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Design, Construction, and Instrumentation of a 1/6-Scale Reinforced Concrete Containment Building

Prepared by D. S. Horschel

Sandia National Laboratories

Prepared for
U.S. Nuclear Regulatory
Commission

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ABSTRACT

This report describes the design, construction, and instrumentation of a 1/6-scale reinforced-concrete containment building that has been built at Sandia National Laboratories in Albuquerque, New Mexico. The model of the Light-Water-Reactor containment building was designed and built to the American Society of Mechanical Engineers Code by United Engineers and Constructors, Inc. As part of the U.S. NRC's program on containment integrity, the model will be tested to failure to determine its response to static internal overpressurization at ambient temperatures. The results from testing the heavily instrumented containment will be used to assess the capability of analytical methods for predicting the performance of containments when subject to severe accident loads.

The scaled dimensions of the cylindrical wall and hemispherical dome are typical of a full-size containment. Features representative of a prototypical containment and included in the heavily reinforced model are equipment hatches, personnel airlocks, several small piping penetrations, and a thin steel liner attached to the concrete by headed studs.

Over 1200 channels of instrumentation will be used to assess the model's behavior during testing. Several video and still camera stations are also used during testing of the containment for both data gathering purposes and for support in conducting the test.

CONTENTS

CONTENTS (Continued)

FIGURES

FIGURES (Continued)

FIGURES (Continued)

FIGURES (Continued)

Page

FIGURES (Concluded)

TABLES

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I wish to acknowledge the expertise and dedication of several people and organizations, both outside and within Sandia, that have made significant contributions to this program.

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The effort of Ruby Cochrell in helping to prepare this report for printing is gratefully acknowledged.

1. INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) is investigating the performance of Light-Water-Reactor (LWR) containments subjected to severe accidents. This work is being performed by the Containment Integrity Division at Sandia National Laboratories (Sandia). The latest research effort involves the testing of a 1/6-scale reinforced-concrete containment model. The containment, which was designed and constructed by United Engineers and Constructors [1-4], is the largest and most complex model of its kind. The design, construction, and preparations for testing of the containment model are the subject of this report.

The objective of the containment model tests is to generate data that can be used to qualify methods for reliably predicting the response of LWR containment buildings to severe accident loads. The data recorded during testing include deformations and leakage from the containment, as well as strains and displacements of the containment shell.

1.1 Background

Research into the behavior of LWR containment buildings subject to hypothesized severe accidents has been ongoing. The containment building, whether it is made of steel, reinforced concrete, or pre-stressed concrete, is the final engineered barrier to prevent the release of fission products and radioactive gases that could be generated during reactor operations with particular emphasis on severe environmental and accident loading conditions. The containment is designed to withstand accident conditions and environmental loadings such as a loss-of-coolant accident and earthquake loadings. To fulfill its function, the containment must remain leak-tight and structurally sound at all times.

In the wake of the Three Mile Island accident, attention was focused on the capability of the containment building to withstand loadings beyond its design basis. The NRC is sponsoring a program at Sandia to study the performance of containment buildings when loaded beyond their design capabilities. Sandia has conducted static overpressurization tests on five scale models of steel containment buildings [5-14] and is currently preparing the reinforced-concrete containment model for testing.

1.2 Program Scope

The testing of the containment models is only one of the programs being sponsored by the NRC to address containment integrity during severe accidents. Other programs that deal with the performance of the containment system are also being sponsored by the NRC and are described below.

Tests and analyses are being conducted on mechanical penetrations of containment buildings, such as personnel airlocks and bellows [15-19]. Some of these tests will include both temperature and pressure as testing parameters. Structural data on equipment hatches, personnel airlocks, and other mechanical penetrations are gathered from the containment tests and used in assessing the need for additional tests on penetrations.

Three tests have been completed on the electrical penetrations assemblies used in containments [20, 21]. These too included temperature and pressure profiles during testing.

Extensive testing on seals and gaskets is also being conducted at Sandia. The elastomers used in sealing the mechanical penetrations are subject to severe accident environments and in some cases even to radiation exposure [22-24]. These tests are used to determine the sealing capabilities of the elastomers when exposed to severe accident environments.

Information gathered from all these programs helps determine the behavior of a containment building subjected to a severe accident. These programs help ensure safe nuclear power generation for the future.

1.3 Schedule

Four 1:32-scale steel containment models were tested between December 1982 and December 1983. These tests were followed by a test of a 1:8-scale steel containment model in November 1984. All tests were quasi-static tests that used nitrogen as the medium of pressurization. All tests were carried out until there was a failure in the containment model. The steel containment tests will be followed by the first reinforced-concrete containment test.

The complexity of the construction of the reinforced-concrete containment was much greater than that of the steel containments. This complexity necessitated much more careful planning and design. The design of the containment model began in January 1985 and was completed in June 1985. To ensure that a high-quality model could be constructed, the design work of the model and a series of preconstruction tests were conducted in parallel. Because of the containment model's size and schedule constraints, particular attention was paid to liner welding, splices for the reinforcing steel, concrete placement, and other construction and sequencing details. Reference 25 is a report on the preconstruction tests conducted during the design phase of the containment model. No problems were found that might have precluded the containment model's construction.

Construction of the containment model began in August 1985 after comments and suggestions made by a peer review panel were incorporated into the design. The basemat concrete was placed in December 1985. Sections of the liner began arriving on site in January 1986, and the liner work was completed in February. The first placing of concrete in the cylinder wall was conducted on March 13 and the last concrete placement was performed on May 15, 1986. All model construction was completed in June 1986, and testing is scheduled to begin in mid-1987.

1.4 Project Organization

Through a competitive bidding process, Sandia project personnel selected United Engineer and Constructors, Inc. (United), as the prime contractor for the design and construction of the containment model. United selected several subcontractors for the completion of the contract. The principal subcontractors are:

- Chicago Bridge and Iron, Co., which designed the portions of the liner not backed by concrete, and fabricated and erected all of the remaining portions of the liner.

- Wiss, Janney, Elstner, and Associates, who performed the support tests to confirm fabrication techniques and performance of the scaled containment elements (splices, studs).

- Harwood Engineering, which fabricated and installed the reinforcing steel in the containment model.

2. CONTAINMENT DESIGN

The 1/6-scale reinforced-concrete containment was designed in accordance with the American Society of Mechanical Engineers (ASME) code and has a design pressure of 46 psig. The diameter of the model is 22 ft with a total height of 37 ft. The cylinder wall is 9-3/4 in. thick and the dome wall is 7 in. thick. This model has #4 (13-mm-diameter) reinforcing bar for the primary reinforcing. The cylinder wall contains two layers of meridional, four layers of circumferential, and two layers of diagonal reinforcing steel. As these layers approach the apex of the dome, some layers are reduced in response to changes in the geometry and loading. The containment also has a steel liner on the inside surface that is 1/16 in. thick along the base and cylinder wall and 1/12 in. thick along the dome wall. The liner is attached to the concrete by headed studs. Two equipment hatches, two airlocks, constrained penetrations, and several piping penetrations are also included in the containment model. All materials used in constructing the model have structural characteristics that are either the same or similar to those of actual containment building materials. A schematic of the containment is shown in Figure 1.

2.1 The Selection of Scale

Whenever a scale model is used, often the major motivating factor is a reduction in cost. As the model is reduced in size more compromises often become necessary, whether it be construction techniques or the need to forsake prototypical materials. Sandia and its peer review group felt it was important to at least use typical materials in fabricating the reinforced-concrete model. With so many phenomena present in reinforced concrete--constitutive behavior of the concrete, and interaction between the materials, such as bond strength, and rebar slip--using surrogate materials could certainly change the model's performance or certainly detract from the "believability" of the results obtained from the model.

To help answer these questions and other construction concerns, two contracts were placed--one with Stone and Webster, and a second with Failure Analysis Associates. Smaller scaling, from 1/14 to 1/10, was first considered. At the conclusion of the two studies, however, smaller scales appeared to be more expensive, since custom fabricated reinforcing steel and special construction techniques were needed. In addition, the construction of the model at smaller scales would be more difficult due to the maintaining of tight tolerances, and the feat of making a representative liner at reduced scales. At the conclusion of these two studies it was decided to use a 1/6 scale, which allowed typical materials, a representative liner, and the best cost/technical value ratio.

2.2 Design Basis

Except for minor modifications necessitated by the scaled-down fabrication and construction requirements, the design reflects the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 1 and Division 2. The design accident pressure was established at 46 psig with no thermal loads included. Since inertial loads do

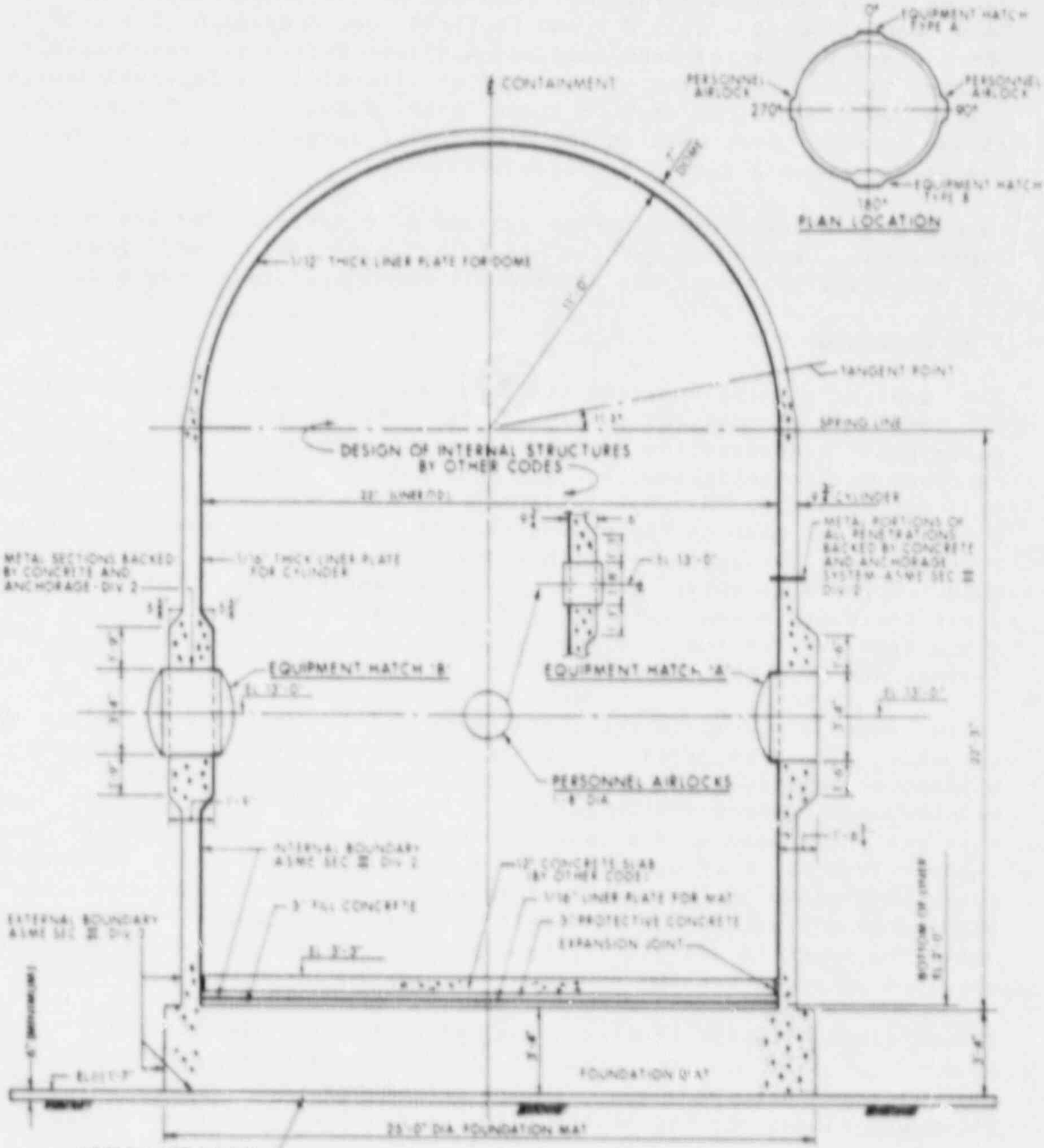


Figure 1. Schematic of the Containment Model.

not scale, the diagonal reinforcement was proportioned to an equivalent Safe Shutdown Earthquake (SSE) of 0.18 g from an existing containment. Because thermal loads were excluded and piping forces were absent and the seismic loading was given an analytical compensation factor, only two load conditions remained as the design basis: Service Load Condition ($D + 1.15\ P_a$) and Factored Load Condition ($D + 1.5P_a$), where D and P_a are the Dead Load and Accident Pressure, respectively. Finite element analyses were used to determine the internal design forces and moments for each of these load conditions. Three-dimensional models were used in the vicinity of large openings to compute forces and moments caused by discontinuities.

Mechanical penetration anchorage systems were designed for scaled pipe break loads. Anchorage for the electrical penetrations was based on 150 psig, which is near the assumed ultimate capacity of the model.

2.3 Concrete

The design of the concrete mix began early in the design process of the containment model and continued into the first phases of the containment construction. In the early phases the use of a microconcrete was investigated, but was abandoned in favor of a more typical concrete mix. Several trial batches of concrete were made before a decision was made on the proportions of the final mix. A well-rounded coarse aggregate with a nominal maximum size of 3/8 in. was used. High-range water reducers (superplasticizers) were used to limit the water/cement ratio to the code specified value of 0.53. The slump required for the concrete lifts was about 8.5 in., except in the basemat and dome apex where the slump was reduced.

To be properly placed in the containment model, the concrete had to be pumpable and flow readily during vibration, yet still consolidate without segregating. To achieve these characteristics, several trial batches of concrete were tested. Trial batches were 4 to 5 yd^3 and were centrally batched and hauled to the site where the concrete was pumped into a mock-up section of the containment wall. Through a plexiglass panel in the mock-up form system, the flow and consolidation characteristics of each trial mix were observed. See Figure 2. While the concrete was still fresh, the mock-up was opened to observe any lack of consolidation.

Travel times from the central mixing plant to the construction site were about 45 min and required the use of extended life superplasticizers that allowed a placing life of about 3 h after batching. Slump was always checked at the site, where some additional superplasticizer was added, as needed, to bring the slump to the desired level.

Measured compressive strengths of the concrete at 28 days of age were about 5300 psi. Cured concrete properties are covered in more detail in Section 5.2.

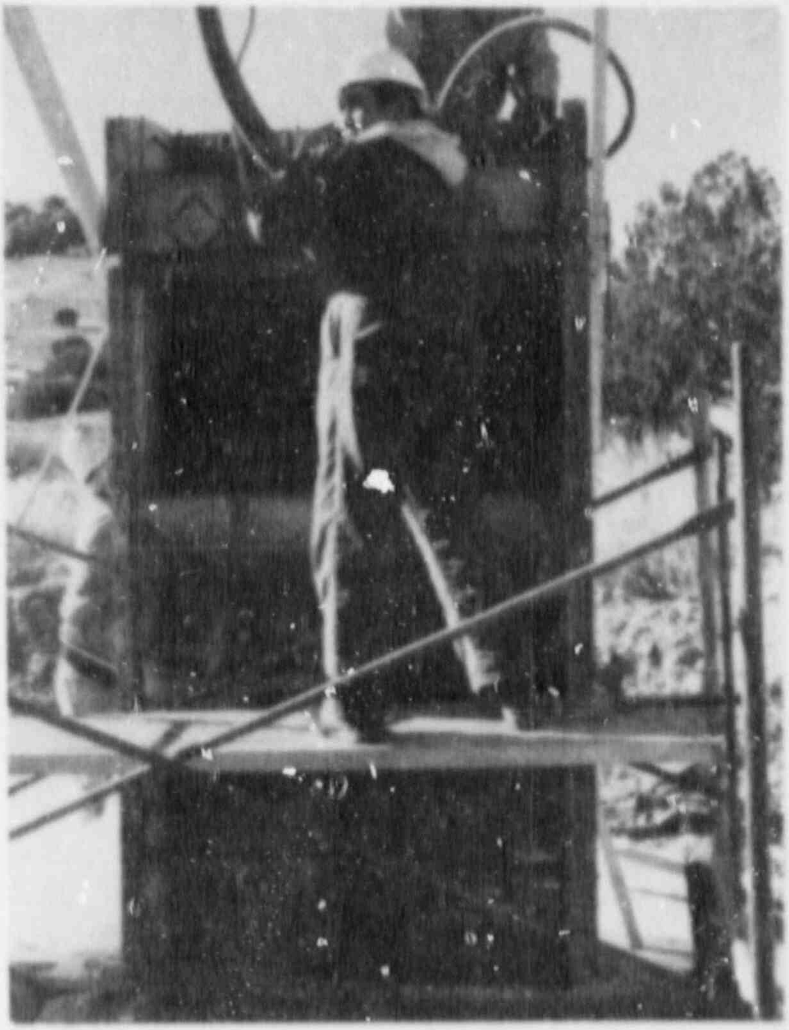


Figure 2. Placing Fresh Concrete in a Mock-up Section.

2.4 Liner

Including a liner in the containment model is important in assessing the containment's ultimate response. The liner is the pressure boundary in U.S. containments and is located on the inside surface of the concrete; therefore, in order for the containment to leak, the liner must be breached in some manner--either by tearing or by excessive deformation of a penetration.

Chicago Bridge and Iron, Co. (CB&I), built the liner and the steel sections of the penetrations. As scaled from a typical containment, the liner material in the 1/6-scale containment is nominally 1/16 in. thick in the basemat and cylinder wall, increasing to 1/12 in. in the dome region of the containment. Near penetrations in the cylinder wall, the liner thickness increases to 3/16 in. Standard pipe sections were used for smaller piping sections, which are made of SA 333 Gr1 steel.

Liners in U.S. containments are generally fabricated of A516 Gr60 steel. This material was used for the thicker (3/16 in.) sections of the liner; however, the A516 Gr60 steel was not readily available in thicknesses of 1/16 in. and 1/12 in. A suitable substitute, A414 GrD, used in the thinner sections, was located after an extensive search by CB&I. Table 1 shows a comparison of A516 Gr60 and A414 GrD material properties.

Table 1

Actual Material Properties of A516 Gr60 and A414 GrD

	Yield Stress (1000 psi)	Ultimate Stress (1000 psi)	Elongation (%)
A516 Gr60*	53.9	67.4	25.4 (in 8")
A516 Gr60**	55.8	79.0	25 (in 2")
A414 GrD	51.4	71.4	24 (in 2")

*From actual containment buildings
**From 3/16-in.-thick plates used for the containment model construction (from Certified Test Reports)

The liner was constructed in sections in CB&I's Kankakee, Illinois, fabrication shop. Included with the liner construction was an internal frame system, which supported the liner during both transportation and construction. A cylindrical section of the liner turned on edge (Figure 3), shows both the outside surface and the internal framing. The liner was held to the support frame by numerous threaded studs attached to the inside of the liner and then bolted to the support frame. The dome section of the liner was dished by a pressing operation before it was attached to the internal support frame. The cylinder sections were deformed elastically to their final shape when they were attached to the support frame. All penetrations were added to the liner at the construction site.

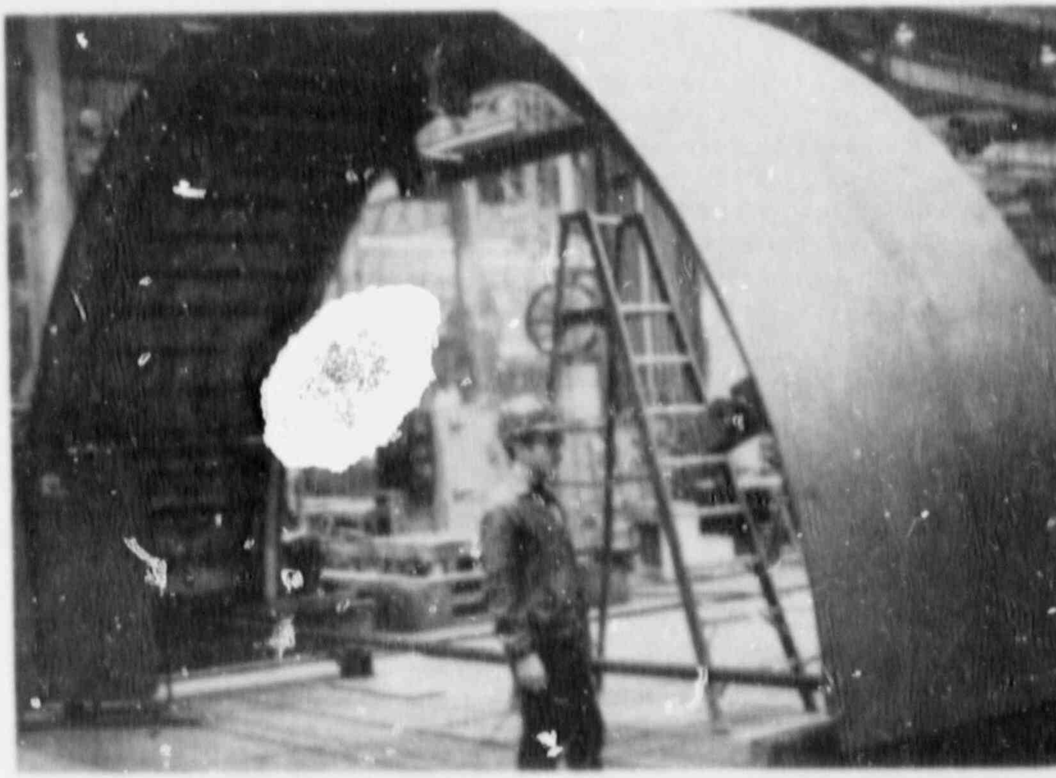


Figure 3. Liner Section and its Support Frame.

2.5 Studs

Over 25,000 headed studs were attached to the outside of the liner. Studs with lengths of 1/2 and 3/4 in. were attached to the model by capacitive-discharge welding. See Figure 4. Although the prototypical stud's length would scale to about 1 in., the use of that length of stud would have caused great inconvenience in construction sequencing, since a 1-in. stud would have penetrated the first layer of reinforcing, making placement of the reinforcing steel extremely difficult. Because final welding of the liner prevented all of the studs from being attached in the shop, several thousand studs were attached at the construction site. Field attachment of the studs on the liner is shown in Figure 5.

At areas of discontinuity in the liner, studs were attached to the liner at the same density as in a full-size containment building--at 2 x 2-in. spacing on the containment model. In areas away from discontinuities, the stud spacing was increased to 4 x 4 in. and 6 x 6 in. in the cylinder wall and to 8 x 8-in. spacing in the dome. The specific stud spacing is covered in the design drawings included in Appendix B.

2.6 Splices

About 5000 mechanically swaged connectors were used in the splicing of the reinforcing steel, the majority being installed on the #4 primary reinforcing steel. These splices allowed for flexible construction procedures--they could be installed either remote from the model, using a bench-mounted press, or at the model itself, using a hand-held press. The performance of the splices is discussed further in Section 3.3. A picture of a splice being installed using the hand-held press is shown in Figure 6. The splices could be fully swaged or they could have various types of threaded ends. Installation of a meridional bar, using swaged connectors with threaded ends, is shown in Figure 7.

Because all U.S. containments built to date have exclusively used a CADWELD-type splice in the reinforcing steel, the use of CADWELDS was desired in some regions of the containment model. CADWELDS used on a

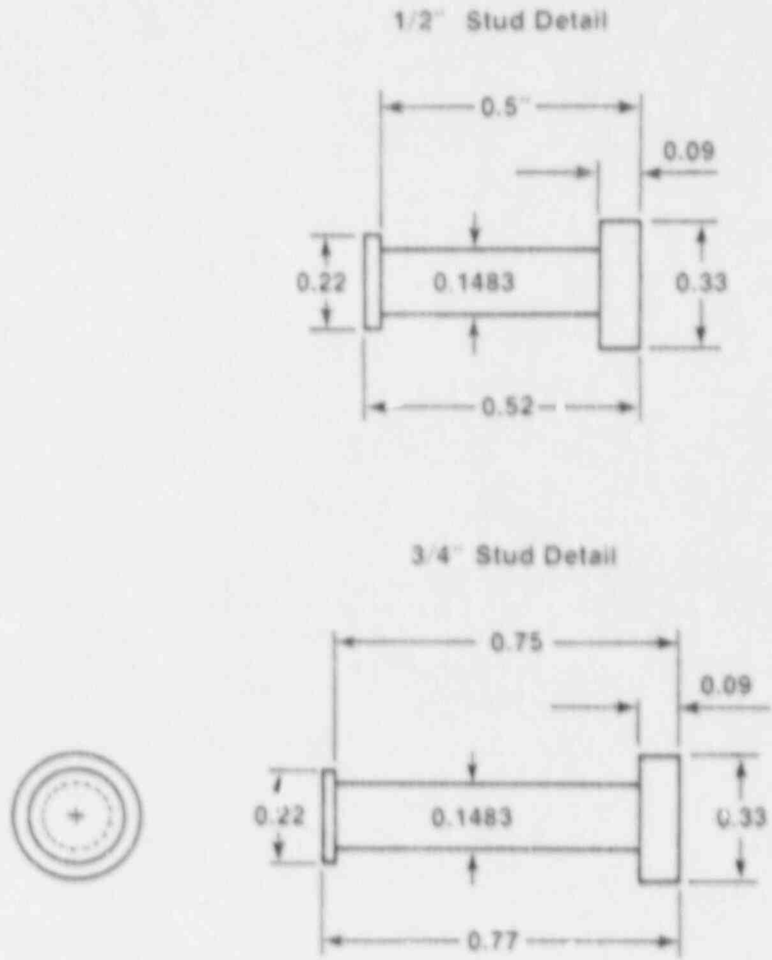


Figure 4. Stud Dimensions.

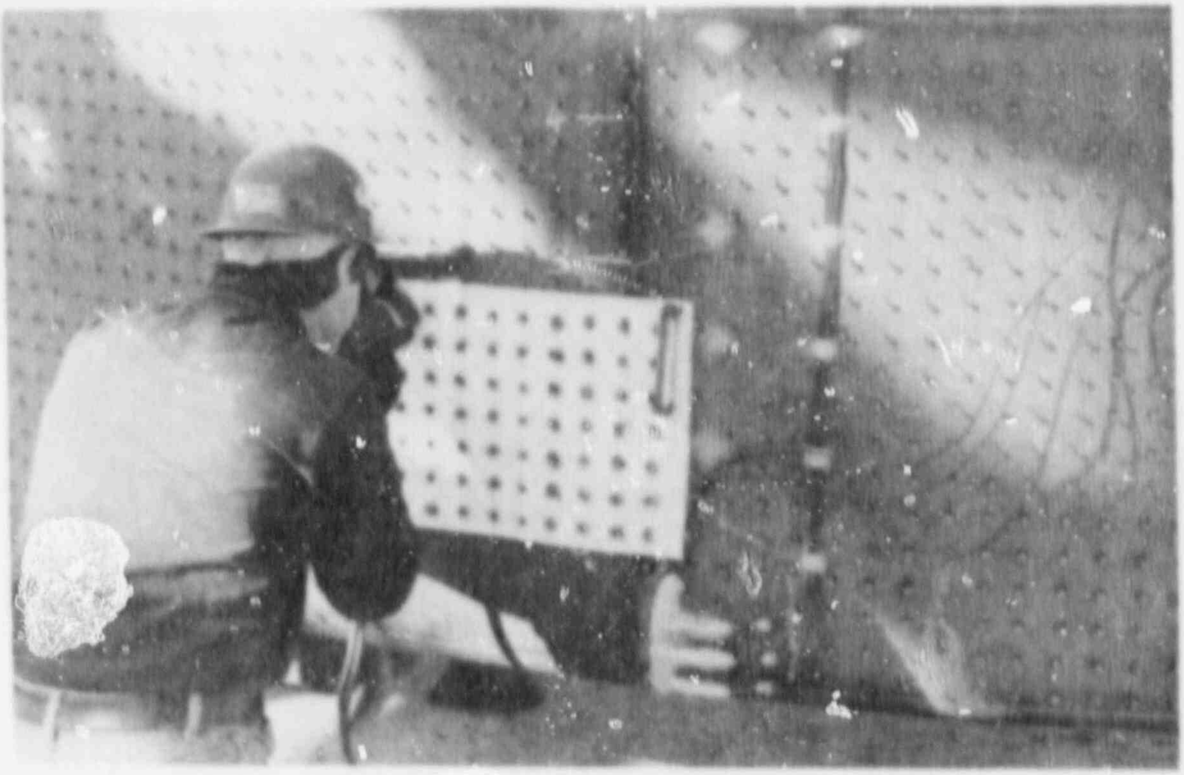


Figure 5. Fie.. ..tachment of Headed Studs.

Figure 6. Swaging of Splices Using Hand-Held Press.

Figure 7. Use of Threaded Couplers on Meridional Bars.

full-size containment have a tendency to slip when subjected to high loads. This characteristic was the major motivation for wishing to include these splices in the containment model; however, tests showed that smaller CADWELD splices did not exhibit this slippage. In fact, the smaller CADWELDS behaved similarly to swaged splices. Modifications to the smaller CADWELDS were not successful in duplicating the response of the larger CADWELD splices; therefore, it was decided to use only one type of splice. Because the swaged splice was easy and quick to make and also developed the strength of the reinforcing steel (as required by the ASME code), swaged splices were selected.

2.7 Basemat

The 40-in.-thick basemat in the 1/6-scale containment is somewhat thicker than would be linearly scaled from most full-size containments and does not include a "reactor cavity." The basemat is somewhat thicker due to the fact that when all dimensions are scaled linearly, gravitational forces in the scale model are equal to the dead weight divided by the scale factor. Because the dead weight of the model was effectively 1/6 that of its full-size counterpart and because no internal structures of a containment were modeled, calculated moments at the base/wall intersection and uplift, due to bulging of the bottom of a linearly-scaled basemat during pressurization, were much higher than would be realized in a full-size containment. After scaling the moments at the basemat/cylinder wall intersection with the use of analyses, a 40-in. basemat thickness was selected.

Inside the cylinder wall a backup bar for welding the liner was cast into a 3-in-thick leveling course--making the basemat 43 in. thick in this region. See Figure 1.

A center shear lug (or key) that is 2 ft in diameter was also included in the center of the basemat. The key was included to prevent the movement of the lower section of the liner during the placing of the first cylinder wall lift.

Not all reinforcing steel in the basemat is laid out in a hoop or radial direction. The bottom layer of reinforcing steel is arranged in an orthogonal pattern, while the top layers of reinforcing steel are arranged in hoop and radial directions, with the very center of the top reinforcing steel also in an orthogonal pattern. See Drawing 7847-F-1200 and 7847-F-1204 in Appendix B on pages B-10 and B-13.

2.8 Dome

The nominal thickness of the dome is 7 in., which is slightly thicker than would scale from a full-size containment. This is chiefly due to the tolerances associated with placing the reinforcing steel and the added thickness of the bars due to the reinforcing splices.

The meridional reinforcing bars continue from the cylinder into the dome. As the bars converge, every other bar is terminated at an angle of 69° from the horizontal, and every other remaining bar is terminated at an angle of 80°. The remaining bars continue to an apex plate that is 36 in. in diameter. The bars are attached to the plate by a threaded coupler. This arrangement can be seen in Figure 8 and in Drawings 7847-F-1270 and 7847-F-1271 in Appendix B on pages B-41 and B-42.

The hoop bars are reduced as the cylinder transitions into the dome. At an angle of 8 to 9° from the horizontal every other hoop bar in the dome is eliminated. The diagonal bars in the dome are also reduced as they pass the springline. (The springline is at an elevation of 24 ft.) At an elevation of 25 ft 6 in. every other diagonal bar is terminated, and finally all diagonal bars are terminated at an elevation of 30 ft 10 in. See Drawings 7847-F-1214 and 7847-F-1215 in Appendix B on pages B-23 to B-26.

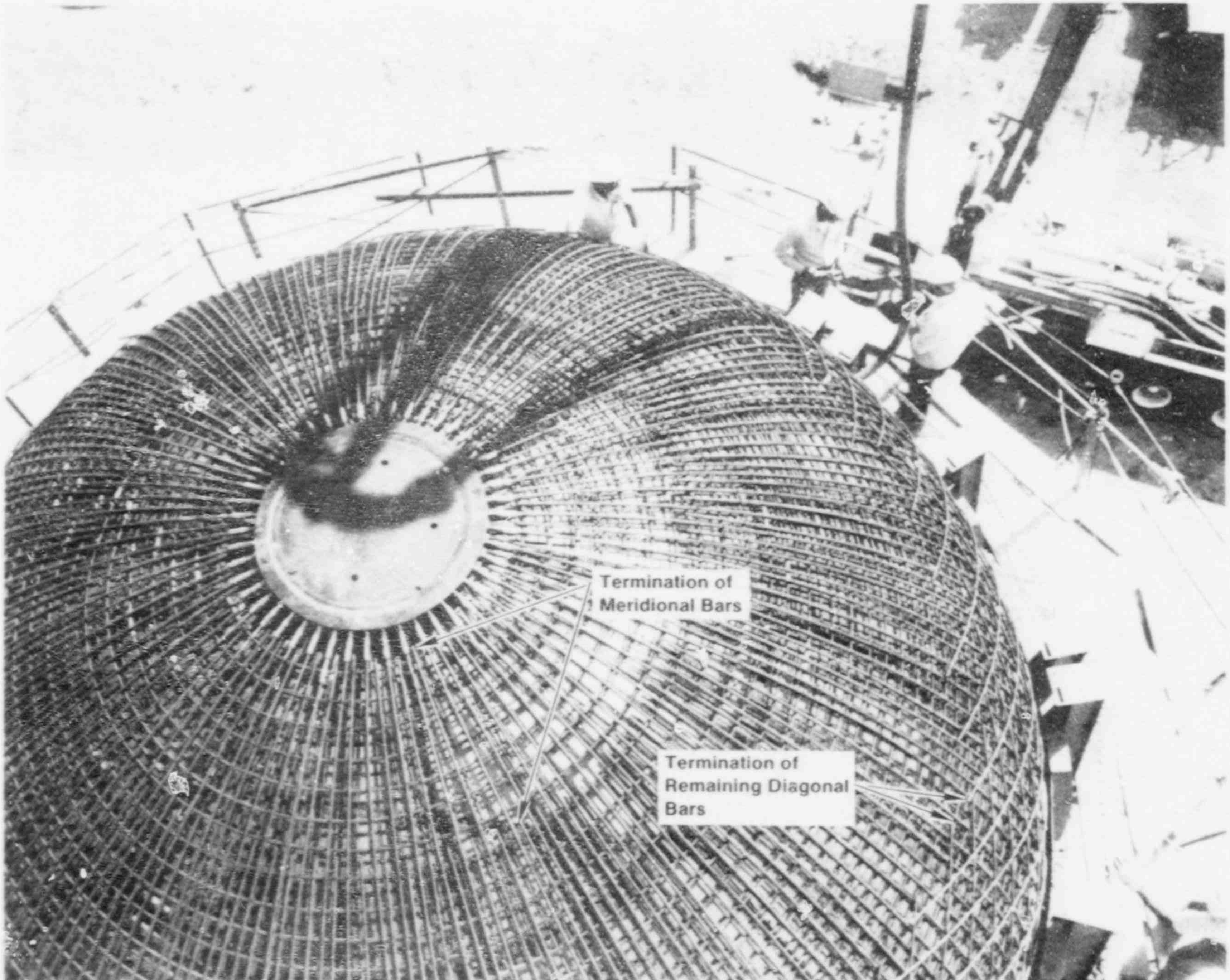


Figure 8. Dome Apex Plate and Termination of Meridional Reinforcing Bars.

2.9 Penetrations

Several types of penetrations were incorporated into the containment model. The majority were scaled from typical penetrations found in full-size containment buildings; however, several other penetrations were included for Sandia's testing purposes.

2.9.1 Personnel Airlocks

Two personnel airlocks are included in the containment, installed at the same elevation (cylinder midheight) but diametrically opposed (180° apart). The sleeve diameter in both airlocks is about 20 in.; other sleeve dimensions were scaled from full-size personnel airlocks. The reinforcing pattern around the penetrations is also identical, but the airlocks themselves are different.

One airlock uses a thick, flat plate as a pressure-unseating door so that it may be used as a "last man out" hatch.

The other personnel airlock has scaled bulkheads and stiffener patterns typical of a full-size airlock. The inner bulkhead is a flat plate with stiffeners; no door or seals are included. The outer bulkhead has a similar stiffener pattern, but no door is represented, allowing for instrumentation to be installed inside the airlock sleeve. A picture of this airlock before the reinforcing steel and concrete were in place is shown in Figure 9.

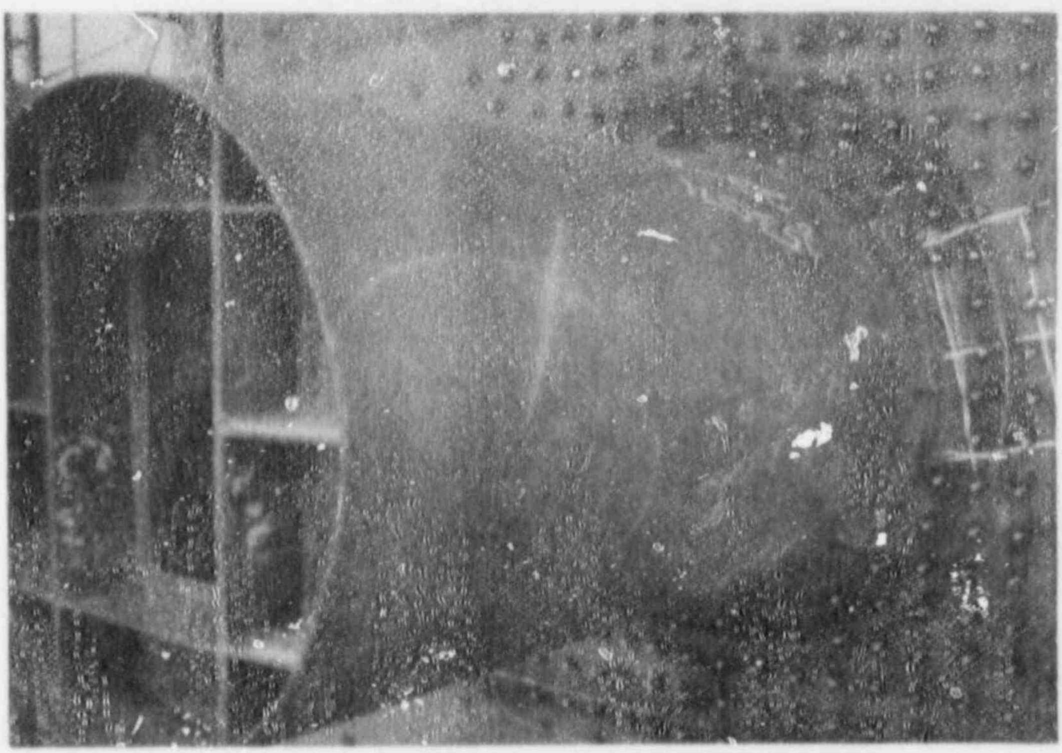


Figure 9. Personnel Airlock at 90° Before Emplacement of Reinforcing Steel.

2.9.2 Equipment Hatches

Two equipment hatches are included in the containment model, installed at the same elevation (cylinder midheight), diametrically opposed, and 90° from the personnel airlocks. Both equipment hatches, including the sealing surfaces of the covers and sleeves, were scaled from typical equipment hatches found in U.S. containment buildings. Both have sleeve diameters of about 40 in. The major difference between the two equipment hatches is that the boss area of one projects entirely outward from the cylinder wall (Equipment Hatch A), whereas the other boss is centered in the wall so that it projects both inward and outward from the cylinder wall (Equipment Hatch B, see Figure 1). The primary reinforcement around each of the equipment hatches is the same, however, their local reinforcement is different.

Equipment Hatch A has a double gumdrop seal in the 1/2-in.-wide mating surface between the cover and the sleeve. This is a pressure-seating cover, i.e., as the pressure inside the containment model increases, it tends to compress the seal. This equipment hatch, as seen from inside the containment model is shown in Figure 10.

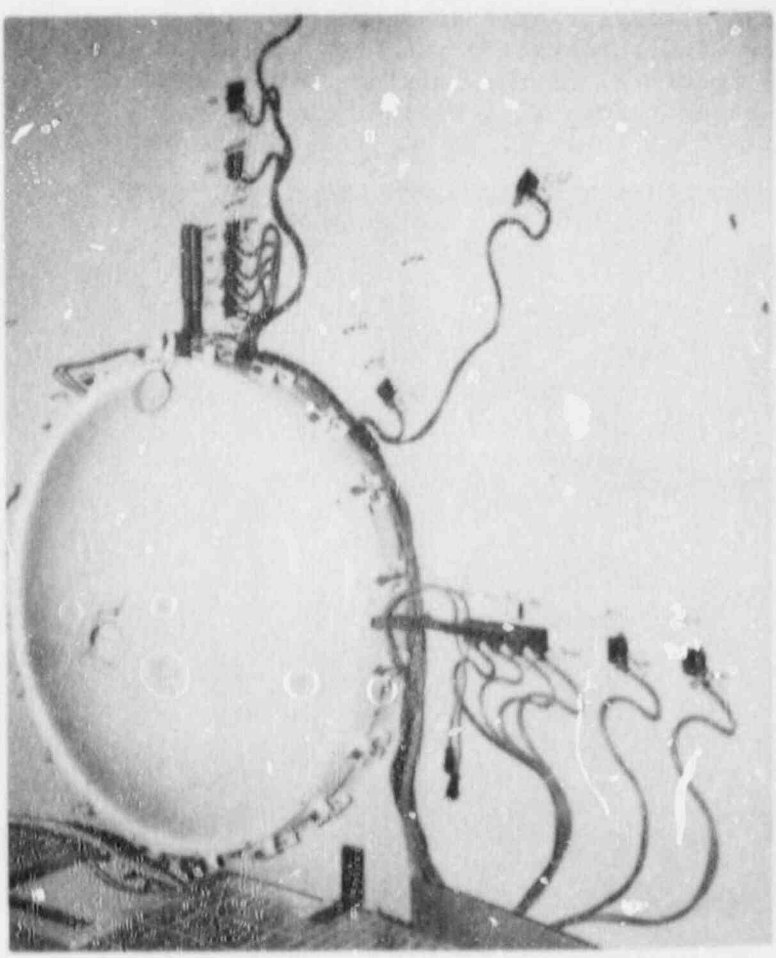


Figure 10. Inside View of Equipment Hatch A.

Equipment Hatch B has two covers, one on the inboard end of the equipment hatch sleeve, which is of the same design as the pressure-seating cover in Equipment Hatch A, and one on the outboard end of the sleeve, which is a pressure-unseating cover. (The inside cover of Equipment Hatch B can be seen in Figure 11. Also note the inward projection of the boss.) Either cover can be used as the pressure boundary during testing by opening and closing remotely controlled valves located in

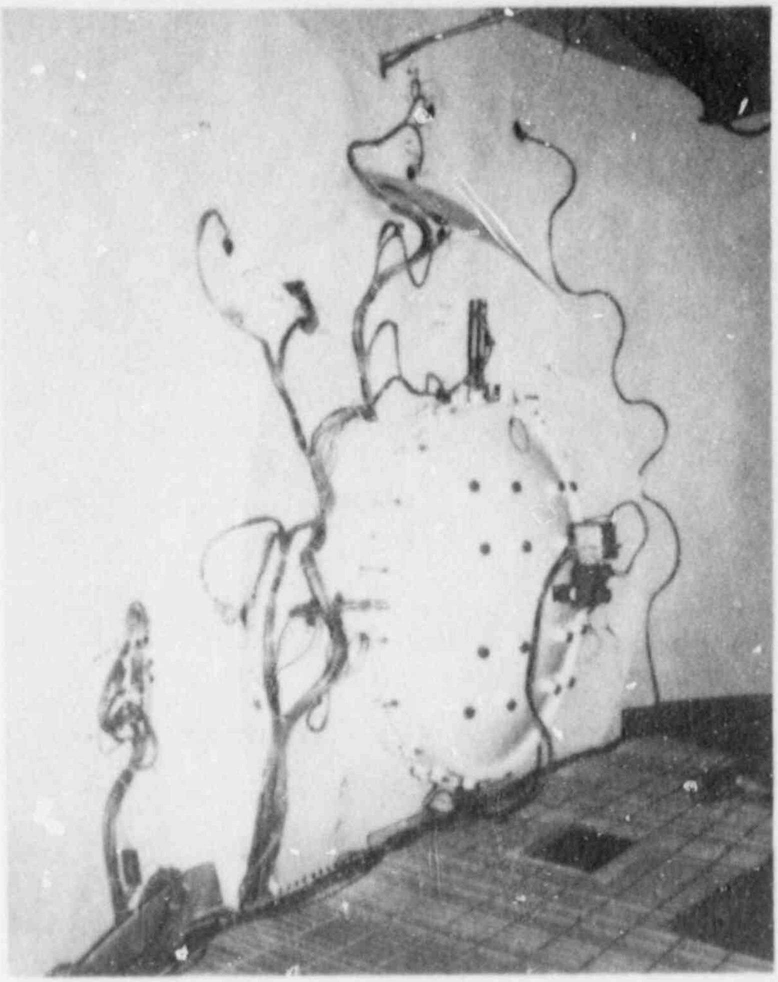


Figure 11. Inside View of Equipment Hatch B.

the equipment hatch covers. The pressure-unseating cover has a double-tongue-and-groove-type seal arrangement in a 3/4-in.-wide sealing surface. An outside view of Equipment Hatch B is shown in Figure 12.

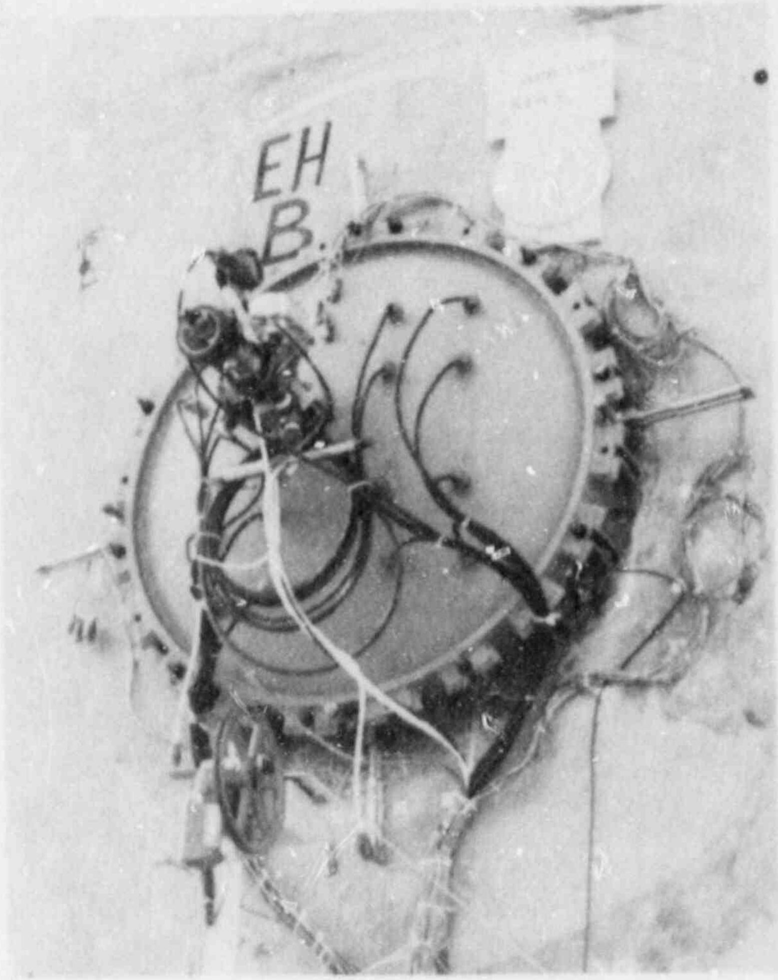


Figure 12. Outside View of Equipment Hatch B.

2.9.3 Constrained Penetrations

There are two 8-in.-diameter penetrations at elevation 21.125' located 180° apart on the cylinder wall. They represent a major steam line penetrating the model. As a containment expands because of overpressurization during a severe accident, the steam line may load the containment because of its inability to move freely. This loading, or constraint, was modeled in the containment by connecting the two penetrations by a small (6-mm-diameter) reinforcing bar. The degree of constraint was selected by analyzing three piping systems of two full-size containment buildings. Although the degree of constraint varied significantly, a "typical" scaled stiffness was selected to represent this constraint in the containment model. One of the constrained penetrations and the bar used to connect it to the other constrained penetration can be seen in Figure 13.

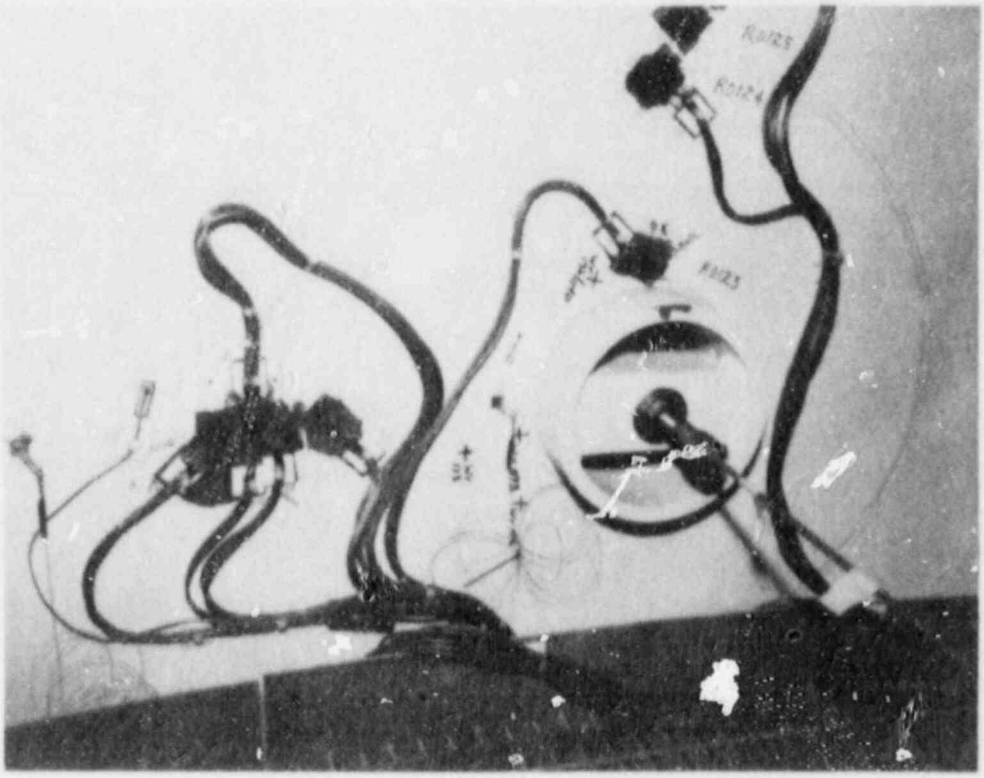


Figure 13. Inside View of the Constrained Penetration.

2.9.4 Other Penetrations

Several other piping penetrations are also included in the containment model. One piping cluster, containing one 8-in., one 4-in., two 2-in., and one 1-in.-diameter penetrations, is located in the containment wall. An inside view of these penetrations can be seen in Figure 14.

The 8-in.-diameter pipe in this cluster was used to pass ac power into the containment model. The box in Figure 14 is a terminal box for the ac power.

Other penetrations included in the containment model were provided to facilitate testing of the containment. These penetrations include five 6-in.-diameter penetrations used to pass through instrumentation wires (see Figure 15), and a 4-in.-diameter penetration, which will be used to connect the pressurization line to the model. The size of the penetrations and the details of the liner around them are typical of those found in a full-size containment.

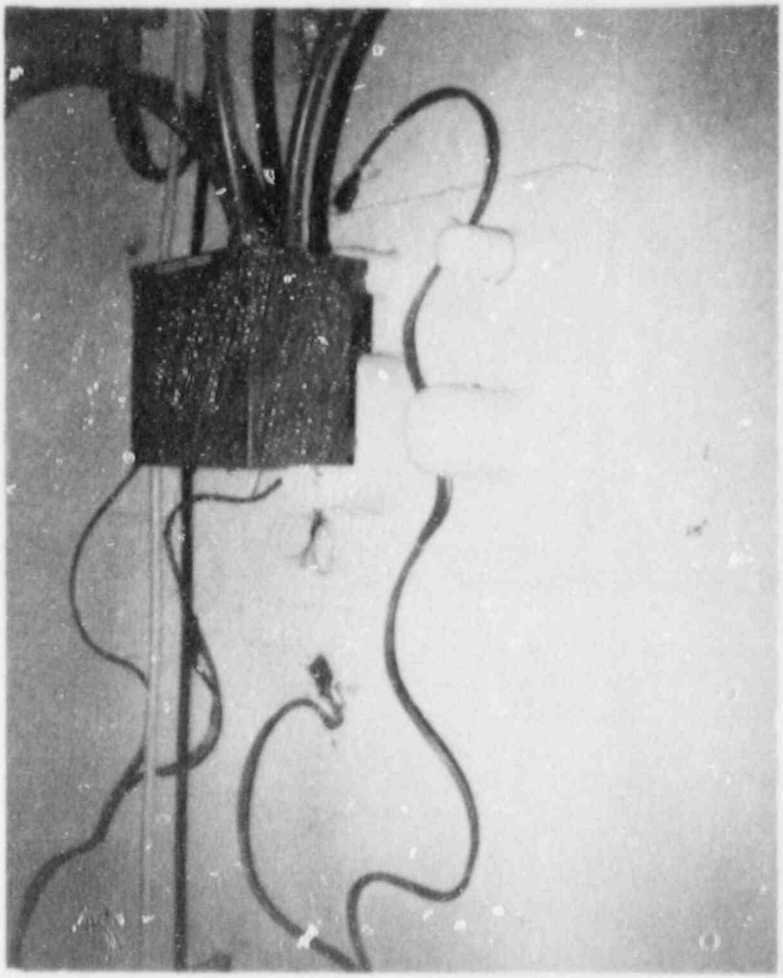


Figure 14. Inside View of Piping Cluster.

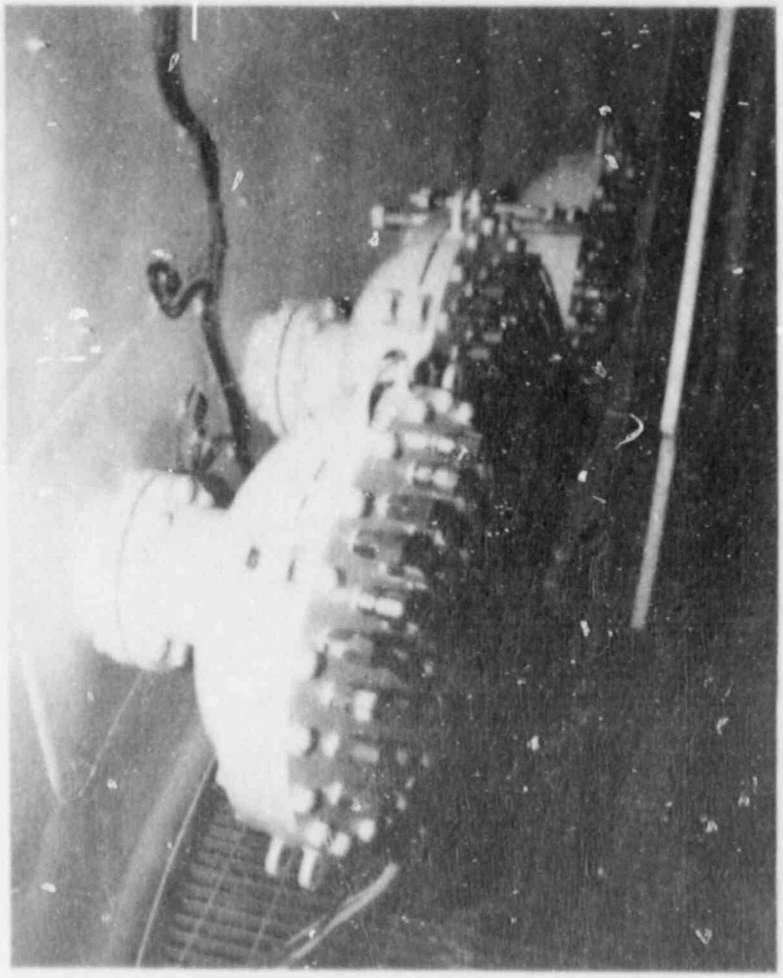


Figure 15. Three of the Five Penetrations Used for Instrumentation Lines.

3. CONTAINMENT CONSTRUCTION

The first concrete placement in the containment occurred in December 1985 and the last occurred on May 15, 1986. Various aspects of the construction are presented in the following sections.

3.1 Sequence of Construction

The construction began along two major parallel paths. In Kankakee, IL, CB&I began the fabrication of the liner for the containment, while in Albuquerque, NM, United began facility work and construction of the basemat at the site.

Tolerances between the basemat dowels (the meridional bars continuing up through the top of the basemat) and the liner were critical to the construction of the containment model. The dowels continued to an elevation of about 6 ft 3 in., and the liner had to be set in place concentrically with the dowels. To ensure that the liner would fit, templates were used to hold the dowels in place and the liner in this region had tighter tolerances. Also, to ease the setting of the liner onto the basemat the stud length was reduced to 1/2 in. at elevations below 6 ft 3 in. Figure 16 shows the lower layer of reinforcing of the basemat and the beginning of the dowels being placed using the template. The template also holds the upper layer of basemat reinforcing steel in place and extends up in the center for the shear lug. See Section 2.7. (Details can be seen in Drawing 7847-F-1401 in

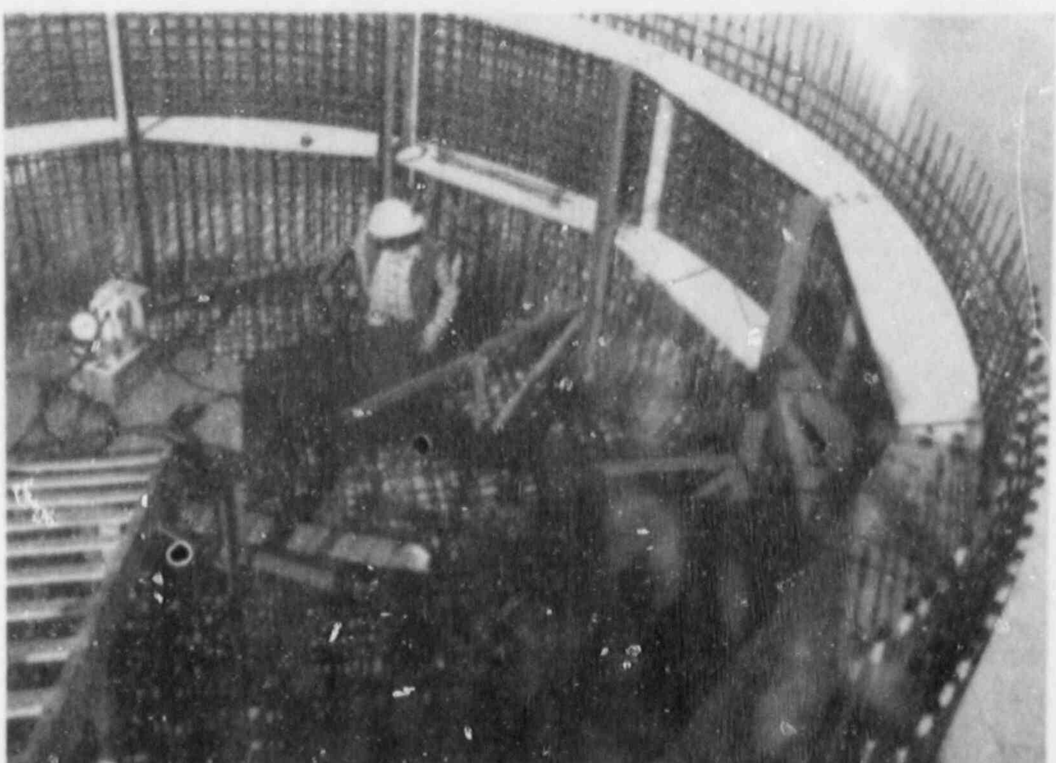


Figure 16. Template for Aligning Dowels and Holding Top Layer of Basemat Reinforcing Steel in Place.

Appendix B on page B-46.) Sections of the template that are above the top of the basemat were cut off after the concrete was placed in the basemat.

The lower layer of reinforcing steel in the basemat was placed on the 6-in.-thick work mat. The majority of the top surface of the work mat was treated with a wax-based curing compound to prevent the basemat from adhering to it; however, in the very center (about 9-ft in diameter) the top of the workmat was intentionally roughened to promote adhesion. This was done to prevent the entire containment from sliding along the workmat during placing of the concrete. (It was feared that an asymmetrical placing of the concrete could induce enough side load to cause the basemat to slip relative to the workmat.) The roughening of the very center would not significantly affect the uplift of the basemat during pressure testing.

The reinforcing pattern in the basemat-cylinder region is shown in a more complete stage in Figure 17. The shear ties angled at 45° and the instrumentation on the seismic bars are also visible in Figure 17.

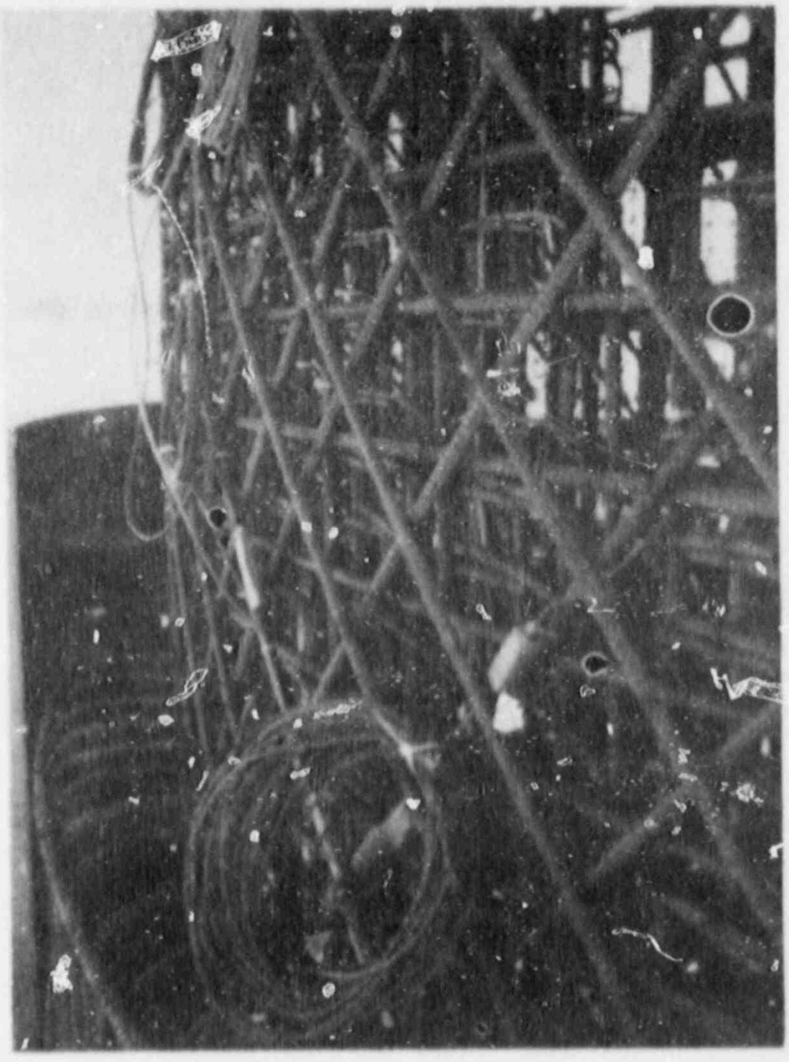


Figure 17. Basemat and Cylinder Wall Reinforcing.

The steel forms used to form the basemat were the same ones that were used to form the cylinder wall. The increased circumference of the basemat was accommodated by placing shims at the joints of the forms.

With the 40-in.-thick basemat lift in place the back-up bars were set on top of it. The back-up bars were used in the welding process of the liner section welds that came in contact with the top surface of the basemat. The back-up bars spanned one diameter and the inside circumference of the cylinder wall as shown in Drawing 7847-F-1301 in Appendix B. The means for leveling the back-up bars can be seen in the same drawing. With the back-up bars in place, an additional 3-in. layer of concrete was placed to bring the top surfaces flush with the concrete surface. Figure 18 shows the back-up bars and center shear lug assembly.

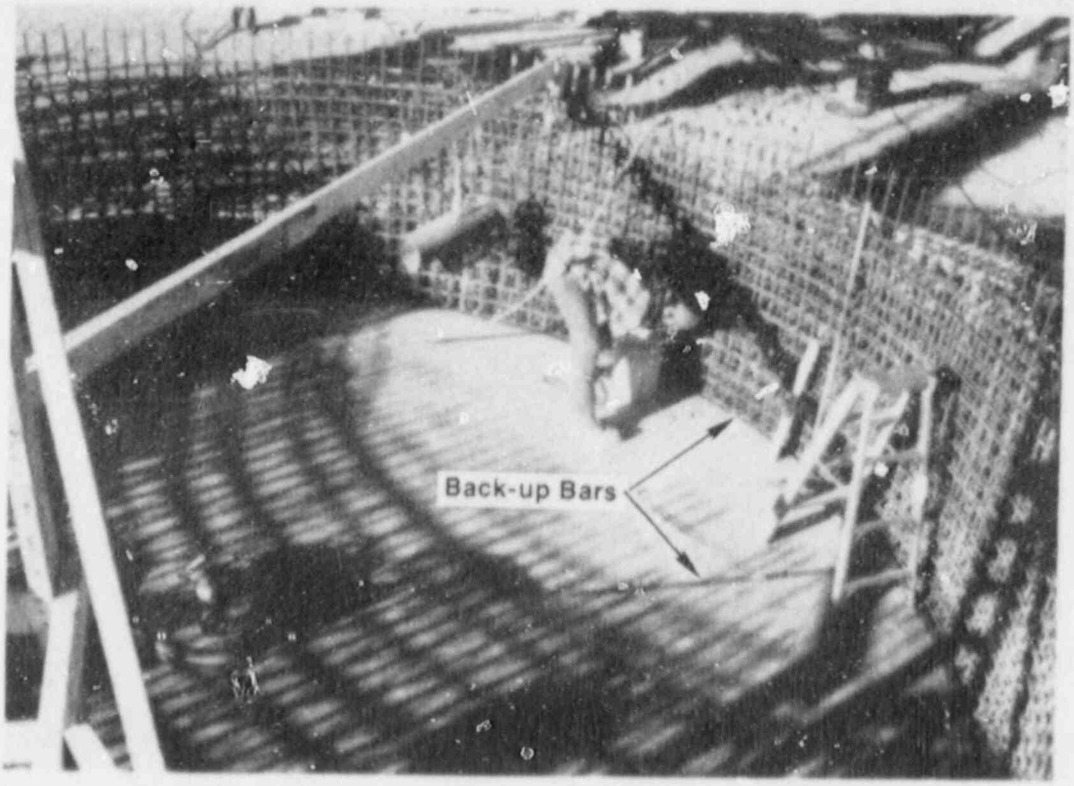


Figure 18. Back-up Bars and 3 in. Leveling Concrete in Place and Ready to Receive Bottom Sections of Liner.

After the leveling course was laid and troweled smooth, the liner floor was set in place as two semi-circles. These two semi-circles were welded together and to the center shear lug. The lower section of cylinder wall liner and the knuckle that transitions from the cylinder to the floor were set in place on the basemat. Figure 19 shows the lower section of the cylinder liner during emplacement.

Steel bars were hung in a vertical position from the top edge of the liner section in several locations about the azimuth. The thickness

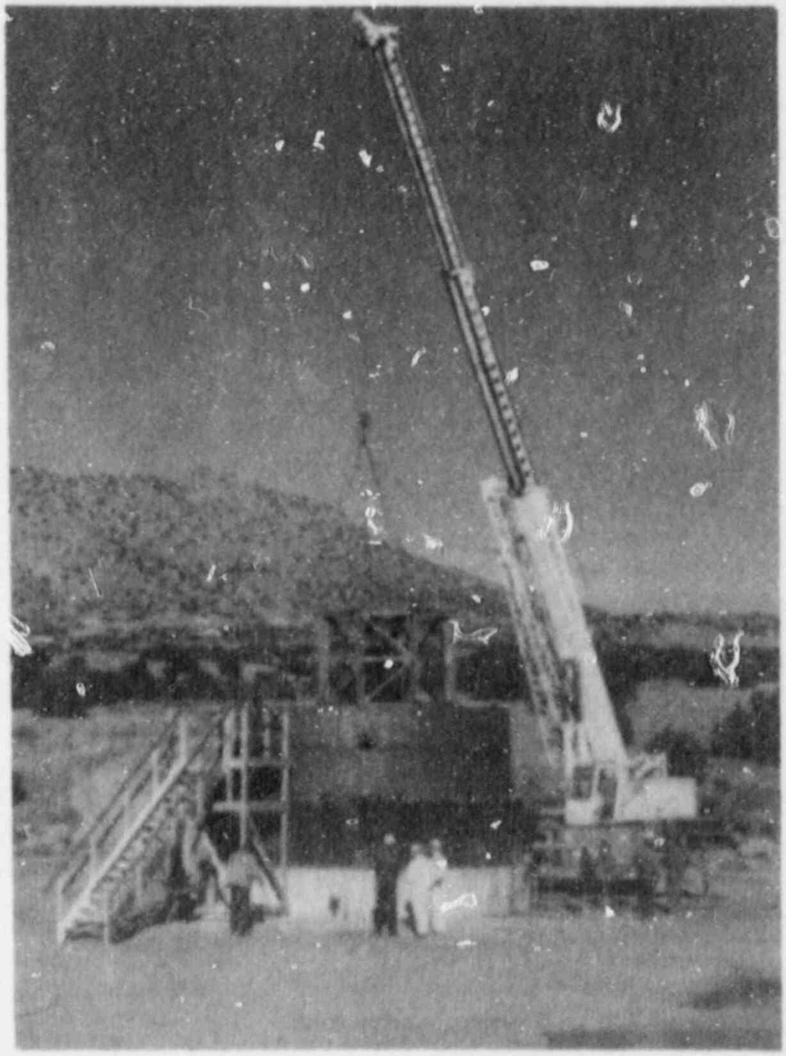


Figure 19. Setting Lower Section of Cylinder Liner into Place.

of the bars was greater than the length of the studs, allowing the bars to act as "shoe horns" as the liner was lowered into the dowels projecting from the basemat. After the cylinder liner section was in place, the steel bars were removed. The cylinder liner section was then welded to the liner floor. The weld, of course, occurred at the back-up bars that were previously embedded in the concrete. As with a full-size containment, the liner floor was not necessarily in direct contact with the concrete underneath it due to neither the liner nor the basemat being perfectly flat, and the lack of mechanical anchors.

A 3-in.-thick protective layer of concrete was placed on top of the liner floor, which protected the thin liner material as workers placed reinforcing steel for the 12-in.-thick fill mat. Both the protective cover and the fill mat had a radius of 9 ft 6 in., leaving the 18 in. between the cylinder wall and these slabs open for instrumentation and inspection during testing. (Details can be seen in Drawing 7847-F-1112 in Appendix B on page B-9.) The fill mat would be used to later support the internal platforms.

The fabrication of the liner progressed rapidly. The half cylinders were joined together to make a continuous ring that was then set on the existing liner sections. After the third section of cylinder wall liner was added, the internal structure was lifted into place as shown in Figure 20.

The internal structure supported the liner via internal bracing during the placement of the concrete and later supported the internal platforms. All penetrations in the liner were added at the construction site. The holes for the insert plate and sleeve of Equipment Hatch A can also be seen in Figure 20. The cylinder section of the liner progressed as in lower sections.

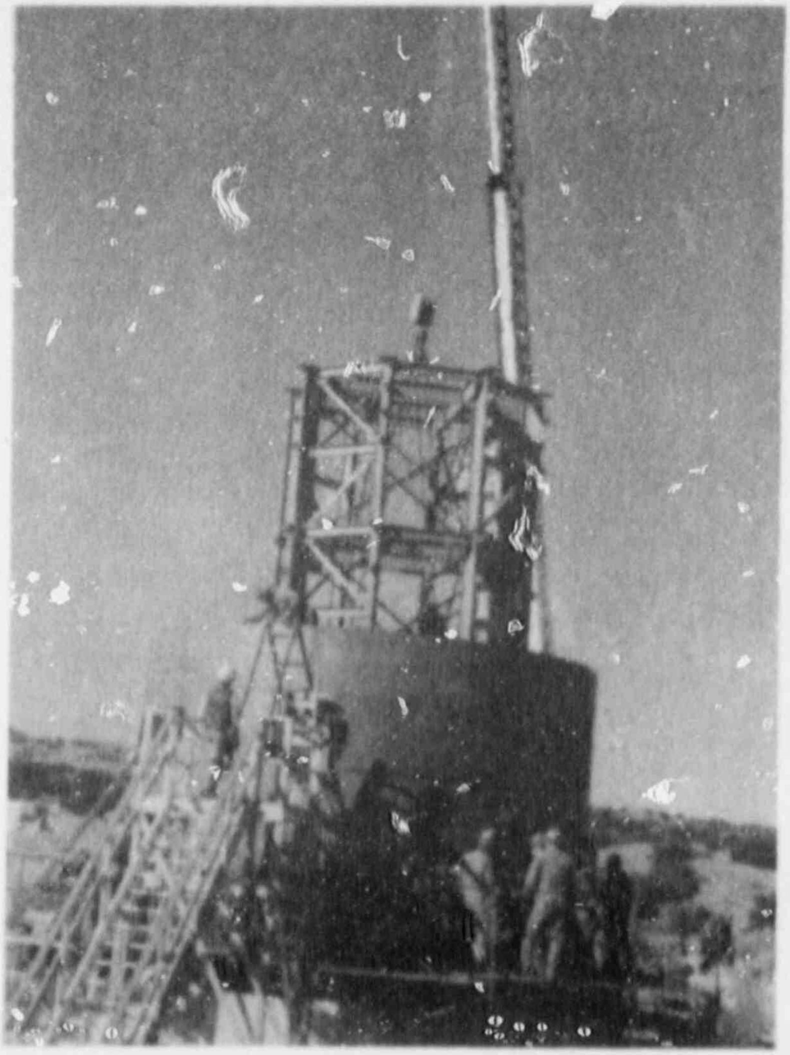


Figure 20. Internal Structure Being Lifted into Place.

The dome sections of the liner were sent to the site in two sections (quarter spheres) and joined together at the site. The entire hemisphere was then picked up and set onto the cylinder liner. The lift of the dome can be seen in Figure 21. Also note the extensive internal support structure that supported the dome during its shipping and construction.

As the liner was being erected, the more complicated reinforcing sections were being fabricated at the site. Templates were built to represent the equipment hatches, the personnel airlocks and the dome. The use of templates not only helped to balance the work load, but also increased the degree of accuracy of these reinforcing sections. The primary reinforcing around the two equipment hatches was the same, as was the primary reinforcing around both the personnel airlocks. This allowed the use of only two templates for the four major penetrations.

Figure 21. Placing the Dome Section of Liner on Cylinder Liner.

The reinforcing in these areas was assembled as a face; that is, the two hoop layers separated by a meridional layer around the penetrations and a single layer of hoop and meridional bars in the dome. These faces were tied together, set off to the side, and instrumented, as reinforcing work for the next face continued. The templates were not used for the seismic (diagonal) layers, which were all assembled on the model. Figure 22 shows a partially complete face of reinforcing for around one of the equipment hatches.

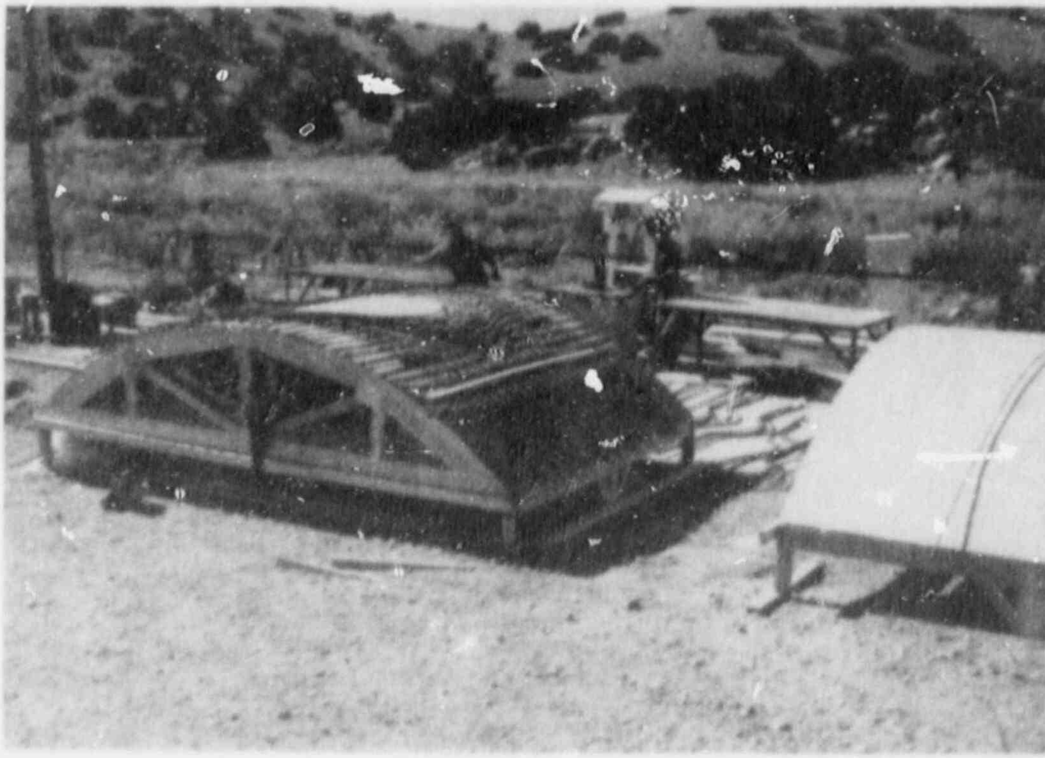


Figure 22. Reinforcing Being Preassembled on a Template.

With the completion of the containment liner, the preassembled sections of reinforcing steel were put in place on the containment model. The inner face of reinforcing was completed first. The face began with the setting of the dome reinforcing steel onto the dome liner (see Figure 23), and was filled in from the dowels projecting from the basemat to the dome.

The outer face of reinforcing and the seismic bars were added as the concrete work progressed. This sequencing of the reinforcing allowed the reinforcing fabrication and the concrete work to continue concurrently, but more importantly it kept the outer face of reinforcing steel low, allowing better access to the concrete during the concrete placing.

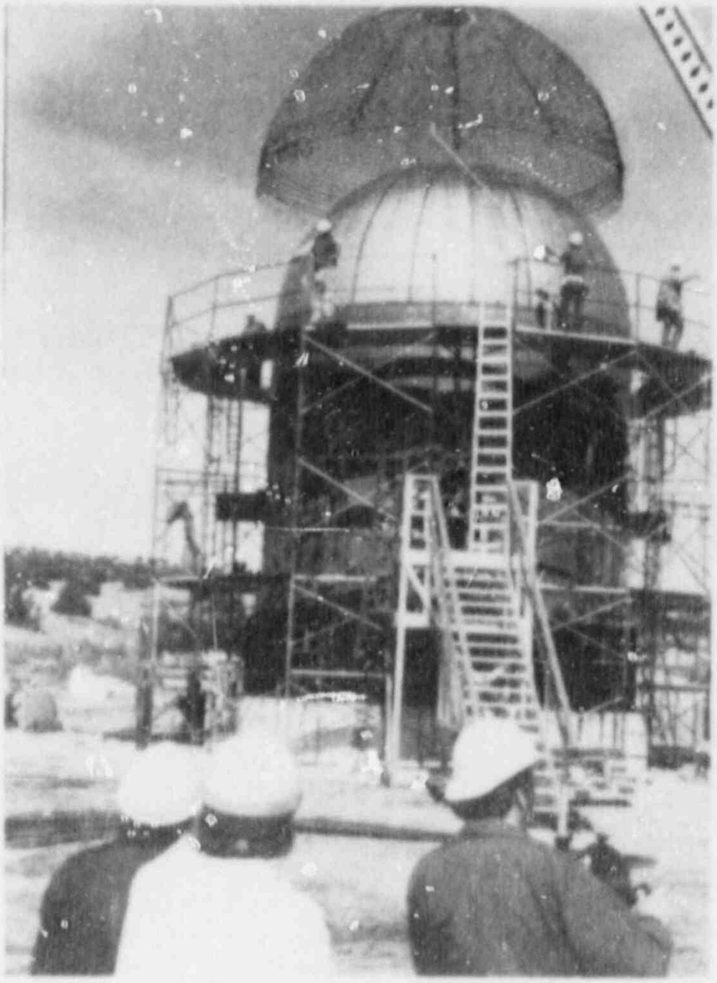


Figure 23. Setting of Inner Layer of Dome Reinforcing Steel.

Access to the fresh concrete around the major penetrations was still a concern, since the penetration sleeve inhibited access to the concrete below it. Access was further complicated by the additional reinforcing required in the boss face. To improve the chance for successful consolidation of the fresh concrete in these areas, several pencil vibrators were strategically placed in the reinforcing lattice before the forms were installed. In Figure 24, four vibrators can be seen in place around boss 'A' before the forms were installed.

Wooden forms were used for the forming of the boss faces of the four major penetrations. Several holes about 3 by 5 in. in size were cut into each of these wooden forms so that the concreting process could be better observed and controlled. The hydrostatic head of the concrete was used to place the concrete underneath the penetration sleeves. Concrete was placed on only one side of the penetration. The concrete was moved around and underneath the penetration sleeve by the use of the pre-placed vibrators and the hydrostatic head that was developed. This process was viewed through the windows in the form to ensure proper consolidation. As the concrete reached the elevation of the window, the window was plugged. Placing of the concrete at boss

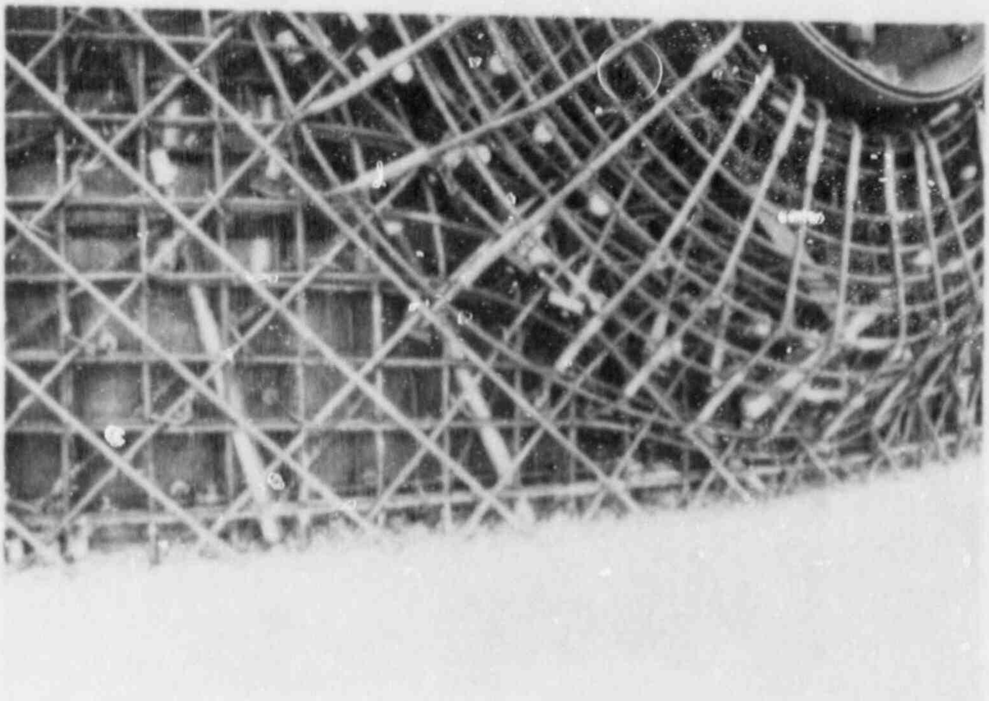


Figure 24. Boss 'A' with Vibrators in Place and Ready for Forms.

'A' and the use of the window can be seen in Figure 25. Also note the hand-held spotlight that aided in the viewing of the concreting process.

As the concreting of the bosses was completed, the pre-placed vibrators were removed. All concrete vibrators were removed without incident.

The concreting continued up the cylinder and into the dome region. Forms were used for all concrete lifts except for the dome apex. At the apex the concrete slump was reduced and the concrete was troweled to its final dimensions. Figure 26 shows a picture of the completed model. Note the forms used for the placing of the dome concrete and the area at the apex that was placed without the use of forms.

With the last placement of concrete, the liner support framing was removed through the equipment hatch penetration, the internal structure was modified to accept the flooring, scaffolds were removed, an overhead structure was erected, and the concrete joints were dressed. All construction activities were completed in June 1986.

With the completion of the containment model construction, instrumenting of it gained full momentum.

Figure 25. Placing of Concrete Around Boss 'A'.

3.2 Concrete

The concrete was centrally batched at Springer Building Materials, a local Albuquerque concrete supplier. The aggregate class was designated as a #7.5-modified, 3/8-in. round. Table 2 lists the size of aggregates and fines for a 627.8-lb sample of the aggregate.

Table 2

Typical Sieve Test of Model Aggregate and Fines

US Sieve Size	Cumulative Weight Retained (lbs.)	Cummulative Percent Retained	Percent Passing
1/2"	0	0	100
3/8"	130.7	20.8	79.2
No. 4	614.3	97.8	2.2
No. 10	624.1	99.4	0.6
No. 40	625.8	99.6	0.4
No. 200	626.5	99.8	0.2

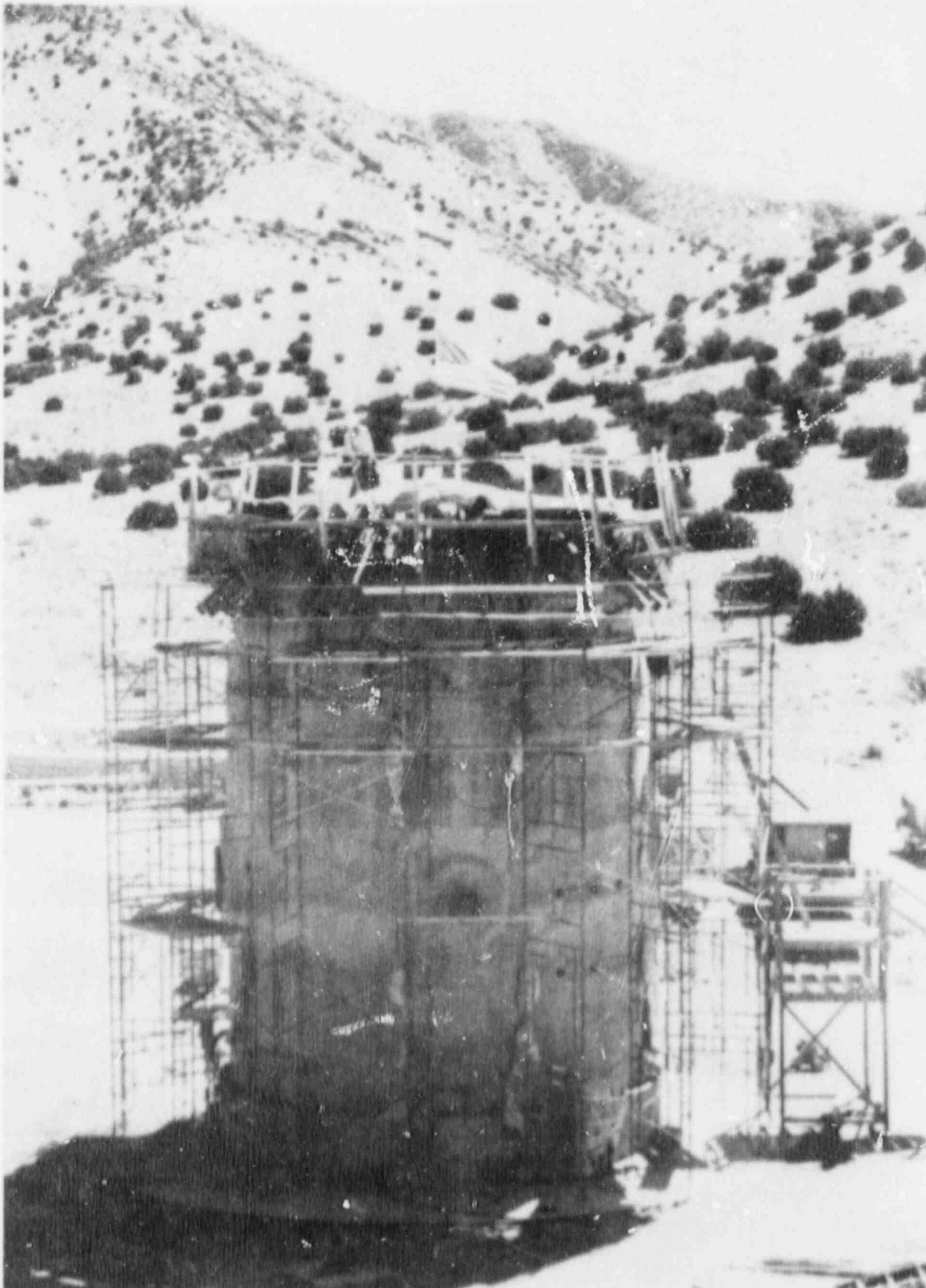


Figure 26. The Completed Concrete Containment.

