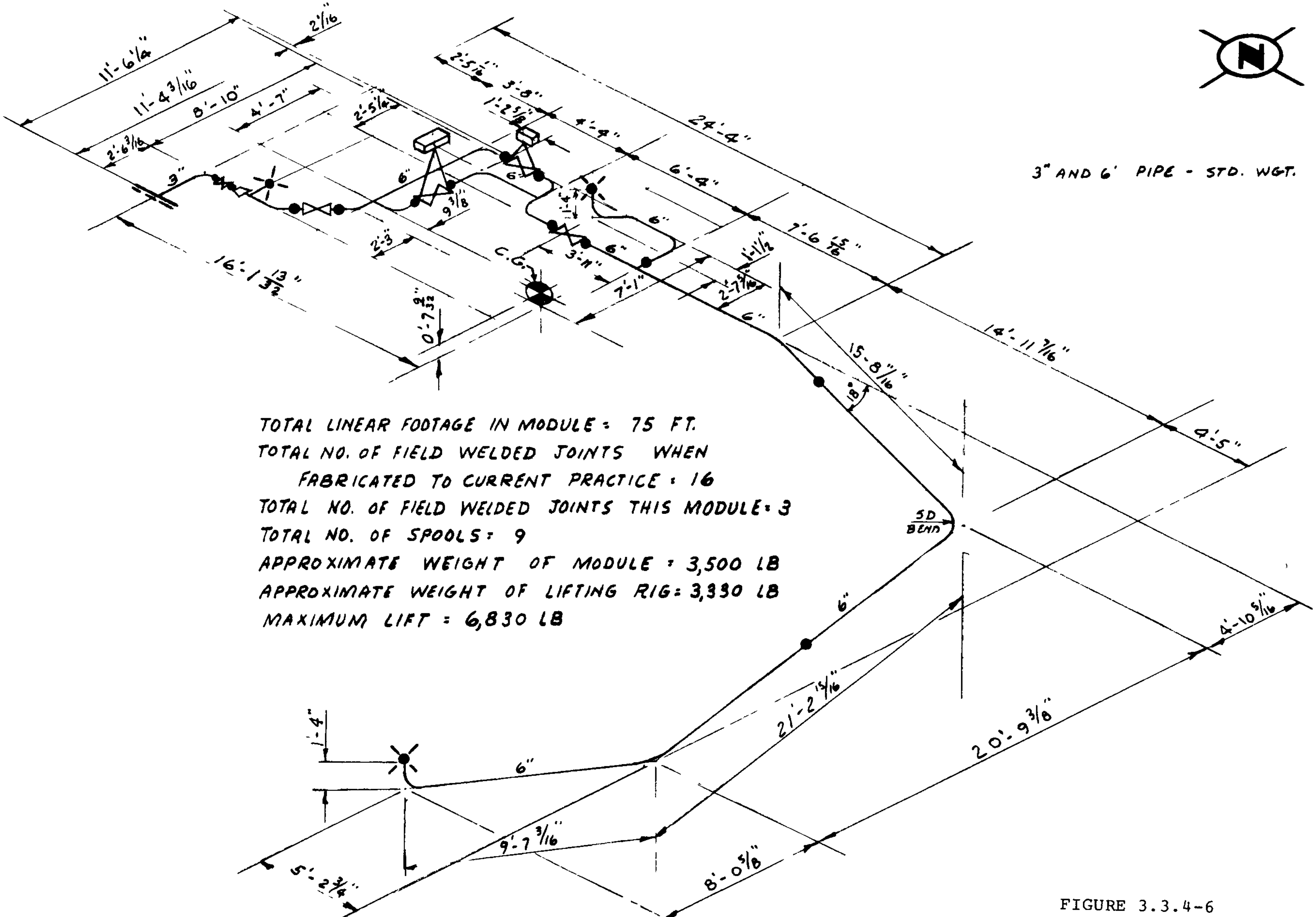


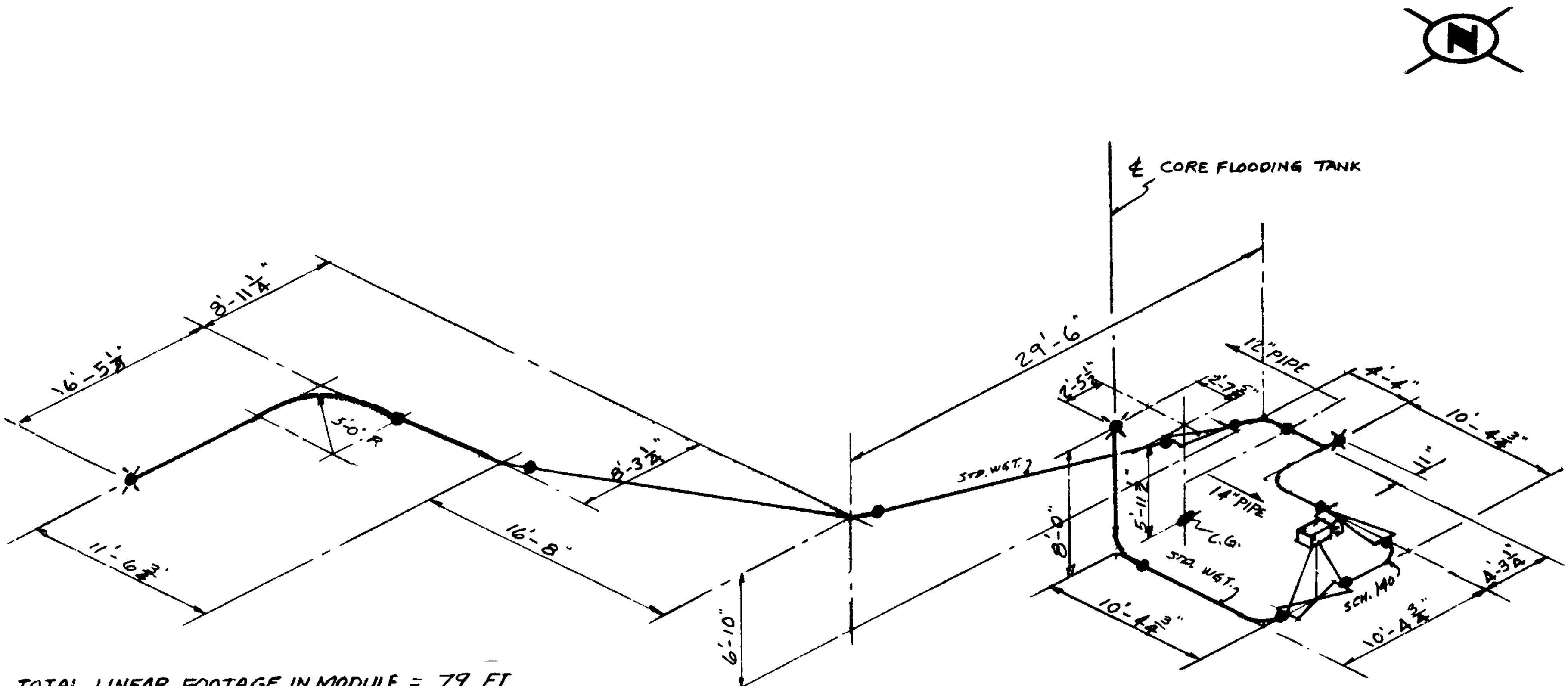
FIGURE 3.3.4-5
DECAY HEAT REMOVAL PIPING
PIPE MODULE NO. 264



FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE.

FIELD JOINT THIS MODULE.

FIGURE 3.3.4-6
CONTAINMENT SPRAY PIPING
PIPE MODULE NO. 294



TOTAL LINEAR FOOTAGE IN MODULE = 79 FT

TOTAL NUMBER OF FIELD WELDED JOINTS WHEN FABRICATED TO CURRENT PRACTICE = 14

TOTAL NUMBER OF FIELD WELDED JOINTS THIS MODULE = 3

TOTAL NUMBER OF SPOOLS = 12

APPROXIMATE WEIGHT OF MODULE = 24,000 LB

APPROXIMATE WEIGHT OF LIFTING RIG = 2,300 LB.

MAXIMUM LIFT = 26,300 LB

FIGURE 3.3.4-7
DECAY HEAT REMOVAL PIPING
PIPE MODULE NO. 342

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE

FIELD JOINT THIS MODULE

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE.

FIELD JOINT THIS MODULE.

TOTAL LINEAR FOOTAGE IN MODULE:	72.1 (FT)
TOTAL NUMBER OF FIELD JOINTS WHEN FABRICATED TO CURRENT PRACTICE:	6
TOTAL NUMBER OF FIELD JOINTS THIS MODULE:	2
TOTAL NUMBER OF FLANGED JOINTS:	0
TOTAL NUMBER OF SPOOLS:	5
APPROXIMATE WEIGHT OF MODULES:	104,188. (LB)
APPROXIMATE WEIGHT OF LIFTING RIG:	0.
MAXIMUM LIFT:	104,188. (LB)

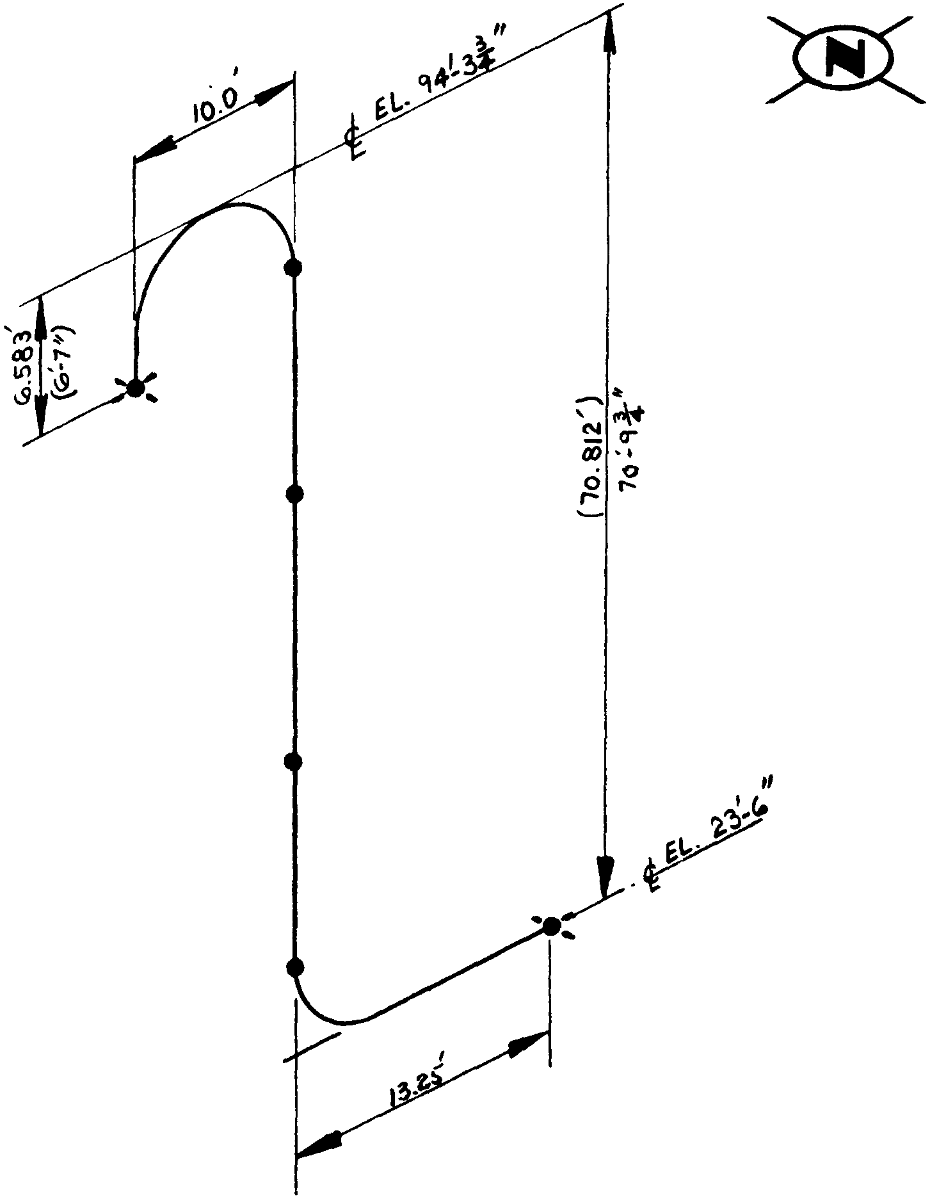


FIGURE 3.3.4-8
PRIMARY COOLANT PIPING
PIPE MODULE NO. 370

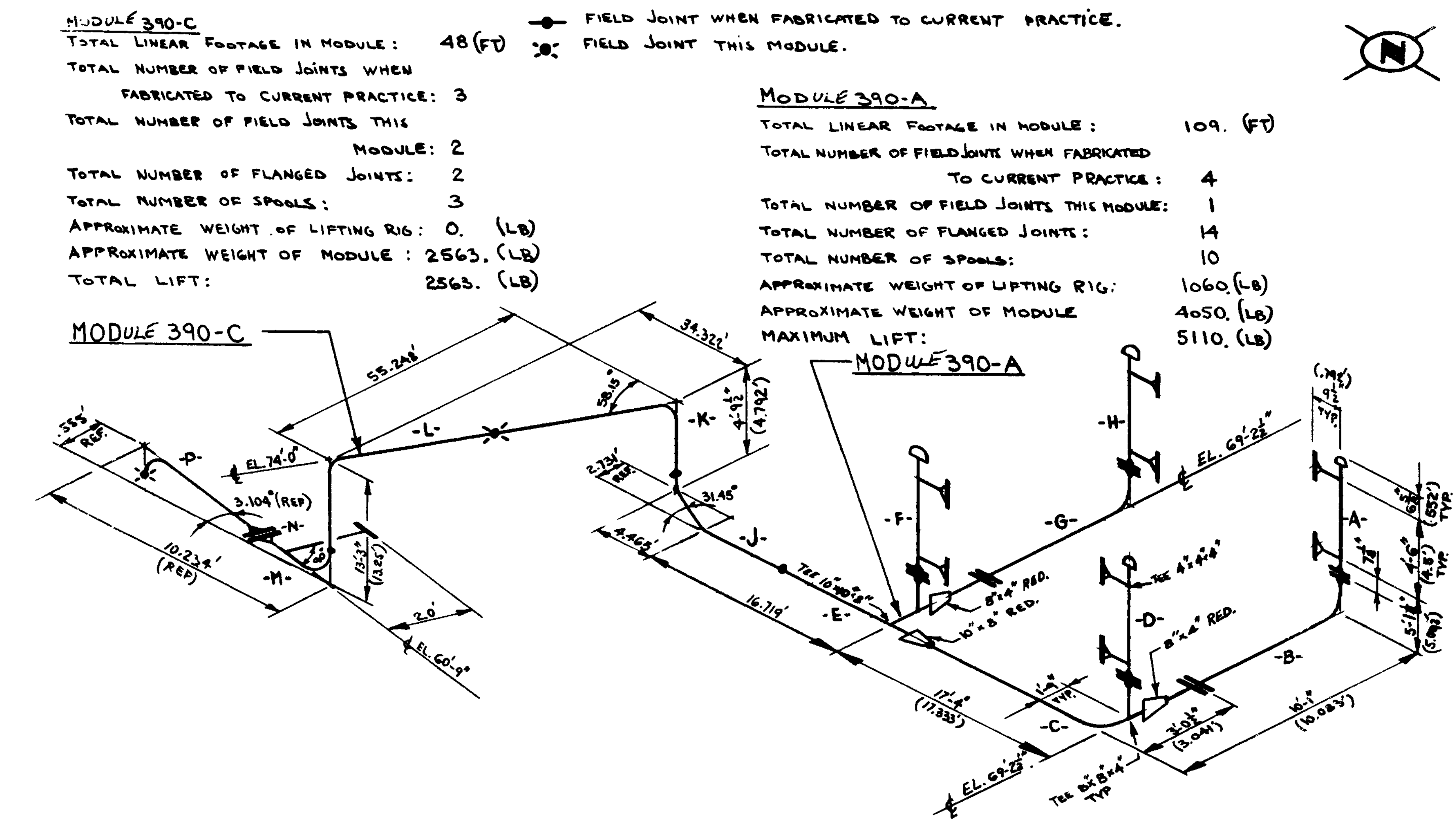
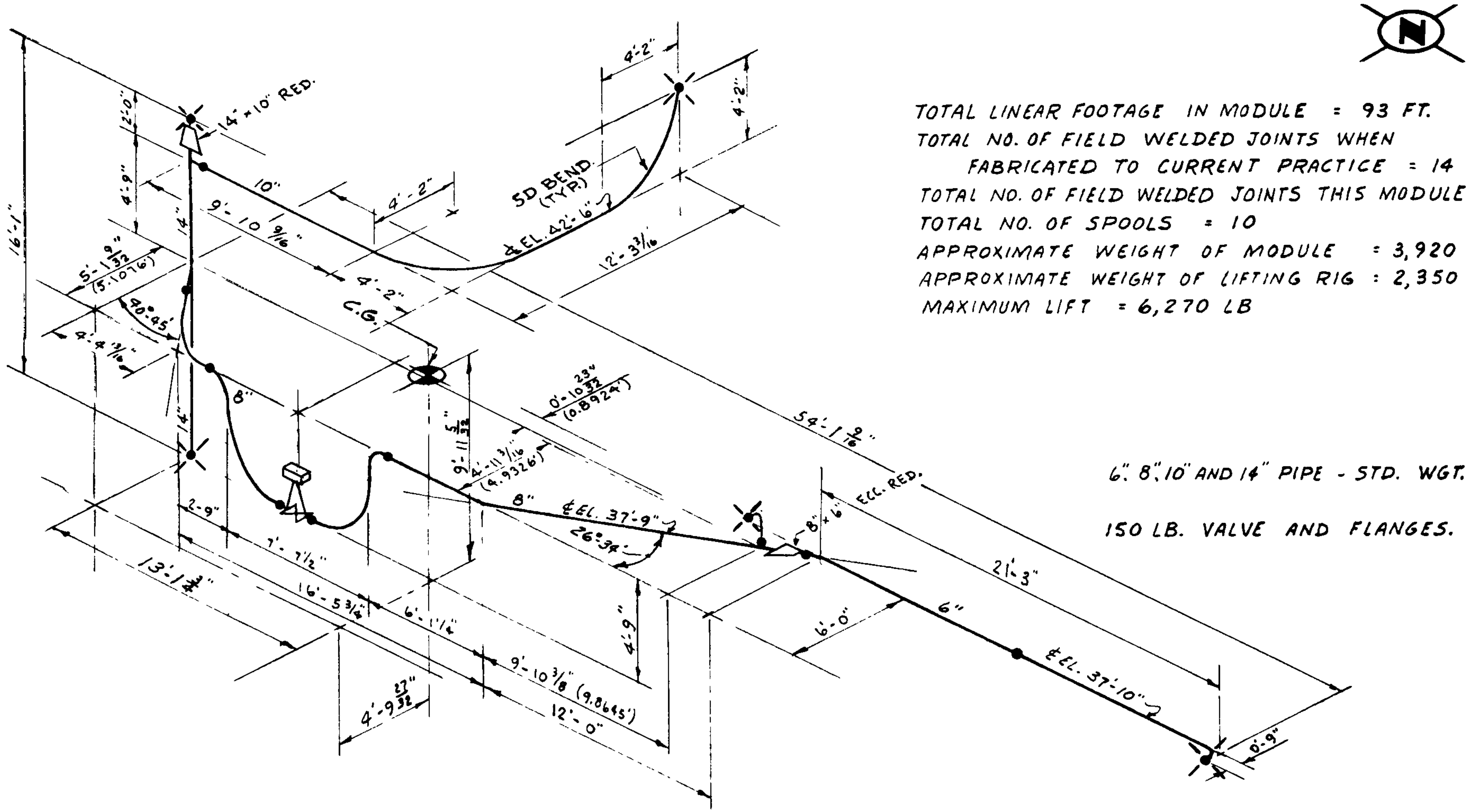


FIGURE 3.3.4-9
REACTOR PLANT COMPONENT
COOLING WATER PIPING
PIPE MODULE NO. 390A & C



TOTAL LINEAR FOOTAGE IN MODULE = 93 FT.
TOTAL NO. OF FIELD WELDED JOINTS WHEN FABRICATED TO CURRENT PRACTICE = 14
TOTAL NO. OF FIELD WELDED JOINTS THIS MODULE = 5
TOTAL NO. OF SPOOLS = 10
APPROXIMATE WEIGHT OF MODULE = 3,920 LB
APPROXIMATE WEIGHT OF LIFTING RIG = 2,350 LB
MAXIMUM LIFT = 6,270 LB

6", 8", 10" AND 14" PIPE - STD. WGT.