The cement used in the makeup of the concrete was a Type I-IILA Portland Cement. The chemical composition of a typical batch of cement used in the concrete for the containment model is listed in Table 3.

Table 3

Typical Chemical Composition of the Cement

Oxides	Weight %
Silicone Dioxide	21.9
Aluminum Oxide	4.4
Ferric Oxide	3.4
Calcium Oxide	64.5
Magnesium Oxide	1.7
Sulfur Trioxide	2.6
Loss on Ignition	1.3
Insoluble Residue	0.2
Major Compounds	**Weight %**
Tricalcium Silicate	55.0
Dicalcium Silicate	22.0
Tricalcium Aluminate	5.9
Tetracalcium Aluminoferrite	10.0
Alkalies (Na_2O Equivalent)	0.60

The specific surface of the cement using the Blaine test is 369 m^2/kg. The soundness of the cement was determined by autoclave expansion and yielded an expansion of 0.01. The set of the cement was determined by the Vicat method with the initial set achieved in 95 min and the final set reached in 265 min. There was also about 8.5% air entrainment by volume. The specification for Portland cements may be found in Reference 26.

To stay within the code limits of the water-to-cement ratio and have the slump in the 8- to 9-in. range, both a water reducer and a superplasticizer were needed. The superplasticizers selected also increased the workable life of the concrete to about 3 h. All admixtures were made by Masters Builders--the water reducer was Pozzolith 300N and the two superplasticizers used were Pozzolith 400N and Pozzolith 440N. (The 400N was used exclusively in the basemat and the 440N was used for all other concrete lifts.)

The basic constituents of the concrete mix are listed in Table 4.

The cement trucks were loaded with batchs of concrete that were typically 4 to 5 yd^3. Once the trucks were batched, travel time to the construction site was about 45 min. The concrete was tested for slump and if necessary, adjusted by adding more superplasticizer to the truck as required. The concrete slump was then tested again. This process was repeated until the proper slump was achieved. Only one load of concrete was rejected because the proper slump could not be obtained.

Table 4

Extended Life Concrete Design Mix

Cement	540 lbs
Water	282 lbs
Fine Aggregate	1317 lbs
Coarse Aggregate	1890 lbs
Water Reducer (300N)	27 oz
Superplasticizer (400N or 440N)	108 oz
Water/Cement ratio	.53
Volume	27 ft^3

The concrete was unloaded into the hopper of a concrete pumping truck, which pumped the concrete through about 100 ft of line. Due to the rebar spacing in most areas the pumping process was quite slow in order that proper consolidation could be achieved as the concrete was placed. Figure 27 shows organization of the trucks and personnel for one of the dome lifts.

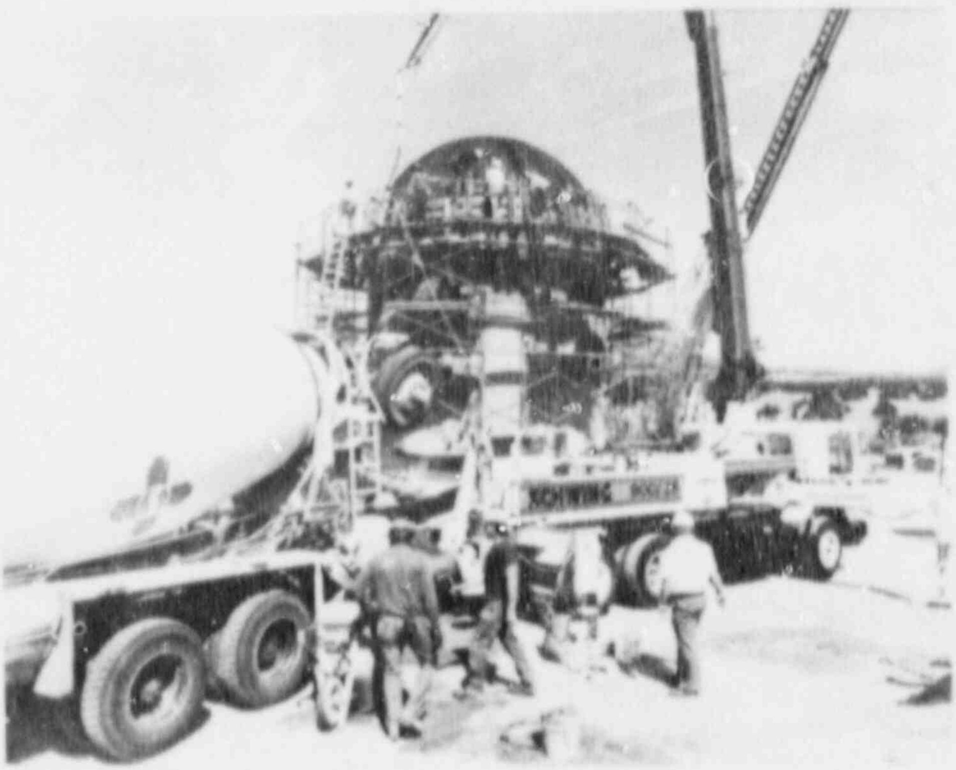


Figure 27. Typical Concreting Setup of Machinery and Personnel.

The tests on the fresh concrete, such as slump, air entrainment, and temperature, were conducted at the truck. All concrete used for the casting of the specimens was taken from the hose of the concrete pump to include any effects of pumping (such as drying of the mix). To minimize the drying of concrete due to pumping, grout was always circulated through the pump and then purged before any concrete placement began for the day.

Vibration of the concrete mix was done with pencil vibrators. Form vibrators were allowed in the specifications for the construction of the containment, but were never used.

All cold joints were treated with a retardant before the concrete set. After the concrete had gained a sufficient set, the cold joint was washed with a high-pressure washer. The high-pressure water adequately removed the surface latency and exposed the aggregate at the joint.

There were 11 lifts used for the construction of the containment shell and three additional lifts on top of the basemat. There was a cold joint between the basemat and each of the six cylinder wall placements and a cold joint between the top of the cylinder and each of the successive dome placements except for the fourth and fifth dome lift. (No forms were used for the dome apex concrete so no cold joint existed between the fourth and fifth dome lift.) On top of the basemat there was a cold joint for the 3-in.-thick leveling course, which was separated from the next 3-in.-thick course by the liner. Over the latter 3-in.-thick course was the 12-in.-thick fill mat that supported the internal structures.

Typically, seven cylinders were taken from each truck for construction tests of the concrete. Three cylinders were compression tested at seven days, three were tested at 28 days, and one was tested at 90 days from its cast date. In addition to these specimens some more samples were taken, as needed. These samples were for

- Conducting direct tension tests (see Section 5.2.2)
- Assessing the effects of field curing
- Obtaining additional information on time-related strength gains (3, 4, 5 and 6 days of age)
- Conducting shrinkage tests
- British cubes (so that concrete strength could be correlated with British Standards)
- Sandia's concrete testing (see Section 5.2.)

The properties for the concrete are reported in Section 5.2 as ascertained by testing performed at Sandia.

Steel forms were used for the majority of the forming of the containment model. Around the four major penetrations--the two equipment hatches and the two personnel airlocks--wood forms were used. Plaster was used for the transition from the cylinder wall to the boss face in the wooden forms, as can be seen in Figure 28.

Figure 28. Fabrication of Wooden Form for the Equipment Hatch Boss.

The wooden forms were painted with a latex paint, which acted as the form release agent. Each one of the forms for the bosses was a two-piece form--one half for the lower section of the boss and the other half for the top section. The form shown in Figure 28 was eventually cut into two sections before use.

3.3 Reinforcing Steel and Splices

All reinforcing steel was cold-worked using an electric-powered production bender. Some final adjustments to the reinforcing steel were done with a lever-type conduit bender. The reinforcing was cut with a rebar shear; a bench-mounted unit was used at the fabrication area or a pneumatically assisted hand-held shear was used at the containment model. No flame cutting of the rebar was conducted.

Although each size of reinforcing was rolled from the same heat of steel there were differences between the deformations on the #4 reinforcing steel. The deformations of the #4 reinforcing steel seemed to be of two different heights. About half of the bars had deformation heights of 0.030 in. while the other half were approximately 0.020 in.

in height, although both meet the ASTM A615 standard (0.020 in. average minimum).

As mentioned in Section 2.6, the cold-swaged splices used on the reinforcing steel could be installed with either a hand-held hydraulic powered press or with a bench-mounted hydraulic press. As prescribed by the ASME code, the minimum strength of the splices should not fall below 1.25 times the minimum specified yield (1.25 x 60,000 psi = 75,000 psi) and the running average of 15 consecutive splice strengths should not fall below the minimum specified ultimate strength of 90,000 psi.

To ensure these ASME code requirements were met, a systematic testing program was developed for this project. In addition to qualification and special test series, about 340 splices for the #4 reinforcing steel were tested. Table 5 lists the ultimate strengths of the reinforcing bar, both swaged and unswaged, and the ultimate strength of the swages.

Table 5

Ultimate Strength of Reinforcing Steel and Splices (psi)

Number of Specimens	Average Strength	Standard Deviation	Splices Y/N	Failure
31*	106,000	1200	No	Bar
60**	104,600	2800	Yes	Bar
122	99,100	6640	Yes	Splice

All test results presented in this table are for #4 reinforcing steel

*Used as a control--no splices were in the specimens

**The 60 were randomly selected from the 218 spliced specimens that failed in the rebar.

The 340 tests on these splices represent about 9% of the total #4 splices used in the construction of the containment model.

3.4 Liner

The liner was built in sections of 180° and attached to a stiff frame. The frame supported the liner during transportation, liner erection, and concrete placement. For the cylindrical sections, the frame was made of steel stringers and webs, to which plywood was attached. The liner was held to the plywood by many threaded studs that were welded to the liner and passed through and bolted to the plywood. The structure of the support frame can be seen in Figure 29.

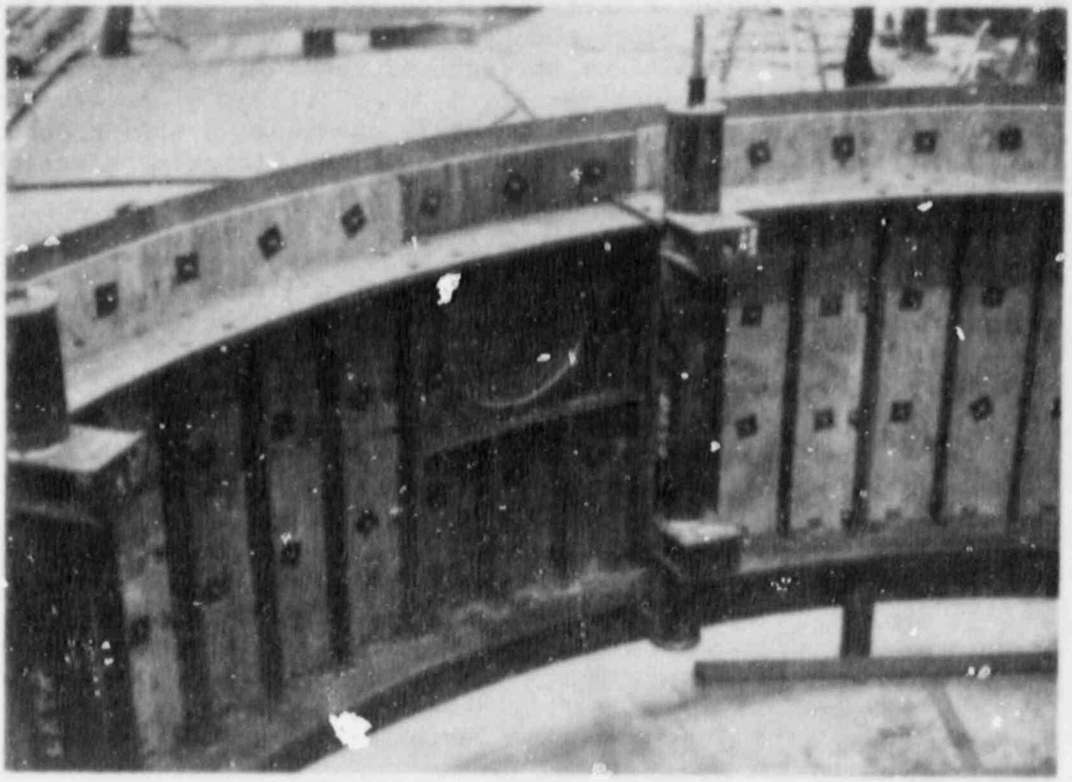


Figure 29. Support Frame for the Liner Cylinder.

The dome was not supported in the same way, since it was difficult to roll the plywood in two planes. For this reason the plywood was omitted and the steel stringers and webs were more closely spaced. This arrangement can be seen in Figure 30.

Again, the dome liner was attached to the frame by the use of threaded studs.

Four weld processes were used for the fabrication of the liner: shielded metal arc, gas metal arc, gas tungsten arc, and capacitor discharge stud welding.

Inspection of the welds was done by several methods in accordance with the ASME Boiler and Pressure Vessel Code, Section V, which includes

- Magnetic particle examination
- Liquid penetrant examination
- Radiographic examination

Figure 30. A Section of the Dome and its Support Frame.

- Vacuum box
- Visual examination.

Most of the liner welds were inspected using the vacuum box technique and a spot radiographic inspection. The areas of inspection as well as the technique used can be ascertained from the liner construction drawings in Appendix B.

3.5 QA/QC

A Sandia QA coordinator was assigned to oversee the construction of the containment model and to ensure that the plans and procedures produced by United Engineers and Constructors (United) were followed, including the proper documentation of the construction activities.

To ensure that the intent of United's Quality Assurance Program was followed, United developed 11 specifications for the construction of the containment model as well as field structural procedures, which included the controls and forms necessary to document the progress of the construction activities and inspection results. This, when taken with the design basis criteria, the construction drawings, and other referenced documents (such as the ASME Code) provided a rigorous quality assurance program.

All subcontractors were required to have a quality assurance program. Subcontractors who did not have an adequate QA program were required to develop and implement their own procedures and documentation. The subcontractor's quality assurance programs were subject to Sandia's and United's review.

United assigned a full-time, on-site QA supervisor to conduct daily and task-specific surveillances of all construction activities.

It was also in the scope of United's quality assurance plans to ensure that all items received at the site from vendors, manufacturers, and fabricators conform to contract requirements prior to fabrication, installation, and erection.

All records were controlled by the respective United or subcontractor personnel and were stored at the site in a fire-proof file. Sandia's QA coordinator made periodic inspections of the files to ensure acceptable identification and retrievability of information.

3.6 Repairs

Several small flaws were detected on the steel liner before it was erected. The liner arrived at the site with a few of the anchorage studs broken off, thereby removing a small "divot" of the liner material. There were also some fairly deep scratches on the liner. Both of these types of flaws were repaired in the same manner; weld material was added to the defect. A scratch in the liner that was repaired can be seen in Figure 31.

This repair was done at azimuth 225 and at an elevation of 5 ft 10 in. on the containment model. About six similar repairs were made at other locations on the liner. In the case of the broken studs, a new stud was installed adjacent to the repair.

After the removal of the internal support framing, three holes were found in the liner. Two of the holes were caused when the support frame was removed. When two of the threaded studs that held the liner to the frame were broken off, the liner material was torn. The cause for the third hole appeared to be from a stray weld arc, and was about the same size as holes caused by the threaded studs: 3/16-in. in diameter. This latter hole is shown in Figure 32.

To repair these areas, a small slot was ground through the defect and a small piece of steel was inserted between the liner and the concrete to serve as a backup bar. The slot was then plug-welded as can be seen in Figure 33.

There were also repairs made to the concrete shell of the containment model. Three voids were found between the cylinder wall and the first wall lift. A fourth area was damaged during construction. The location and size of these areas are shown in Drawing 7847-F-1280AB in Appendix B on page B-43. A picture of one of the voids is shown in Figure 34.

All of the unsound concrete was chipped away to reveal sound concrete. The remaining hole was then shaped (by removing sound concrete, if necessary) to ease the placing of the repair concrete. The exposed concrete surfaces were covered with an epoxy-bonding compound before the repair concrete was placed. To form the area, a small wooden box was made. The top of the box extended above the repair, which allowed the hydrostatic weight of the concrete to aid in the consolidation of the repair concrete. Figure 35 shows the wooden box filled with the repair concrete.

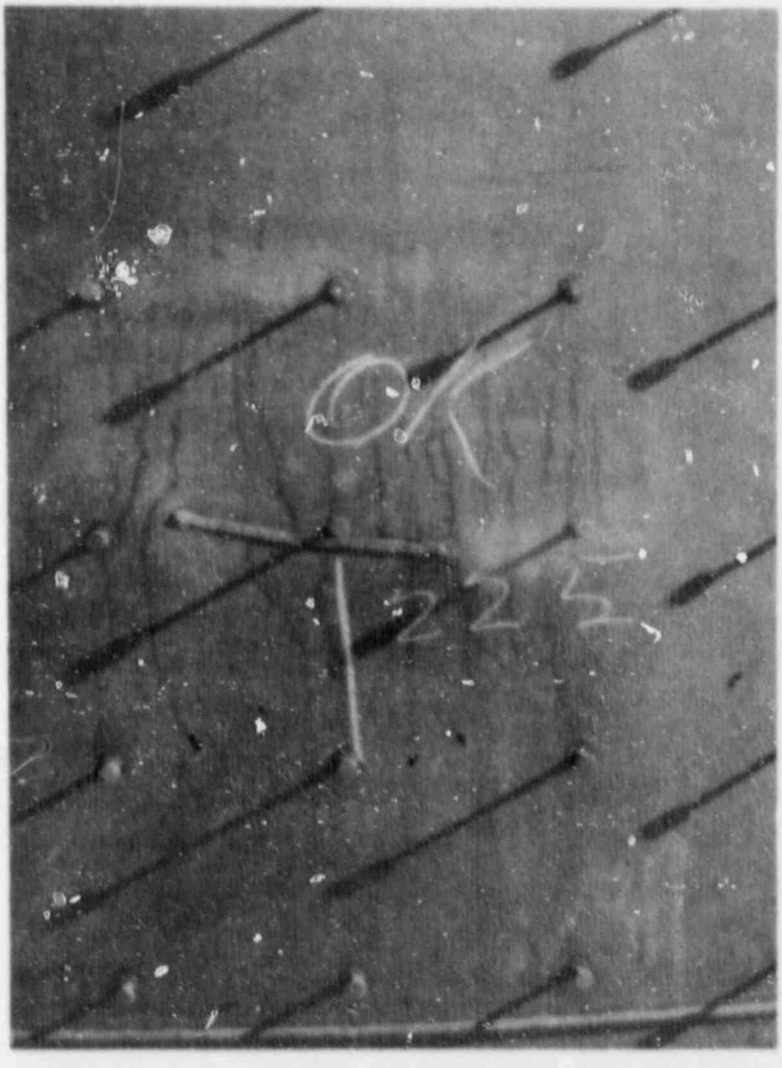


Figure 31. Repaired Scratch in the Liner.

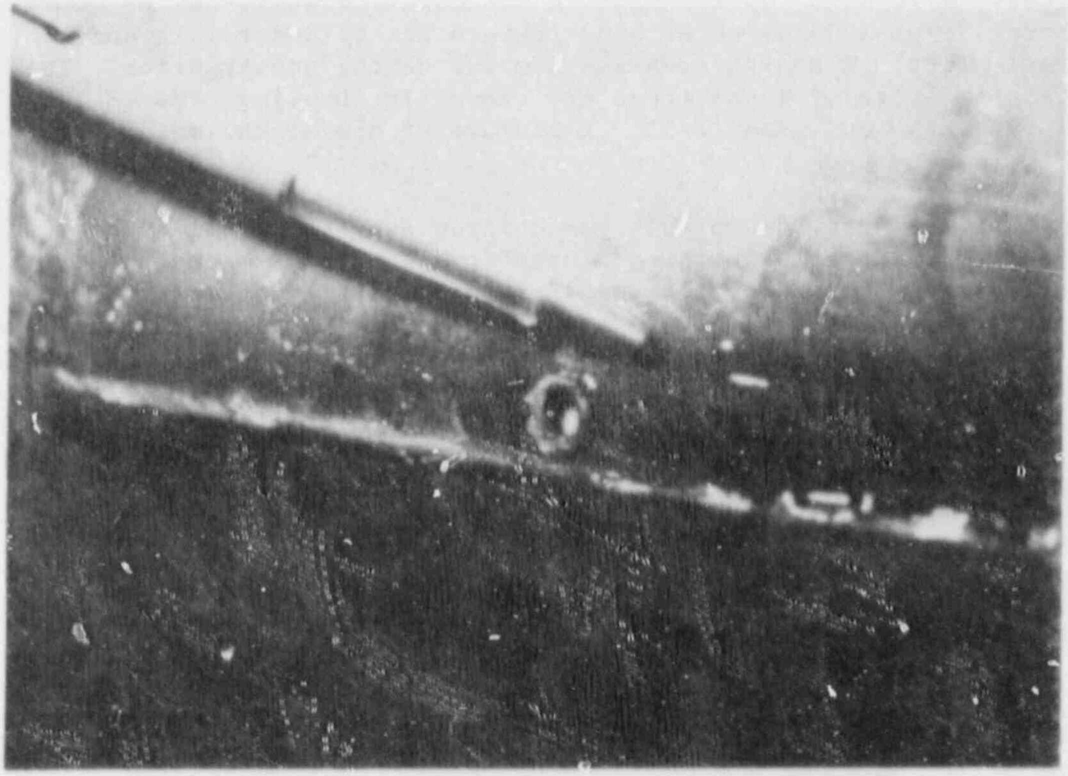


Figure 32. Hole in Liner.

Figure 33. Repaired Liner Flaw.

Figure 34. Concrete Void in First Cylinder Wall Lift.

Figure 35. Repair Process of the Concrete Void in the First Cylinder Lift.

It should be noted that the repair concrete was the same as the rest of the concrete used in the construction of the containment model. After the concrete attained some strength, the wooden forms were removed and the excess repair concrete was chipped away. All three areas in the first cylinder-wall lift were repaired in the same manner.

The fourth concrete flaw was caused by a pulled form anchor. This flaw can be seen in Figure 36. The concrete was chipped back so that the minimum depth of repair was 1 in. This allowed the containment concrete to be used in the repair. The original steel forms were used to form the repair area.

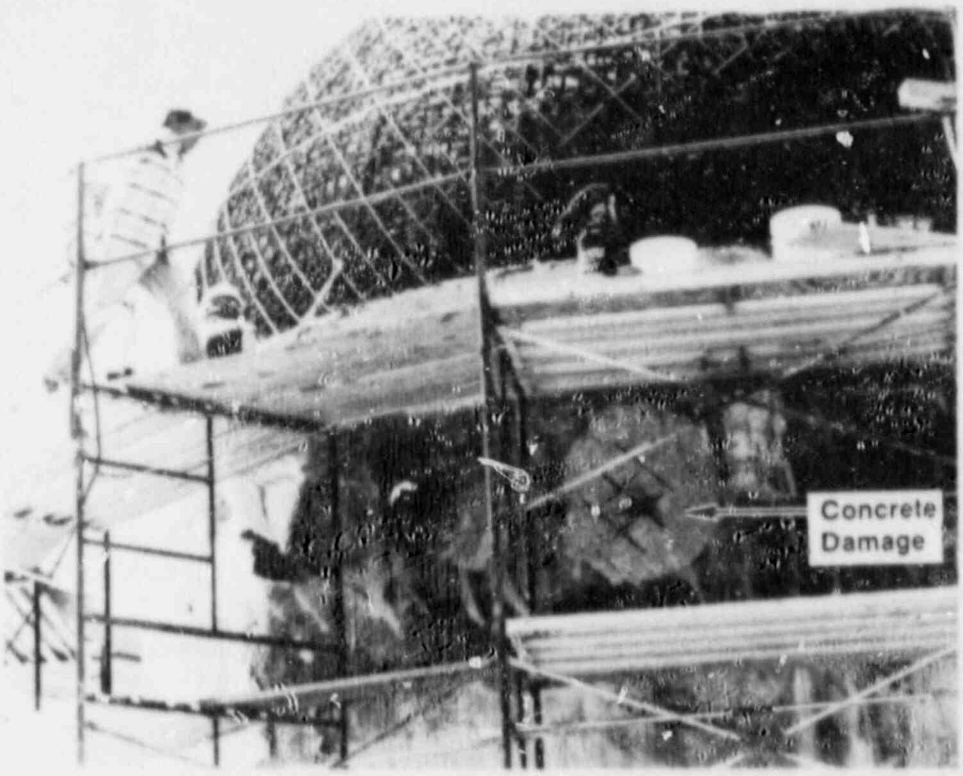


Figure 36. Concrete Damage Caused by a Pulled Form Anchor.

As with the other repaired concrete areas, the surfaces were coated with an epoxy bonding compound and the form was placed so that the hydrostatic head aided in consolidating the fresh concrete.

One other notable incident occurred during the construction of the containment model: a concrete vibrator became stuck in the first dome lift. Although workers tried to remove the vibrator, they were unable to free it. The end of the vibrator that was embedded in the concrete was cut off and the shaft housing was sealed with epoxy.

3.7 Facility Work

The containment model was constructed at a remote site in the same location as the previous containment model tested by Sandia: the 1:8-scale steel containment. To prepare for the construction of the reinforced-concrete containment, work pads for the previous test had to be removed, and areas graded for the several work areas needed for the concrete containment.

A roof was also placed over the containment model. This afforded some weather protection during the instrumenting of the containment model and was also used to attach some of the still and video cameras used during testing of the containment model.

4. INSTRUMENTATION

The containment model was instrumented to assess its structural behavior, which includes large strains and displacements, as well as its leakage characteristics during testing. The transducers used to accomplish this goal are connected to a group of clustered data acquisition and control units located in the signal conditioning bunker, adjacent to the containment model. Data scans are transmitted to the data acquisition computer, located in the command bunker about 1500 ft away from the containment model. The site layout is shown in Figure 37.

The majority of transducers on the containment are strain gages and displacement transducers. Over 300 strain gages were attached to the reinforcing steel during construction and over 160 strain rosettes, (480 gages) 160 single and strip gages, and over 30 thermocouples were applied to the steel liner. Also embedded in the concrete wall are about 40 thermocouples and 20 embedment gages. There are over 130 displacement gages located about the containment model. Including other groups of instrumentation, this brings the total number of transducers to over 1200. A list of the transducers that will be used for the containment test can be found in Table 6. In addition to these discrete transducers, several video and still cameras will be used during testing to provide both qualitative and quantitative data.

Table 6

Transducers Planned for Containment Tasting

295	Weldable Strain Gages on Rebar
29	Bondable Gages on Rebar
161	Rosettes on the Liner (483 gages)
101	Strip Gages
59	Single Gages
137	Displacement Transducers
73	Thermocouples
17	Embedment Gages
5	Precsure Gages
13	RTDs
8	Inclinometers
3	Weather Channels
1	Load Link
1224	Total Transducers

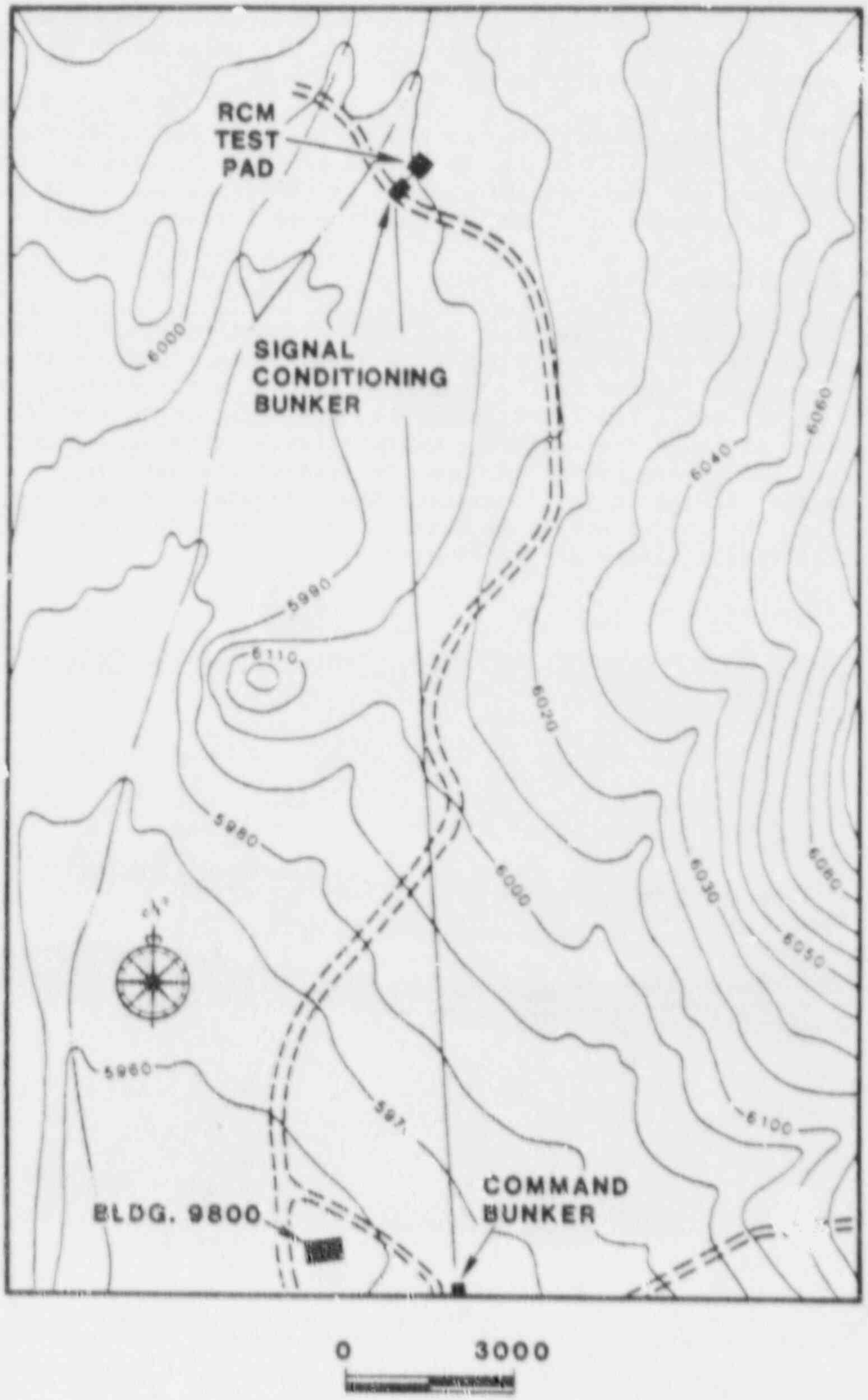


Figure 37. Layout of the Containment Test Site.

All transducers that require calibration were calibrated at Sandia using standards that are traceable to the National Bureau of Standards. Manufacturer's calibrations were not used, which ensured that the calibration did not change or that the transducers were not in some way damaged during shipping.

All of the instrumentation on the containment model is graphically presented in Figures 42 to 61, which are grouped together at the end of this chapter. Further information on the instrumentation may also be found in Appendix A: Type and Location of Instrumentation.

4.1 Strain Gages

Encapsulated, weldable gages of a single-element NiChrome design were predominantly used on the reinforcing steel. Their small size allowed them to be spot-welded to the reinforcing steel with minimal disturbance to the bar. Figure 38 shows the gage attached to a #4 reinforcing bar. Although the gages are quite durable, they were coated with silicone rubber and potted in epoxy to protect the gage during installation and placing of the concrete. The weldable gages are capable of measuring 6 to 7% strain as determined by tests conducted at Sandia (manufacturer's claims are to 2% strain).

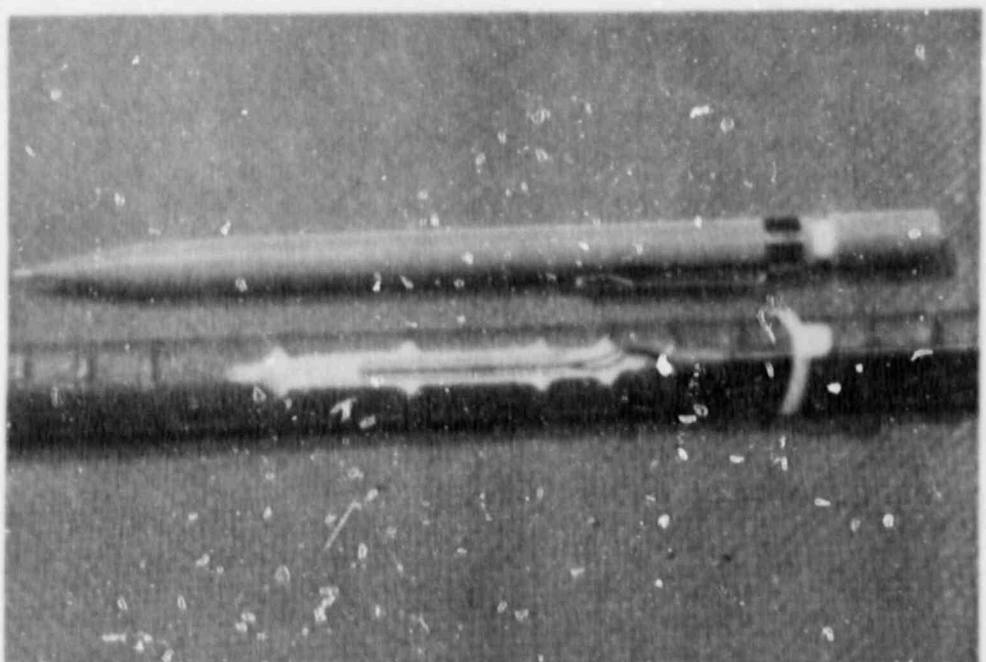


Figure 38. Weldable Strain Gage Attached to a Piece of Reinforcing Steel.

Special attention was also given to the strain relief loop on each weldable strain gage. The strain relief loop is placed between the gage and the leadwires. This loop must be allowed to straighten as the reinforcing steel lengthens under load. To ensure that the loop could move freely, a dab of silicone grease was placed under the loop before it was sealed with silicone rubber and potted in epoxy. A cross section of the potted gage is shown in Figure 39.

Figures 49 to 57 show the location of the strain gages that were attached to the reinforcing steel and/or embedded in the containment wall.

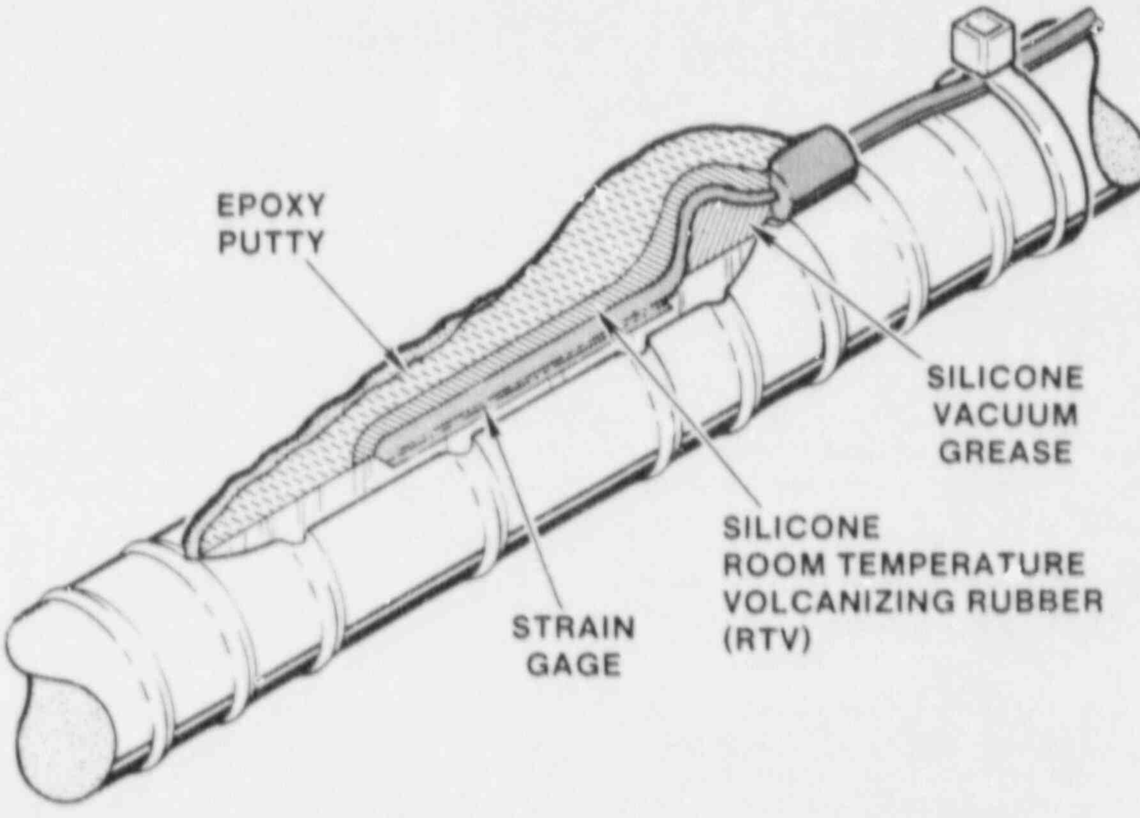


Figure 39. Cross Section of a Strain Gage on a Reinforcing Bar.

The majority of the gages on the liner are three-arm 45° rosettes, which are made of Annealed Constantan and have a polyimide backing. Although the liner must be carefully prepared and the Armstrong A12 epoxy must be heat-cured for several hours, the rosettes are capable of measuring strains to 20% [27]. Single gages and strip gages with the same properties as the rosettes are also used at various places on the containment liner. The strip gages are made of 10 single gages attached to a common backing and are used to measure strain gradients.

Two styles of strip gages are used: one has an overall length of .795 in., each gage being 0.062 in. in length; the second style has an overall length of 1.59 in., each gage being 0.125 in. in length.

Figures 43 to 47 and 59 to 61 show the gages that are attached to the liner.

4.2 Displacement Transducers

Nearly 140 displacement transducers are used on the containment model. Linear potentiometers and Linear Variable Differential Transformers (LVDT) are used to measure displacements of 4 in. or less. They are predominantly used to measure local deformations of the penetrations and to monitor crack widths during testing.

Cable potentiometers, with maximum ranges of 5 to 300 in., are used to measure the displacement of the model. Several displacement transducers are attached at discrete locations to measure global deformations of the containment, and to augment them, 9-track transducers were designed and built, which are discussed later.

Most of the global displacements will be measured from the internal column located in the center of the containment. The column is treated as the reference system upon which all other internal global measurements will be based. Some measurements will also be taken from the internal platform in the containment model. To correct for relative movement between the column and platform, measurements will be taken between the two. Figure 58, detail 11, shows the locations of the displacement transducers used to measure the relative motion between the platform and the reference column.

Figure 48 shows the location of the displacement transducers on the containment model that are used to measure global response. Figures 59 to 61 show the instrumentation located around the major penetrations.

The track transducers are, as their name implies, mounted on tracks and powered by a gear motor as shown in Figure 40. The motor pulls the transducer along a track, while an arm follows the contour of the containment. Each track system has two transducers mounted on them: one will measure the location along the track, while the other will measure the movement of the track-arm perpendicular to the track.

Nine track systems will be used during testing. One track is located in a horizontal position and will measure the "dishing" of the basemat. The remaining eight systems will measure displacement of the cylinder wall. Four track systems are located below the two equipment hatches: two inside and two outside the containment. The remaining four track systems are located next to the two personnel airlocks and travel the length of the cylinder, about 20 ft. Two of the tracks are inside and two are outside the containment.

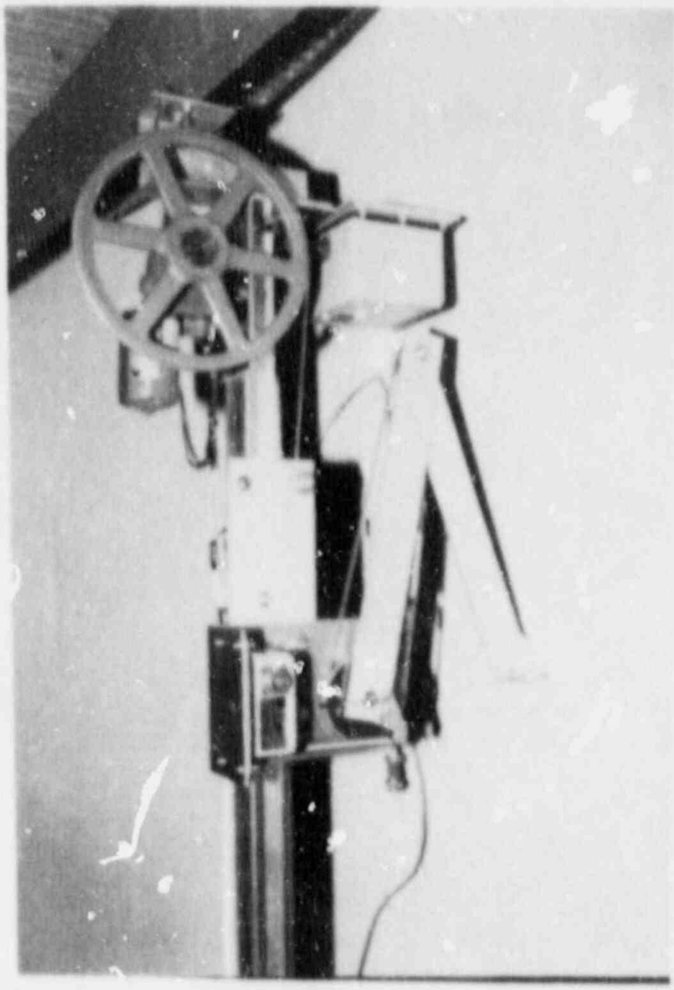


Figure 40. A Track Transducer System for Measuring Displacements of the Containment Model.

4.3 Other Transducers

There are over 40 thermocouples embedded in the containment wall and several more on the inside of the containment liner. The thermal data will be used in the correction of the apparent strain read by the strain gages. Also located in the containment wall are embedment gages. Although they are similar to a strain gage and measure strain, they are not attached to the reinforcing steel, but placed directly in the concrete. A photograph of an embedment gage is shown in Figure 41. The length between the ends of the gage (gage length) can be 2, 4 or 6 in. All three gage lengths were used in instrumenting the containment model.

Other instrumentation used for the containment testing will include eight inclinometers, three weather channels, three pressure channels, and 12 resistance temperature detectors, and a load link.

The inclinometers will be used to measure tilt of the internal column, and the tilt of the two longer outside track systems. In addition,

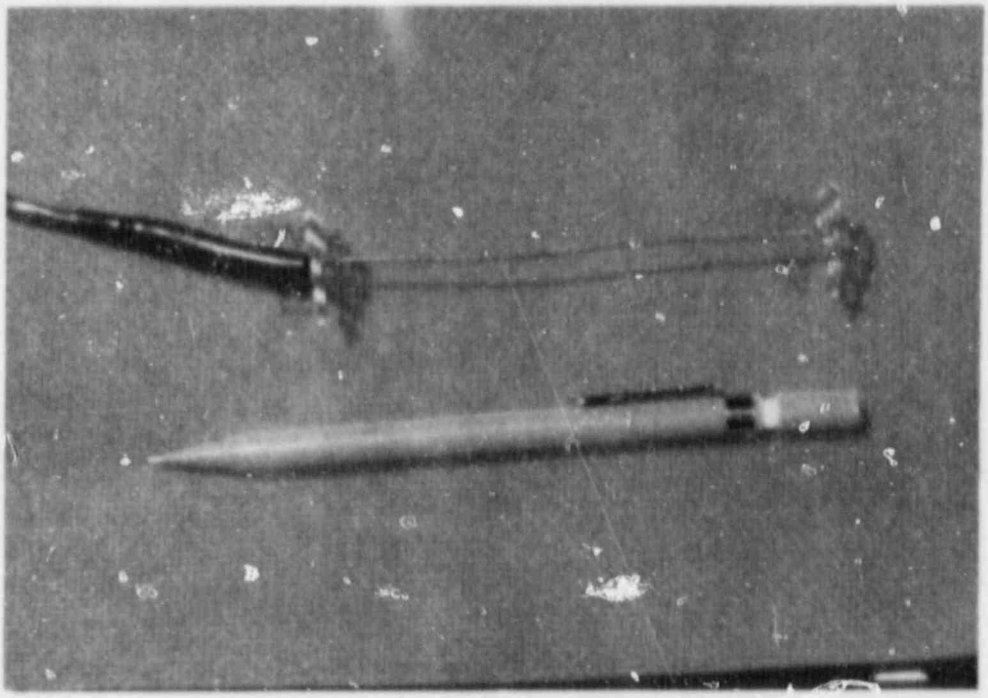


Figure 41. A Typical Embedment Gage.

three sensors will be used to measure the uplift of the basemat by attaching them to a beam that rests on the edge of the basemat while the other end of the beam is supported and allowed to pivot about a column that is located radially about 10 ft from the basemat edge. See Figure 58. By knowing the length of the beam, the tilt measured can be converted to a measurement of the basemat uplift.

The three weather channels will measure wind speed and direction, and barometric pressure. Ambient temperature will be measured by using thermocouples.

Pressure will be measured by five pressure transducers. Two are quartz manometer type transducers that measure absolute pressure. The three remaining pressure transducers measure gage pressure.

Thirteen resistance temperature detectors will be used in the containment model to measure the gas temperature during leak-rate measurements.

A single load link will be used to measure the force in the reinforcing bar that connects the two constrained penetrations. See Section 2.9.3.

4.4 Optical Coverage

Although subject to change, 18 still camera stations will be located about the containment at the time of the high-pressure test. Twelve of the stations will be adjacent to the model and focused on particular areas of interest; the remaining six stations will be located at a distance and photograph an overview of the containment during testing. Twelve video cameras (including monitors and recorders) are also planned for use during high-pressure testing; one of these will be inside the containment model. The feedback from the cameras will be used extensively during high-pressure testing to aid in selecting pressure step size, determining the length of hold periods, and possibly for selecting specific transducers to monitor in areas exhibiting interesting or unusual behavior.

4.5 Acoustic Coverage

The monitoring of acoustic emissions in a complex reinforced-concrete structure is not a well-defined technology. Few previous experiments on acoustic monitoring of reinforced concrete have been conducted, let alone reinforced concrete stressed in biaxial tension. The primary purpose of the acoustic system is to determine if a leak is present in the containment model and to give a vicinity of where it is leaking, but not a specific location. The placement of eight, low-frequency acoustic sensors in the containment model will be based on areas where leakage is most likely to occur. For this experiment the acoustic sensors will be placed near the major penetrations and near the basemat-cylinder wall junction.

The acoustic system is based on an extensively modified Acoustic Emission Technology (AET) Model 4900 [28]. The system was also modified for use with a MicroVax II computer. The sensors chosen are manufactured by Physical Acoustic Corporation and have a maximum response between 30 kHz and 100 kHz. The sensors have an internal amplifier that boosts the signal by 40 dB, which is again amplified another 40 dB at the AET 4900.

The data from the sensors will be processed for both burst noise and steady-state noise. Although it is not possible to totally separate the two types of noise with any system, it is estimated that more than 90% separation can be achieved in the containment experiment.

As leaks are detected with the acoustic system, test personnel can determine the leak rate by conducting mass measurements of the gas in the containment over a period of time if leakage is small or by the use of flow meters if the leakage is larger.

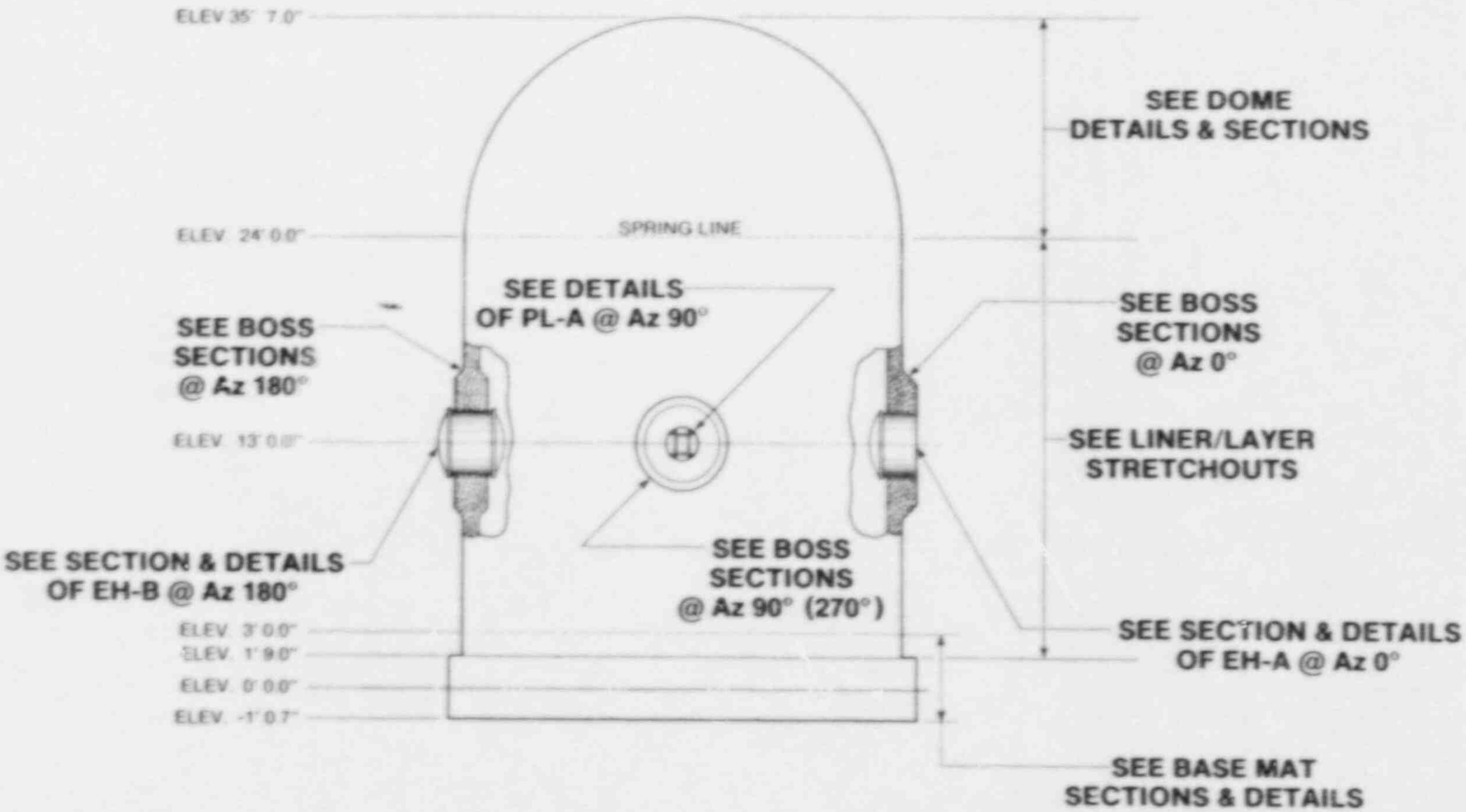


Figure 42. Index to Instrumentation Drawings.

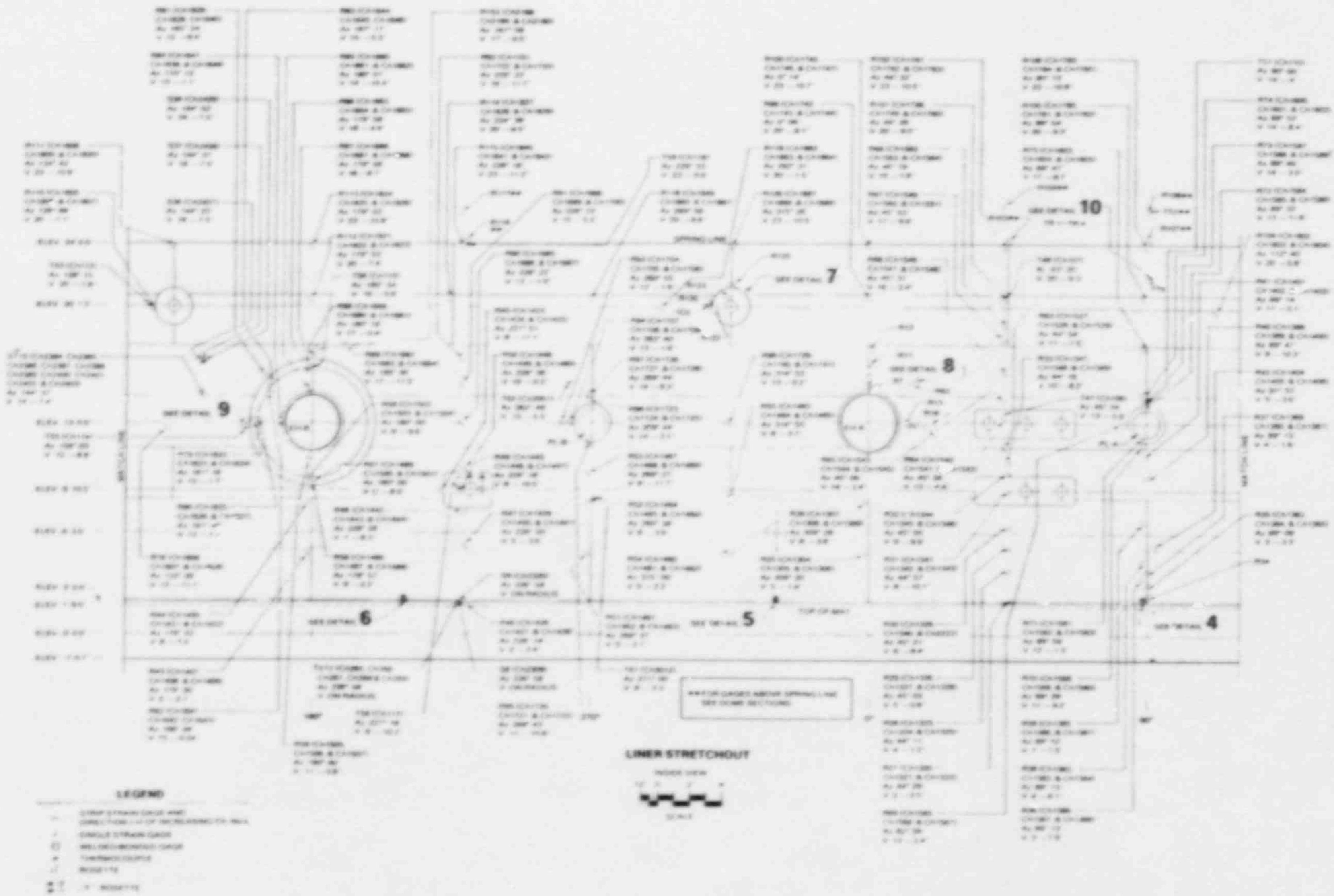


Figure 43. Liner Strain Gages and Thermocouples.

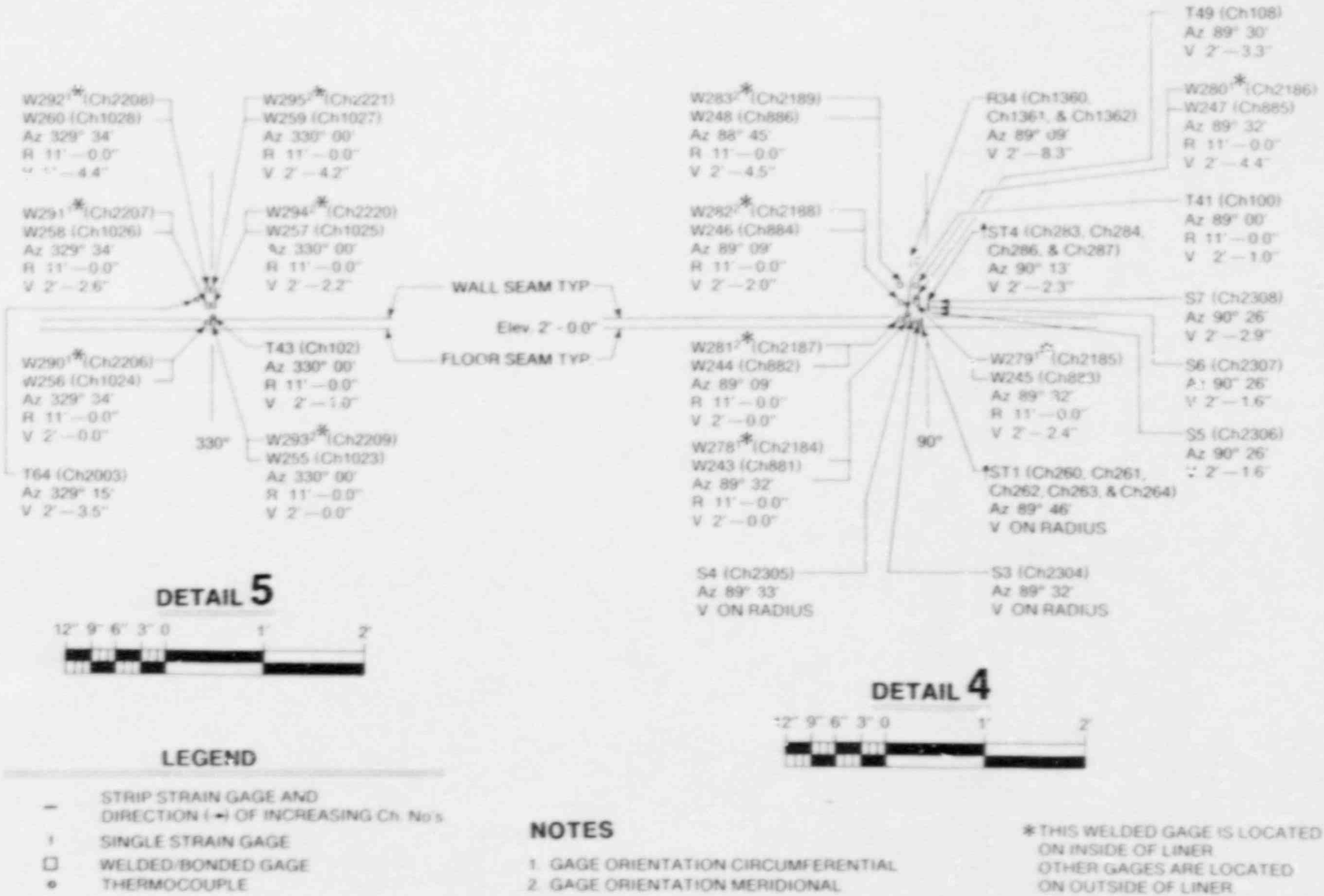


Figure 44. Details of Instrumentation on the Liner Knuckle.

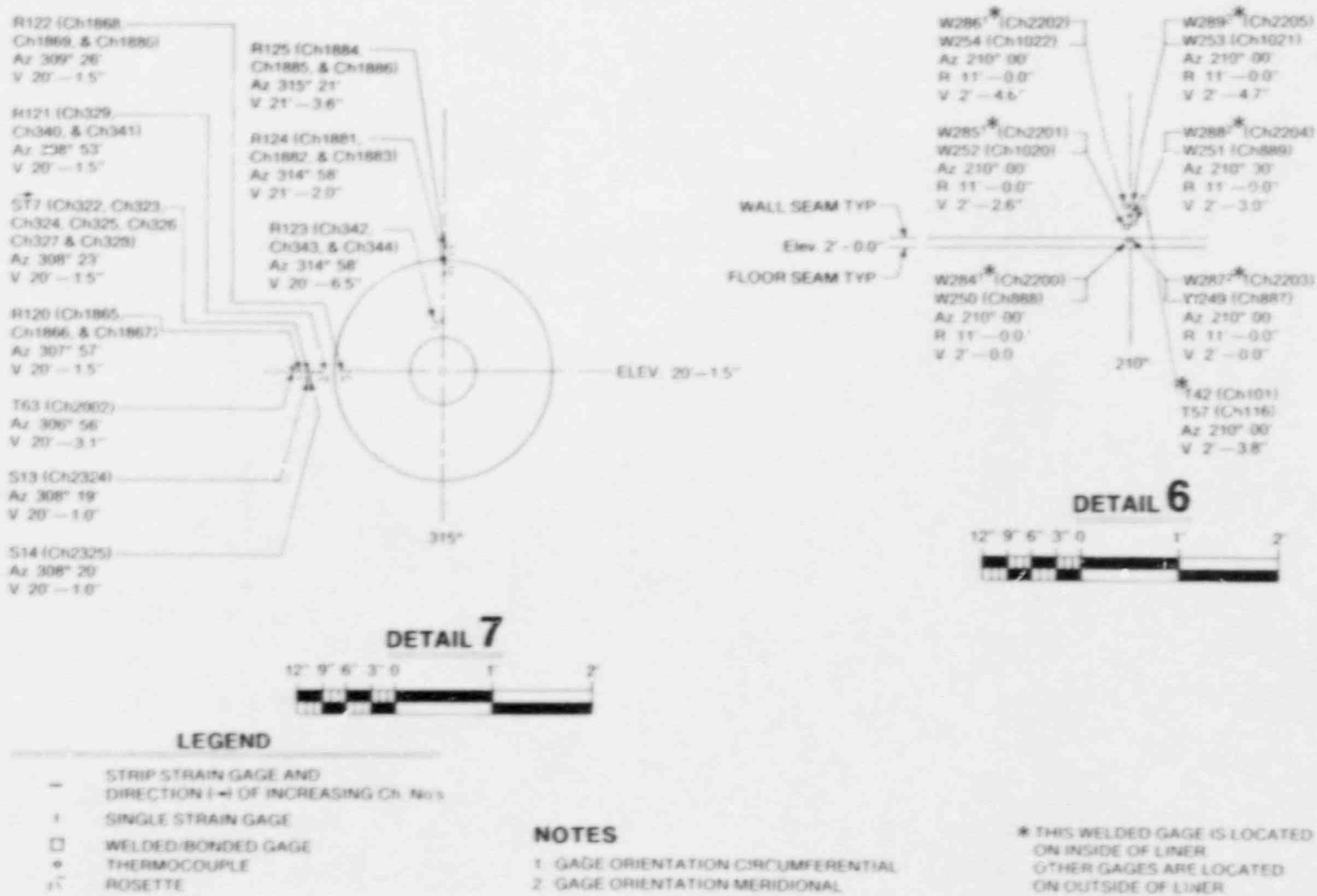


Figure 45. Details of Gages on the Liner Knuckle and the Constrained Penetration.

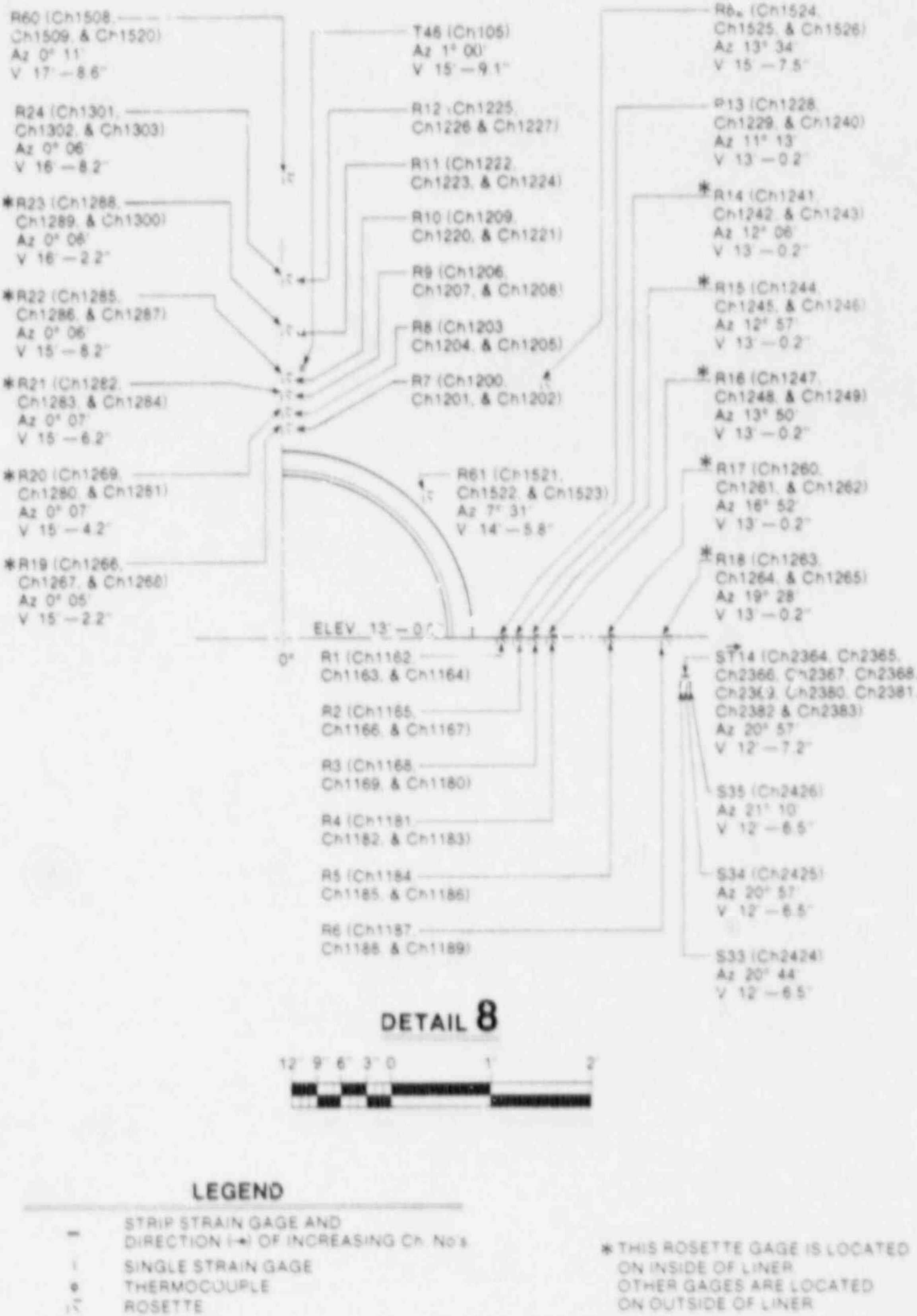


Figure 46. Detail of Liner Gages Around Equipment Hatch 'A'.

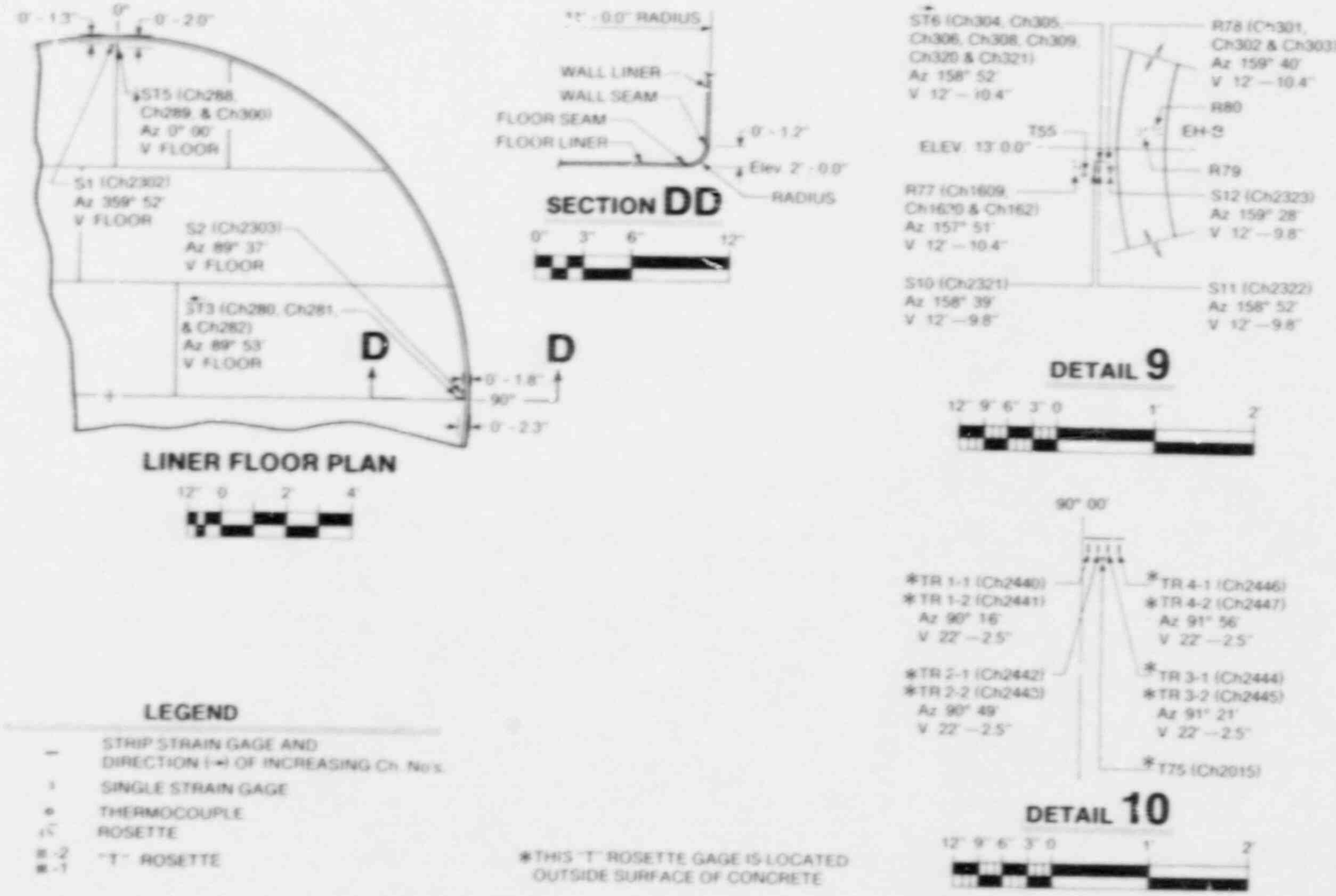


Figure 47. Details of Gages on the iner Floor, Equipment Hatch 'B', and Tee-Rosettes on thə (u'side Concrete Surface.

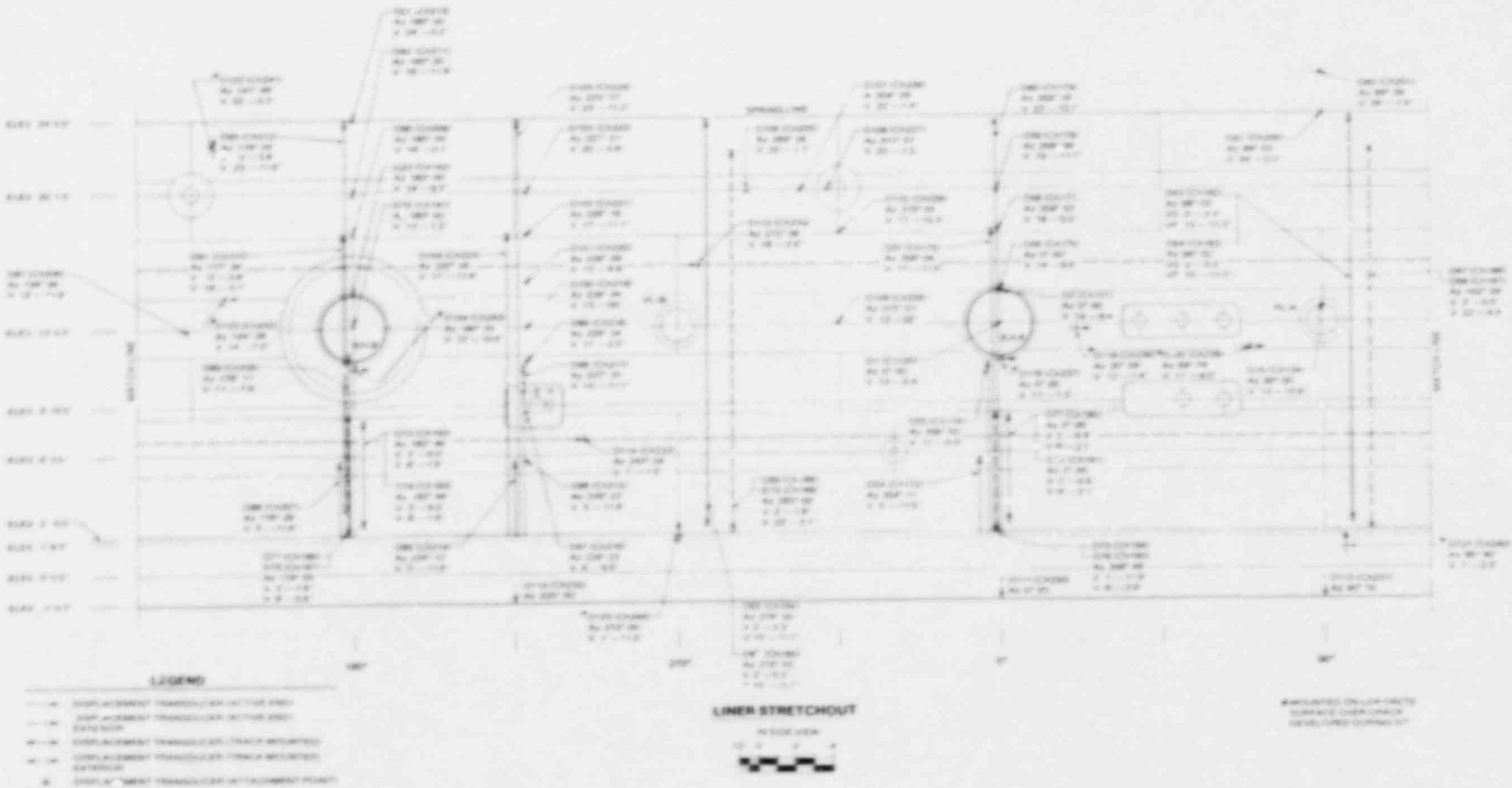


Figure 48. Displacement Transducers Used to Measure Global Displacements.

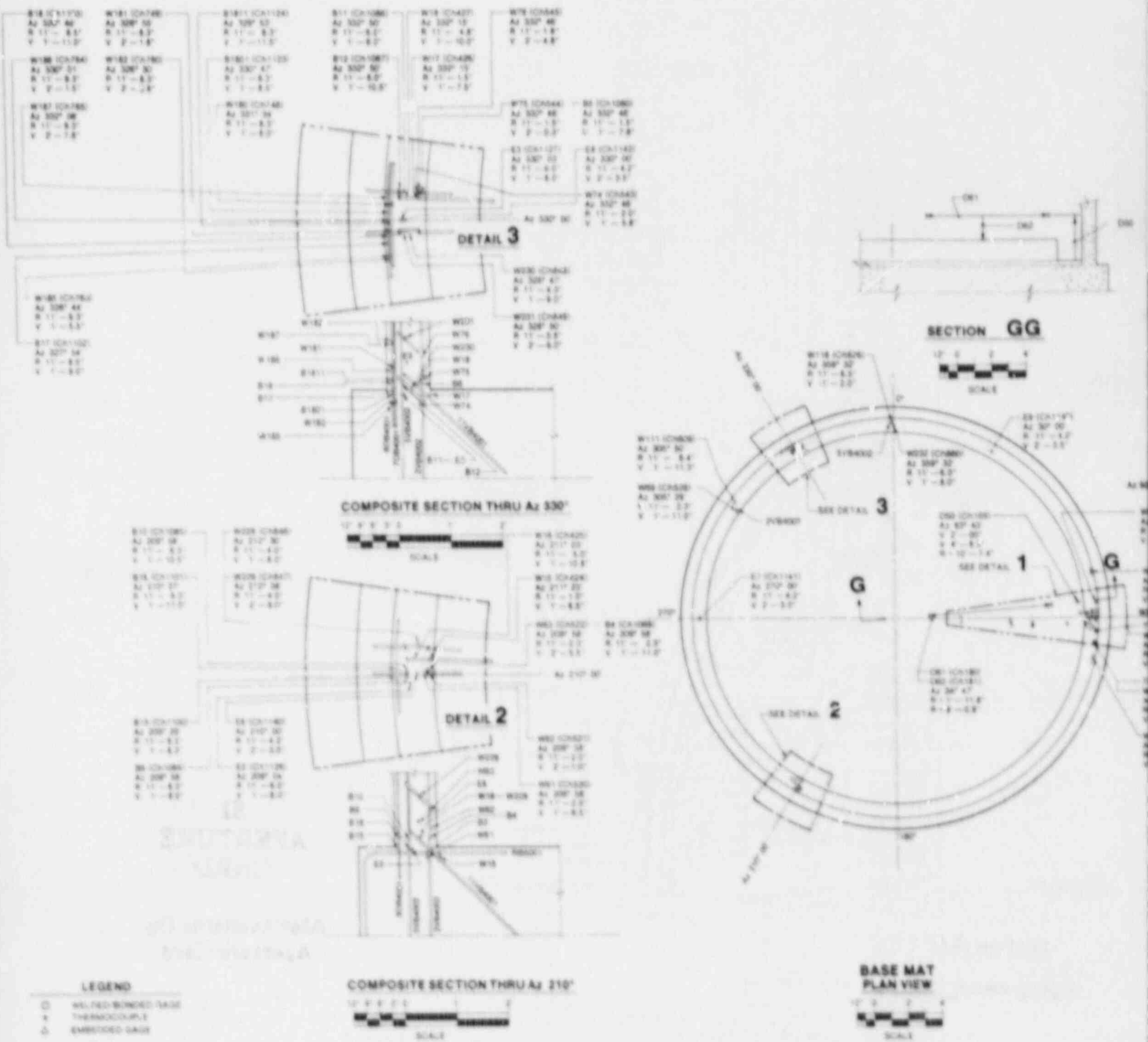
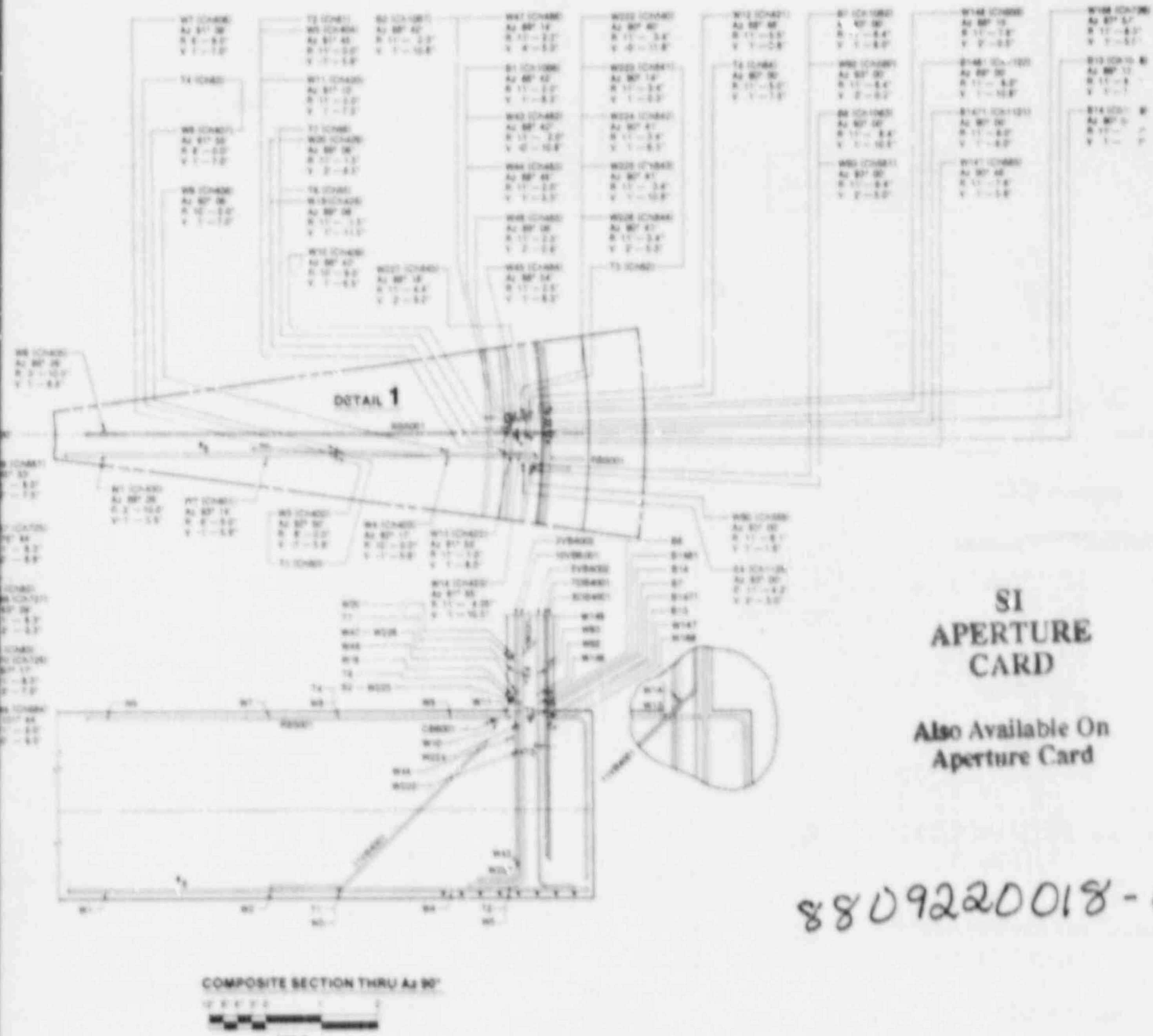


Figure 49. Instrumenta



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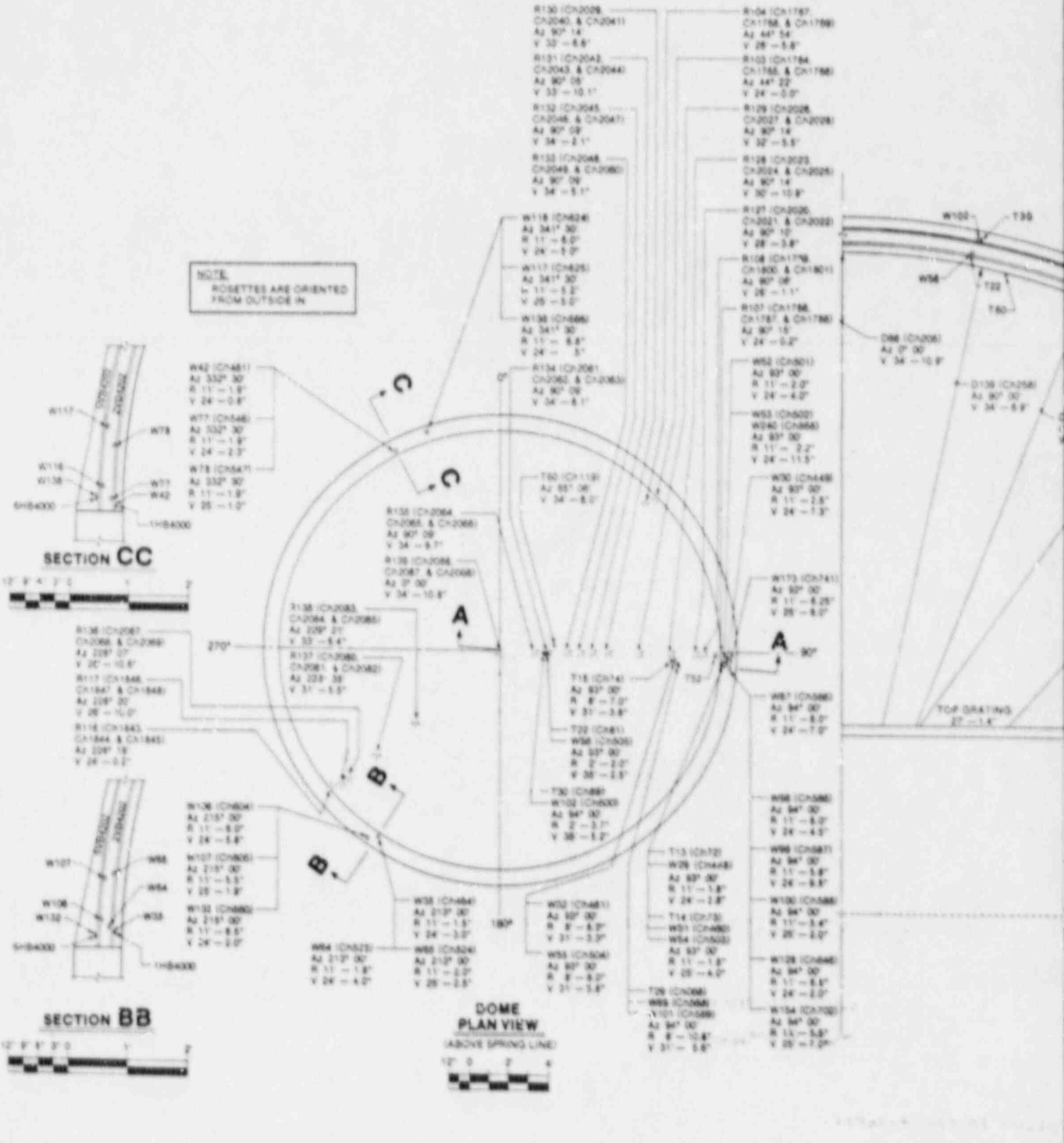
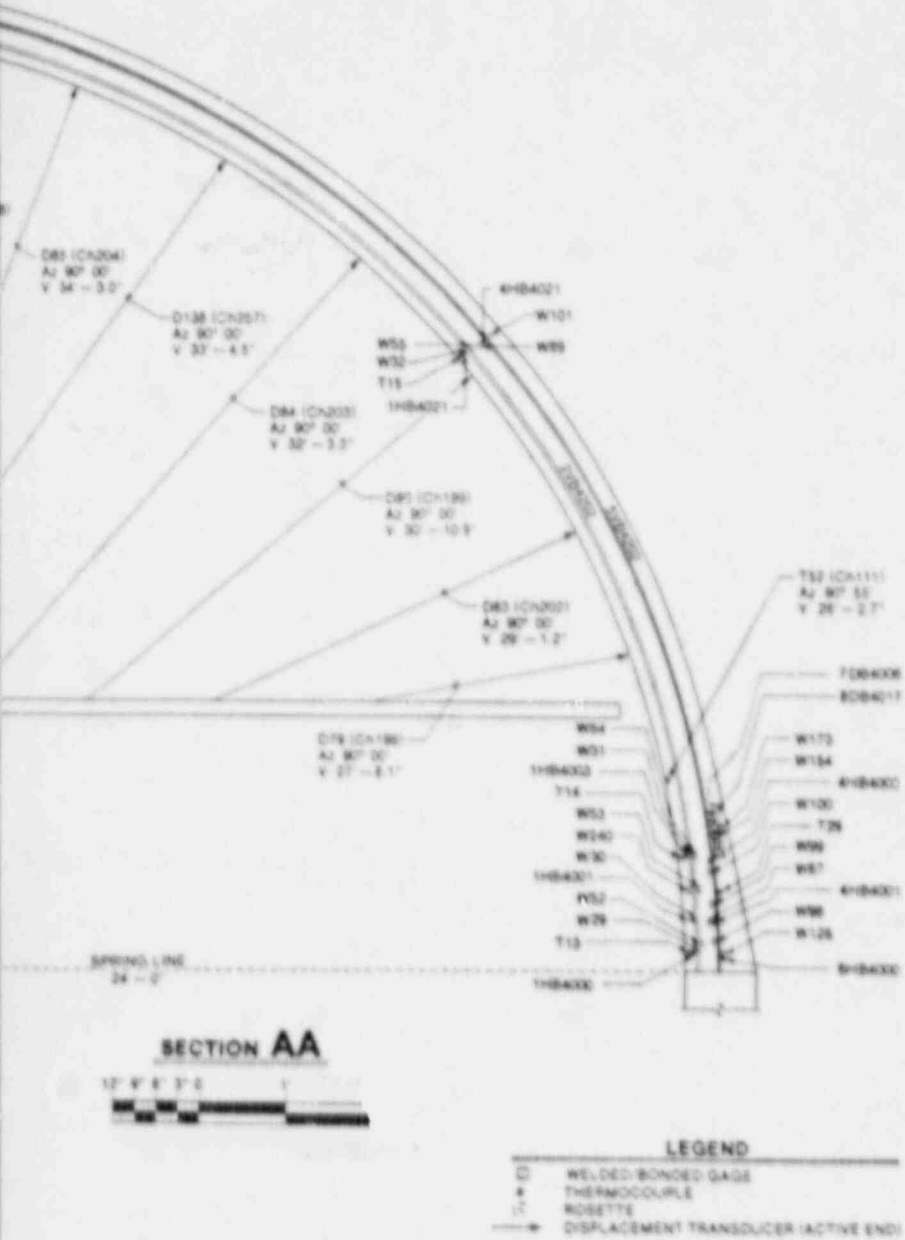


Figure 50. Dome Instrumentation.



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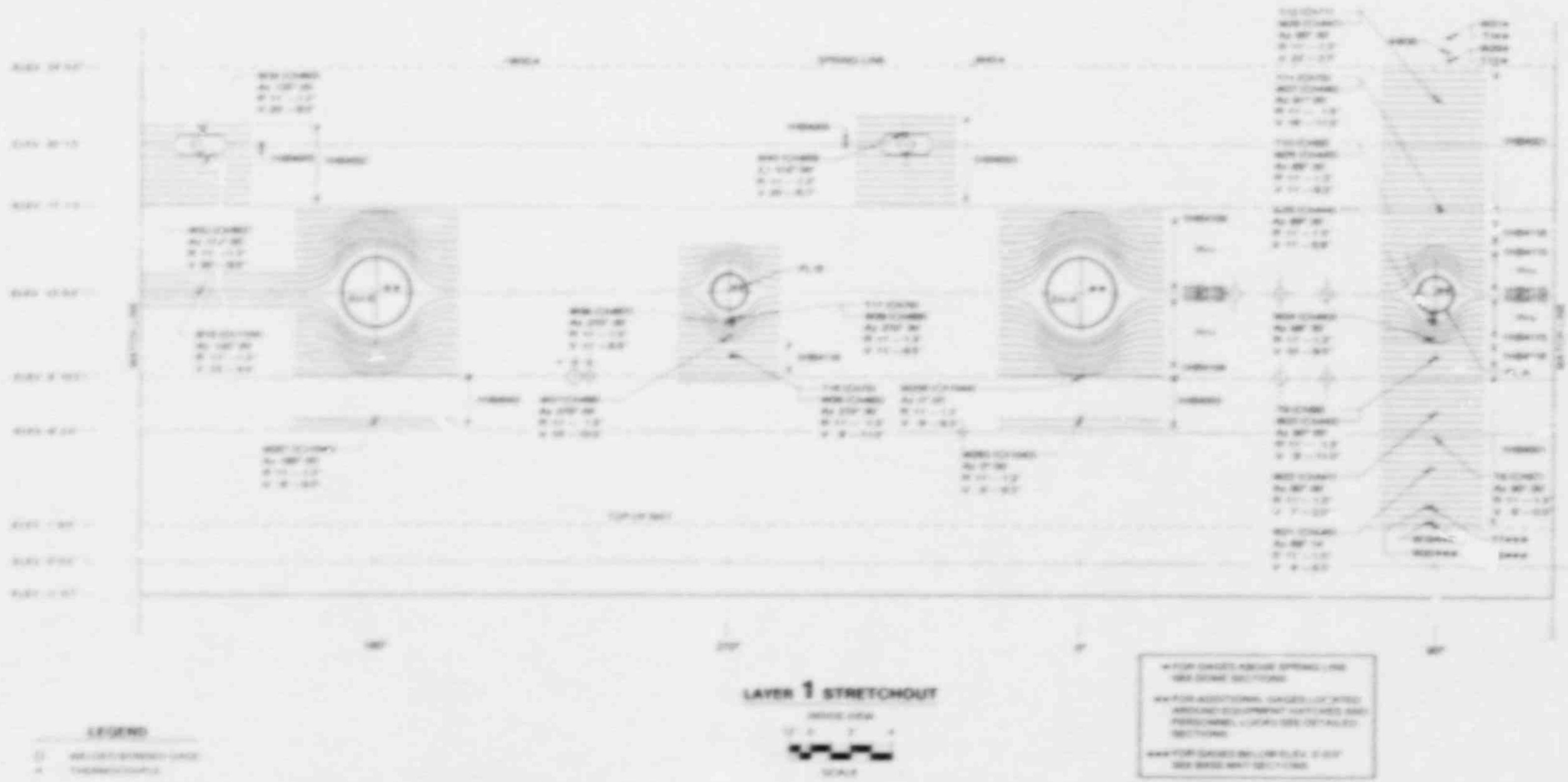

Figure 51. Embedded Instrumentation Mounted on or Near Layer 1 Reinforcing Steel.

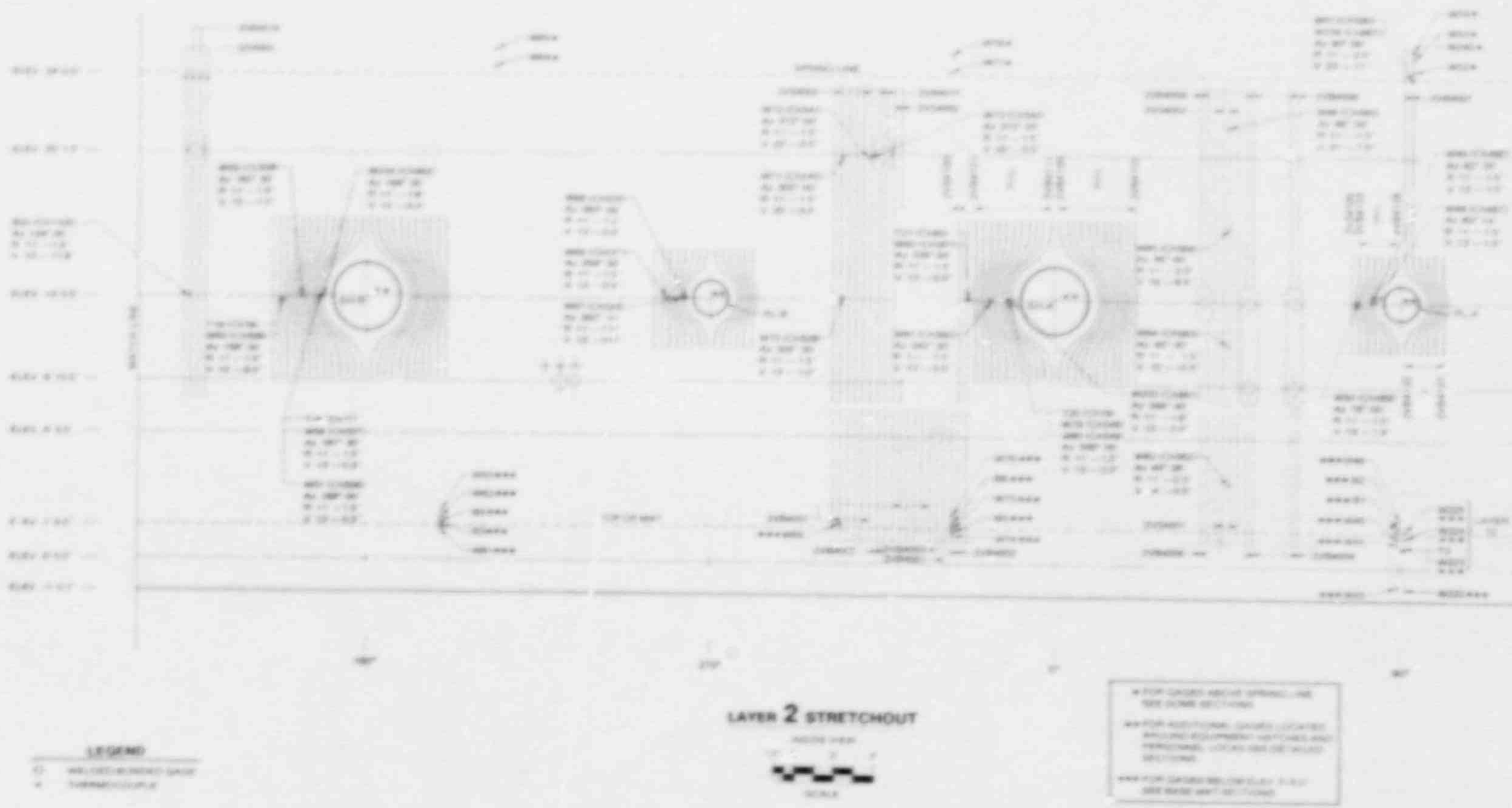

Figure 52. Embedded Instrumentation Mounted on or Near Layer 2 Reinforcing Steel.

Figure 53. Embedded Instrumentation Mounted on or Near Layer 5 Reinforcing Steel.

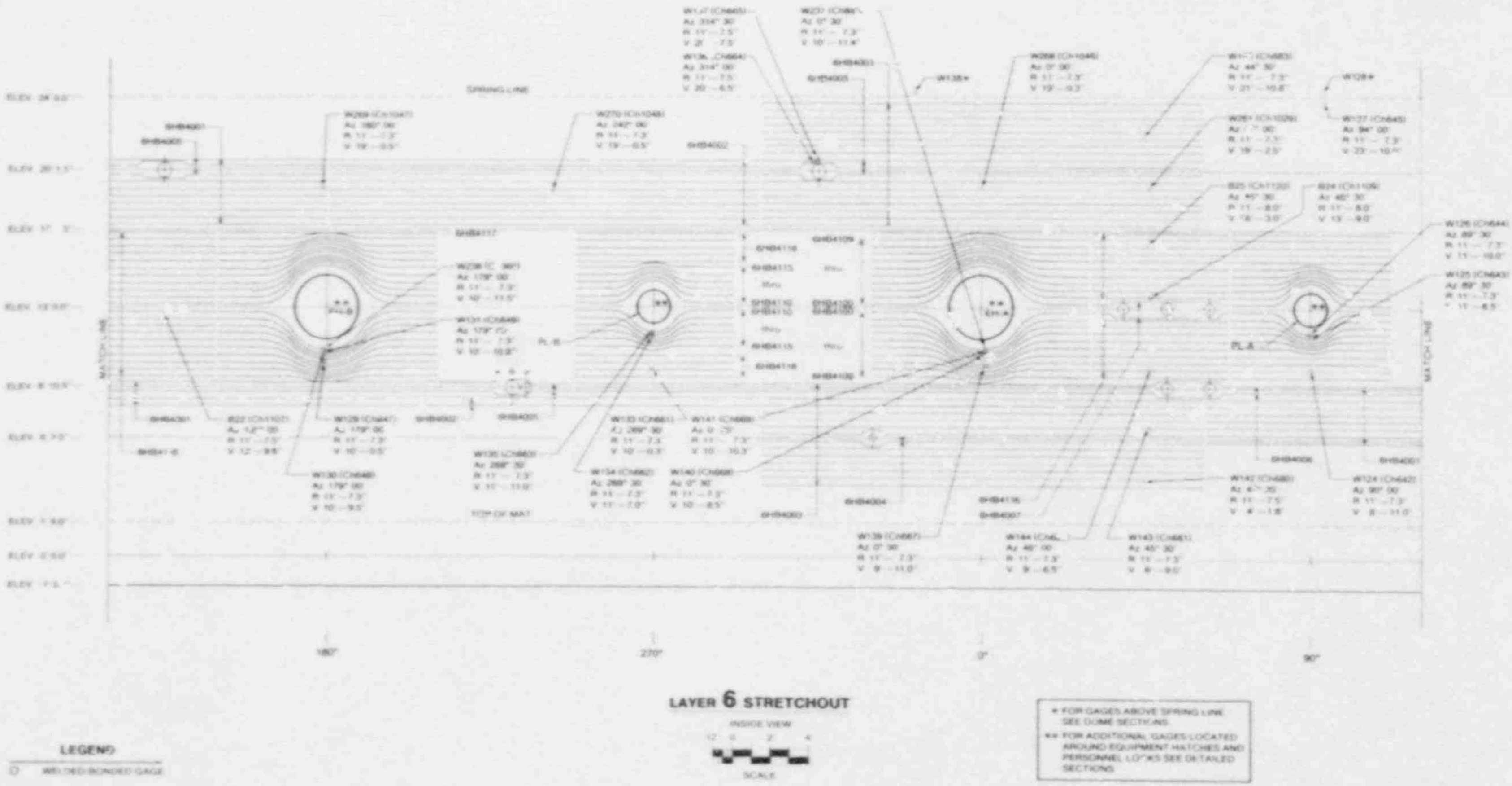

Figure 54. Embedded Instrumentation Mounted on or Near Layer 6 Reinforcing Steel.

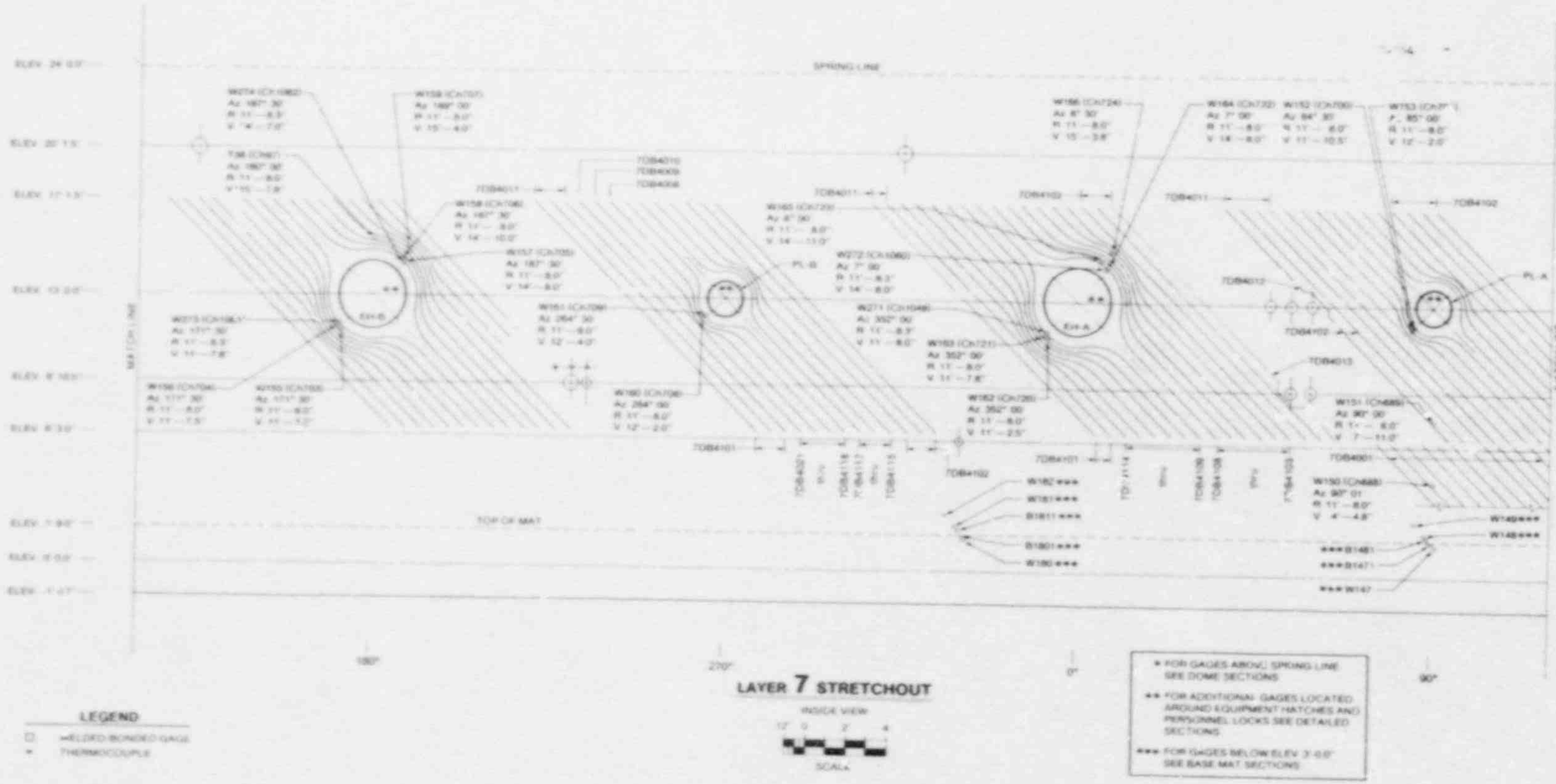

Figure 55. Embedded Instrumentation Mounted on or Near Layer 7 Reinforcing Steel.

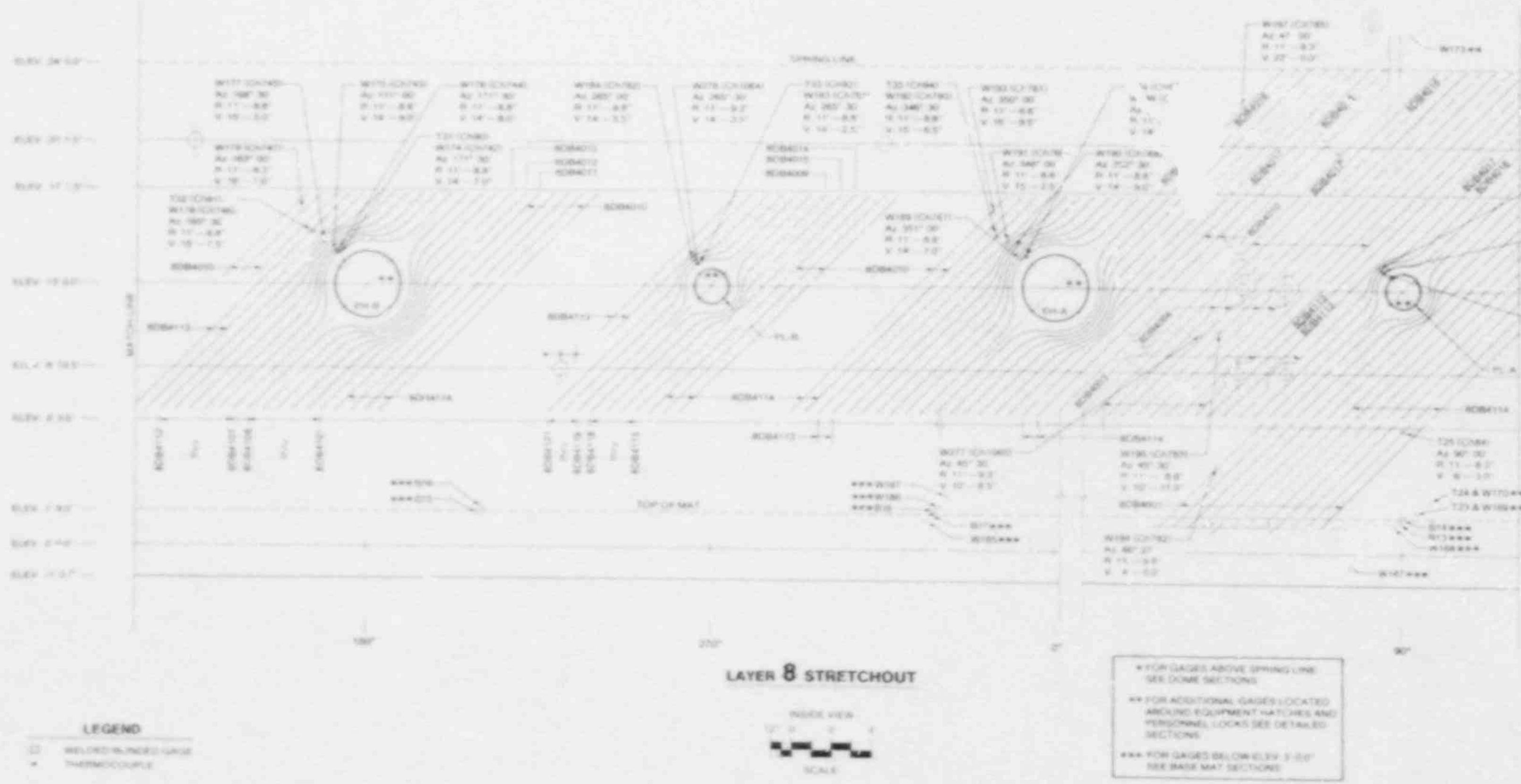

Figure 56. Embedded Instrumentation Mounted on or Near Layer 8 Reinforcing Steel.

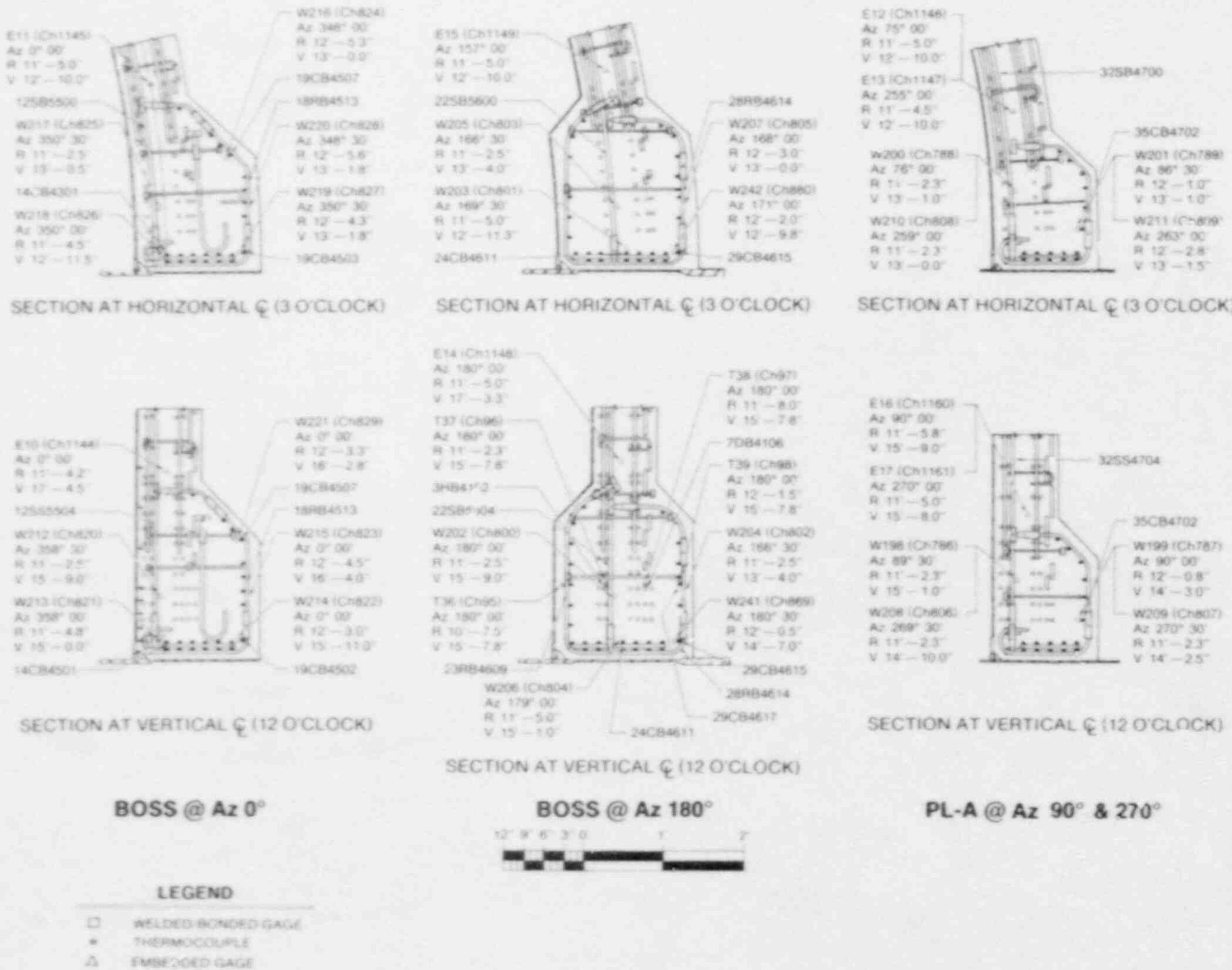

Figure 57. Embedded Instrumentation Located in the Bosses of the Major Penetrations.

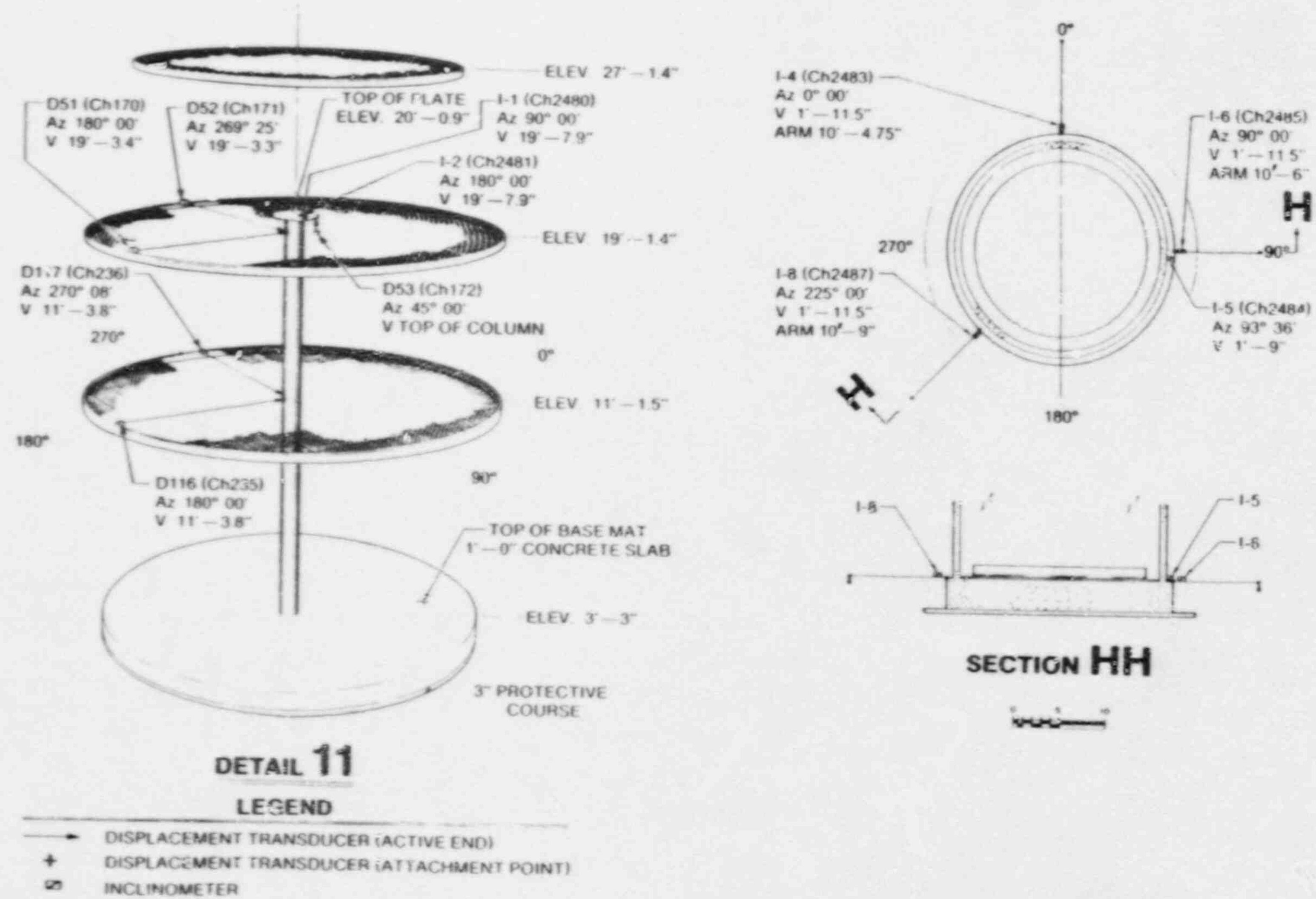

Figure 58. Details of Transducers Used to Measure Relative Motion of Platform and Reference Column, Tilt Sensors, and Tilt Sensors Used to Measure Basemat Uplift.

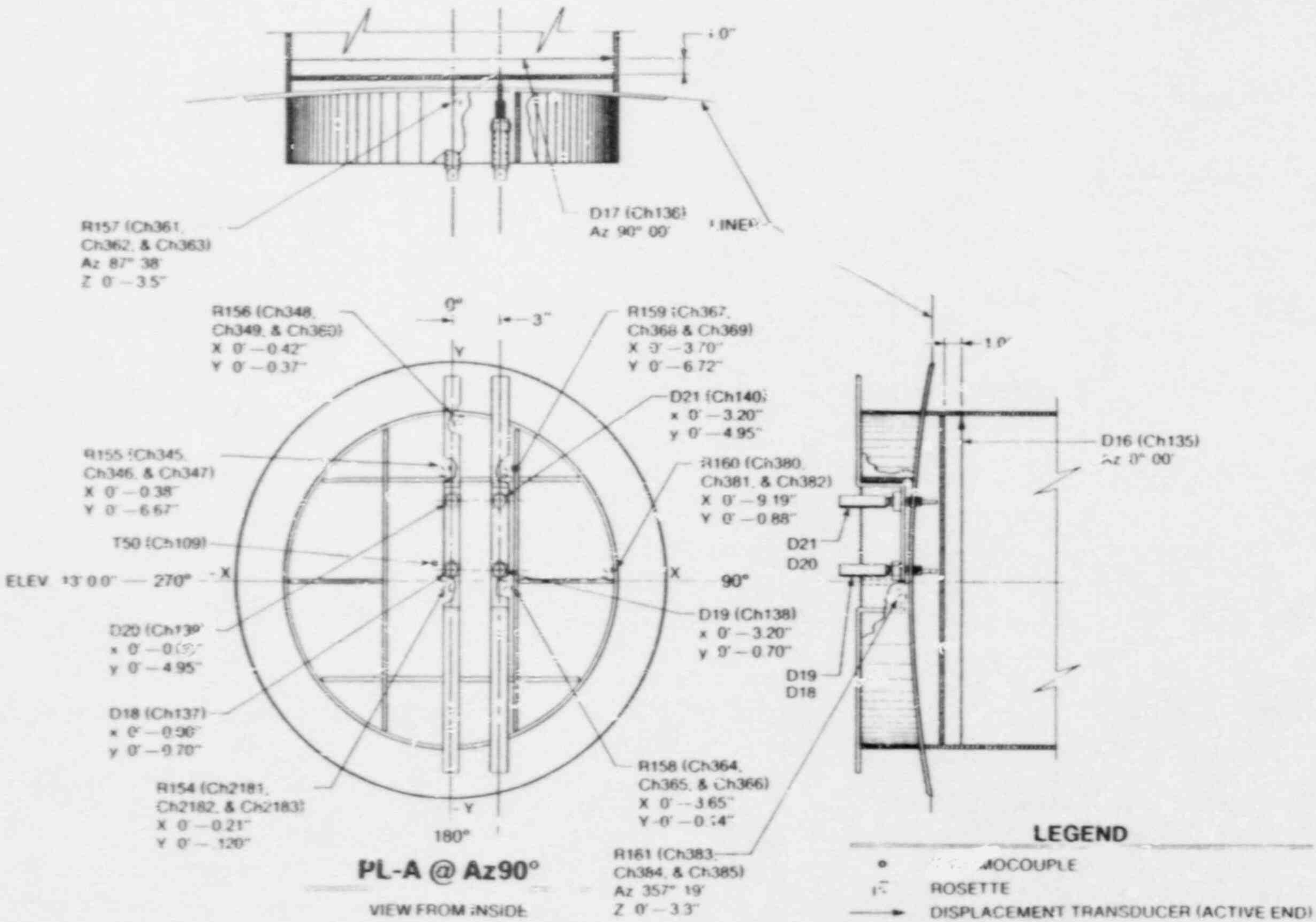

Figure 59. Instrumentation on the Steel Sections of Personnel Air Lock 'A'.

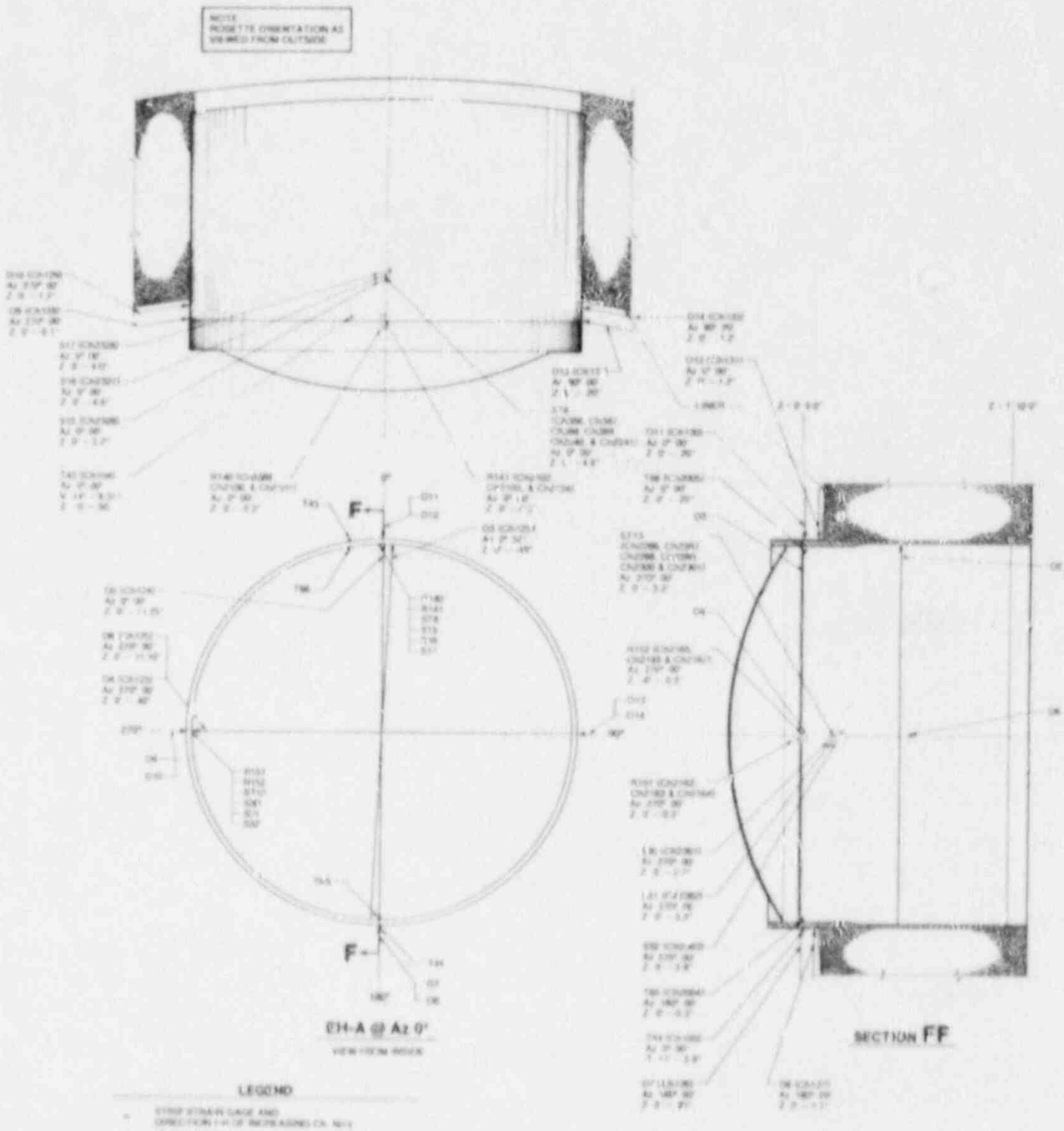

Figure 60. Instrumentation on the Steel Sections of Equipment Hatch 'A'.

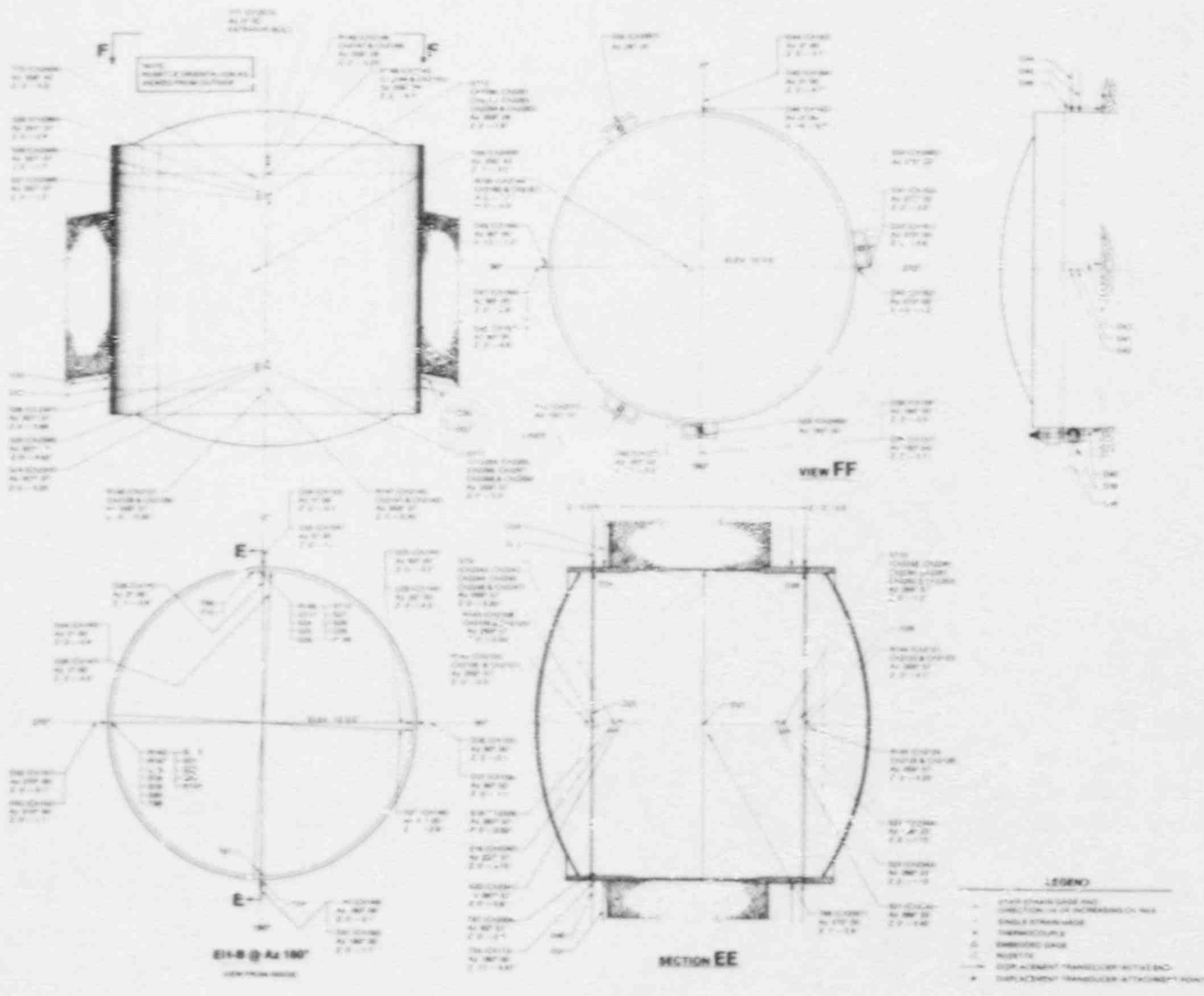

Figure 61. Instrumentation of the Steel Sections of Equipment Hatch 'B'.

5. MATERIAL PROPERTIES TESTING

Material properties are the crucial link between the containment model and the finite element analyses. In addition to the many material tests conducted during the design and construction phases of the containment, Sandia has taken material specimens and has conducted additional material testing. Since the material properties are important, more material samples were taken than those needed for tests presented in this report and may be used later for yet undefined material testing.

5.1 Soil Testing

A plate-load-bearing test was performed in situ on the fill soil under the containment model by Western Technologies, Inc. (Note that a reinforced-concrete working mat was placed over the soil and the containment model was built on top of the working mat.) The fill soil was imported to the site and compacted to a thickness of about 15 in to replace a concrete slab that was removed with the last containment model. The tests were conducted in accordance with ASTM D-1194 [29] by loading three plates--12, 18 and 30 in. in diameter--while deflections were measured by two dial gages 180° apart on the plates. All tests were conducted on the soil at its existing water content.

Each plate was loaded and unloaded in about 2 h. The pressure and deflection measured during testing for each plate is listed in Table 7.

The plates were all within the outline of the basemat and each test was located at least a couple of plate diameters from other plate tests.

Six soil tests on the imported soil indicated a maximum dry density of 137.2 lb/ft^3 with an optimum moisture content of 6.9%. The natural soil below the import soil was also tested. The maximum dry density for the five samples tested is 127.6 lb/ft^3 with an optimum moisture content of 8.9%. The in-place characteristics of the subgrade soil are listed in Table 8.

5.2 Concrete Testing

All fresh concrete testing was conducted at the site by Western Technologies, Inc., [30, 31]. They also completed the strength tests of the concrete per ASTM C39 [32] for construction purposes. See Section 3.2. For purposes of analysis more data were obtained. Typically, fifteen cylindrical specimens were taken for each lift in the containment shell, as well as three dogbone-shaped specimens for direct tension testing.

Table 7

Plate Pressure and Deflection for the Subgrade Soil
of the Concrete Containment Model

12-in. Plate		18-in. Plate		30-in. Plate	
Pressure*	Deflection**	Pressure	Deflection	Pressure	Deflection
2715.8	0.020	1207.0	0.015	348.6	0.004
2928.5	0.025	1301.5	0.024	611.2	0.009
4329.0	0.036	1924.0	0.037	916.7	0.021
5602.3	0.053	2489.9	0.051	1234.5	0.036
7002.8	0.089	3112.3	0.094	1527.9	0.053
8403.4	0.104	3734.8	0.123	1833.5	0.064
9676.6	0.119	4300.7	0.143	2139.0	0.079
10949.9	0.150	4866.6	0.169	2281.6	0.084
12350.4	0.160	5489.1	0.194	2444.6	0.103
13751.0	0.185	6111.5	0.210	2628.0	0.103
8403.4	0.176	3734.8	0.204	1752.0	0.099
2928.5	0.163	1924.0	0.186	896.4	0.091
0.0	0.122	0.0	0.131	0.0	0.057

*Pressures are in pounds per square foot.
**Deflections are in inches.

Table 8

In-Place Characteristics for the Subgrade Soil
of the Concrete Containment Model

Test	Import Soil			Native Soil		
	Moisture (%)	Dry Density lb/ft^3	Relative Compact. (%)	Moisture (%)	Dry Density lb/ft^3	Relative Compact. (%)
1	7.5	133.3	97	10.4	119.4	94
2	7.4	127.7	93	9.3	120.8	95
3	7.9	127.0	93	11.9	119.1	93
4	7.0	127.7	93	11.9	120.8	95
5	7.1	127.5	93	12.3	122.4	96
6	7.3	131.0	95			

To analyze the containment, the following additional properties of the cured concrete were needed:

- Stress-strain curve for uniaxial compression
- Stress-strain curve for uniaxial tension
- Split cylinder strength.

Some tests completed during the design phases of the containment were repeated at Sandia. Concrete/stud interaction tests were modified and repeated using actual construction materials. The results from these tests are in Section 5.2.4.

All concrete testing conducted at Sandia used one of two MTS servo controlled loading frames. One was a 220,000-lb load frame while the second had a 1,000,000-lb capacity. All test specimens were loaded using stroke control on a machine-mounted LVDT. Data were gathered during the tests with the use of a Digital Equipment Corporation's (DEC) LSI, and later transferred to a DEC VAX for plotting. All transducers used for testing--both load cells on the load frame and displacement transducers on the load frame and specimen--have calibrations that are traceable to the National Bureau of Standards.

5.2.1 Compression Testing

For determining the stress-strain curve for unconfined uniaxial compression of the concrete, a standard (6-in.-diameter x 12-in.-long) cylinder was used. The ends of each of the specimens were ground flat and parallel to minimize end effects. Figure 62 shows a specimen being prepared. Water was used as the cutting fluid/lubricant. Each specimen was dimensionally inspected per ASTM C39 [32] before being compression-tested.

ASTM C39 [32] procedures were followed for the loading of the specimen and the addition of two radial displacement transducers and a longitudinal transducer were used to measure loading-induced strains. The two radial displacement transducers measured lateral strains at about mid-height while the longitudinal strain was measured by the longitudinal displacement transducer. A typical test set up is shown in Figure 63.

Note the use of the spherically seated loading platen and the metal plates used between the specimen and the loading platens. The gage length used to measure the longitudinal strains was typically about 4 in.

The concrete was typically tested at ages of 28 days, 4 months, 6 months and again at the time of the containment test.[1] Plots of the results at these times are shown in Figures 64 to 67.

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[1] This work was conducted at Sandia in the Geomechanics Division by Michael J. McNamee.

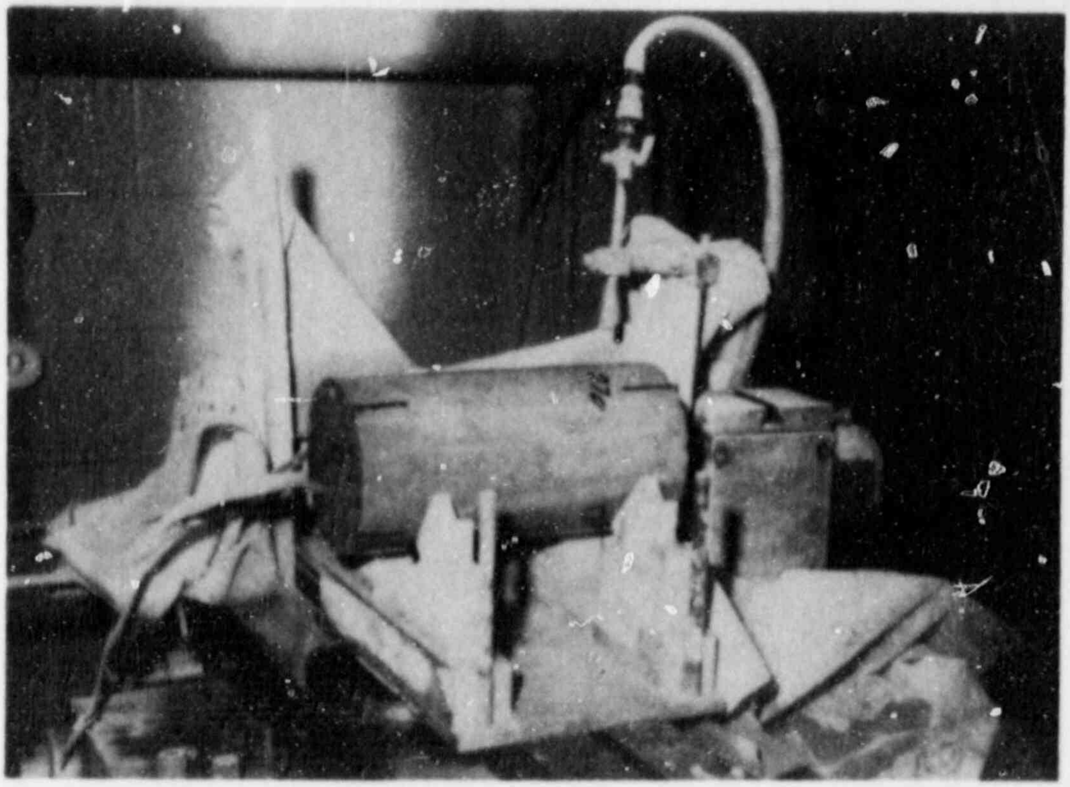


Figure 62. The Ends of a Concrete Specimen Being Ground Flat and Parallel.

A summary of the average of the ultimate strength of the concrete at various specimen ages and at test time is listed in Table 9.

Table 9

Ultimate Compressive Strength of Concrete (psi)

Time of Test	Number of Specimens	Average Strength	Standard Deviation
28 days	6	5260	260
4 months	10	6520	700
6 months	11	6980	600
at test time	11	6180	470

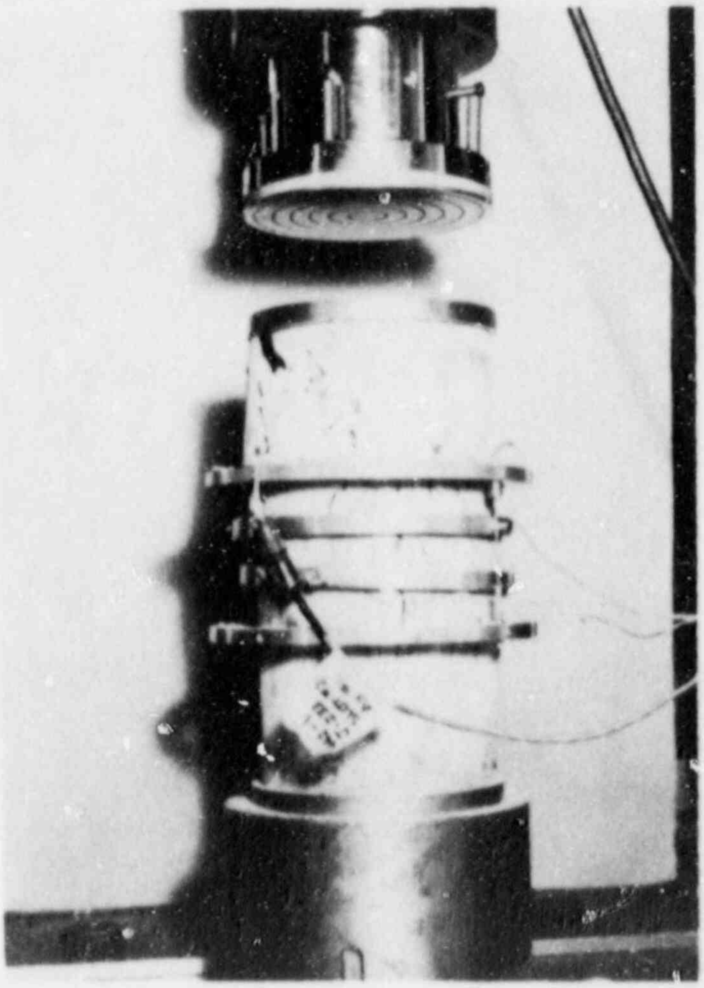


Figure 63. Concrete Specimen Shown After Compression Testing.

5.2.2 Tension Testing

Tensile testing of the concrete was also conducted. Initial tests using the standard 6 in. by 12 in. cylindrical specimens proved to be difficult. Although care was taken to eliminate bending through the use of loading chains as suggested in ASTM D2936 [33], the end plates appeared to influence specimen failure.

To simplify direct tension testing, a dogbone-shaped specimen was developed. United Engineers and Constructors designed and used the specimens during the initial phases of the refining of the concrete mix. The dogbone specimen is shown in Figure 68.

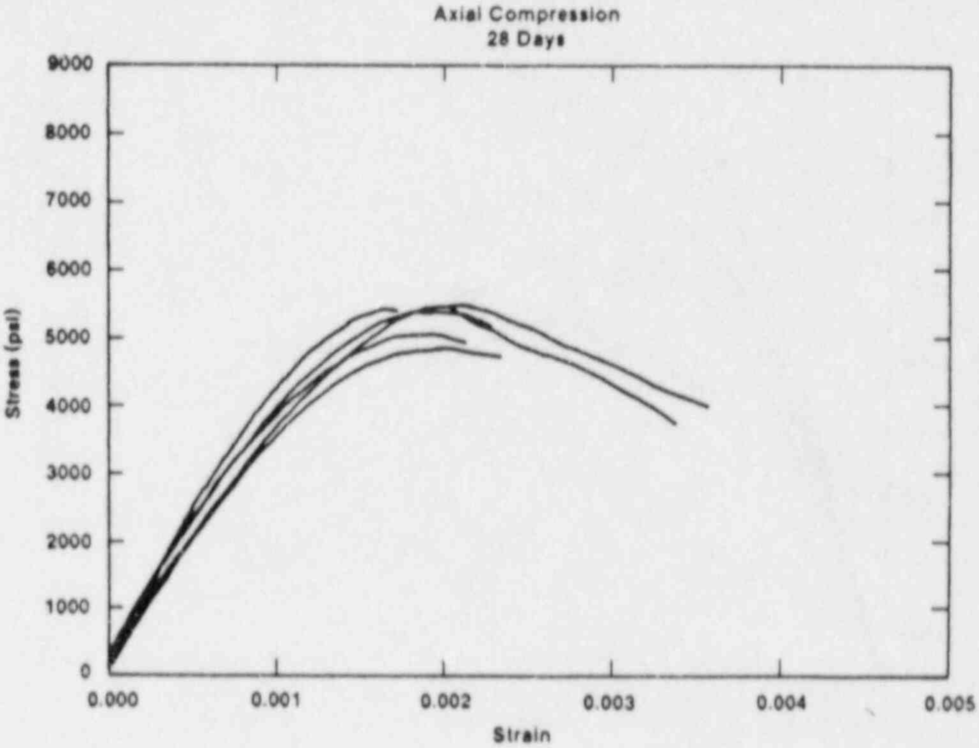


Figure 64. Concrete Compressive Strengths at Specimen Age of 28 Days.

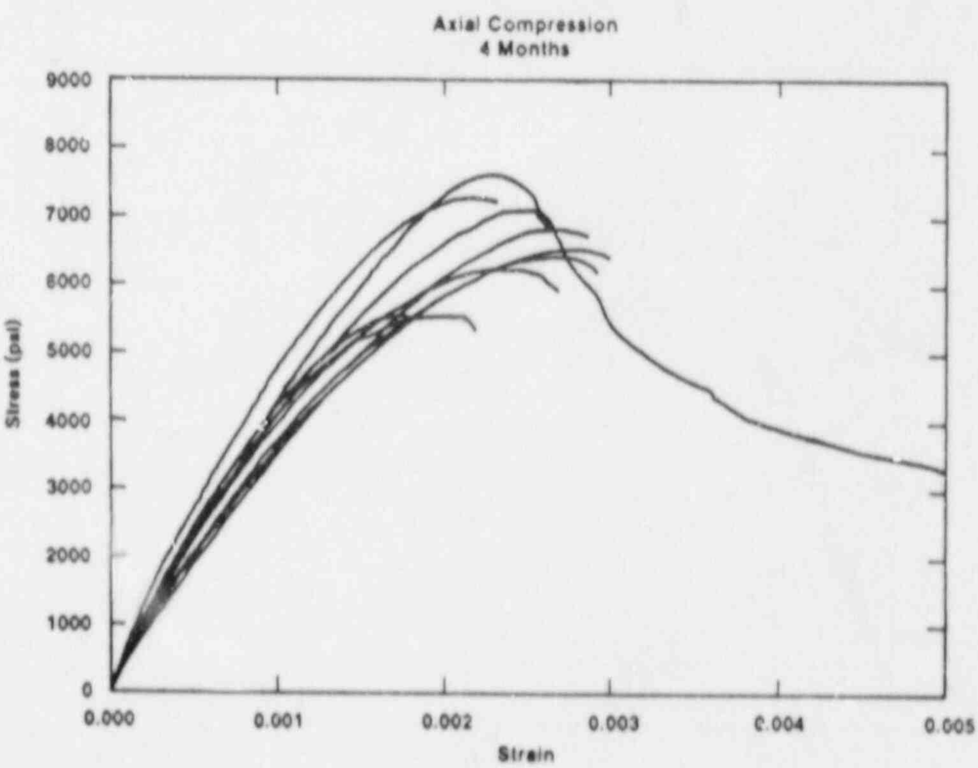


Figure 65. Concrete Compressive Strengths at Specimen Age of 4 Months.

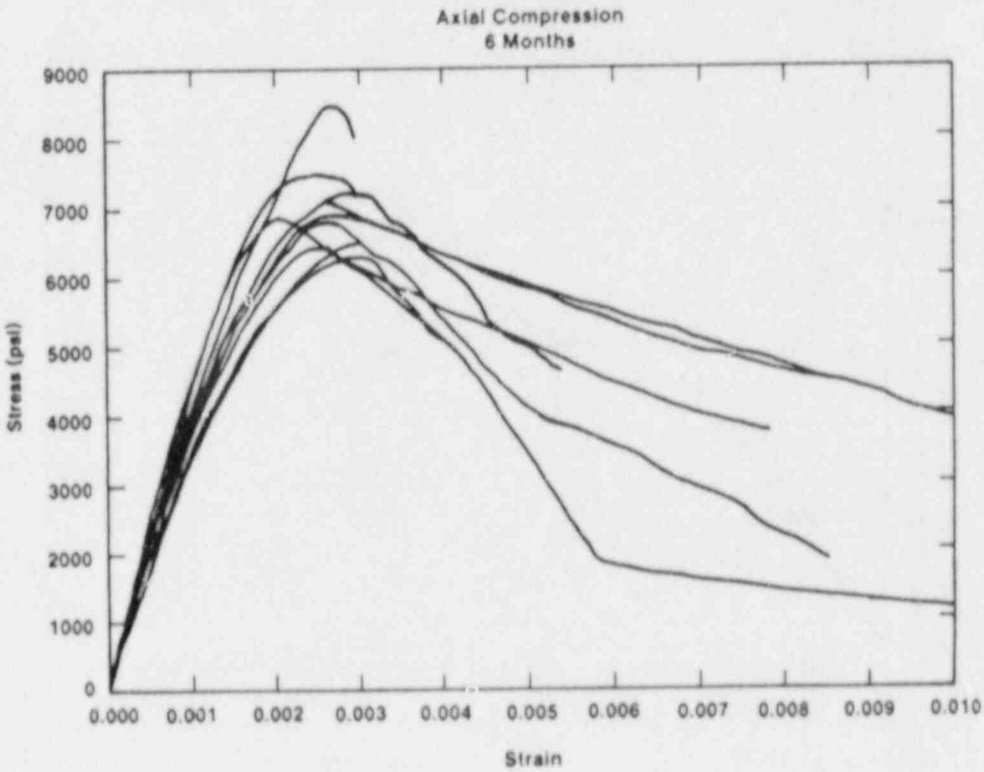


Figure 66. Concrete Compressive Strengths at Specimen Age of 6 Months.

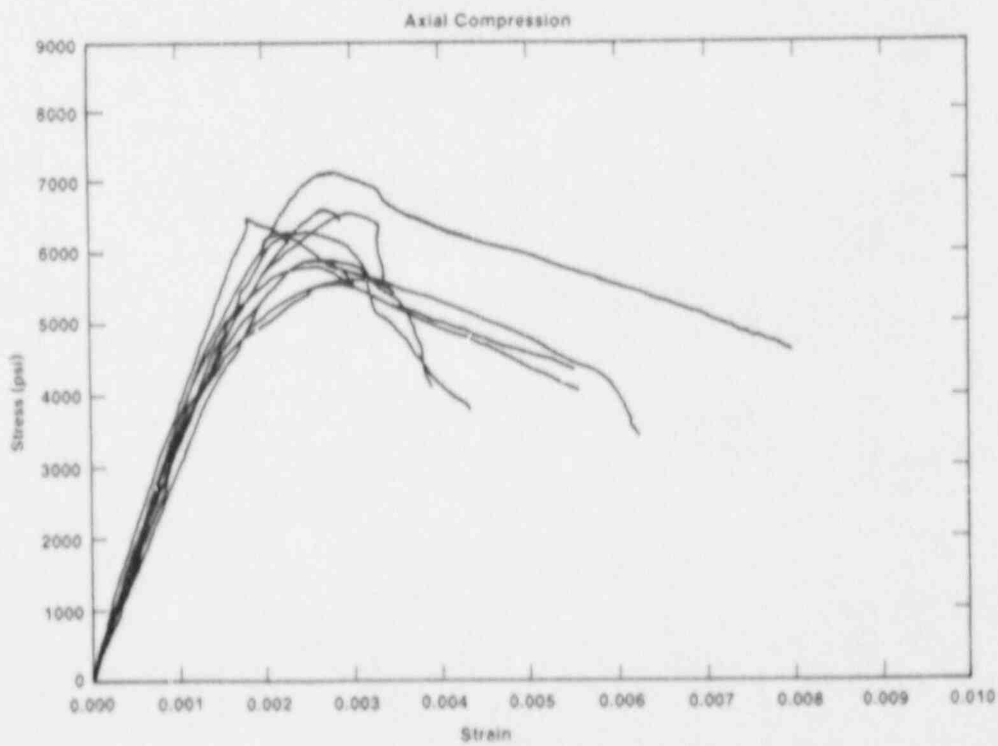


Figure 67. Concrete Compressive Strengths at Containment Test Time.

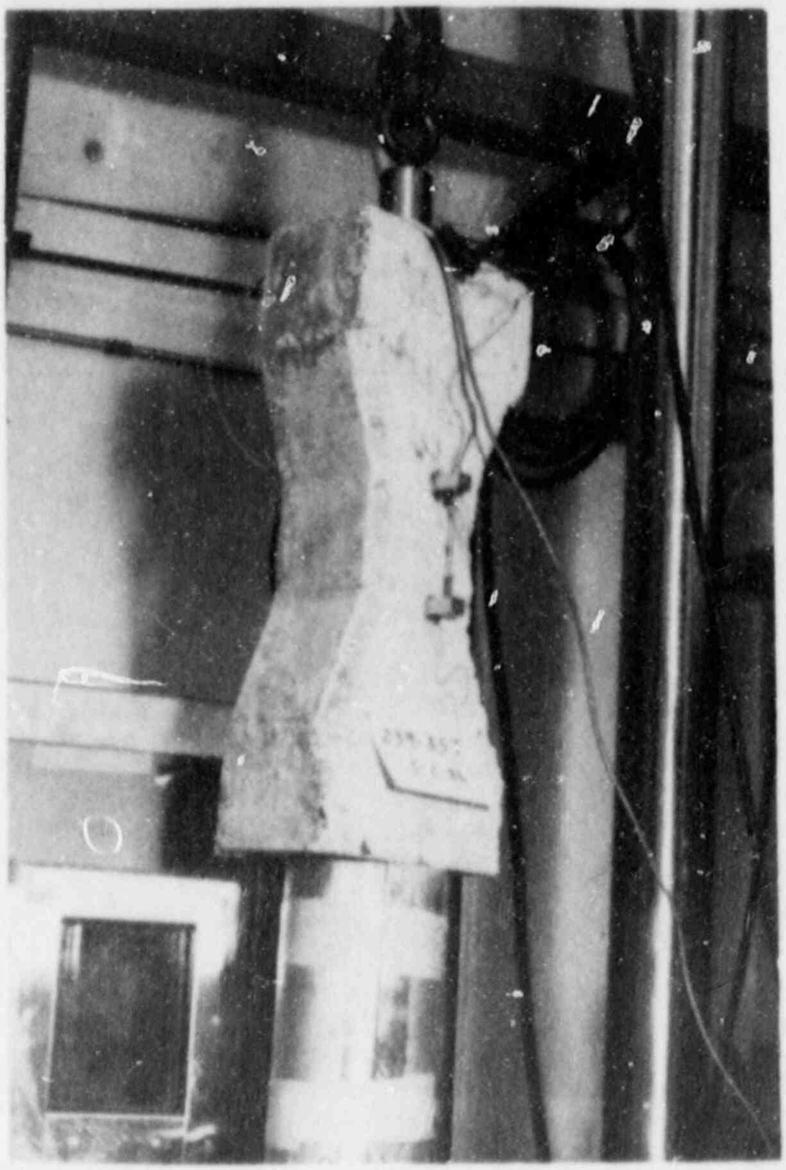


Figure 68. Dogbone Specimen Used to Measure Concrete Tensile Strength.

Sandia's use of the dogbone specimens met with only limited success. Failures were again associated with the ends and were generally located away from the necked-down region of the specimen at a point where the specimen was reinforced to provide adequate anchorage of the bars used to load it. In other cases, proper care was not exercised when the specimens were cast, resulting in a poor sample and poor results.

Again, the specimen was loaded using chains to minimize any bending induced by the load, but measurements from the LVDTs attached to two opposite sides indicated that some bending was present during loading of the specimen. The bending is probably introduced by the anchor bars not being perfectly parallel to the axis of loading. Even in the presence of the bending and the poor breaks, the results seem to be fairly consistent. Figure 69 shows the data pairs for four direct tension specimens. Testing was conducted at the time of the containment test.

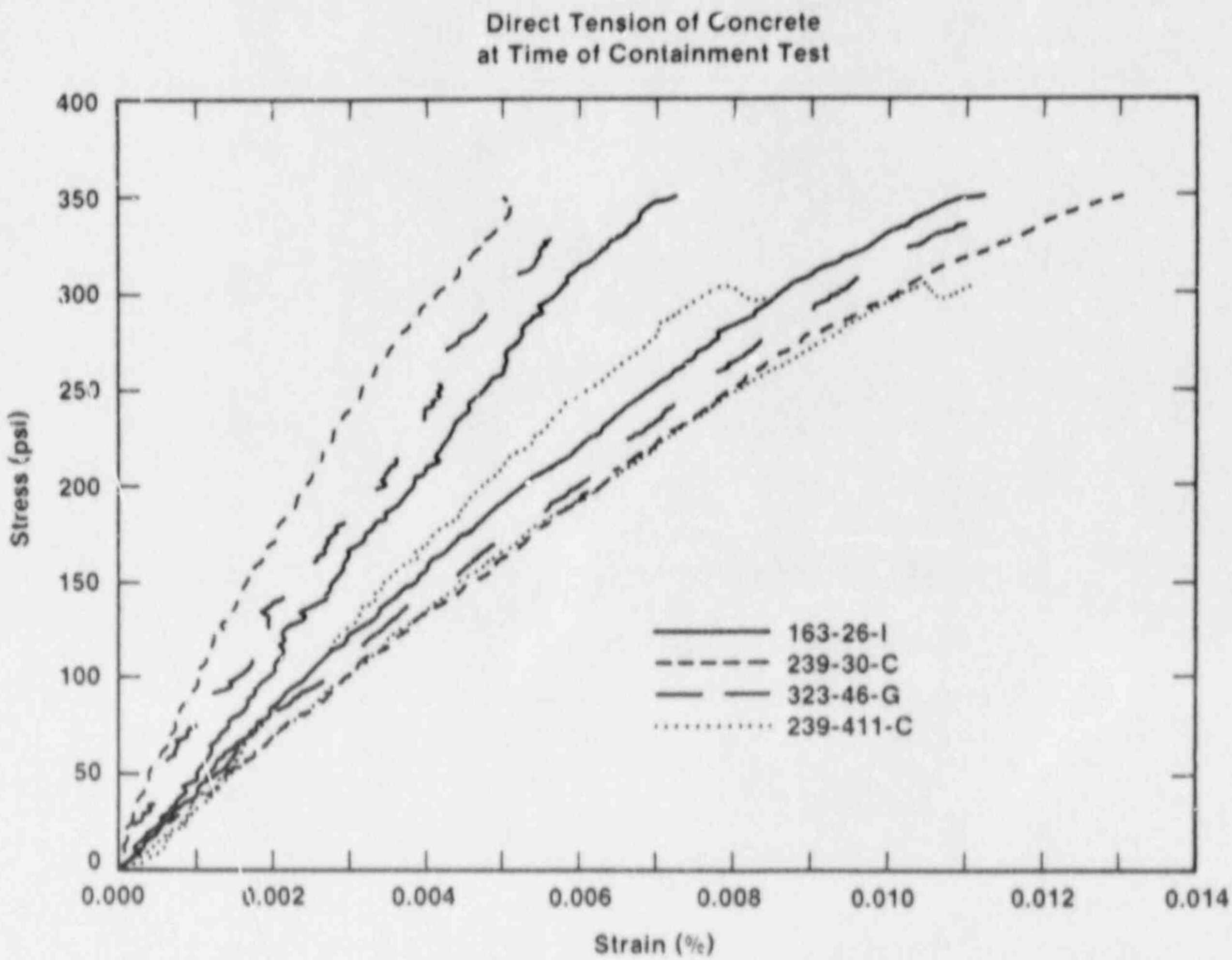


Figure 69. Results of Direct Tension Tests of the Dogbone-Style Specimens.

Since there were two LVDTs per specimen, there are eight lines for the four specimens tested. Other dogbone style specimens were tested, but were so poor in quality the results are omitted from this report.

One other specimen was tested in direct tension. A standard 6-by-12 cylinder was ground into a necked-down shape and ends were epoxied to it. The specimen was instrumented and loaded using chains, as can be seen in Figure 70. The specimen failed in the reduced area just outside the instrumented region.

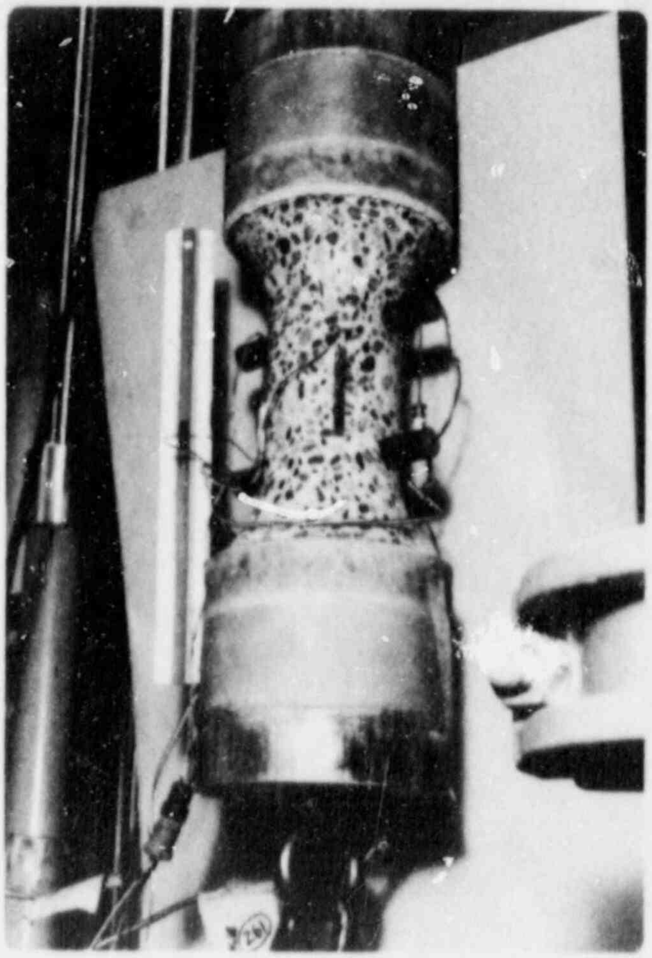


Figure 70. Specimen Ground to Shape and Loaded in Direct Tension.

Two strain gages and two LVDTs were used to measure strain during loading. The results from this test are plotted in Figure 71. This specimen was tested about five months after the testing of the containment model.

5.2.3 Split Tensile Testing

The split cylinder strength test, ASTM C496 [34], also known as the Brazil test, was completed on the concrete used in the containment model. The specimen was sandwiched between two strips of thin plywood before it was loaded in the platens of the testing machine. The plywood acts as bearing strips as suggested by ASTM C496. A typical test setup is shown in Figure 72.

At test time the tensile strength of the concrete averaged about 450 psi as determined by the splitting tensile strength of the cylinders. See Table 10. It should be noted that the splitting tensile strength is estimated to be about 15% higher than the direct tensile strength and that the tensile strength of concrete does not generally

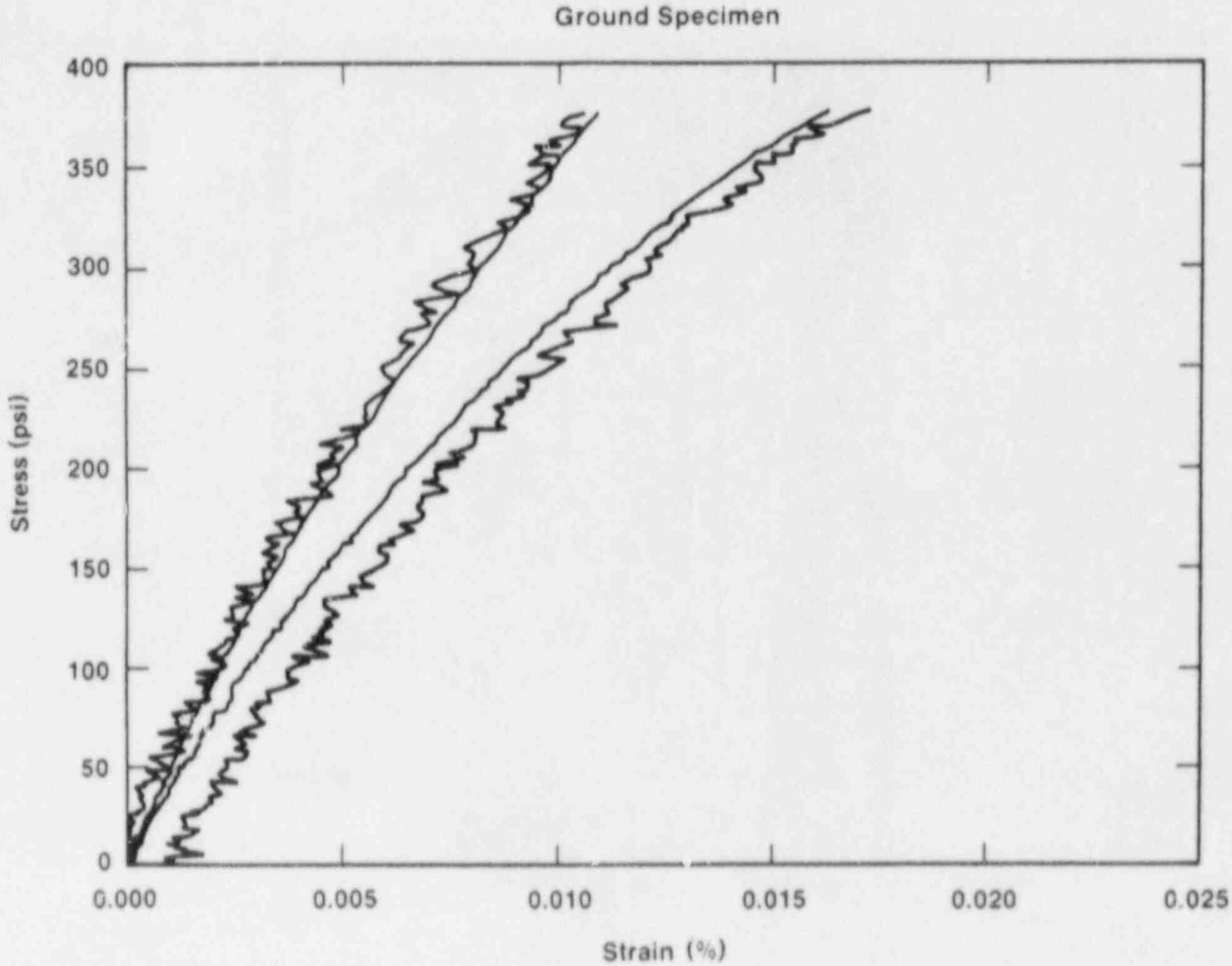


Figure 71. Stress-Strain Curve for Direct Tension Testing of the Ground Specimen.

Table 10

Splitting Tensile Stress of Concrete (psi)

Time of Test	Number of Specimens	Average Stress	Standard Deviation
28 days	6	385	27
4 months	10	479	43
6 months	11	498	39
at test time	10	449	29

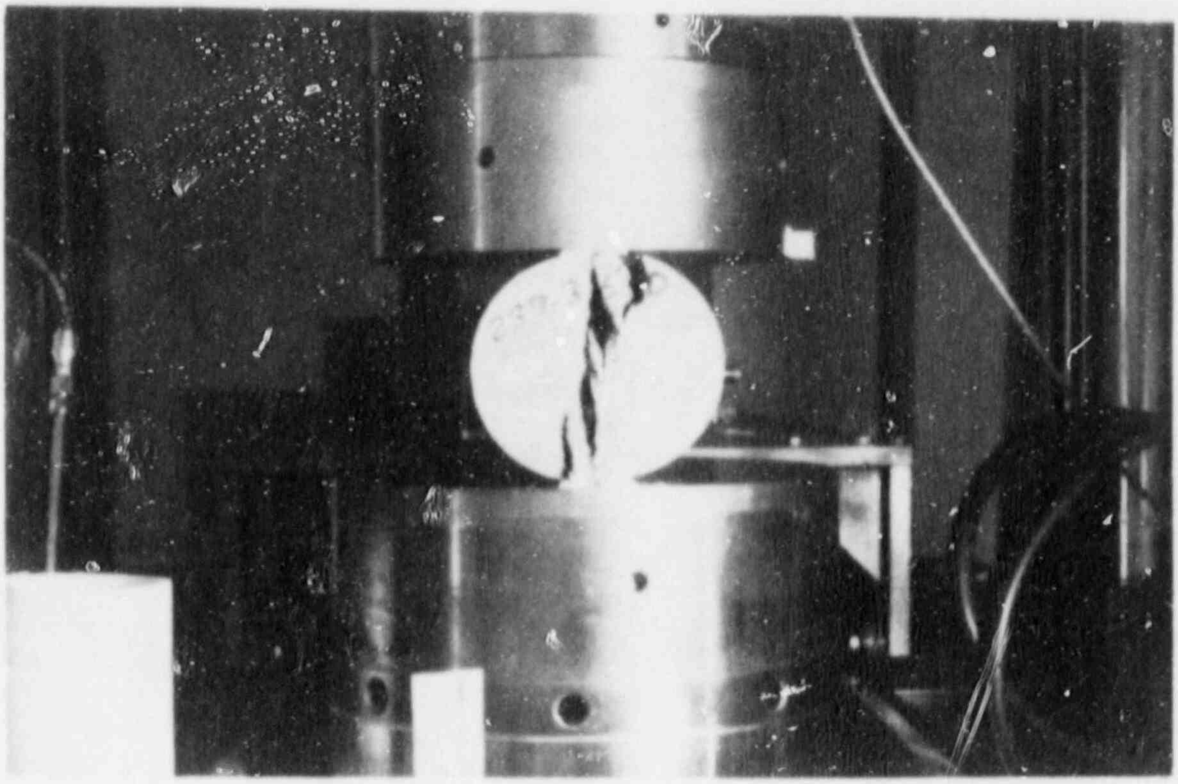


Figure 72. Typical Test Setup for Indirect Tensile Testing.

generally exceed 600 psi [35]. Note that the average splitting tensile strength is about 19% higher than the results from the direct tension test of the ground specimen.

5.2.4 Stud/Concrete Testing

Some tests were developed to determine the strength and capabilities of the studs embedded in the concrete. Much of the pioneering effort on these tests was conducted at Wiss, Janney, Elstner and Associates [25]; however, these tests did not use the actual liner material and concrete used in the model containment construction. Sandia essentially conducted the tests again (with some minor improvements) using materials used in the construction of the containment model.

Two groups of tests were conducted on the 3/4-in.-long studs.[1] (No tests were conducted at Sandia on the 1/2-in.-long studs.) The first was a simple pullout of the stud from the concrete. The specimen was designed so that a failure mode of the liner could occur during testing. The specimen consisted of a 4-in. x 4-in. square of liner material with a 3/4-in.-long stud located at its center. The stud was cast in a concrete block. On the exposed side of the liner, four

[1] These tests were conducted at Sandia in the Geomechanics Division by Michael J. McNamee.

threaded studs were attached at the corners of the specimen and were used to load the embedded stud. A sketch of the specimen is shown in Figure 73.

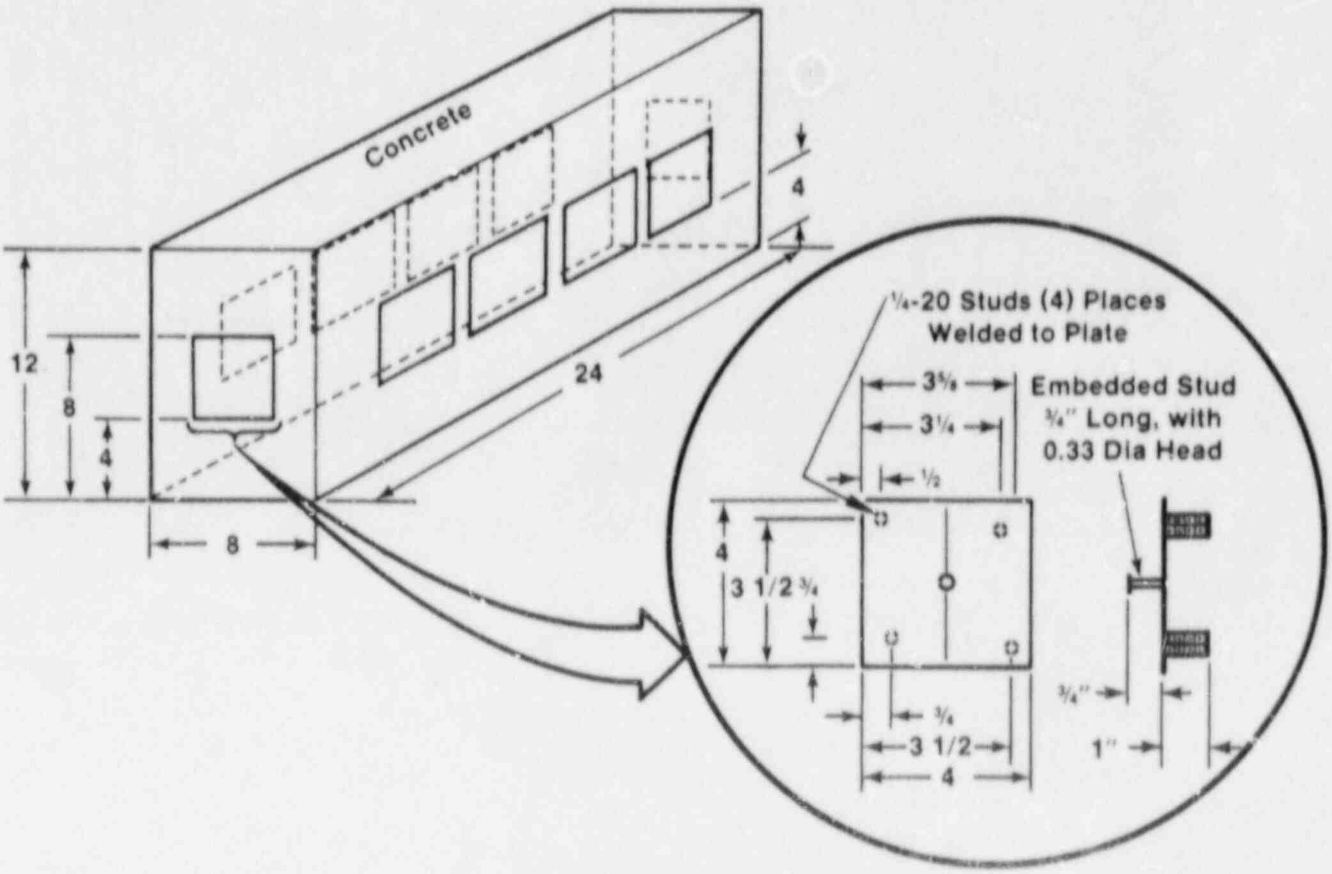


Figure 73. Specimen to Test Stud Pullout.

A 1/4-in.-thick steel plate and eye-bolt assembly was bolted to the specimen via the threaded studs. The concrete block and the test specimen were aligned in the load frame. The load was introduced by a chain coupled with a load cell as can be seen in Figure 74.

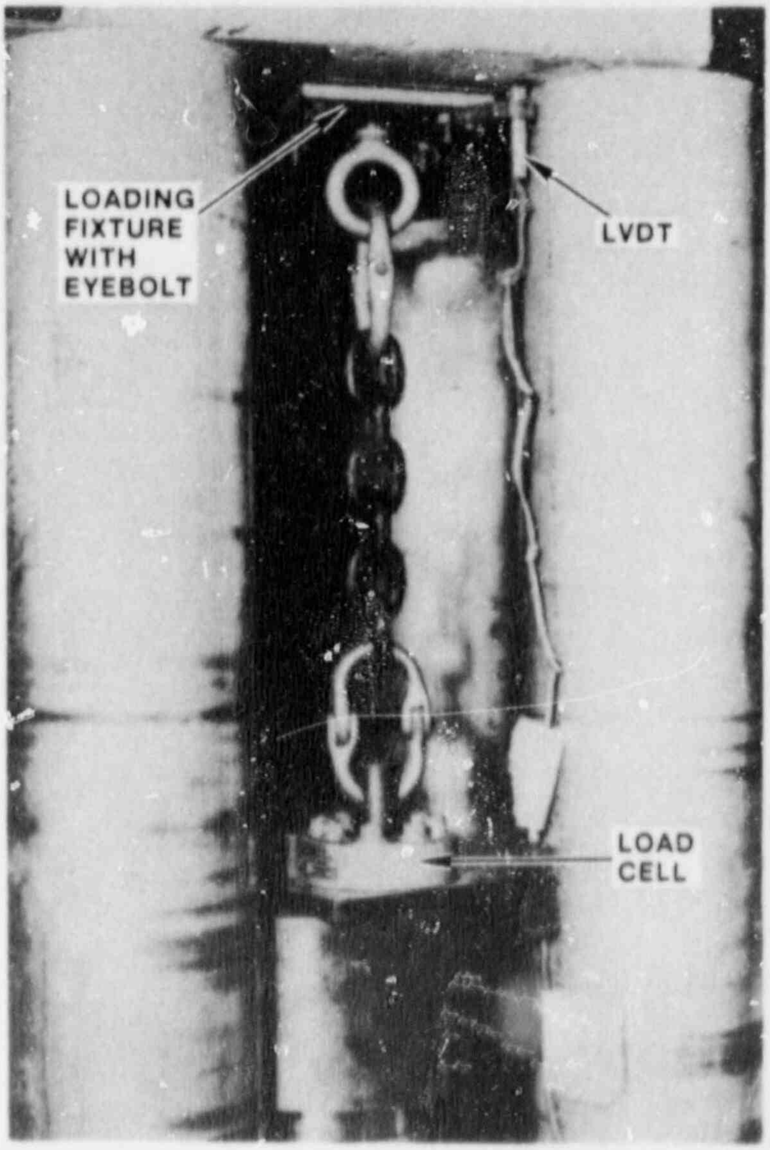


Figure 74. Test Setup for Tension Testing of the 3/4-in. Studs.

The results of these tests are presented in Table 11.

Two of these failure modes can be seen in Figure 75.

The second series of 3/4-in.-long stud tests consisted of loading the studs in shear. For these tests, one, two, or four studs were attached to the liner specimen as shown in Figure 76 and were embedded in concrete.

The test setup was much the same as for the pullout tests as can be seen in Figure 77.

Table 11

Summary of Results for Pullout Tests of 3/4-in.-Long Studs

Specimen ID	Maximum Load (lbs)	Failure Mode
CONP11	983	Concrete failure, stud pullout
CONP12	853	Fixture failure
CONP13	1089	Concrete failure, stud pullout
CONP14	1016	Concrete failure, stud pullout
CONP15	1104	Liner tear at stud weld
CONP16	1060	Concrete failure, stud pullout
CONP17	1010	Concrete failure, stud pullout
CONP18	1042	Stud weld failure (no hole in liner)
CONP19	1075	Liner tear at stud weld
CONP10	1088	Concrete failure, stud pullout

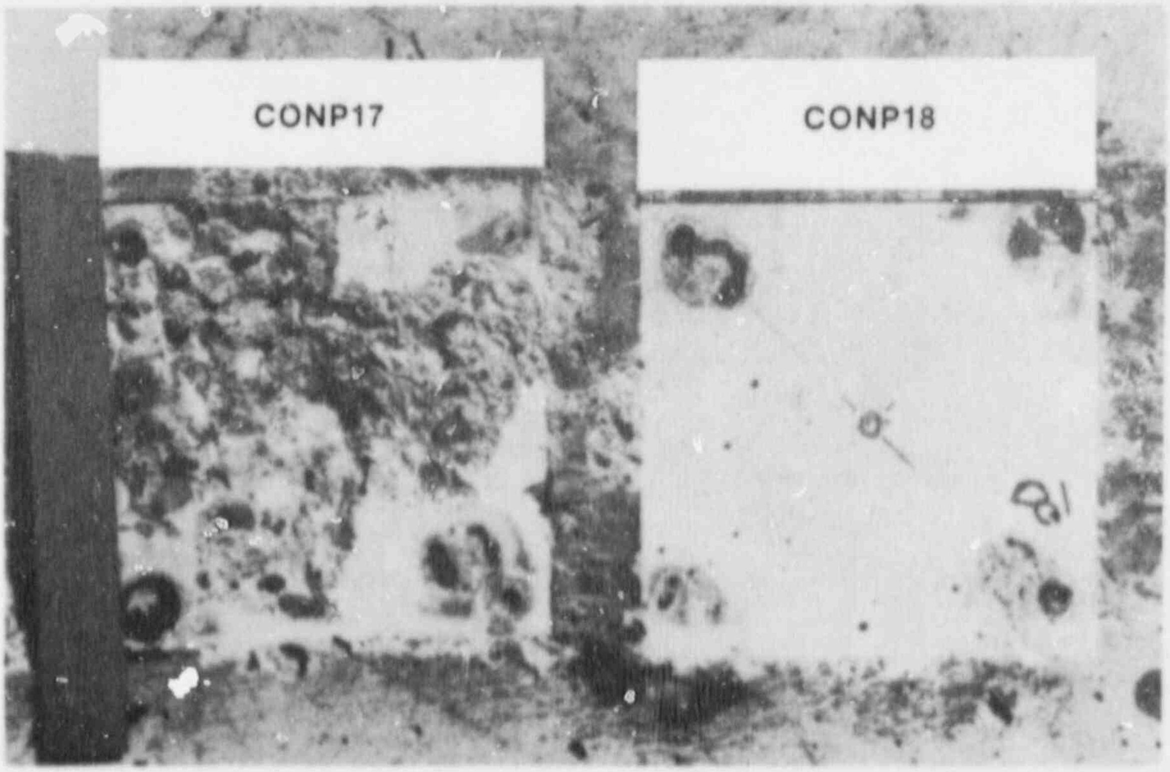


Figure 75. Typical Failure for Stud Pullout Tests.

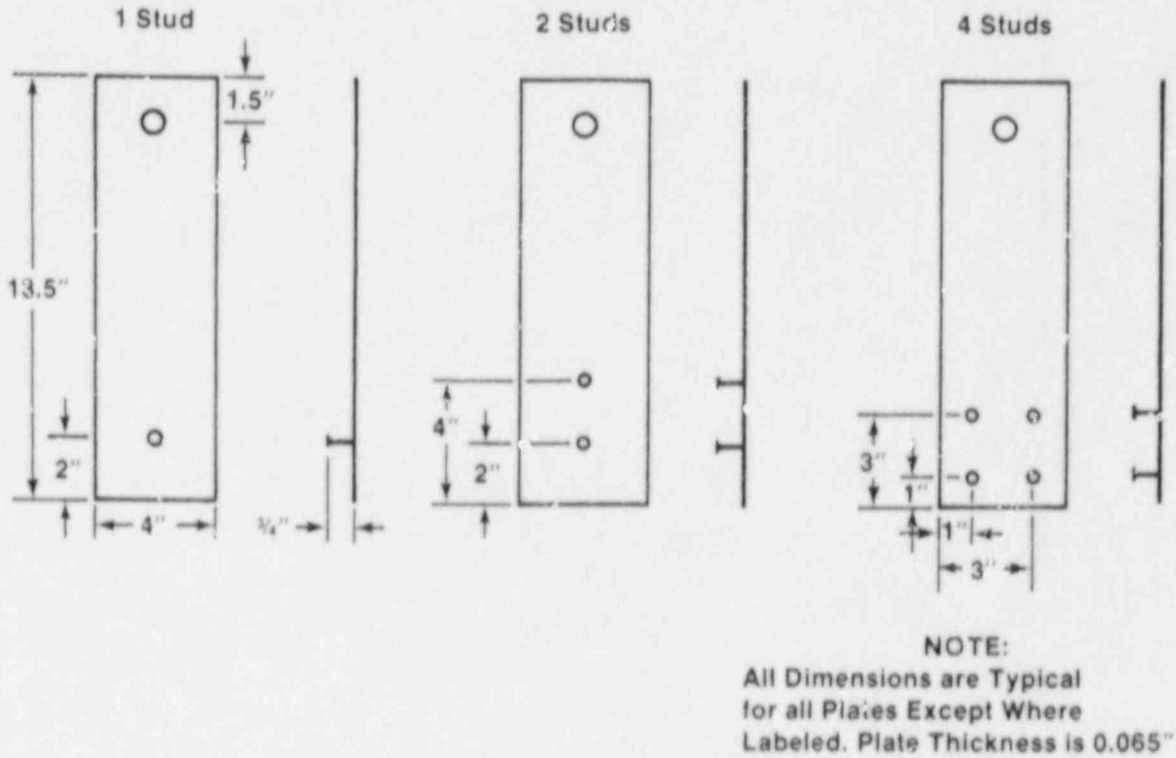


Figure 76. Specimen to Test Stud Shear Behavior.