150 LB. VALVE AND FLANGES.

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE.

FIELD JOINT THIS MODULE.

FIGURE 3.3.4-10
REACTOR PLANT COMPONENT
COOLING WATER PIPING
PIPE MODULE NO. 390B

TOTAL LINEAR FOOTAGE IN MODULE: 73.5 (FT)
TOTAL NUMBER OF FIELD JOINTS WHEN FABRICATED TO CURRENT PRACTICE: 5
TOTAL NUMBER OF FIELD JOINTS THIS MODULE: 2
TOTAL NUMBER OF FLANGED JOINTS: 0
TOTAL NUMBER OF SPOOLS: 4
APPROXIMATE WEIGHT OF MODULE: 16752 (LB)
APPROXIMATE WEIGHT OF LIFTING RIG: 2701 (LB)
MAXIMUM LIFT: 19453 (LB)

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE.
FIELD JOINT THIS MODULE.

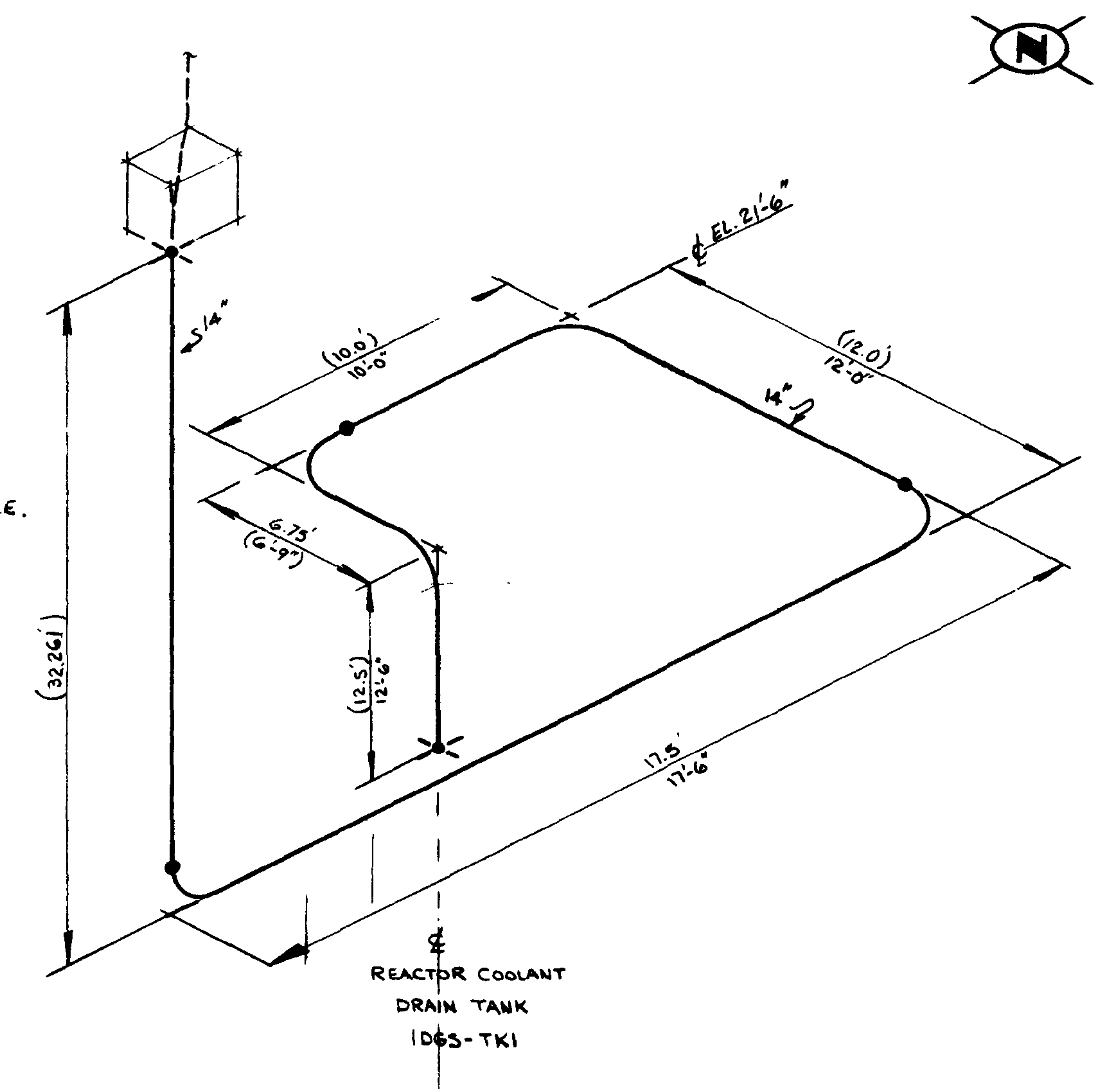


FIGURE 3.3.4-11
REACTOR COOLANT PIPING
PIPE MODULE NO. 391

TOTAL LINEAR FOOTAGE IN MODULE . 78.5 (FT)

TOTAL NUMBER OF FIELD JOINTS WHEN FABRICATED TO CURRENT PRACTICE: 5

TOTAL NUMBER OF FIELD JOINTS THIS MODULE : 2

TOTAL NUMBER OF FLANGED JOINTS · 0

TOTAL NUMBER OF SPOOLS · 4

APPROXIMATE WEIGHT OF MODULES . 53734. (LB)

APPROXIMATE WEIGHT OF LIFTING RIG: 0.

MAXIMUM LIFT: ~ 53750 (LB)

FIELD JOINT WHEN FABRICATED TO CURRENT PRACTICE

FIELD JOINT THIS MODULE.

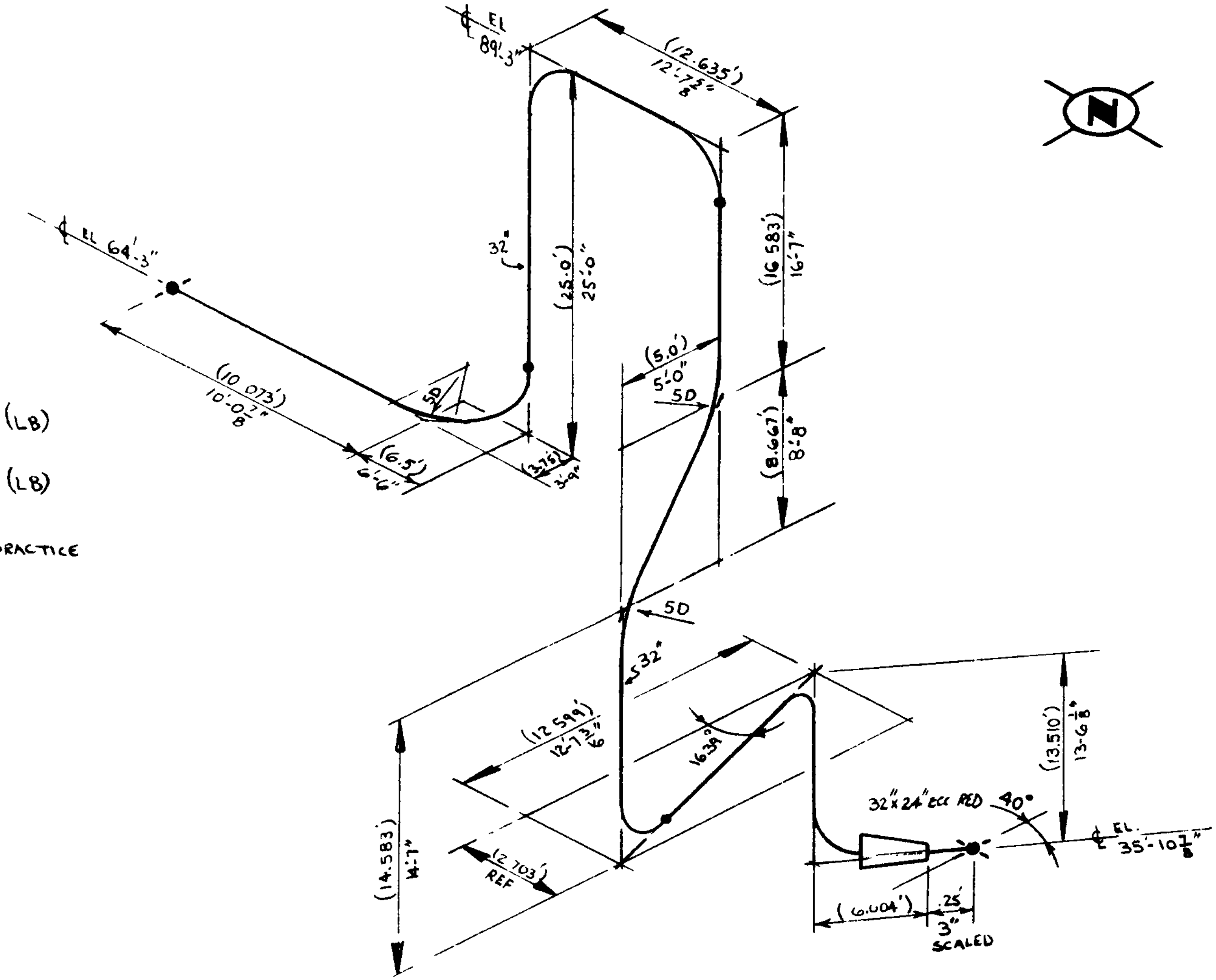


FIGURE 3.3.4-12
MAIN STEAM PIPING
PIPE MODULE NO. 410

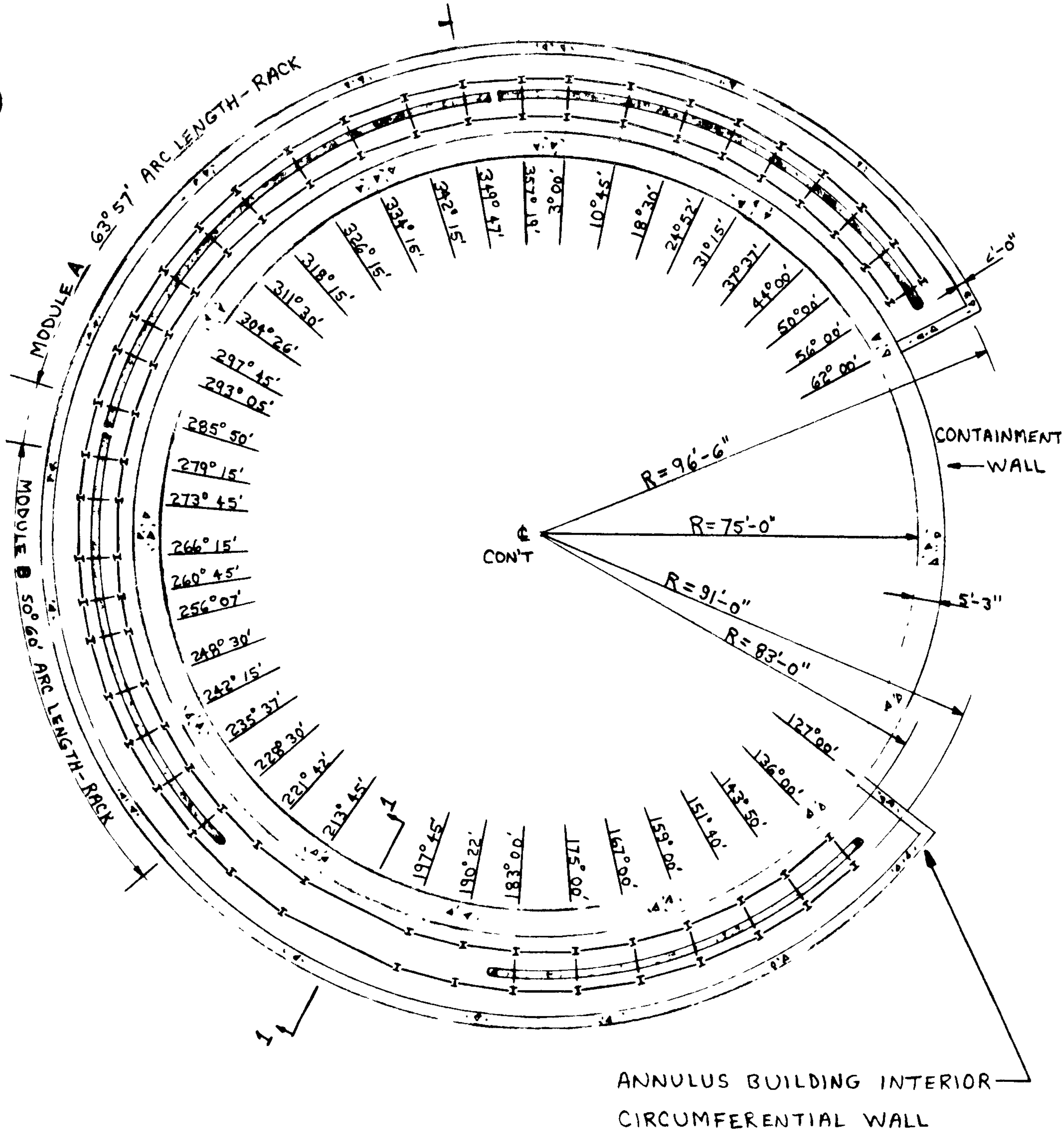


FIGURE 3.3.5-1
MODULARIZATION OF
PIPE RACKS WITH PIPING

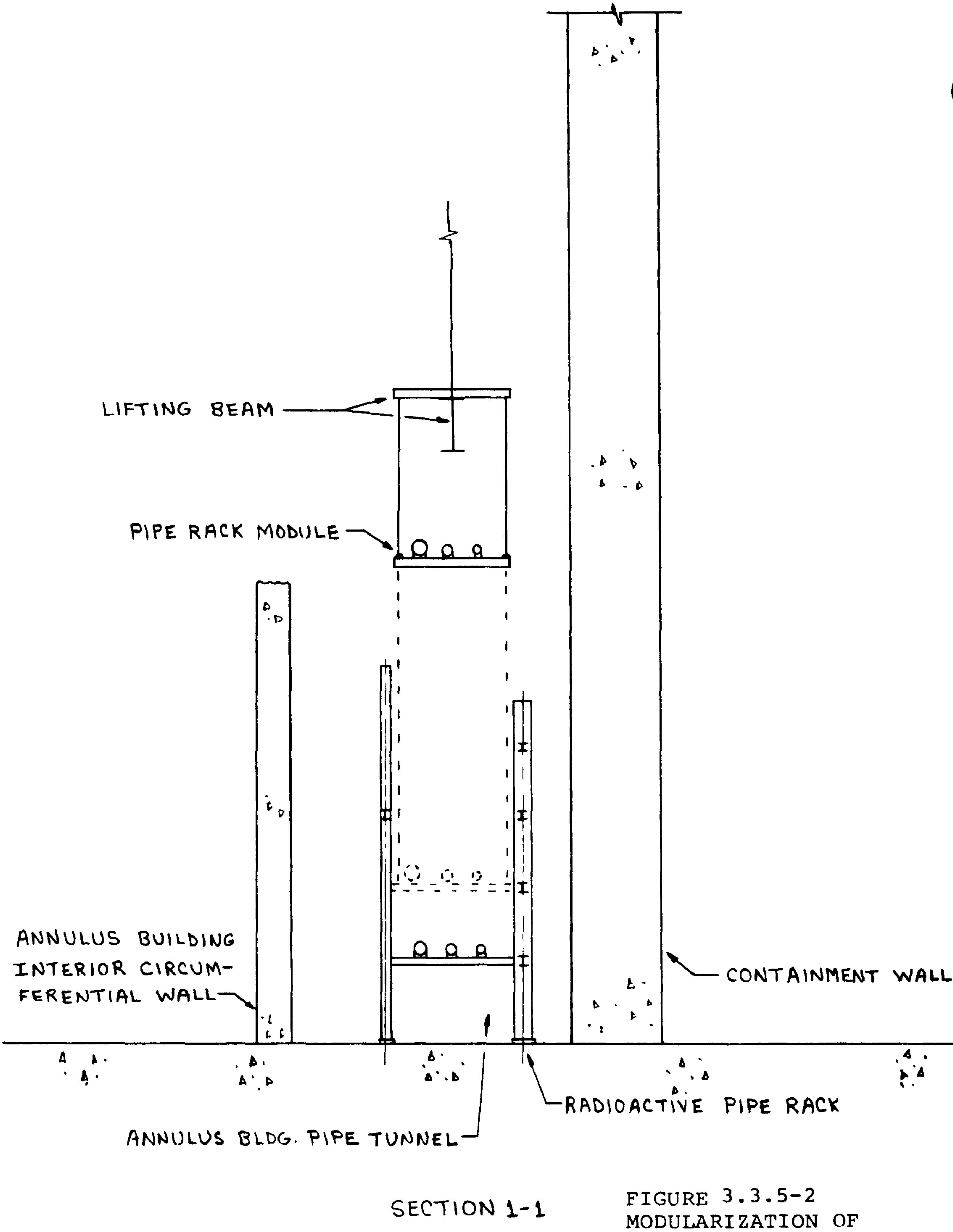


FIGURE 3.3.5-2
MODULARIZATION OF
PIPE RACKS WITH PIPING

3.4 Electrical Modules

3.4.1 Non-Seismic Cable Trays

3.4.1.1 Current Construction Method

The cable tray supports for non-seismic design are shown in Figure 3.4.1-1. The design consists of vertical 3/4 in. threaded rod attached to 3/4 in. bolts or studs that are welded to supporting steel or secured to concrete as shown in Figures 3.4.1-2 sheets 1 and 2. The horizontal support is a unistrut member with holes near each end. This horizontal support member is positioned at the desired elevation on the vertical rods and secured by flat washers and nuts.

The basic design is for a maximum of 10 trays with support spans not greater than 8 ft. The tray loading is 50 pounds per foot.