With the specimens using multiple studs, it was anticipated that there would be some rotation of the specimen due to the load not being in line with the studs as studs failed. Although this rotation was observed and measured, it did not affect the results as much as anticipated. The average maximum load per stud was 1199 lbs, 1521 lbs, and 1417 lbs for the single-stud specimen, the two-stud specimen, and the four-stud specimen, respectively. The results from the ten shear tests are presented in Table 12.

5.3 Steel Testing

The testing of the steel constituents of the containment model was conducted at Sandia. A detailed report of the testing has been prepared [36] that describes the chemical composition of the steels, the effects of creep on the material properties, and the effects of construction practices on the prediction of yield and fracture stresses (such as cold working and the Bauschinger effect).

Some of the plots of the material properties found in Reference 36 are reproduced here.

5.3.1 Reinforcing Steel

The majority of the reinforcing steel used in the construction of the containment model was #4, which has a nominal diameter of 1/2 in. Other sizes of reinforcing steel were also used: #6, #5, and #3, as

Table 12

Summary of Results for Shear Tests of 3/4-in.-Long Studs

Specimen ID	Number Studs	Maximum Load (lbs)	Displacement at Max. Load (in.)	Load at Failure (lbs)	Displacement at Failure (in.)	Failure Mode
CONT11	1	1440	0.066	1095	.070	Shearing of stud material
CONT16	1	1136	0.039	1042	.052	Failure of weld
CONT17	1	756	0.012	756	.012	Failure of weld
CONT18	1	1463	0.038	1149	.054	Shearing of stud material
CONT22	2	3023	0.027	2801	.055	Shearing of stud material
CONT24	2	3165	0.025	2708	.043	Shearing of stud material
CONT25	2	2940	0.036	2563	.053	Shearing of stud material
CONT43	4	5729	0.014	5030	.043	2 studs shear 2 weld failures
CONT49	4	5356	0.034	4818	.052	3 studs shear 1 weld failure
CONT40	4	5918	0.028	5171	.044	Shearing of stud material

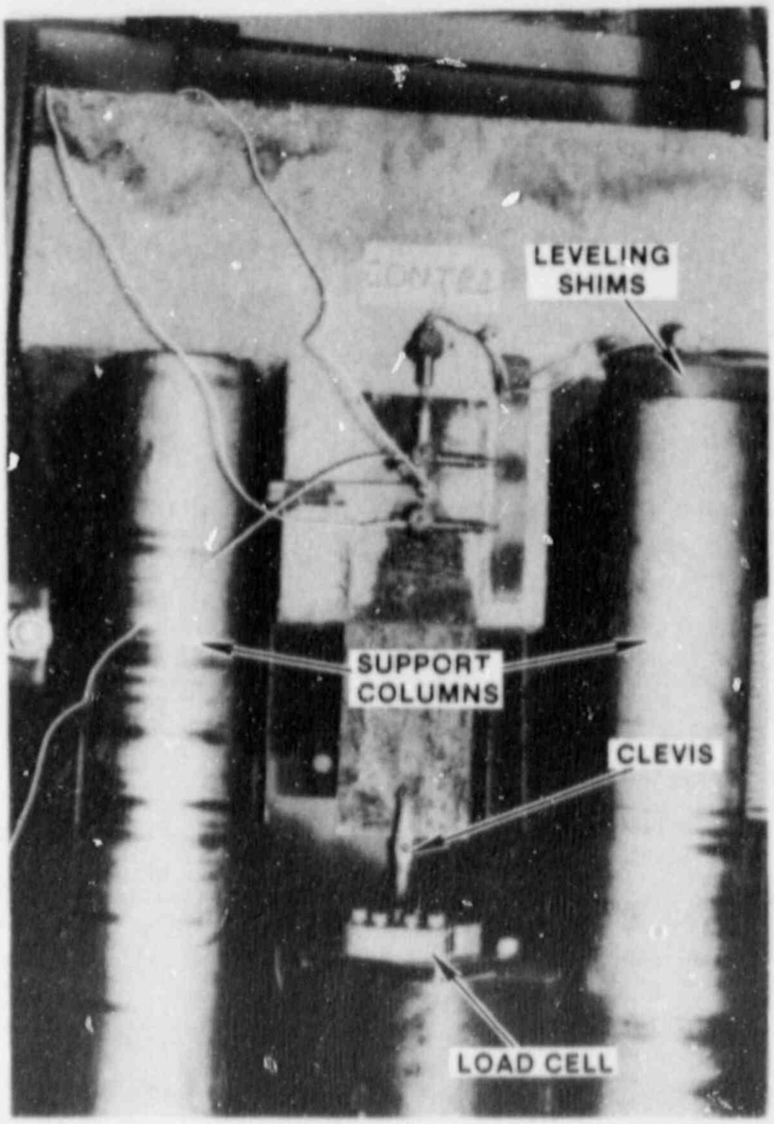


Figure 77. Typical Test Setup for Stud Shear Testing of the 3/4 in. Studs.

well as some imported reinforcing steel that was 6 mm in diameter. The ϕ6 through ϕ3 reinforcing was obtained from the same manufacturer, making their chemical and material properties very similar. Each size of reinforcing steel was rolled from one heat of steel, thus minimizing variations of the material properties for each size rebar.

A typical load-versus-strain plot is shown in Figure 78 for a specimen of ϕ4 reinforcing steel.

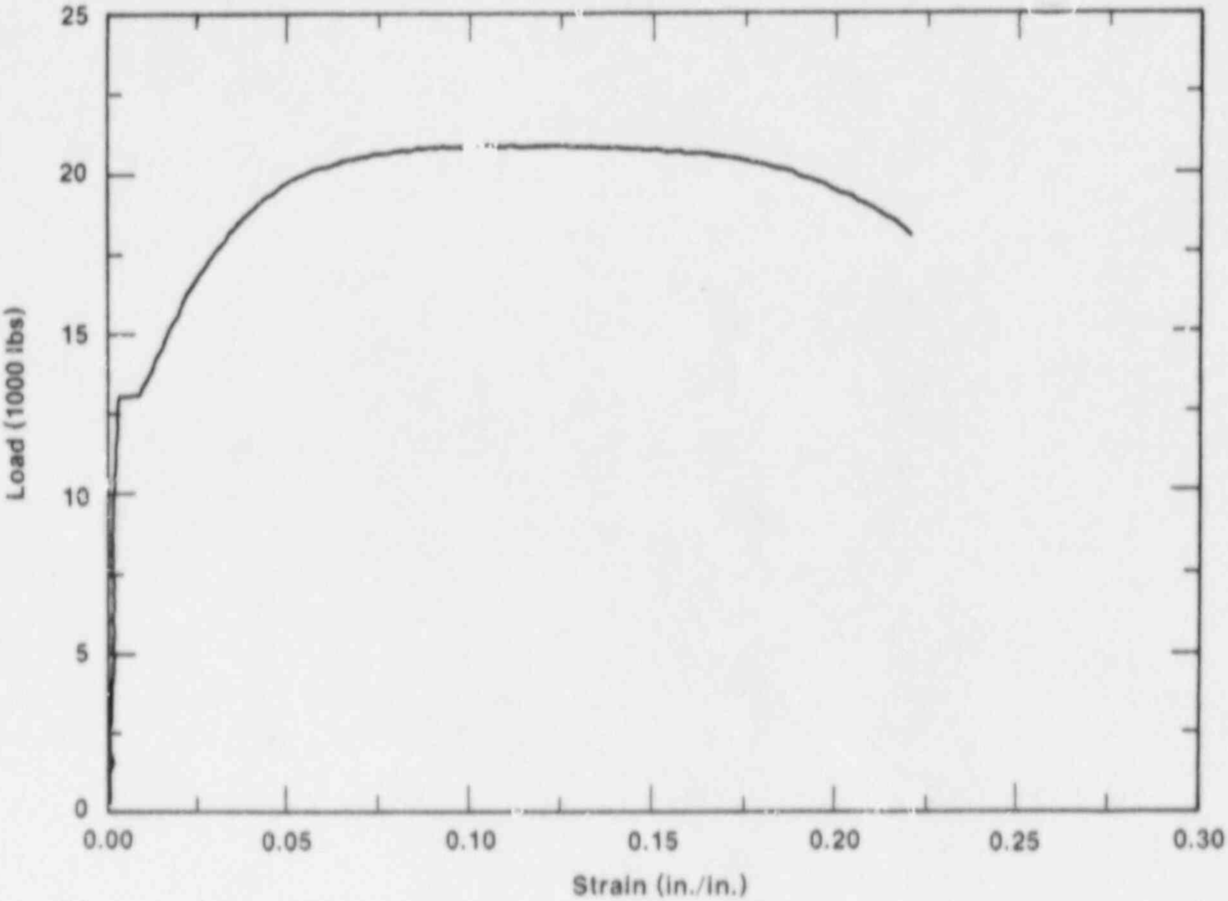


Figure 78. Typical Load/Engineering Strain Curve of the #4 Reinforcing Steel.

5.3.2 Liner Material

The liner material was also tested for both its chemical and structural properties [36]. Some typical engineering stress-strain curves are shown in Figure 79. The curves included in this figure were tested both parallel and perpendicular to the major rolling direction.

The stress used for plotting Figure 79 is based on the actual material thickness, which is 0.0680 in. thick.

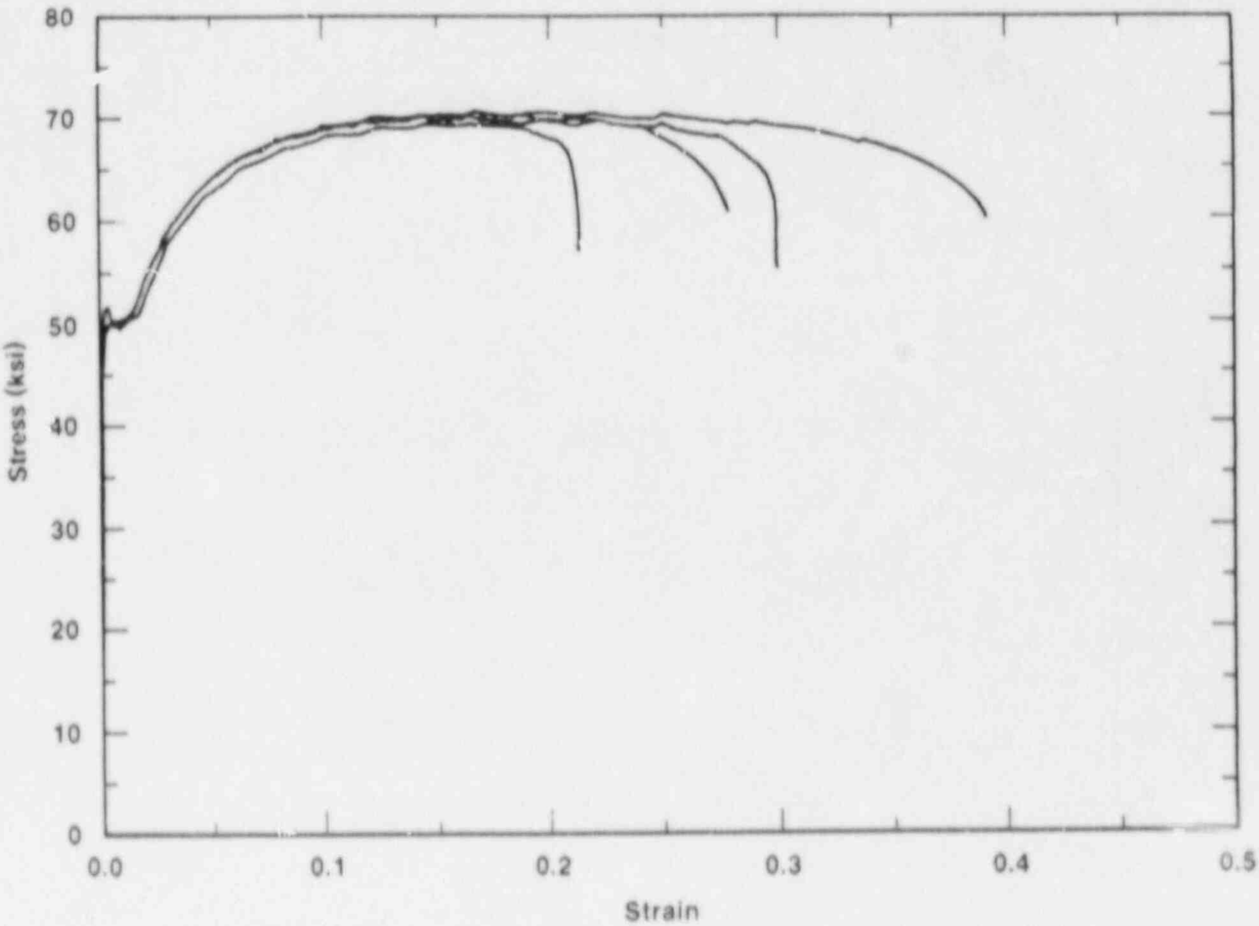


Figure 79. Engineering Stress-Strain Curves for the Cylinder Liner Material.

The liner material used in the dome was also tested. Samples were taken both before and after the dishing operation was performed. Figure 80 shows the results from these tests. As with the cylinder material, specimens that were taken both parallel to and perpendicular to the major rolling direction are plotted in the figure.

The stress plotted in Figure 80 is based on the actual material thickness, not the nominal thickness. The thickness of the dome liner material is 0.090 in. A well-defined yield plateau was not present in either the virgin material or the dished material.

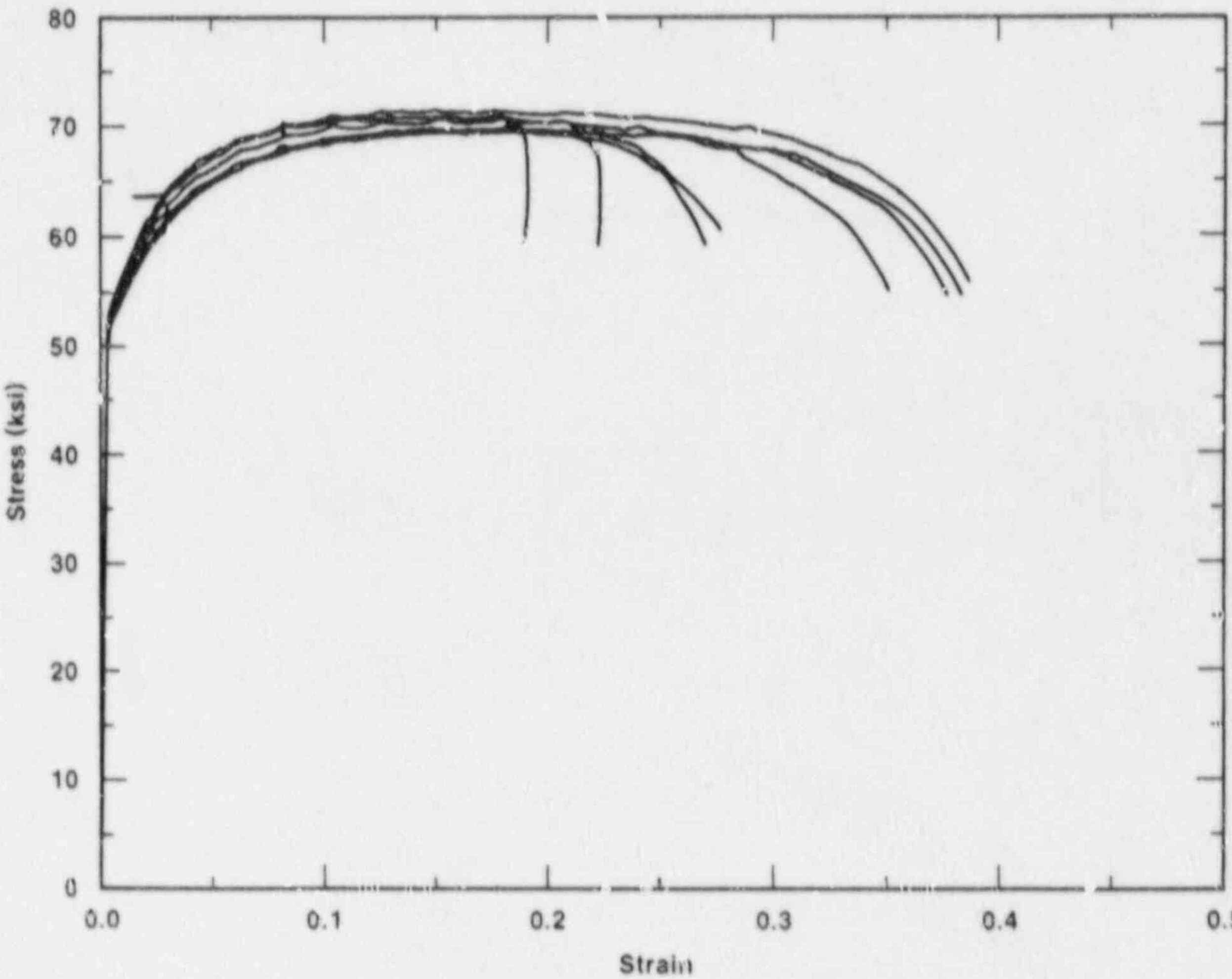


Figure 80. Engineering Stress-Strain Curves for the Dome Liner Material.

The insert plates that surround the penetration in the liner are made of A516 steel, with a thickness of 0.20 in. The engineering stress-strain curves for six samples of the insert plate material are plotted in Figure 81.

5.3.3 Weld Material

The strength and ductility of the weld material was also analyzed during the course of material testing. A stress-strain curve for the all-weld metal is shown in Figure 82 for the weld metal used for liner-to-liner welds in the cylinder. Additional all-weld and cross-weld samples were made and tested. The results from these tests are published in Reference 16.

The welds were found to be stronger than the material joined and the ductility of the all-weld material samples ranged from 8% to over 20% strain with a gage length of about 2 1/2".

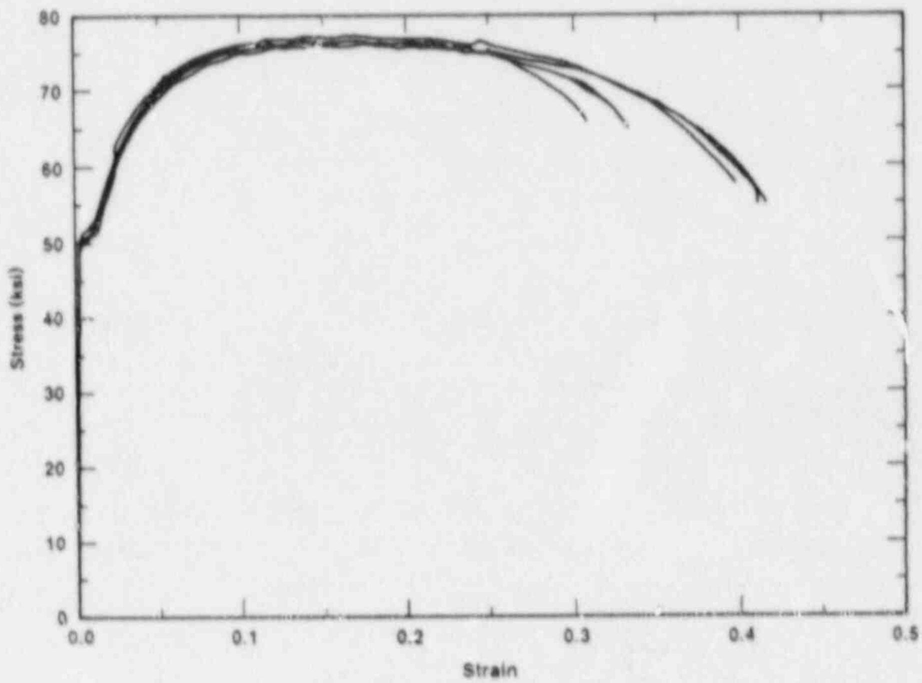


Figure 81. Engineering Stress-Strain Curves for the Liner Insert Plates.

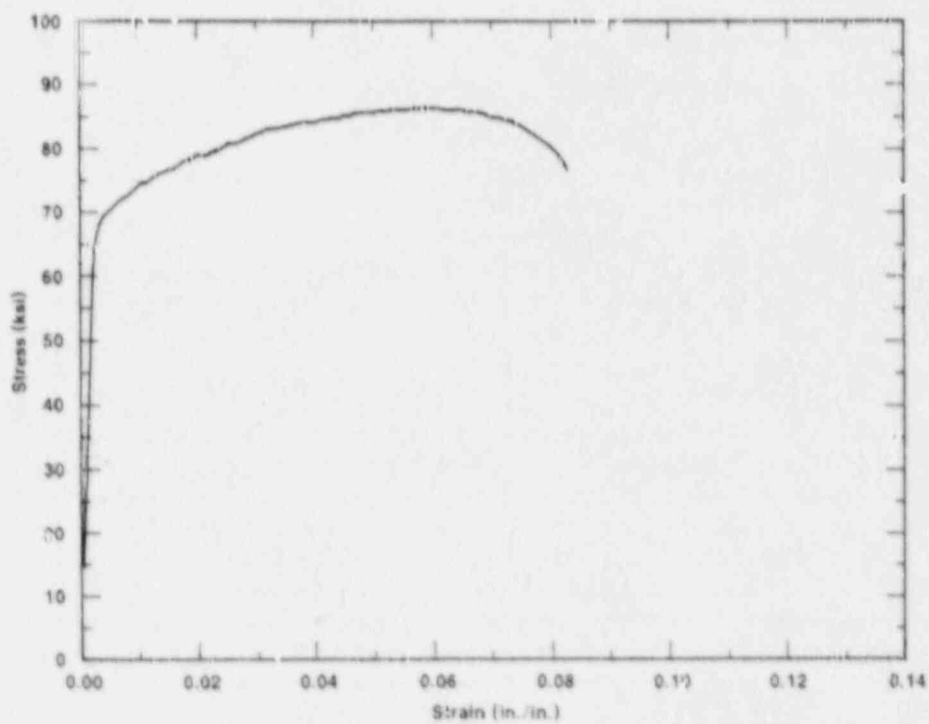


Figure 82. Engineering Stress-Strain Curve for All-Weld Metal Taken From a Cylinder Liner to Cylinder Liner Weldment.

5.3.4 Tests of Reinforcing Steel Splices[1]

Although many construction tests on the splices were performed during the course of construction, these tests only provided strength data and failure modes. A few splice specimens were tested at Sandia to determine the strain in both the bar and across the splice. Four of the samples and the attachment of instrumentation are sketched in Figure 83a-d. The measurements of the samples tested are listed in Table 13.

Table 13

Splice Samples Tested

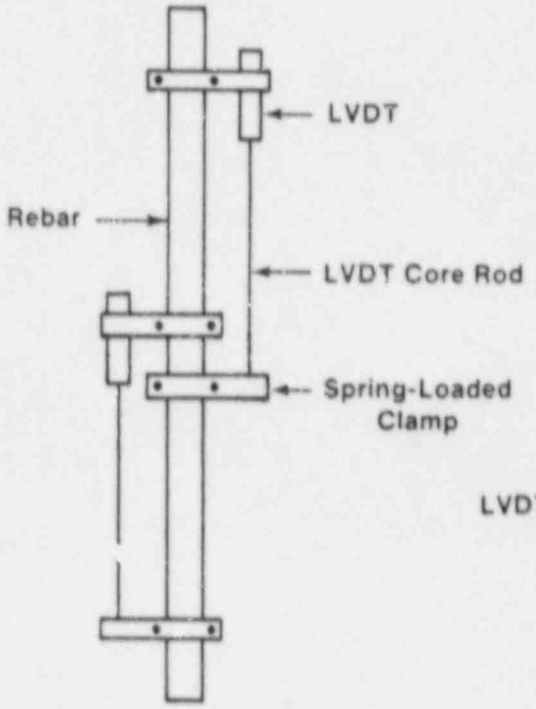
Joint Type	Size	Total Bar Lenth (in.)	Joint Length (in.)	LVDT Gage Lengths* Rebar(in.)	Joint(in.)
None	4	32.0		12.0	
Swaged	4	32.0	4.375	8.0	3.75
Threaded	4	31.875	6.125	9.0	5.75
Threaded Coupling	4	31.875	8.0	8.0	7.3

*See Figure 82.

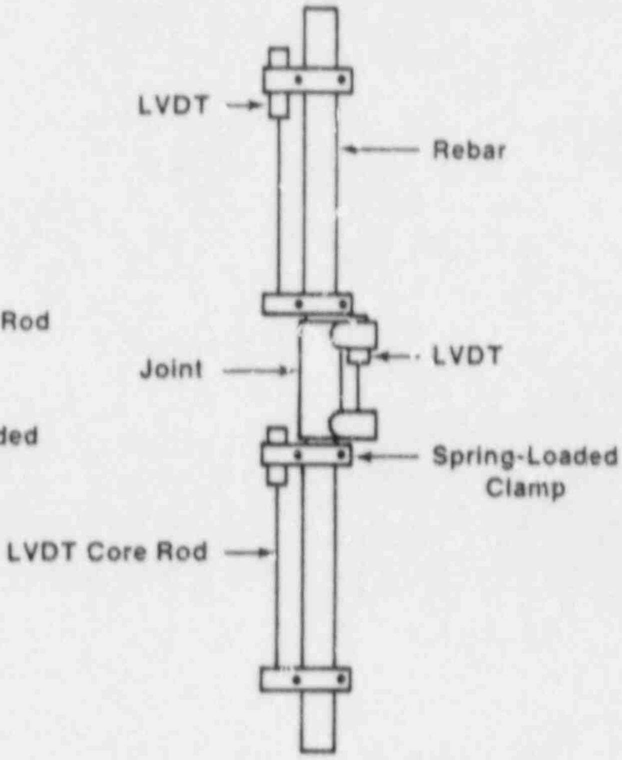
The splice specimens were tested in a 220,000-lb. testing machine with a constant rate ram displacement of approximately .005 in./s. As shown in Figure 83, the LVDTs were held to the specimen in two ways: spring-loaded clamps and epoxy. Machine load and stroke and the strains calculated from the LVDTs were recorded during the test. The amount of pullout of the reinforcing steel from the splice was measured with a steel ruler.

The results of the splice testing are shown in Table 14. All strain values listed in Table 14 are as measured at maximum load. By measuring the strain of sections of the specimen, the strain in a section and interaction with other sections can be deduced; however, the method in which total strains were calculated needs some explanation. The total bar strain was calculated by adding the displacements of the sections as measured by the LVDTs, adding in the amount of slippage of the reinforcing steel from the splice and dividing the sums by the

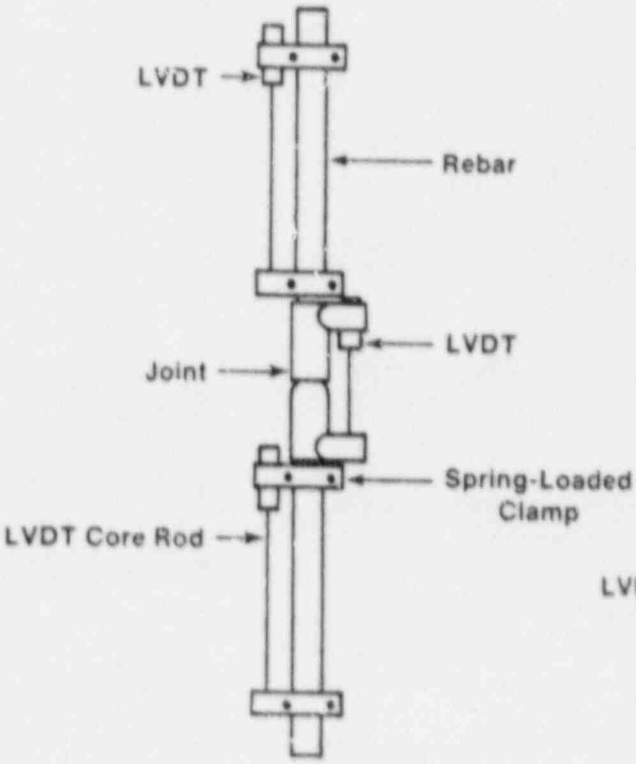
[1]This work was conducted at Sandia in the Geomechanics Division by Mark E. Stavik.



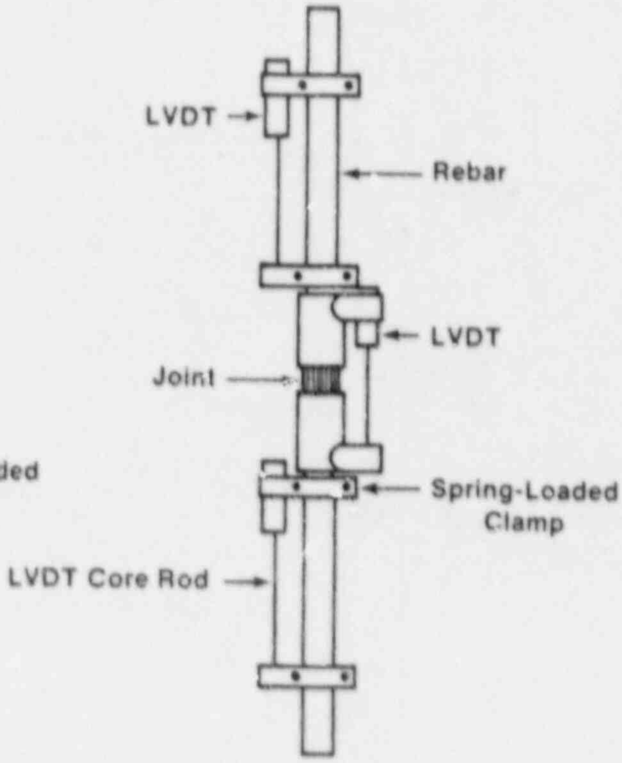
83a. Control Sample



83b. Fully Swaged Sample



83c. Threaded Joint Sample



83d. Threaded Coupling Sample

Figure 83. Reinforcing Splice Specimens.

Table 14

Results of Splice Tests

Sample ID	Joint	Size	Max Load (Kips)	Rebar Strain (%)	Joint Strain (%)	Total Bar Strain (%)	Comments
REBAR1	(None)	4	19.8	10.1		10.1	
REBAR2	(None)		20.6	10.0		10.0	
REBAR3	(None)		20.5	10.4		10.4	
FT1	Swaged	4	19.7	9.4	0.36	8.3	
FT2			19.4	10.7	0.51	9.5	
FT3			19.6	11.9	0.20	10.5	
FT4			19.1	8.6	0.18	7.7	
FT5			20.1	11.0	0.05	9.7	
FT6			20.0	9.2	0.25	8.2	
FT7			20.3	10.8	0.11	9.4	
FT8			20.4	8.6	0.10	7.7	
FT9			20.8	10.7	0.08	9.5	
FT1215	Threaded	4	21.0	8.9	0.48	7.5	
FT1114			21.0	9.3	0.39	7.7	
FT1013			--	--	--	-	Jaws failed[1]
FT1619	Threaded Coupling	4	--	--	--	-	Jaws failed[1]
FT1720			20.8	11.6	0.39	9.0	
FT1821			20.5	10.1	0.49	7.9	

[1]Clamping jaws failed before maximum load was reached.

entire bar length (including the section of the bar that was in the jaws of the testing machine.)

A typical engineering load-strain plot for the sections of the spliced reinforcing bar is shown in Figure 84.

The amount of slippage of the reinforcing steel from each end of the splice was approximately 1/16 in. in every test. In every test presented, failure occurred in the reinforcing steel. (In two tests the testing jaws failed, however, the results from these tests are not presented.)

Other steel materials were used in the construction of the containment model. Information on these other materials as well as additional information on the liner material may be found in Reference 36.

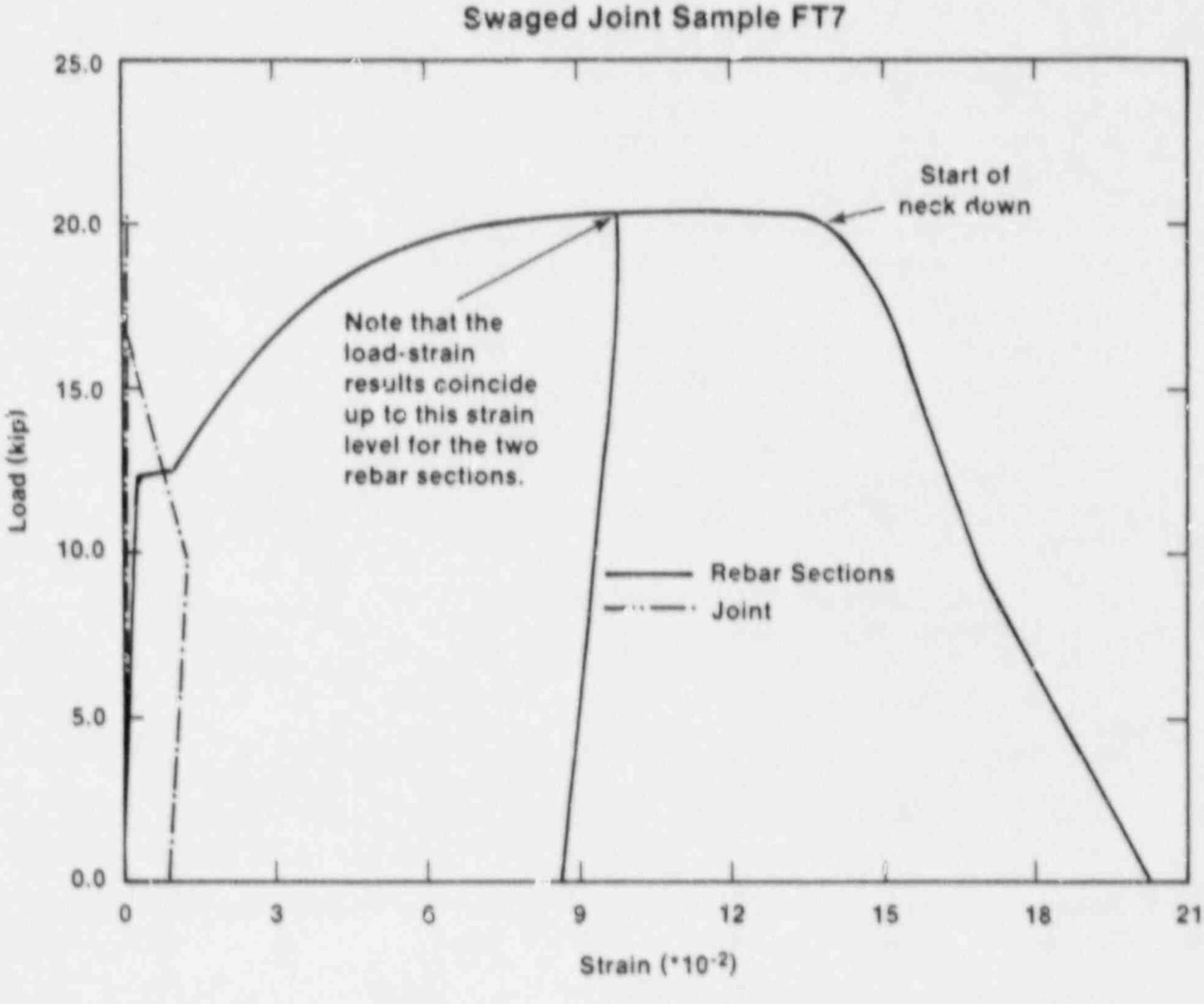


Figure 84. Typical Engineering Load-Strain Plot for Sections of a Spliced Reinforcing Bar

6. CONTAINMENT TESTING

The model will be tested much as a full-size prototypical containment would be, that is, a Structural Integrity Test (SIT) and an Integrated Leak Rate Test (ILRT) will be conducted. A computer-controlled valve gallery controls gas flow both into and out of the containment model. The valve system has a maximum flow rate of 6 lbm/s, allowing a small increase in pressure to be applied in fractions of a minute.

6.1 Plans for Low-Pressure Testing

After all instrumentation has been checked, the containment model will be pressurized in five steps, using dry air, to 53 psig, 1.15 times its design pressure. Inspection of the containment model, including measuring and mapping cracks in specific areas, will be conducted at each pressure step. The pressure in the containment model will be reduced back to ambient in five steps; however, crack mapping will be conducted at ambient pressure only. A full scan of all transducers will also be conducted at each step as pressure is both increased and decreased.

Following the SIT, instrumentation will be added to the cracks that formed during testing. Twenty displacement transducers are reserved for attachment across cracks, and about 40 strain gages will be used to measure strain in the vicinity of the cracks (both on the concrete and at the liner). An ILRT will be conducted after the SIT.

The ILRT will be performed at 46 psig and leakage will be brought into less than 0.2% mass/day. The method for calculating the leak rate is based on ANSI 56.8 [37]. Two methods, total time and mass-point-leak-rate, will be used during leakage testing. Following the ILRT, small orifices will be placed in the containment model (through a port at the valve gallery) and leakage will again be measured. This will serve as a check on the implementation of the ANSI leak rate equations.

A flow meter will be used to measure larger leaks, should they occur during high-pressure testing.

6.2 Plans for High-Pressure Testing

High-pressure testing will be conducted as a continuous test, being manned 24 h a day. Nitrogen gas will be used to pressurize the containment for high-pressure testing. The nitrogen will be trucked to the site in liquid form and gasified as it enters the pressure lines. In this way, a large amount of gas is available and can be fed into the lines at high flow rates if significant leakage develops during testing.

Initial pressure steps will be about 10 psi and will be reduced as the containment begins to respond nonlinearly. The temperature in the containment is controlled to slightly above ambient. Shortly after each pressure step all transducers will be scanned. As these data are being reviewed, selected transducers on the containment model will be scanned to monitor creeping of the model, photographs will be taken, and the model will be surveyed with the remotely controlled video cameras. It is anticipated that these activities will take about 1 h. It is also anticipated that the containment model will not fully stabilize, especially at higher pressures during this time. The pressure will, nevertheless, be increased to the next pressure step after another complete scan of the transducers has been completed. This sequence will be completed several times until the containment model fails. Intermittently throughout this sequence of transducer scans and pressurization, leak-rate measurements will be taken. The frequency and duration of leak-rate measurements will depend on testing conditions, the state of the containment model, and feedback from the acoustic emission system.

The test will be terminated when either excessive leakage or structural failure of the containment model occurs. Obviously, leakage out of the containment can only be fed if it does not exceed the system's capacity. The leakage could be due to excessive deformations around penetrations or due to a local failure of the containment shell. After depressurization and inspection of the containment, the model may be repaired and retested.

An energetic failure of the containment model may also conclude the test. This type of failure is usually associated with a more complete failure of the containment model and is not conducive to repair or retesting. The containment model is scheduled to begin low-pressure testing in July 1987, followed by high-pressure testing.

7. ANALYSES

Performing an adequate analysis of the containment model subjected to overpressurization is indeed the motivating factor behind this testing program. This experiment is seen as a challenge to the analyst and the analyst's tools. It is highly impractical to test every design of containment according to every accident scenario because of time and cost considerations. The intent of the program has been to generate data that can be used to qualify analytical tools. These analytical tools can then be used to extrapolate the performance of full-size containment buildings subjected to hypothesized severe accidents. To this end, Sandia, as well as several other national and international organizations, conducted pretest analyses of the containment building. The following list identifies the groups that participated and are published in Reference 38:

- Sandia National Laboratories (USA)
- Argonne National Laboratory (USA)
- Electric Power Research Institute (USA)
- Commissariat a l'Energie Atomique (France)
- HM Nuclear Installations Inspectorate (U.K.)
- Comitato Nazionale per la ricerca e per lo sviluppo dell-'Energia Nucleare e delle Energie Alternative (ENEA) (Italy)
- U.K. Atomic Energy Authority, Safety and Reliability Directorate (U.K.)
- Gesellschaft fuer Reaktorsicherheit (GRS) (Federal Republic of Germany)
- Brookhaven National Laboratory (USA)
- Central Electricity Generating Board (U.K.).

Each group that performed an analysis was given detailed construction drawings and specifications, and actual material properties of the construction materials as they became available. Each organization worked independently using an analytical method of its choosing. The results of these analyses are presented in Reference 38. Further pretest analyses performed by Sandia can be found in References 39, 40.

8. REFERENCES

[1] D. S. Horschel, "Construction of a 1/6-Scale Concrete Containment," Nuclear Engineering and Design, Vol. 104, p. 341-347, 1987.

[2] J. J. Ucciferro, A. J. Hulshizer, and G. E. Gray, "Design and Construction of a 1/6 Scale LWR Reinforced Concrete Containment Model," in Proceedings of the American Power Conference, Chicago, Illinois, April 1986.

[3] D. S. Horschel, "The Testing of a 1:6-Scale Reinforced-Concrete Containment Model," in Proceedings of the American Power Conference, Vol. 49, Chicago, Illinois, April 1987.

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APPENDIX A
TYPE AND LOCATION OF INSTRUMENTATION

Paul Lefebre
David Leyva

CONTENTS

A-1. INTRODUCTION

This series of mechanical inspection reports was produced by Paul Lefebre and David Leyva of Sandia's Mechanical Measurements Division. The measurements, explanations of the measurements, and drawings of several features of the containment model are included. Some instrumentation, however, is not included in this appendix: the instrumentation that was embedded in the containment wall. The information on the embedded instrumentation may be found in the drawings included in the body of this report.

Accuracy of Measurements

Linear measurement inaccuracies were maintained within 1/8 in. and angular measuring inaccuracies were maintained within two minutes for the measurements presented in this appendix.

Summary

This report documents the mechanical measurement tasks that were performed on the 1:6 reinforced-concrete model located at the 9806 test area. General measurements of the reinforced-concrete model (rcm) are included along with detailed measurement data for particular features, strain gages, displacement gages, thermocouples, acoustic sensors, tilt sensors, and related internal and external structures. The measurement data are presented in pictorial form in the appendix.

A-2. GENERAL INFORMATION

Location, Size, Inward Projection of Penetrations
Vertical Locations of Concrete and Gratings

Work this report with drawings A1, A5, or A8, which are located at the end of this appendix.

Detail	Azimuth	Vertical	Inward Project	Diameter
EH-A	zero set	156.370"	4.430"	O.D. 41.00"
19-A	same	same		
EH-B	180.008	157.220"	10.150"	O.D. 41.100"
15-A	159.602			
	201.266			
E-1	51.077	106.625"		O.D. 7.750"
E-2	62.753	106.625"		O.D. 7.750"
25-B	34.702	117.200"		
	66.985	96.200"		
E-3	39.090	158.550"		O.D. 7.750"
E-4	50.823	158.400"		O.D. 7.750"
E-5	62.465	158.350"		O.D. 7.750"
25-A	34.516	169.625"		
	67.173	148.625"		
PL-A	89.881	156.430"	4.400"	I.D. 20.000"
22-A	same	same		O.D. 27.800"
R-1	134.975	241.440"	3.500"	O.D. 8.600"
29-A	same	same		O.D. 27.800"
A	234.497	106.450"	5.700"	O.D. 4.500"
B	226.706	115.488"	4.930"	O.D. 1.323"
C	230.612	115.410"	4.850"	O.D. 2.380"
D	234.519	115.555"	4.750"	O.D. 2.390"
I	230.577	106.300"	4.850"	O.D. 8.500"
24-A	222.192	119.600"		
	237.601	92.900"		
PL-B	269.972	156.560"	4.350"	I.D. 19.100"
21-A	same	same		O.D. 27.900"
R-2	314.943	241.500"	3.500"	O.D. 8.680"
29-A	same	same		O.D. 26.880"
P	329.906	45.100"	0	I.D. 3.825"
23-A	same	same		O.D. 14.625"
BTM/Contmnt		24.000"		
Concrete		39.750"		
Grating		133.500"		
Grating		229.400"		
Grating		325.400"		
Dome/cyl		287.625"		
Top Column		235.850"		

A-3. STRAIN GAGE DATA

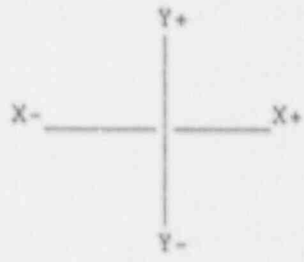
A-3.1 Description of Coordinate Systems

1. The location of each gage is described using the (a) global, (b) local, or (c) cartesian coordinate system as defined below. The coordinate system (a, b, or c) used to describe the location of each gage is noted in column 4 of the listed data.

   a. The global coordinate system is used to describe the location of gages about the vessel. Angular location of each gage is in a clockwise direction from penetration EH-A centerline (00 degrees) as viewed from above the vessel. The vertical location of each gage is from a benchmark located outside the vessel and marked -1.667 ft.

   b. The local system is used to describe the location of gages about the penetrations. The local system is a cylindrical system with the zero-degree orientation at the top and angular increases in the clockwise direction (viewing the penetration from inside the model). The linear measurement recorded indicates gage location relative to the data identified on the detail drawing of the related penetration.

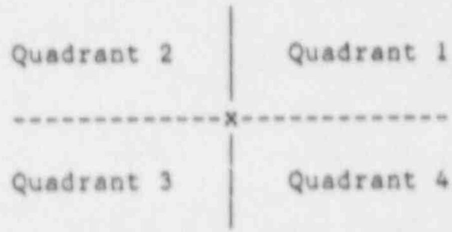
   c. The cartesian coordinate system is used to describe the location of gages located on flat features of penetrations (i.e. PL-A). The center of the penetration is the origin of this system with the "x" axis being horizontal location and the "y" axis being the vertical location (as viewed from inside the model). The sign preceding each recorded value is pictorially represented below.



2. All strain gages of the same type are listed together in assigned numerical sequence.

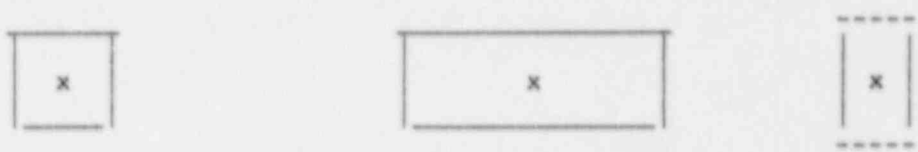
3. The measured point of each 45-degree rosette is the intersection arrow on each gage.

4. The orientation of each 45-degree rosette is represented using the quadrant system pictured below (viewing the gage). The intersection arrow, located on the gage, points to the intersection of the quadrant lines (x) in all cases.



5. The measured point of each single strain gage, strip strain gage and Tee-Rosette strain gage is the center of the gage as pictured below.

Single Strain Gage | Strip Strain Gage | Tee-Rosette



6. The orientation of each single gage and strip gage, denoted by "M" for meridional or "C" for circumferential, indicates the direction in which the gage measures.

7. All angular values listed in the azimuth column are in decimal degrees.

8. All linear values listed in the vertical column are in inches and are measured from the benchmark located outside the model (-1.677 ft).

9. The numbered columns on the succeeding pages contain gage information as listed below:

    1. Quadrant (i.e., 1, 2, 3, or 4)
    2. Tap test (S= solid, H= hollow)
    3. Special location (i.e., EH-A, EH-B, PL-A, etc.)
    4. System used to locate gage (i.e., a, b, or c from preceding page.)

A.3.2. <u>Data on 45-degree Rosettes</u>

Work this report with drawings A1 through A7, which are located at the end of this appendix.

Gage #	Gage type	Azimuth	Vertical	1	2	3	4
R013	350 OHM	11.221	156.150"	4	S		A
R014	350 OHM	12.094	156.200"	4	S		A
R015	350 OHM	12.953	155.200"	4	S		A
R016	350 OHM	13.831	156.200"	4	S		A
R017	350 OHM	16.869	156.200"	4	H		A
R018	350 OHM	19.470	156.200"	4	S		A
R019	350 OHM	0.087	182.200"	4	S		A
R020	350 OHM	0.115	184.200"	4	S		A
R021	350 OHM	0.116	186.200"	4	S		A
R022	350 OHM	0.100	188.240"	4	S		A
R023	350 OHM	0.092	194.200"	4	H		A
R024	350 OHM	0.092	200.200"	4	H		A
R025	350 OHM	359.500	61.900"	3	S		A
R026	350 OHM	359.470	99.750"	3	H		A
R027	350 OHM	44.478	26.500"	4	S		A
R028	350 OHM	44.175	49.200"	4	S		A
R029	350 OHM	45.043	65.900"	4	S		A
R030	350 OHM	45.347	80.400"	4	S		A
R031	350 OHM	44.956	106.100"	4	S		A
R032	350 OHM	45.086	117.900"	1	S		A
R033	350 OHM	45.303	128.205"	4	S		A
R034	350 OHM	89.153	32.320"	4	S		A
R035	350 OHM	89.153	39.320"	4	S		A
R036	350 OHM	89.218	43.870"	3	S		A
R037	350 OHM	89.218	49.590"	4	S		A
R038	350 OHM	89.218	54.120"	2	S		A
R039	350 OHM	89.869	85.500"	3	H		A
R040	350 OHM	89.782	118.300"	4	S		A
R041	350 OHM	89.240	132.110"	4	S		A
R042	350 OHM	91.888	63.600"	1	H		A
R043	350 OHM	179.500	62.050"	3	H		A
R044	350 OHM	179.557	99.280"	3	H		A
R045	350 OHM	221.856	107.120"	3	S		A
R046	350 OHM	228.234	26.350"	4	S		A
R047	350 OHM	228.334	63.600"	1	S		A
R048	350 OHM	228.473	92.300"	4	S		A
R049	350 OHM	228.300	106.520"	3	S		A
R050	350 OHM	228.603	120.220"	1	S		A
R051	350 OHM	269.609	62.100"	3	H		A
R052	350 OHM	269.630	99.630"	3	H		A
R053	350 OHM	269.444	119.740"	3	S		A
R054	350 OHM	315.000	62.160"	4	S		A
R055	350 OHM	314.913	99.660"	4	H		A

Gage #	Gage type	Azimuth	Vertical	1	2	3	4
R056	350 OHM	179.947	110.150"	2	S		A
R057	350 OHM	180.000	116.000"	3	S	15-A	
R058	350 OHM	180.000	117.600"	3	S	15-A	
R059	350 OHM	180.000	135.770"	3	S	15-A	
R060	350 OHM	0.197	212.600"	4	H		A
R061	350 OHM	7.526	173.800"	4	S		A
R062	350 OHM	13.572	187.500"	4	H		A
R063	350 OHM	44.908	139.500"	3	S		A
R064	350 OHM	45.928	160.440"	3	S		A
R065	350 OHM	45.103	169.380"	2	S		A
R066	350 OHM	45.515	194.420"	3	S		A
R067	350 OHM	45.884	213.820"	2	H		A
R068	350 OHM	46.321	229.760"	3	S		A
R069	350 OHM	82.987	158.360"	3	S		A
R070	350 OHM	89.481	141.240"	3	S		A
R071	350 OHM	89.976	145.320"	3	S		A
R072	350 OHM	89.536	167.550"	2	S		A
R073	350 OHM	89.819	170.980"	2	S		A
R074	350 OHM	89.862	176.350"	2	S		A
R075	350 OHM	89.775	212.730"	3	H		A
R076	350 OHM	133.642	155.130"	3	S		A
R077	350 OHM	157.841	154.350"	3	H		A
R078	350 OHM	159.665	154.350"	3	S		A
R079	350 OHM	161.269	157.740"	2	S	15-A	
R080	350 OHM	161.754	157.740"	[illegible]	S	15-A	
R081	350 OHM	165.403	189.350"	2	S		A
R082	350 OHM	166.778	180.200"	3	S	15-A	
R083	350 OHM	167.283	185.300"	3	S	15-A	
R084	350 OHM	170.193	157.060"	3	S	15-A	
R085	350 OHM	180.008	178.380"	2	S	15-A	
R086	350 OHM	179.963	196.920"	3	S	15-A	
R087	350 OHM	179.963	198.720"	3	S	15-A	
R088	350 OHM	180.262	204.420"	1	S		A
R089	350 OHM	189.508	215.340"	4	H		A
R090	350 OHM	228.366	156.950"	3	S		A
R091	350 OHM	228.366	185.500"	3	S		A
R092	350 OHM	228.366	203.650"	3	S		A
R093	350 OHM	260.912	157.600"	3	S		A
R094	350 OHM	263.673	157.600"	3	S		A
R095	350 OHM	269.727	142.820"	3	S		A
R096	350 OHM	269.735	156.250"	2	S		A
R097	350 OHM	269.735	176.330"	2	S		A
R098	350 OHM	314.879	156.250"	3	S		A

Gage#	Gage type	Azimuth	Vertical	1	2	3	4
R099	350 OHM	0.093	249.125"	3	S		A
R0100	350 OHM	0.226	286.650"	3	H		A
R0101	350 OHM	44.462	249.000"	3	H		A
R0102	350 OHM	44.525	286.500"	3	H		A
R0103	350 OHM	44.358	288.000"	1	S	DOME	A
R0104	350 OHM	44.901	317.751"	3	S	DOME	A
R0105	350 OHM	89.901	249.290"	3	S		A
R0106	350 OHM	90.214	286.820"	3	H		A
R0107	350 OHM	90.244	288.230"	1	H	DOME	A
R0108	350 OHM	90.137	313.089"	4	H	DOME	A
R0109	350 OHM	112.663	240.850"	3	S		A
R0110	350 OHM	128.794	241.110"	3	S		A
R0111	350 OHM	134.703	286.900"	3	S		A
R0112	350 OHM	179.859	247.375"	3	S		A
R0113	350 OHM	179.888	286.930"	3	H		A
R0114	350 OHM	224.644	248.450"	3	H		A
R0115	350 OHM	228.297	287.150"	3	H		A
R0116	350 OHM	228.322	288.150"	1	H	DOME	A
R0117	350 OHM	228.326	312.987"	3	S	DOME	A
R0118	350 OHM	269.938	248.750"	3	S		A
R0119	350 OHM	292.522	241.500"	3	S		A
R0120	350 OHM	307.943	241.500"	3	H		A
R0121	120 OHM	308.879	241.480"	3	S		A
R0122	350 OHM	309.436	241.480"	4	S		A
R0123	120 OHM	314.974	246.550"	2	S		A
R0124	350 OHM	314.969	254.000"	4	S		A
R0125	350 OHM	315.351	255.570"	1	S		A
R0126	350 OHM	315.438	286.490"	4	H		A
R0127	350 OHM	90.163	339.875"	4	S	DOME	A
R0128	350 OHM	90.239	370.875"	4	S	DOME	A
R0129	350 OHM	90.234	389.500"	4	S	DOME	A
R0130	350 OHM	90.097	402.625"	4	H	DOME	A
R0131	350 OHM	90.091	406.875"	4	S	DOME	A
R0132	350 OHM	90.150	410.125"	4	S	DOME	A
R0133	350 OHM	90.150	413.125"	4	H	DOME	A
R0134	350 OHM	90.150	416.125"	4	S	DOME	A
R0135	350 OHM	90.150	417.675"	4	S	DOME	A
R0136	350 OHM	228.119	346.125"	3	H	DOME	A
R0137	350 OHM	228.585	377.500"	3	S	DOME	A
R0138	350 OHM	229.345	402.375"	3	H	DOME	A
R0139	350 OHM	TDC	418.875"	1	H	DOME	A
R0140	350 OHM	0.000	PROJ. -.300"	4	S	COVER A	B
R0141	350 OHM	0.000	PROJ. +.300"	1	S	EH-A	B

Gage #	Gage type	Azimuth	Vertical	1	2	3	4
RO142	350 OHM	269.954	-0.200"	3	S	COVER B	B
RO143	350 OHM	269.954	0.300"	4	S	EH-B	B
RO144	350 OHM	269.954	28.650"	3	S	EH-B	B
RO145	350 OHM	269.954	29.250"	4	S	COVER B	B
RO146	350 OHM	359.622	-0.300"	4	S	COVER B	B
RO147	350 OHM	359.622	0.300"	4	S	EH-B	B
RO148	350 OHM	359.479	28.700"	3	S	EH-B	B
RO149	350 OHM	359.479	29.250"	4	S	COVER B	B
RO150	350 OHM	X=-1.700	Y=00.000"	3	S	EXT.EH-B	C
RO151	350 OHM	270.000	PROJ. -.300"	2	S	COVER A	B
RO152	350 OHM	270.000	PROJ. +.300"	3	S	EH-A	B
RO153	350 OHM	181.998	213.010"	3	H		A
RO154	350 OHM	X=+0.210"	Y=-0.120"	3	S	PL-A	C
RO155	120 OHM	X=+0.380"	Y=+6.670"	2	S	PL-A	C
RO156	120 OHM	X=+0.420"	Y=+9.370"	4	S	PL-A	C
RO157	120 OHM	87.640	PROJ.3.500"	3	S	PL-A	B
RO158	120 OHM	X=+3.650"	Y=-0.140"	3	S	PL-A	C
RO159	120 OHM	X=+3.700"	Y=+6.720"	2	S	PL-A	C
RO160	120 OHM	X=+9.185"	Y=+0.880"	2	S	PL-A	C
RO161	120 OHM	357.315	PROJ.3.300"	3	S	PL-A	B

A-3.3. Single Strain Gages

Gage #	Horizontal angle	Vertical angle	Tap test	Note #2	Note #1
S1	359.868	24.000"	S	C	1.300" From wall
S2	89.624	24.000"	H	M	1.760" From wall
S3	89.550	24.000"	S	M	Bottom of Radius
S4	89.550	24.000"	S	M	Top of Radius
S5	90.433	25.640"	S	M	On wall
S6	90.433	26.350"	S	M	On wall
S7	90.433	26.890"	S	M	On wall
S8	226.960	24.000"	S	C	On Radius
S9	226.960	24.000"	S	C	On Radius
S10	158.653	153.850"	S	C	On wall
S11	158.871	153.850"	H	C	On wall
S12	159.462	153.850"	H	C	On wall
S13	308.318	241.000"	H	C	On wall
S14	308.460	241.000"	H	C	On wall
S15	0.000	PROJ. 5.200"	S	C	EH-A (Local B)
S16	0.000	PROJ. 4.600"	S	C	EH-A (Local B)
S17	0.000	PROJ. 4.000"	S	C	EH-A (Local B)
S18	267.949	PROJ. 2.550"	S	C	EH-B (Local B)
S19	267.949	PROJ. 3.150"	S	C	EH-B (Local B)
S20	267.949	PROJ. 3.800"	S	C	EH-B (Local B)
S21	268.378	PROJ.24.450"	S	C	EH-B (Local B)
S22	268.378	PROJ.25.125"	S	C	EH-B (Local B)
S23	268.378	PROJ.25.750"	S	C	EH-B (Local B)
S24	357.617	PROJ.4.620"	S	C	EH-B (Local B)
S25	357.617	PROJ.5.250"	S	C	EH-B (Local B)
S26	357.617	PROJ.5.880"	S	C	EH-B (Local B)
S27	357.617	PROJ.25.150"	S	C	EH-B (Local B)
S28	357.617	PROJ.25.750"	S	C	EH-B (Local B)
S29	357.617	PROJ.26.350"	S	C	EH-B (Local B)
S30	270.000	PROJ. 2.700"	S	C	EH-A (Local B)
S31	270.000	PROJ. 3.300"	S	C	EH-A (Local B)
S32	270.000	PROJ. 3.900"	S	C	EH-A (Local B)
S33	20.745	150.450"	S	M	Inside (Post sit)
S34	20.962	150.450"	S	M	Inside (Post sit)
S35	21.179	150.450"	S	M	Inside (Post sit)
S36	144.384	199.500"	S	M	Inside (Post sit)
S37	144.628	199.500"	S	M	Inside (Post sit)
S38	144.873	199.500"	S	M	Inside (Post sit)
S54	276.660	Gages numbered 54 through 59 are located on the exterior bolts around EH-B. The system used to describe the location of the gages is the local system (B).			
S55	276.660				
S56	28.276				
S57	28.276				
S58	180.000				
S59	180.000				

Notes: 1. Denotes that the gage is located on the feature listed in the last column.

2. The "C" listed in this column indicates circumferential measuring direction relative to the axis of the feature on which the gage is located. The "M" listed in this column indicates meridional measuring direction relative to the axis of the feature on which the gage is located.

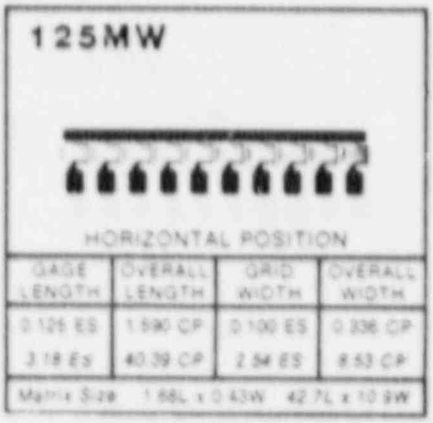
A-3.4 <u>Strip-Type Strain Gages</u>

Gage #	Horizontal angle	Vertical angle	Tap test	Note #1	Gage Type	
ST-1	89.776	24.000"	S	M	062	On floor, wall radius
ST-2	226.960	24.000"	S	M	062	On floor/wall radius
ST-3	89.888	24.000"	H	C	125	2.250" from wall
ST-4	90.216	26.320"	S	C	125	On wall
ST-5	00.000	24.000"	S	M	125	2.000" from wall
ST-6	158.871	154.350	H	M	125	On wall
ST-7	308.386	241.500"	H	M	125	On wall
ST-8	0.000	PROJ. 4.600"	S	M	125	EH-A (Local B)
ST-9	269.954	PROJ. 3.200"	S	M	125	EH-B (Local B)
ST-10	269.954	PROJ.25.200"	S	M	125	EH-B (Local B)
ST-11	359.622	PROJ. 5.300"	S	M	125	EH-B (Local B)
ST-12	359.479	PROJ.25.750"	S	M	125	EH-B (Local B)
ST-13	270.000	PROJ. 3.300	S	M	125	EH-A (Local B)
ST-14	20.962	151.200"	S	C	125	Inside (Post sit)
ST-15	144.628	175.375"	S	C	125	Inside (Post sit)

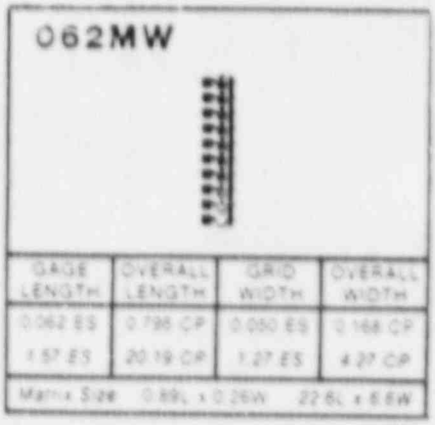
Note 1. The "C" listed in this column indicates circumferential measuring direction relative to the axis of the feature on which the gage is located.
The "M" listed in this column indicates meridional measuring direction relative to the axis of the feature on which the gage is located.

Gage Type

125:



062:



A-3.5 Tee-Rosette Strain Gages

This report lists the locations of the Tee-Rosettes installed post sit. The measured point on each Tee-Rosette gage is the center of the gage. The coordinate system used to locate each Tee-Rosette gage is the global coordinate system.

The "Tee"-gages were attached to the outside concrete surface between two well-defined cracks that developed during the Structural Integrity Test.

I.D.	Azimuth	Vertical
TR-1	90.271	266.500"
TR-2	90.814	266.500"
TR-3	91.355	266.500"
TR-4	91.940	266.500"

A-4. DISPLACEMENT GAGE DATA

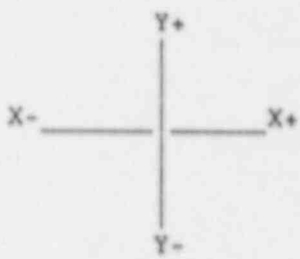
A-4.1 Description of Coordinate Systems

1. The location of each gage is described using the (a) global,(b) local or (c) cartesian coordinate system as defined below. The coordinate system (a, b, or c) used to describe the location of each gage is noted in column 4 of the listed data.

   a. The global coordinate system is used to describe the location of gages about the vessel. Angular location of each gage is in a clockwise direction from penetration EH-A centerline (00 degrees) as viewed from above the vessel. The vertical location of each gage is from a benchmark located outside the vessel and marked -1.667 ft.

   b. The local system is used to describe the location of gages about the penetrations. The local system is a cylindrical system with the zero-degree orientation at the top and angular increases in the clockwise direction (viewing the penetration from inside the model). The linear measurement recorded indicates gage location relative to the data identified on the detail drawing of the related penetration.

   c. The cartesian coordinate system is used to describe the location of gages located on flat features of penetrations (i.e. PL-A). The center of the penetration is the origin of this system with the "x" axis being horizontal location and the "y" axis being the vertical location (as viewed from inside the model). The sign preceding each recorded value is pictorially represented below.



2. Displacement gages are listed together in assigned numerical sequence.

3. The measured point of each cable-type displacement gage is the cable port.

4. The measured point of each plunger-type displacement gage is the point of contact.

5. The measured point for bridge-type displacement gages is the intersection of the plunger and the feature which it straddles.

6. Unless otherwise noted, all angular values listed in the horizontal angle columns are in decimal degrees.

7. Unless otherwise noted, all linear values listed in the vertical columns are in inches and are relative to the benchmark located outside the model (-1.677 ft).

A-4.2 Data on Displacement Gages

This report lists the locations of displacement gages about the Reinforced-Concrete Model. Work this report with drawings A8 through A10, which are located at the end of this appendix.

I.D.#	Ser. #	Gage Horizontal angle	Vertical location	Attachment point Horizontal	Attachment point Vertical	Note #1
D-1	A31224	353.395	155.587"	0.000	156.370"	Column
D-2	A31209	355.452	175.920"	0.000	176.370"	Column
D-3	1021	2.664	Local (B)	0.400"		EH-A
D-4	1017	270.000	Local (B)	0.400"		EH-A
D-5	1080	0.000	Local (B)	11.250"		EH-A
D-6	983	270.000	Local (B)	11.100"		EH-A
D-7	5024	180.000	Local (B)	0.050"		EH-A
D-8	5017	180.000	Local (B)	1.100"		EH-A
D-9	4996	270.000	Local (B)	0.100"	*5.000	EH-A
D-10	5035	270.000	Local (B)	1.200"	*5.000	EH-A
D-11	4990	0.000	Local (B)	0.200"		EH-A
D-12	5018	0.000	Local (B)	1.200"		EH-A
D-13	5031	90.000	Local (B)	0.200"	*5.000	EH-A
D-14	4995	90.000	Local (B)	1.200"	*5.000	EH-A
D-15	A15776	87.388	166.963"	90.000	166.563"	Column
D-16	4004	0.000	Local (B)	1.000"		PL-A Ext.
D-17	3999	90.000	Local (B)	1.000"		PL-A Ext.
D-18	7725	Local (C)	X= 00.000"	Y=+00.700"		PL-A
D-19	7721	"	X=+03.200"	Y=+00.700"		PL-A
D-20	7720	"	X= 00.000"	Y=+04.950"		PL-A
D-21	7722	Local (C)	X=+03.200"	Y=+04.950"		PL-A
D-22	A31218	177.412	157.353"	180.008	157.220"	Column
D-23	A31212	180.328	178.060"	180.008	177.220"	Column
D-24	1018	2.003	* Local (B)	0.400"		EH-B
D-25	1022	92.003	"	0.200"		EH-B
D-26	1023	0.000	"	14.750"		EH-B
D-27	1012	90.000	"	14.500"		EH-B
D-28	1016	2.003	"	28.500"		EH-B
D-29	1020	92.003	"	28.500"		EH-B
D-30	5004	180.000	* Local (B)	0.100"		EH-B
D-31	5034	180.000	"	1.100"		EH-B
D-32	5030	270.000	"	0.100"	*2.000	EH-B
D-33	4992	270.000	"	1.100"	*2.000	EH-B
D-34	5023	0.000	"	0.100"		EH-B
D-35	5027	0.000	"	1.100"		EH-B
D-36	5000	90.000	"	0.100"	*3.500	EH-B
D-37	5006	90.000	"	1.100"	*3.500	EH-B
D-38	5011	180.000	Local (B)	27.700"		EH-B Ext.

Note 1. This column lists the locations of the gage anchor points.

* For gages on the equipment hatches the values listed in the horizontal column are measured from the pressure seating sealing surface.

Gages D-24 through D-37 are plunger type, Gages D-24 through D-29 are located inside EH-B.

The value listed in the horizontal angle column plus 180 degrees locates the opposite end of the gage. The values listed in the attachment horizontal column represent the outward projection from the inside sealing surface of EH-B. For gages numbered D-9, D-10, D-13, D-14, D-32, D-33, D-36, and D-37, the values listed in the attachment vertical column represent angular orientation relative to the sleeve O.D. required to clear the curvature of feature 19-A.

The following report lists the locations of displacement gages about the RCM.

I.D.#	Ser. #	Gage Horizontal angle	Vertical location	Attachment point Horizontal	Attachment point Vertical	Note #1
D-39	4986	180.000	Local (B)	28.800"		EH-B Ext.
D-40	7719	180.000	Local (B)	Horizontal	137.220"	EH-B Ext.
D-41	5029	270.000	Local (B)	27.800"		EH-B Ext.
D-42	5013	270.000	Local (B)	28.800"		EH-B Ext.
D-43	7724	270.000	Local (B)	Horizontal	157.220"	EH-B Ext.
D-44	5015	0.000	Local (B)	27.700"		EH-B Ext.
D-45	4985	0.000	Local (B)	28.700"		EH-B Ext.
D-46	7723	0.000	Local (B)	Horizontal	.77.220"	EH-B Ext.
D-47	4988	90.000	Local (B)	27.800"		EH-B Ext.
D-48	4998	90.000	Local (B)	28.900"		EH-B Ext.
D-49	7726	90.000	Local (B)	Horizontal	157.220"	EH-B Ext.
D-50	A27985	83.727	24.000"	83.727	56.500"	R=127.437"
D-51	A30811	179.741	228.100"	180.000	231.375"	Column
D-52	A30810	270.851	232.100"	269.415	231.328"	Column
D-53	J-6	45.000	240.000"	R.=14.250"	Top/Col	Top/Column
D-54	A27980	354.292	24.000"	354.183	71.650"	R=129.687"
D-55	A31400	356.896	24.000"	356.918	132.000"	R=130.000"
D-56	A31215	357.795	181.100"	000.000	177.600"	Column
D-57	A31244	358.198	24.000"	358.133	215.600"	R=118.162"
D-58	A31242	338.385	216.865"	359.843	216.000"	Column
D-59	A31240	358.836	240.600"	359.657	239.719"	Top/Column
D-60	A27510	359.392	24.000"	359.300	286.650"	R=118.162"
D-61	A30998	84.791	D-61 and D-62 Horizontal Track BTM/Concrete			
D-62	A31257	84.791	Measure Lift From R=23.750" TO R=108.875"			
D-63	A27778	98.046	D-63 and D-64 are Mounted Internal Vertical			
D-64	A31258	98.046	Track System Between 29.187" and 291.30"			
D-65	A27774	278.084	D-65 and D-66 are Mounted Internal Vertical			
D-66	A31254	278.034	Track System Between 29.312" and 291.70"			
D-67	A27776	102.481	D-67 and D-68 are Mounted Exterior Vertical			
D-68	A31255	102.481	Track System Between 24.000" and 268.300"			
D-69	A27777	285.000	D-69 and D-70 are Mounted Exterior Vertical			
D-70	A17140	285.000	Track System Between 25.750" and 267.100"			
D-71	A3[illegible]97	2.431	D-71 and D-72 are Mounted Internal Vertical			
D-72	A3[illegible]56	2.431	Track System Between 30.875" and 98.120"			
D-73	A[illegible]003	182.778	D-73 and D-74 are Mounted Internal Vertical			
D-74	A[illegible]247	182.778	Track System Between 29.987" and 97.600"			
D-75	A31004	358.825	D-75 and D-76 are Mounted Exterior Vertical			
D-76	A31245	358.825	Track System Between 23.875" and 99.937"			

Note 1. This column lists the locations of the gage anchor points.

The following report lists the locations of displacement gages mounted inside the RCM.

I.D.#	Ser. #	Gage Horizontal angle	Vertical location	Attachment point angle: Horizontal	Attachment point angle: Vertical	Note #1
D-77	A30999	179.091	D-77 and D-78 are Mounted Exterior Vertical			
D-78	A31246	179.091	Track System Between 25.937" and 101.625"			
D-79	A31237	90.000	325.400"	90.000	332.055"	R=88.875"
D-80	A31223	90.000	325.400"	90.000	370.875"	R=49.000"
D-81	A31211	89.861	287.225"	89.890	287.965"	R=69.000"
D-82	A31214	89.773	301.325"	89.658	313.865"	R=69.000"
D-83	A31401	90.000	325.400"	90.000	349.232"	R=67.250"
D-84	A31239	90.000	325.400"	90.000	387.272"	R=32.875"
D-85	A31208	90.000	325.400"	90.000	410.952"	R=15.125"
D-86	A31235	00.000	325.400"	00.000	418.875"	R=0.00
D-87	A31233	133.436	156.447"	134.110	155.875"	Column
D-88	A27981	176.484	24.000"	176.484	71.750"	R=128.437"
D-89	A31398	179.218	24.000"	179.181	139.870"	R=124.344"
D-90	A31230	182.136	217.506"	180.000	216.137"	Column
D-91	A31243	177.352	39.750"	177.612	216.137"	R=108.187"
D-92	A31210	177.862	240.900"	180.000	239.937"	Top/Column
D-93	A27509	178.350	39.750"	178.476	287.600"	R=108.000"
D-94	A31225	177.352	288.900"	180.000	288.200"	Extend/Col
D-95	A30859	225.065	24.000"	225.207	71.570"	R=129.187"
D-96	A31238	230.166	72.134"	228.376	71.820"	Column
D-97	A31216	229.278	102.500"	228.376	102.560"	Column
D-98	A31399	227.626	24.000"	227.626	131.720	R=129.500"
D-99	A31228	232.659	134.470"	228.571	134.450"	Column
D-100	A31217	233.531	156.304"	228.571	156.000"	Column
D-101	A31241	235.556	185.420"	228.484	184.850"	Column
D-102	A31220	238.986	214.330"	228.276	215.063"	Column
D-103	A31222	227.912	240.900"	227.860	240.750"	Top/Column
D-104	A31249	223.198	24.000"	222.980	215.600"	R=126.312"
D-105	A27511	225.933	24.000"	225.954	287.150"	R=126.375"
D-106	A31231	275.685	240.900"	289.435	241.062"	Top/Column
D-107	A31221	296.542	240.900"	304.482	241.390"	Top/Column
D-108	A31232	003.270	239.300"	311.949	241.469"	Top/Column
D-109	A31227	310.390	156.291"	315.024	156.000"	Column
D-110	A31226	312.133	214.131"	315.088	214.313"	Column
D-111	84202-5	0.000	Gages Numbered D-111, D-112, and D-113 are			
D-112	84202-2	90.000	Mounted @ Mud Mat/Base Mat Intersection			
D-113	84202-1	225.000	Measurement Direction is Meridional.			
D-114	A30996	243.906	91.500"	243.906	85.500"	Beltline

Note 1. This column lists the locations of the gage anchor points.

The following report lists the locations of displacement gages mounted about the RCM.

I.D.#	Ser. #	Gage Horizontal angle	Vertical location	Attachment point angle Horizontal	Vertical	Note #1
D-115	A31001	275.643	201.250"	275.643	194.625	Beltline
D-116	A27967	182.837	135.228"	180.000	135.770"	Column
D-117	A30858	272.377	135.000"	270.143	135.820"	Column
D-118	84185-7	0.434	133.250"	Circumferential		
D-119	84185-15	20.970	151.375"	Circumferential		
D-120	84185-17	69.482	140.000"	Circumferential		
D-121	84185-14	95.669	26.250"	Meridional		
D-122	84185-9	141.772	269.000"	Meridional		
D-123	84185-10	144.632	175.000"	Circumferential		
D-124	84185-16	180.582	130.000"	Circumferential		
D-125	84185-13	270.000	23.000"	Meridional		
D-126						
D-127						
D-128						
D-129						
D-130						
D-131						
D-132						
D-133						
D-134						
D-135						
D-136						
D-137						
D-138	A31251	90.000	325.400"	90.000	400.505"	R=15.125"
D-139	A31250	90.000	325.400"	90.000	416.920"	R= 7.875"
D-140	A17137	102.481	259.876"	Vert. Track to S.W. Corner Beam		
D-141	A16962	285.000	255.813"	Vert. Track to N.E. Corner Beam		

Notes:

1. This column lists the locations of the gage anchor points.

2. Gages numbered D-118 through D-125 were installed over cracks which appeared after the low-pressure test. The measured point for the gages numbered D-118 through D-125 is the point of intersection of the plunger and the crack over which the plunger extends.

A-5. THERMOCOUPLE LOCATIONS

This report lists all thermocouple locations and should be worked with drawings A5-A7, which are located at the end of this appendix.

I.D. #	Azimuth (decimal degrees)	Vertical (inches)	
T1-T43	Embedded in the containment wall: see figures in the body of the report for locations		
T44	00.000	135.870"	
T45	00.000	Proj. 0.500"	EH-A (Local B)
T46	1.000	189.140"	
T47	45.406	161.940"	
T48	43.333	249.300"	
T49	89.500	27.300"	
T50	X=(-.150")	Y=(+.500")	PL-A (Local B)
T51	90.000	171.980"	
T52	90.918	314.689"	
T53	128.251	241.810"	
T54	180.000	136.670"	
T55	158.058	152.750"	
T56	180.570	197.570"	
T57	210.000	27.800"	
T58	227.300	106.220"	
T59	229.555	285.850"	
T60	85.110	416.000"	
T61	271.000	99.330"	
T62	262.804	185.500"	
T63	306.943	243.100"	
T64	329.261	27.500"	
T65	180.000	Proj. 0.300"	EH-A (Local B)
T66	0.000	Proj. 0.250"	EH-A (Local B)
T67	182.859	.400"	EH-B (Local B)
T68	270.000	15.875"	EH-B (Local B)
T69	358.713	15.875"	EH-B (Local B)
T70	355.711	Proj.29.000"	EH-B (Local B)
T71	0.000	Exterior Bolt	EH-B Cover
T72	150.236	Exterior Bolt	EH-B Cover
T73	Thermocouples Numbered T73 and T74 are Located		
T74	Outside the Model Under TB-6 to Monitor Ambient		

A-6. WELDABLE GAGE LOCATIONS

This report lists the locations of weldable gages. Work this report with Drawing A5, which is located at the end of this appendix.

I.D. #	Azimuth	Vertical	Note #1	
W278	89.543	[illegible].000"	C	Floor to Wall Radius
W279	89.543	26.420"	C	
W280	89.543	28.420"	C	
W281	89.153	24.000"	M	Floor to Wall Radius
W282	89.153	26.000"	M	
W283	88.762	28.520"	M	
W284	210.000	24.000"	C	Floor to Wall Radius
W285	210.000	26.600"	C	
W286	210.000	28.600"	C	
W287	210.000	24.000"	M	Floor to Wall Radius
W288	210.000	27.000"	M	
W289	210.000	28.700"	M	
W290	329.565	24.000"	C	Floor to Wall Radius
W291	329.565	26.600"	C	
W292	329.565	28.400"	C	
W293	330.000	24.000"	M	Floor to Wall Radius
W294	330.000	26.200"	M	
W295	330.000	28.200"	M	

Note 1. The "C" listed in this column indicates circumferential measuring direction relative to the axis of the feature on which the gage is located. The "M" listed in this column indicates meridional measuring direction relative to the axis of the feature on which the gage is located.

A-7. RTD LOCATIONS

Work this report with Drawing A5, which is located at the end of this appendix.

Type/I.D.#	Azimuth	Radius	Vertical
RTD-100	286.859	66.000"	184.500"
RTD-101	286.859	65.000"	89.500"
RTD-104	151.912	69.000"	184.500"
RTD-106	151.912	70.000"	280.400"
RTD-107	286.859	65.000"	280.744"
RTD-108	44.166	67.000"	184.000"
RTD-109	44.166	66.000"	90.500"
RTD-110	151.912	71.000"	88.500"
RTD-111	284.985	67.676"	351.400"
RTD-112	153.038	72.785"	351.400"
RTD-113	63.254	53.330"	351.400"
RTD-114	44.166	66.000"	280.650"

Note: All temperature devices listed on this page are located using the global coordinate system (a).

A-8. ACOUSTIC SENSORS

This report describes the locations of the pac acoustic sensors.

I.D.	Azimuth	Vertical
#1 PAC	140.099	27.450"
#2 PAC	234.140	28.250"
#3 PAC	319.882	27.900"
#4 PAC	49.819	28.600"
#5 PAC	236.551	Exterior EH-B (Local B)
#6 PAC	114.000	Proj. 12.150" EH-A (Local B)
#7 PAC	315.	156" (Location Estimated)
#8 PAC	135.	156" (Location Estimated)

A-9. TILT SENSORS

This report lists the locations of the tilt sensors mounted about the reinforced-concrete model.

I.D.	Ser. #	Azimuth	Vertical	Notes
1	0118	90.000	235.850"	Top Column Oriented 90 deg.
2	0122	180.000	235.850"	Top Column Oriented 180 deg.
3	0123	0.000	127.000"	Top of Track System @ 0 deg.
4	0116	0.000	23.500"	Ext. Rail Moment Arm=124.750"
5	0117	93.612	21.000"	Mounted on Top Outer Edge of Base Mat
6	0124	90.000	23.500"	Ext. Rail Moment Arm=126.000"
7	0115	180.000	127.000"	Top of Track System @ 180 deg.
8	0120	225.000	23.500"	Ext. Rail Moment Arm 129.000"

A-10. EH-B EXTERIOR O-RING DETAILS

A-10.1 Measurements of EH-B O-Ring Grooves

This report lists the exterior EH-B O-Ring groove details.

Angular Station	Inside O-Ring Groove			Outside O-Ring Groove		
	Depth	Radius	Width	Depth	Radius	Width
0	.102"	20.050"	.117"	.101"	20.290"	.119"
36	.098"	20.100"	.113"	.100"	20.350"	.116"
72	.100"	20.060"	.115"	.102"	20.310"	.117"
90	.099"	20.030"	.116"	.101"	20.280"	.120"
108	.1[illegible]"	20.010"	.115"	.100"	20.260"	.118"
144	.100"	20.040"	.115"	.102"	20.280"	.118"
180	.100"	20.060"	.119"	.101"	20.300"	.121"
216	.099"	20.120"	.118"	.101"	20.360"	.11[illegible]"
252	.100"	20.110"	.115"	.101"	20.360"	.116"
270	.101"	20.090"	.115"	.101"	20.315"	.117"
288	.102"	20.070"	.114"	.101"	20.310"	.117"
324	.101"	20.040"	.115"	.102"	20.280"	.118"

A-10.2 Surface Finish for Grooves in Equipment Hatch B

The table below contains the surface finish values of the exterior EH-B O-Ring grooves which were taken at three approximately equally spaced stations.

	Surface Finish Inner O-Ring Groove	Surface Finish Outer O-Ring Groove
Sample 1	80	80
Sample 2	100	90
Sample 3	30	72

A-10.3 Tongues and Seated O-Rings

This report details the outside sealing tongues for EH-B outside cover.

Angular Station	Inside Tongue I.D.	Inside Tongue Thickness	Outside Tongue O.D.	Outside Tongue Thickness
0-'8.	40.222"	0 - .048"	40.787"	0 - .043"
		180 - .044"		180 - .044"
36-216	40.216"	36 - .047"	40.784"	36 - .043"
		216 - .045"		216 - .044"
72-252	40.220"	72 - .046"	40.790"	72 - .043"
		252 - .043"		252 - .045"
90-270	40.218"	90 - .046"	40.738"	90 - .044"
		270 - .048"		270 - .043"
108-288	40.225"	108 - .046"	40.792"	108 - .045"
		288 - .048"		288 - .043"
324-144	40.228"	324 - .048"	40.800"	324 - .043"
		144 - .047"		144 - .044"

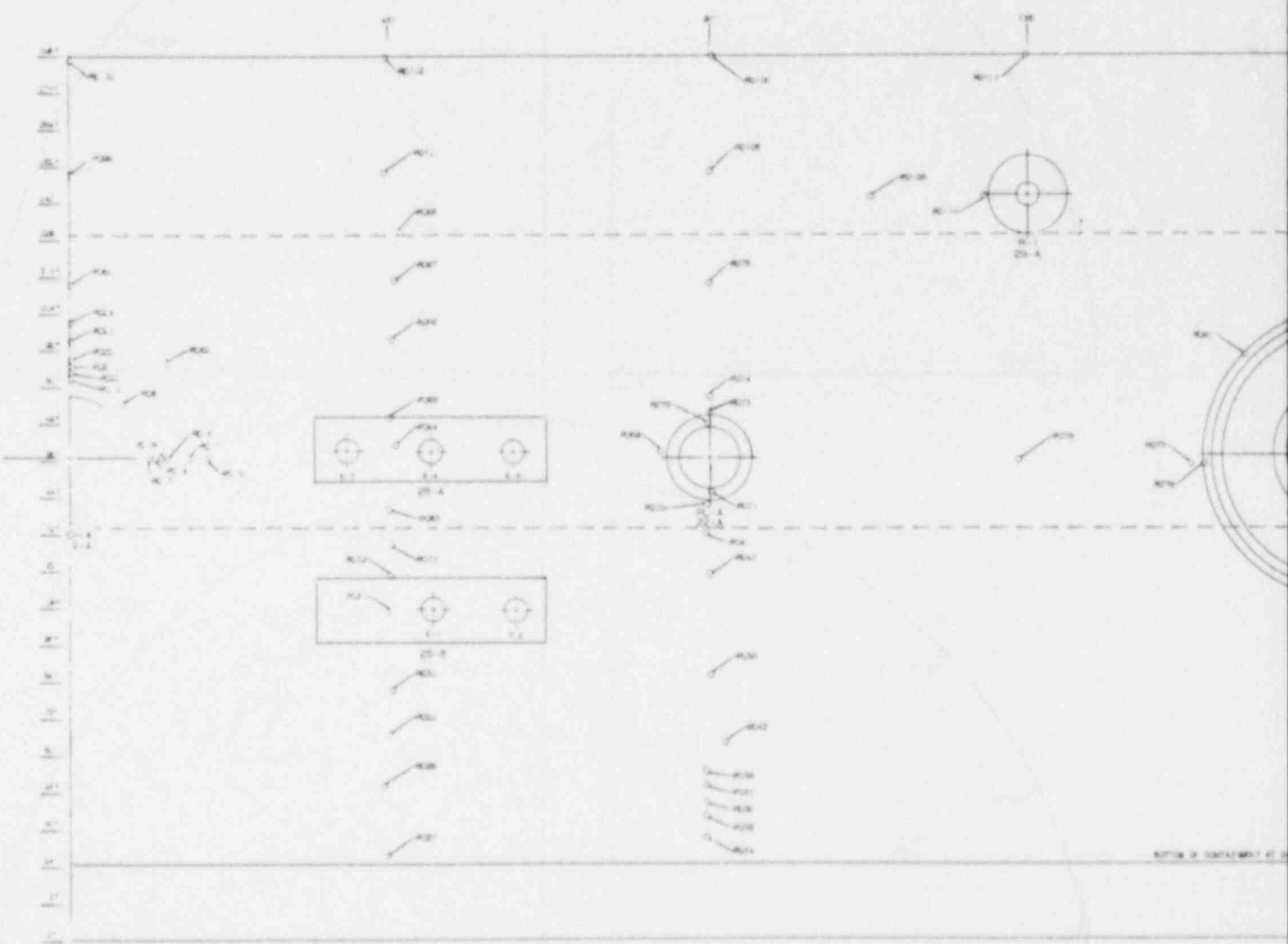
The following table lists the tongue heights relative to the inner, central, and outside sealing surfaces of the outside cover.

Angular Station	Inner	Central	Outside
0	.048"	.062"	.052"
36	.046"	.065"	.052"
72	.046"	.066"	.053"
90	.047"	.065"	.052"
108	.046"	.063"	.051"
144	.048"	.065"	.052"
180	.045"	.065"	.053"
216	.048"	.065"	.053"
252	.046"	.066"	.052"
270	.046"	.065"	.053"
288	.046"	.065"	.052"
324	.046"	.062"	.052"

A-10.4 Distance Values of O-Rings in Equipment Hatch B

The following table lists the distance of the seated O-Ring relative to the exterior mating surface of EH-B. All values listed in the table are below the mating surface. Values listed in Column 1 are measured prior to sit. Values listed in Column 2 are measured post sit. Values listed in Column 3 are the new set of O-Rings installed and measured prior to hi-pressure. All values listed in Columns 1, 2, and 3 are in inches.