3.4.1.2 Proposed Module Description

A factory fabricated ladder type support would be used as shown in Figure 3.4.1-3, sheets 1 and 2. There would be no change in the anchorage details. The attachment to the anchorage is with a 3/4 in. coupling and a threaded 3/4 in. rod. A number 2 1/2 clevis is threaded to the rod which is then pinned to the support side member. A Globe ladder type steel cable tray, used in a vertical position as a tray support, has been analyzed to the same criteria as used in current construction. The tray rung spacing is 18 in. with an inside rail dimension of 36 in. The rail of the horizontal tray is 30 in. and rests upon the rungs of the vertical supports. This ladder type vertical support is light duty 3 in. nominal depth but requires a heavy duty rung. Other supports were investigated and found to be adequate as a support system. These were Chalfant aluminum tray C55A with number 11120 or 11119 rung. Commercially available structural tubing 1 by 1 by 1/8 in. ASTM A5010 36KS1 could also be used as an all welded support.

3.4.1.3 Site Requirements/Assumptions

Due to the limited cable tray support design data available, quantities were estimated based on more detailed information from an 850 MWe nuclear plant which was factored upward. The assumed quantities for cable tray supports are shown in Table 3.4.1-1.

3.4.1.4 Engineering Impact

All material is commercially available and does not require any advance purchases. Standard detail drawings will be required. A load capacity test using 10 trays should be conducted.

3.4.1.5 Cost Savings

Cost savings are estimated to be $340,000 utilizing the proposed support system.

3.4.1.6 Schedule Savings

The cable support system is not on the critical path.

3.4.1.7 Savings Criteria

The cost savings criterion is met.

3.4.1.8 Recommendations

It is recommended that a ladder type tray support system be considered on a case-by-case basis. It is not the intent to replace the present rod type tray support completely. However, where greater flexibility is required, or space problems occur, the rod type hanger cable tray support should be used. A further study should be conducted to determine the savings associated with longer span trays.

3.4.2 Non-class IE Cable Installation

3.4.2.1 Current Construction Method

The current electrical non-class IE cable installation method is to assign a separate control cable for each piece of equipment activated. This separate assignment is applied throughout the electrical design to include interlocks and alarm functions. This design results in a large percentage, approximately 95 percent, of control cables having 8 or less conductors per cable that require identification, pull tickets, and tags for installation. As an example the distribution of types of No. 12 AWG control cables purchased for an operating 850 megawatt pressurized water reactor is as follows:

No. of Conductors per Cable:	1	2	3	4	6	8	12	19
Percent:	1	37	10	13	22	12	4	1

This trend has been verified for an 850 megawatt boiling water reactor plant presently under design which has placed purchase orders for 1,000,000 ft of two-conductor No. 12 AWG control cable and an additional 500,000 ft of two-conductor No. 14 AWG control cable. This represents 30 percent of the 5,000,000 linear feet of control cable purchased.

Although more recent plants have been making wider use of termination cabinets in conjunction with control board designs, this has not changed the number of 8 or less conductor control cables required from actuated equipment to the termination cabinets.

The cabinets allow field cables to be terminated independently of the control board installation schedule. The wires from the control board are connected to the termination cabinets by plug connectors using 25 or 37 conductor cables.

3.4.2.2 Proposed Module Description

To reduce the large number of individual cables, it is proposed to utilize a larger number of conductors per cable, i.e., 25 or 37 conductor cables for non-class IE control cables. Extending the termination cabinet concept to the electrically actuated equipment permits connecting cables from the control board termination cabinets to the electrical equipment termination cabinets without regard for electrically actuated equipment delivery dates.

The comparison of the current to the proposed method was evaluated as 18 separate cases. Table 3.4.2-1 is a cable schedule for the current design that identifies type of cable, quantity, to and from distance, and total point to point linear footage for each type of cable. Table 3.4.2-2 is a cable schedule for the proposed design which has information similar to Table 3.4.2-1.

Cases 1 to 8 are a comparison for eight motor control centers (MCC) in the turbine building where the point of control is in the main control room. The cost evaluation was for material and labor of cable installation and only material for the termination section associated with each MCC.

Cases 9 to 17 are a comparison for switchgear and load center that are located in a normal switchgear building adjacent to the turbine building where the point of control is in the main control building.

For the proposed design, a double door termination cabinet is located either midway to the rear of each bus lineup or at one end. The cost evaluation was for material and labor of cable installation plus the nine termination cabinets. Termination labor for 1,800 additional points was considered in the evaluation.

Case 18 is a comparison for replacing 1,750 two-conductor cables with 95 thirty-seven conductor cables. The cost evaluation was for material and labor of cable installation plus 48 termination cabinets. Termination labor for 2,000 additional points was considered in the evaluation.

3.4.2.3 Site Requirements/Assumptions

The labor installation time of 27 and 37 conductor cables was extrapolated from a curve plotted of known multiconductor cable installation time.

3.4.2.4 Engineering Impact

The overall engineering impact to design a cable system should be a reduction in engineering man-hours due to the decrease in the number of cables that require identification, pull tickets, and tags. No credit was assumed in the cost savings.

3.4.2.5 Cost Savings

The net cable installation cost saving is $535,000. This includes the addition of 65 termination cabinets installed with the cost of terminations included.

3.4.2.6 Schedule Savings

No critical path savings were identified since additional detailed design is required.

3.4.2.7 Savings Criteria

The cost savings criterion is met by this cable installation technique.

3.4.2.8 Recommendations

Although no impact on overall plant availability is anticipated when using the proposed cable installation technique, additional analysis is recommended to verify this assumption. On this basis, non-class IE cable installation using a larger number of conductors per cable is recommended.

TABLE 3.4.1-1

NON-SEISMIC CABLE TRAY SUPPORTS

Number Trays per Support	Number of Supports
1	135
2	273
3	471
4	484
5	296
6	270
7	129
8	40
9	7
10	56
Total	2,161

TABLE 3.4.2-1

CURRENT DESIGN CABLE SCHEDULE

Case	From Control Board Termination Cabinet	To Motor Control Center	Conductors Per Cable	Distance Ft	Quantity	Linear Feet Cable
1	5N	3A1	9	548	4	2,192
	6N	3A1	7	554	5	2,770
	7N	3A1	9	560	1	560
2 Note 1	5N	3A2	12	648	1	648
	6N	3A2	9	654	8	5,232
			7		1	654
			3		1	654
	7N	3A2	9	660	8	5,280
			7		1	660
			5		1	600
3	5N	3A3	9	773	2	1,546
			7		1	773
	6N	3A3	7	779	3	2,337
4 Note 2	6N	3B1	7	769	1	769
	7N	3B1	7	775	4	3,100
5 Note 3	5N	3B2	9	603	3	1,809
	6N	3B2	9	609	1	609
			7		3	1,827
	7N	3B2	9	618	2	1,236
			7		4	2,472
			5		2	1,236
6	5N	4A1	12	878	1	878
			9		3	2,634
	7N	4A1	12	890	1	890
			9		4	3,560
			7		3	2,670
			5		1	890
7 Note 4	6N	4B1	7	779	3	2,337
	7N	4B1	7	785	1	785
8	5N	4B2	12	868	2	1,736
			9		5	4,340
	6N	4B2	9	874	4	3,496
			7		1	874
			3		1	874
	7N	4B2	9	880	3	2,640
			7		3	2,640

1 of 2

TABLE 3.4.2-1 (CONT)

Case	From Control Board Termination Cabinet	To Switchgear	Conductors Per Cable	Distance Ft	Quantity	Linear Feet Cable
9		13.8 kV SWG-1	9	420	10	4,200
10		13.8 kV SWG-2	9	440	12	5,280
11		13.8 kV SWG-3	9	460	10	4,600
12		4 kV SWG-1	9	420	7	2,940
13		4 kV SWG-2	9	440	7	3,080
14		4 kV SWG-3	9	460	7	3,220
15		480 V LC 1A & 3A	9	400	15	60,000
16		480 V LC 1B & 3D	9	420	15	63,000
17		480 V LC 1C & 3C	9	440	15	66,000
18		General	2	420	1,750	735,000

Notes:

1. Cable jumpered to 6N for proposed design in Table 3.4.2-2
2. Cable jumpered to 7N for proposed design in Table 3.4.2-2
3. Cable jumpered to 6N for proposed design in Table 3.4.2-2
4. Cable jumpered to 6N for proposed design in Table 3.4.2-2

TABLE 3.4.2-2

PROPOSED DESIGN CABLE SCHEDULE

Case	From Control Board Termination Cabinet	To Motor Control Center	Conductors Per Cable	Distance Ft	Quantity	Linear Feet Cable
1	5N	3A1	37	548	1	548
	6N	3A1	37	554	1	554
	7N	3A1	25	560	1	560
2	6N	3A2	37	654	3	1,962
	7N	3A2	37	660	2	1,320
			25			
3	5N	3A3	37	773	1	773
	6N	3A3	25	779	1	779
4	7N	3B1	37	775	1	775
	6N	3B1	37	609	1	609
			25		1	609
	7N	3B1	37	618	1	618
			25		1	618
5	6N	3B2	37	609	1	609
	7N	3B2	25		1	609
6	5N	4A1	37	878	1	878
	7N	4A1	37	890	2	1,780
7	6N	4B1	37	779	1	779
8	5N	4B2	37	868	1	868
			25		1	868
	6N	4B2	37	874	1	874
			25		1	874
	7N	4B2	37	880	1	880
			25		1	880

TABLE 3.4.2-2 (CONT)

Case	From Control Termination Cabinet	To Switchgear	Conductors Per Cable	Distance Ft	Quantity	Linear Feet Cable
9		13.8 kV SWG-1	37	420	2	840
			25		1	470
10		13.8 kV SWG-2	37	440	3	1,320
11		13.8 kV SWG-3	37	460	2	920
			25		1	460
12		4 kV SWG-1	37	420	1	420
			25		1	420
13		4 kV SWG-1	37	440	1	440
			25		1	440
14		4 kV SWG-1	37	460	1	460
			25		1	460
15		480 V LC 1A & 3A	37	400	3	1,200
			25		1	400
16		480 V LC 1B & 3B	37	420	3	1,260
			25		1	420
17		480 V LC 1C & 3C	37	440	3	1,320
			25		1	440
18		General	37	400	95	38,000
			2	20	1,750	15,000

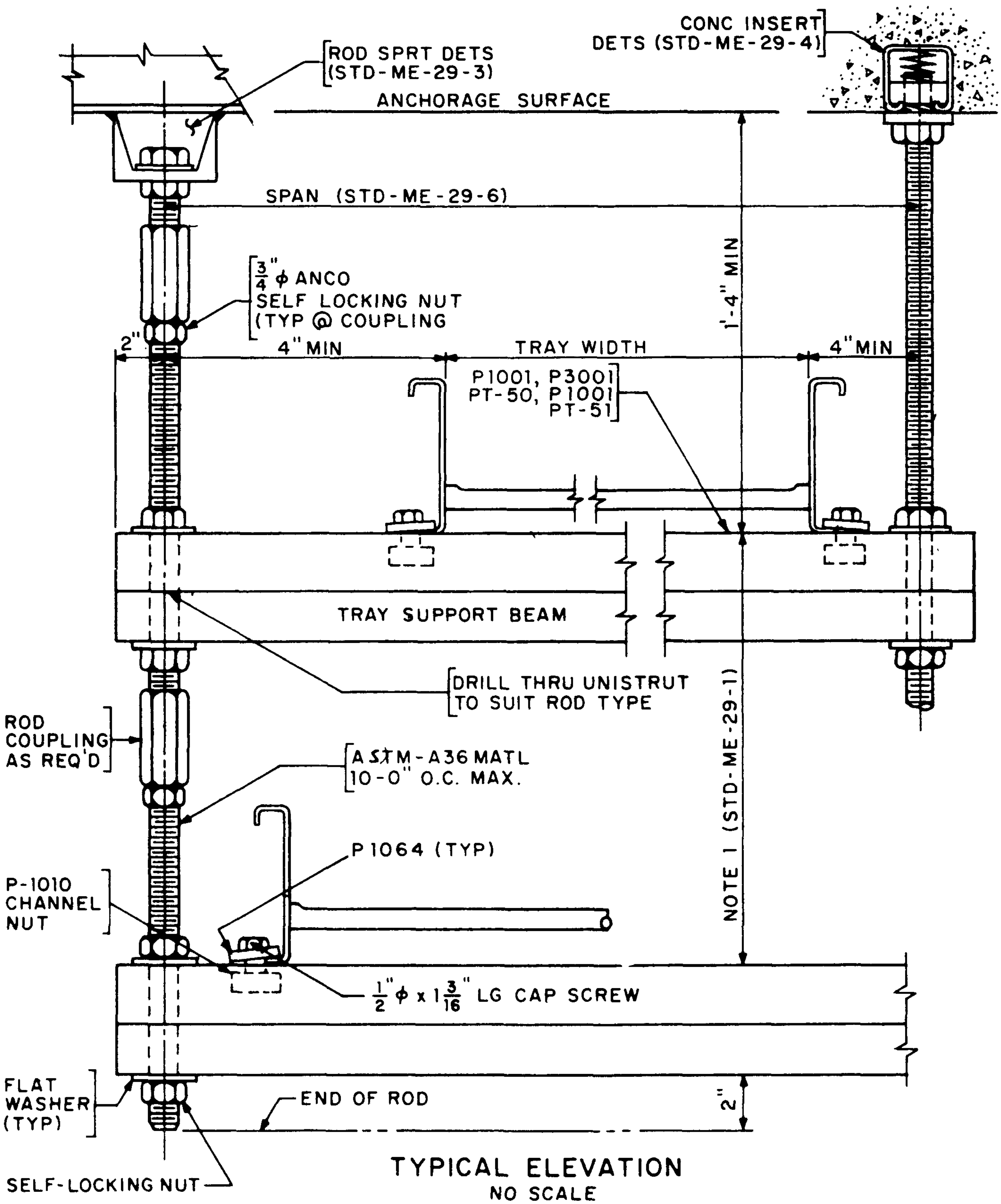


FIGURE 3.4.1-1
NON-SEISMIC CABLE TRAY SUPPORT,
ROD HANGER TYPE

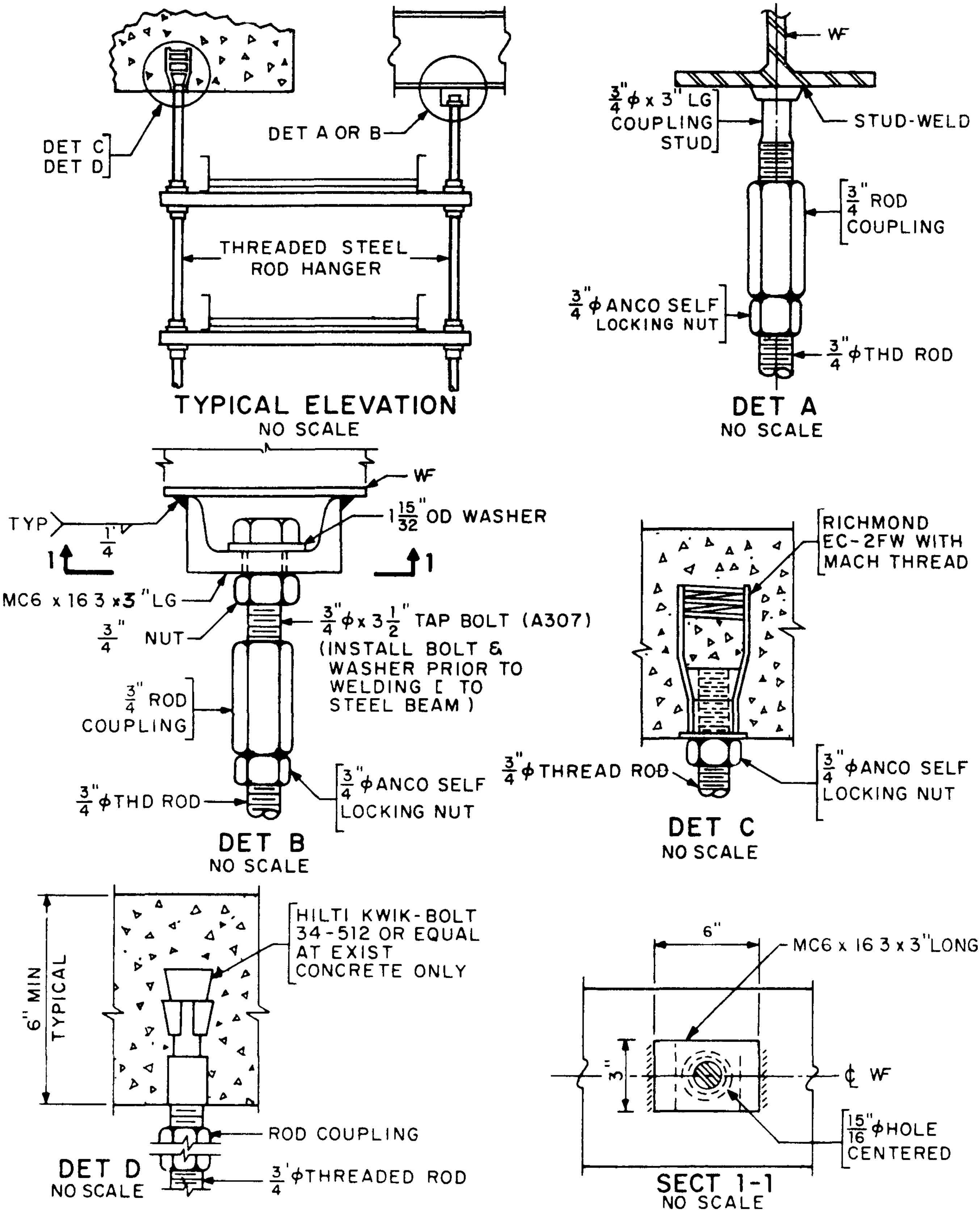
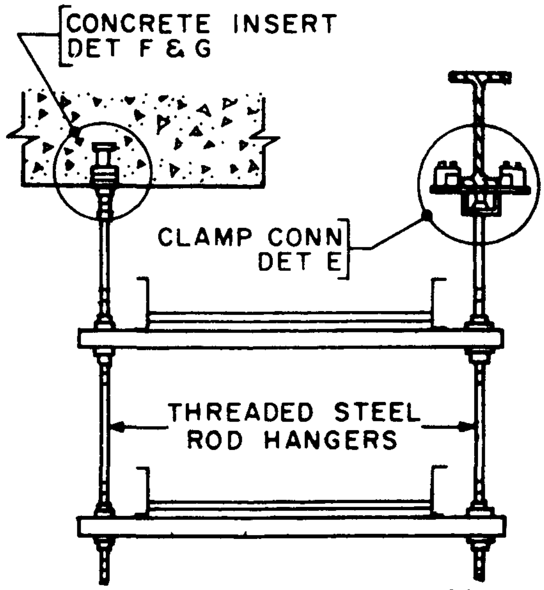