Angular	Inside O-Ring			Groove			Outside O-Ring			Groove		
Station	1	2	3	1	2	3	1	2	3	1	2	3
0	.010	.016	.015	.022	.030	.035	.021	.022	.018	.030	.026	.030
36	.017	.020	.006	.031	.025	.019	.023	.022	.012	.032	.027	.023
72	.022	.022	.014	.032	.029	.025	.024	.019	.018	.034	.020	.026
90	.014	.014	.021	.025	.026	.025	.025	.017	.025	.033	.028	.030
108	.016	.010	.013	.026	.025	.021	.020	.013	.025	.031	.027	.030
144	.016	.012	.011	.028	.027	.023	.025	.020	.021	.036	.034	.024
180	.010	.020	.025	.022	.021	.035	.020	.020	.030	.035	.032	.040
216	.019	.022	.020	.030	.025	.028	.023	.012	.023	.034	.018	.026
252	.023	.024	.021	.029	.026	.028	.022	.020	.015	.034	.013	.028
270	.016	.024	.019	.027	.027	.032	.027	.011	.023	.035	.026	.033
288	.020	.006	.020	.030	.025	.030	.023	.002	.025	.031	.018	.029
324	.023	.014	.015	.033	.030	.027	.022	.015	.015	.032	.032	.026



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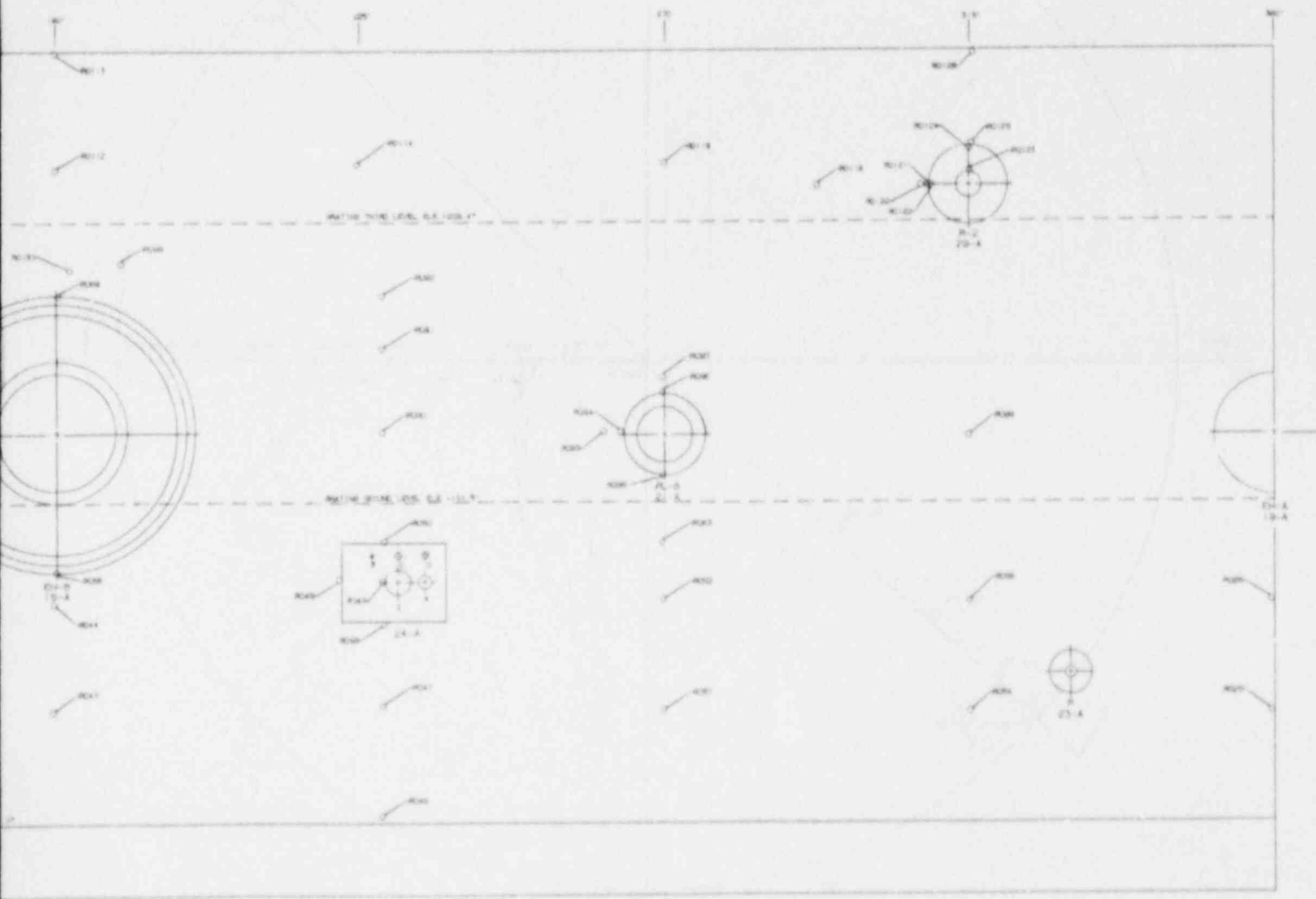

...HED OUT VIEW OF T.D.
...T STRAIN GAGES RO TYPE
...00"

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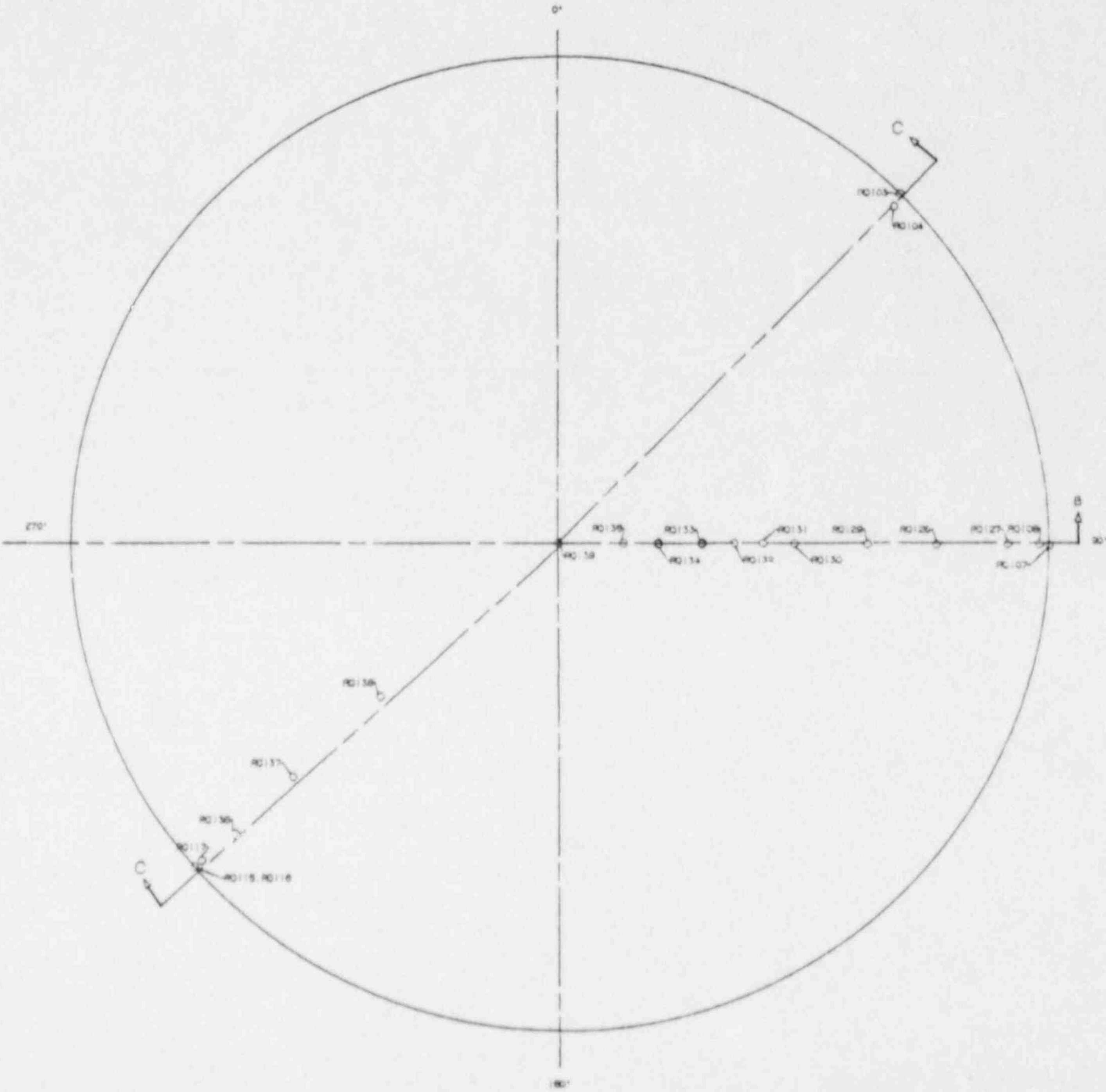

PLAN VIEW OF DOME LEVEL

LOCATION OF STRAIN GAGES RO TYPE

SCALE: .030"=1.000"

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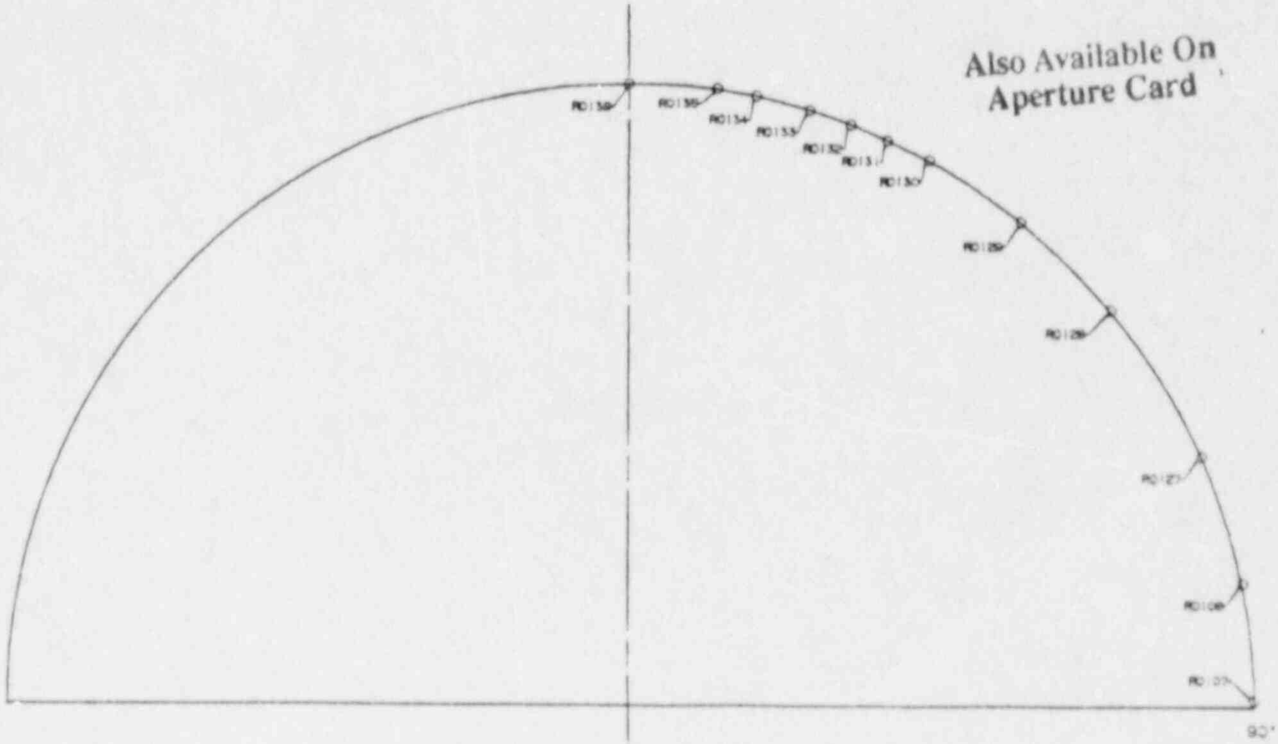
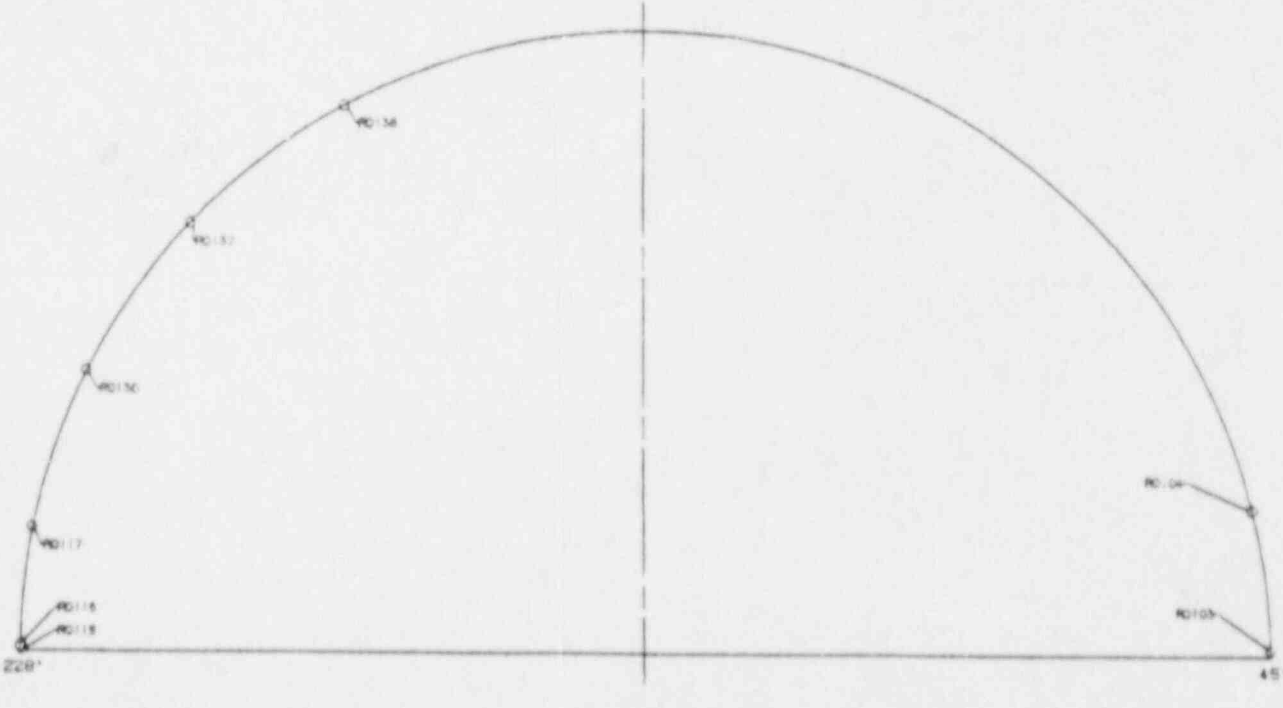


SECTION B-B



SECTION C-C

LOCATION OF STRAIN GAGES RC TYPE

SCALE: .030"=1.000"

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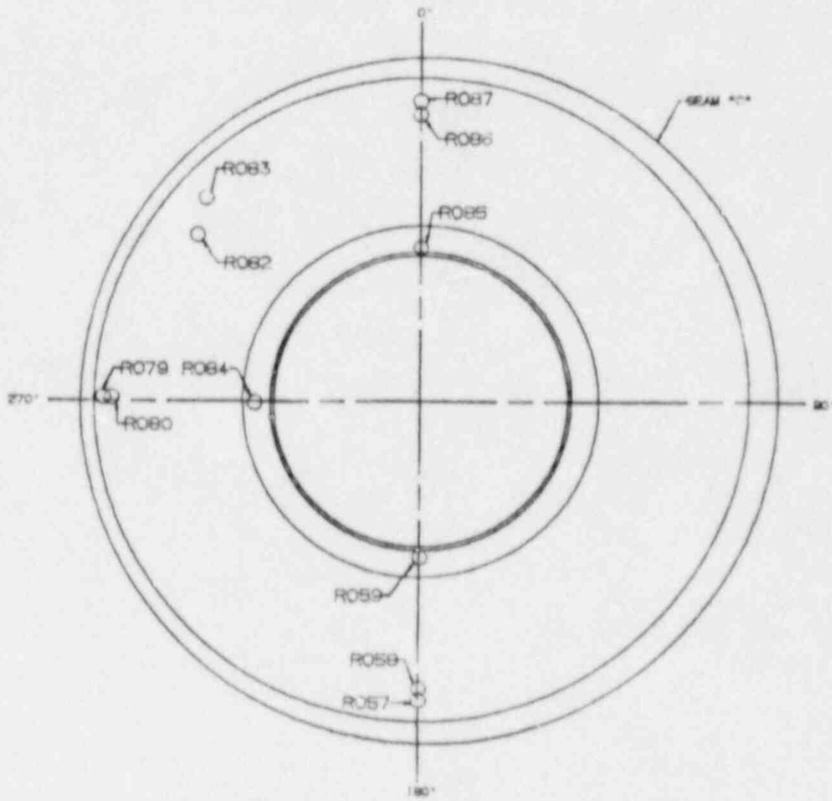
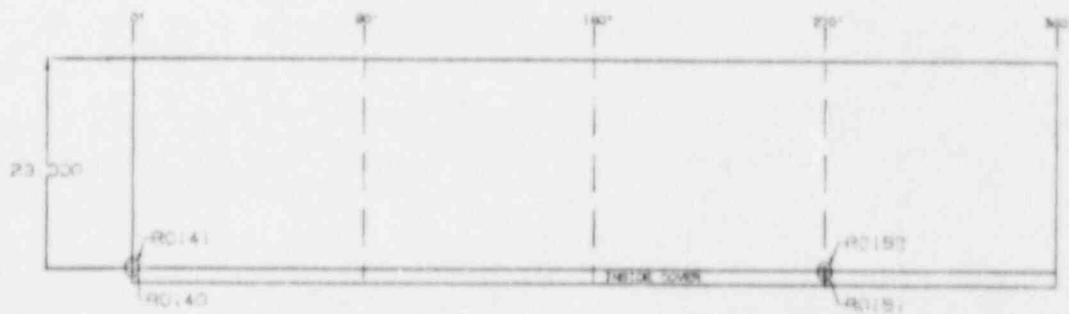


INSIDE VIEW
HATCH A
LOCATION OF STRAIN GAGES RO TYPE

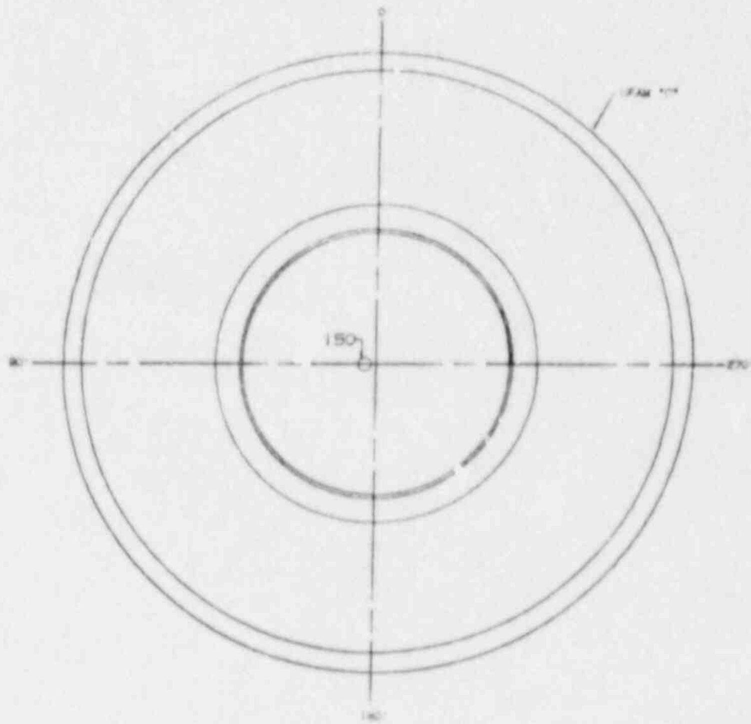
SCALE: .040"=1.000"



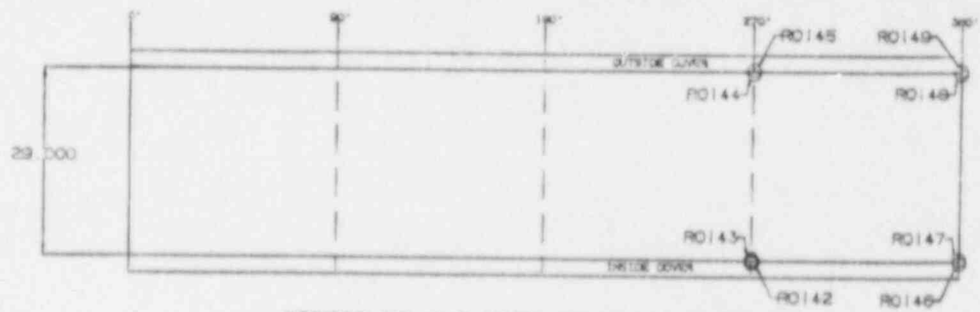
STRETCHED OUT VIEW OF HATCH A (I.D.)
LOCATION OF STRAIN GAGES RO TYPE

SCALE: .040"=1.000"

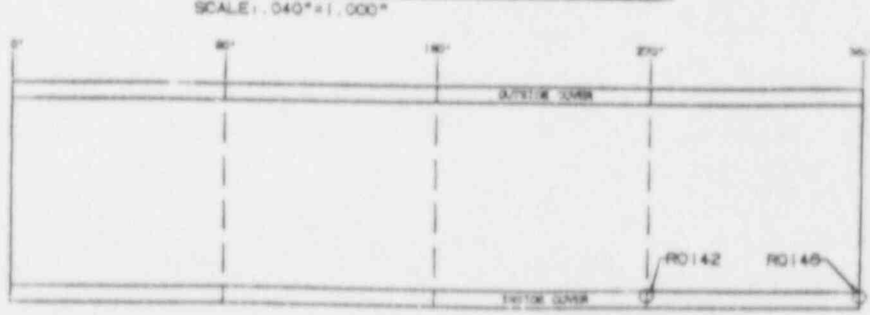
Drawing A2



OUTSIDE VIEW
HATCH B
LOCATION OF STRAIN GAGES RO TYPE
SCALE: .040"=1.000"

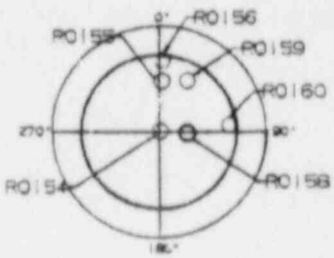


STRETCHED OUT VIEW OF HATCH B (I.D.)
LOCATION OF STRAIN GAGES RO TYPE
SCALE: .040"=1.000"



STRETCHED OUT VIEW OF HATCH B (O.D.)
LOCATION OF STRAIN GAGES RO TYPE
SCALE: .040"=1.000"

Drawing A3



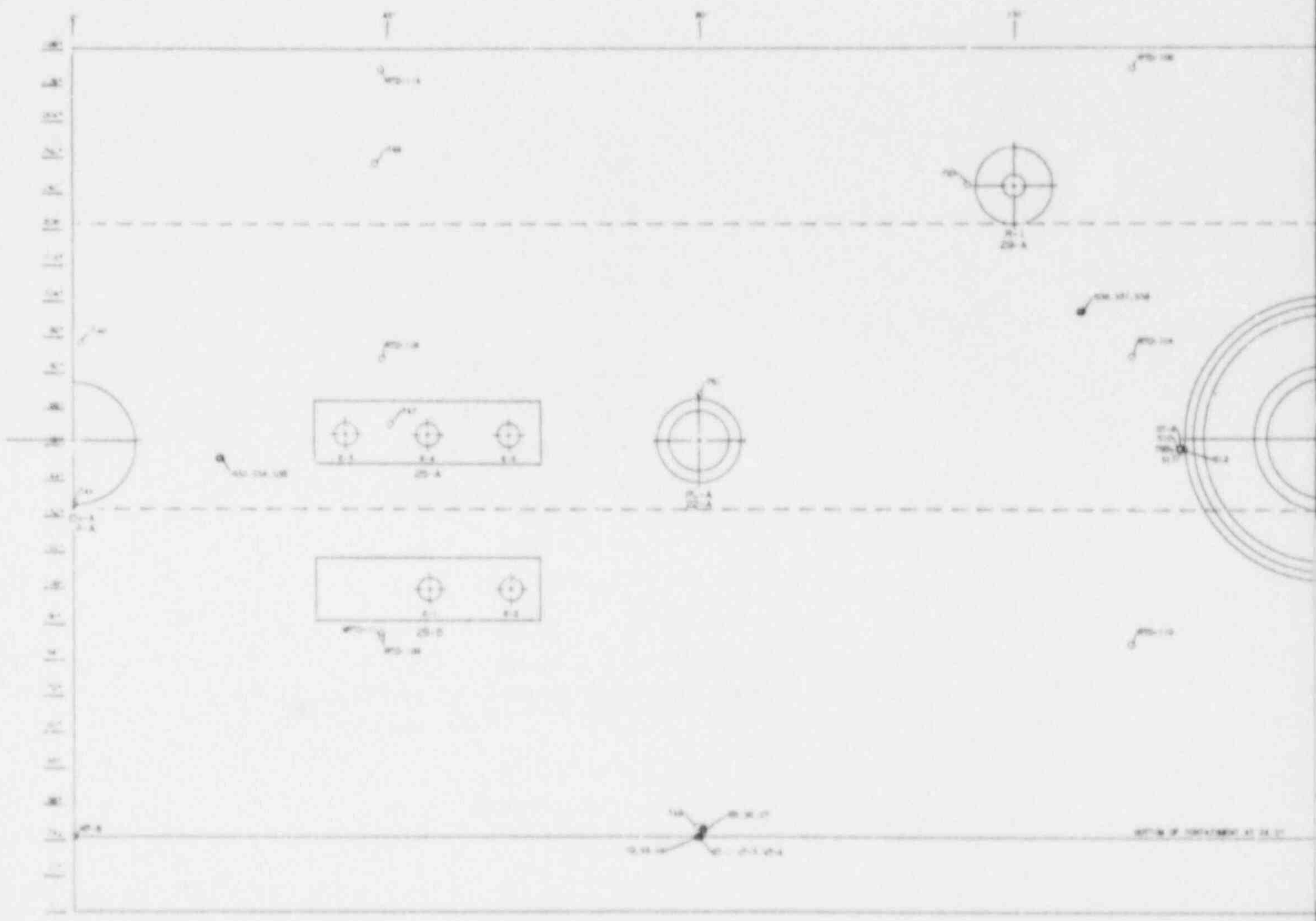
PL-A

22-A

LOCATION OF STRAIN GAGES RO TYPE

SCALE: .040"=1.000"

Drawing A4



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LOCATION OF SINGLE AND

LOCATION OF MRTD,RTD

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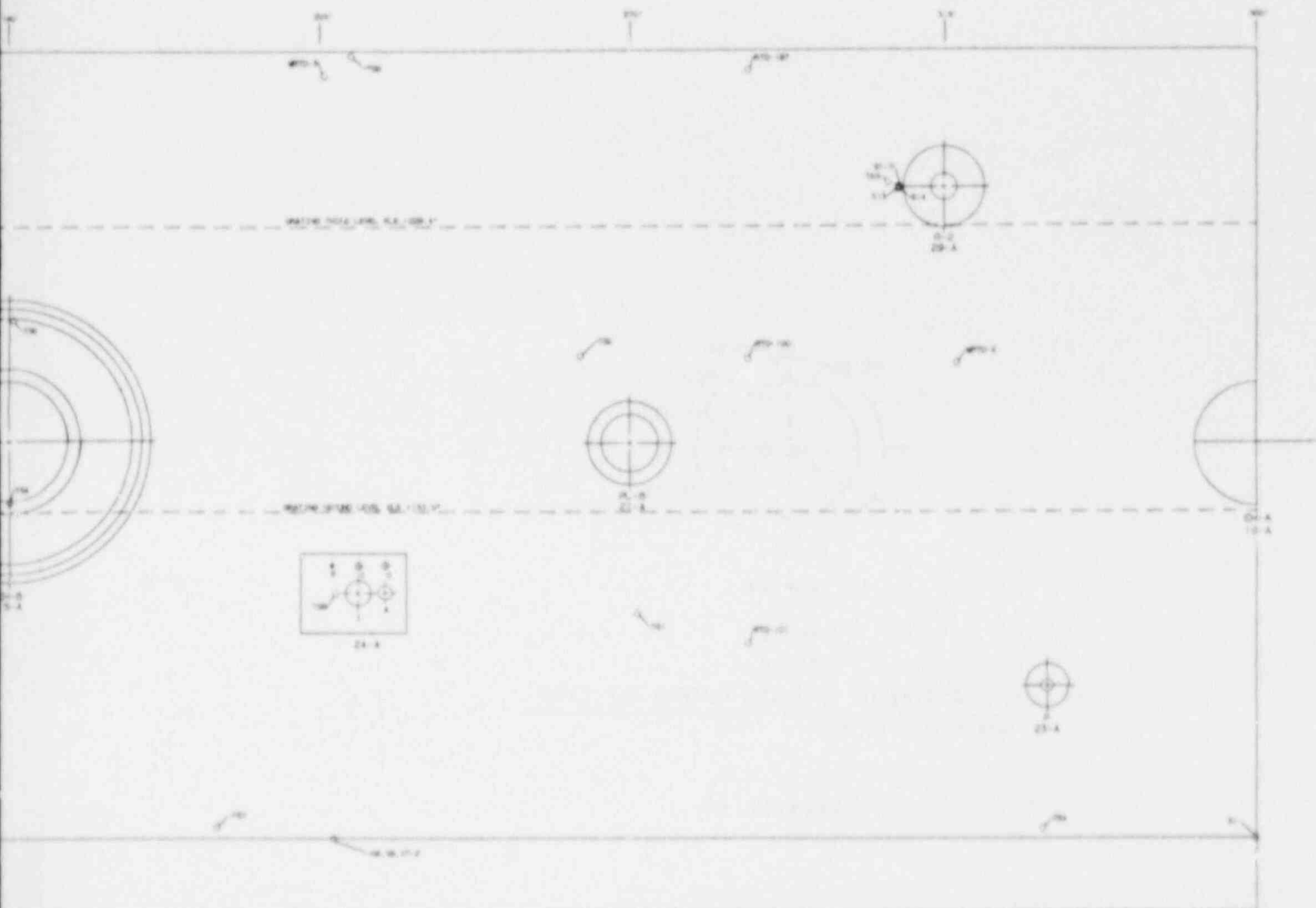

T VIEW OF I.D.
STRIP TYPE STRAIN GAGES
AND THERMOCOUPLE GAGES

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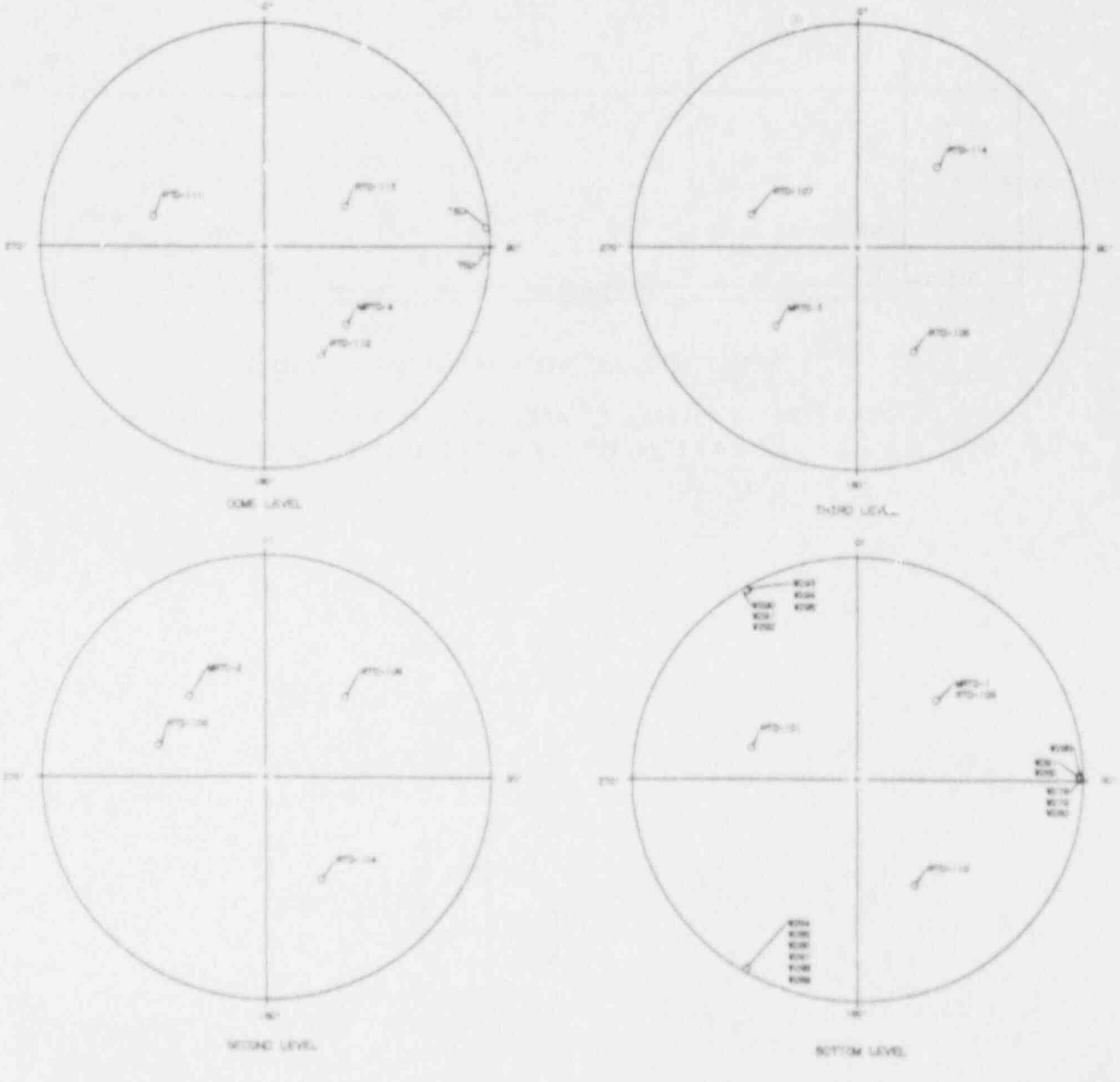
g A5a

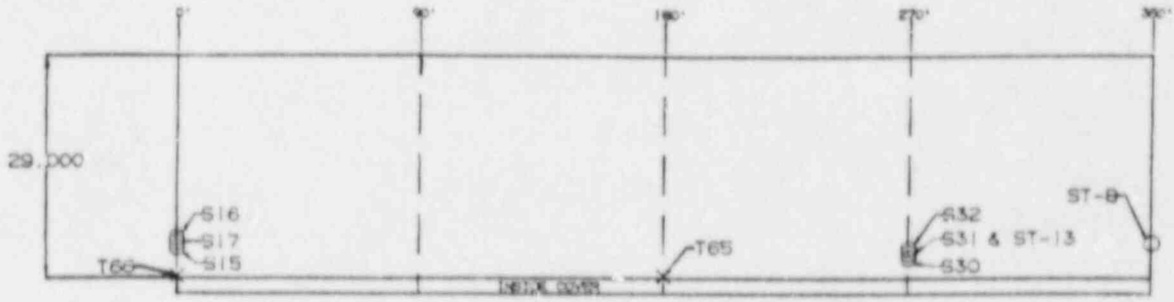


PLAN VIEW OF LEVELS

LOCATION OF SINGLE AND STRIP TYPE STRAIN GAGES

LOCATION OF MRTD, RTD, AND THERMOCOUPLE GAGES

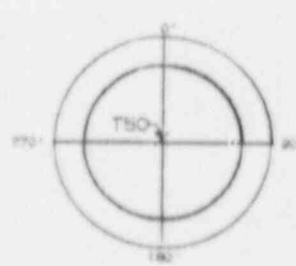
Drawing A5b



STRETCHED OUT VIEW OF HATCH A (I.D.)

LOCATION OF SINGLE AND STRIP TYPE STRAIN GAGES
LOCATION OF TEMPTERATURE GAGES

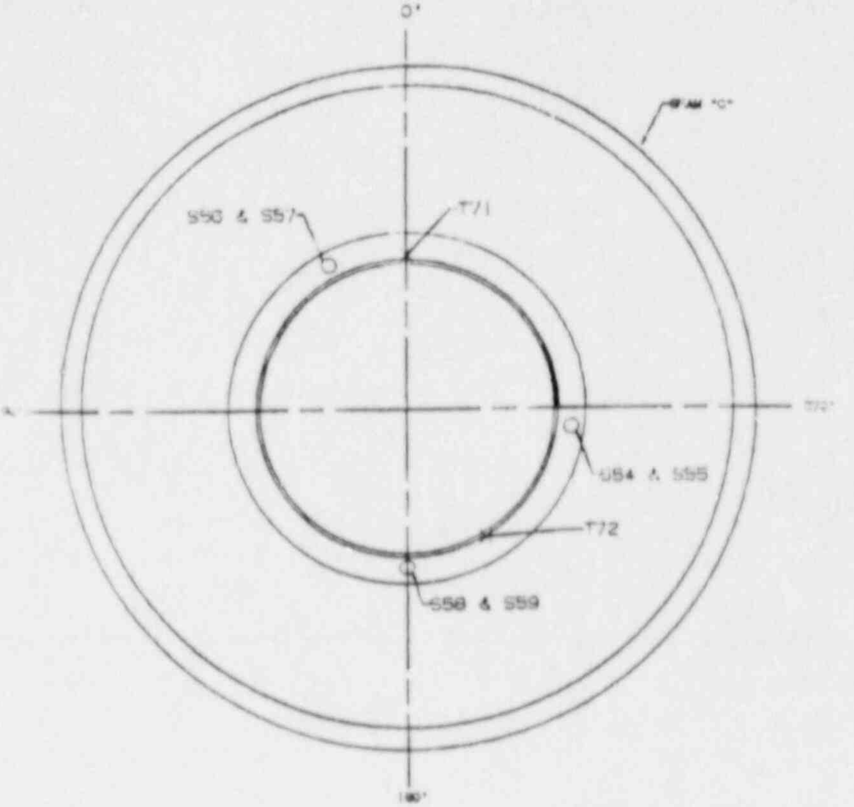
SCALE: .040"=1.000"



INSIDE VIEW PL-A

SCALE: .040"=1.000"

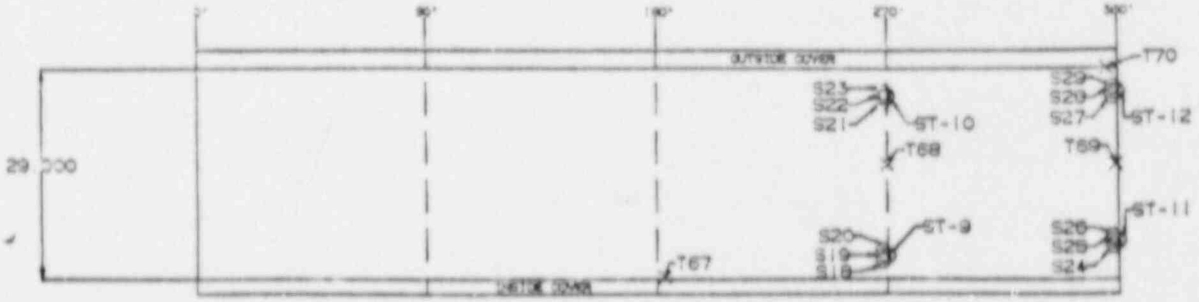
Drawing A6



OUTSIDE VIEW HATCH B

LOCATION OF SINGLE AND STRIP TYPE STRAIN GAGES
LOCATION OF TEMPTERATURE GAGES

SCALE: .040"=1.000"

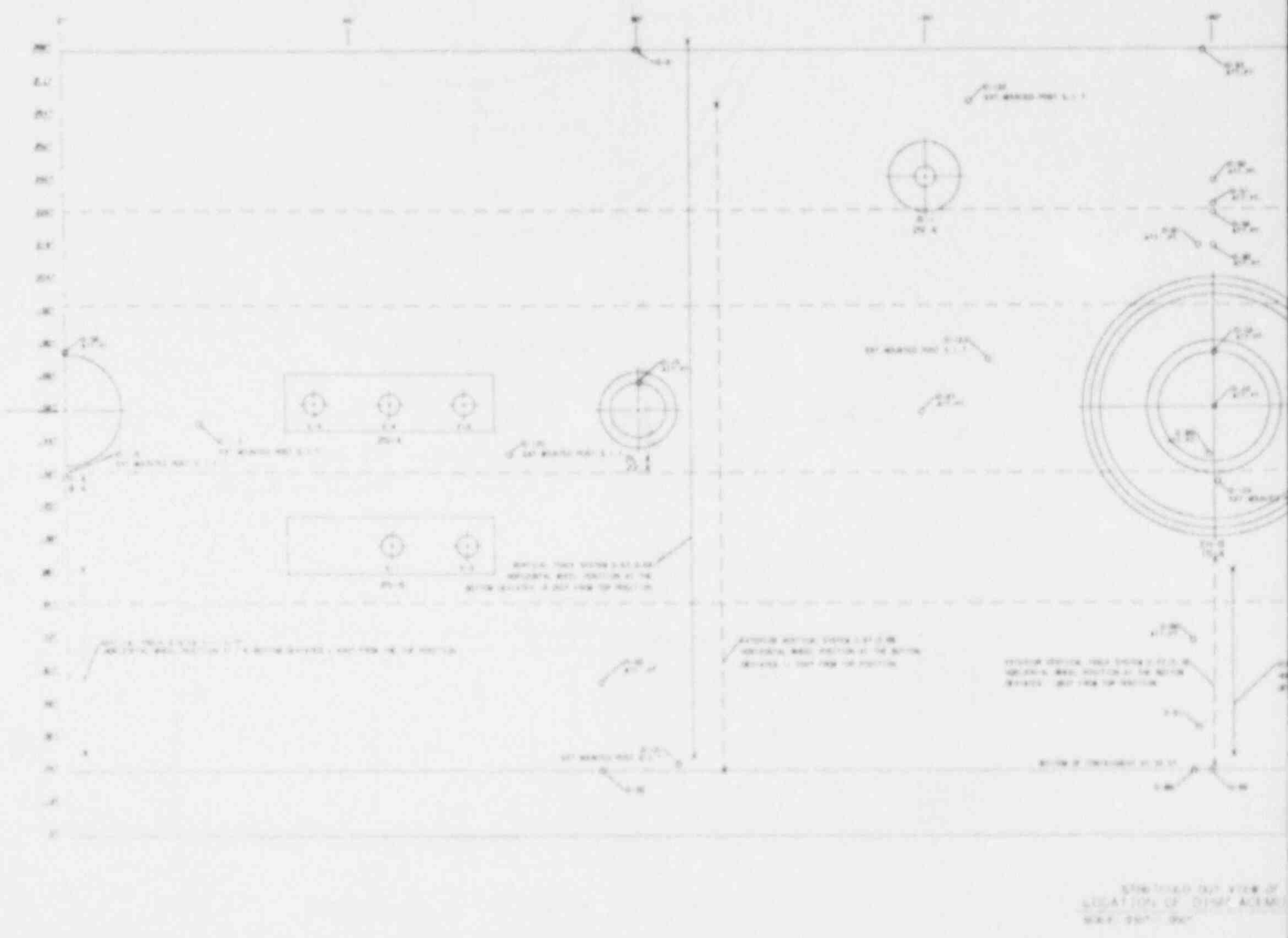


STRETCHED OUT VIEW OF HATCH B (I.D.)

LOCATION OF SINGLE AND STRIP TYPE STRAIN GAGES
LOCATION OF TEMPTERATURE GAGES

SCALE: .040"=1.000"

Drawing A7



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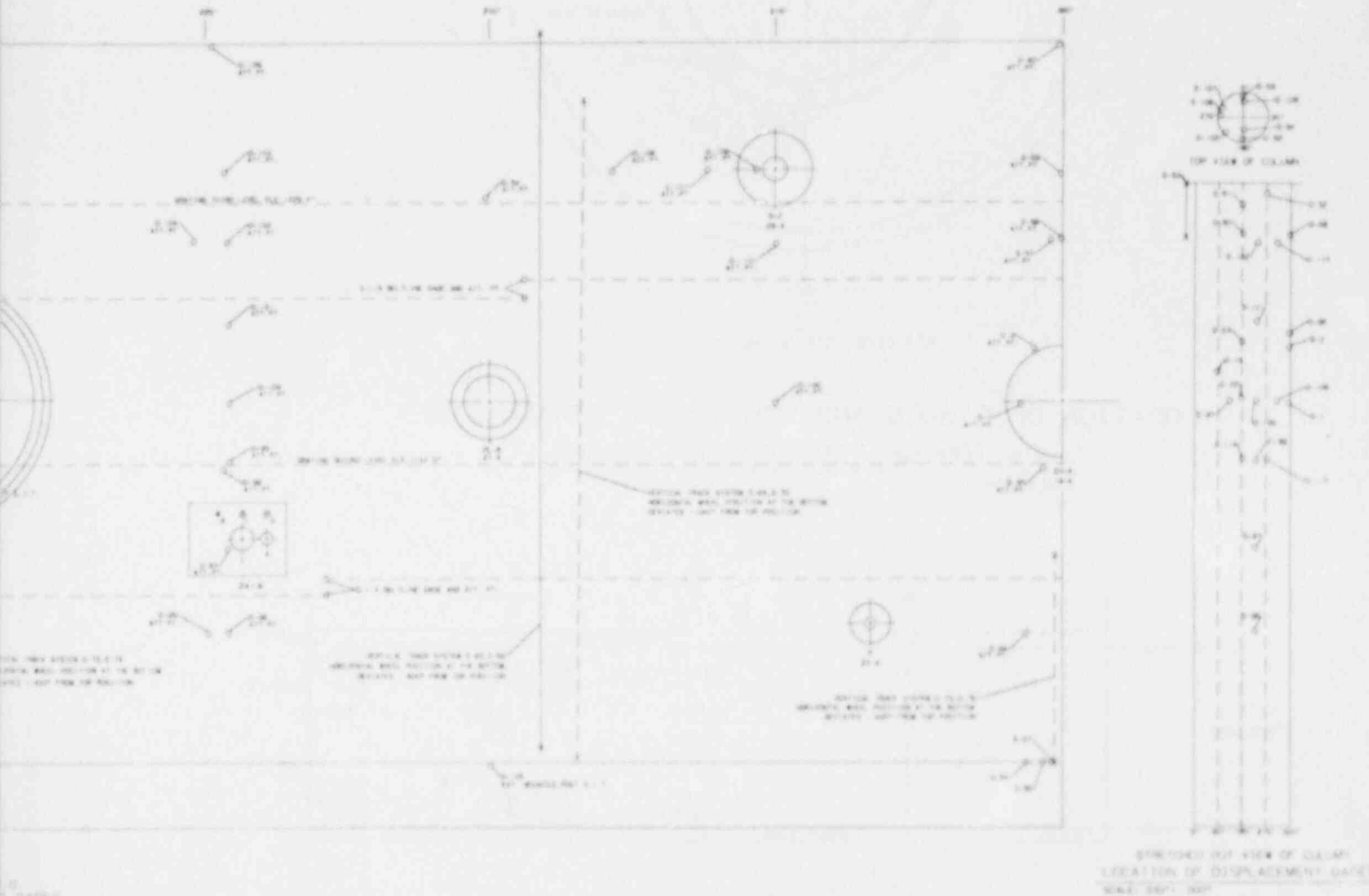

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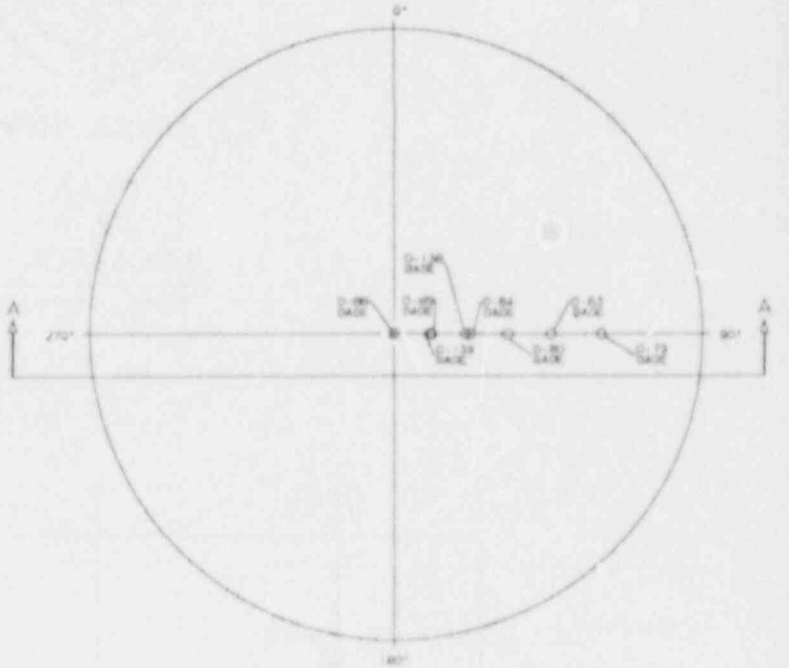
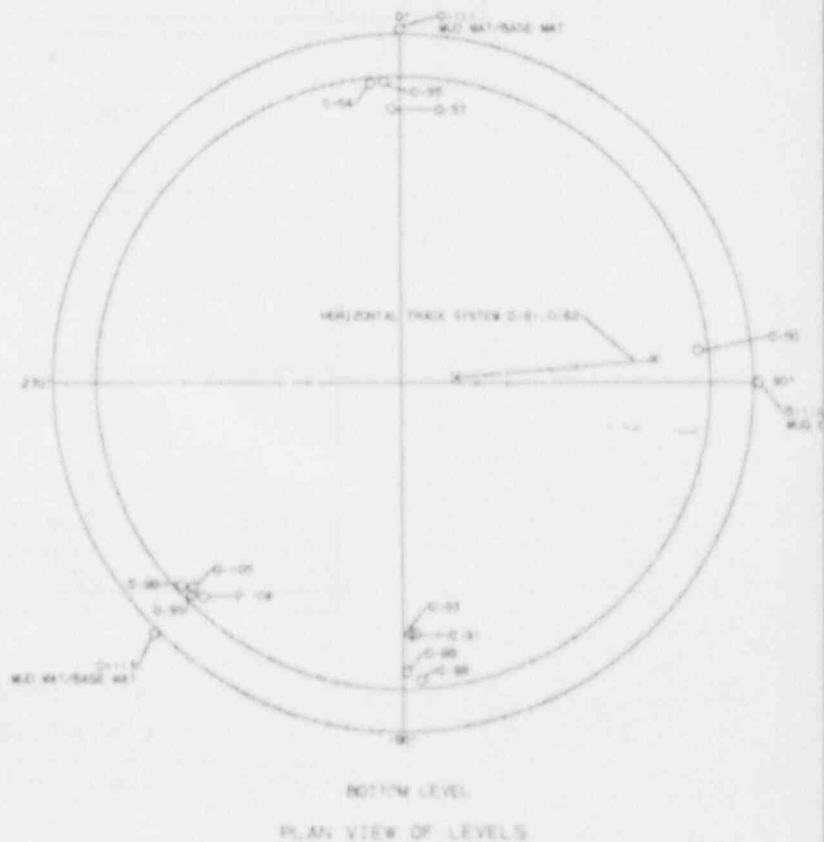
ing A8a



DOME LEVEL



BOTTOM LEVEL

PLAN VIEW OF LEVELS

LOCATION OF DISPLACEMENT GAGES

SCALE: 0.15"=1,000"

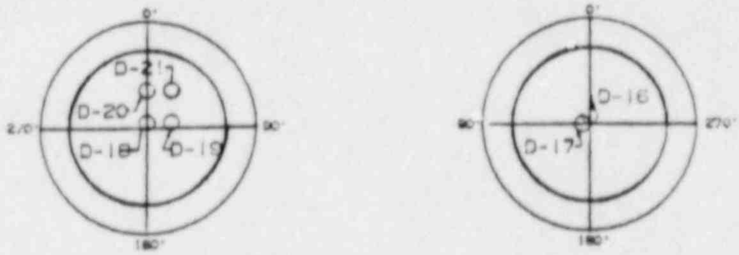
SECTION A-A

DOME LEVEL

LOCATION OF DISPLACEMENT GAGES

SCALE .030"=1.000"

Drawing A8b



INSIDE VIEW

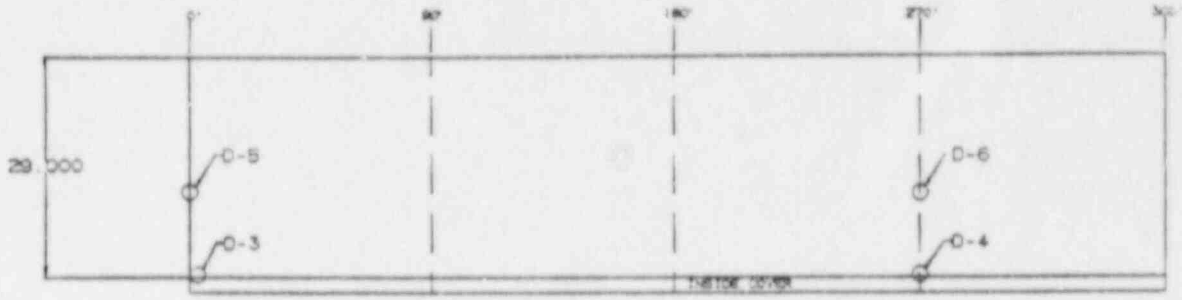
OUTSIDE VIEW

PL-A
22-A

PL-A
22-A

LOCATION OF DISPLACEMENT GAGES

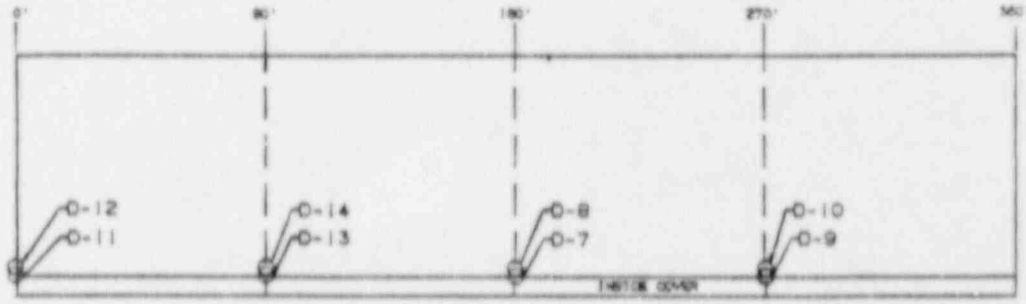
SCALE .040"=1.000"



STRETCHED OUT VIEW OF HATCH A (I.D.)

LOCATION OF DISPLACEMENT GAGES

SCALE: .040"=1.000"

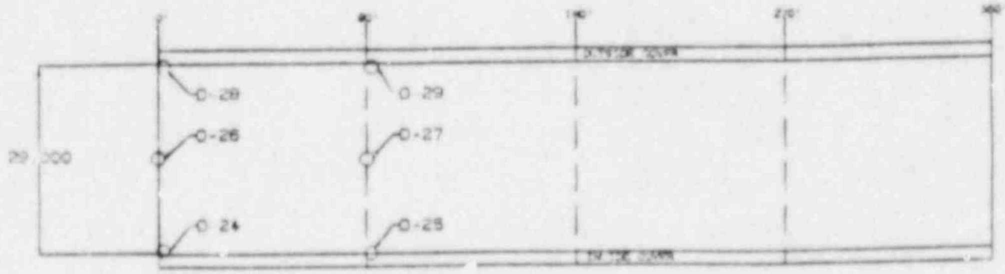


STRETCHED OUT VIEW OF HATCH A (O.D.)

LOCATION OF DISPLACEMENT GAGES

SCALE: .040"=1.000"

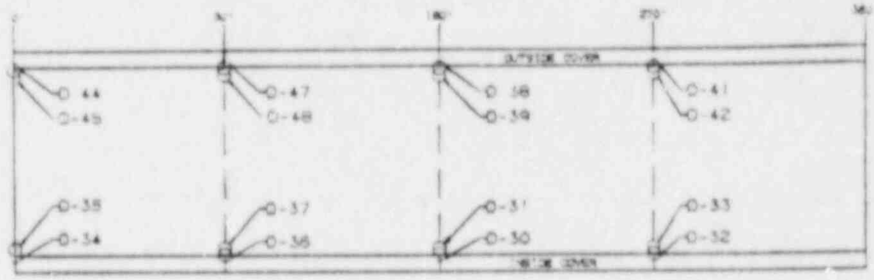
Drawing A9



STRETCHED OUT VIEW OF HATCH B (I.D.)

LOCATION OF DISPLACEMENT GAGES

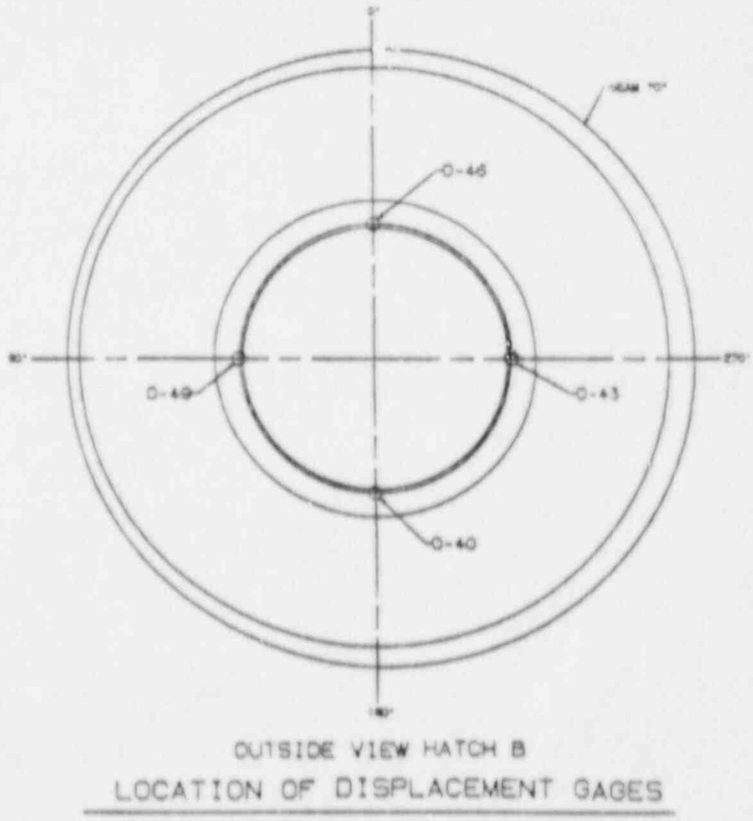
SCALE: .040"=1.000"



STRETCHED OUT VIEW OF HATCH B (O.D.)

LOCATION OF DISPLACEMENT GAGES

SCALE: .040"=1.000"



OUTSIDE VIEW HATCH B

LOCATION OF DISPLACEMENT GAGES

SCALE: .040"=1.000"

Drawing A10

FOUNDATION ELEVATIONS

STA. #1		STA. #2		STA. #3		STA. #4	
DATE	DISTANCE	DATE	DISTANCE	DATE	DISTANCE	DATE	DISTANCE
4-11-87	24.313"	4-11-87	24.188"	4-11-87	24.000"	4-11-87	24.375"
7-10-87	24.063"	7-10-87	23.937"	7-10-87	23.812"	7-10-87	24.219"
7-31-87	24.031"	7-31-87	23.937"	7-31-87	23.812"	7-31-87	24.218"
4-11-88	24.1653"	4-11-88	24.1875"	4-11-88	24.0938"	4-11-88	24.2188"

BASE MAT ELEVATIONS

STA. #1		STA. #2		STA. #3		STA. #4	
DATE	DISTANCE	DATE	DISTANCE	DATE	DISTANCE	DATE	DISTANCE
7-10-87	65.281"	7-10-87	65.125"	7-10-87	64.375"	7-10-87	65.032"
4-11-88	64.875"	4-11-88	65.000"	4-11-88	64.281"	4-11-88	64.344"

NOTE:
FOUNDATION AND BASE MAT ELEVATIONS ARE IN RELATION TO THE TOOLING BALL LOCATED ON THE ROOF OF BUILDING 880B. DISTANCE RECORDED IS THE DISTANCE FROM THE TOP [OF] THE TOOLING BALL TO THE BRASS CAPS LOCATED ON THE FOUNDATION AND BASE MATS. SEE PLAN VIEW FOR STATION LOCATIONS.

Drawing A11

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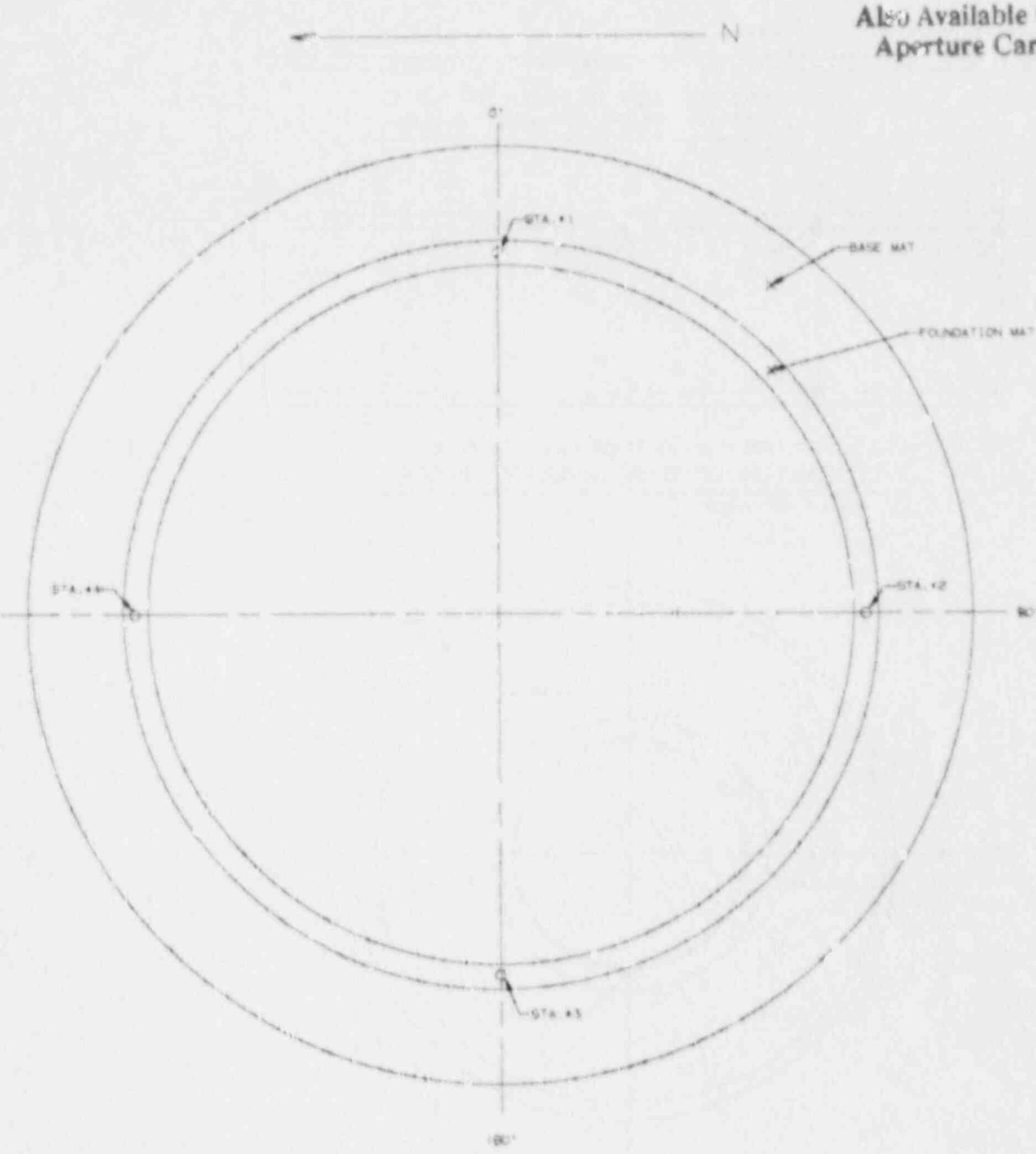

PLAN VIEW
CONTAINMENT VESSEL

SCALE: .015"=1.000"

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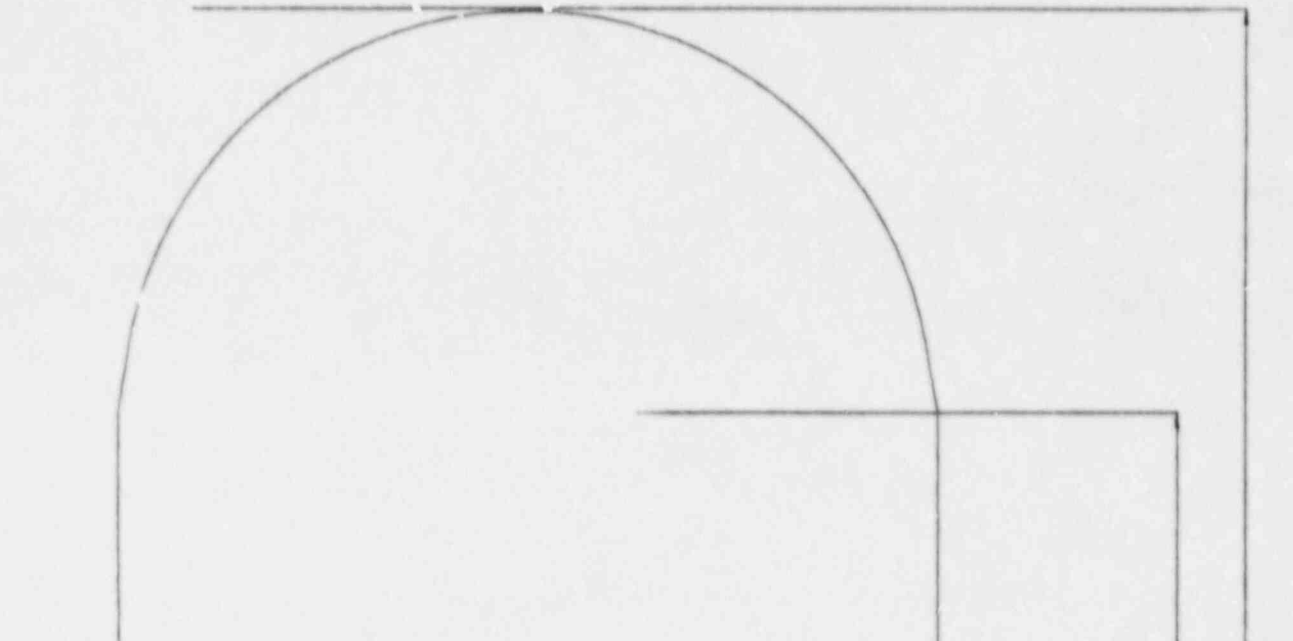
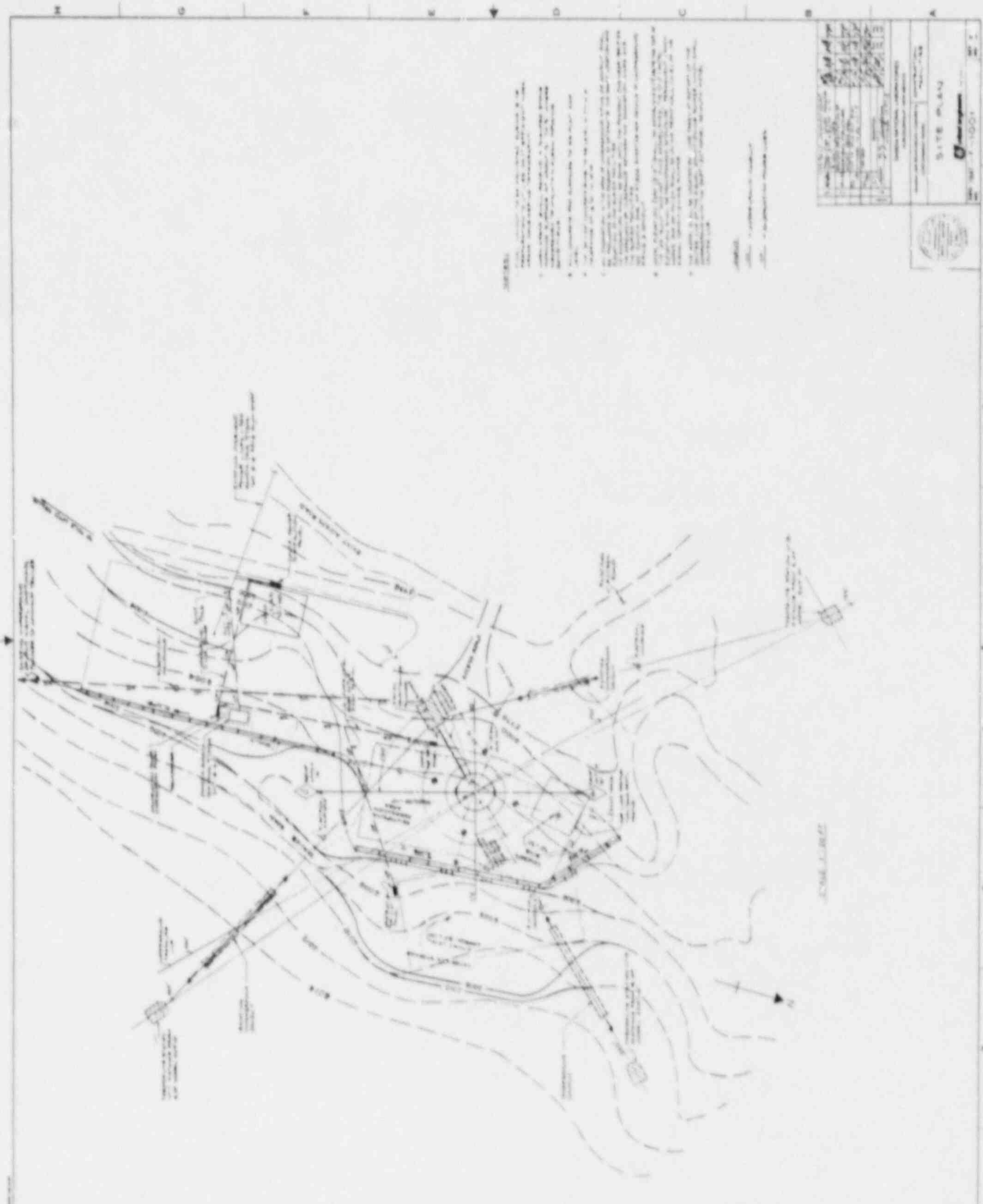


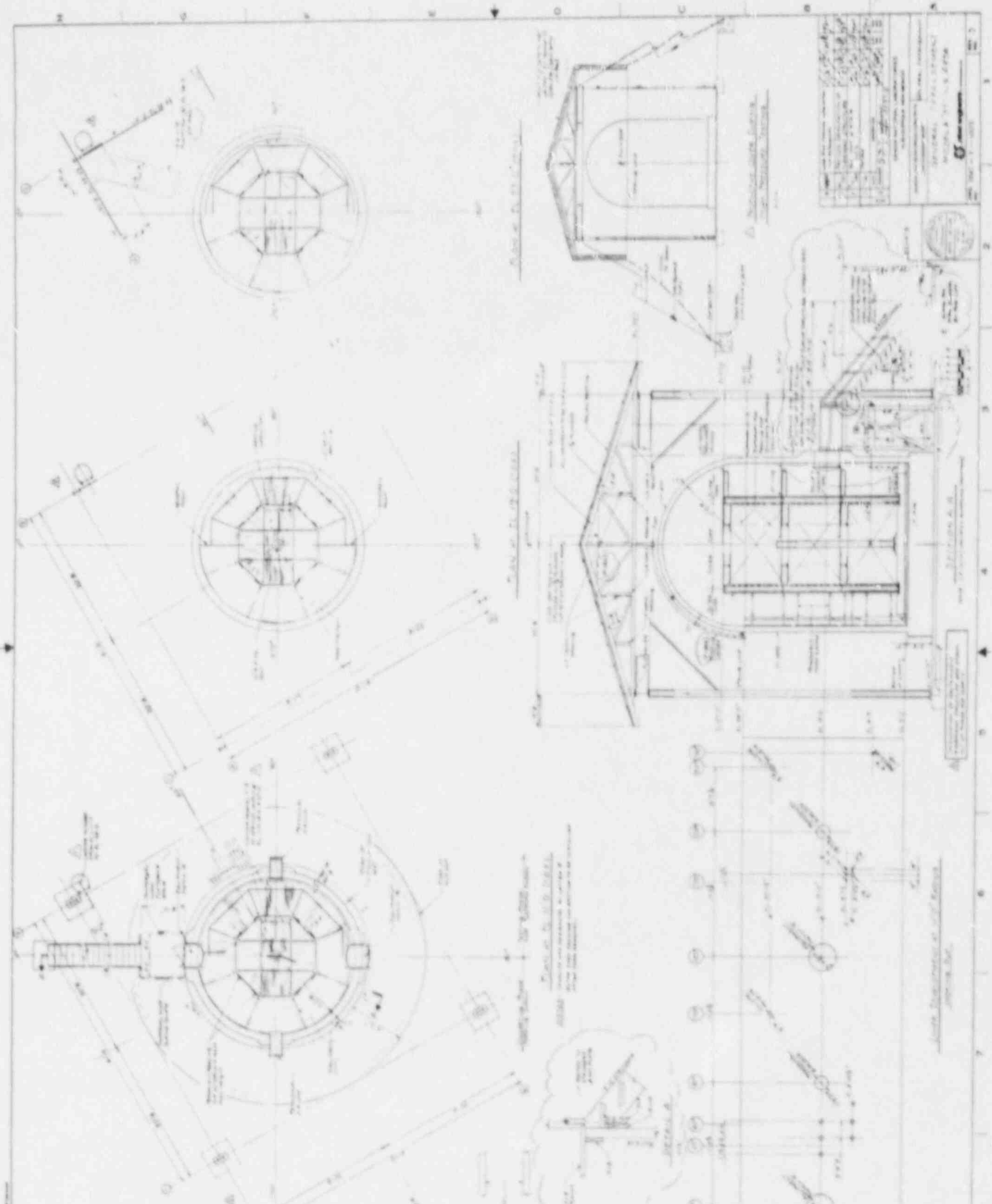
ELEVATION CONTAINMENT VESSEL

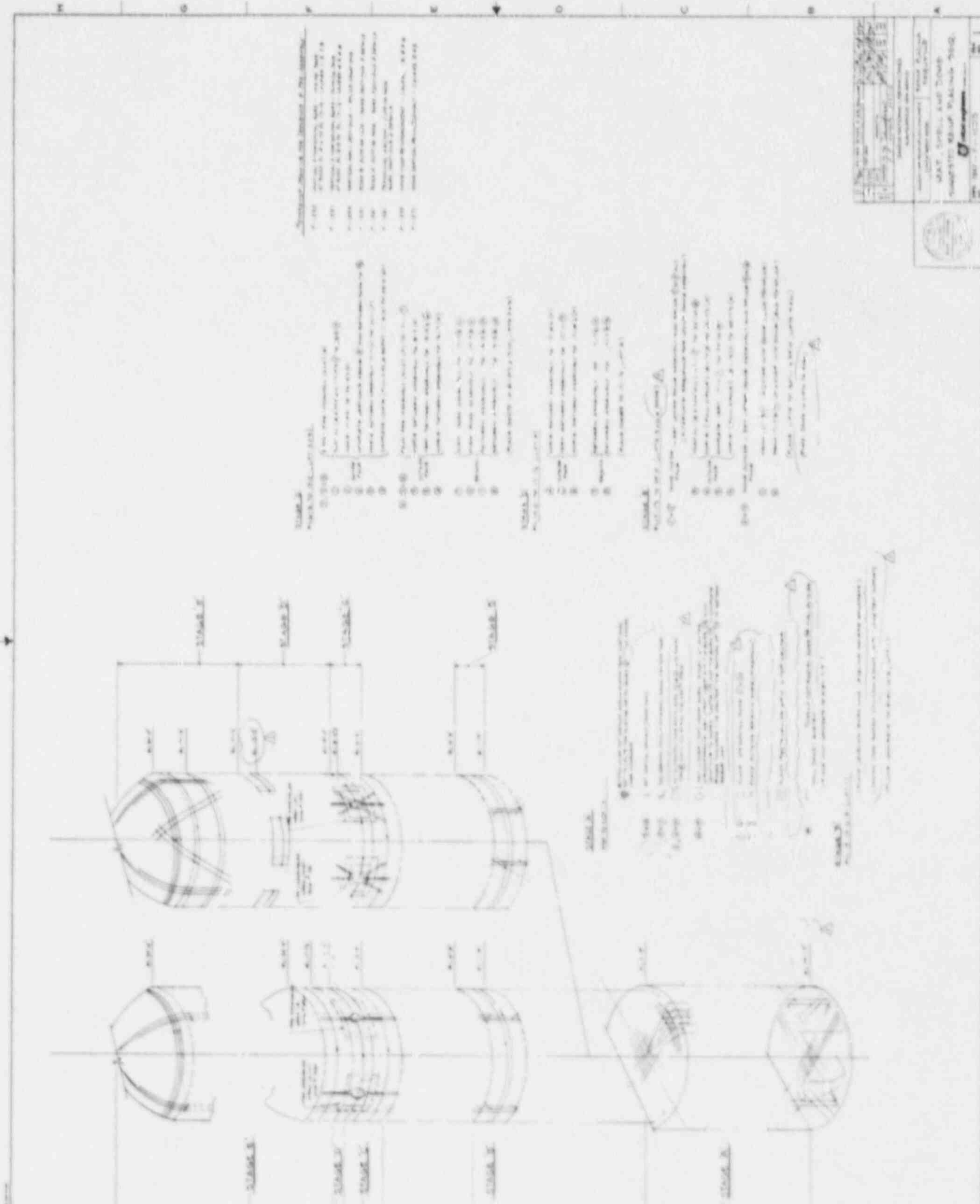
SCALE: .018"=1.000"