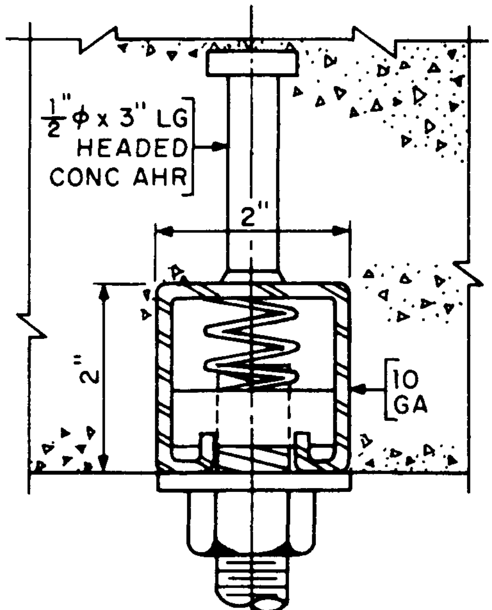
FIGURE 3.4.1-2
NON-SEISMIC CABLE TRAY SUPPORTS, ROD HANGER TYPE, ANCHORAGE DETAILS, SHEET 1

NO. OF TRAYS IN STACK	SPACING FOR HANGERS SYMMETRICAL ABOUT ℄ TRAYS				
	CONCRETE INSERTS		CLAMPS IN PAIRS 4" ON CENTER CONNECT TO STL BEAM FLANGE		
	PT-50-N	P3200 OR PS200	U79	U77	U81
1	10'-0"	10'-0"	10'-0"	10'-0"	10'-0"
2	10'-0"	10'-0"	10'-0"	10'-0"	10'-0"
3	10'-0"	10'-0"	10'-0"	10'-0"	10'-0"
4	10'-0"	10'-0"	10'-0"	10'-0"	10'-0"
5	10'-0"	10'-0"	10'-0"	10'-0"	8'-0"
6	10'-0"	10'-0"	10'-0"	9'-6"	6'-9"
7	10'-0"	10'-0"	10'-0"	8'-0"	5'-9"
8	10'-0"	10'-0"	8'-9"	7'-0"	5'-0"
9	10'-0"	10'-0"	7'-9"	6'-3"	4'-6"
10	10'-0"	10'-0"	7'-0"	5'-6"	4'-0"

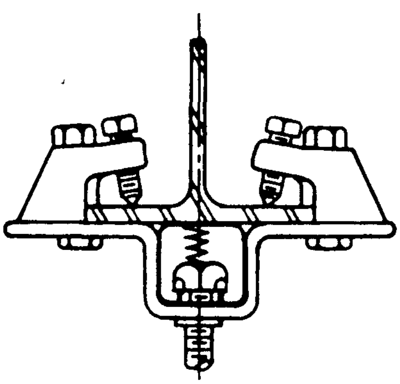
LONGITUDINAL DISTANCE BETWEEN SUPPORT: 8FT MAX (NOTE 1 STD-ME-29-2)



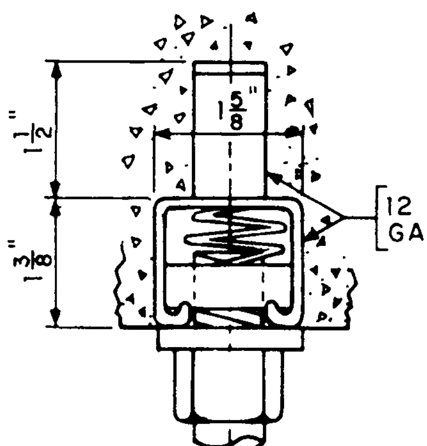
TYPICAL ELEVATION
NO SCALE



DET G
PT-50 N CONCRETE
CHANNEL INSERT
NO SCALE



DET E
TYP CLAMP CONN
NO SCALE



DET F
P3200 OR PS200
CONCRETE INSERT
NO SCALE

FIGURE 3.4.1-2
NON-SEISMIC CABLE TRAY SUPPORTS,
ROD HANGER TYPE, ANCHORAGE
DETAILS, SHEET 2

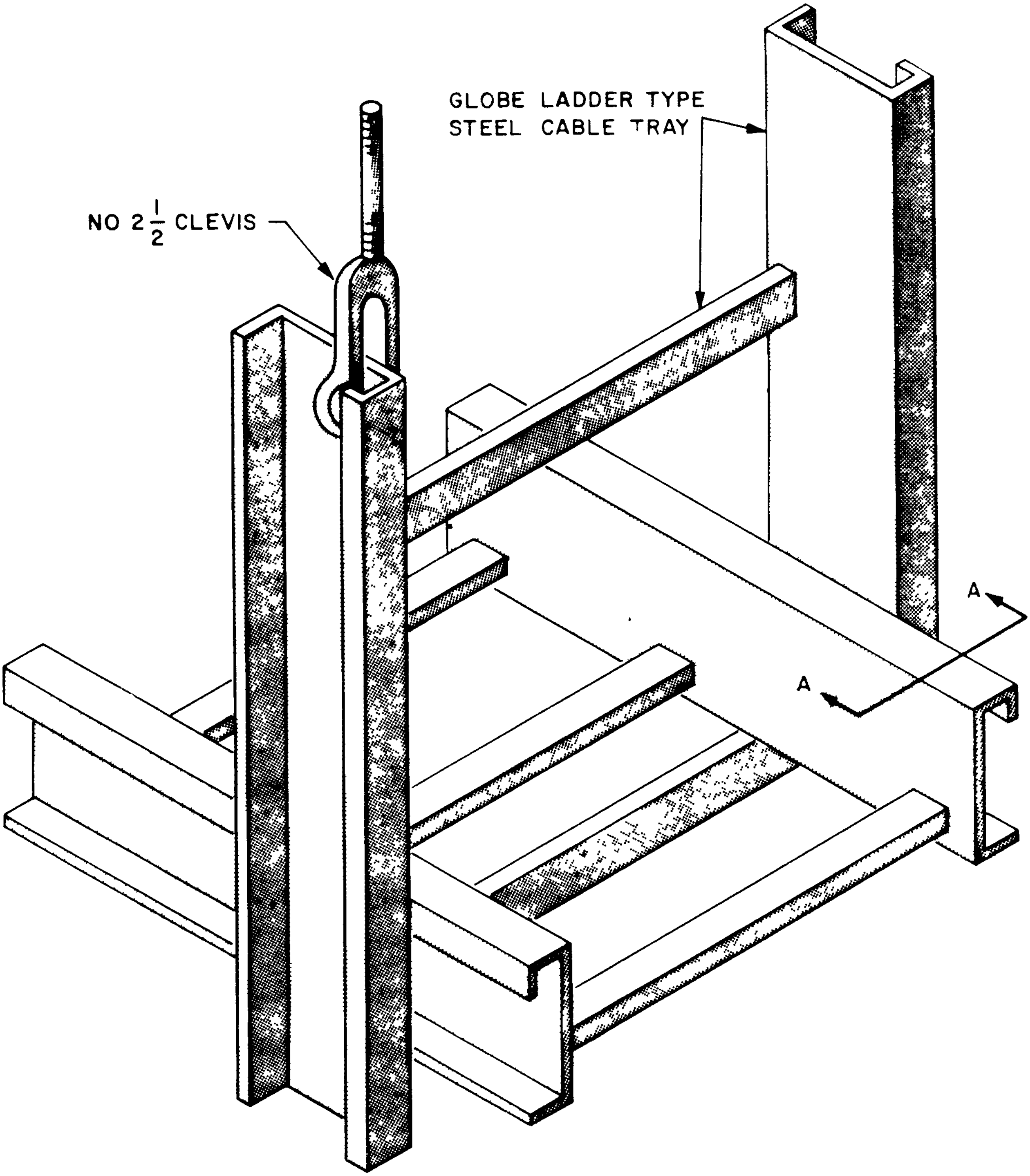
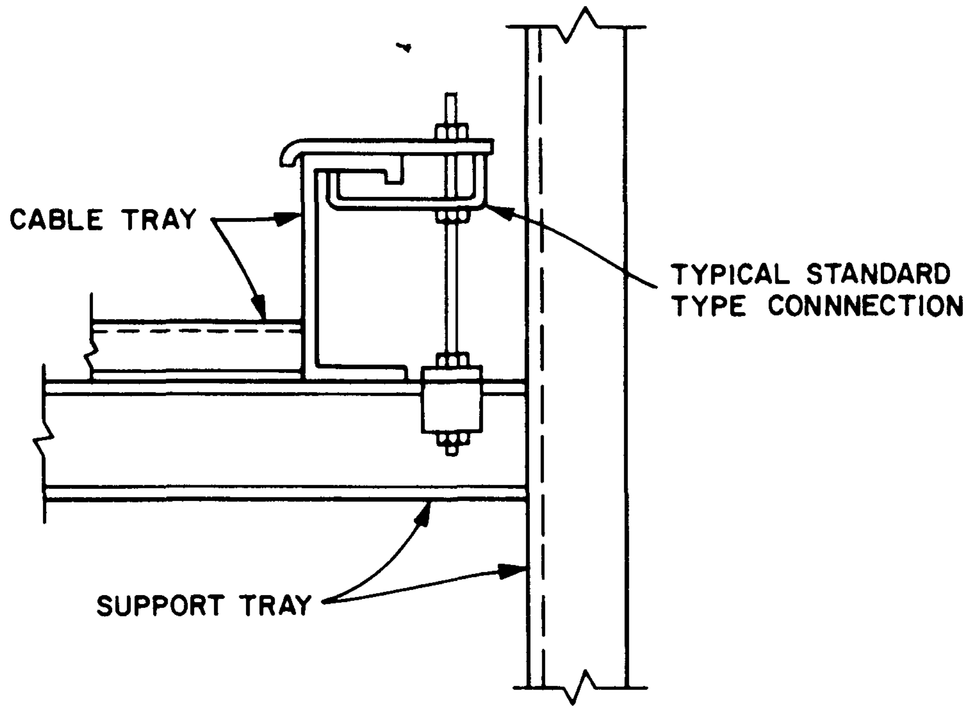


FIGURE 3 4 1-3 (SH 1 OF 2)
LADDER TYPE
CABLE TRAY SUPPORT



SECTION A-A

FIGURE 3.4.1-3 (SH.2 OF 2)
CABLE TRAY TO SUPPORT
CONNECTION DETAIL

4. CONCLUSIONS AND RECOMMENDATIONS

Critical path schedule savings found in this study are solely from a reduction in the construction time required for the containment and annulus buildings. Even though savings were found in the construction of other buildings, these were not considered direct critical path savings. By delaying the construction of the other buildings, thus allowing increased access to the containment and annulus structures, it is expected that the increased access will reveal additional critical path schedule savings.

Table 4-1 summarizes the cost and critical path schedule savings identified for all modules investigated in this study. Modularization concepts which may permit offsite fabrication are also indicated in Table 4-1. Such modules must be capable of barge, rail, or road transportation to the construction site. Typical weight and size limitations are given in Table 3.1-1, but must be verified for each site. As indicated in Table 4-1, the modules showing the highest potential for cost savings, schedule savings, or both are:

Reinforcing Steel
Structural Steel
Polar Crane Supports
Pipe Modules
Pipe Racks

Some or all of these concepts should be implemented on a nuclear plant during the construction phase to demonstrate the cost and/or schedule savings. Such implementation requires an early and continuing commitment during the engineering and design phase of the plant(s). This is particularly important for the pipe and pipe rack modules since early design and procurement are necessary and a detailed scheduling analysis must be performed to maximize savings.

Although the modules recommended for implementation could be utilized to some degree on any nuclear plant, the results of this study are most adaptable to plants utilizing the annulus building and common mat concept. Such plants include the Greene County Nuclear Power Plant and Sundesert Nuclear Power Plant (two units) currently under design by the Power Authority of the State of New York and San Diego Gas and Electric Company, respectively.

To fully evaluate the practicability and desirability of the identified preassembly modules and recommend a basis for application to a new nuclear power plant, the Sundesert Nuclear Plant presently planned for southern California has been identified for possible implementation of modular construction techniques. The program has been modified to include evaluation of the most promising areas for modular consideration based on the level of the Sundesert Project engineering design completion

and the feasibility of their incorporation into the plant 63
construction effort. This evaluation will develop for the 64
Sundesert Nuclear Plant drawings, erection sequences, and models
for the modular construction of the mat reinforcing and liners in 65
the Containment/Annulus Building. Conclusions regarding the 66
feasibility and application of mat reinforcing and liners,
recommended subsequent phases for implementation in the Sundesert 67
Plant and a generic application of these modules to other plant 68
designs including those by other architect/engineers will be 69
developed. A final report supplement will be prepared for the 70
Sundesert evaluation.

Similar evaluations of application of other modules with 72
potential for high cost savings, schedule savings, or both should 73
be initiated. Pending favorable conclusions from these 74
evaluations, demonstrations of the most promising modular 75
concepts should be arranged during the design and construction
phases.

TABLE 4-1

SUMMARY OF COST AND SCHEDULE SAVINGS

Module	Discussion Section	Cost Savings (Dollars)[1]	Critical Path Schedule Savings	Recommendations	Remarks
Reinforcing Steel	3.2.1	1,099,000	21 weeks	Use	Cost savings greater if precast concrete modules are not used.
Structural Steel	3.2.3	574,000	0	Use	
Polar Crane Supports	3.2.5	0	5 weeks	Use	
Piping[2]	3.3.4	3,000,000 to 6,000,000	16 weeks	Use	Detailed schedule analysis required.
Pipe Racks	3.3.5	675,000 to 975,000	Included in piping	Use	Detailed schedule analysis required in conjunction with piping.
Liners	3.2.4				
Containment		Undetermined	1 day (minimum)	Use	
Fuel Related[2]		470,000	0	Use	
Skid Mounted[2]	3.3.1				
Sumps		9,100	0	Use	
Demineralizer & filters		195,000 to 275,000	0	Use	
Condenser[2]	3.3.2	See remarks.	See remarks.	Use on case-by-case basis.	Site-related. Requires bids for evaluation.
Tanks	3.3.3	25,000 to 109,000	0	Use on case-by-case basis.	Requires bids for evaluation.
Non-Seismic[2] Cable Trays	3.4.1	340,000	0	Use	Additional detailed design required.
Cable Installation	3.4.2	535,000	0	Use	Additional detailed design and reliability analysis required.

TABLE 4-1 (CONT)

Module	Discussion Section	Cost Savings (Dollars)[1]	Critical Path Schedule Savings	Recommendations	Remarks
Precast Concrete	3.2.2	3,100,000	2 weeks	Future consideration See remarks.	Requires NRC review
Skid Mounted	3.3.1				
Moisture-Separator Reheater		4,400	0	Not recommended.	
Compressed Air System[2]		3,600	0	Not recommended.	
Feedwater Pump/Turbine[2]		82,500	0	Not recommended.	Only one manufacturer.
Condensate Polishing[2] Components		0	0	No recommended	Already modularized to maximum extent feasible.

[1]Dollars represent total construction costs with present day at March 1, 1976.
[2]Offsite fabrication may be feasible.

APPENDIX A

EXCERPTS FROM INITIAL REPORT

2. SUMMARY

Preliminary criteria (Section 3.1) developed included road, rail, and barge size and wight limitations for establishing a basis for shop versus field fabrication. In addition, modules identified in Phase I for further evaluation during Phase II had to meet one of the following criteria:

Savings of $50,000

Savings of 5 percent (minimum) of material or labor costs based on previous jobs.

Savings of one day on the critical path

In some instances modularization is feasible, but insufficient information has been developed to establish definitely whether one or more of these criteria has been met. These cases are included for further study under Phase II. At that time, they will be either eliminated or retained, depending upon their conformance to the criteria.

The review of P&IDs required knowledge of the location of the equipment, piping, and valves in the various structures. Therefore, the results of this effort are reflected in Section 3.3 for each building. Examples of potential modules identified during this review included skid-mounting of various diesel generator auxiliary components and instrument and service air system components in the diesel generator building and turbine building, respectively.

The major effort during Phase I of this study involved the review of general arrangement drawings (Sections 3.2 and 3.3) by all engineering disciplines and construction personnel. Examples of modules identified during this review included reinforcing steel modules for the containment/annulus mat and reactor cavity shield wall, fuel pool and refueling cavity liners, shop tubing and fabrication of the main condenser and piping modules.

Section 4 summarizes the concepts for modularization identified in Phase I that will be evaluated in more detail during Phase II.

The Appendixes to this report include copies of all general arrangement drawings and P&IDs from SWESSAR-P1 that were reviewed during Phase I of the study.

Although several Stone & Webster proprietary drawings were also utilized during Phase I of this study, only the specific drawings requested by ERDA will be furnished upon request and then, only in accordance with the proprietary provisions of letter contract No. E(11-1)-4039.

3. ANALYSIS

3.1 Preliminary Criteria

3.1.1 Savings Criteria

To establish a basis for evaluating various modularization concepts, the following savings criteria were established.

Savings Criterion 1 - Savings of $50,000.

Savings Criterion 2 — Savings of 5 percent (minimum) of material or labor costs based on previous nuclear jobs.

Savings Criterion 3 - Savings of one day of critical path construction time.

The interpretation of Savings Criteria 1 and 2 are straightforward. To meet Savings Criterion 3, two definitions are used. First, any module of systems, components, or structures known or assumed to be on the critical path that could decrease the in-place erection time by one day is considered an adequate basis. Second, any module of systems, components, or structures which would delay in-place construction time by one day and allow some other critical path activity to be performed, or the area used for some other critical purpose, is also considered an adequate basis. For example, it could be assumed that the annulus building is on the critical path and that precasting floor slabs in this building would cost approximately the same as pouring them in place. By precasting the floor slabs, however, in-place erection time is substantially reduced, thereby saving critical path schedule time in the erection sequence.

3.1.2 Weight and Size Limitations

The following weight and size limitations were developed for determining whether module fabrication could take place in the shop or in the field. Shop fabrication guidelines have both weight and size limitations. Field fabrication guidelines have only weight limitations.

Envelope A included shop fabricated assemblies that meet the weight and size limitations for road and rail. These are described in Table 3.1.2. Two road limitations are given. The second is for oversize loads and requires a permit. Two or more of these shop assemblies could be combined in the field before installation.

Envelope B included shop fabricated assemblies that meet the weight and size limitations of barges used on most inland waterways. These are also described in Table 3.1.2. Note that not all sites have navigable water access.

Envelope C included shop fabricated assemblies that fall within the envelope required for the movement of the reactor pressure vessel and reactor vessel support structure. This is described in Table 3.1.2. Special provisions and plans are required for these types of moves. Assemblies falling within this envelope were carefully reviewed because of the problems involved.

Envelope D includes field-fabricated assemblies that can be moved and installed with normal construction equipment. This is described in Table 3.1.2.

The weight and size limitations described are a general guide only. Exceptions could be taken to these limitations for any given modularization concept investigated if warranted.

TABLE A3.1.2

SHOP AND FIELD LIMITATIONS

Envelope A

Road

	No Permit	Permit
Height of Load (Using "Lowboy")	10'-6"	11'-6"
Width of Load	8'-0"	10'-0" (may go to 16 ft in some states)
Length of Load	50'-0"	50'-0"
Net Weight	20 Tons	30 Tons

Note: These limitations vary between states and between interstate and state highways.

Rail

	Normal	Special
Height of Load	11'-0"	13'-0"
Width of Load	10'-8"	12'-0"
Length of Load	60'-0"	60'-0"
Net Weight	125-200 tons	300 tons

Envelope B

Barge - Inland Waterway

Width	30'-0"
Length	180'-0"
Net Weight	1,000 tons

Envelope C

Height	21'-6"
Width	21'-0"
Length	100'-0"
Net weight	500 tons

Envelope D - Field Fabrication	
Inside Containment Structure	500 tons (polar crane capacity)
Other Structures	
Group 1 - using one or two crawler cranes as guyed derricks	240 tons/crane
Group 2 - using crawler transporters and jacks	1,000 tons

3.2 Modularization Concepts Generally Applicable to All Structures

This section discusses some general conclusions on the use of various concepts or techniques applicable to most structures.

3.2.1 Construction of Concrete Structures

For the containment and annulus buildings, the placement of concrete is a critical path activity. Time for concrete placement can be reduced by using some form of precast or prestressed concrete. However, the use of precast and prestressed concrete in Seismic Category I structures poses some additional design considerations since they are usually heavily reinforced concrete structures that require complete structural continuity to carry large loads.

The use of precast concrete modules and connections between these elements must maintain continuity of the structure. Commercial type welded connections are considered incapable of providing the necessary strength and continuity and still be economical. The capability of these types of connections to stop postulated tornado missiles is not well understood or documented. It is concluded, therefore, that precast concrete elements should be used in conjunction with cast in-place concrete closure pours. The size of these pours will be based on the length of the reinforcing steel splices required to maintain structural continuity. With this type of construction technique, the closure pour should completely fill the void in the enclosed form. Some type of grouting may be required.

Use of prestressed concrete in Seismic Category I structures has been previously limited to containment structure shells in light water reactor plants. In-service inspection is required for these types of structures. If prestressed concrete were used in other Seismic Category I structures, it is likely that regulatory agencies would establish in-service inspection procedures for these structures as well. This would negate any economic advantage of prestressed concrete.

Nuclear power plant structures do not normally contain several repeatable concrete elements of the same size. Therefore, the economic advantage of manufacturing similar precast concrete elements is not the same as in many commercial buildings. The advantage of precasting is the shortened in-place construction schedule time required to erect the structure. When these activities are on the critical path, there is the potential of decreasing the duration of the construction schedule, thus meeting Savings Criterion 3 (Section 3.1).

Specific applications of precast concrete in various structures are discussed in Section 3.3.

3.2.2 Field Shop Welding of Large Segments of Piping

Modularization of piping could be accomplished by three methods.

1. Fabricating piping subassemblies larger and more complex than utilized previously.

2. Fabricating modules of piping-component combinations prior to building installation (Section 3.2.3).

3. Fabricating total cubicle modules with piping and components prior to installation.

For the purposes of this study, all the above methods were considered practical depending on the area of concern. Savings in man-hours were based on the following assumptions:

1. Fully equipped piping fabrication shop onsite

2. Availability of two 250 ton mobile cranes.

3. Material available as required

4. Walls or slabs erected above working levels after modules are installed.

A large percentage of the man-hours for field welding and piping installation could be saved. The reasons for these savings are small diameter pipe bending in the shop, welding operations under shop type conditions, more efficient material control, and assembly line efficiency. In addition, a substantial decrease in weld rejection and rework should be possible, a savings which is difficult to quantify, but which has historically required a large number of man-hours. Use of these modularization techniques meet one or more of the three savings criteria of Section 3.1.

3.2.3 Skid-Mounting of Equipment and Closely Associated Piping and Valves

Skid-mounting two or more pieces as a unit with associated interconnected piping, valves, and instrumentation, or skid-mounting one large piece with closely associated piping, valves, and instrumentation can produce cost advantages. The advantages of skid-mounting equipment are twofold. First, modules can be assembled for lower cost in the shop because of savings in shop vs field welding (Savings Criteria 1 or 2), although additional material costs would offset some of the savings. Secondly, the installation of many pieces of equipment can be on the critical path. Skid-mounting can provide schedule savings in many instances (Savings Criterion 3).

The details of various skid-mounting concepts are discussed in Section 3.3 under each building evaluated.

3.2.4 Cable Pulling

Although not specifically a modularization technique, cable pulling operations in nuclear plant construction currently require 0.025 to 0.04 man-hours per linear foot of installed cable. New methods could possibly be developed and evaluated to reduce total man-hours required for cable installation. Such methods could permit a larger group to be pulled without exceeding existing tension limits. Savings Criteria 1 or 2 could be met.

3.3 BUILDINGS OR AREAS

3.3.1 Containment

3.3.1.1 General

The applicable SWESSAR P&IDs (Appendix A) and the containment general arrangement drawings from Appendix B (Fig. 1.2-3) were reviewed for modularization concepts. Where available, proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted. The results are discussed in Sections 3.3.1.2 through 3.3.1.4.

3.3.1.2 Modularization Concepts for Phase II Evaluation (Table 4.1)

3.3.1.2.1 Containment Shell

The reinforcing steel in the shell could be made into cages and installed before placing the concrete. The containment erection procedure could be as follows:

1. Install liner modules (Section 3.3.1.2.6).

2. Install inner face reinforcing steel modules.

3. Attach anchor studs to liner.

4. Install outer face reinforcing steel modules.

5. Install outer face diagonal reinforcing steel and outermost layer of hoop reinforcing steel in individual bars.

6. Complete form work.

7. Place concrete.

The largest reinforcing steel module would be approximately 60 ft long (arc length) and 70 ft high, weighing 100 tons. The inner face modules would include all the hoop bars and vertical bars. The outer face modules would include the two layers of vertical bars and one layer of hoop bars. Modules would be prefabricated at the jobsite.

This reinforcing steel modularization concept meets Savings Criterion 1.

3.3.1.2.2 Containment/Annulus Building Mat

One of the most promising areas for modlarization is the reinforcing steel in the containment/annulus building common concrete mat. The reinforcement can be preassembled into segments weighing from 65 to 145 tons. Approximately 50 modules would be made, of which 30 are critical to the installation schedule. Module assembly would begin during the excavation activities, allowing modules to be completed before they are required to be installed. After the excavation is complete, installation of the bottom layer reinforcing steel modules would start, followed by the top layer. Paralleling these activities allows for significant savings on the critical path meeting Savings Criterion 3.

3.3.1.2.3 Containment Internal Structure

Reinforcing steel could be modularized by making cages out of the reinforcing steel on each face of the wall. The largest steel module would weigh approximately 85 tons. This reinforcing steel module meets Savings Criterion 3.

3.3.1.2.4 Polar Crane Supporting Structures

The polar crane support structure comprises the crane runway girder, the vertical steel frame supporting the girder from the operating floor, and the horizontal truss support of the crane runway near the bend line. The crane support girder could be modularized into 60 ft segments weighing approximately 150 tons apiece which could be welded together in place. The vertical steel frame and the horizontal steel truss could also be modularized into large units weighing about 150 tons.

Since the polar crane is used to install the NSSS equipment, the installation of the steel structure would save time on the critical path, thus meeting Savings Criterion 3.

3.3.1.2.5 Miscellaneous Structures, Shield Walls, Elevator Shafts, Etc.

Miscellaneous structures, such as shield walls or elevator shafts, could be modularized by the use of precast concrete panels or prefabricated structural frames. Maximum module weights would be less than 100 tons. Although these items are not on the critical path, delaying the construction of these items could provide more access inside the containment, thus facilitating other critical path construction and meeting Savings Criterion 3.

3.3.1.2.6 <u>Containment Liner</u>

It could be possible to prefabricate on the jobsite large cylindrical modules of the containment liner weighing approximately 140 to 170 tons. Following the placement of the mat liner plate, the knuckle plate, and a small portion of the shell liner, the remaining portion of the wall section (approximately 160 ft) could be set in four to six subassemblies. The dome can be installed in about three subassemblies. The modules would be lifted from the bottom with spider shaped assemblies of structural steel members to keep the shape of the section circular. The anchor studs would not be attached to the liner until the inside face reinforcing steel (Section 3.3.1.2.1) module is in place.

Labor costs of fabricating the liner plates in modules outside the containment area should be less than the handling of individual plates and erecting them in place. Contributing factors to reduced labor costs include less handling time, reduced welding time, better quality control, and easier repair of welds when required. Additional costs of handling large modules would offset some of this savings. Liner modularization meets Savings Criteria 1 and 3.

3.3.1.2.7 <u>Refueling Cavity Liner</u>

The refueling cavity liner has a complex geometry. Modularization could require several modules. The liner could be fabricated at the jobsite or at the factory depending upon the site conditions, transportation facilities, and the fabricator. Maximum module weights would be about 15 tons. Modularization of the refueling cavity liner meets Savings Criterion 3.

3.3.1.2.8 <u>Piping Modules</u>

Specific piping modules recommended for further evaluation during Phase II are given in Table 4.1.

3.3.1.3 <u>Existing Modularization Concepts (Table 3.3.1.1)</u>

Stone & Webster's current practice is to prefabricate the entire reactor vessel support structure in one piece prior to installation.

Other portions of the NSSS support system are provided by the NSSS Vendor. These supports are comprised of very large structural members and snubbers that are already modularized.

Various skid-mounted modules such as the charcoal filter train, fans and motors for the containment atmosphere filtration system, the air handling units for the containment purge system, and the containment atmospheric recirculation system and water chiller are already modularized.

3.3.1.4 <u>Rejected Modularization Concepts (Table 3.3.1.2)</u>

It is not feasible to modularize the containment shell and the dome through the use of precast concrete panels, since the high density of reinforcing steel and required structural continuity make it impractical.

The containment internal structure is comprised of 4 ft thick walls that are heavily reinforced. The reinforcing steel must be continuous and the walls contain a large number of embedments. Therefore, the internal structure cubicles, slabs, and the primary shield wall are not suitable for modularization by the use of precast concrete.

In certain cubicles such as the residual heat removal (RHR) cubicles in the design utilizing the Westinghouse 3,800 MWt NSSS design, all the piping, the heat exchanger, and the controls could possibly be modularized by supporting them from a self-standing structural steel frame as shown in Fig. 3.3.1.4. The steel frame, which would form part of the permanent support system, could be built at a fabricating shop on the site with the equipment and piping placed inside. The entire module could then be lifted into place and the concrete shield wall attached to the structural steel support to form the permanent structure. Piping could then be welded to interfacing piping. This type modularization is not deemed feasible, however, because the modules would become too large to handle and connections to concrete structures which have to withstand very large loads and be continuous are not practical. In addition, such modules would require significant redesign of the existing containment internal structure.

Boiling water reactors have been fabricated with reactor vessel internals installed in the shop. Such a technique does not appear to be feasible, however, for pressurized water reactors based on the design of the internals structural configuration. The only feasible way this could be achieved would be for the NSSS Vendors to redesign the reactor vessel internals.

3.3.2 Annulus Building

3.3.2.1 General

The applicable SWESSAR P&IDs (Appendix A) and the annulus building general arrangement drawings from Appendix B (Figure 1.2-4) were reviewed for modularization concepts. Where available proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted.

3.3.2.2 Modularization Concepts for Phase II Evaluation (Table 4.2)

3.3.2.2.1 Precast Concrete Modules

In reviewing the construction sequence of the annulus building, some areas appeared to lend themselves to the use of precast concrete more readily than others. For example walls requiring large numbers of penetrations do not since repeatability of panels is limited and should be poured in place. Those walls and slabs which show a potential for modularization using precast concrete are the exterior wall above El -25 ft-0 in., the outer interior circumferential wall, floor slabs for cubicles, floor slabs for the inner circumferential tunnels, and the roof slab.

The use of precast wall and slab panels assumes that the necessary fabrication shops, transporters, rigging, lifting, and tilt-up capacities to handle panels weighing up to 300 tons will be available. These precast concrete modularization techniques meet Savings Criterion 3.

3.3.2.2.1.1 Circumferential Walls

The exterior wall could be constructed utilizing precast wall panels alternating with cast-in-place wall sections such that all structural elements are two-way continuous. The cast-in-place sections would be approximately 7 ft wide. Figure 3.3.2.2.1.1 demonstrates this procedure. The exterior annulus building wall could be cast in place from El -51 ft (top of mat) to El -25 ft-0 in. due to the complexity of the radial shear bars, No. 14 vertical reinforcing bars which require Cadweld connections, and a heavy 4 ft wide concrete wall section. The first set of precast panels would be placed between El -18 ft-0 in. and El -1 ft-6 in. with the 7 ft section below El -18 ft-0 in. cast in place after panel erection. There will be approximately fifteen 290 ton, 58 ft long precast panels, each abutting a 7 ft cast-in-place section on each side of the panel. Panels would be supported vertically by embedded wide-flanged beams and by horizontal wall braces prior to closure pours. Similar precast panel construction would continue above El -1 ft-6 in. with allowances for cast-in-place closure pours at each floor level and between abutting panels. This method of precast panel construction would also be utilized for the construction of the outermost interior circumferential wall. The amount of openings and penetration in this wall, however, diminishes the potential for panel replication.

3.3.2.2.1.2 Roof and Floor Slabs

As with precast concrete wall panels, precast concrete slabs require closure pours to tie the slab to the wall and maintain the continuity of the structure. Slabs would be set on concrete haunches poured with the wall. This technique is illustrated in Figures 3.3.2.2.1.2 A and B.

Precast concrete floor slabs eliminate the requirement for structural steel and decking to support poured-in-place slabs. However, provisions would have to be made to embed a series of plates in these slabs so that pipe hangers and cable trays could be supported.

The maximum precast concrete slab should weigh approximately 300 tons. This slab modularization concept meets Savings Criterion 3.

3.3.2.2.2 Cubicle Floor Framing

An alternative to precast concrete slabs is the preassembly of cubicle floor framing with metal decking for forms, reinforcing steel, pipe supports, ducts, etc, attached. This technique can only be used in cubicles where the steel framing has adequate secondary members to stiffen the assembly sufficiently so that it can be lifted without distorting. Figure 3.3.2.2.2 depicts a floor framing module. The maximum weight of such a module would be approximately 50 tons. This technique meets Savings Criterion 2 and 3.

3.3.2.2.3 Preassembly of Reinforcing Steel (Poured in place concrete)

Reinforcing steel for concrete walls and slabs could be assembled in a yard area and erected as a unit. Each face of reinforcing would be preassembled separately. Savings in labor costs are realized by assembling the reinforcing steel cages on the ground instead of in the air, e.g., for a wall. The maximum weight of such a module would be approximately 7 tons. These modules meet Savings Criterion 2.

3.3.2.2.4 Preassembly of Sections of Pipe Racks With Pipes and Restraints

Pipe racks in the radioactive pipe tunnel, the nonradioactive pipe tunnel, and for the chemical volume and control system (CVCS) could be prefabricated and installed as units. Each unit would include structural steel for the pipe rack, pipes, and pipe supports.

The number of modules would be limited primarily by size and not the weight of complete modules. The fewest field welds could be obtained with the largest possible module. For Phase I the breakdown of the radioactive pipe rack into quadrants was assumed. A typical section of a pipe rack module is shown in Figure 3.3.2.2.4.

Modules could be nearly 90 degrees in curvature, 130 ft across diagonally, and approximately 20 ft high. The estimated weight of the heaviest module is 75 tons with structural steel accounting for 50 tons and piping 25 tons. Pipe sizes would range from 2 to 24 in. in diameter.

Modularization of the pipe racks assumes the availability of necessary materials and labor to complete module assemblies before the expected installation date. Steel erection would begin outside the pipe fabrication shop while pipe lines are assembled in the shop. Pipes would be installed in each layer of the rack after steel beams for that layer are installed.

These modules would require a crane with lifting capacity of at least 100 tons at a 100 ft radius to allow the modules to be moved into position in the radioactive pipeway. A greater crane range or other means of transporting modules would be required to move the modules from the fabrication area into position for the final lift. The rigging for lifting modules would have to support each column in the rack to avoid placing bending loads in the frame structure. Once in place, modules could be bolted with erection bolts until all piping is fitted up. Approximately one day would be required for placement of each module.

This modularization technique meets all three savings criteria.

3.3.2.2.5 <u>Tanks</u>

All tanks could be fabricated in the field shop and lifted into place. This would include the auxiliary feedwater storage tank, the refueling water storage tank, the high level waste drain tank as well as the smaller tanks lcoated throughout the building. The maximum module weight would be approximately 50 tons. Savings Criterion 2 would be met.

3.3.2.2.6 <u>Piping Modules</u>

Specific piping modules recommended for further evaluation during Phase II are given in Table 4.2.

3.3.2.2.7 <u>Skid-Mounted Equipment Modules</u>

Several skid-mounted equipment modules were identified as being acceptable for modularization as listed below. These skids would weigh less than 10 tons and are generally repeating type modules. Savings Criterion 2 should be met for these modules.

Ion exchangers with associated piping

Demineralizer with connecting piping and valves

Filter units with connecting piping and valves

Sump pumps with pumps, piping, and instrumentation

3.3.2.2.8 Preassembly of Cable Trays

The majority of cable trays are run in groups of five or more. Groups of trays, five high by 12 feet long, could be prefabricated with their associated supports and installed as a module weighing a maximum of 1 ton. This technique meets Savings Criterion 2.

3.3.2.3 Existing Modularization Concepts (Table 3.3.2.1)

Stairs and miscellaneous platforms are currently fabricated in a field shop. This has the advantage of assembling steel elements on the ground instead of up in the air.

Sample area panels, coolers, valves, and water lines associated with this area are currently modularized and skid-mounted by the manufacturer.

The hydrogen recombiner is currently skid-mounted with the cooler, heater, and associated piping and instrumentation by the manufacturer.

Various HVAC system components and charcoal filter assemblies are already modularized.

3.3.2.4 Rejected Modularization Concepts (Table 3.3.2.2)

3.3.2.4.1 Preassembly of Reinforcing Cages with Both Faces of Reinforcing

There is only a slight cost advantage in tying two faces of reinforcing and lifting them as a unit compared to preassembling just one face. The additional design required to prevent the two faces from "racking" negates the cost savings.

3.3.2.4.2 Precast Concrete Labyrinths

Many cubicles in the annulus building are radioactive. The entrances to these cubicles are protected by concrete labyrinths to prevent radiation streaming. Although labyrinths could be precast, no potential savings could be identified.

3.3.2.4.3 Precast Concrete T-Beams to Support Floor Slabs

This concept considers replacing the majority of the structural steel floor framing with precast concrete T-beams. These T-beams would function in a manner similar to the steel floor framing and decking. They would act as a form for the slab and support all permanent vertical loads. However, the T-beams were found to be more costly than the structural steel, and therefore, not acceptable. No schedule savings could be identified.

3.3.2.4.4 Skid-Mounted Equipment Modules

The distillate pump, distillate cooler, evaporator condenser, and distillate tank could be modularized along with their interconnecting piping and all placed at one elevation. This module was not acceptable since it would require major rearrangement of equipment and piping. Potential cost savings were also inadequate to justify this module.

Other skid-mounted modules which could not be economically justified were:

Redundant components of the same system

Auxiliary condensate pumps

Auxiliary feedwater pumps

Boron thermal regeneration system, chiller tank, chiller pumps, and surge tank

Flash tank, pump, and piping

Ammonia and hydrazine equipment for steam generator chemical feed

The component cooling water surge tank with piping and instrumentation

Containment spray pump and piping

Unit coolers including fans, pipe connections, and supports

HVAC systems

Portions of the control rod drive cooling system

Low level waste pumps, piping, and valves

Evaporator condenser and connecting piping

Refueling water chemical addition tank, pump, and piping

Component cooling water pumps and suction and discharge piping

3.3.3 Fuel Building

3.3.3.1 General

The applicable SWESSAR P&IDs (Appendix A) and the fuel building general arrangement drawings from Appendix B (Fig. 1.2-8) were reviewed for modularization concepts. Where available, proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted. Results are discussed in Sections 3.3.3.2 through 3.3.3.4.