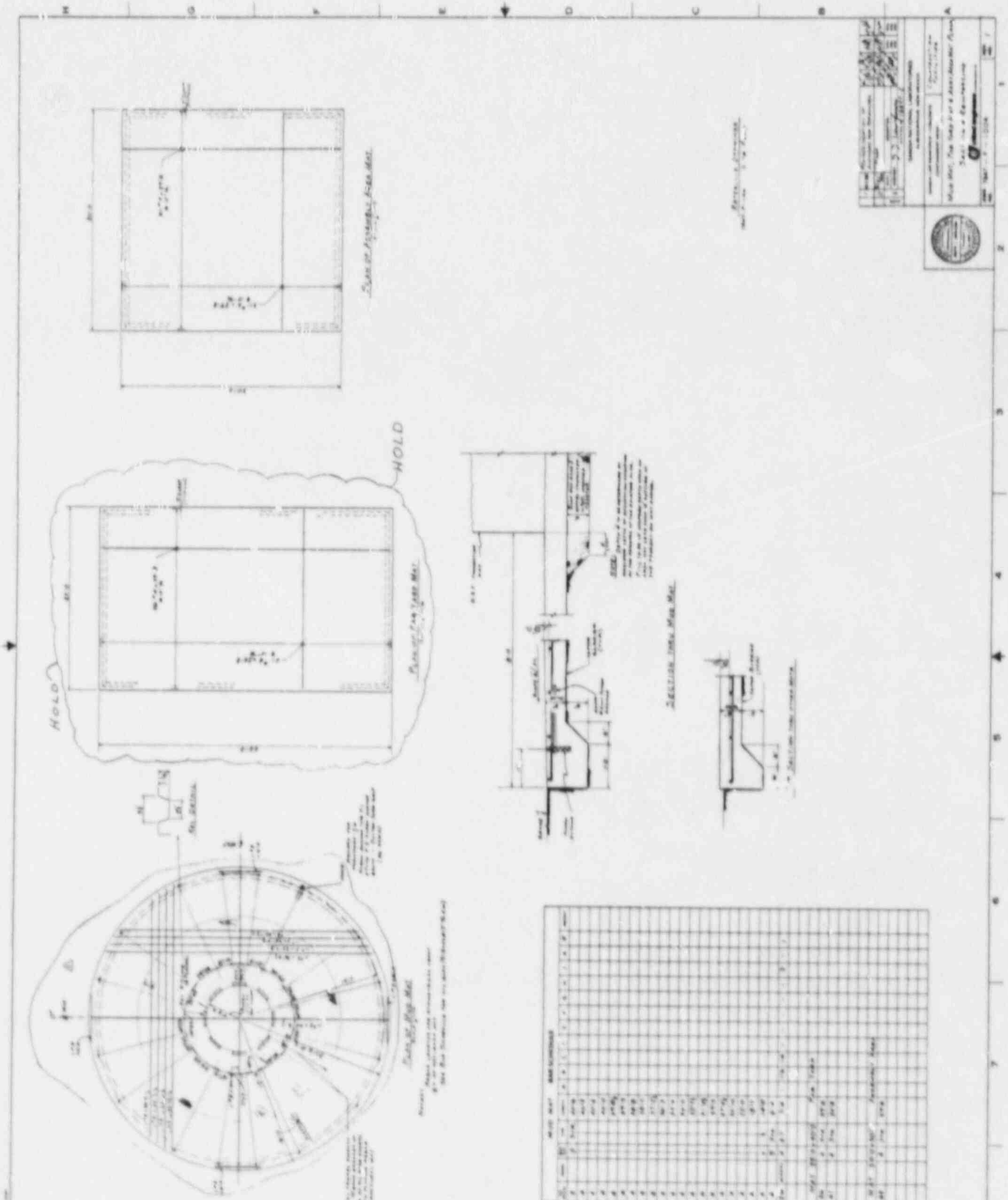
Drawing A12

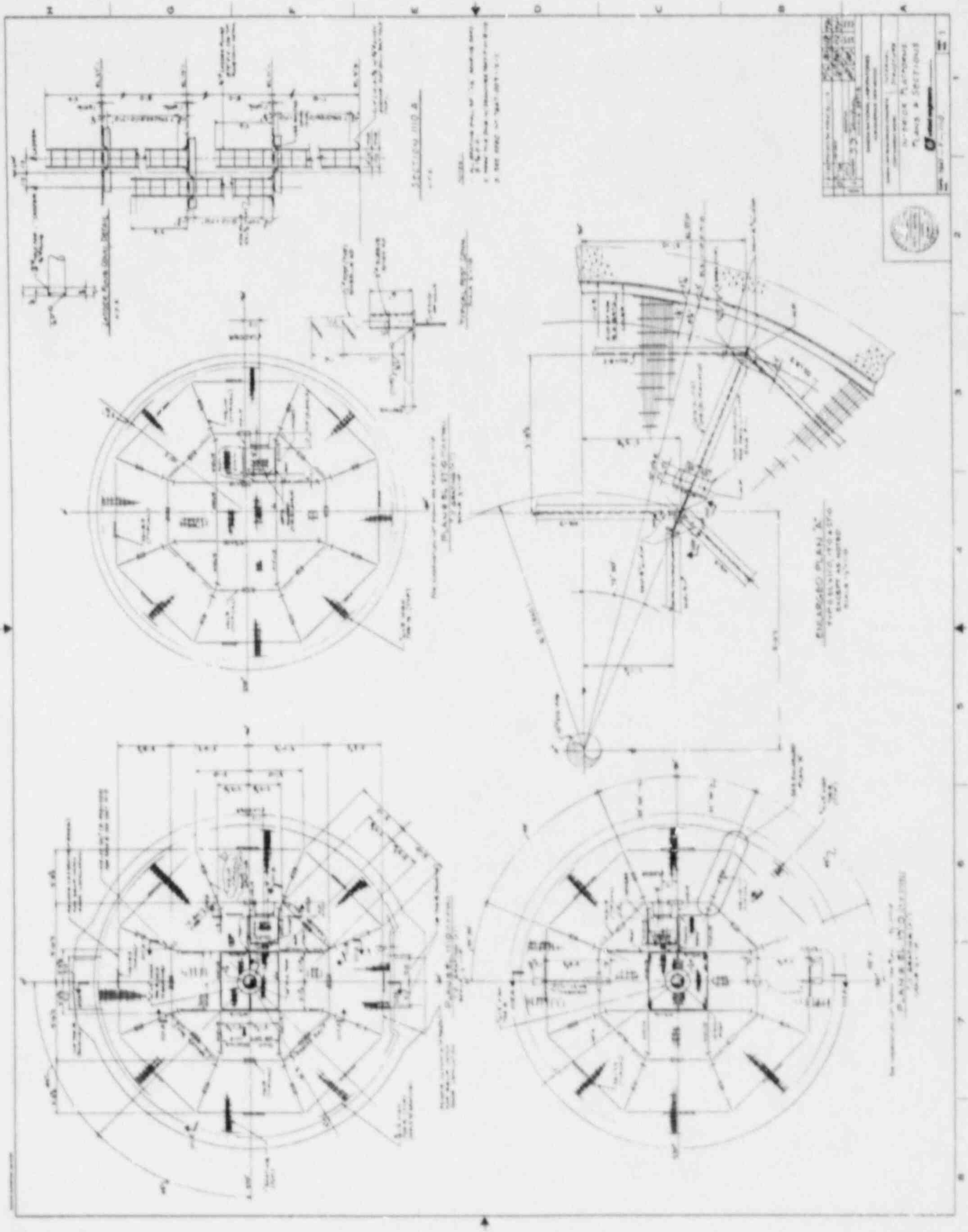
APPENDIX B
UNITED AND CB&I CONSTRUCTION DRAWINGS

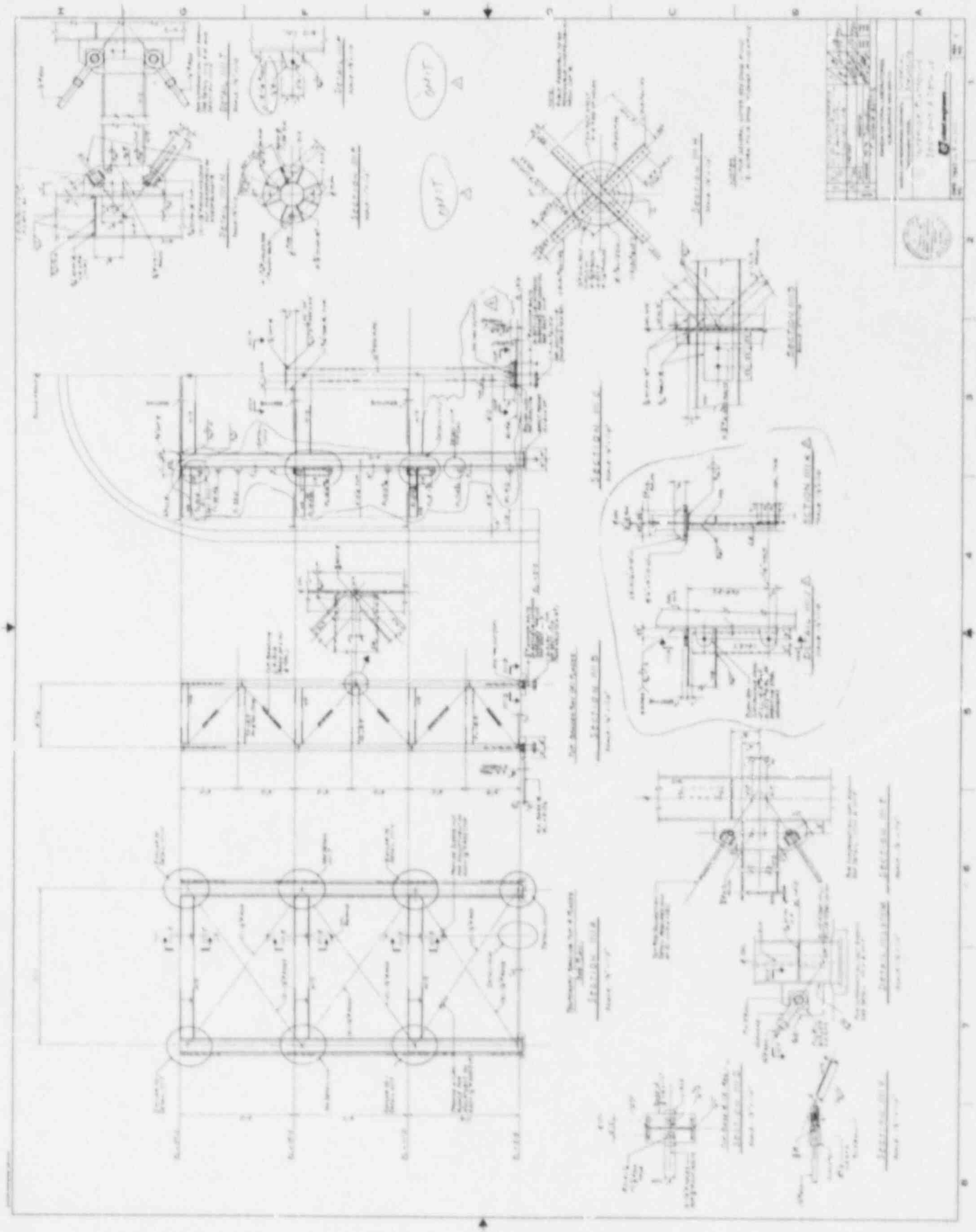

SITE PLAN

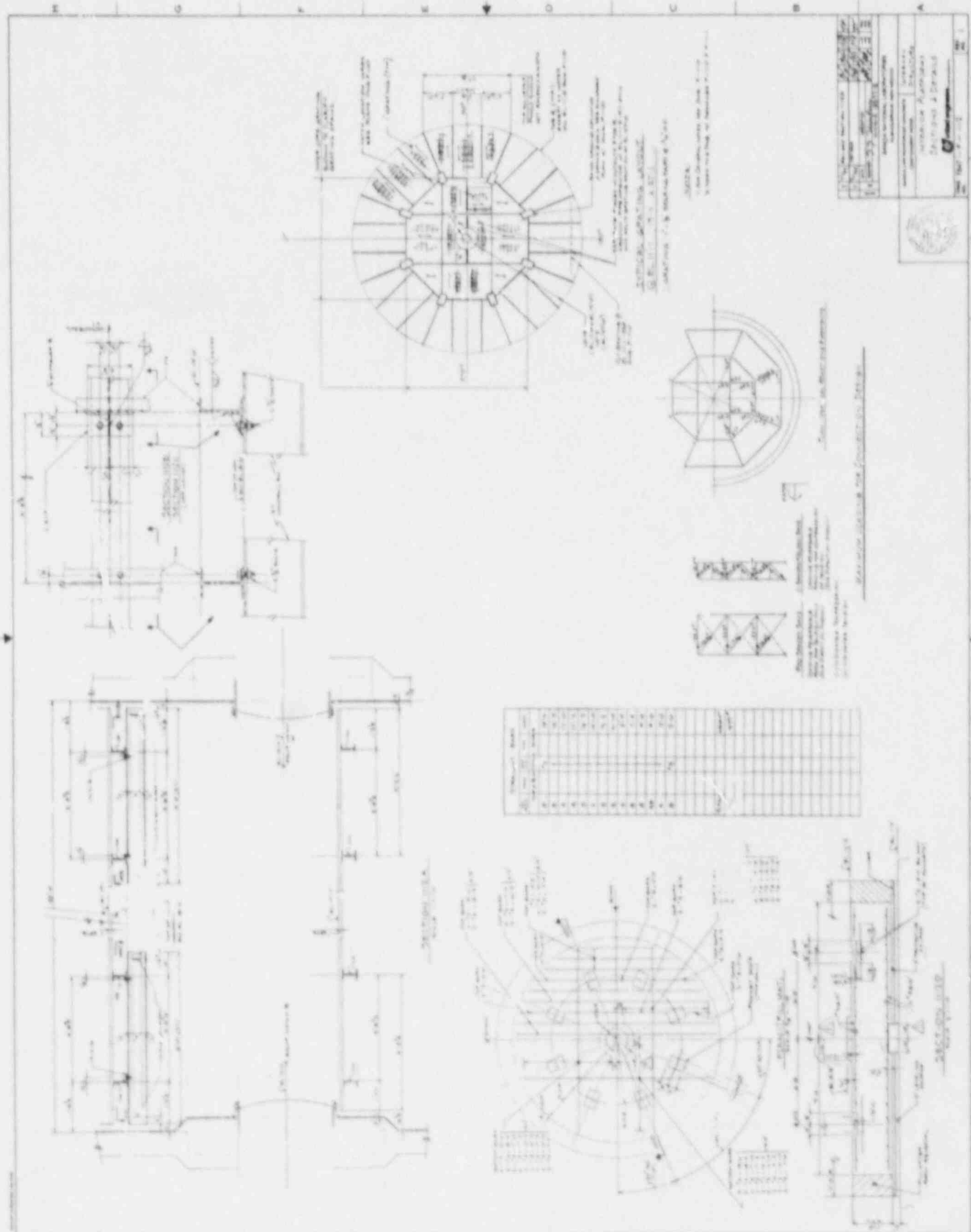


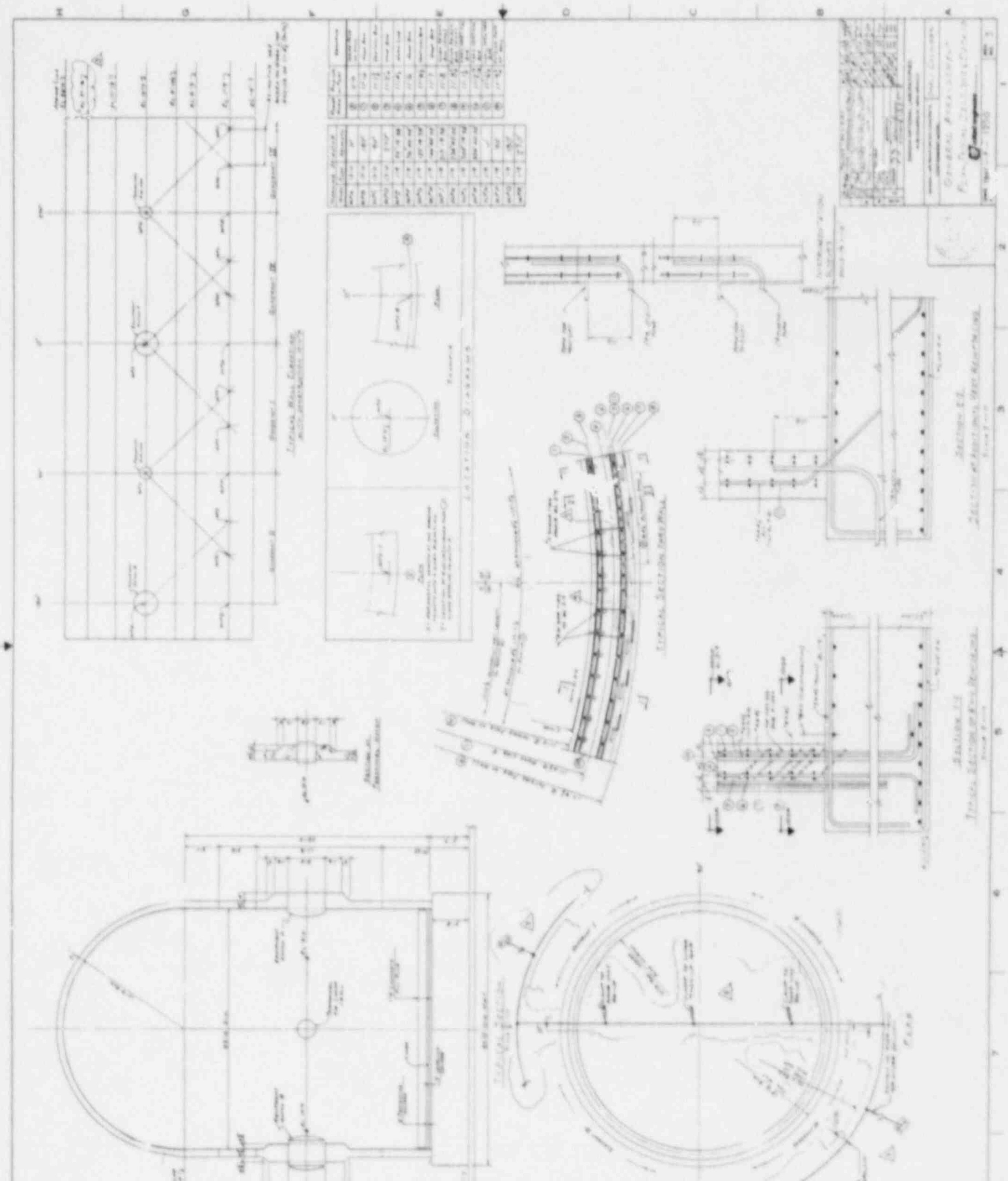


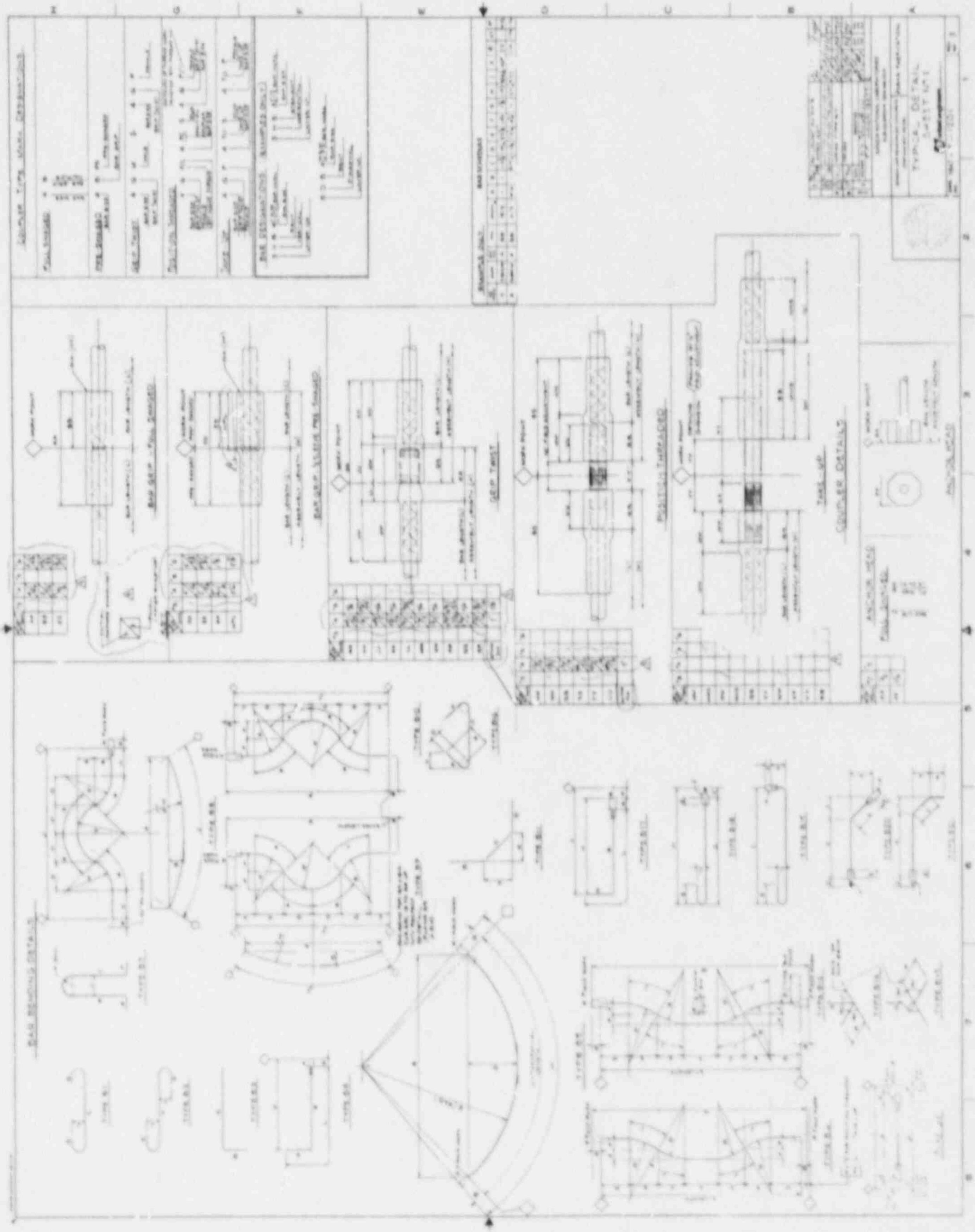

HOLD
HOLD

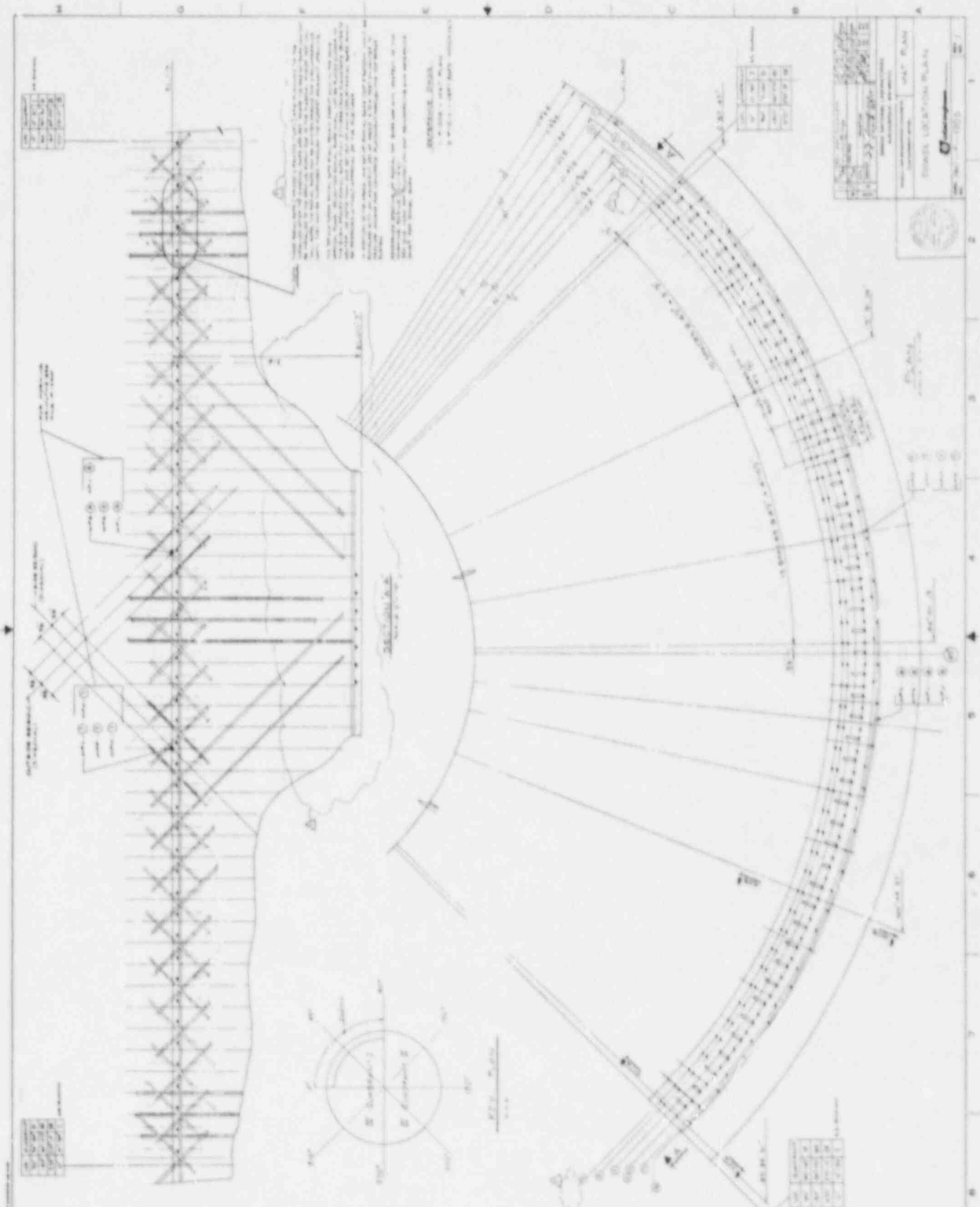


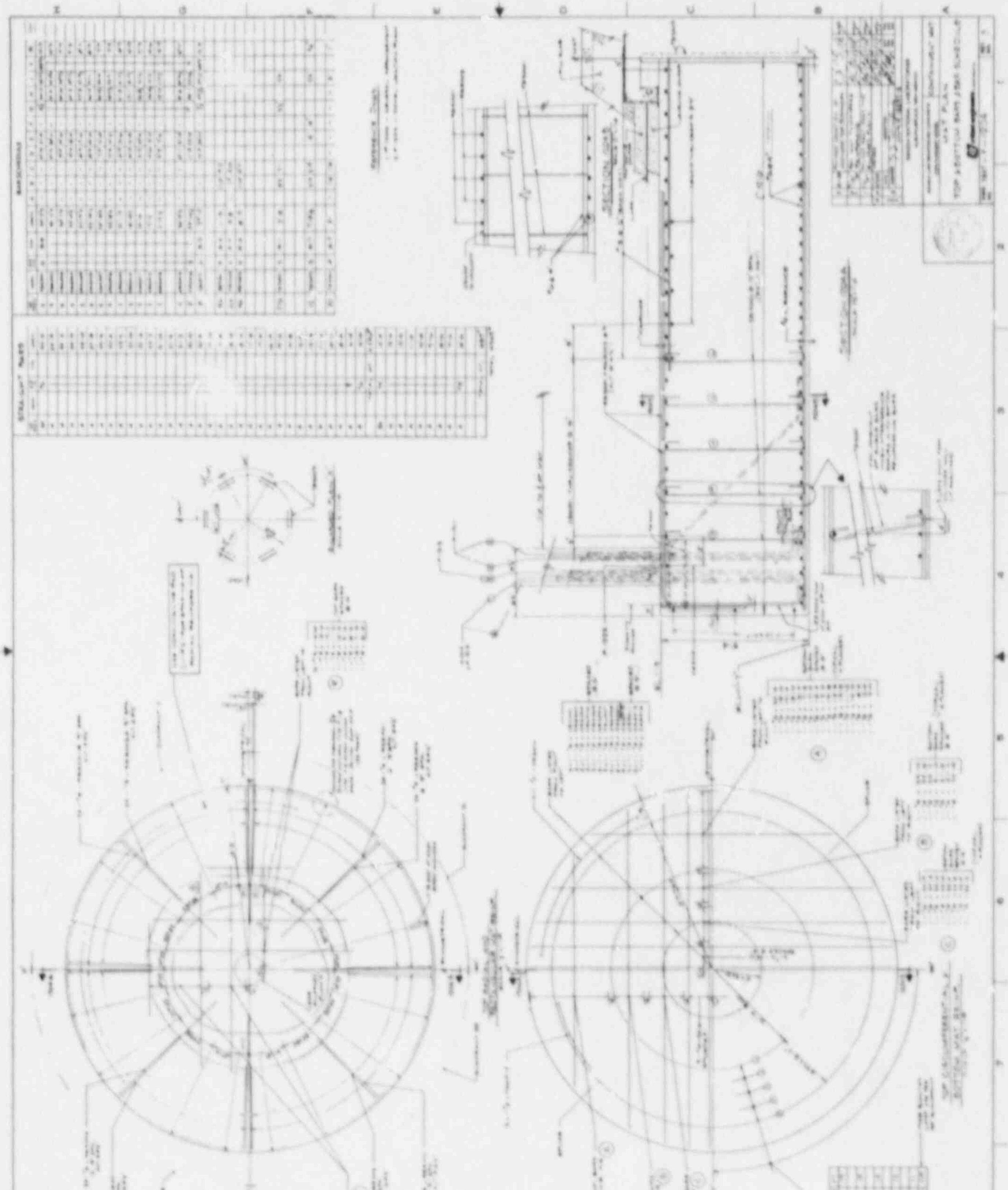


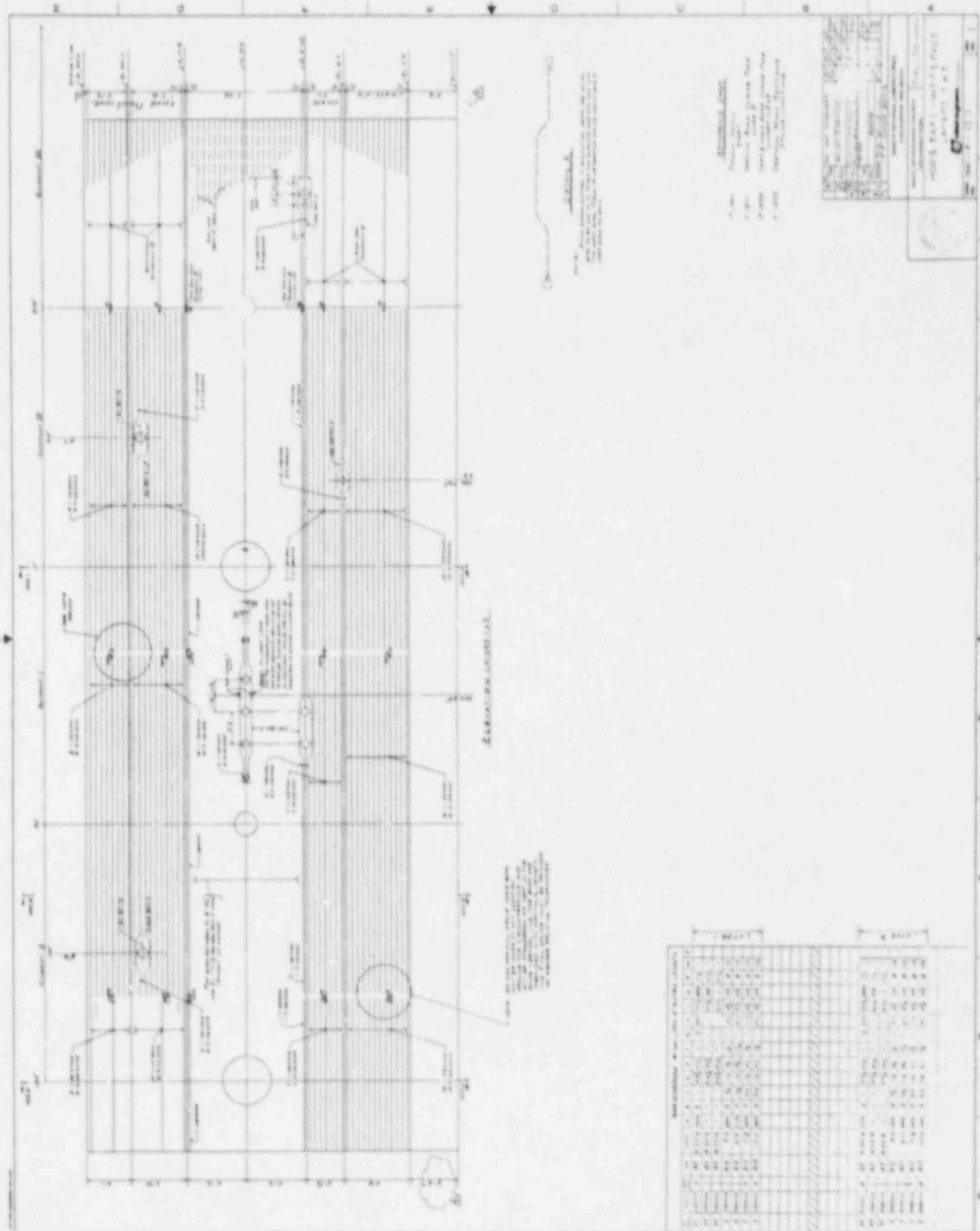


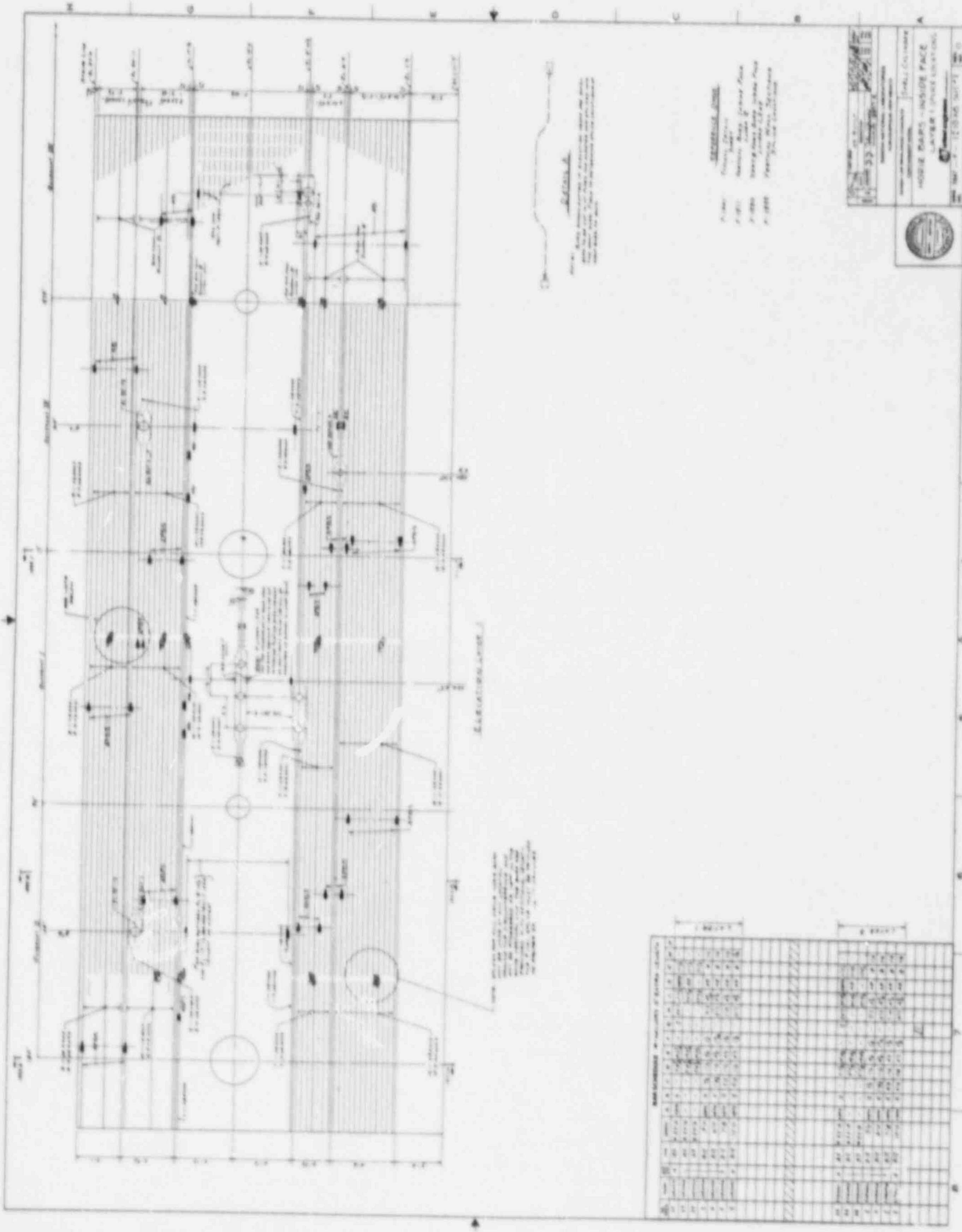


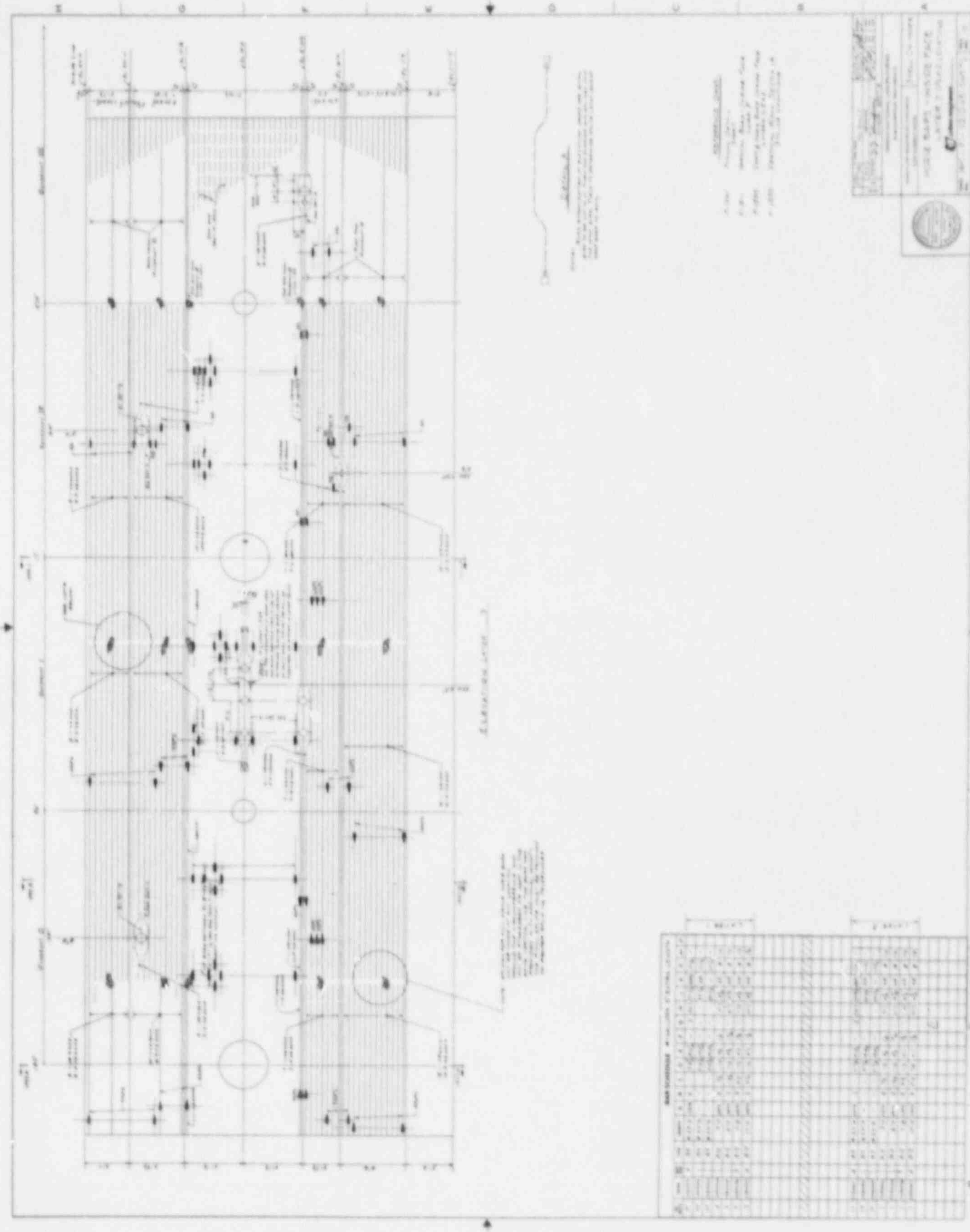


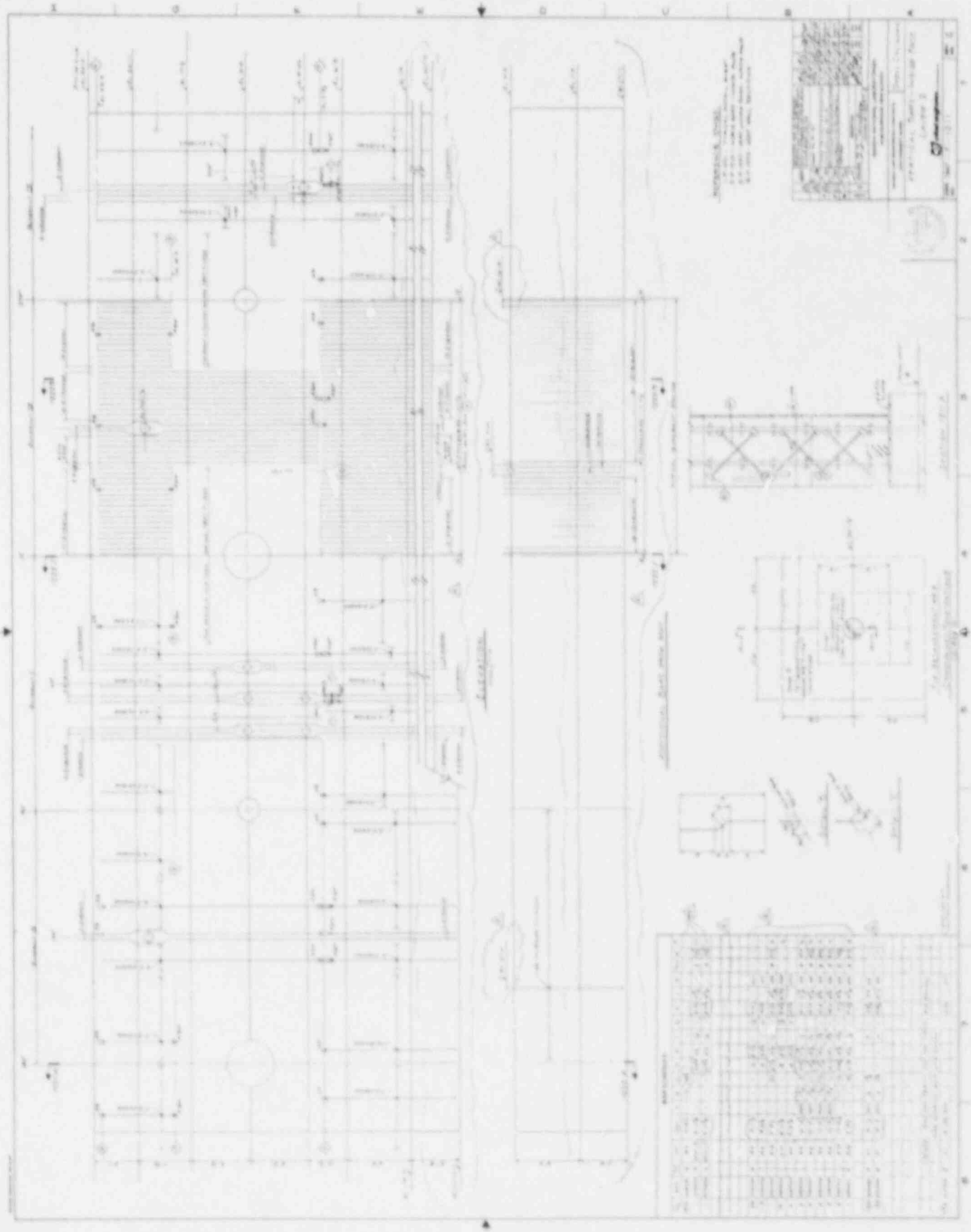


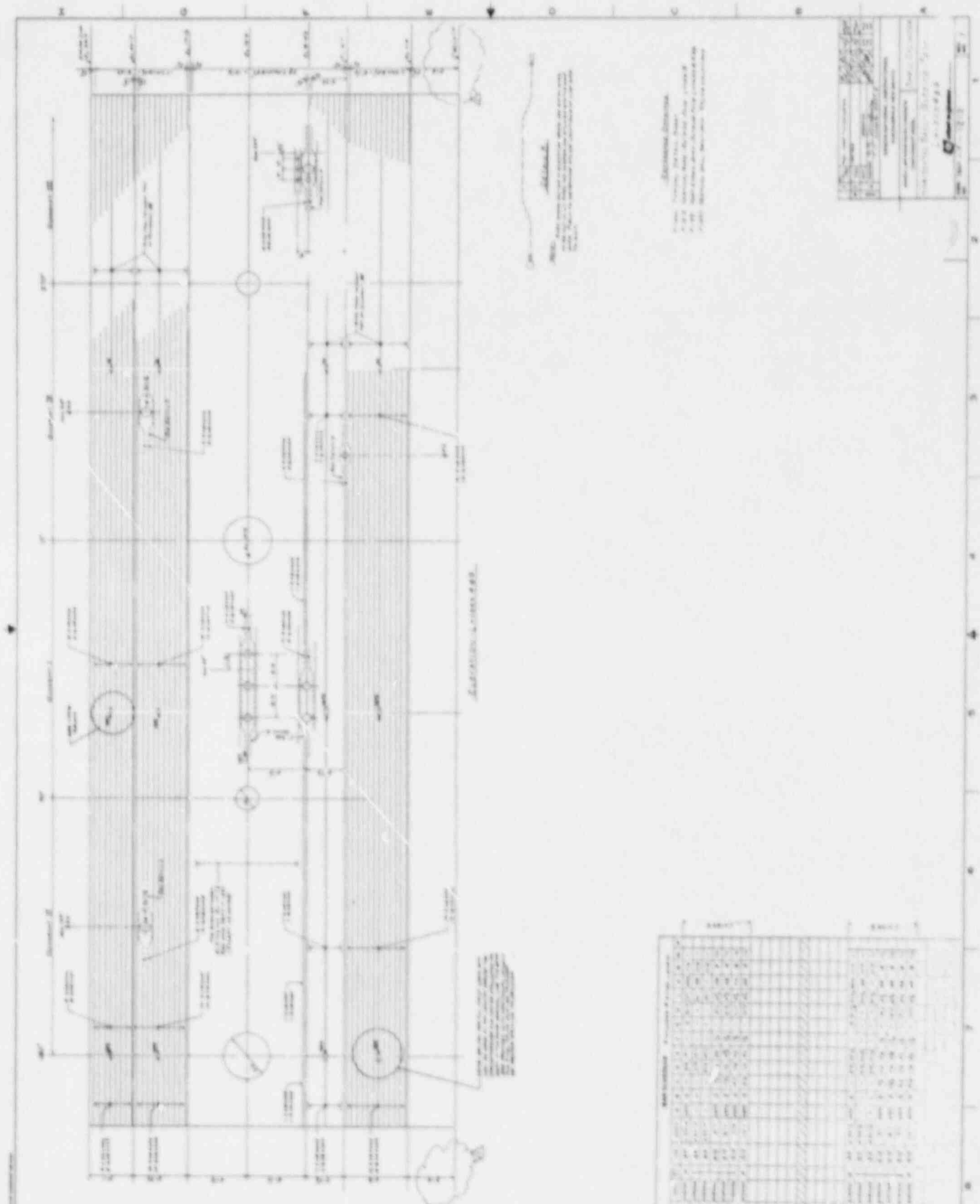


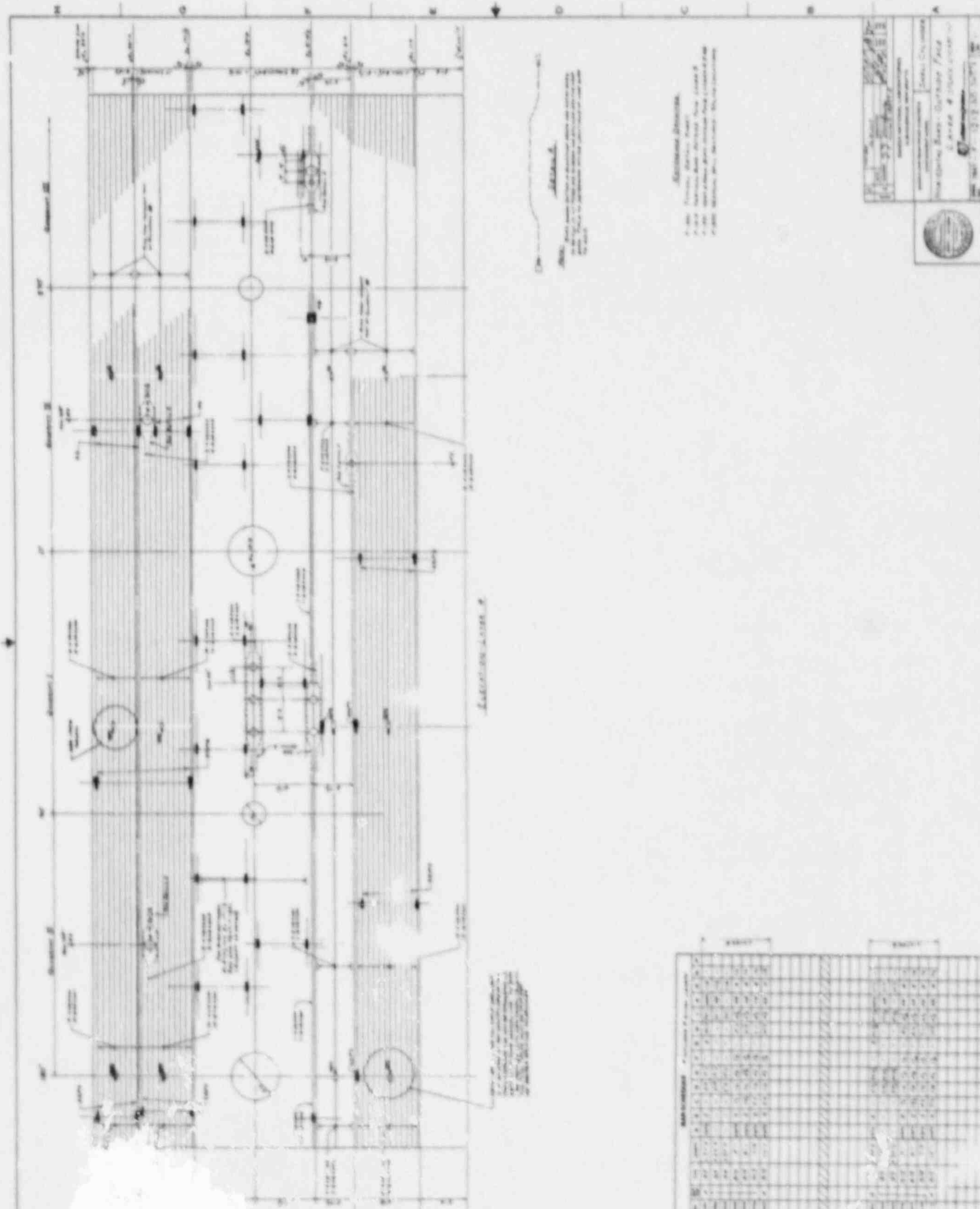


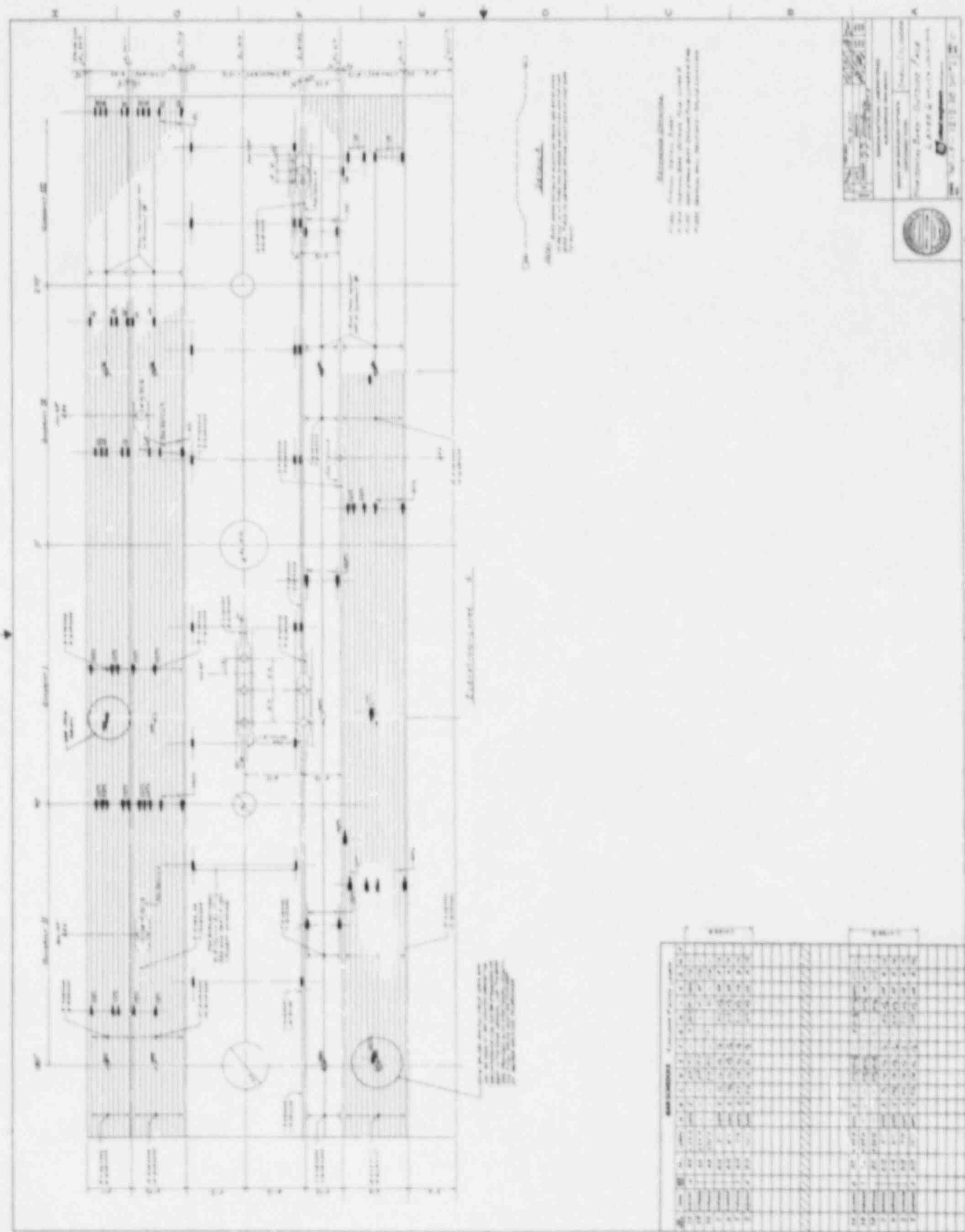


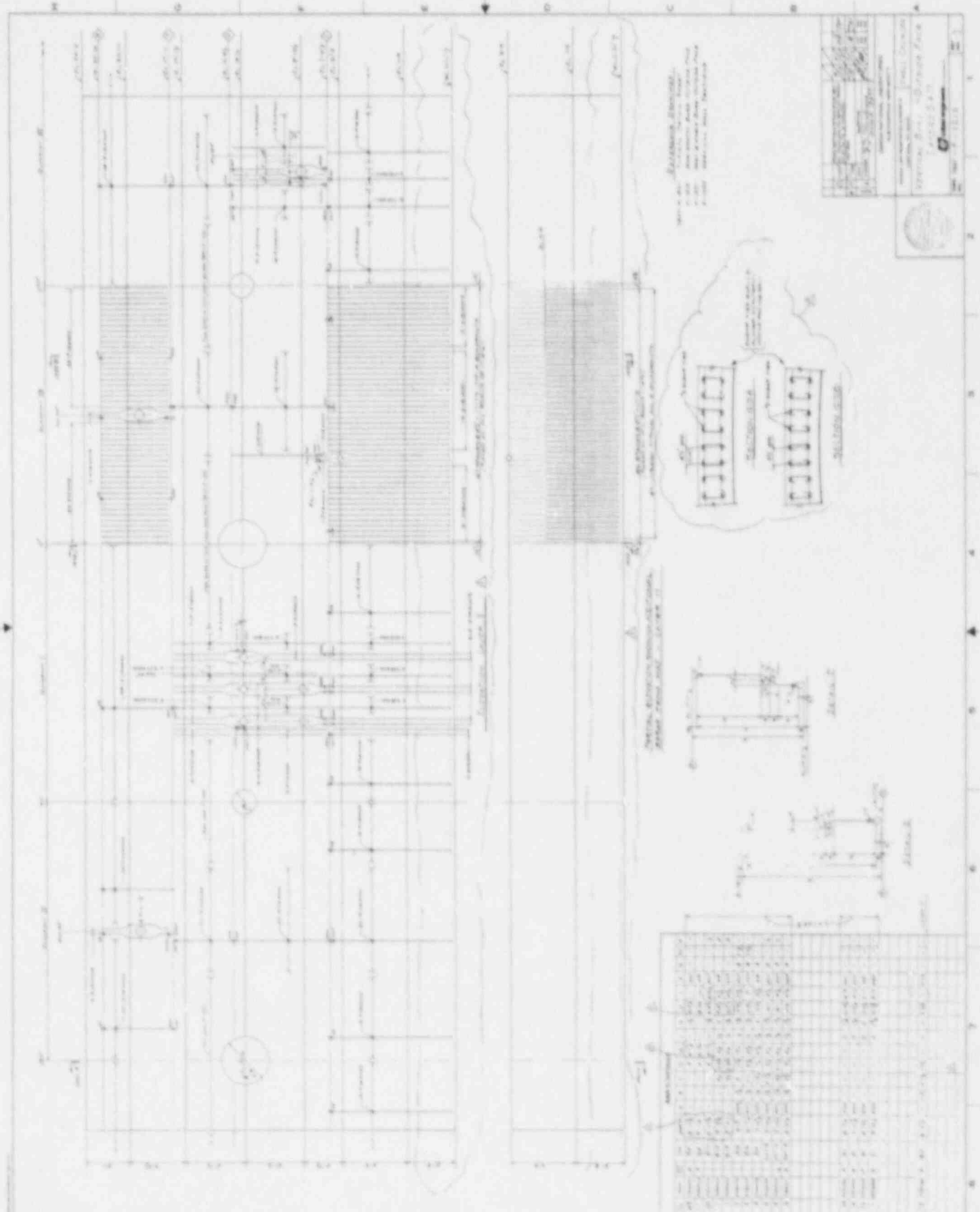


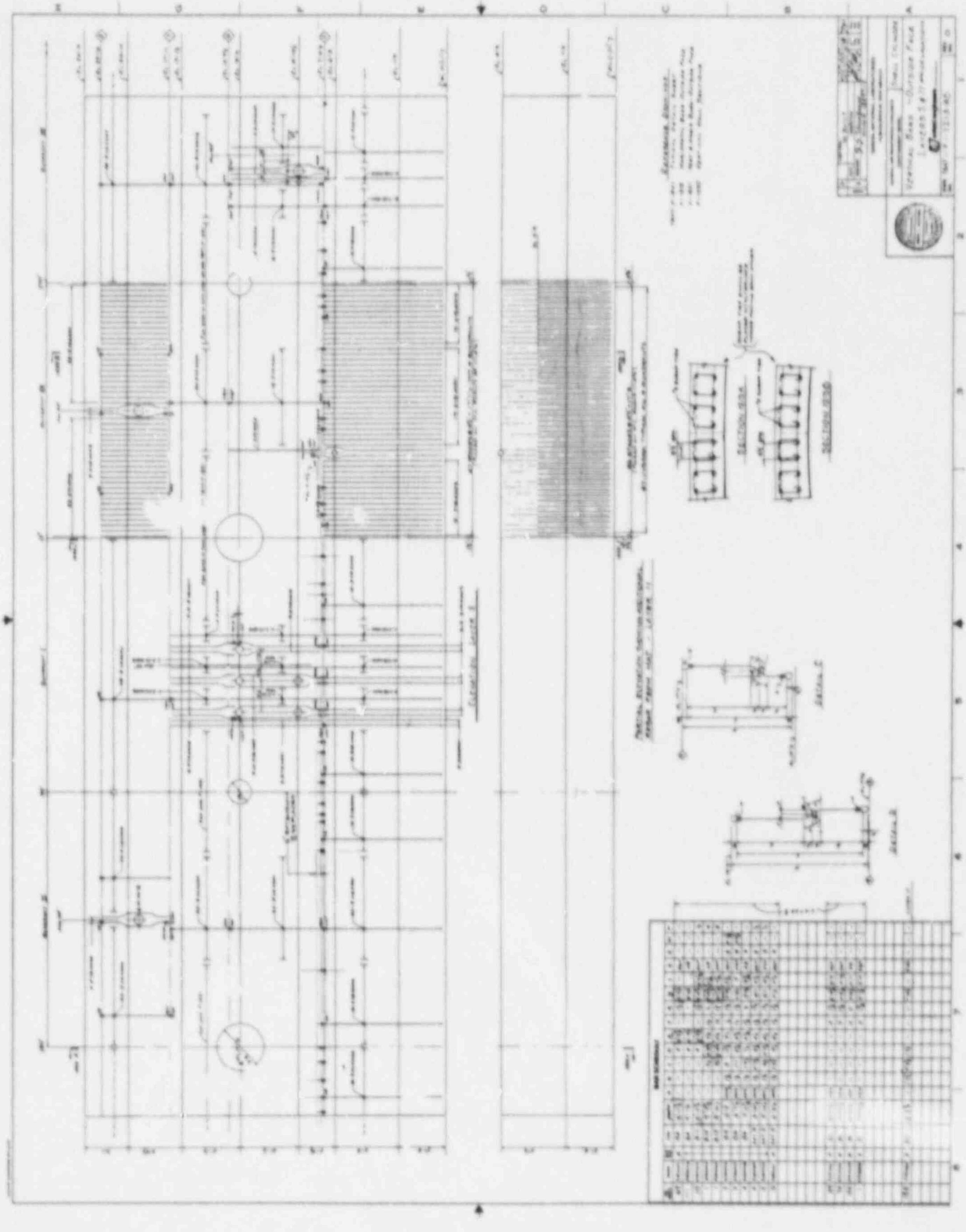


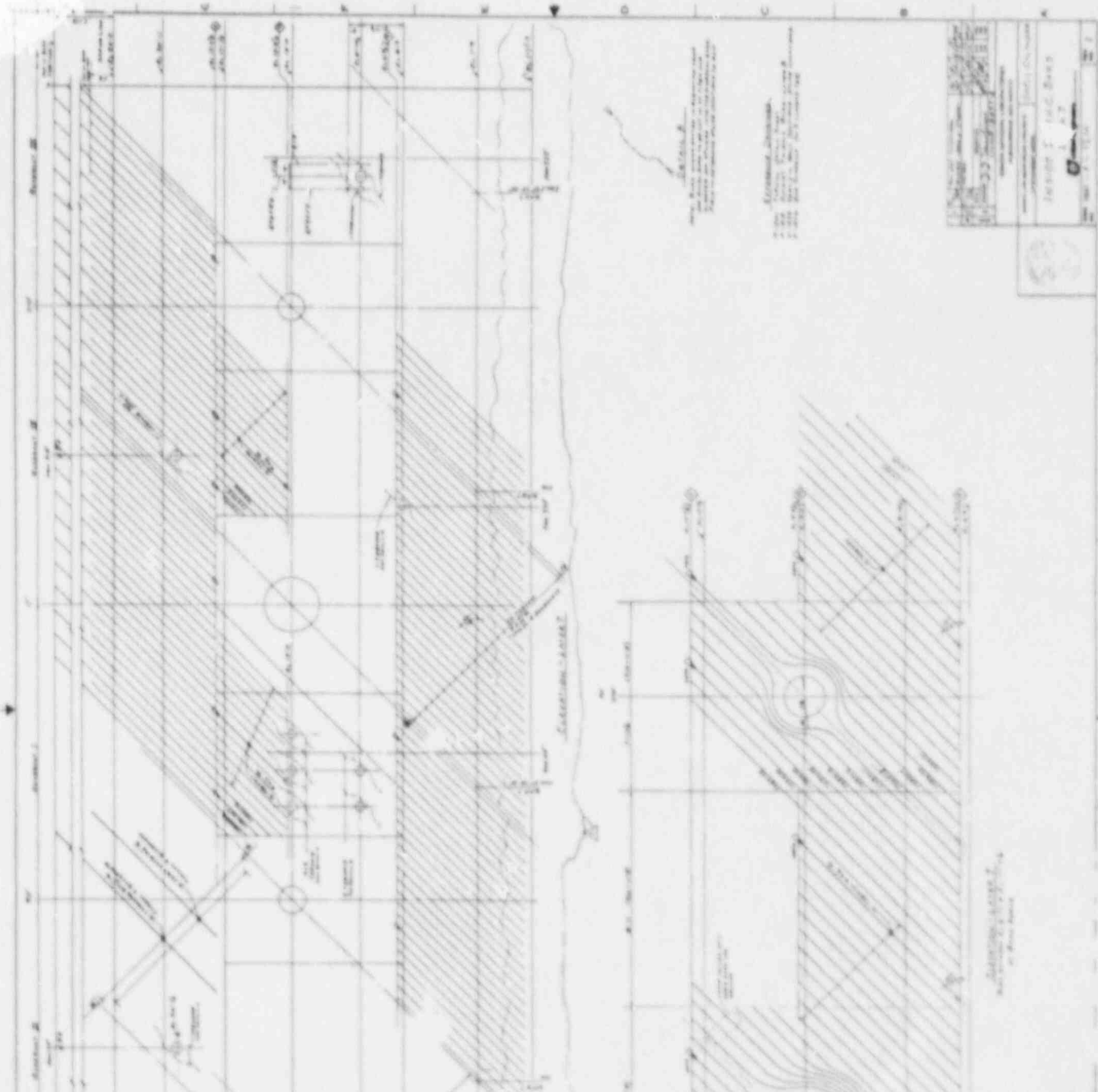


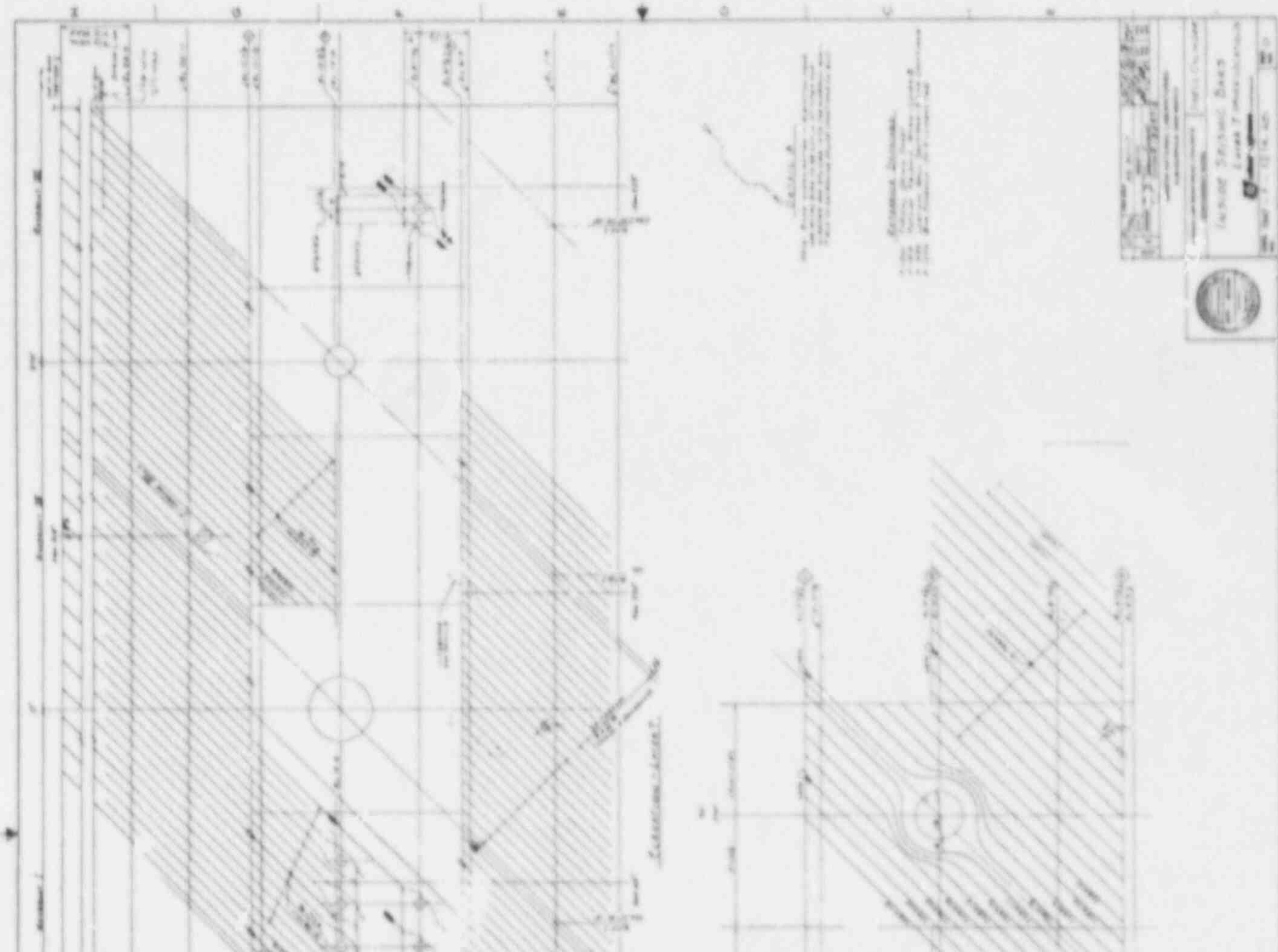


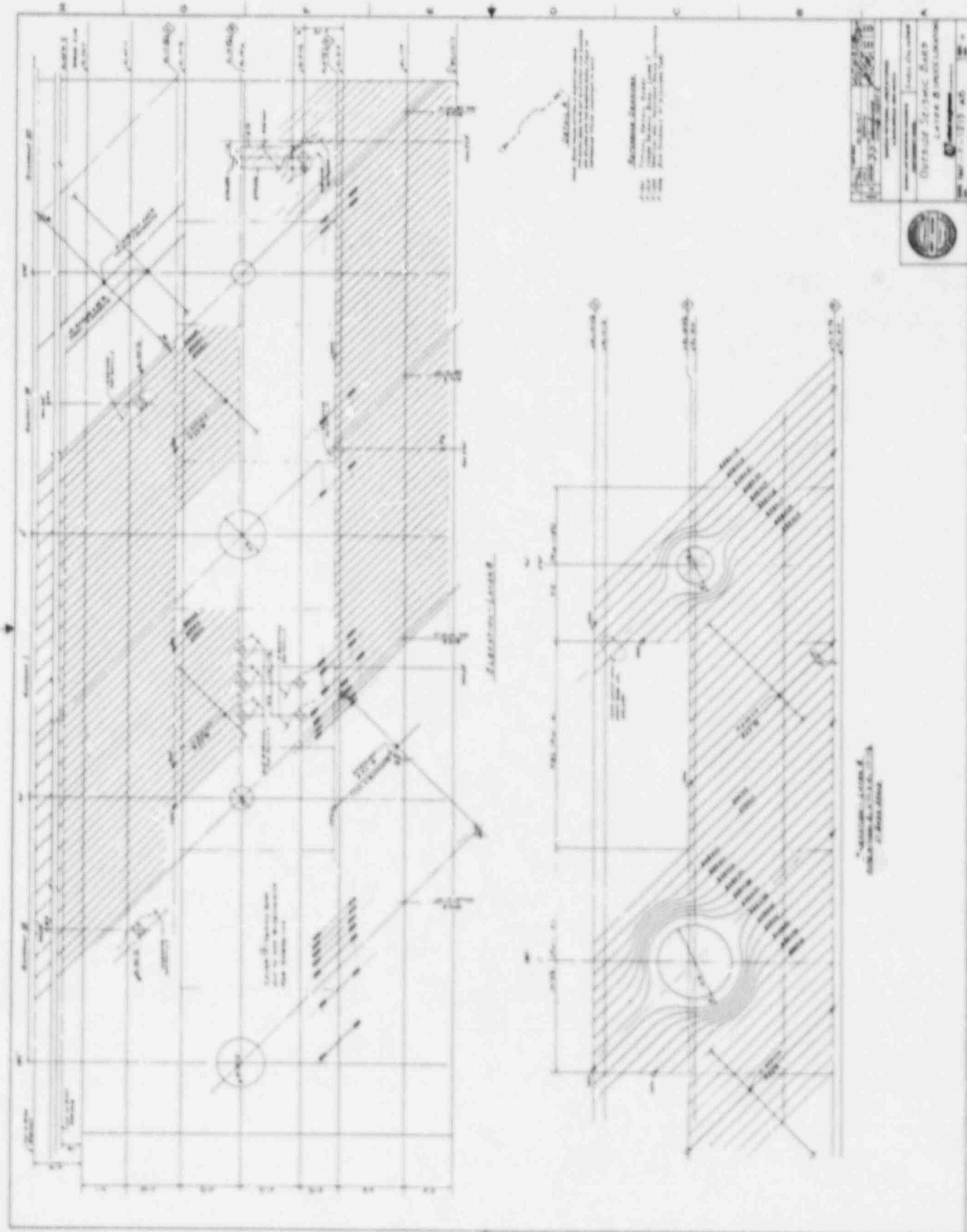


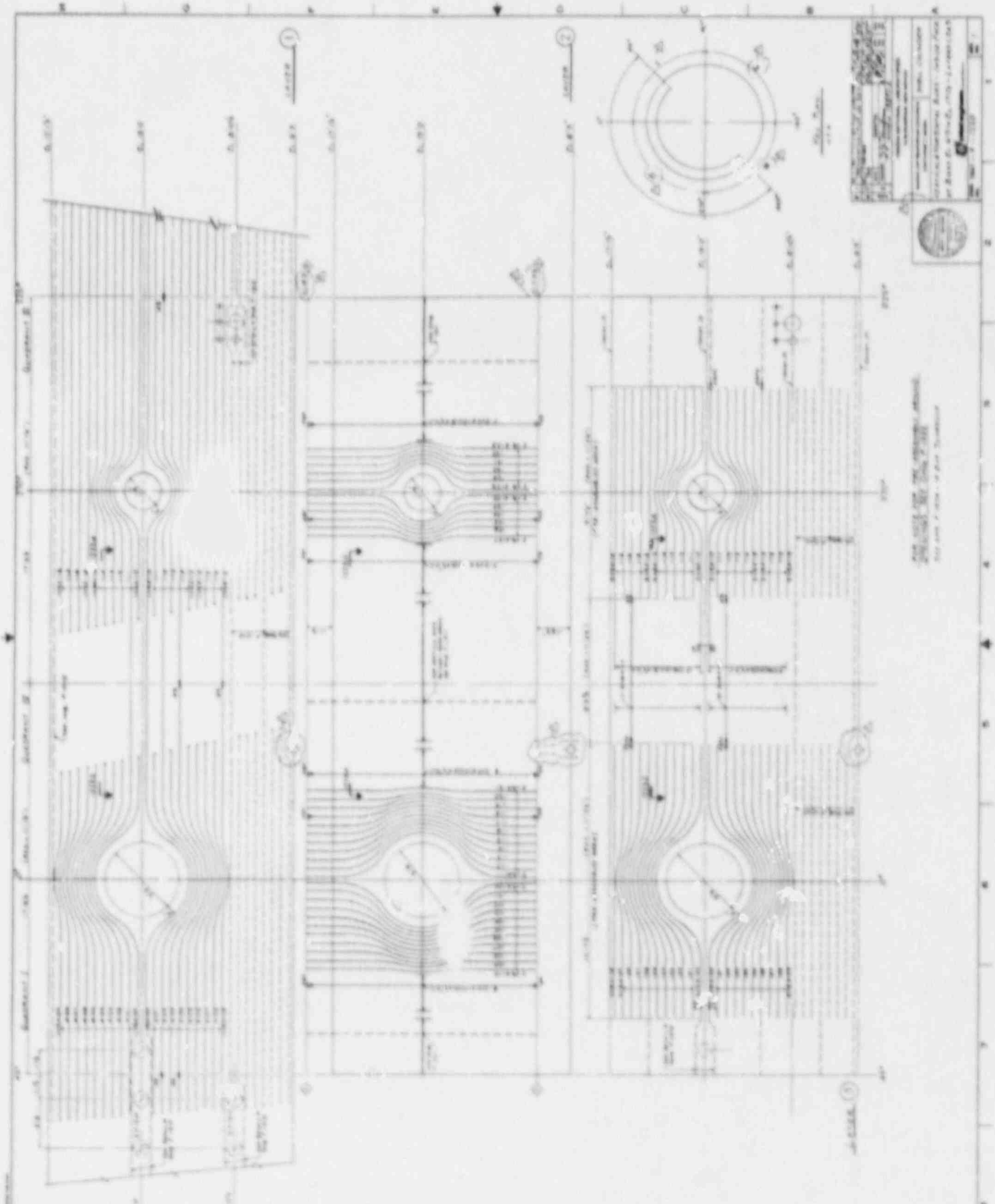


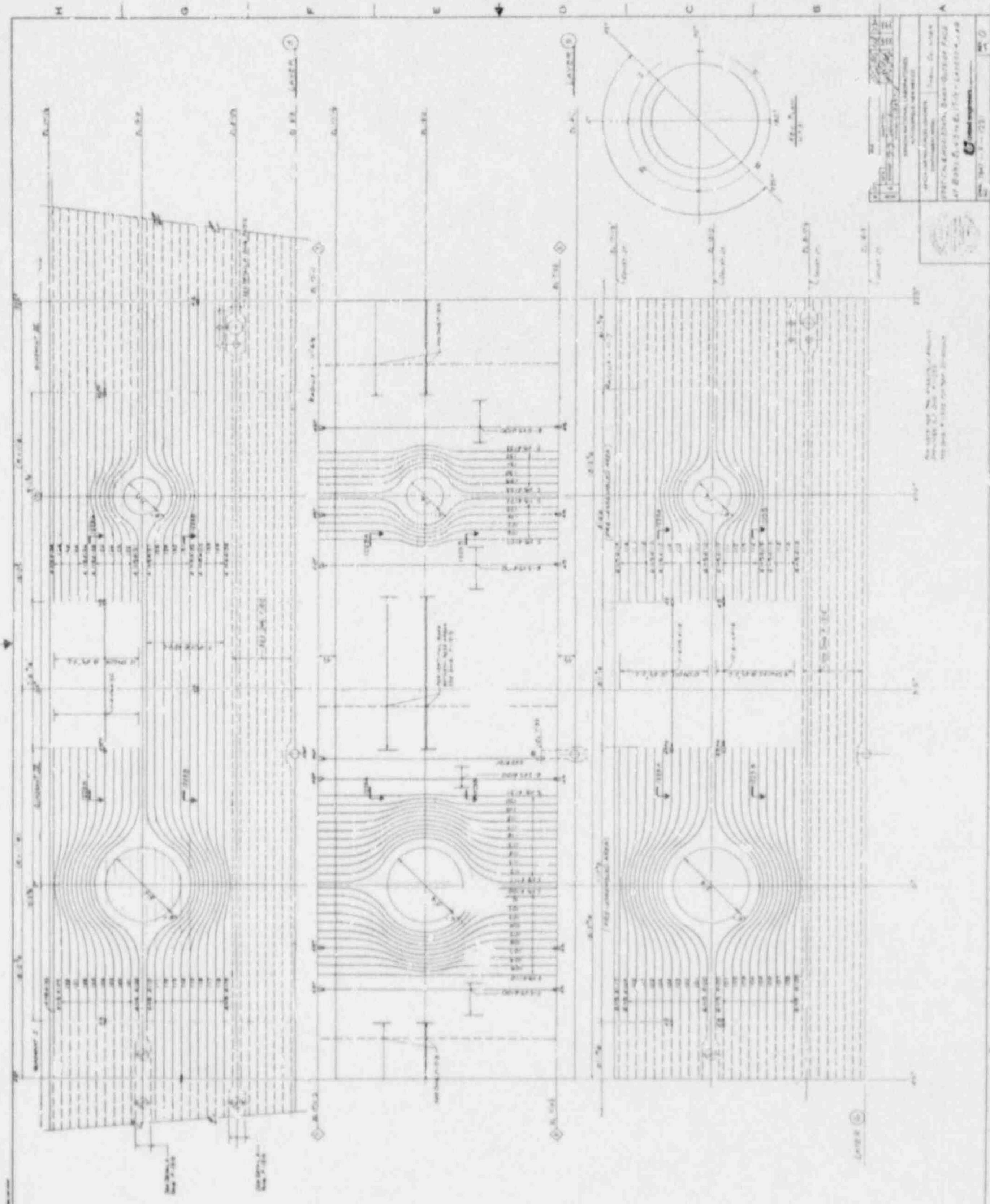


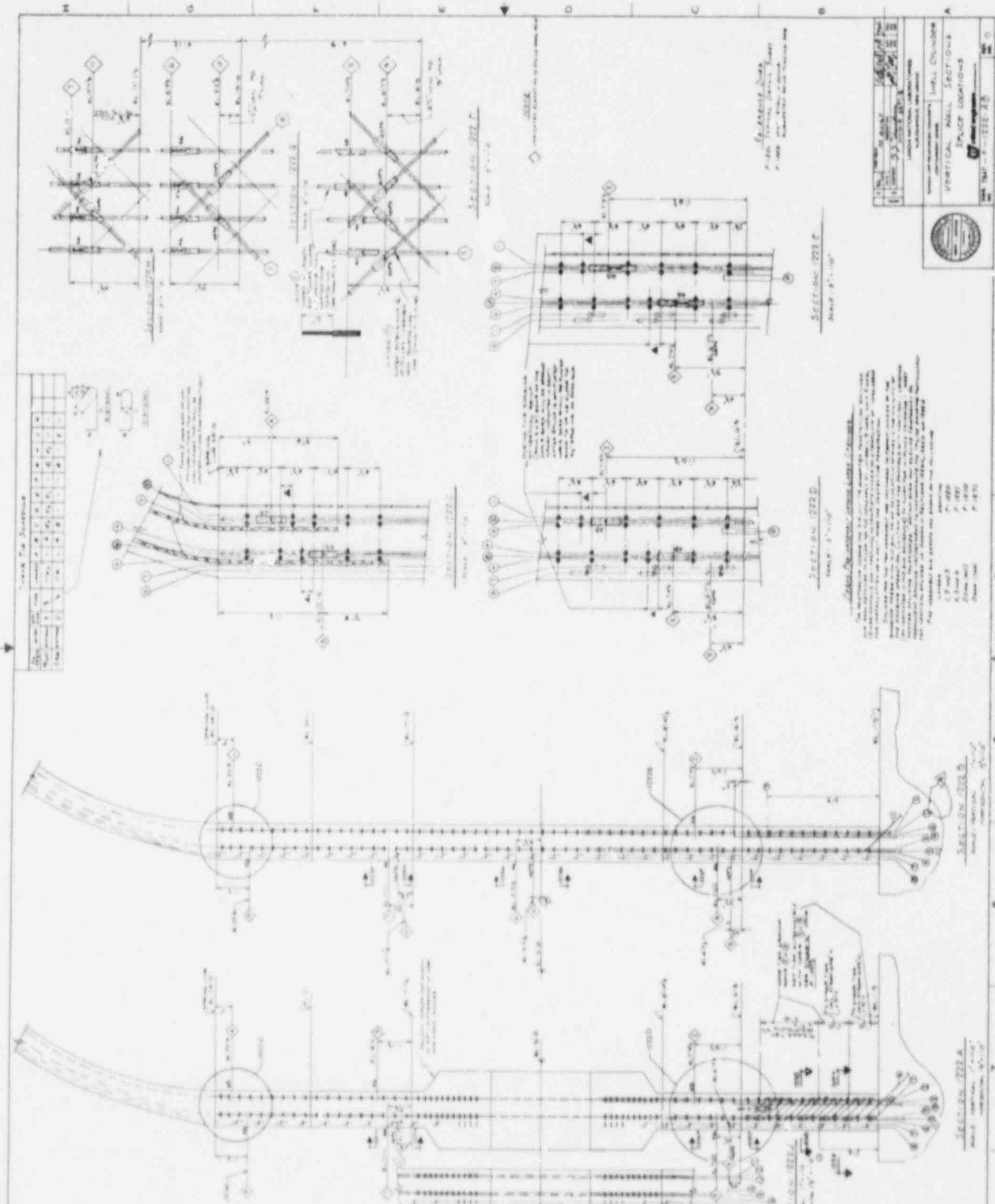


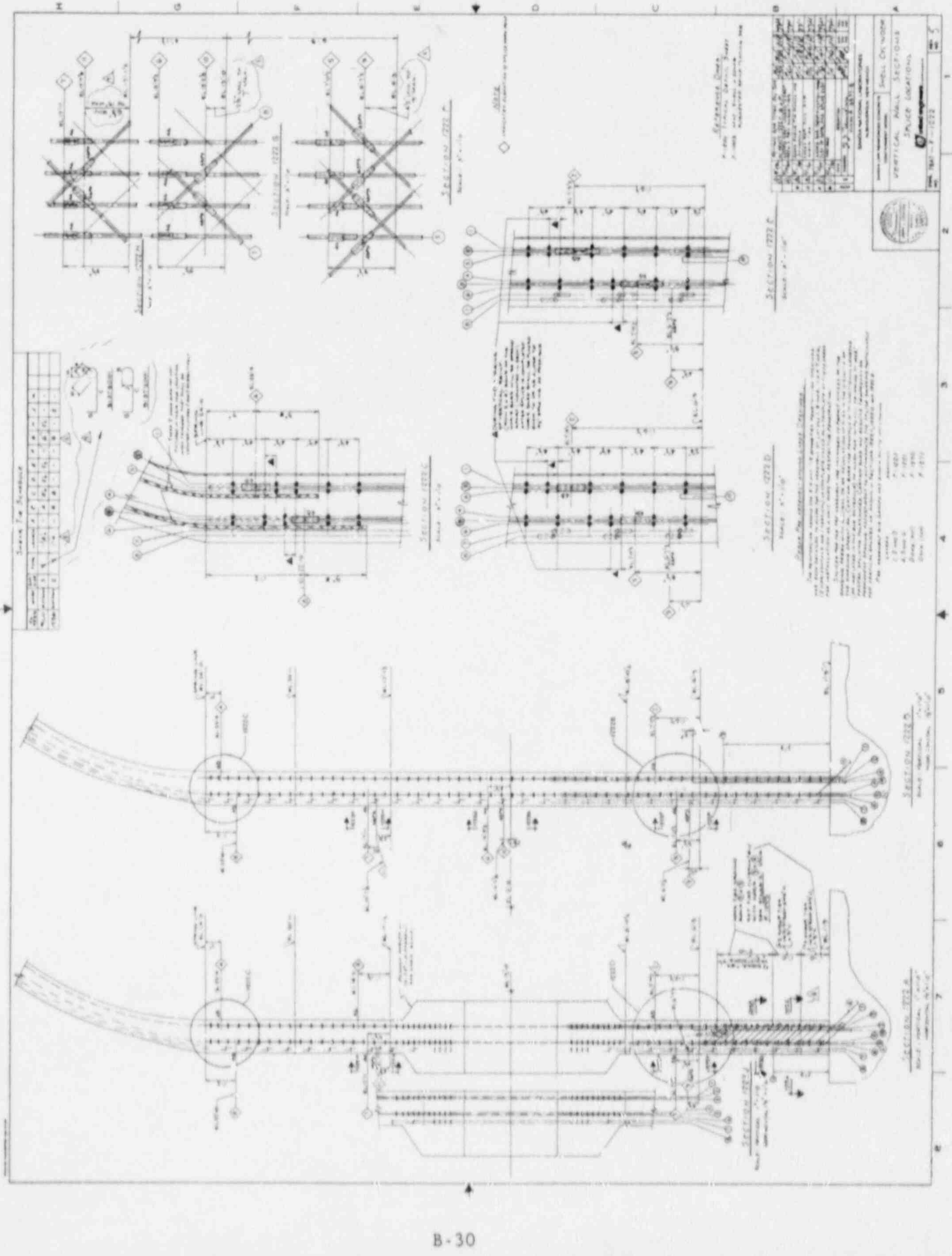


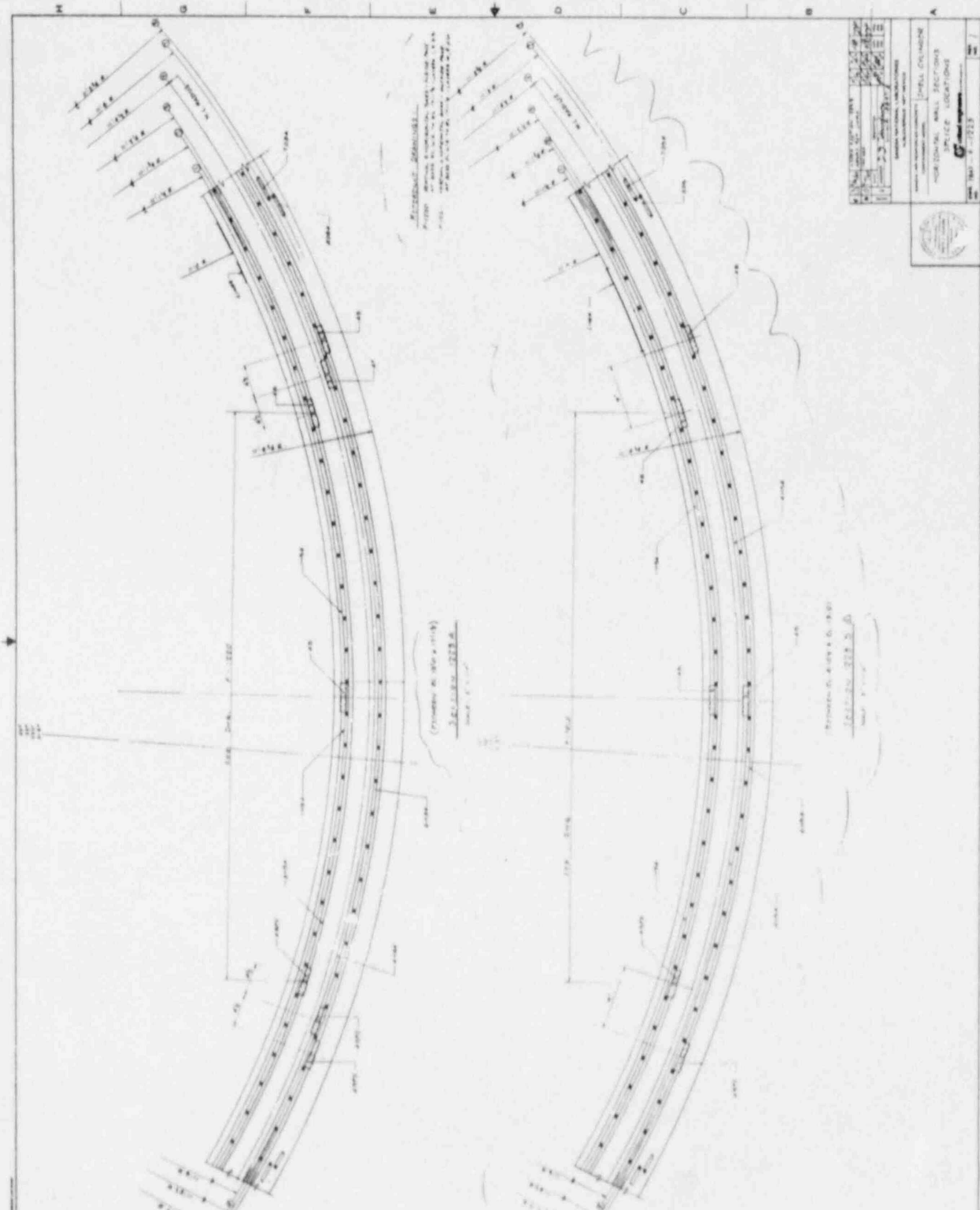


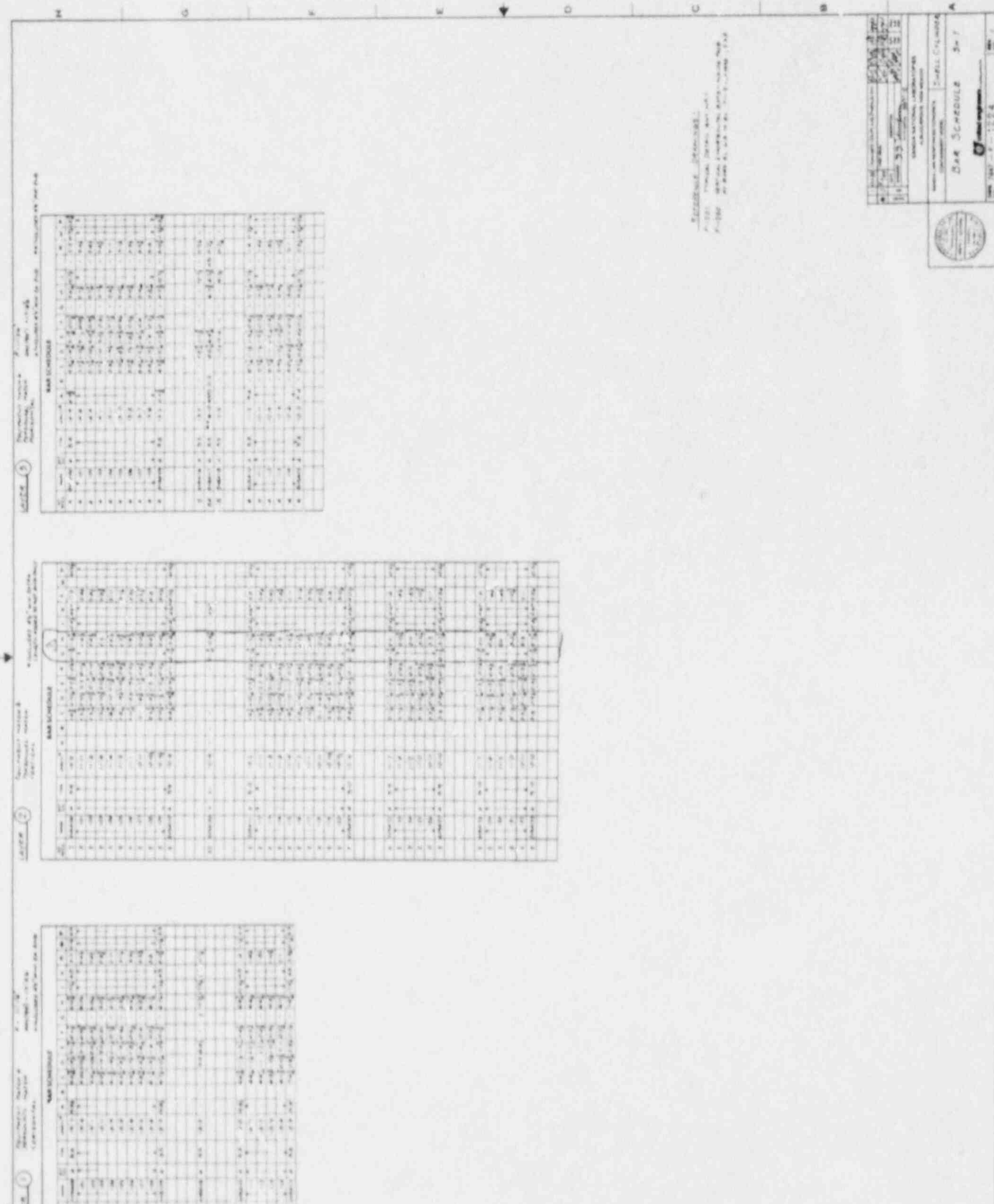





SHELL CYLINDER
VERTICAL WALL SECTIONS
SPLICE LOCATIONS

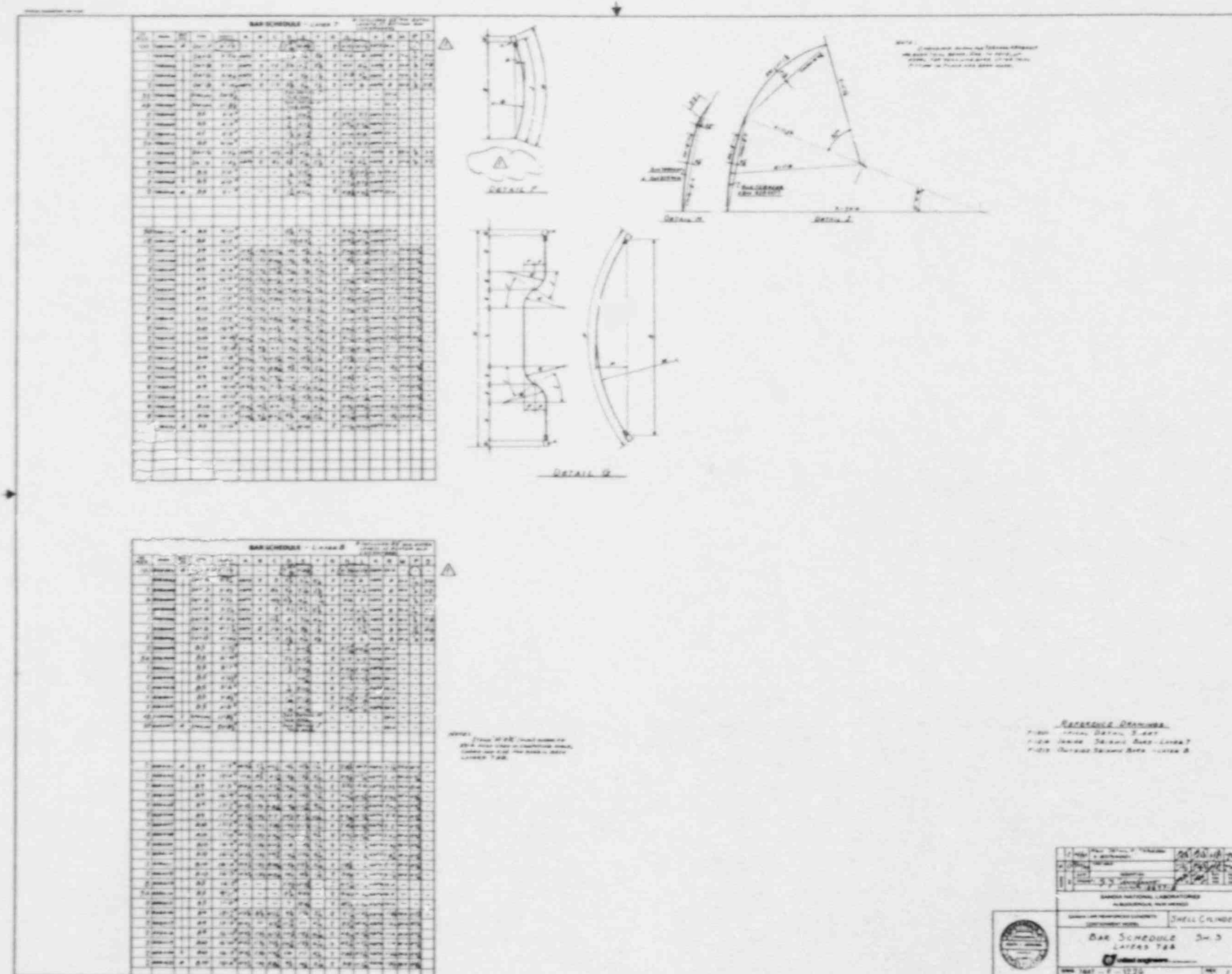


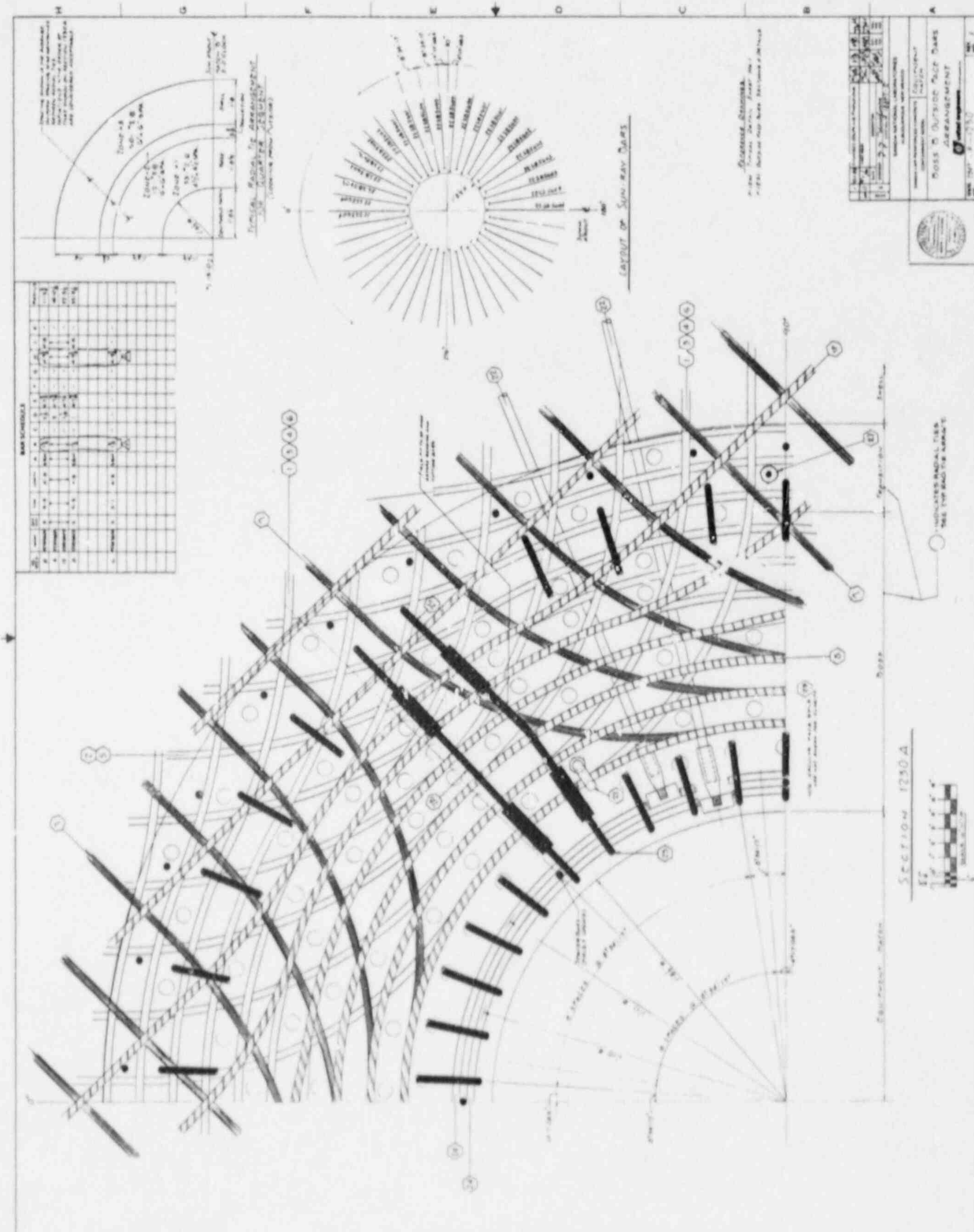

SHELL CYLINDER
HORIZONTAL WALL SECTIONS
SPLICE LOCATIONS

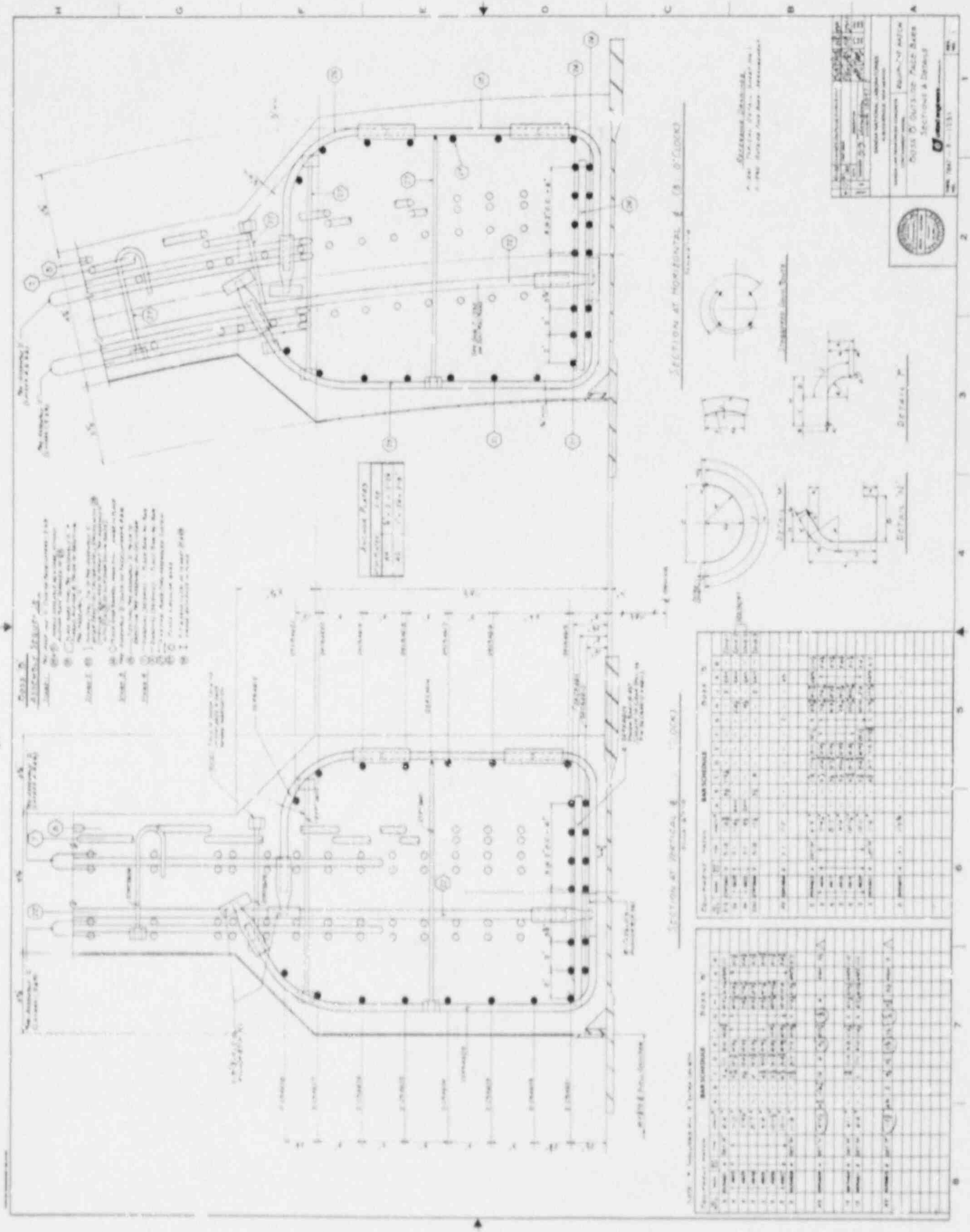


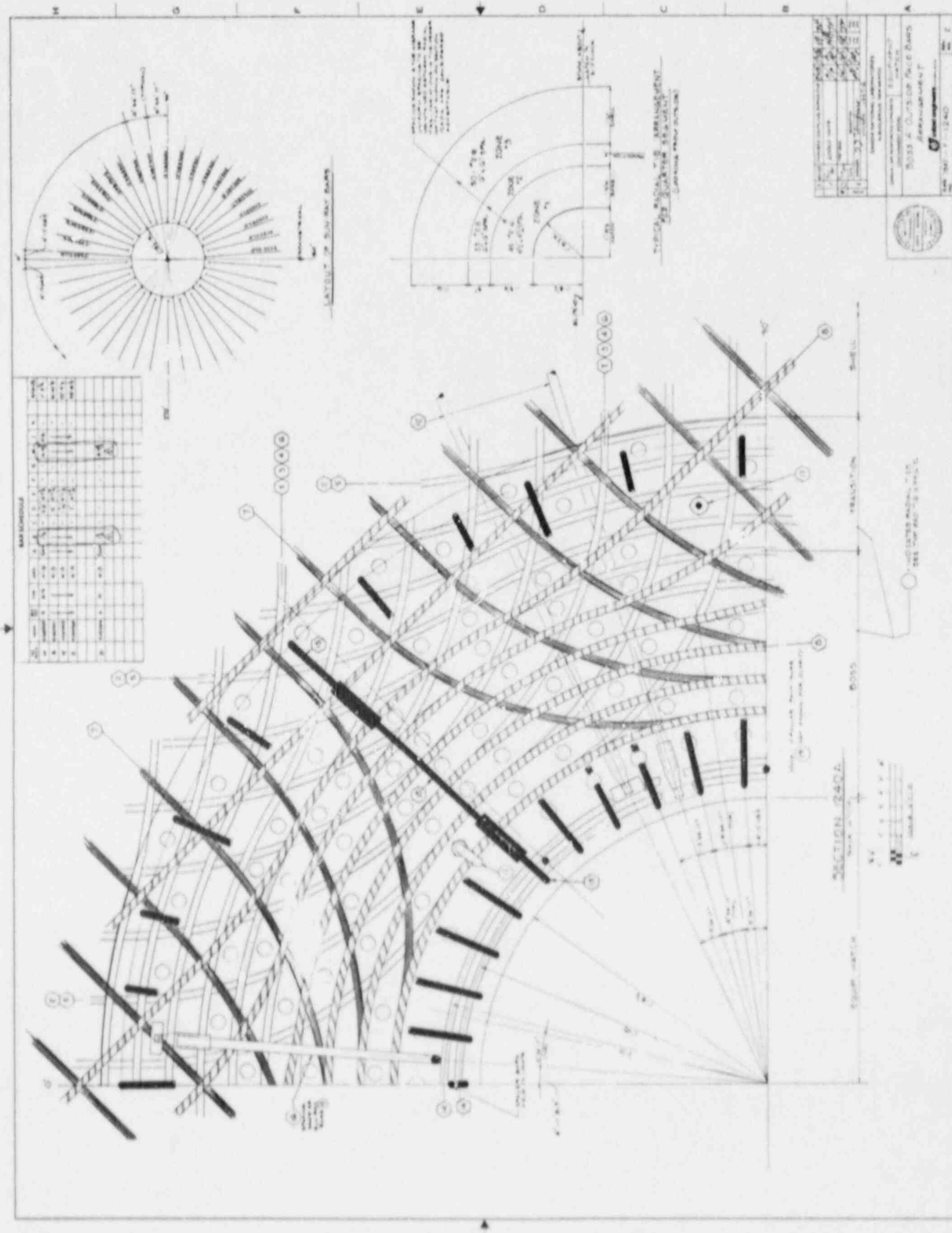
BAR SCHEDULE
Reference Drawings:
Bar Schedule B-1
Shell Cylinder

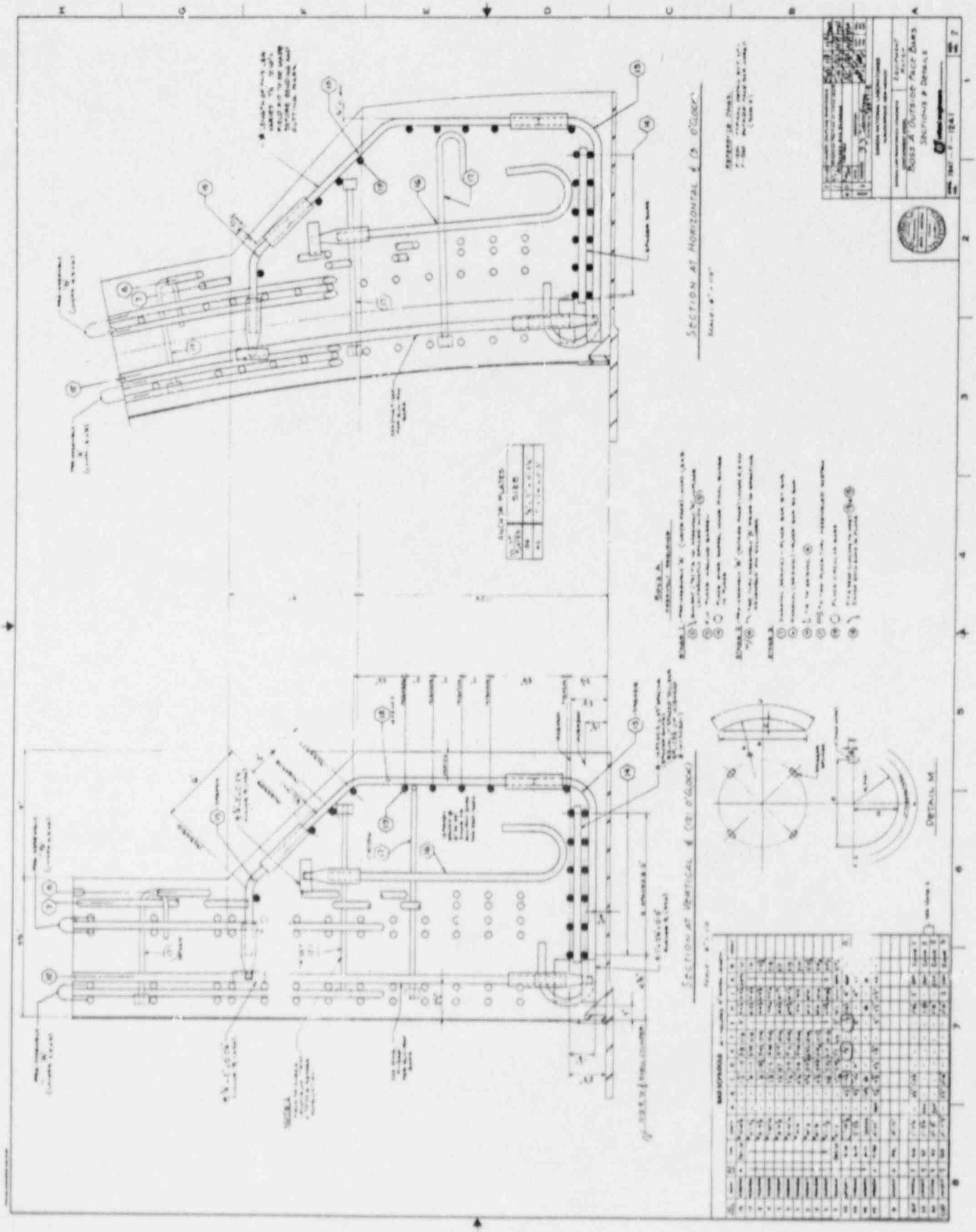

LAYER 4
LAYER 5
LAYER 6
BAR SCHEDULE
REFERENCE DRAWINGS:
SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO
STEEL CYLINDER
BAR SCHEDULE SH 2
REV NO. 1

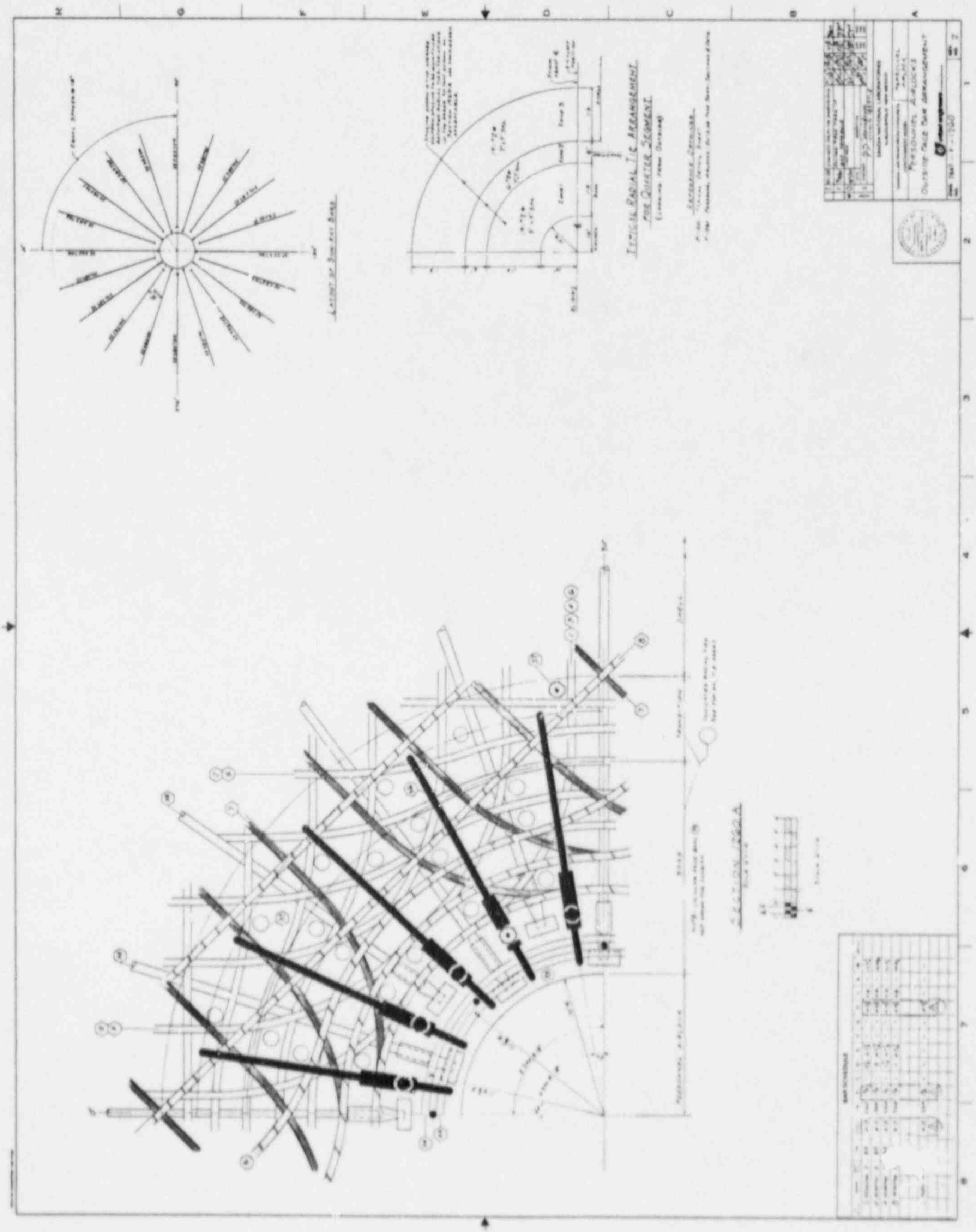

BAR SCHEDULE - LAYER 7
BAR SCHEDULE - LAYER 8
DETAIL F
DETAIL G
DETAIL H
DETAIL I
REFERENCE DRAWINGS
SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO
SHELL CYLINDER
BAR SCHEDULE SH. 3
LAYERS 7&8


SECTION 1230A
LAYOUT OF SUN-RAY BARS
BAR SCHEDULE
BOSS & OUTSIDE FACE BARS ARRANGEMENT

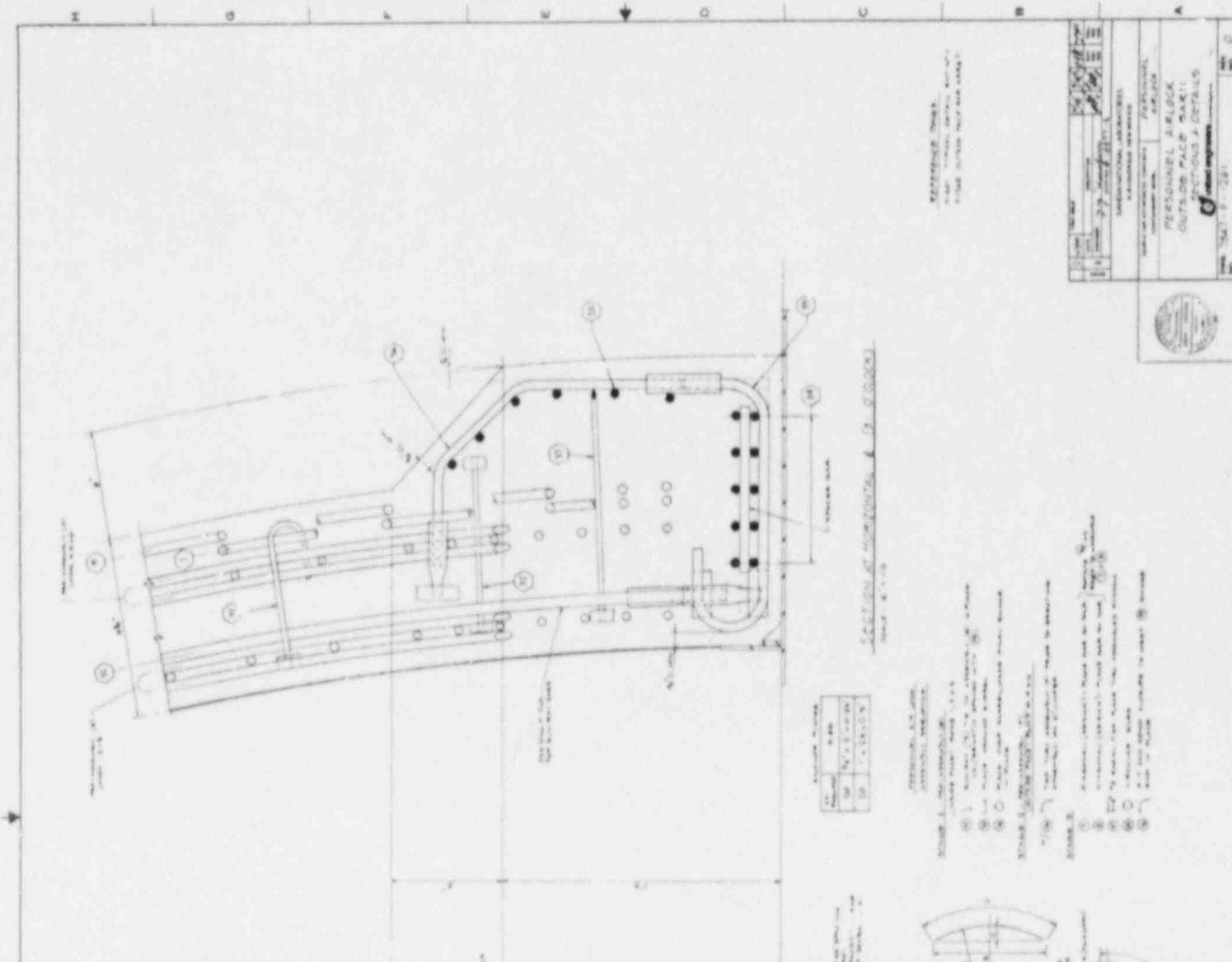


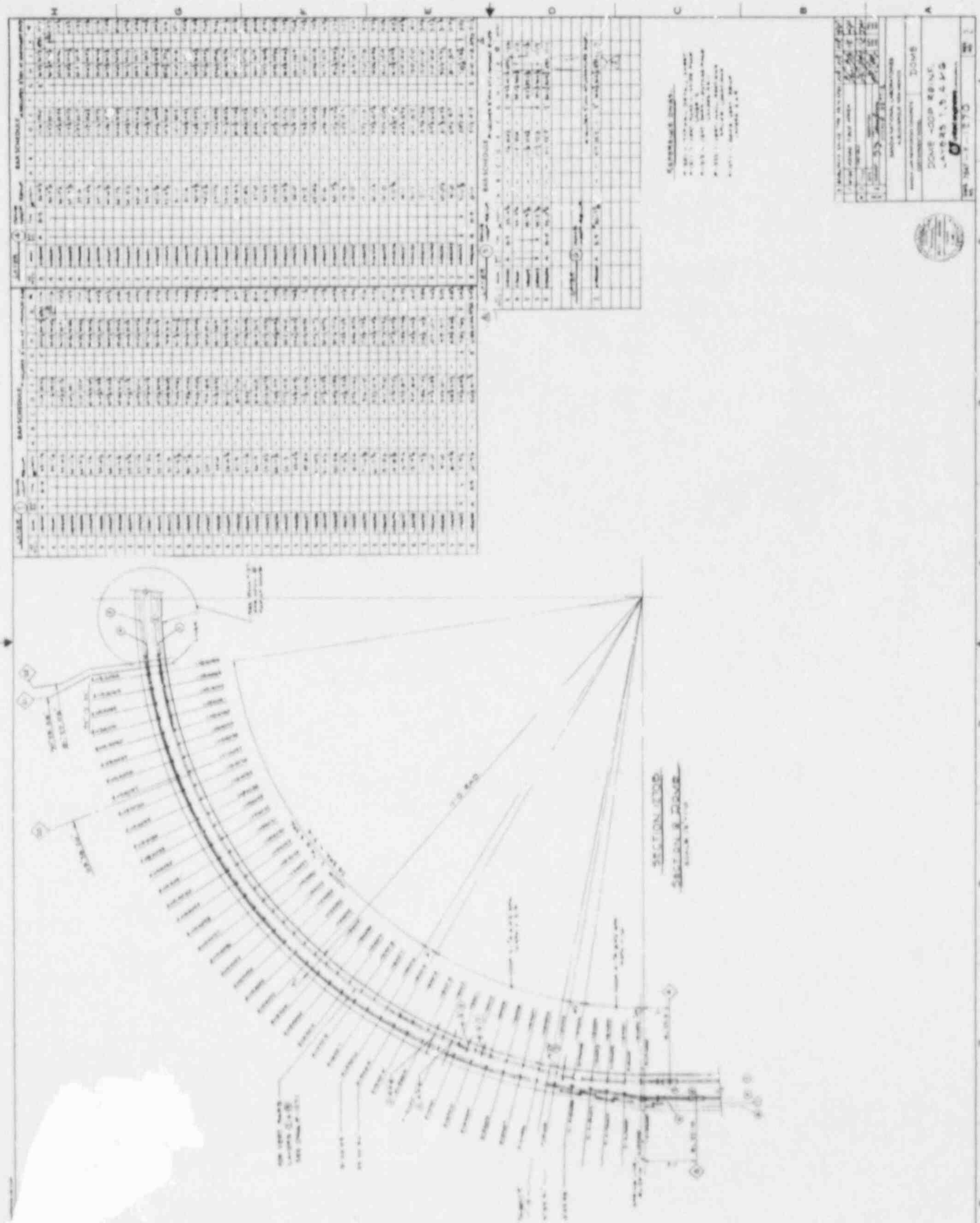


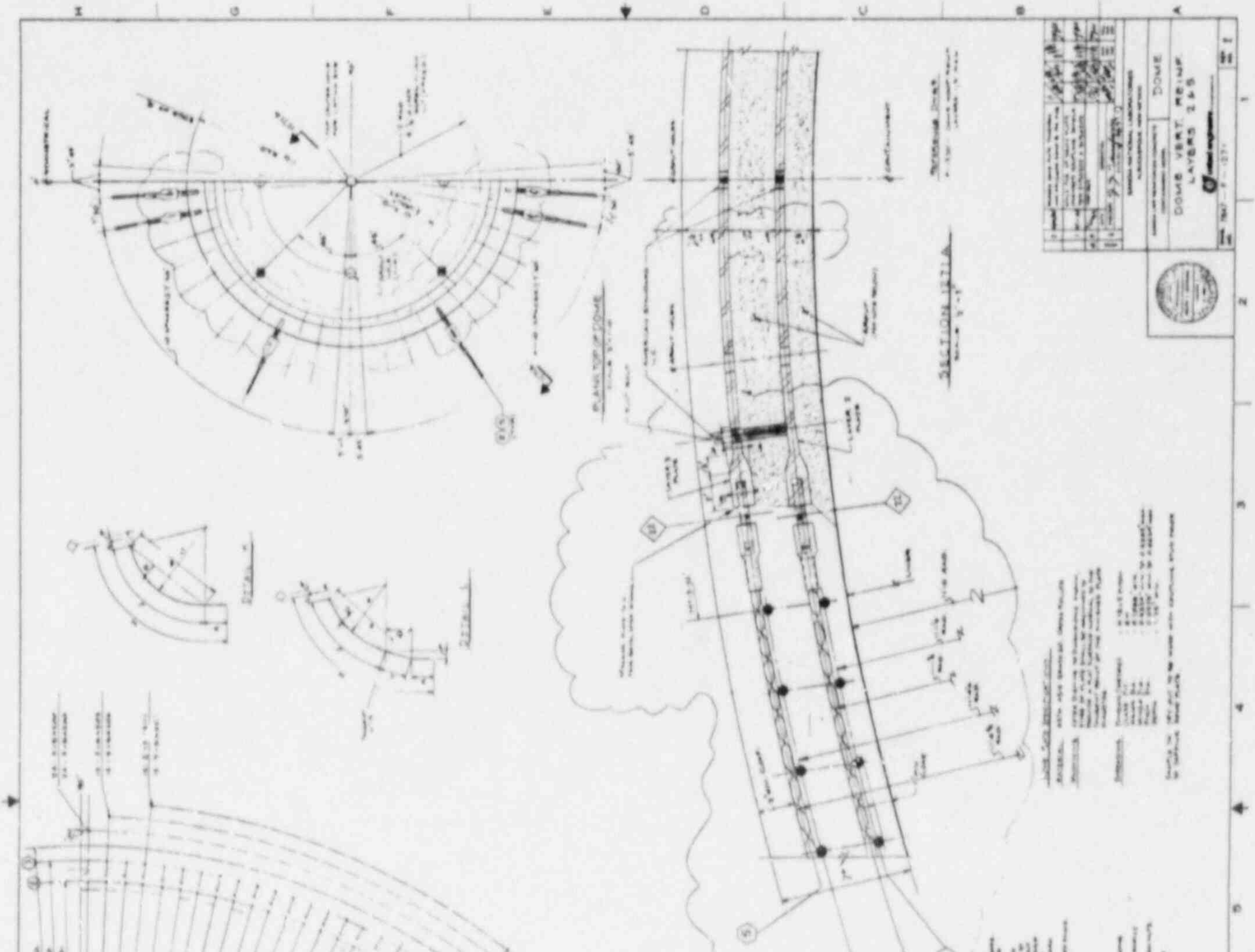


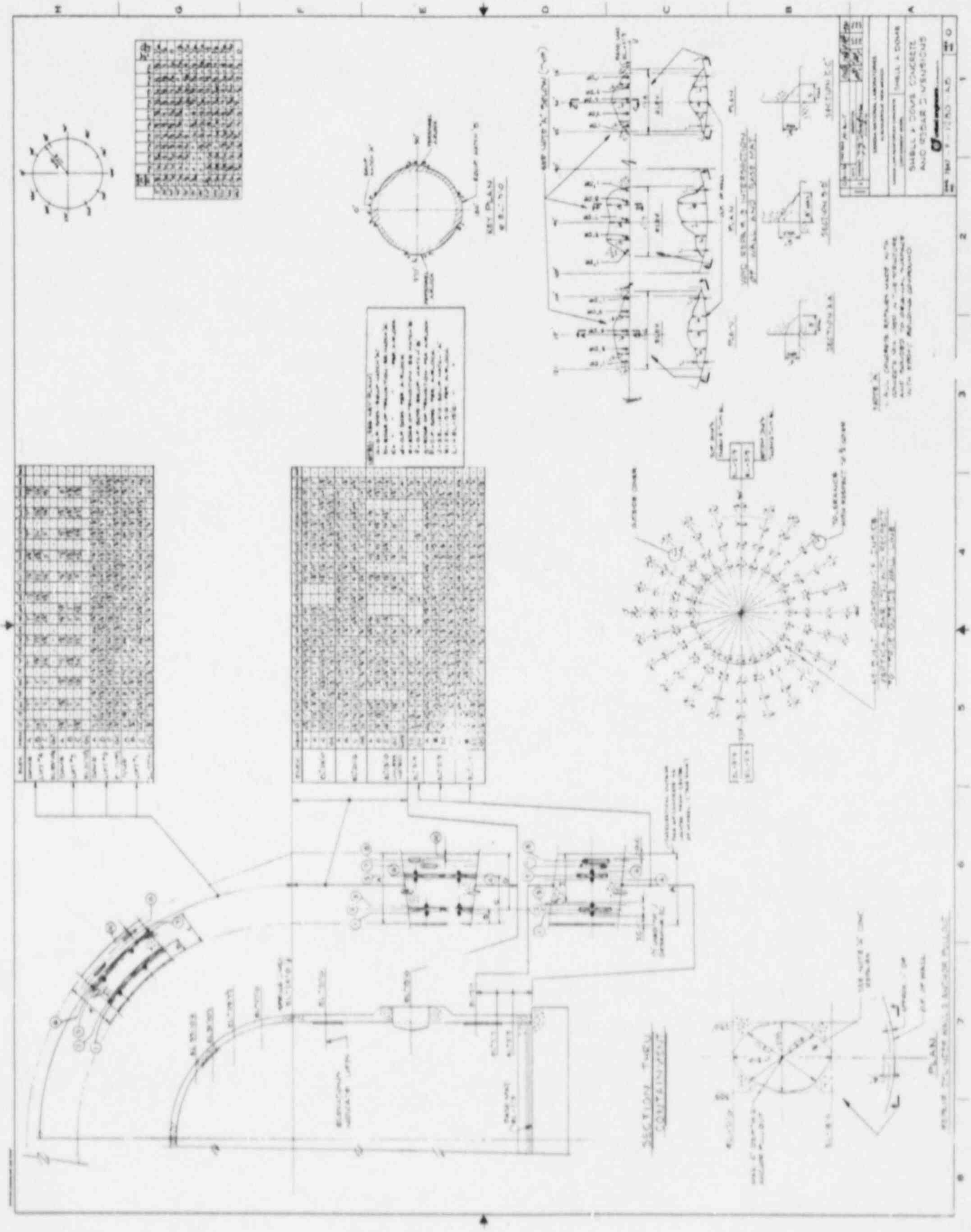


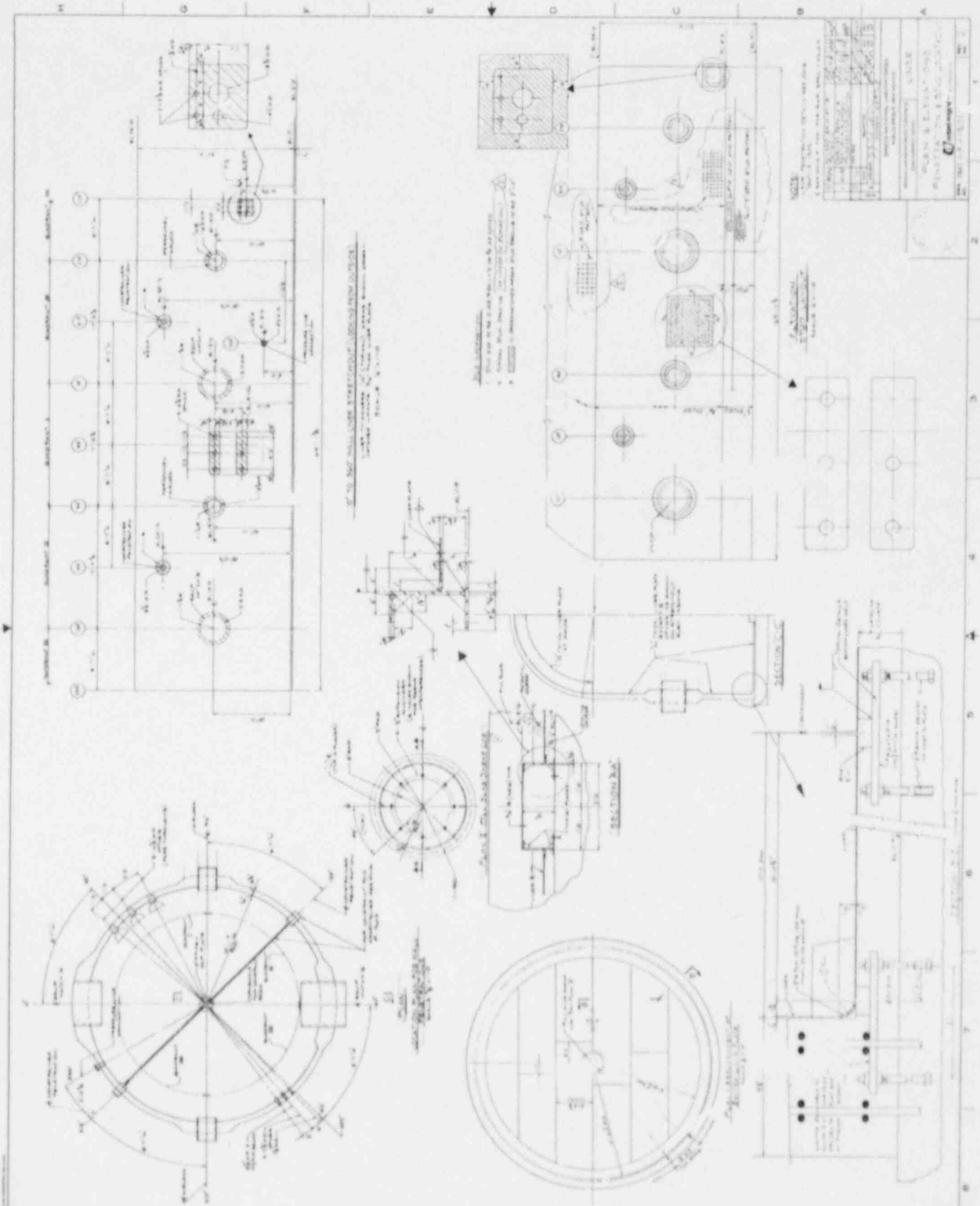
TYPICAL RADIAL TIE ARRANGEMENT
FOR QUARTER SEGMENT
PERSONNEL AIRLOCKS
OUTSIDE TIE BAR ARRANGEMENT

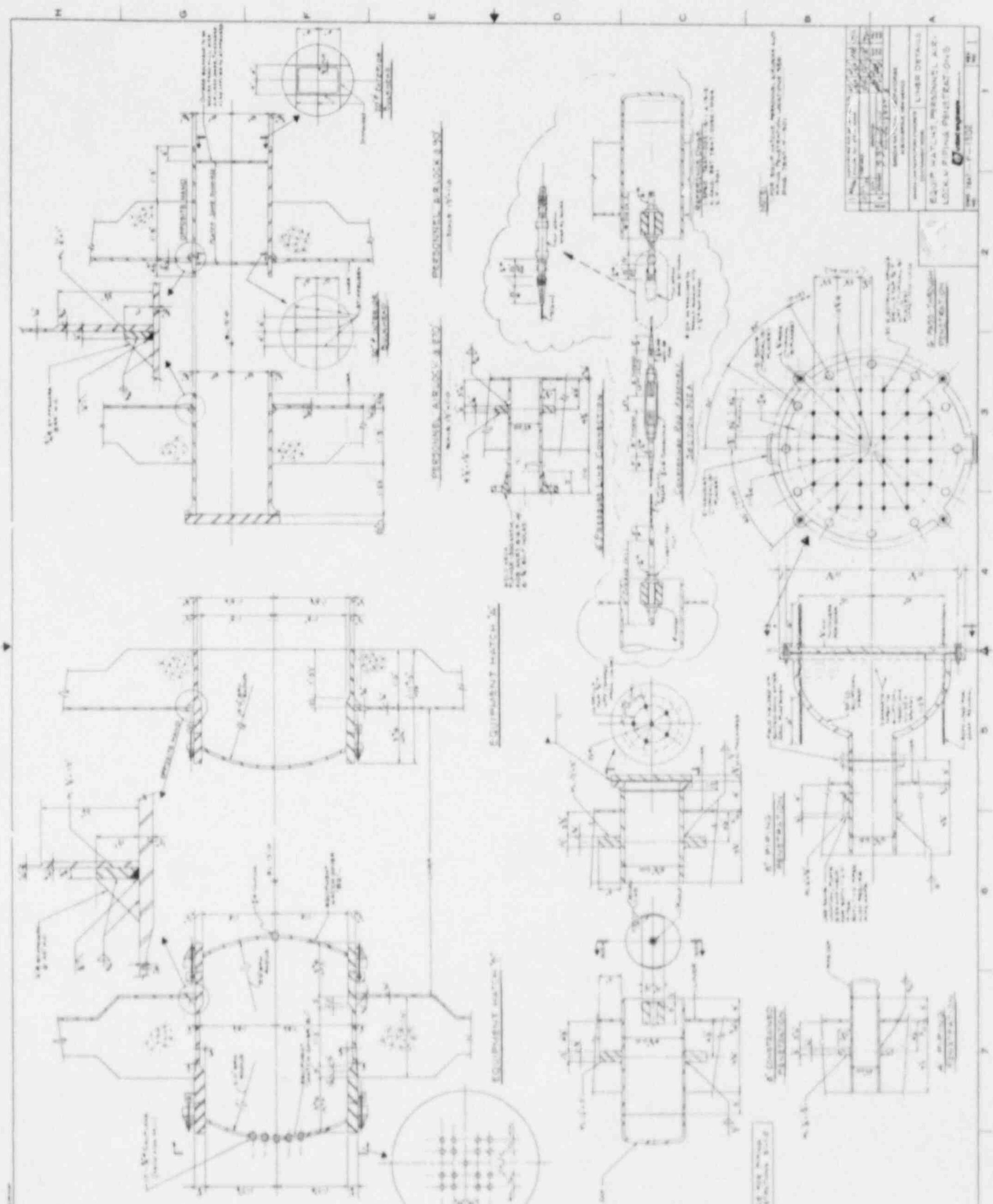


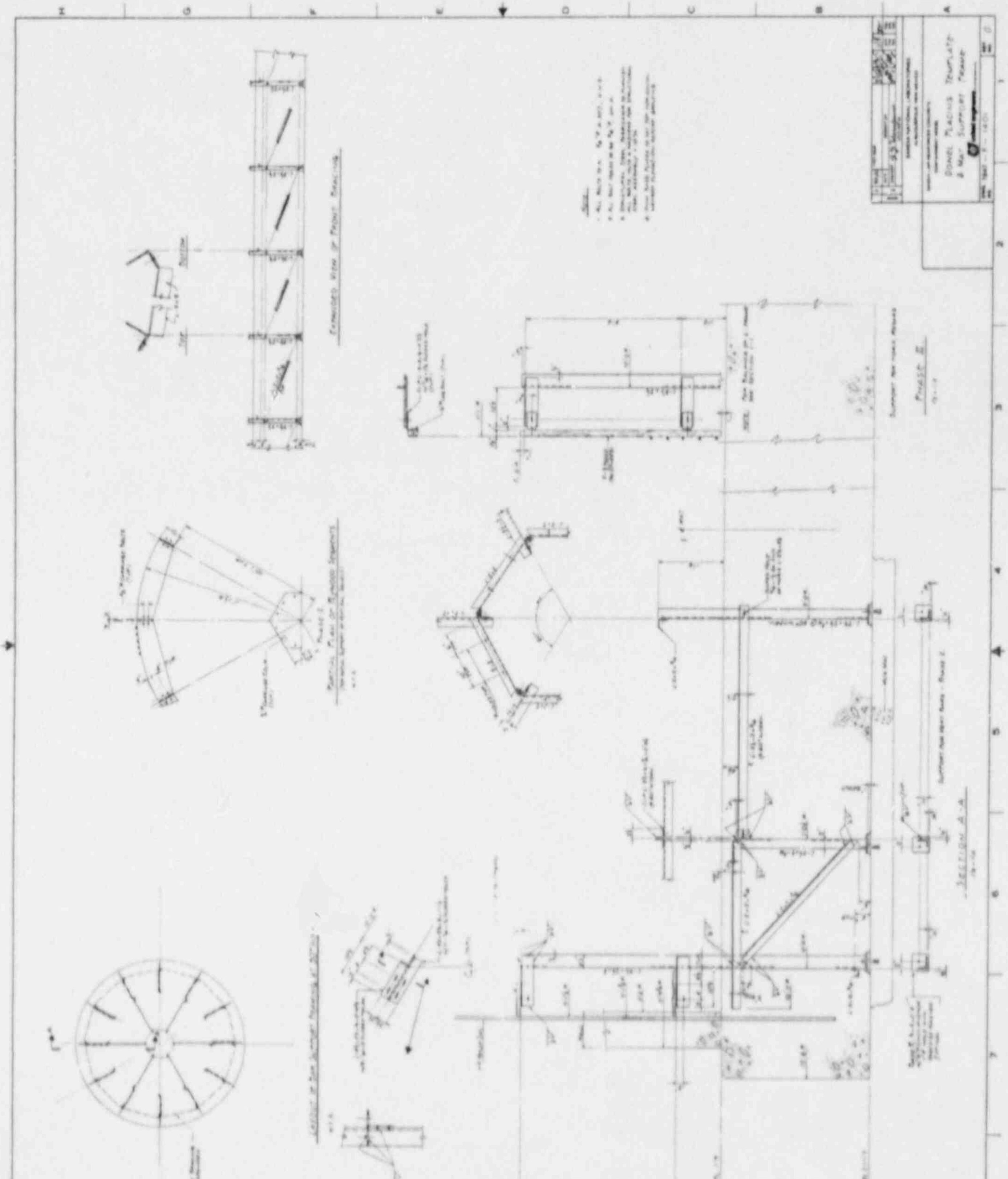


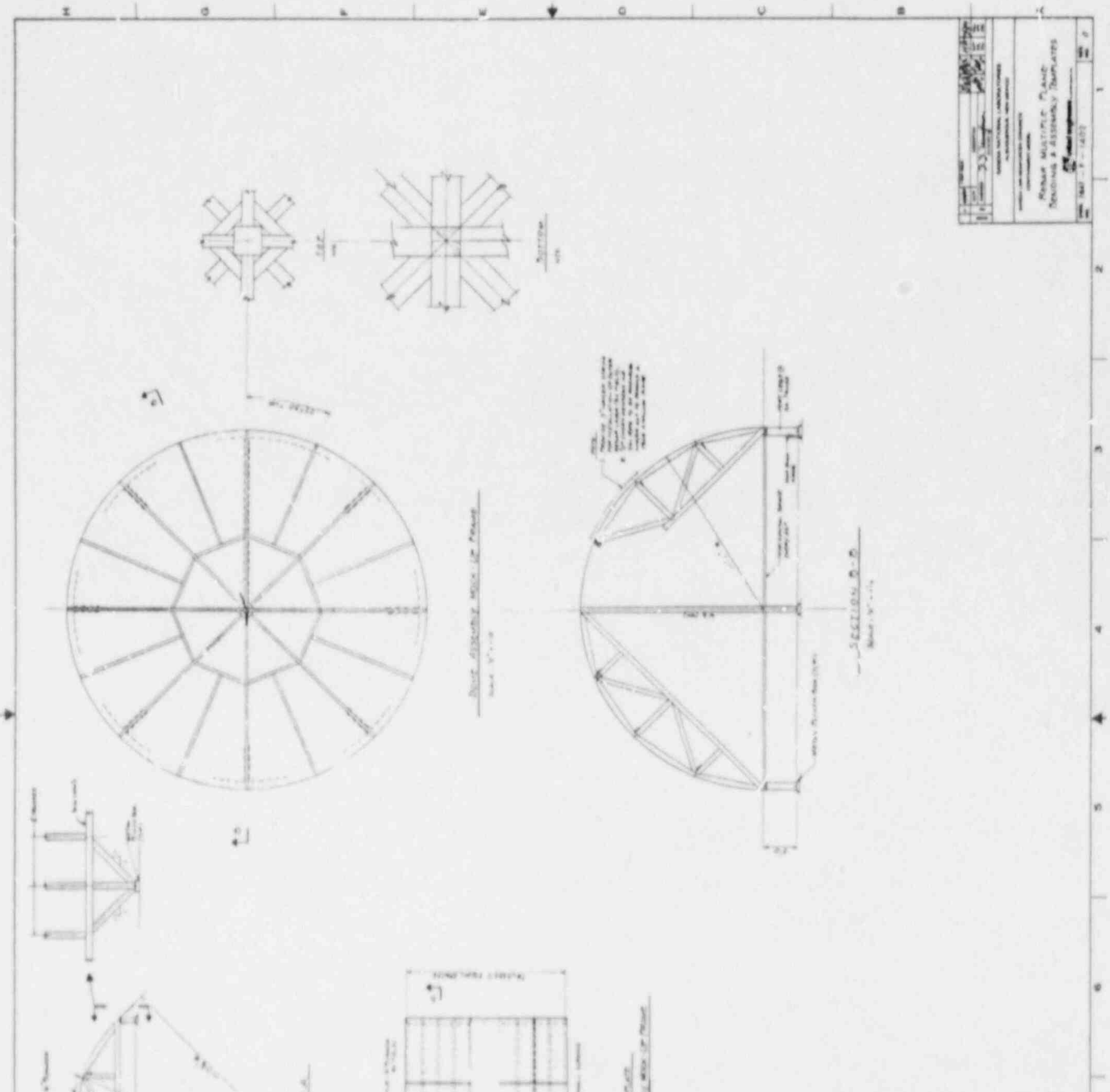


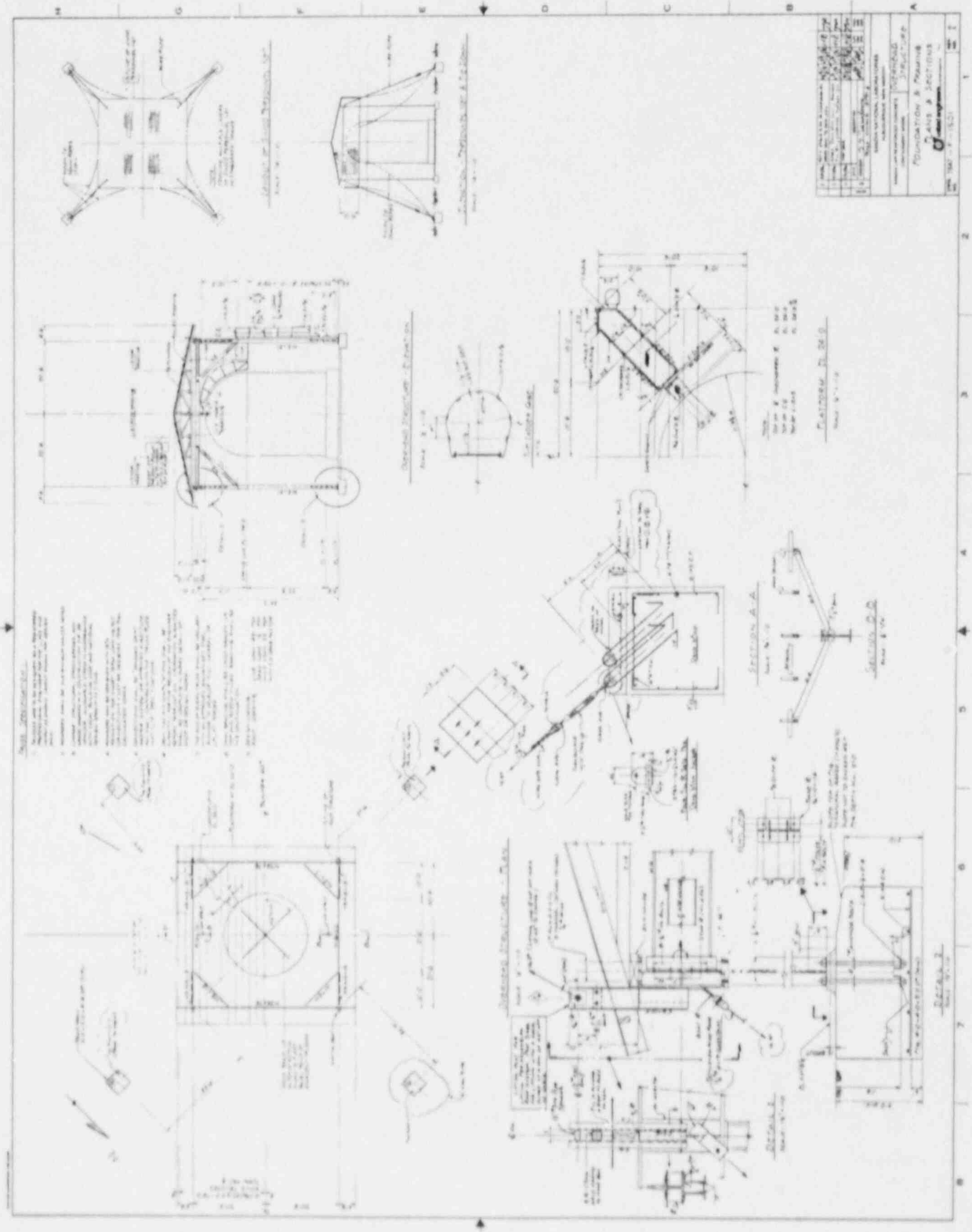

SECTION THRU CONTAINMENT
KEY PLAN
SECTION A-A
SECTION B-B
SECTION C-C
PLAN
SANDIA NATIONAL LABORATORIES
SHELL & DOME
SHELL & DOME CONCRETE AND REBAR DIMENSIONS

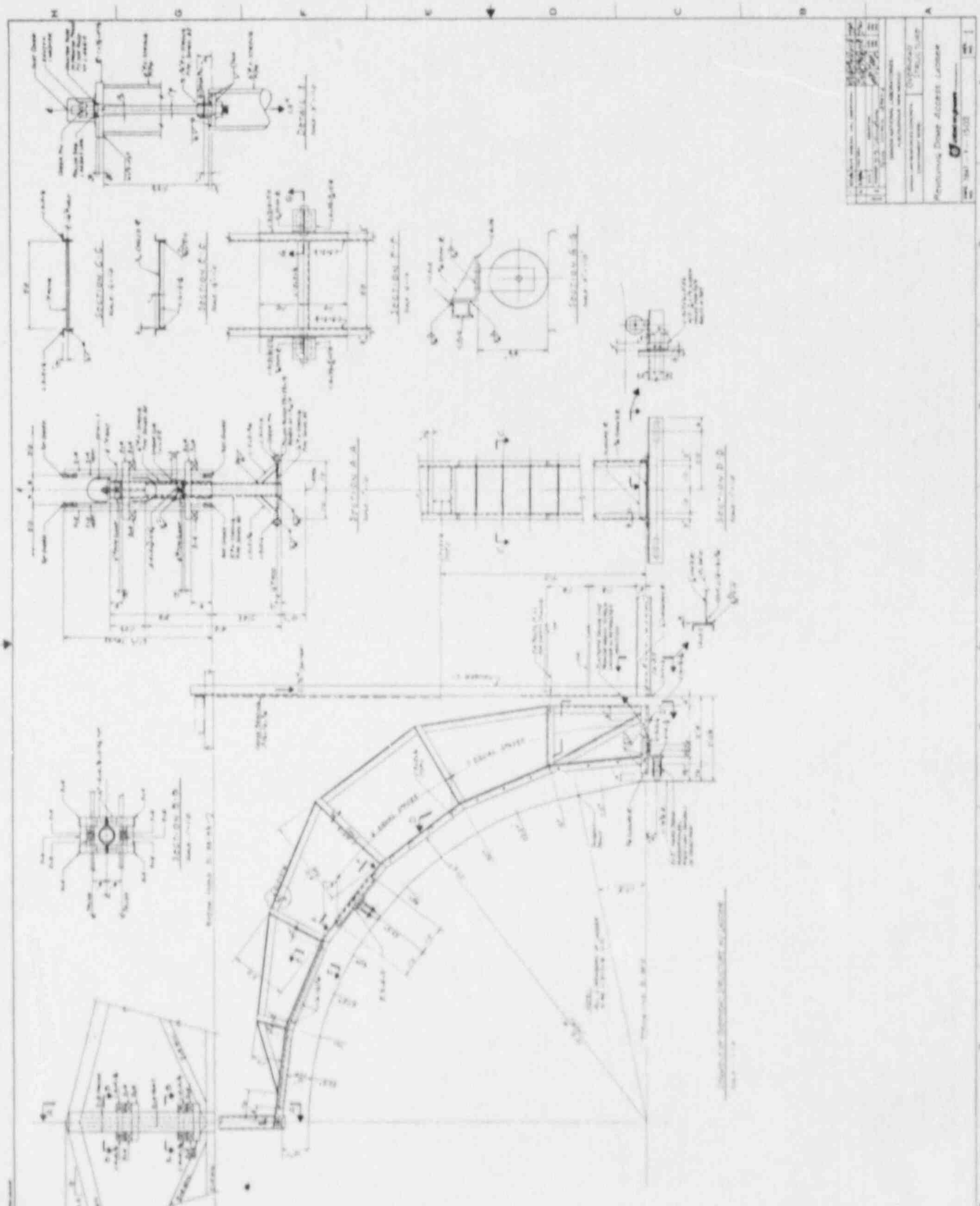









FOUNDATION & FRAMING
PLANS & SECTIONS
OVERHEAD STRUCTURE
SECTION A-A
SECTION B-B
DETAIL 1
DETAIL 2



1	4	GENERAL PLAN	
2	2	GENERAL NOTES	
7	1	ANCHOR BOLT PLAN	
8	2	SHEARING LUG ASSM	
9	4	BACK-UP BAR RING	
10	4	PLAN of BOTTOM	
11	3	BOTTOM PL DETAILS	
12	6	SHELL STRETCHOUT	
13	5	BOTTOM SHELL w/KNUCKLE ASSM	
14	4	TOP HEAD & SHELL PL ASSM	
15	6	EQUIPMENT HATCH "B"	
16	4	↕	
17	2	↕	
18	4	EQUIPMENT HATCH "B"	
19	4	EQUIPMENT HATCH "A"	
20	4	EQUIPMENT HATCH "A"	
21	2	AIR LOCK MK "PLB" (AZ-270°)	
22	3	AIR LOCK MK "PLA" (AZ-90°)	
23	5	4"ø 300# NOZZLE MK "P"	
24	4	INSERT PL ASSM (PENET MK X [illegible])	
25	3	INSERT PL ASSM (PENET MK E1 thru E5)	
26	5	6"ø PASS THRU PENET MK E1 thru E4	
27	2	6"ø PASS THRU PENET MK E2,E3 thru E5	
28	1	LOCATION of 6"ø PASS THRU PENET	
29	2	[illegible] CONSTRAINED PENET (MK R1 thru R2)	
30	2	SHELL PL ASSY'S ([illegible])	
31	1	WELD STUD LOCATIONS - FIELD	
32	1	WELD STUD LOCATIONS - FIELD	
33	1	DOME VERT REINF LAYER ASSM (OUTER)	
34	1	DETAILS for ASSM 33 A	
35	1	DOME VERT REINF LAYER ASSM (INNER)	
36	1	DETAILS for ASSM 35 A	

26'-8" O.D. × 22'-0" LENGTH
CONTAINMENT LINER MODEL
for UNITED ENGINEERS & CONST.
for SANDIA NATIONAL LABS.
ALBUQUERQUE, NEW MEXICO

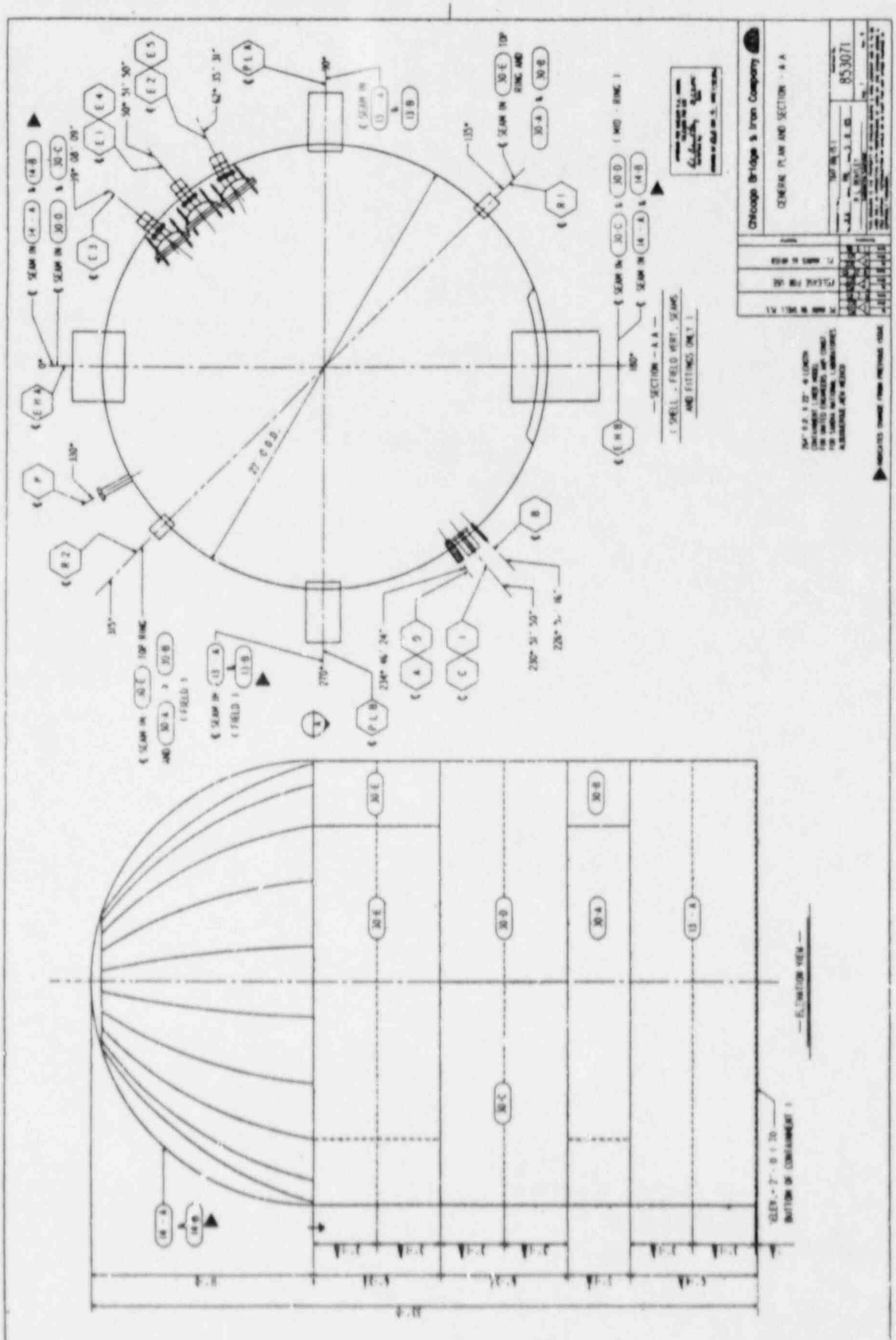
Chicago Bridge & Iron Company CBI

PRINT CONTROL RECORD

7847-001-15-1
8-22-85
853071
PC-1

14 24
1 2 & 12
15 & 17
14

[illegible]


Chicago Bridge & Iron Company
GENERAL PLAN AND SECTION - A A
853071
SECTION - A A
ELEVATION VIEW

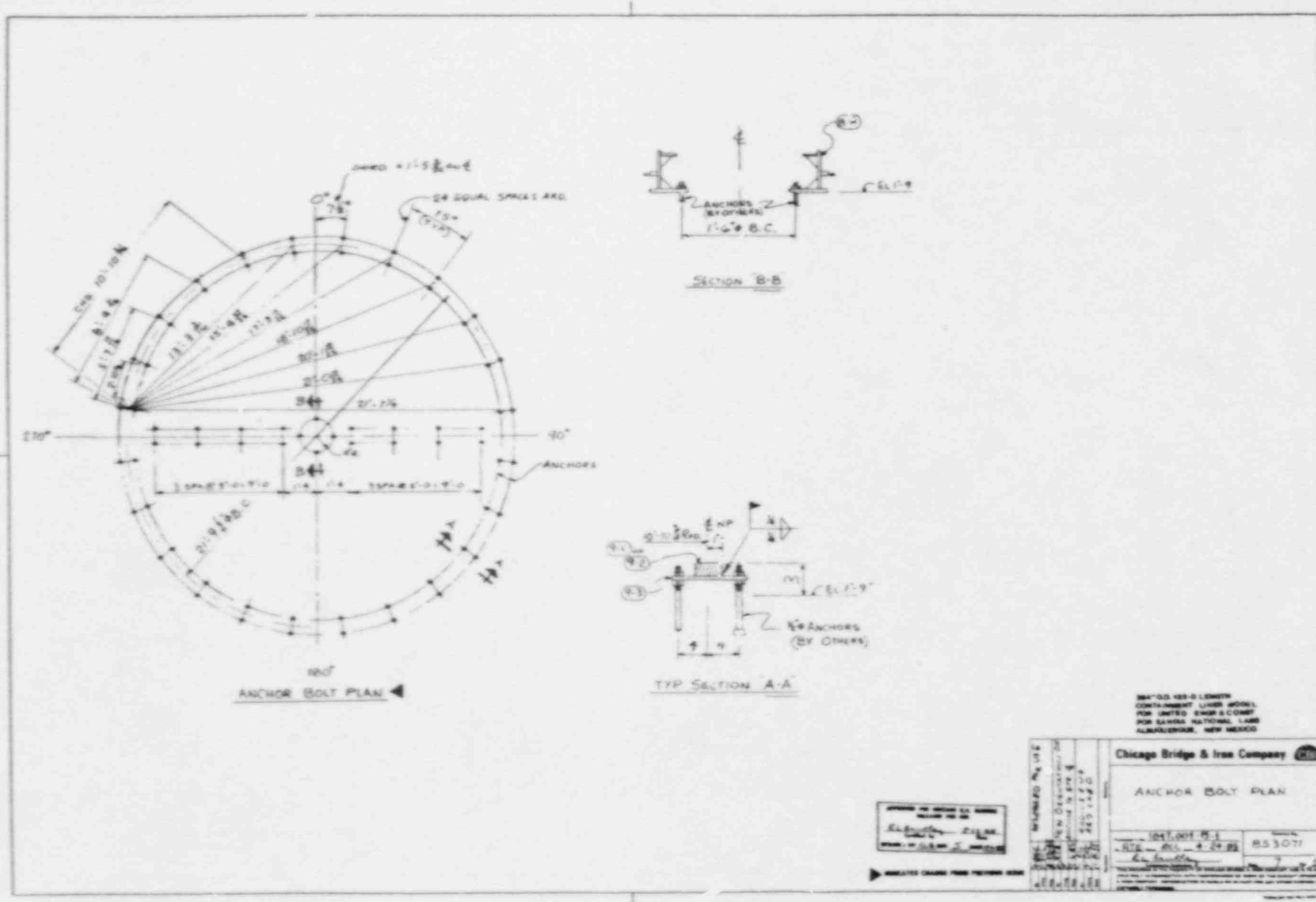
GENERAL NOTES

PENETRATION SCHEDULE					
MARK	DWG #	ELEV	AZIMUTH	SIZE	SERVICE
A	24	8'-10	234°-45'-31"	4"ϕ SCH 40	CAPPED
B	24	9'-7½	66°-57'-10"	1"ϕ SCH 80	CAPPED
C	24	9'-7½	230°-51'-30"	2"ϕ SCH 80	CAPPED
D	24	9'-7½	234°-45'-31"	2"ϕ SCH 80	CAPPED
E1	25	8'-10½	50°-51'-30"	6"ϕ 150# RF	ELECT. FEED THRU
E2	25	8'-10½	62°-34'-31"	6"ϕ 150# RF	↕ (ELECT. FEED THRU)
E3	25	13'-G	19°-08'-0"	6"ϕ 150# RF	↕ (ELECT. FEED THRU)
E4	25	13'-0	50°-51'-30"	6"ϕ 150# RF	↕ (ELECT. FEED THRU)
E5	25	13'-0	62°-34'-31"	6"ϕ 150# RF	ELECT. FEED THRU
EH-A	19	13'-0	0°	41' OD × ½ WALL	EQUIPMENT HATCH
EH-B	15	13'-0	180°	41' OD × ½ WALL	EQUIPMENT HATCH
I	24	8'-10½	230°-51'-30"	8"ϕ 150# RF	INSTRUMENTATION
P	23	4'-3	330°	4"ϕ SCH 40	PRESSURE CONN
PL-A	22	13'-0	90°	20' OD × ½ WALL	PERSONNEL LOCK
PL-B	21	13'-0	270°	20' OD × ½ WALL	PERSONNEL LOCK
R1	29	20'-1½	135°	8"ϕ	CONSTRAINED PENET
R2	29	20'-1½	315°	8"ϕ	CONSTRAINED PENET

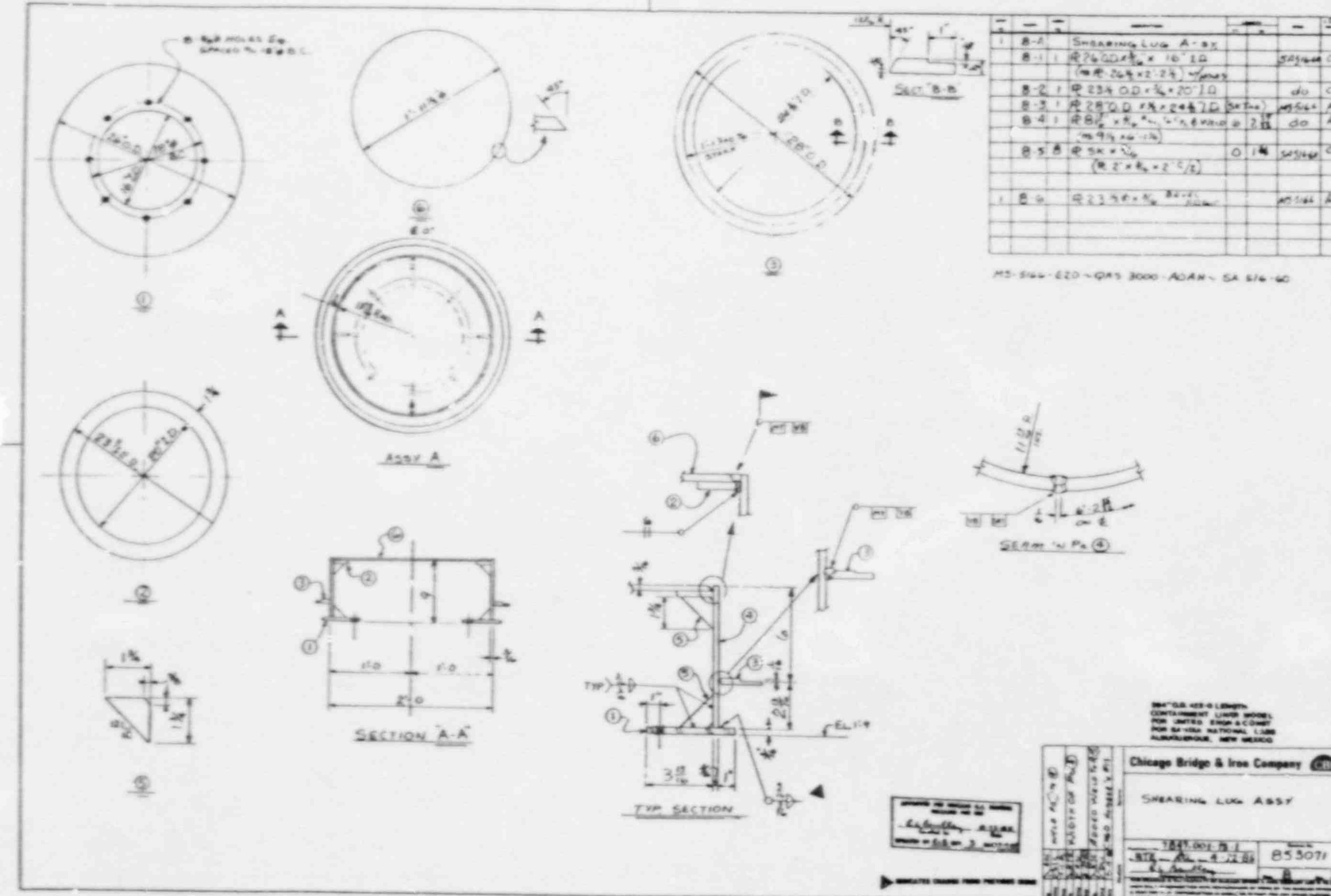
Chicago Bridge & Iron Company

GENERAL NOTES

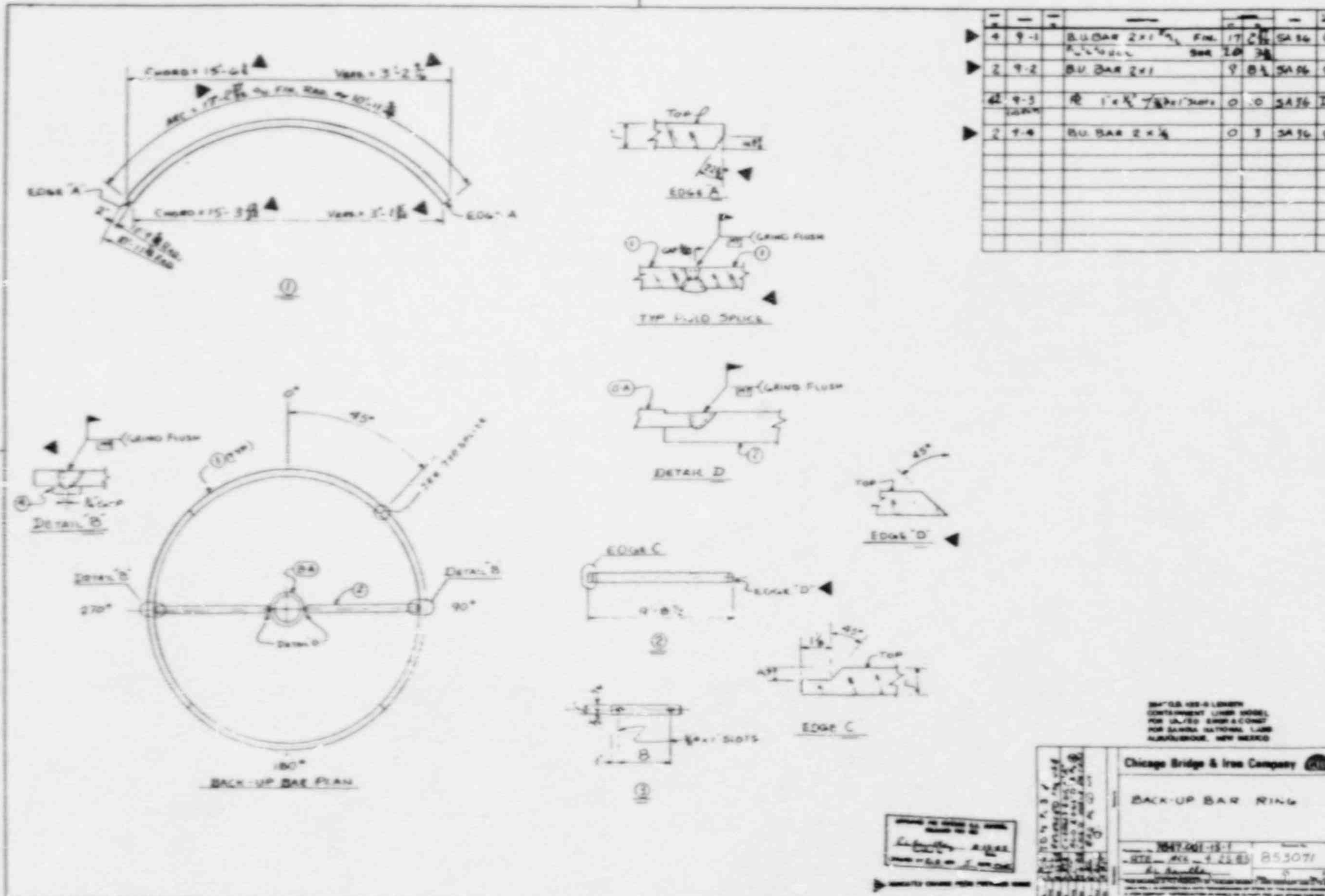
853071



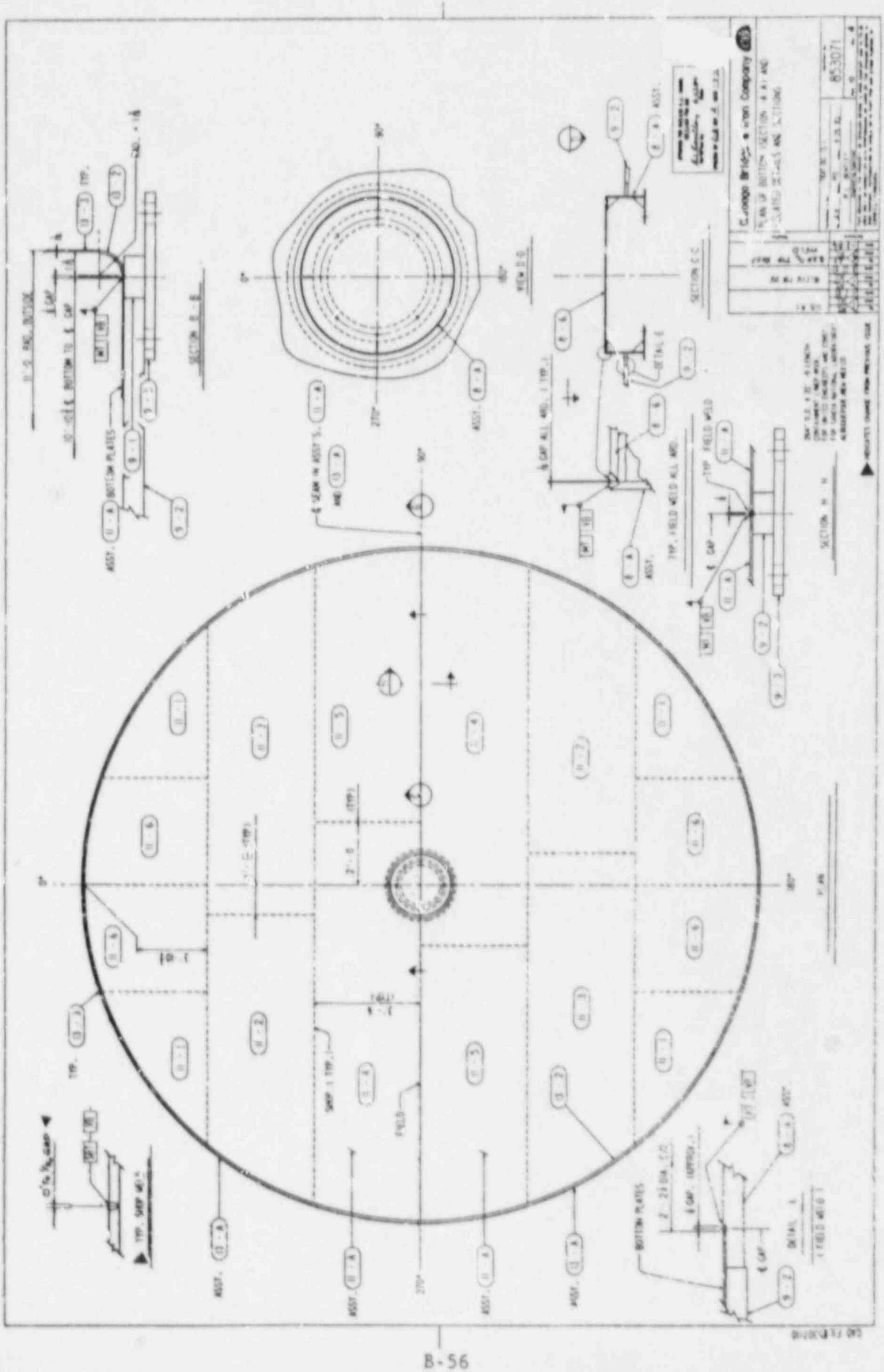
0°
270°
90°
180°
24 EQUAL SPACES ARC.
ANCHORS
ANCHOR BOLT PLAN
SECTION 'B-B'
ANCHORS (BY OTHERS)
TYP SECTION 'A-A'
(BY OTHERS)
CONTAINMENT LINER MODEL
FOR UNITED ENGRS & CONST
FOR SANDIA NATIONAL LABS
ALBUQUERQUE, NEW MEXICO
Chicago Bridge & Iron Company
ANCHOR BOLT PLAN
853071



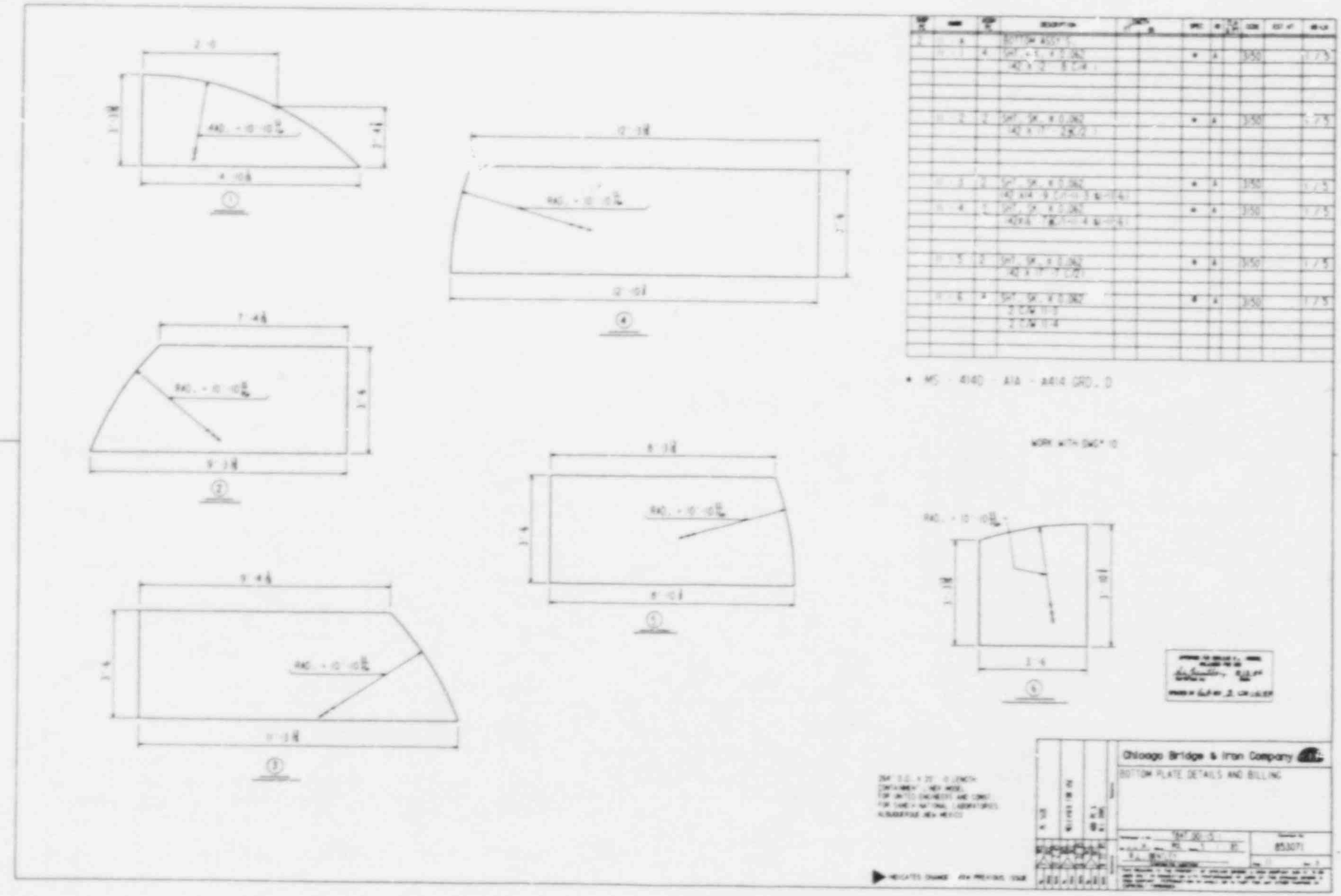
SHEARING LUG A-SX
SECT "B-B"
ASSY A
SECTION "A-A"
TYP SECTION
SEAM "N PC 4
MS-5166-E20-QAS 3000-ADAH-SA 6/6-60
Chicago Bridge & Iron Company
SHEARING LUG ASSY
853071

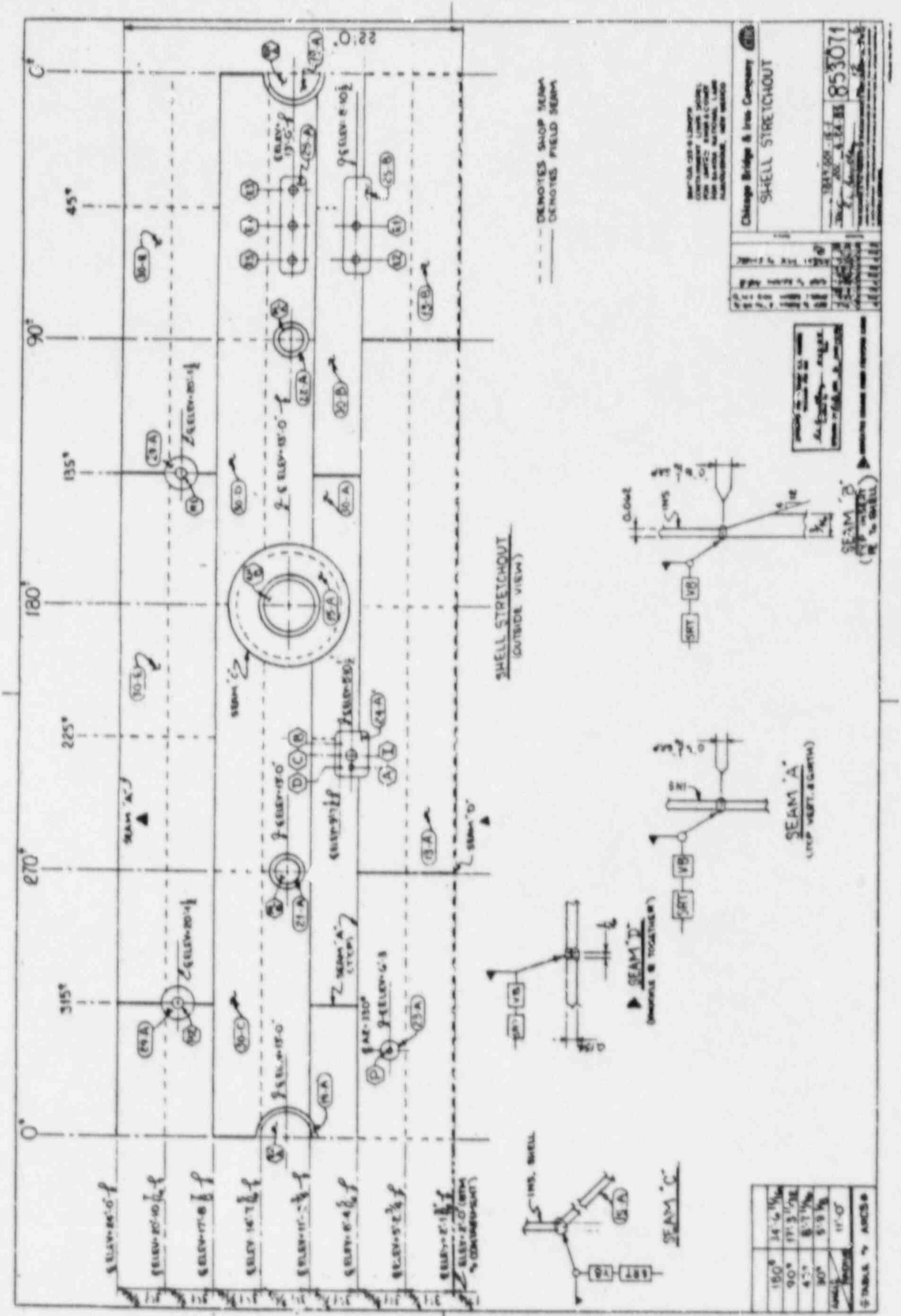


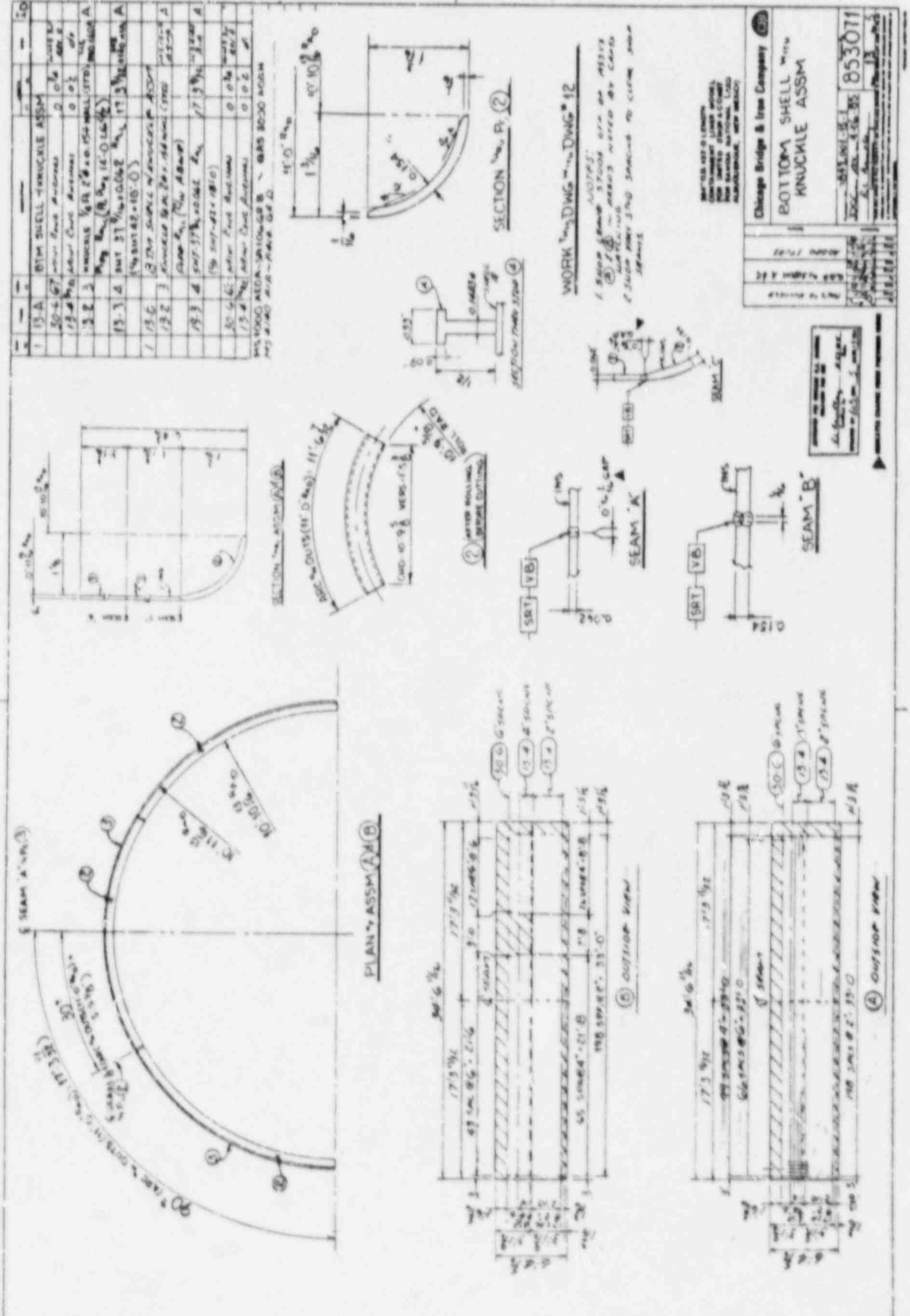
4	9-1		B.U. BAR 2×1 FIN. BAR	17	2	SA36	C
2	9-2		B.U. BAR 2×1	9	8	SA36	C
2	9-3		PL 1×8	0	10	SA36	D
2	9-4		B.U. BAR 2×¾	0	3	SA36	C