3.3.3.2 Modularization Concepts for Phase II Evaluation (Table 4.3)

The liners in the fuel transfer canal, spent fuel pool, and the new fuel pool can be effectively modularized. Each of these liners can be installed in one piece or the walls or the floor portions could be installed separately. The liner could be fabricated either at the fabricator's shop or at the jobsite depending upon the site location and the fabrication contractor. The approximate weight of such a module would be 50 tons. The primary considerations for liner modularization, however, would generally be the size and method of transportation. Modularization of the liners meets Savings Criterion 1.

Piping modules have not yet been specifically identified. This will be accomplished during Phase II.

The fuel pool purification system demineralizers and filters could be preassembled at the factory. The maximum weight should be less than 3 tons, and would meet Savings Criterion 1.

3.3.3.3 Existing Modularization Concepts (Table 3.3.3.1)

The fuel racks which are provided in the fuel pools are already modularized.

3.3.3.4 Rejected Modularization Concepts (Table 3.3.3.2)

The structural aspects of the fuel building were reviewed for the use of prestressed or precast configurations. No significant savings were identified.

The fuel handling crane can be assembled at the jobsite before installation. The frame support runway girders and their structural support could also be prefabricated. No savings were identified.

3.3.4 Solid Waste and Decontamination Building

3.3.4.1 General

The applicable SWESSAR P&IDs (Appendix A) and the solid waste and decontamination building general arrangement drawings from Appendix B (Fig. 1.2-9) were reviewed for modularization concepts. Where available, proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted. Results are discussed in Sections 3.3.4.2 through 3.3.4.4.

3.3.4.2 Modularization Concepts for Phase II Evaluation (Table 4.4)

Demineralizers are located in adjacent shielded cubicles. Their respective process lines and valves are located in separate shielded cubicles below the demineralizers. This arrangement lends itself to preassembling of the demineralizer and piping in the demineralizer cubicle and the preassembly of the process piping and valves in the cubicles below. Such modules could be installed with a minimum of field welds. Normally these cubicles have limited access during construction. Any decrease in the number of field welds should reduce welding man-hours and increase weld quality. Such modules would weigh approximately 3 tons. Savings Criterion 2 would be met using this concept.

3.3.4.3 Existing Modularization Concepts (Table 3.3.4.1)

The waste forwarding pump, waste sludge tank strainer, spent resin dewatering pump, and the process mixer are all located in one area, interconnected, and already skid-mounted.

The urea-formaldehyde pumps and the catalyst pump piping are also a skid-mounted module.

Electrical equipment such as control panels and motor control centers consist of cabinets and are preassembled in modules prior to intallation.

3.3.4.4 Rejected Modularization Concepts (Table 3.3.4.2)

Since many of the walls in this building are for shielding and not structural support, they could possibly be modularized. No savings were identified, however.

Modularization of the laundry distillate tank, pump, and piping on one skid is possible. However, the arrangement is a function of the Vendor's standard design and potential cost savings are not adequate to justify further study.

Small radioactive pumps such as the boron test tank pumps and waste test tank pumps could be skid-mounted with their piping preassembled; however, no saving were identified.

3.3.5 Turbine Building

3.3.5.1 General

The applicable SWESSAR P&IDs (Appendix A) and the turbine building general arrangement drawings from Appendix B (Fig. 1.2-7) were reviewed for modularization concepts. Where available, proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted. The results are discussed in Sections 3.3.5.2 through 3.3.5.4.

3.3.5.2 Modularization Concepts for Phase II Evaluation (Table 4.5)

3.3.5.2.1 Precast Concrete

Foundation piers and grade beams could be precast, set in place when the schedule requires, and joined to previously placed concrete or other modules by cast in-place closure pours. A typical detail is sketched in Fig. 3.3.5.2.1.

Walls in the pits below grade, shield walls around the condensate polishing area and fire walls adjacent to the normal switchgear building could also be precast and joined together by cast in-place closure pours.

Where cast in-place concrete is used, reinforcing steel modules could be prepared in advance and inserted in place when needed.

The maximum weight of any precast module would be approximately 150 tons. All the above precast techniques have a potential for meeting Savings Criterion 3. By decreasing the total time required to construct the turbine building, the start of construction can be delayed, thus allowing critical path work in the annulus building to proceed at a more efficient pace.

3.3.5.2.2 Structural Steel Framework and Trusses

The roof framing steel for the condensate polishing area could be preassembled. In this area, pipe supports could be attached to the roof framing steel prior to its placement. In addition, the roof metal decking could be preinstalled on the framing steel.

Structural steel foor systems with metal decking, reinforcing, and possibly drain piping could be preassembled and lifted into place in bays.

The maximum weight of any such modules would be approximately 60 tons. The above structural steel concepts meet Savings Criterion 3.

3.3.5.2.3 Main Condenser

Shop fabrication and tubing of the main condenser allow for significant time and dollar savings. Large sections of the condenser would be assembled in the Vendor's shop for rail or barge shipment to the site. The sections can then be installed with the overhead turbine room crane directly in place between the pedestal legs or, if early setting of turbine equipment is necessary, sections can be assembled and the condenser skidded into position. The maximum weight of sections would be 250 tons. Savings Criteria 1, 2, and 3 could be met using this concept.

3.3.5.2.4 Piping Modules

Specific piping modules recommended for further evaluation during Phase II are given in Table 4.5.

3.3.5.2.5 Skid-Mounted Equipment

3.3.5.2.5.1 Compressed Air Equipment

The compressed air system located at ground grade consisting of three air compressors, three aftercoolers, three air receivers, and dryer could be skid-mounted prior to installation with connecting piping on either one large skid or several small skids. Such skids could be moved in place by sliding them between the turbine building columns. The maximum weight of such modules would be approximately 5 tons. Savings Criterion 2 would be met using this concept.

3.3.5.3.5.2 Condensate Polishing Equipment

Equipment in the condensate polishing system consisting of repetitive water treating types of equipment could be preassembled on large skids with tanks, pumps, piping, and valves set in the condensate polishing area prior to placement of the exterior concrete walls. There would be approximately 24 modules in all. The maximum weight of any module would be approximately 15 tons. This technique meets Savings Criterion 2.

3.3.5.2.5.3 Turbine Generator Equipment

Four moisture separator reheaters (two on each side of the turbine) have the potential for modularization. These modules would include the drain tanks for the moisture separator and reheater and drain piping. Such modules would weigh approximately 75 tons. Savings Criterion 2 would be met using this concept.

3.3.5.2.5.4 Other Skid-Mounted Equipment

The main feedwater pump, with turbine, could be skid-mounted with its associated support systems, such as lubricating oil, steam seal, control oil, steam admission, valves, etc. The maximum weight of any given module would be approximately 65 tons. Savings Criterion 2 would be met by utilizing these concepts.

3.3.5.2.6 Preassembly of Cable Trays

The majority of cable trays are run in groups of five or more. Groups of trays, five high by 12 ft long, could be prefabricated with their associated supports and installed as a module weighing less than 1 ton. This technique meets Savings Criterion 2.

3.3.5.3 Existing Modularization Concepts (Table 3.3.5.1)

Stair towers are currently preassembled and lifted into the concrete shell that surrounds the stairs.

Turbine building roof trusses are assembled on the ground with cables and lighting already attached. The assembled trusses are lifted to the top of the building and attached to the wall framework.

The majority of the equipment purchased with the turbine-generator is already provided in modularized form. These typically include the electrohydraulic reservoir, lube oil reservoir with pumps, hydrogen seal oil unit, and stator winding liquid cooling unit.

Lubricating oil conditioner and carbon dioxide storage and vaporizing units are also provided in modularized forms.

In addition, much of the HVAC equipment is already provided in modularized form.

3.3.5.4 Rejected Modularization Concepts (Table 3.3.5.2)

Modularization of the condenser tube cleaning equipment, auxiliary condensate pumps, condenser air removal pumps, steam jet air ejectors, and vacuum priming pumps could also be modularized to some degree. These concepts are so insignificant that potential savings are considered negligible.

3.3.6 Control Building

3.3.6.1 General

The applicable SWESSAR P&IDs (Appendix A) and the control building general arrangement drawings from Appendix B (Figure 1.2-5) were reviewed for modularization concepts. Where available, proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted. The results are discussed in Sections 3.3.6.2 through 3.3.6.4.

3.3.6.2 Modularization Concepts for Phase II Evaluation (Table 4.6)

Most of the concrete wall sections and slabs could be precast using techniques such as those outlined in the discussion on the annulus building (Section 3.3.2). The maximum weight of any such module would be approximately 200 tons. Savings Criterion 3 would be met using this concept. By precasting, the start of construction can be delayed allowing critical path work in the annulus building to proceed at a faster pace.

As an alternative to the above, prefabricated bays consisting of structural steel metal decking and reinforcing steel attached could be utilized. The maximum weight of any given module would be approximately 50 tons. The use of this modularization concept would meet Savings Criterion 3.

Chilled water piping subassemblies weighing less than 1 ton and meeting Savings Criterion 2 could be provided.

Prefabrication of cable trays in the spreading areas and electrical tunnels could also be accomplished. The maximum weight of any such module would be approximately 1 ton. Savings Criteria 1 and 2 would be met utilizing this concept.

3.3.6.3 Existing Modularization Concepts (Table 3.3.6.1)

Electrical switchgear, control boards and panels, motor control centers, and substations are already modularized.

Air conditioning units, charcoal filter assemblies, chillers, ventilation units, and fans are also modularized.

3.3.6.4 Rejected Modularization Concepts (Table 3.3.6.2)

Preassembly of batteries, racks, and connectors could be provided. The maximum weight of such modules would be approximately 4 tons. This concept was rejected due to potential damage to the batteries.

Prefabrication of each switchgear room using steel instead of concrete construction with equipment installed and prewired was evaluated. Each module could be moved into place similar to techniques now used in the shipbuilding industry. Since no savings criteria could be met, this concept was rejected.

3.3.7 Diesel Generator Building

3.3.7.1 General

The applicable SWESSAR P&IDs (Appendix A) and the diesel generator building general arrangement drawings from Appendix B (Figure 1.2-6) were reviewed for modularization concepts. Where available, proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted. The results are discussed in Sections 3.3.7.2 through 3.3.7.4.

3.3.7.2 Modularization Concepts for Phase II Evaluation (Table 4.7)

Precasting of the diesel generator building and fuel oil storage tank vault walls and roof slabs could be achieved. The maximum weight of any given module would be approximately 150 tons. Savings Criterion 3 would be met using this modularization technique.

Skid-mounting of the air start system could be achieved. Interconnecting piping/between various components is frequently complex. Therefore, the design and labor involved should benefit by such preassembly. Savings Criterion 1 should be met using this technique.

The combustion air intake system, including the air silencer, ducts, and supports could be prefabricated. The maximum weight would be approximately 4 tons. Savings Criterion 1 or 2 would be met.

3.3.7.3 Existing Modularization Concepts (Table 3.3.7.1)

The diesel generator and auxiliary systems are skid-mounted.

3.3.7.4 Rejected Modularization Concepts (Table 3.3.7.2)

Modularization of the exhaust system, including the muffler, and the ventilation air systems were evaluated. No significant cost savings could be identified.

3.3.8 Normal Switchgear Building

3.3.8.1 General

The applicable SWESSAR P&IDs (Appendix A) and the normal switchgear building general arrangement drawings from Appendix B (Figure 1.2-2) were reviewed for modularization concepts. Where available, proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted. The results are discussed in Sections 3.3.8.2 through 3.3.8.4.

3.3.8.2 Modularization Concepts for Phase II Evaluation (Table 4.8)

Preassembly of various sections of cable trays is possible. The maximum weight of any given module would be approximately 1 ton. Savings Criterion 1 would be met using this concept.

The nonsafety diesel generator could be skid-mounted with the auxiliary lubrication, cooling, and starting equipment. The weight would be approximately 50 tons. Savings Criterion 1 should be met.

3.3.8.3 Existing Modularization Concepts (Table 3.3.8.1)

Switchgear is already modularized at the factory.

3.3.8.4 Rejected Modularization Concepts (Table 3.3.8.2)

The prefabrication of the entire floor module with diverse equipment installed was also evaluated. Again, no significant savings could be identified.

3.3.9 Yard Area

3.3.9.1 General

The applicable SWESSAR P&IDs (Appendix A) and the yard general arrangement drawings from Appendix B (Figure 1.2-1) were reviewed for modularization concepts. Where available, proprietary structural, piping, electrical, HVAC, and composite drawings were also consulted. The results are discussed in Sections 3.3.9.2 through 3.3.9.4.

3.3.9.2 Modularization Concepts for Phase II Evaluation

No areas were identified for potential savings.

3.3.9.3 Existing Modularization Concepts (Table 3.3.9.1)

Catch basins for the yard drainage systems are generally cast in a manufacturing facility and shipped to the jobsite.

Prefabrication of yard tankage, such as the demineralized water storage tank, fuel oil storage tank, condensate storage tank, primary grade water tanks, and boron recovery tanks is already accomplished.

3.3.9.4 Rejected Modularization Concepts (Table 3.3.9.2)

The concrete fire wall between the transformers located in the yard area could be precast. No significant savings could be identified using this technique.

The fire pump house could be skid-mounted with pumps and associated piping in a vendor's shop and transported to the jobsite. The maximum weight of any module would be 20 tons. No significant savings could be identified.

Non-safety related electrical manholes could be precast in the manufacturer's shop and shipped to the field. The maximum weight of any module would be 8 tons. No significant savings could be identified.

TABLE A3.3.1.1

CONTAINMENT
EXISTING MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Reactor vessel support structure	All	1.2-3	160	M
2. Other NSSS component support systems	All	1.2-3	10	M
3. Skid-mounted HVAC equipment	All	1.2-3	5	M,F

TABLE A3.3.1.2

CONTAINMENT
REJECTED MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Use of precast concrete for containment shell, mat, and internal structure	All	1.2-3	100	F
2. Large modules of equipment and piping, and controls (RHR)	All	1.2-3	100	F
3. Reactor vessel internals installed prior to shipment to job site	All	1.2-3	900	M

TABLE A3.3.2.1 ANNULUS BUILDING EXISTING MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (Tons)	Manuf Shop (M) or Field (F)
1. Stairs and miscellaneous platforms	All	1.2-4	30	F
2. Sample panels, cooler valves, water lines	All	1.2-4, 9.3.2-1	4	M
3. Hydrogen recombiner	All	1.2-4, 6.2.5-1	5	M
4. HVAC components and charcoal filter assemblies	All	1.2-4	5	M or F

TABLE A3.3.2.2 ANNULUS BUILDING REJECTED MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (Tons)	Manuf Shop (M) or Field (F)
1. Reinforcing steel cages with two faces of reinforcing	All	1.2-4	15	F
2. Precast concrete labyrinths	All	1.2-4	18	F
3. Precast concrete T-beams	All	1.2-4	50	F
4. Skid-mount equipment and closely associated valves and piping				
a. Distillate pump and cooler	All	1.2-4, 9.3.6-1, 11.2-1	2	F
b. Redundant components of the same system	All	1.2-4	Varies	F
c. Auxiliary condensate pumps	All	1.2-4, 10.4.12-1	10	F
d. Auxiliary feedwater pumps	All	1.2-4, 10.4.10-1	10	F
e. Boron thermal regeneration system chiller, two chiller pumps, and chiller surge tank	W	1.2-4	5	F
f. Flash tank, pump, and piping	All	10.4.8-1	2	F
g. Ammonia and hydrazine equipment	All	1.2-4	5	F
h. Component cooling water surge tank level instrumentation and surge tank piping inside cubicle. W - 3 modules B&W, C_E, W-3S - 2 modules	All	9.2.2-1	2	F
i. Containment spray pump and piping	All	6.2.2-1	1	F
j. Unit coolers including unit cooler fans and piping	All	9.4-1	5	F
k. HVAC systems	All			
Charcoal filter trains		1.2-4	18	M

TABLE A3.3.2.2 (CONT)

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (Tons)	Manuf Shop (M) or Field (F)
Fans and motors		1.2-4	2	M
Ventilation air supply units		1.2-4	5	M
l. Portions of the control rod drive cooling system	B&W	1.2-4	2	F
m. Low level waste pumps, piping, and valves	All	11.2-1	5	F
n. Evaporator condenser and connecting piping	All	11.2-6 9.3.6-1	2	F
o. Refueling water chemical addition tank pump and piping	All	6.2.2-1	1	F
p. Component cooling water pumps with suction and discharge piping	All	9.2.2-1	25	F

TABLE A3.3.3.1

FUEL BUILDING EXISTING MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Fuel racks	All	1.2-8	10	M

TABLE A3.3.3.2

FUEL BUILDING REJECTED MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Building structure	All	1.2-8	100	F
2. Cranes and crane support structure	All	1.2-8	100	M, or F

TABLE A3.3.4.1

SOLID WASTE AND DECONTAMINATION BUILDING EXISTING MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max. Weight (Tons)	Manuf Shop (M) or Field (F)
1. Waste forwarding pump, waste sludge tank strainer, and spent resin dewatering pump, process mixer. All are located in one area and are interconnected.	All	1.2-9 11.5-1	1	M
2. Urea formaldehyde tank, pump and catalyst pump on one skid.	All	11.5-1 1.2-9	1	M
3. Control panels and MCC's	All	1.2-9	1	M

TABLE A3.3.4.2

SOLID WASTE AND DECONTAMINATION BUILDING REJECTED MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max. Weight (Tons)	Manuf Shop (M) or Field (F)
1. Precast panels for shielding walls.	All	1.2-9	150 tons	F
2. Laundry distillate tank and pump on one skid with associated piping.	All	1.2-9 11.2-1	2	F
3. Boron test tank pumps on same base with associated piping and valves. Same for primary grade water pumps and waste test tank pumps.	All	1.2-9 9.3.6-1 11.2-1 9.2.7-1	1 ton each base for each pair of pumps	F

TABLE A3.3.5.1

TURBINE BUILDING EXISTING MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Stair towers	All	1.2-7	25	F
2. Turbine building roof trusses with cable and lighting	All	1.2-7	100	F
3. Turbine-generator skid-mounted modules				
a. Electrohydraulic reservoir with associated piping and components	All	1.2-7	13	M
b. EHC control panels	All	1.2-7	1	M
c. Lubricating oil reservoir and pumps with associated piping and components	All	1.2-7	34	M
d. Hydrogen seal oil unit with associated piping and components	All	1.2-7	10	M
e. Stator winding liquid cooling unit with associated piping and components	All	1.2-7	16	M
4. Sample panels	All	1.2-7 & 9.3.2-2	5	M&F
5. Lubricating oil conditioner with associated piping and components	All	1.2-7	3	M
6. CO2 storage and vaporizing units with associated piping and components	All	1.2-7	7	M
7. Turbine building HVAC equipment	All	1.2-7	15	M

TABLE A3.3.5.2

TURBINE BUILDING REJECTED MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Skid-mounted modules				
a. Condenser tube cleaning recirculation and and reinjection pumps, and ball colection tank	All	1.2-7	1	F
b. auxiliary condensate receiver and pumps with associated piping and valves	All	1.2-7 & 10.4.12-1	3	F
c. Condenser air removal pumps, silencers, and related piping	All	1.2-7	1	F
d. Steam jet air ejectors	All	1.2-7	1	F
e. Vacuum priming pumps, silencers, and priming tank	All	1.2-1	1	F

TABLE A3.3.6.1 CONTROL BUILDING
EXISTING MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Switchgear, control boards and panels, motor control centers and unit sub-stations.	All	1.2-5	1	M
2. Air conditioning units, charcoal filter assemblies, chillers, ventilation units, and fans.	All	1.2-5 9.4.1-1 through 9.4.1-6	1	M

TABLE A3.3.6.2 CONTROL BUILDING
REJECTED MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Batteries, racks, and connectors	All	1.2-5	4	F
2. Prefabricate each switch-gear room complete, using steel instead of concrete construction with equipment installed and pre-wired. Then move into place and weld together, similar to techniques now used in the shipbuilding industry.	All	1.2-5		F

TABLE A3.3.7.1

DIESEL GENERATOR BUILDING
EXISTING MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Weight (tons)	Manuf. Shop (M) or Field (F)
1. Skid-mount diesel generator and auxiliary systems.	All	1.2-6	150	M

TABLE A3.3.7.2

DIESEL GENERATOR BUILDING
REJECTED MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Weight (tons)	Manuf. Shop (M) or Field (F)
1. Prefabrication of diesel exhaust system and ventilation air system.	All	1.2-6		F

TABLE A3.3.8.1

NORMAL SWITCHGEAR BUILDING
EXISTING MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Onsite assembly of high voltage switchgear	All	1.2-2	20	M

TABLE A3.3.8.2

NORMAL SWITCHGEAR BUILDING
REJECTED MODULARIZATION CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)
1. Prefabrication of entire normal switchgear building floor.	All	1.2-2		F

TABLE A3.3.9.1

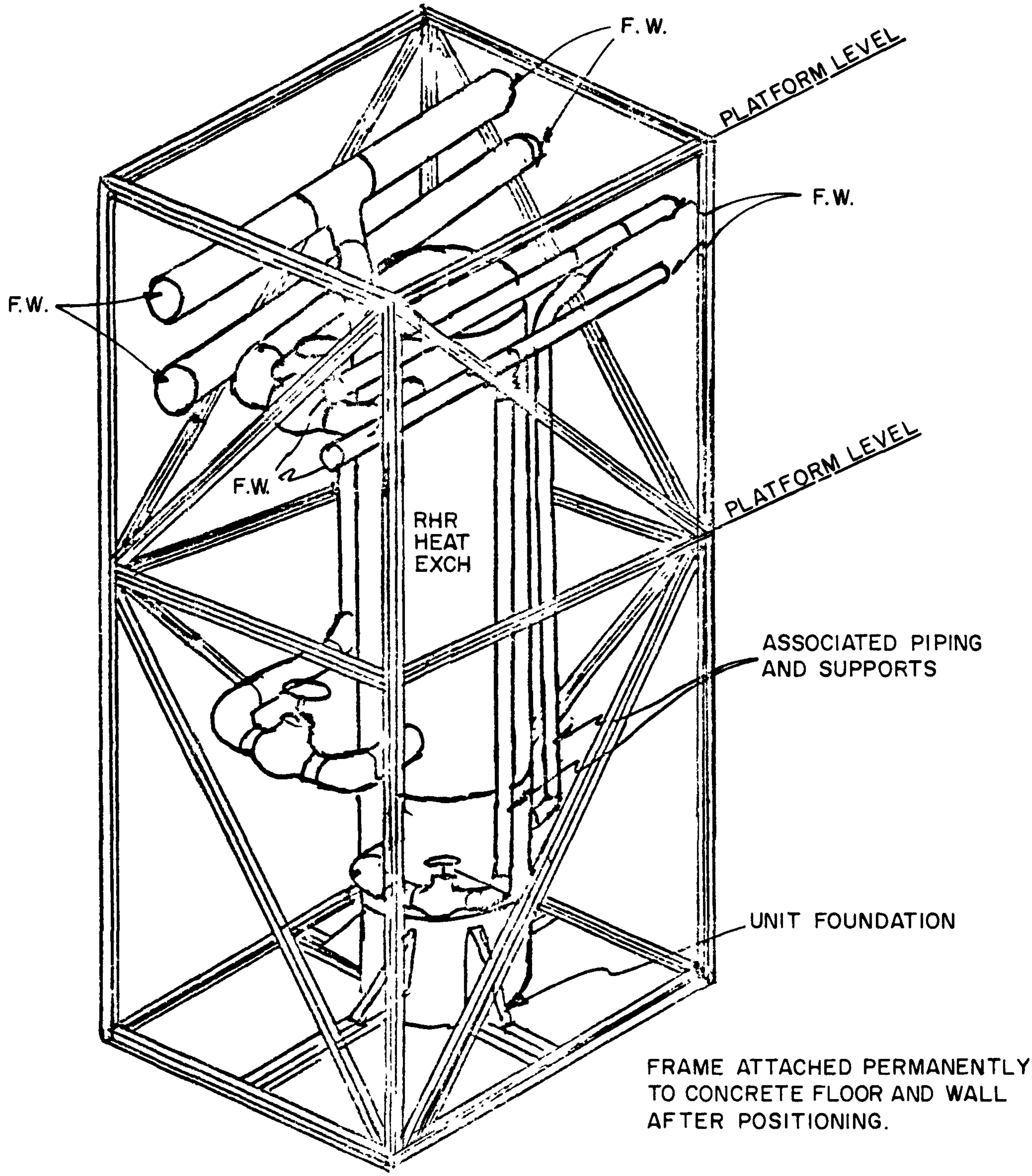
YARD AREA
EXISTING MODULAR CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (Tons)	Manuf Shop (M) or Field (F)
1. Precast catch basins	All	1.2-1	4	M
2. Yard tanks	All	1.2-1	20 to 50	M or F

TABLE A3.3.9.2

YARD AREA REJECTED MODULAR CONCEPTS

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max. Weight (Tons)	Manuf Shop (M) or Field (F)
1. Fire walls between transformers	All	1.2-1	50	F
2. Fire pump house	All	1.2-1	20	M or F
3. Precast electrical manholes	All	1.2-1	8	M



NOTE:

LADDERS, GRATING, ETC. WILL BE FABRICATED WITH MODULE.

FIGURE A3.3.1.4
POTENTIAL RHR MODULE
PLANT SYSTEMS/COMPONENTS
MODULARIZATION STUDY

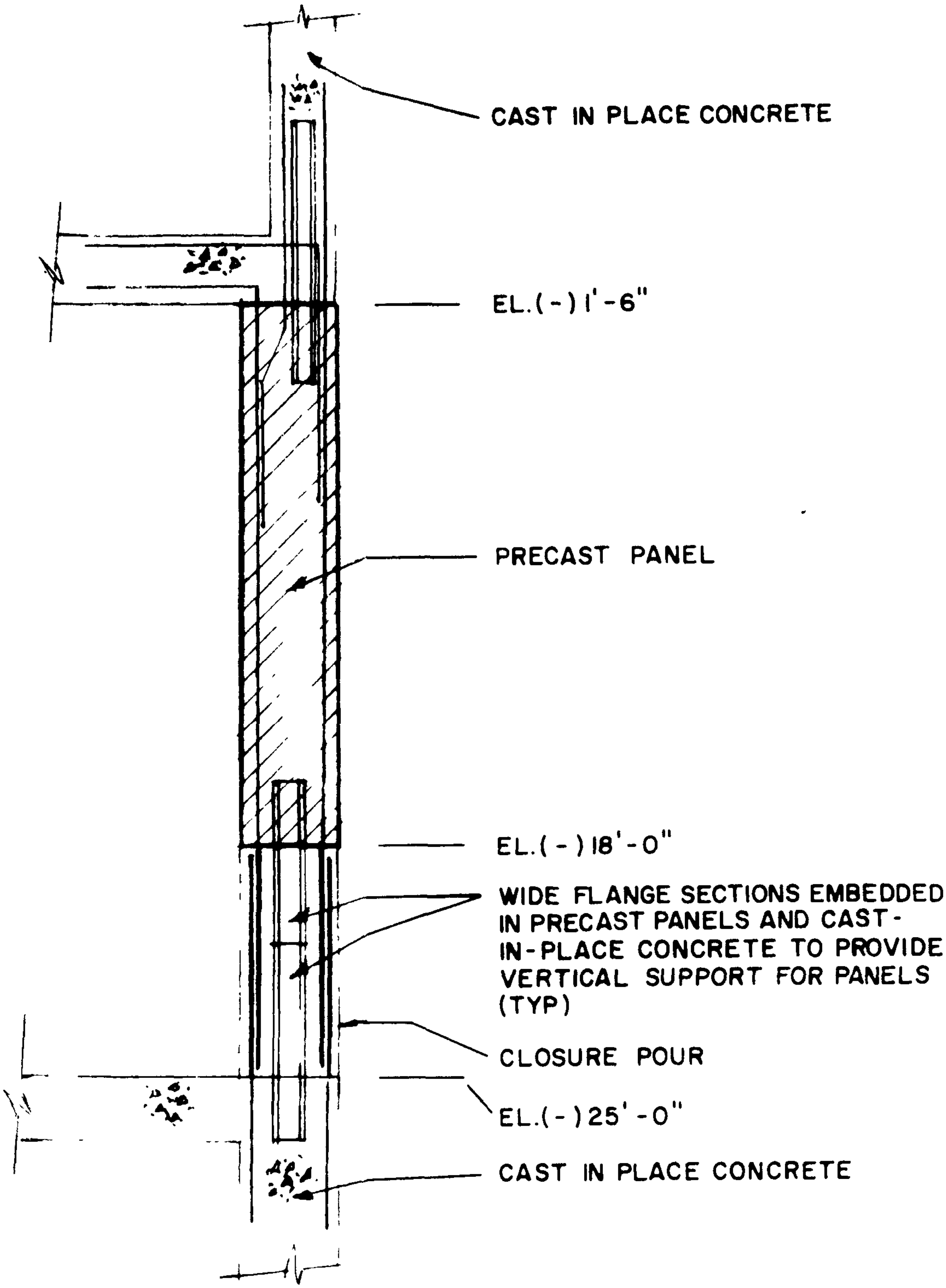
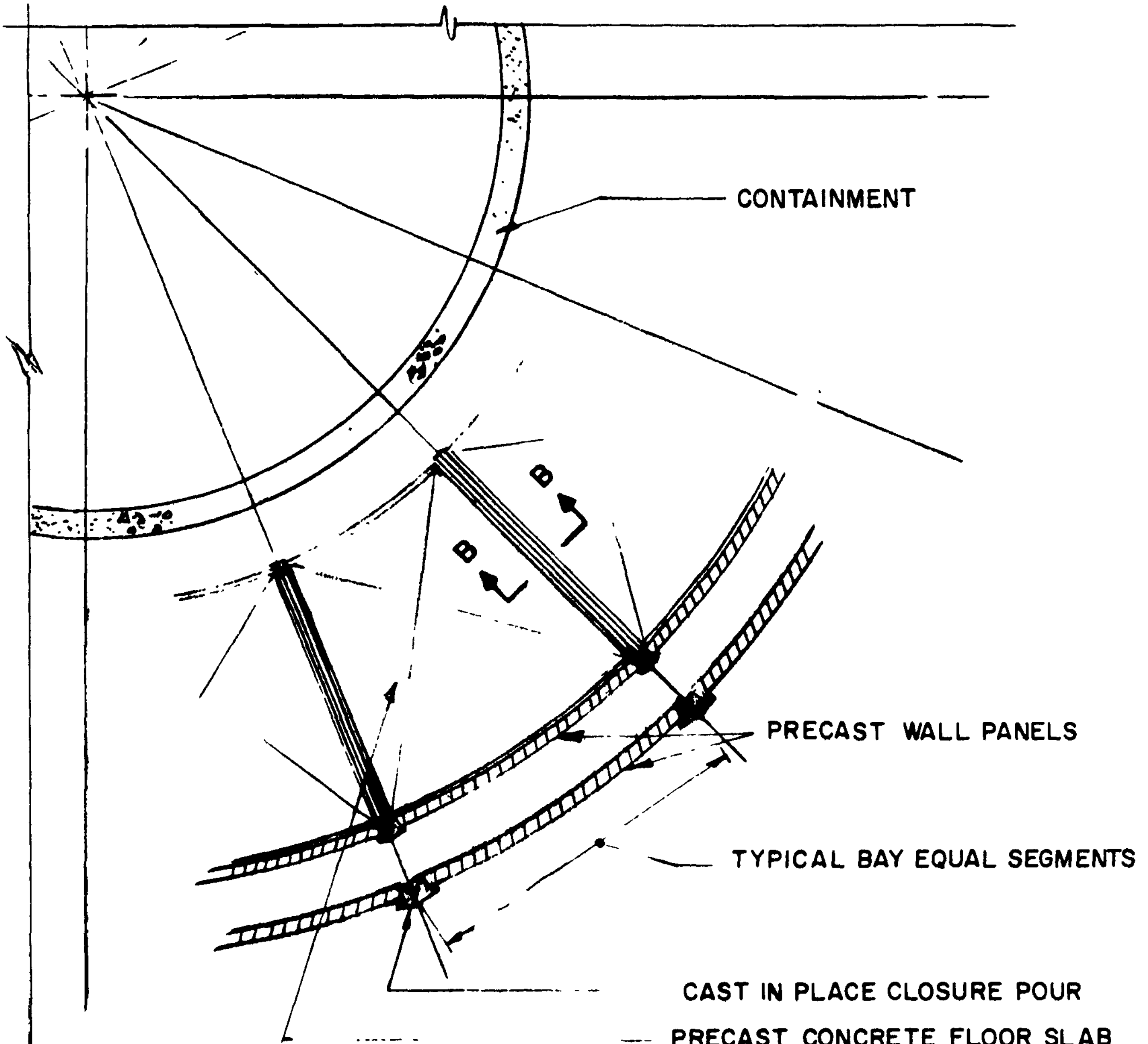
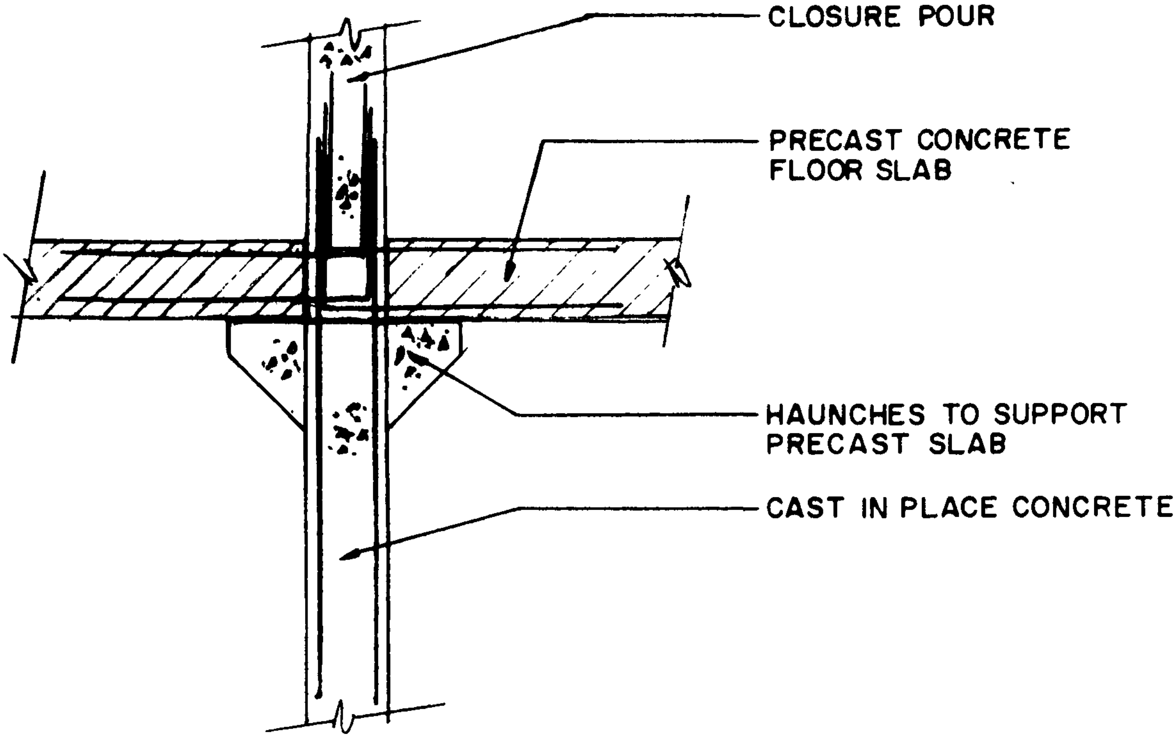


FIGURE A3.3.2.2.1.1
TYPICAL PRECAST WALL CLOSURE-POUR
PLANT SYSTEMS/COMPONENTS MODULARIZATION STUDY



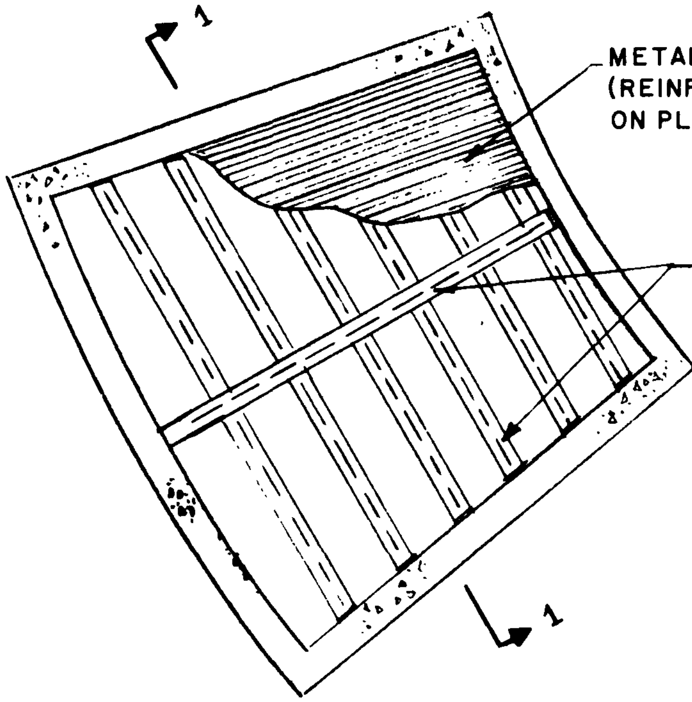
PLAN EL.(-) 15'-6"

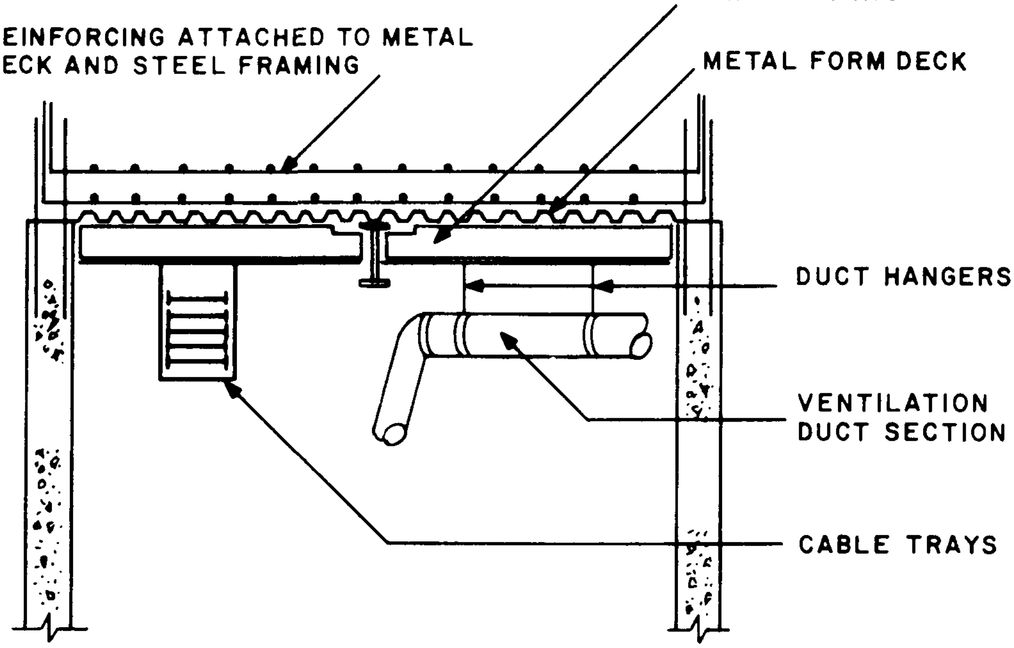
FIGURE A3.3.2.2.1.2 A
TYPICAL PRECAST
WALL PANELS & SLABS
PLANT SYSTEMS/COMPONENTS
MODULARIZATION STUDY



SECTION "A-A"

FIGURE A3.3.2.2.1.2.B
TYPICAL PRECAST SLAB CLOSURE-POUR
PLANT SYSTEMS/COMPONENTS MODULARIZATION STUDY



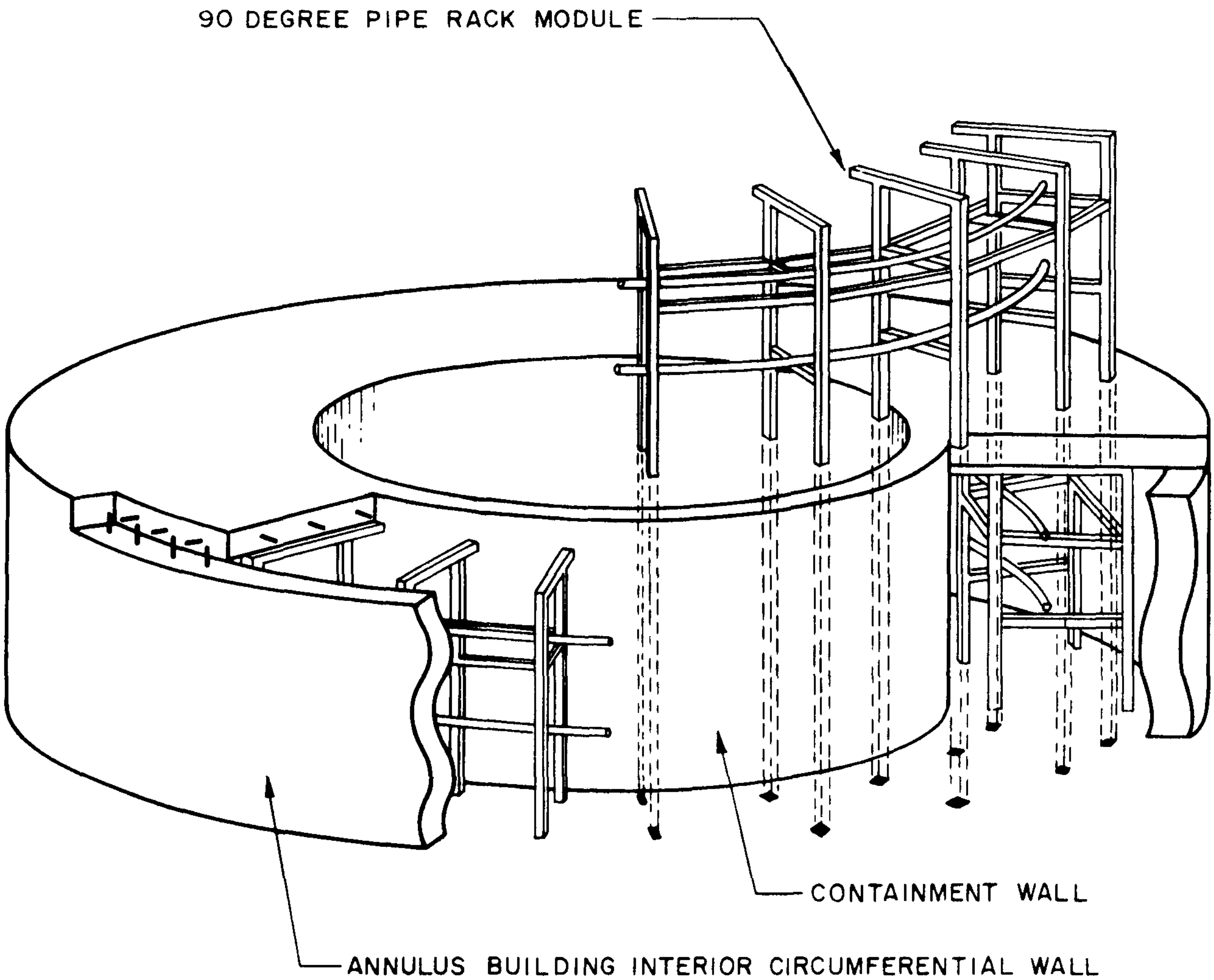


SECTION 1-1

FIGURE A3.3.2.2.2.

FLOOR FRAMING MODULE

PLANT SYSTEMS / COMPONENTS
MODULARIZATION STUDY



NOTE:

1. PIPE RACK IS TO BE PLACED IN 90 DEGREE SEGMENTS.
2. PIPE RESTRAINTS AND PIPES ARE ATTACHED TO THE RACKS PRIOR TO INSTALLATION.

FIGURE A3.3.2.2.4

TYPICAL PIPE RACK MODULE

PLANT SYSTEMS/COMPONENTS MODULARIZATION STUDY

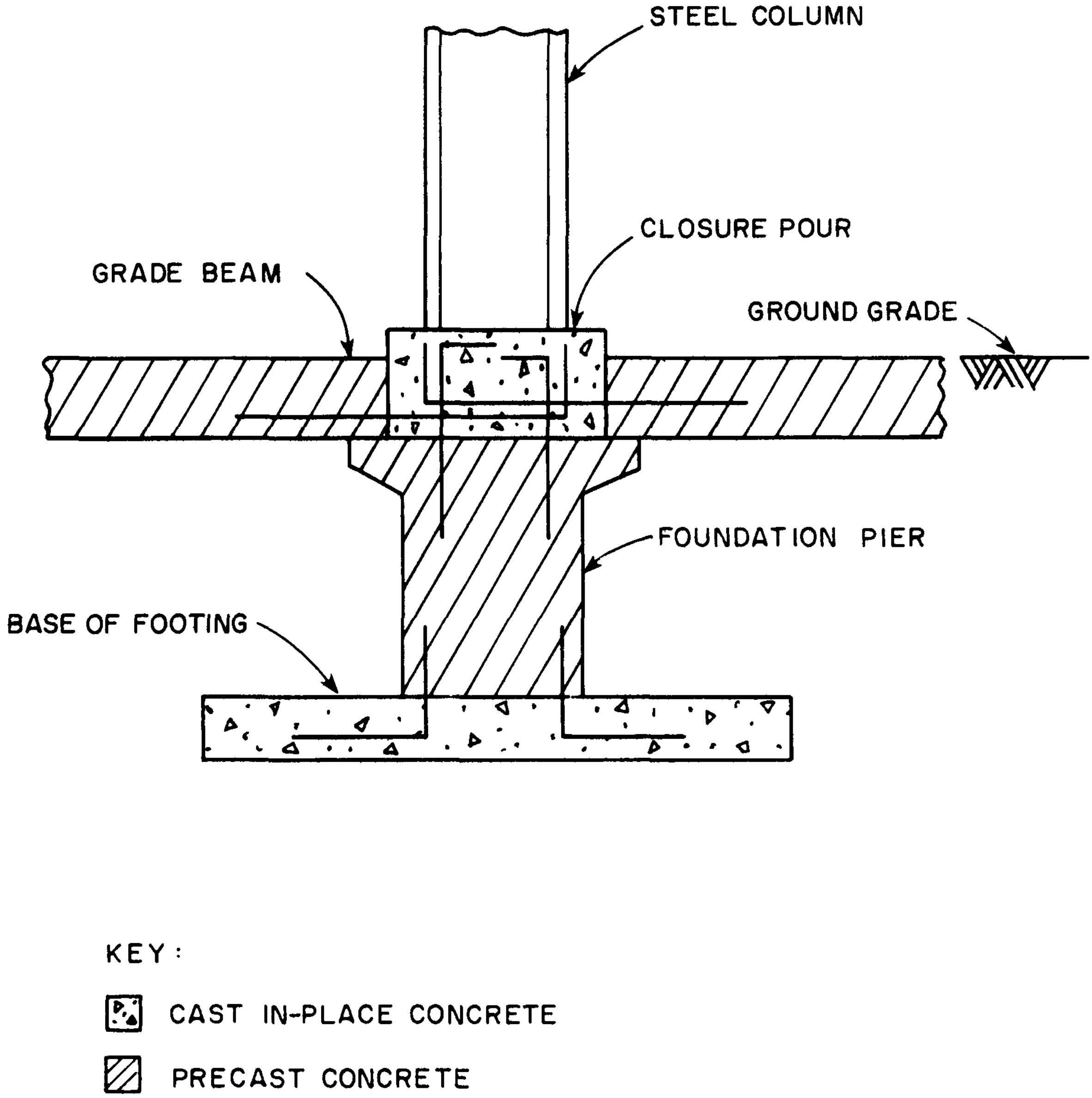


FIGURE A3.3.5.2.1
TYPICAL PRECAST CONCRETE FOUNDATION COLUMN AND GRADE BEAM
PLANT SYSTEMS/COMPONENTS MODULARIZATION STUDY

4. RECOMMENDATIONS

Tables 4.1 through 4.8 list modularization concepts identified to date that are recommended for further evaluation during Phase II. More specific conclusions and recommendations will be given at the end of Phase II.

The preliminary savings criteria which were developed during Phase I established minimum limits. During Phase II of this study, these criteria should be modified to increase the amount of savings potential required in order to identify areas for which the maximum amount of cost or schedule savings can be achieved.

Improved cable pulling techniques (Section 3.2.4) should be evaluated during Phase II. Although such techniques are not modularization oriented, the potential schedule improvement and savings are high.

TABLE A4.1

CONTAINMENT
RECOMMENDATIONS FOR PHASE II EVALUATION

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
1. Containment shell reinforcing steel	All	1.2-3	100	F	1	
2. Containment and Annulus Building mat reinforcing steel	All	1.2-3	150	F	3	
3. Containment internal structure reinforcing steel	All	1.2-3	85	F	3	
4. Polar crane support steel structure	All	1.2-3	150	F	3	
5. Miscellaneous STructures	All	1.2-3	100	F	3	
6. Containment liner	All	1.2-3	170	F	1,3	
7. Refueling cavity liner	All	1.2-3	15	F	3	Size limitations govern
8. Major piping						The modules will be identified in more detail during Phase II.
a. Main steam	All	1.2-3, 10.3-1	-	F	3	
b. Feedwater	All	1.2-3, 10.4.7-2	-	F	3	
c. Residual or decay heat removal	All	1.2-3	-	F	3	
d. Pressurizer safety and relief	All	1.2-3	-	F	3	
e. Pressurizer spray	All	1.2-3	-	F	3	
f. Accumulator discharge (core flood)	All	1.2-3	-	F	3	
g. Low head safety injection	All	1.2-3	-	F	3	
h. High head safety injection	All	1.2-3	-	F	3	
i. Pressurizer surge	All	1.2-3	-	F	3	
j. Chemical and volume control	All	1.2-3,	-	F	3	
k. Component cooling	All	1.2-3, 9.2.2-1	-	F	3	
l. NSSS primary loop	All	1.2-3	-	M,F	3	

TABLE A4.2

ANNULUS BUILDING RECOMMENDATIONS FOR PHASE II EVALUATION

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (Tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
1. Precast concrete walls and slabs with closure pour	All	1.2-4	300	F	3	
2. Preassemble cubicle floor framing	All	1.2-4	50	F	2,3	
3. Preassemble reinforcing steel cages	All	1.2-4	7	F	2	
4. Preassemble pipe racks with pipes and restraints						
Radioactive tunnel pipe rack	All	1.2-4	75	F	1,2,3	
Nonradioactive tunnel pipe	All	1.2-4	4	F	1,2,3	
CVCS area pipe rack	All	1.2-4	20	F	1,2,3	
5. Tanks	All	1.2-4	50	F	2	
6. Weld large segments of piping.						
A. Feedwater piping from containment penetrations up to and including the elbow riser. Westinghouse - 4 modules C-E, B&W - 2 modules	All	10.4.7-2	25	F	2	
b. Main steam line from containment penetrations up to and including the elbow riser; to include MSIV piping to flange for safety valves and MSIV bypass. Use 4 modules.	All	10.3-1	25	F	2	
c. Auxiliary steam and condensate lines with control stations. Use 12 modules.	All	10.4.12-1	1	F	2	
d. Piping and valves associated with the auxiliary condensate pumps	All	10.4.12-1	1	F	2	

TABLE A 4.2 (CONT)

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (Tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
e. Steam supply lines with valves to auxiliary feed-water pump turbine	All	10.3-1	1	F	2	
f. Main steam line with piping stub to atmospheric dump valve and maintenance block valve inlet and discharge - approximately 20 modules	All	10.3-1	1	F	2	
g. Feedwater line with flow element and isolation valves	C-E	10.4.7-2	3	F	2	
h. Piping inside cubicles for CVCS heat exchangers	All	1.2-4	1	F	2	
i. Steam generator blowdown piping and flow elements downstream of containtment penetration. Westinghouse - 4 modules C-E - 2 modules	W, C-E	10.4.8-1	2	F	2	Not applicable to B&W
7. Skid-mount equipment and closely associated valves and piping.						
a. Preassemble demineralizers with connecting piping and valves	All	1.2-4 9.3.6-1 11.2-1	2	F	2	Repeating module
b. Filters with connecting and valves	All	9.3.6-1 11.2-1	2	F	2	Repeating module
c. Sumps with piping and instrumentation	All	9.3.3-1	3	F	2	Repeating module
8. Cable trays and supports	All	1.2-4	1	M or F	1, 2	

TABLE A4.3

FUEL BUILDING RECOMMENDATIONS FOR PHASE II EVALUATION

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
1. Fuel building liners	All	1.2-8	50	F	1	
2. Piping	All	1.2-8	-	F	2	The modules will be identified in more detail during Phase II.
3. Demineralizers and filters	All	1.2-8	3	F or M	1	

TABLE A4.4

SOLID WASTE AND DECONTAMINATION BUILDING RECOMMENDATIONS FOR PHASE II EVALUATION

Module Identification	NSSS Vendor	Reference Dwg From Appendixes	Estimated Max. Weight (Tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
1. Demineralizers and piping on a standard base for placement in present cubicle.	All	1.2-9 11.5-1	3	F	2	Recurring Module

TABLE A4.5

TURBINE BUILDING RECOMMENDATIONS FOR PHASE II EVALUATION

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
1. Precast foundation piers and grade beams	All	1.2-7	150	F	3	
2. Precast walls of pits and shielding walls in condensate polishing area and fire walls	All	1.2-7	100	F	3	
3. Preassemble roof structural steel, metal deck, pipe supports, and reinforcing steel in the condensate polishing area	All	1.2-7	50	F	2,3	
4. Floor system steel with one column attached, metal decking, reinforcing, and piping	All	1.2-7	80	F	3	
5. Prefabricate and pretube main condensers	All	1.2-7	250	M	All	
6. Piping modules						
a. Steam seal piping in vicinity of main turbine stop valves	All	1.2-7	1	F	2	
b. Main steam double manifold configuration	B&W	10.3-1	75	F	2	
c. Feedwater piping and valves; feedwater pump discharge, feedwater pump discharge manifold, inlets/outlets of feedwater heaters, outlet manifold with bypass manifold, control valve stations, flow element installation.	All	10.4.7-2	75	F	2	
d. Heater drain piping and valves; level instrument manifolds on each feedwater heater and tank,						

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
level valves in drain lines to the succeeding heaters and to the condenser and also on outlet of drain coolers, valves on drain pump discharge, and loop seal and level instruments on 6th point heater discharge	All	1.2-7	10	F	2	
e. Extraction steam piping and valves; manifolds with valves on high pressure extractions, valves in series on low pressure extractions	All	1.2-7	10	F	2	
f. Valves in series on drain lines from moisture separator and moisture separator reheater	All	1.2-7	5	F	2	
g. Condensate piping and valves; condensate pumps discharge, crossconnect with condensate polishing, air ejector bypass upstream of feedwater pumps, exhaust hood spray line, desuperheating spray line, and valve seal lines.	All	10.4.7-1	15	F	2	
h. Circulating water piping	All	1.2-7	Depends on pipe material	F	2	
7. Skid-mounted modules						
a. Instrument and service air system air compressor aftercooler, and receiver	All	1.2-7 & 3.1-1	5	F	2,3	
b. Condensate polishing equipment	All	1.2-7	1	F	1,2	
c. Moisture separator reheater, moisture separator drain tank, reheater drain tank, with associated piping and valves	All	1.2-7	75	F	2,3	
d. Feedwater pump and turbine with associated turbine						

TABLE A4.5 (CONT)

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
systems (steam seal, lubricating oil, control oil, etc)	All	1.2-7 & 10.4.7-2	65	M	2	
8. Cable trays	All	1.2-7	1	F	1,2	

TABLE A4.6

CONTROL BUILDING
RECOMMENDATIONS FOR PHASE II EVALUATION

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
1. Batteries, racks, and connectors installed in a unit	All	1.2-5	4	F	2	
2. Precast concrete wall sections and slabs	All	1.2-5	200	F	3	
3. Prefabricate bays of floor framing with metal deck and reinforcing	All	1.2-5	50	F	3	
4. Chilled water piping subassemblies	All	1.2-5	1	F	2	
5. Preassemble cable trays banks in the cable spreading areas and tunnels	All	1.2-5	1	M or F	1, 2	

TABLE A4.7

DIESEL GENERATOR BUILDING
RECOMMENDATIONS FOR PHASE II EVALUATIONS

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Weight (tons)	Manuf. Shop (M) or Field (F)	Saving Criteria	Remarks
1. Precast walls and roof slabs	All	1.2-6	150	F	3	
2. Skid-mount, pre-assemble the diesel generator air start system.	All	1.2-6	5	M	1	
3. Combustion air intake system, including air silencer, ducts, and supports.	All	1.2-6	4	F	1, 2	

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TABLE A4.8

NORMAL SWITCHGEAR BUILDING
RECOMMENDATIONS FOR PHASE II EVALUATION

Module Identification	NSSS Vendor	Reference Dwg from Appendixes	Estimated Max Weight (tons)	Manuf Shop (M) or Field (F)	Savings Criteria	Remarks
1. Preasembly of cable trays	All	1.2-2	1	M or F	1	
2. Prefabrication of the nonsafety a-c power supply	All	1.2-2	50	F	1	