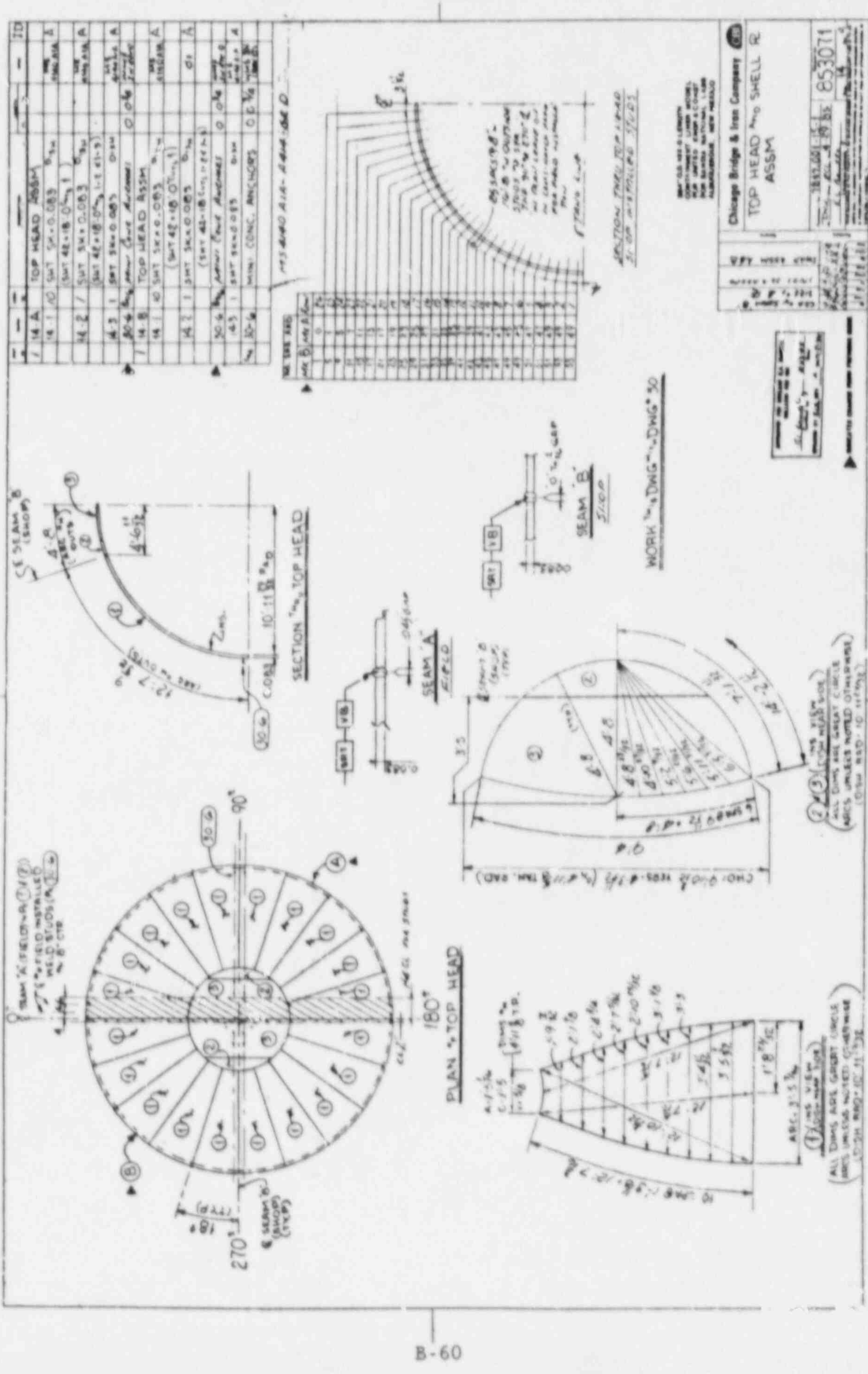


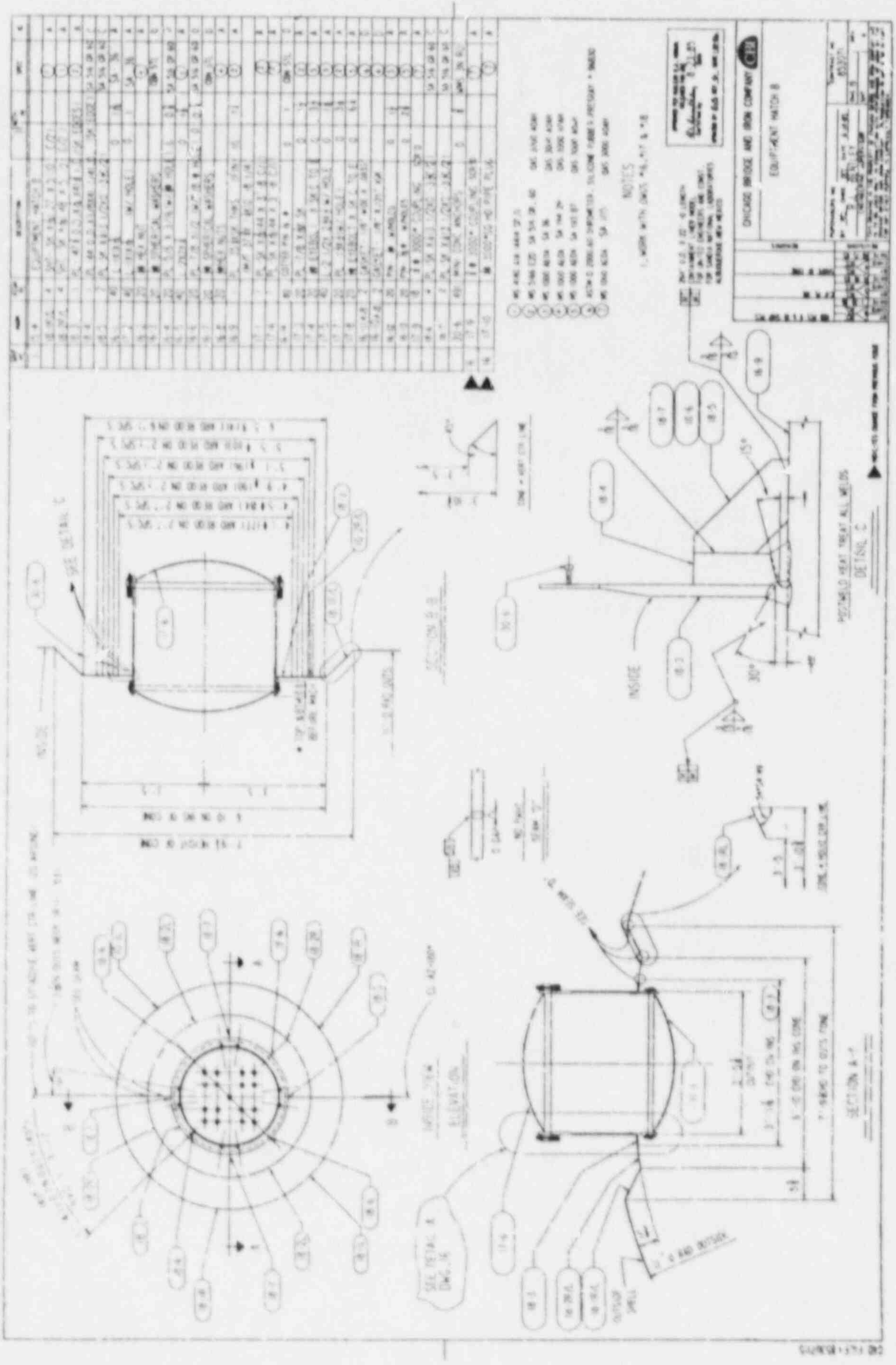
PLAN
SECTION B-B
SECTION C-C
SECTION H-H
VIEW D-D
BOTTOM PLATES
853071

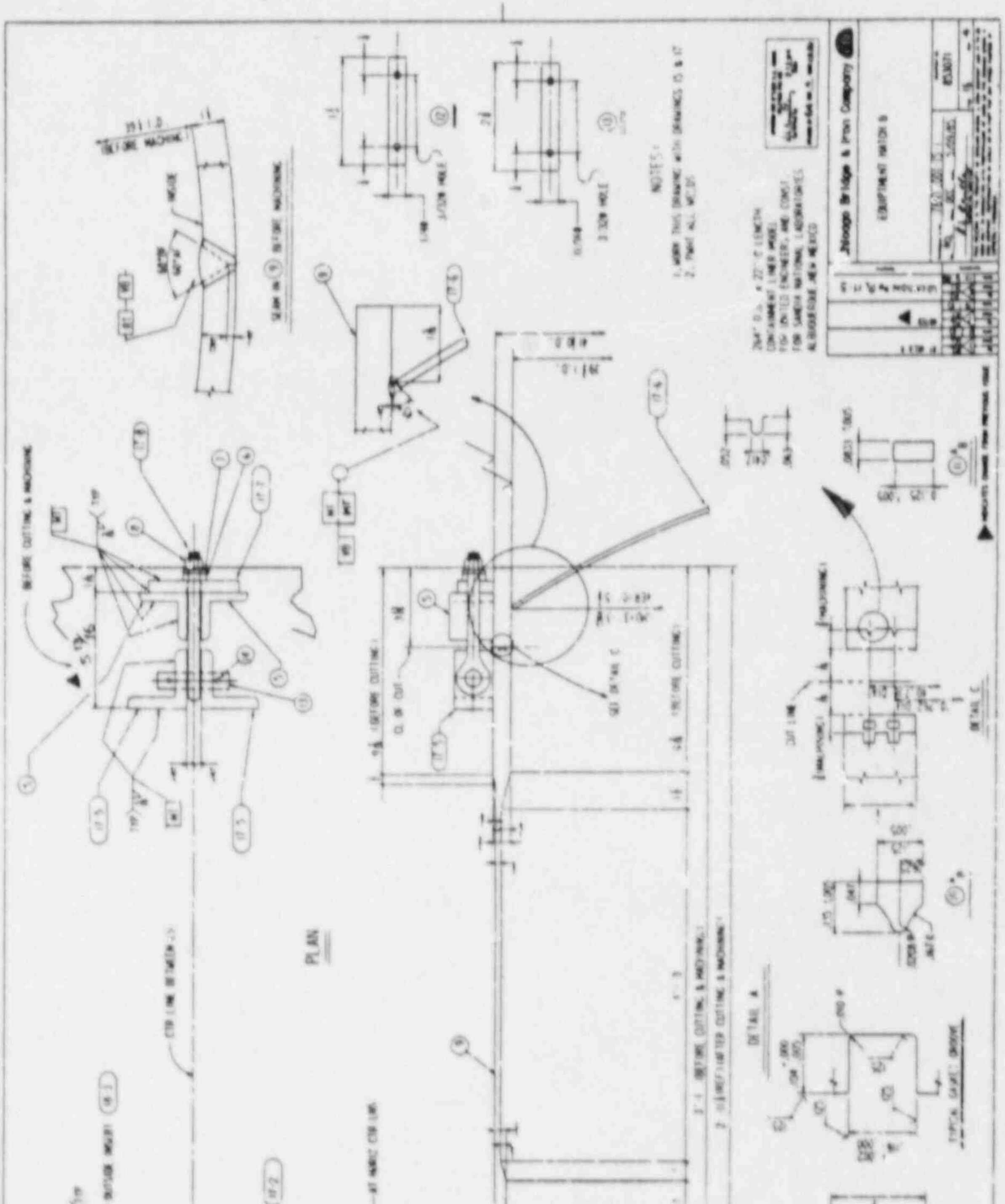

Chicago Bridge & Iron Company
BOTTOM PLATE DETAILS AND BILLING


SHELL STRETCHOUT
(OUTSIDE VIEW)
DENOTES SHOP SEAM
DENOTES FIELD SEAM
SEAM 'A'
SEAM 'B'
SEAM 'C'
SEAM 'D'
Chicago Bridge & Iron Company
SHELL STRETCHOUT
853071
0°
315°
270°
225°
180°
135°
90°
45°
22'-0"

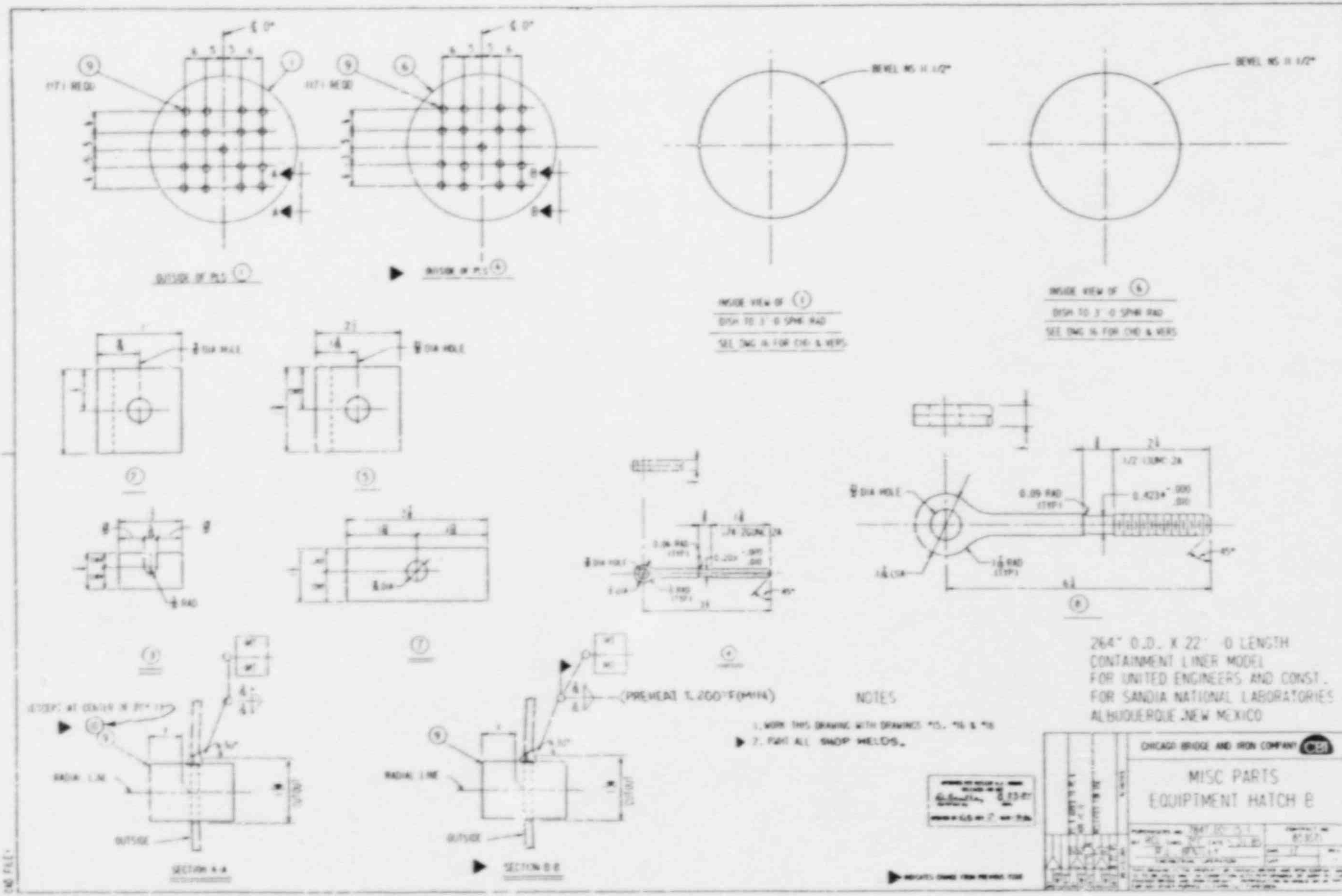

Chicago Bridge & Iron Company
BOTTOM SHELL WITH KNUCKLE ASSM
PLAN OF ASSM (A) & (B)
SECTION THRU PL (2)
WORK WITH DWG 12
SEAM 'A'
SEAM 'B'
OUTSIDE VIEW

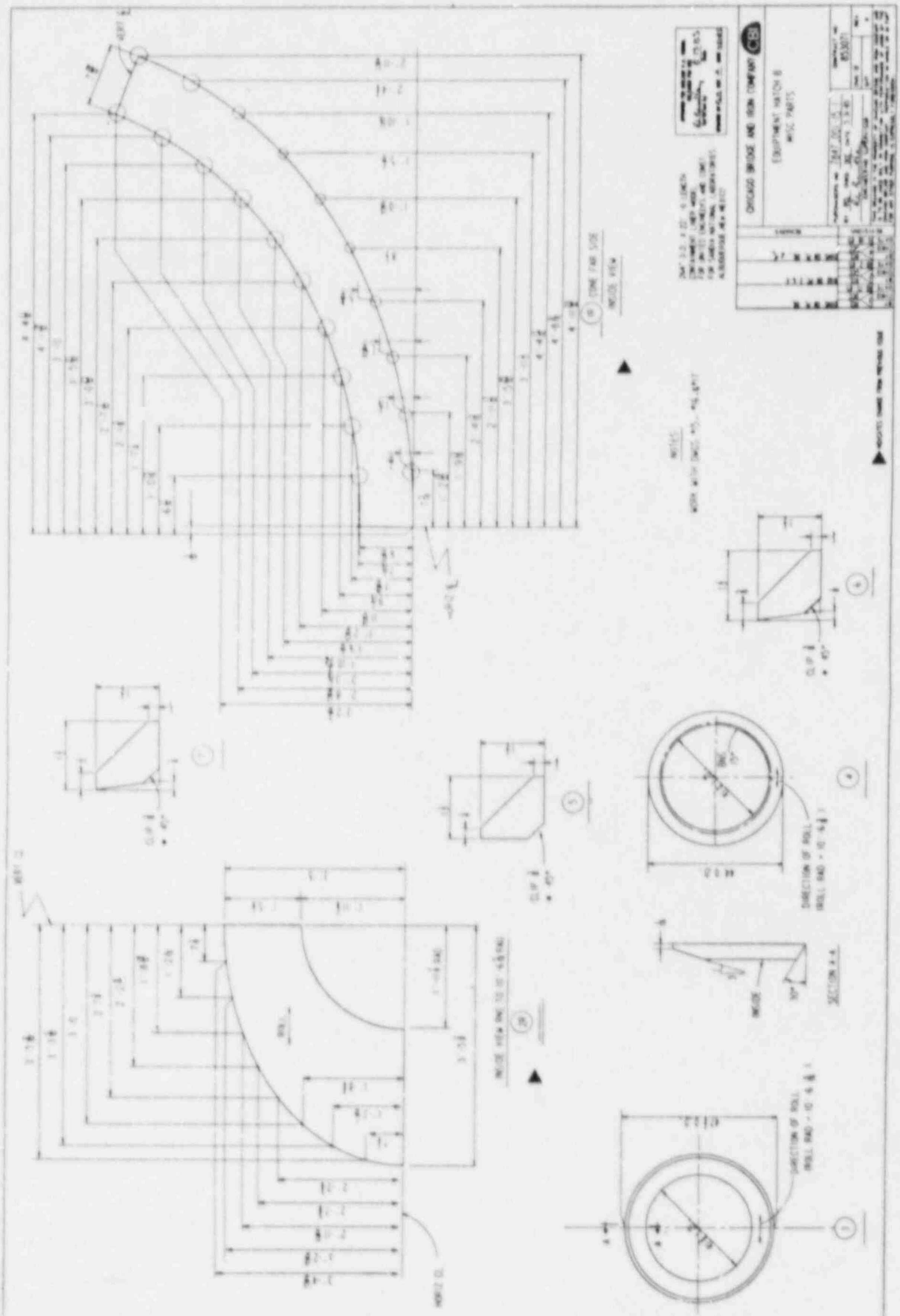

PLAN OF TOP HEAD
SECTION THRU TOP HEAD
SEAM "A"
SEAM "B"
Chicago Bridge & Iron Company
TOP HEAD AND SHELL R ASSM
853071

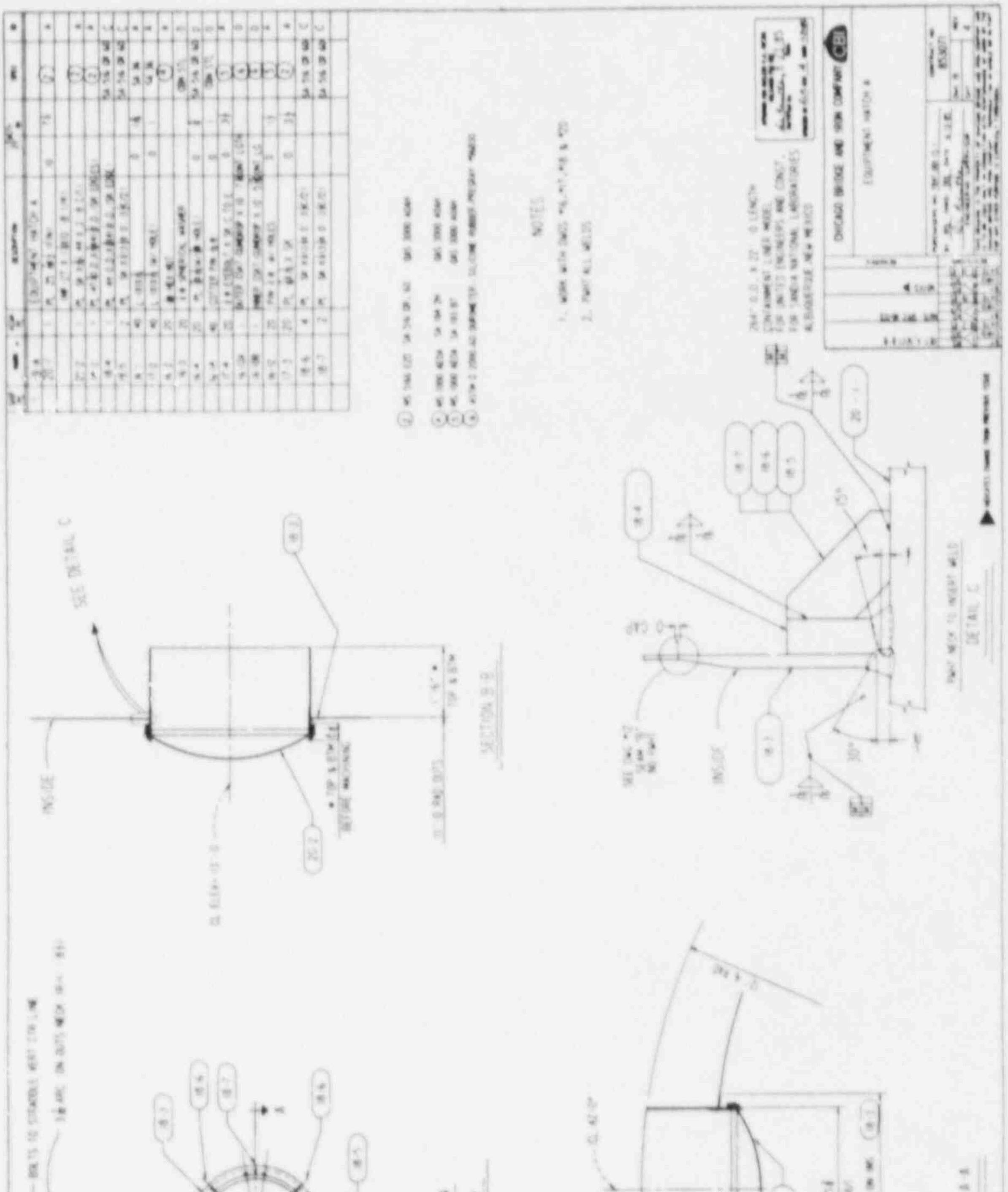

CHICAGO BRIDGE AND IRON COMPANY
EQUIPMENT HATCH B
NOTES
SECTION A-A
SECTION B-B
DETAIL C
INSIDE



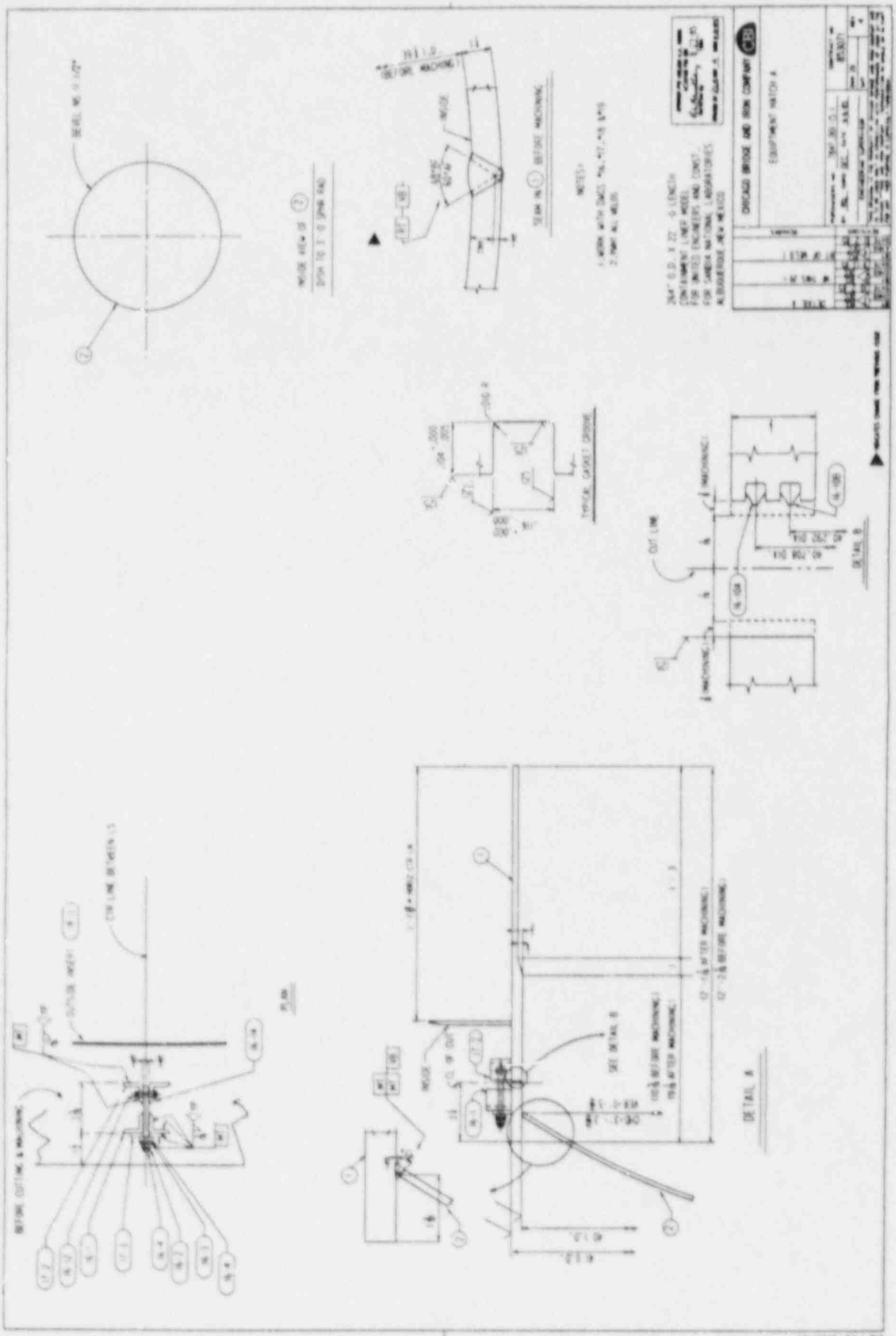
PLAN
DETAIL A
DETAIL B
DETAIL C
NOTES:


264" O.D. X 22' -0 LENGTH
CONTAINMENT LINER MODEL
FOR UNITED ENGINEERS AND CONST.
FOR SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO
CHICAGO BRIDGE AND IRON COMPANY
MISC PARTS
EQUIPMENT HATCH B
NOTES
1. WORK THIS DRAWING WITH DRAWINGS
2. PWHT ALL SHOP WELDS.
(PREHEAT 1,200°F(MIN))
BEVEL NS X 1/2"
INSIDE VIEW OF
DISH TO 3'-0 SPHR RAD
SEE DWG 16 FOR CHD & VERS
SECTION A-A
SECTION B-B
RADIAL LINE
OUTSIDE

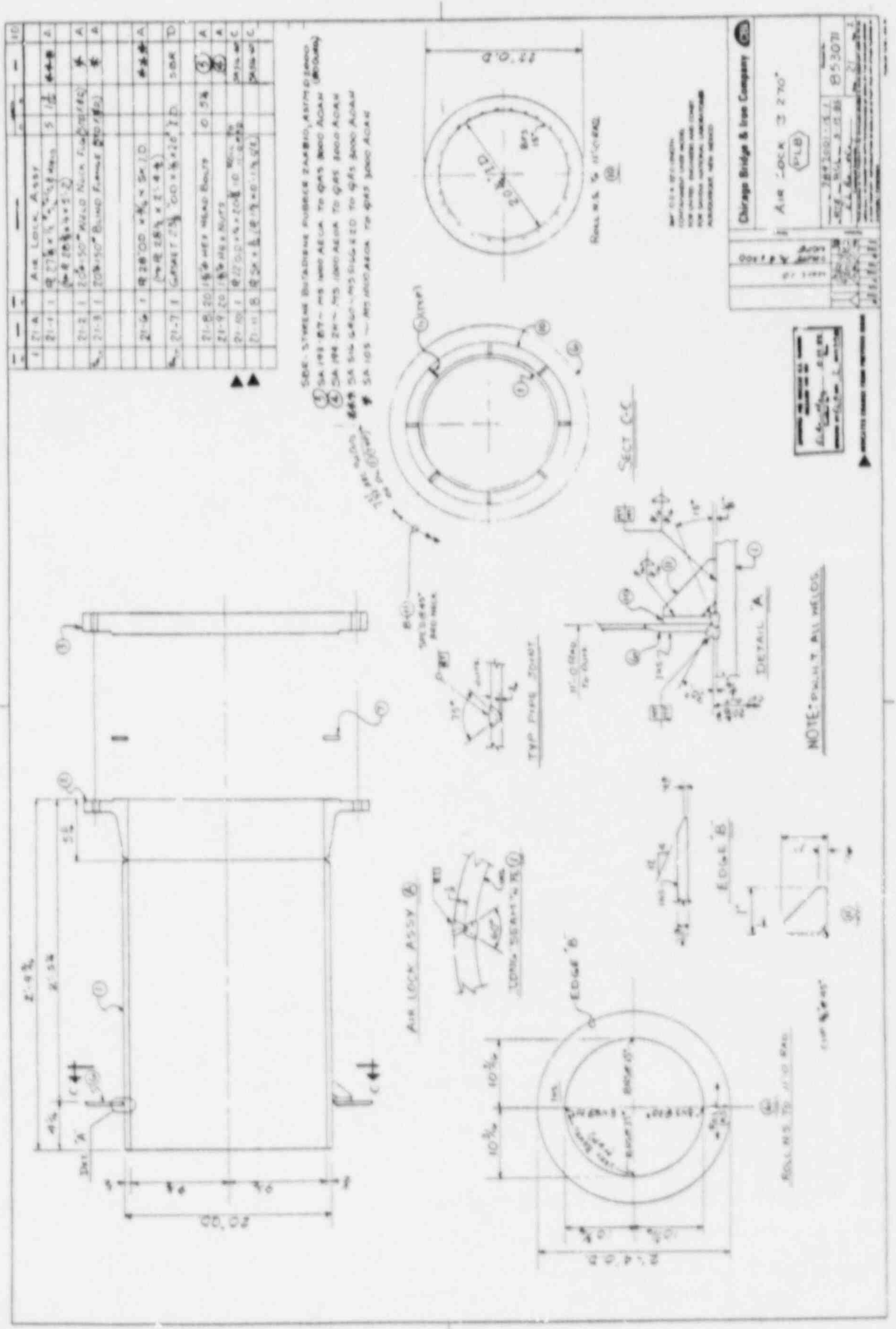

CHICAGO BRIDGE AND IRON COMPANY
EQUIPMENT HATCH B
MISC PARTS
SECTION A-A

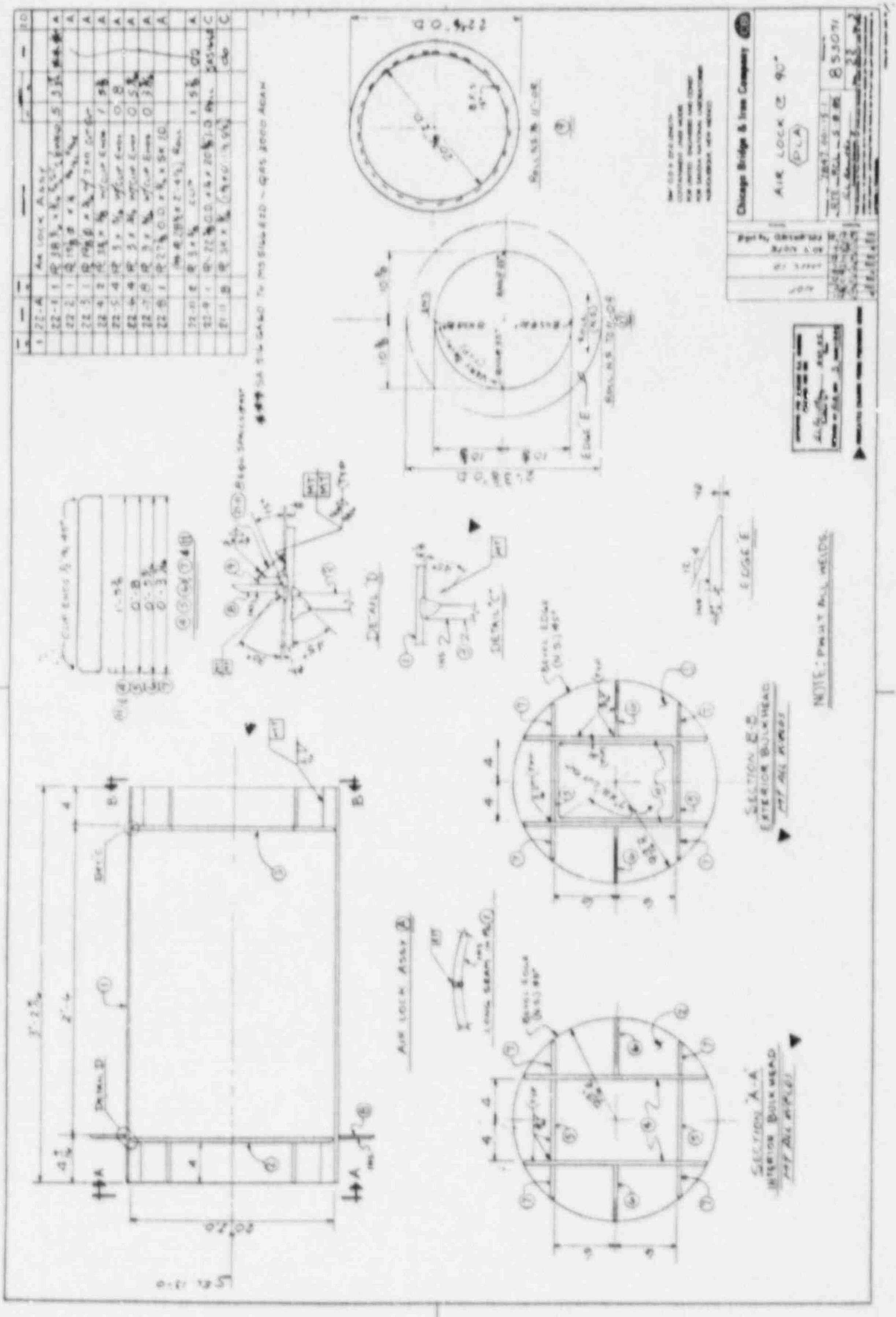


INSIDE VIEW
ELEVATION
SECTION A-A
SECTION B-B
SEE DETAIL C
DETAIL C
INSIDE
OUTSIDE SHELL
NOTES
CHICAGO BRIDGE AND IRON COMPANY
EQUIPMENT HATCH A

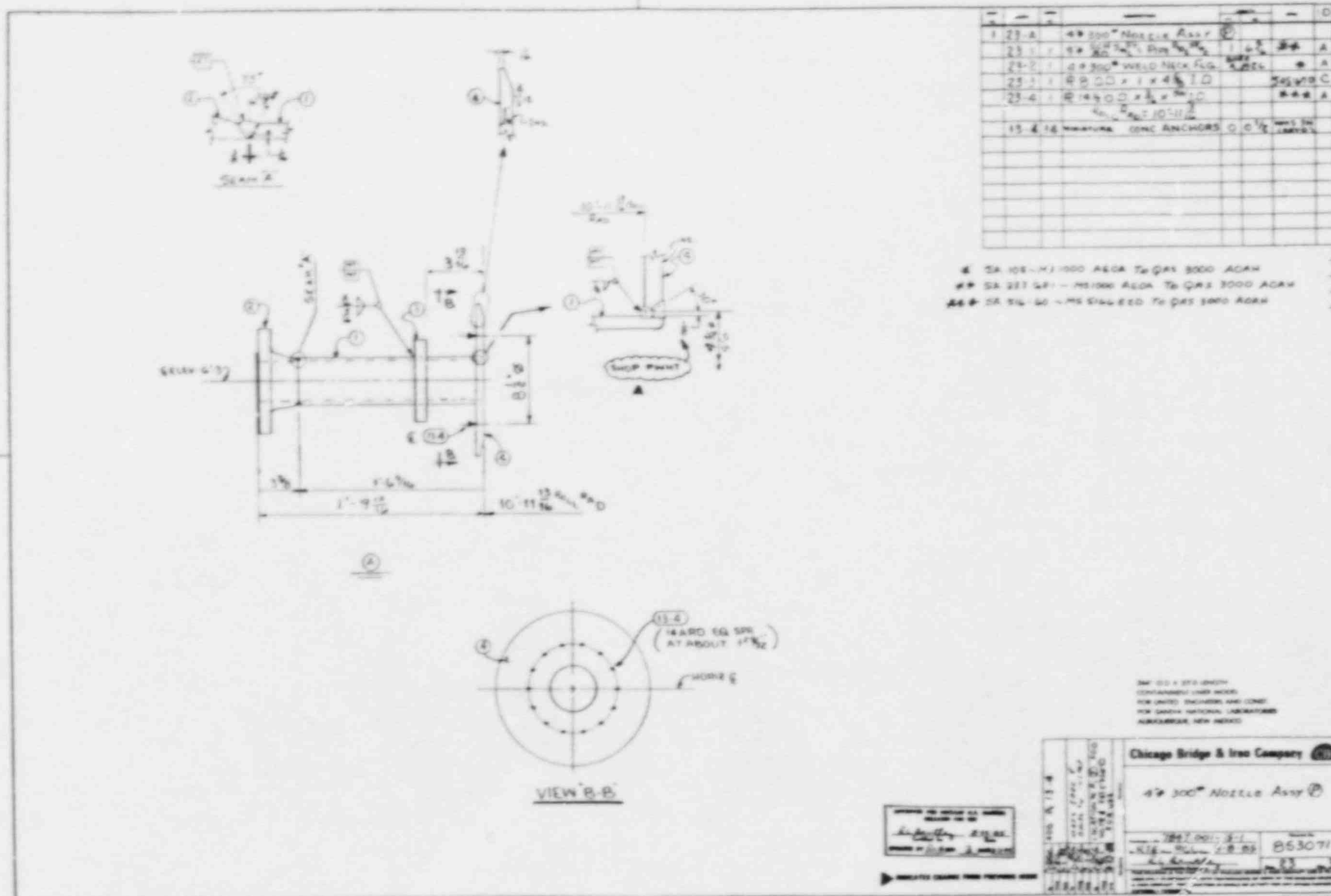


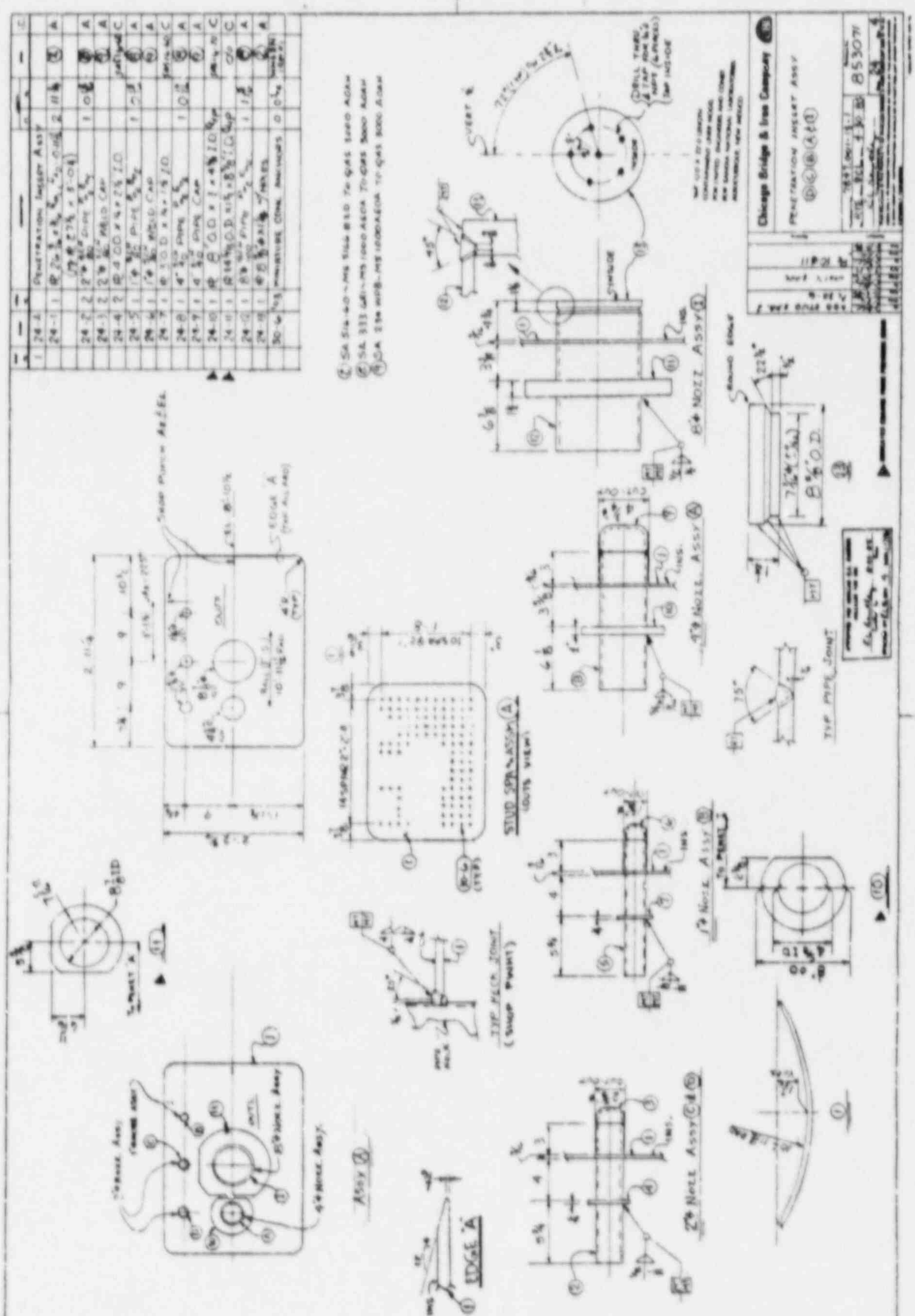
264" O.D. X 22'-6 LENGTH
CONTAINMENT LINER MODEL
FOR UNITED ENGINEERS AND CONST.
FOR SANDIA NATIONAL LABORATORIES
ALBUQUERQUE NEW MEXICO
CHICAGO BRIDGE AND IRON COMPANY
CBI
EQUIPMENT HATCH A
DETAIL A
DETAIL B
TYPICAL GASKET GROOVE
PLAN
SEE DETAIL B
CUT LINE
BEFORE CUTTING & MACHINING
CTR LINE BETWEEN
OUTSIDE
INSIDE
BEVEL
NOTES:
2. PWHT ALL WELDS
(BEFORE MACHINING)
CAD FILE: 85307120

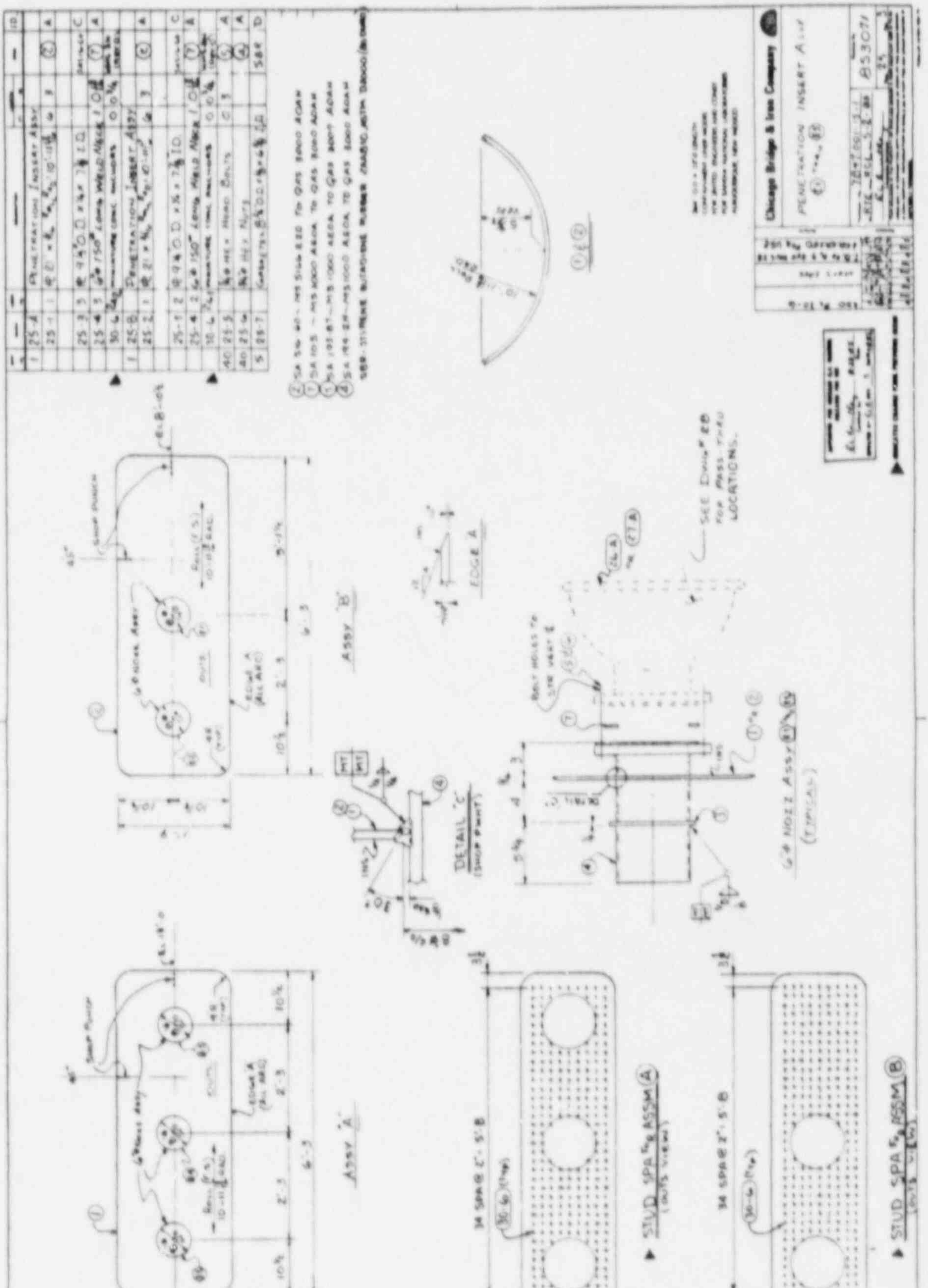

Chicago Bridge & Iron Company
AIR LOCK ASSY
SECT C-C
DETAIL 'A'
EDGE 'B'
TYP PIPE JOINT
NOTE: PWHT ALL WELDS

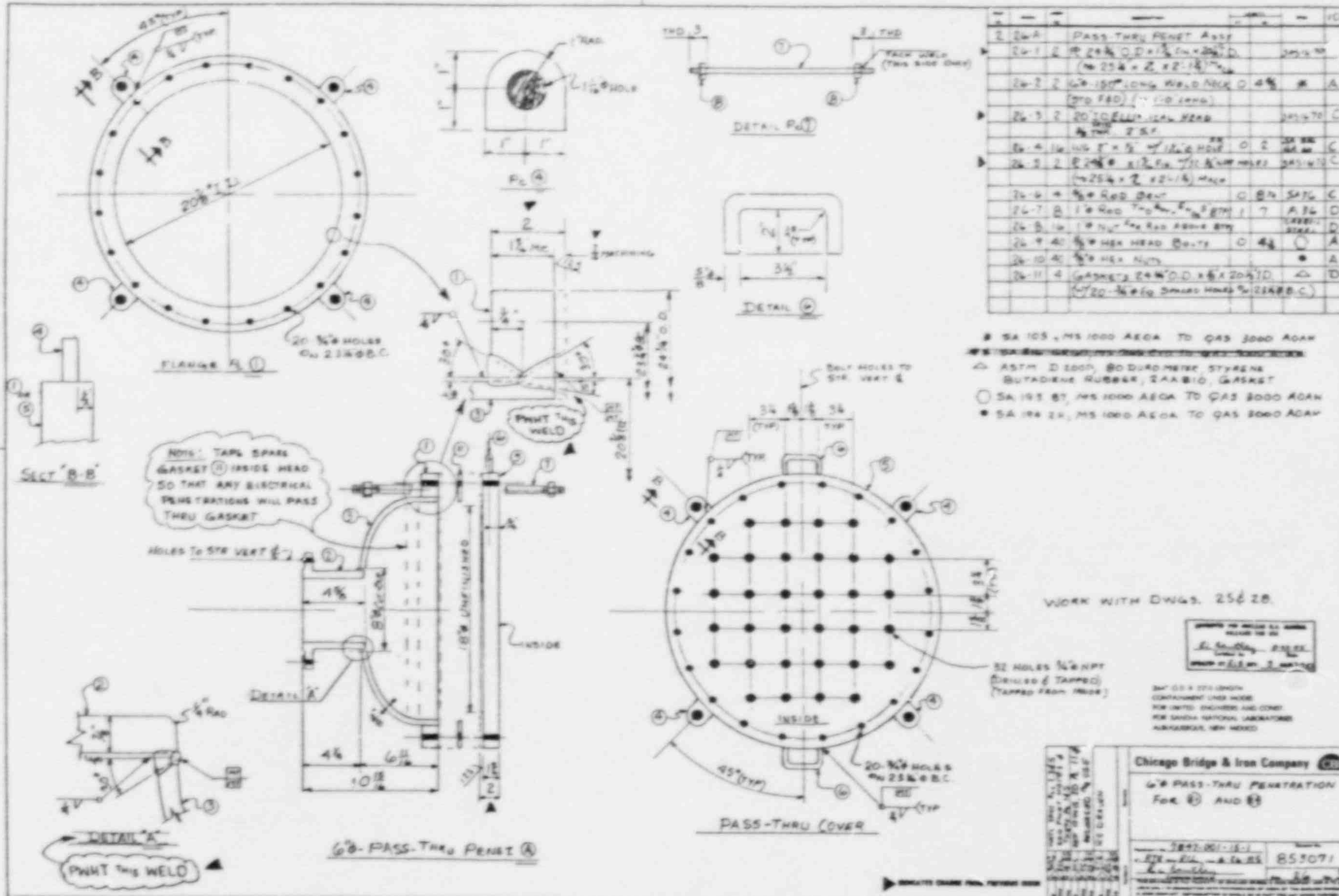


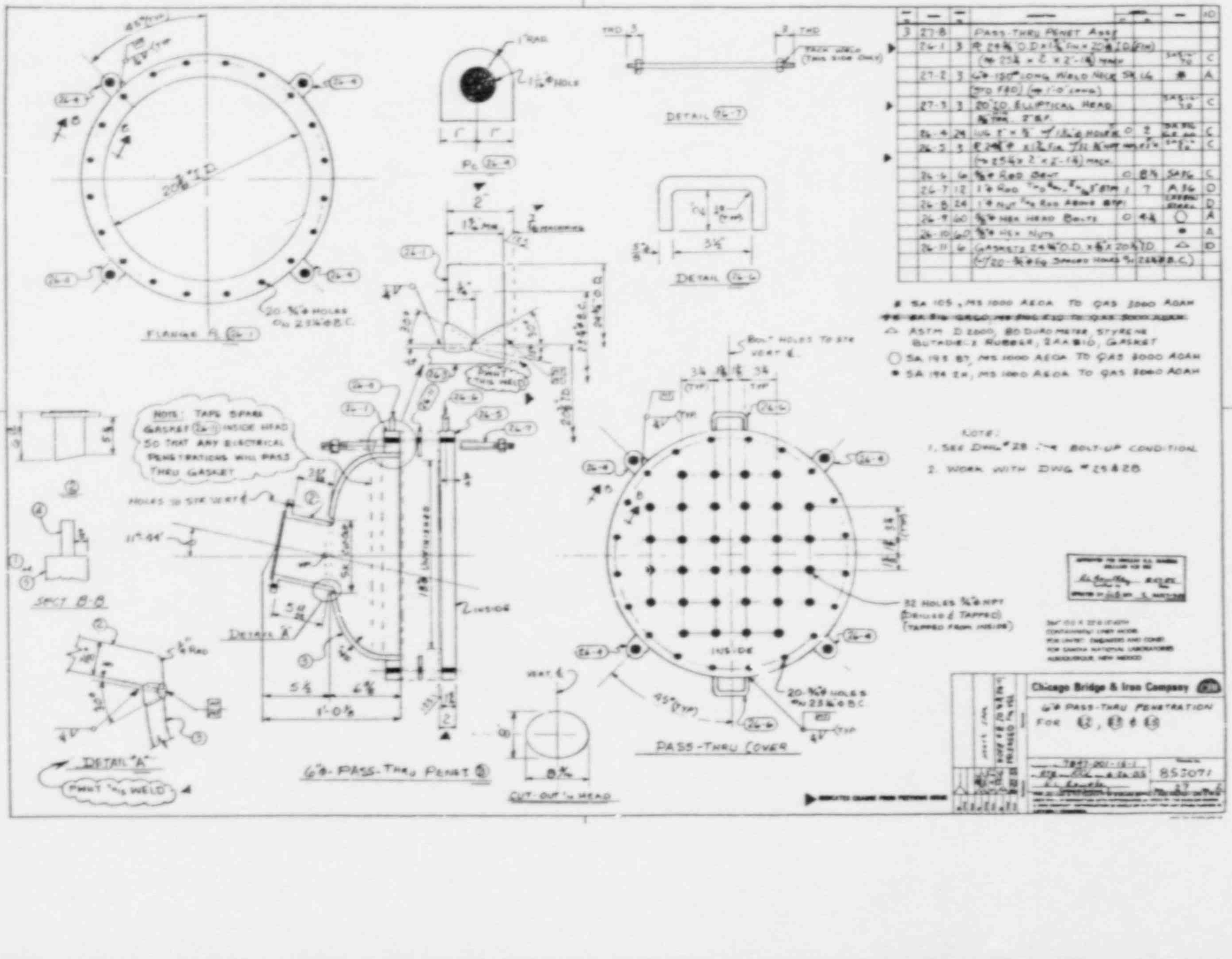
Chicago Bridge & Iron Company
AIR LOCK @ 90°
SECTION "A-A"
INTERIOR BULKHEAD
SECTION "B-B"
EXTERIOR BULKHEAD
AIR LOCK ASSY
DETAIL "D"
DETAIL "C"
EDGE "E"
NOTE: PAINT ALL WELDS.

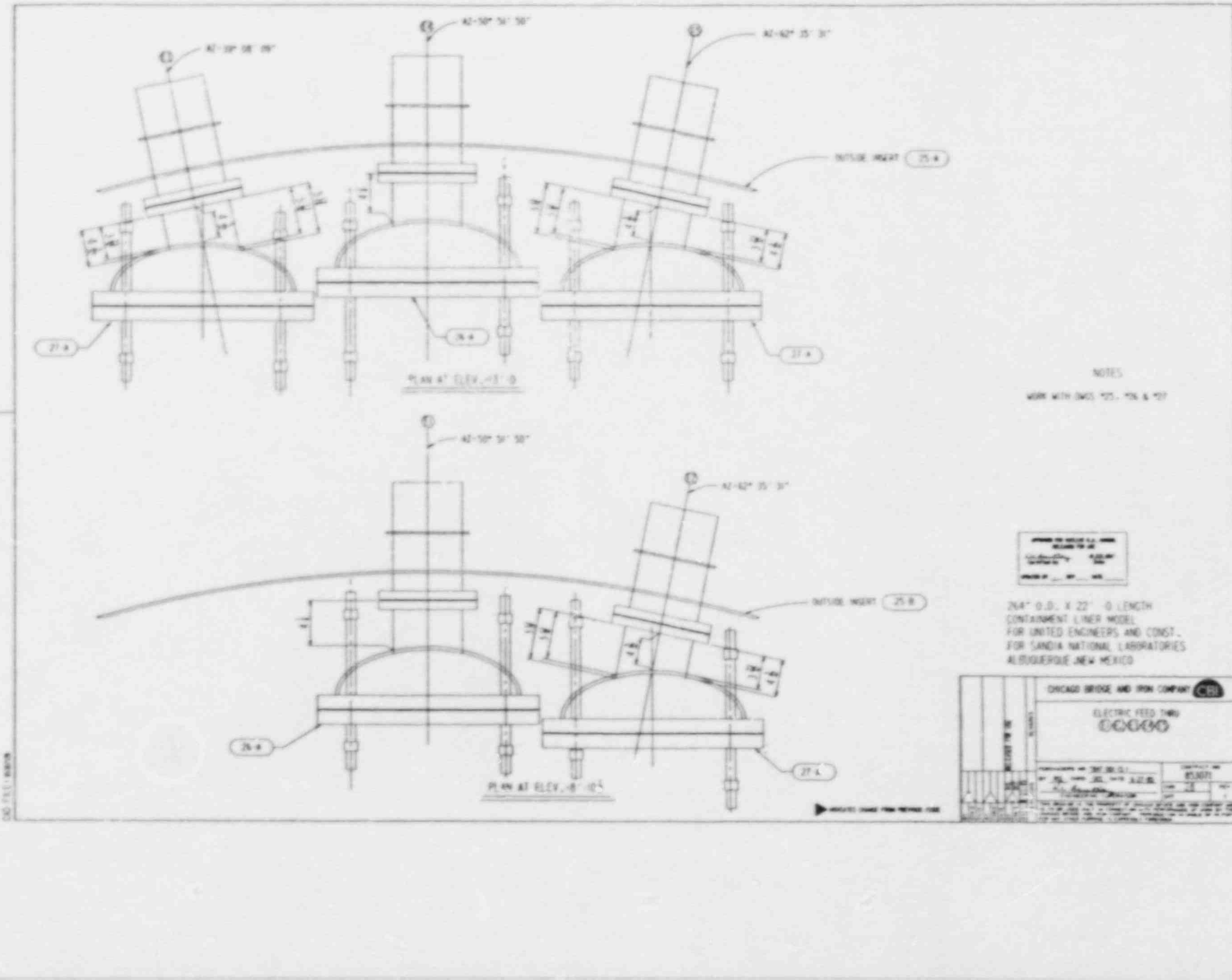

Chicago Bridge & Iron Company
4" 300# NOZZLE ASSY
B53071
VIEW "B-B"
SEAM "A"
SHOP PAINT
CONC ANCHORS
WELD NECK FLG.

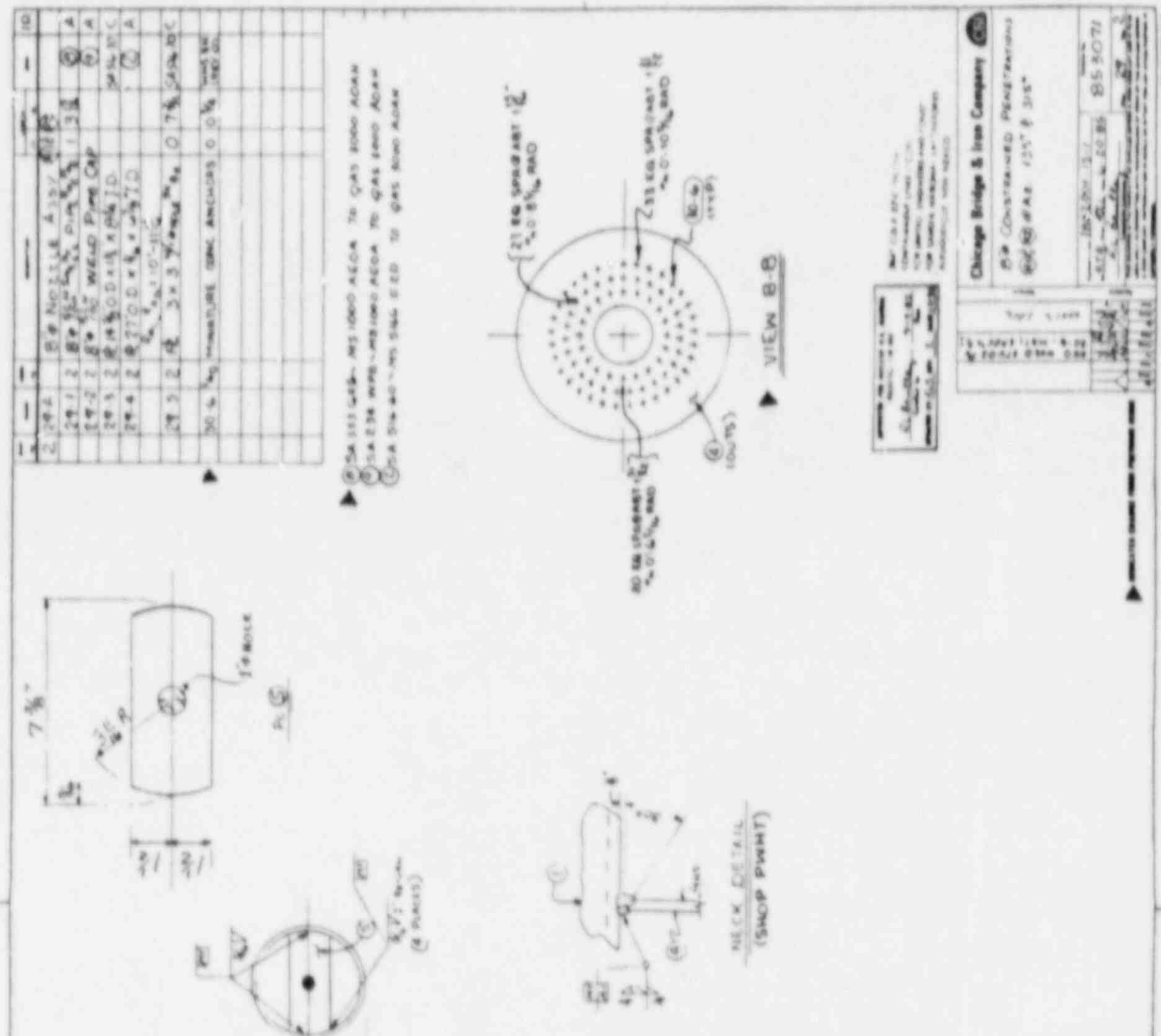

Chicago Bridge & Iron Company

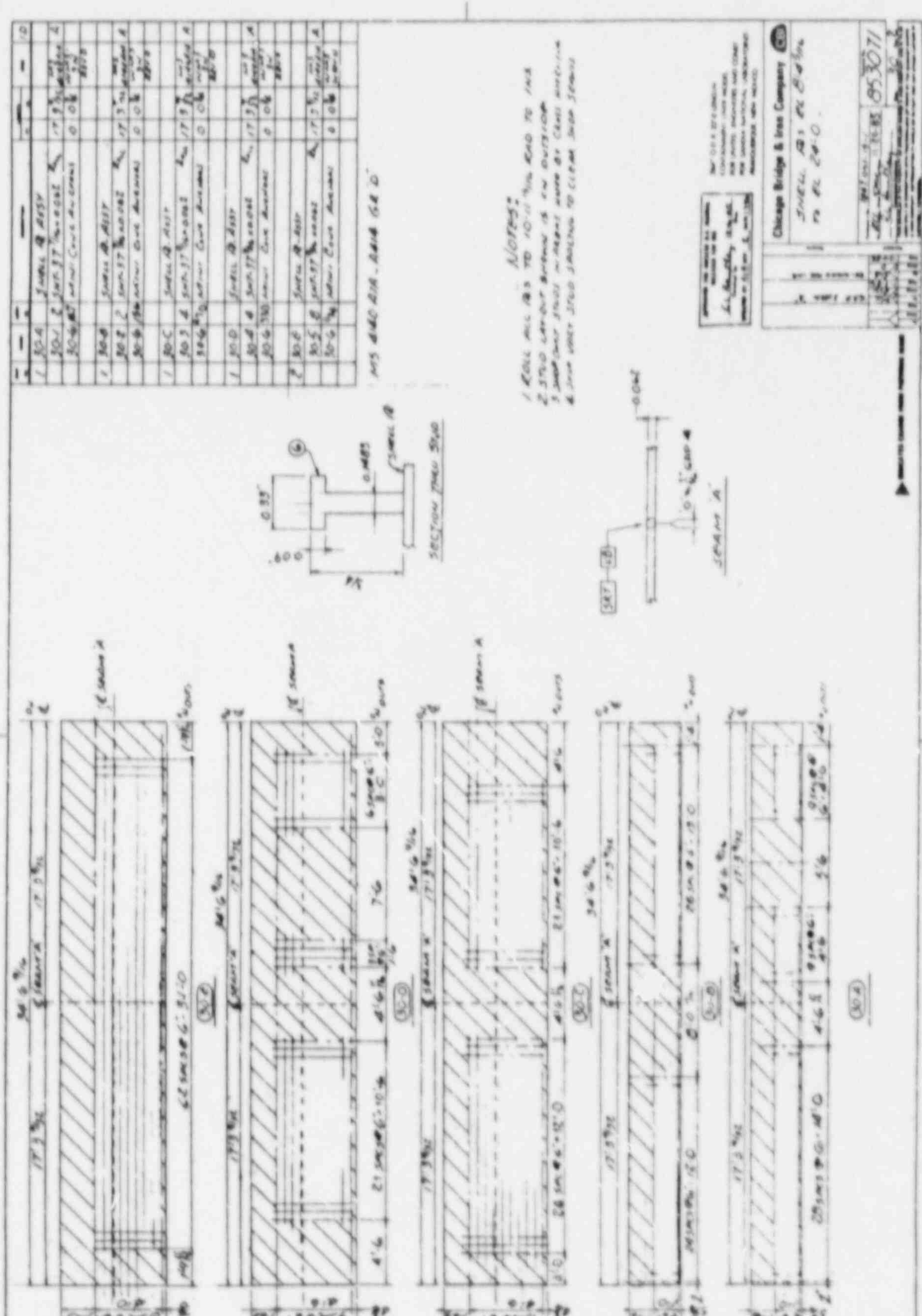

Chicago Bridge & Iron Company
ASSY 'A'
ASSY 'B'
DETAIL 'C'
EDGE A


Chicago Bridge & Iron Company
6" PASS-THRU PENETRATION
853071
6" PASS-THRU PENET. (A)
PASS-THRU COVER
FLANGE PL (1)
SECT "B-B"
DETAIL "A"
PWHT THIS WELD
NOTE: TAPE SPARE GASKET (11) INSIDE HEAD SO THAT ANY ELECTRICAL PENETRATIONS WILL PASS THRU GASKET
HOLES TO STR VERT ℄
BOLT HOLES TO STR. VERT ℄
INSIDE
20-⅞" HOLES ON 23⅛" B.C.
32 HOLES ¾" NPT (DRILLED & TAPPED) (TAPPED FROM INSIDE)
WORK WITH DWGS. 25 & 28.
PASS-THRU PENET ASSY
HEX HEAD BOLTS
HEX NUTS
ASTM D 2000, 80 DUROMETER, STYRENE BUTADIENE RUBBER, 2AA810, GASKET

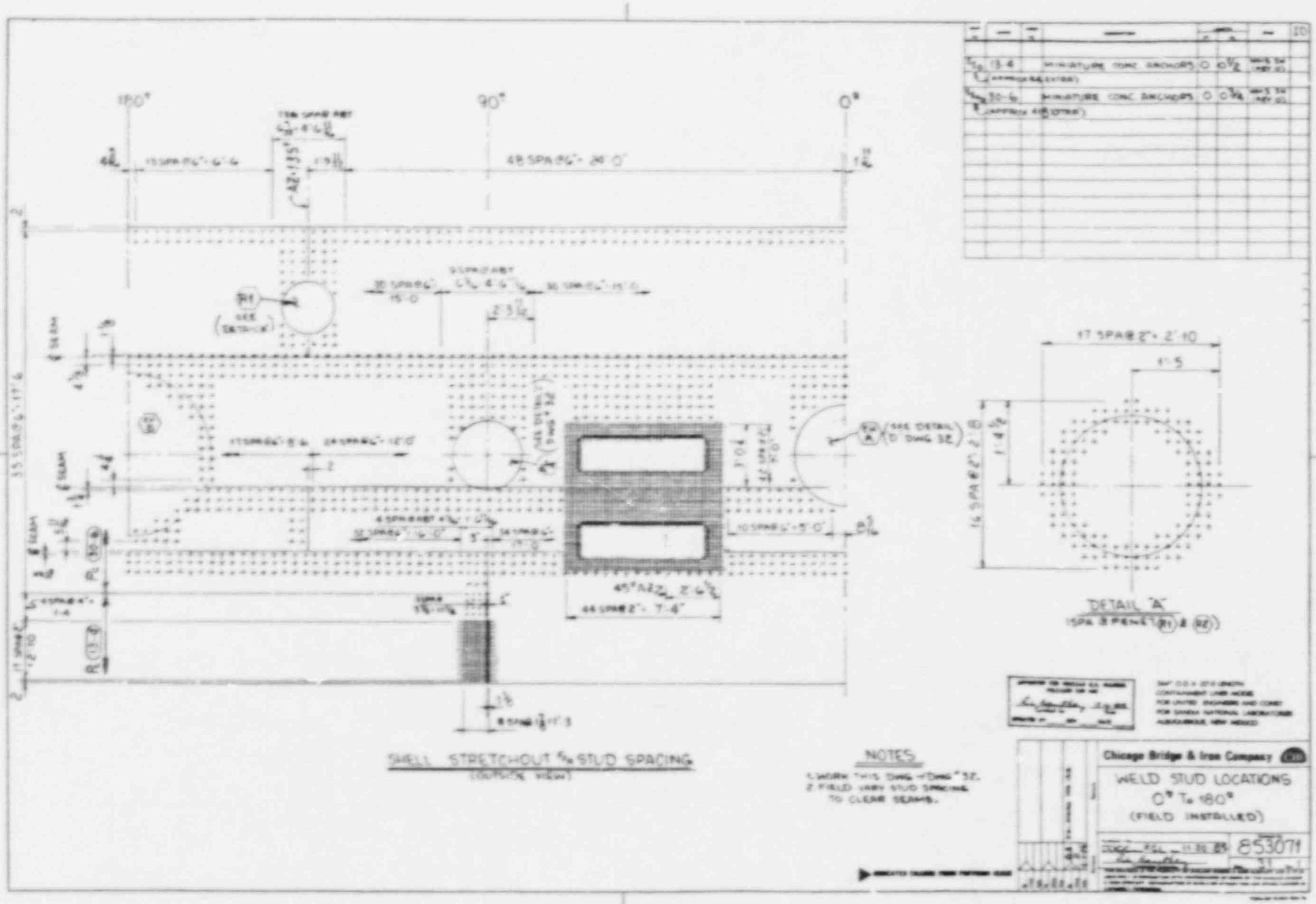

Chicago Bridge & Iron Company
6" PASS-THRU PENETRATION
853071
FLANGE
DETAIL "A"
DETAIL 'A'
SECT B-B
6" PASS-THRU PENET
PASS-THRU COVER
CUT-OUT IN HEAD
INSIDE
NOTE: TAPE SPARE GASKET INSIDE HEAD SO THAT ANY ELECTRICAL PENETRATIONS WILL PASS THRU GASKET
NOTE:
1. SEE DWG. #28 FOR BOLT-UP CONDITION
2. WORK WITH DWG #25 & 28
PASS-THRU PENET ASSY
20" I.D. ELLIPTICAL HEAD
HEX HEAD BOLTS
HEX NUTS
ASTM D 2000, 80 DUROMETER, STYRENE BUTADIENE RUBBER, 2AA810, GASKET
32 HOLES 3/4" NPT (DRILLED & TAPPED) (TAPPED FROM INSIDE)

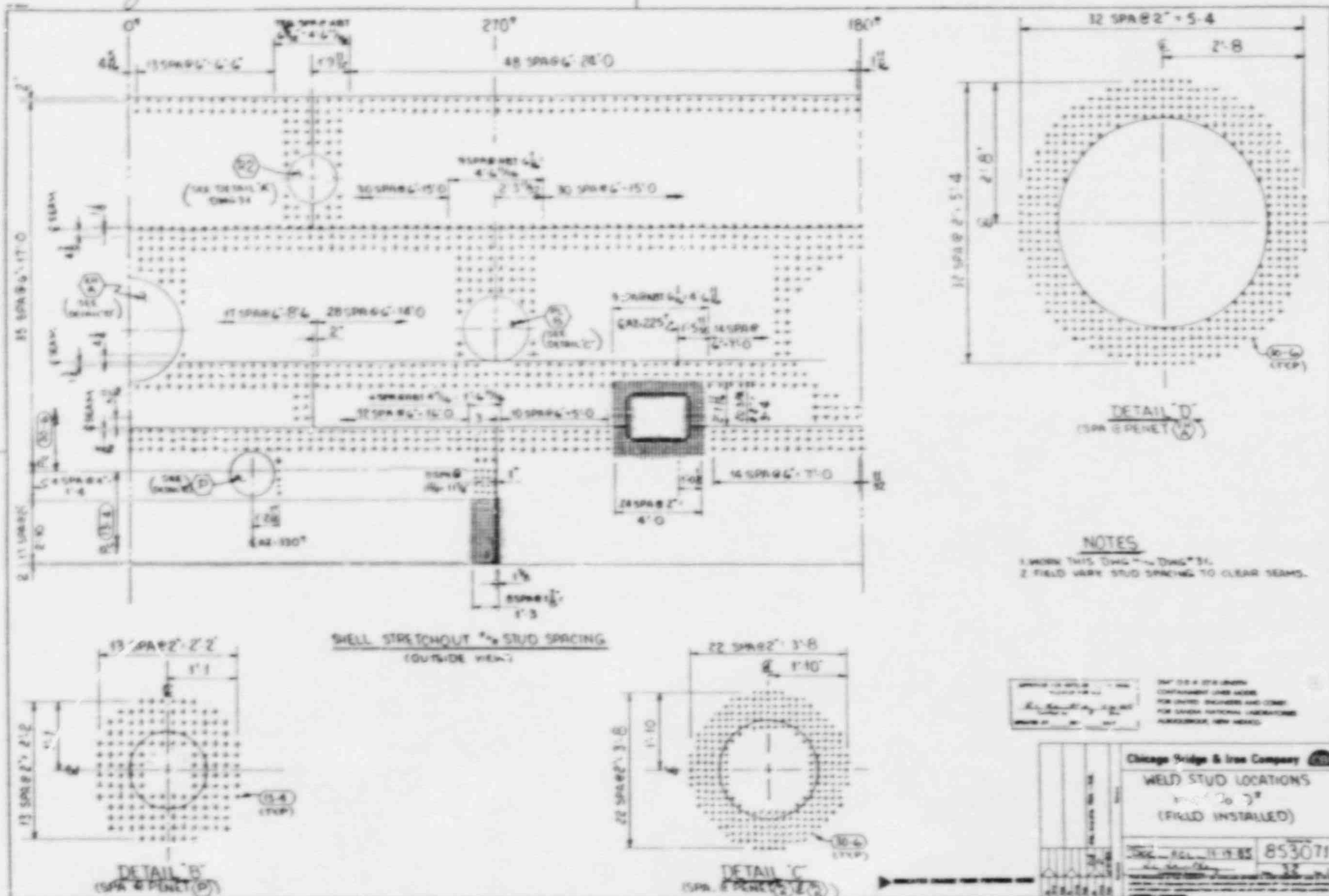

AZ-30° 08' 09"
AZ-50° 54' 50"
AZ-62° 35' 31"
OUTSIDE INSERT
25-A
27-A
26-A
PLAN AT ELEV.+13'-0
NOTES
WORK WITH DWGS #25, #26 & #27
AZ-50° 54' 50"
AZ-62° 35' 31"
OUTSIDE INSERT
25-B
26-B
27-L
PLAN AT ELEV.+8'-10⅝
264" O.D. X 22'-0 LENGTH
CONTAINMENT LINER MODEL
FOR UNITED ENGINEERS AND CONST.
FOR SANDIA NATIONAL LABORATORIES
ALBUQUERQUE,NEW MEXICO
CHICAGO BRIDGE AND IRON COMPANY
CBI
ELECTRIC FEED THRU

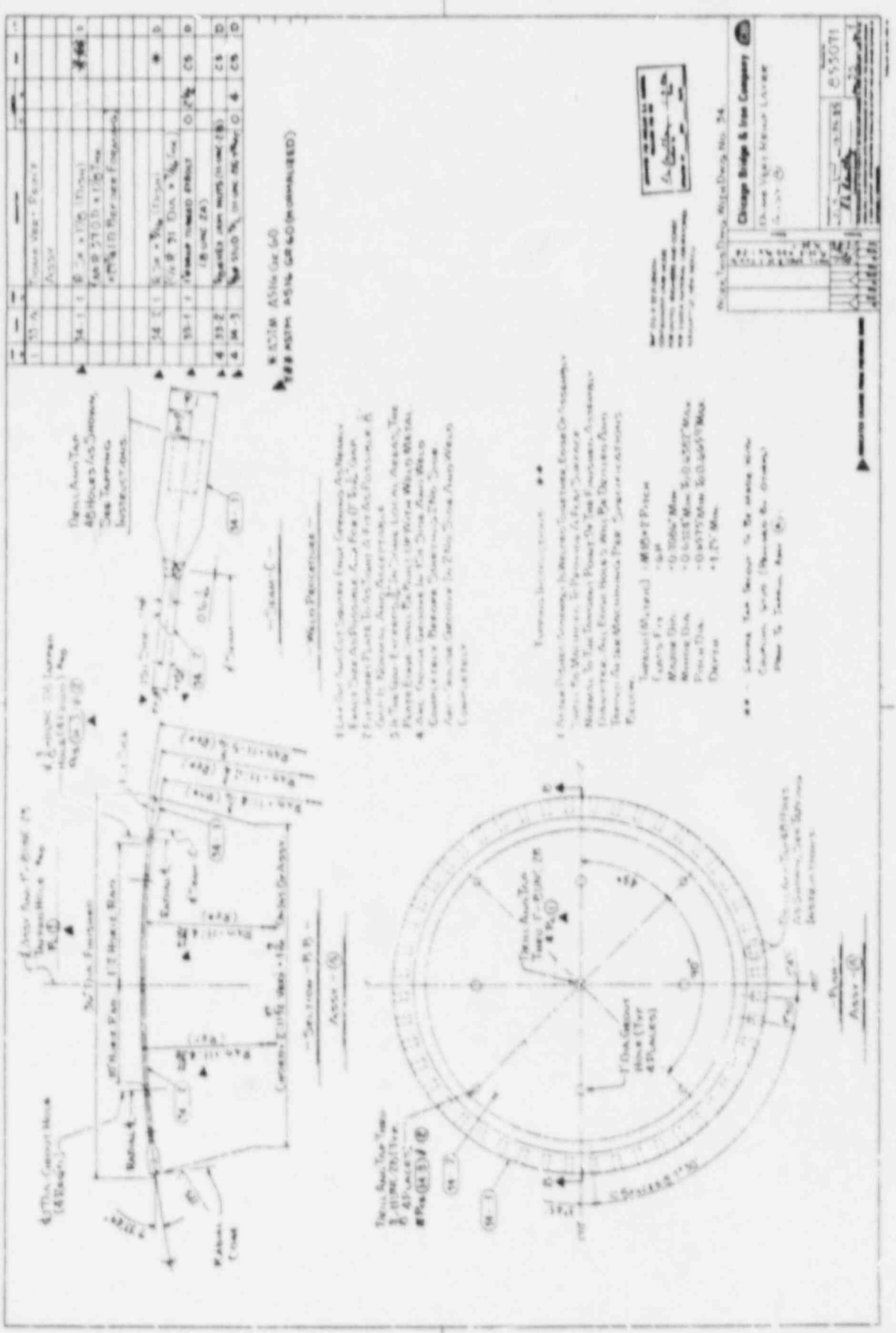

VIEW B-B
NECK DETAIL
(SHOP PWHT)
DETAIL A
Chicago Bridge & Iron Company
85-3071

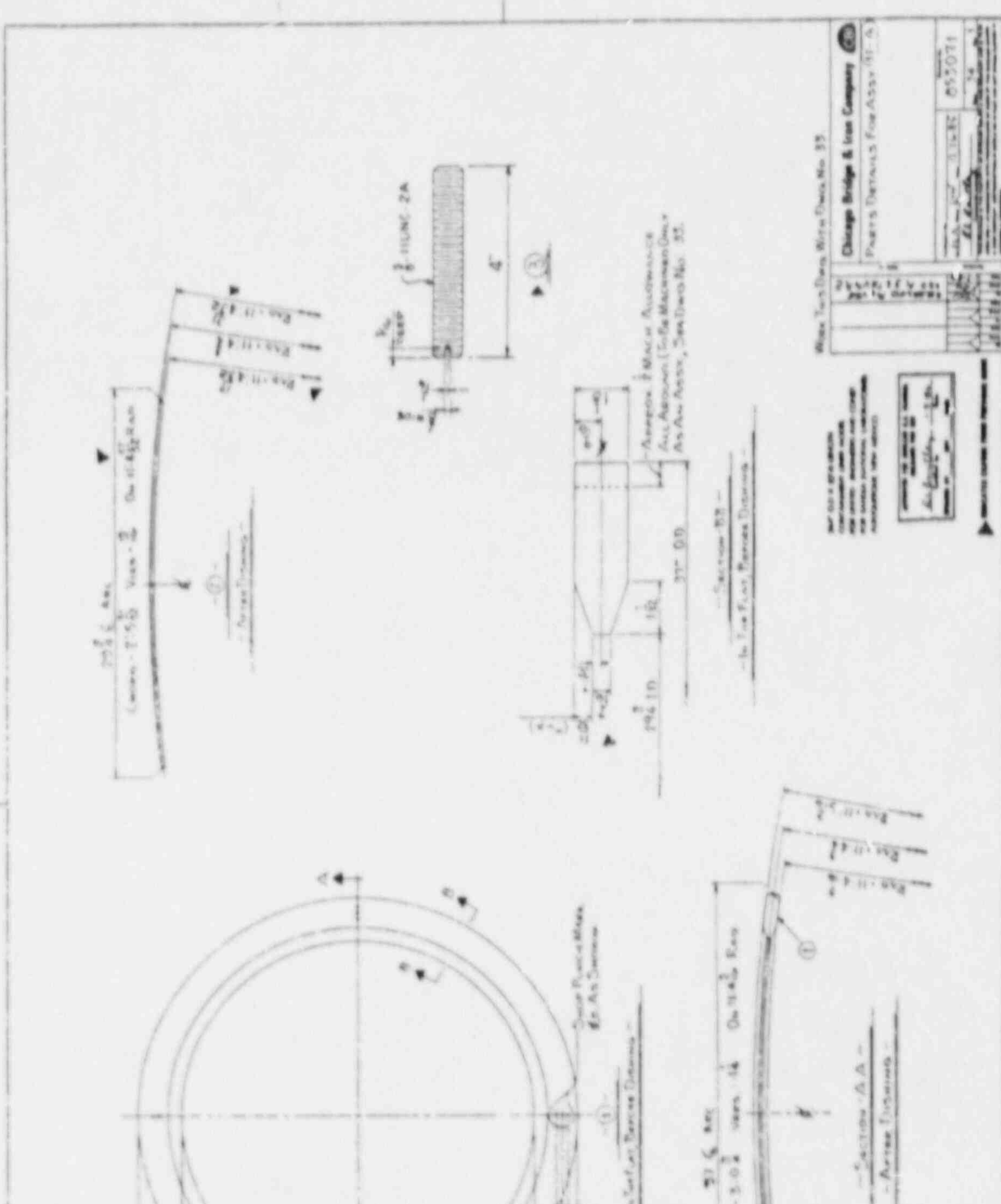


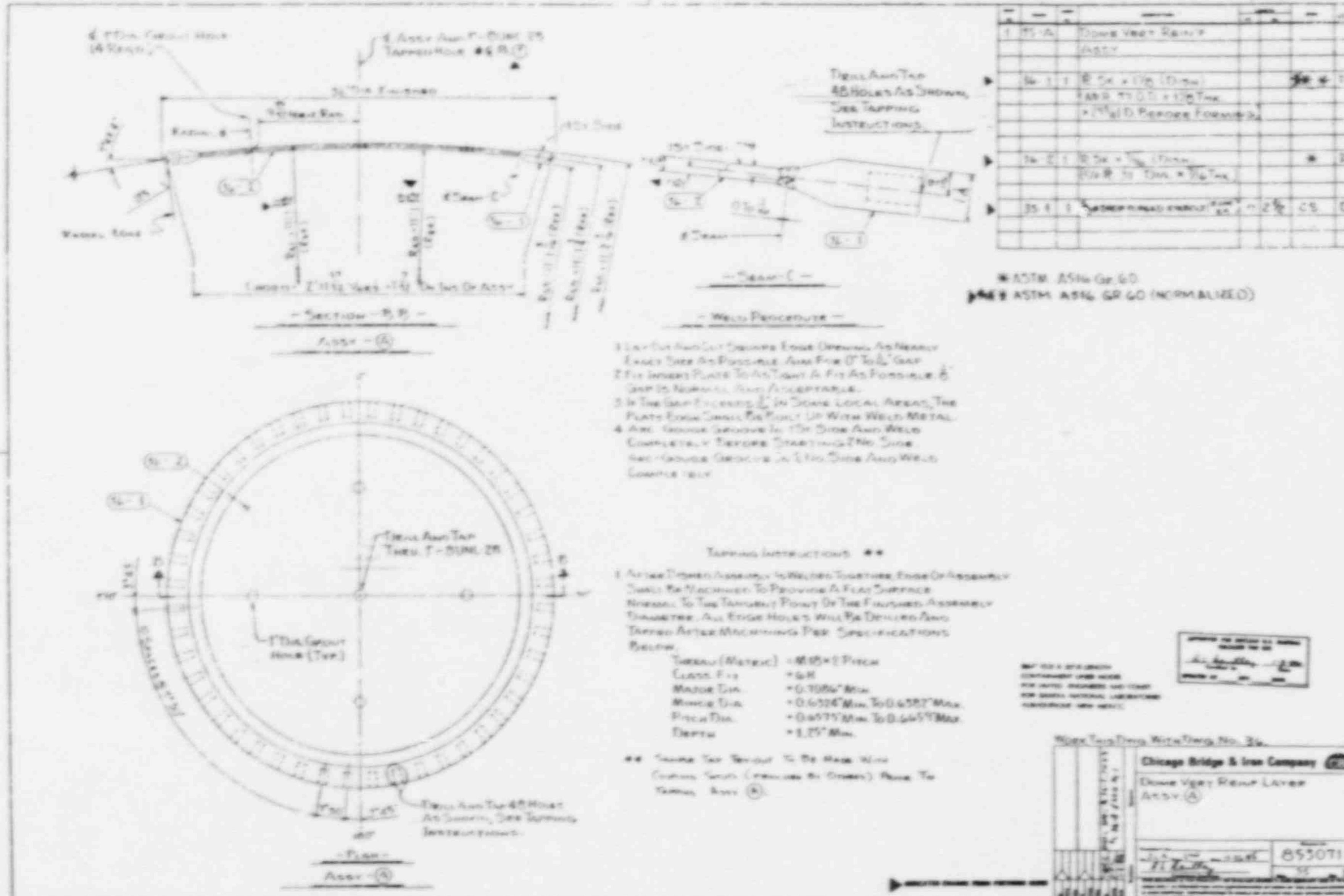
Chicago Bridge & Iron Company
853071
SECTION THRU STUD
SEAM 'A'
NOTES:


SHELL STRETCHOUT & STUD SPACING
(OUTSIDE VIEW)
180°
90°
0°
48 SPA @ 6" = 24'-0"
DETAIL "A"
17 SPA @ 2" = 2'-10
NOTES
1. WORK THIS DWG. W/ DWG. 32.
2. FIELD VARY STUD SPACING TO CLEAR SEAMS.
Chicago Bridge & Iron Company
WELD STUD LOCATIONS
0° To 180°
(FIELD INSTALLED)
853071
MINIATURE CONC. ANCHORS

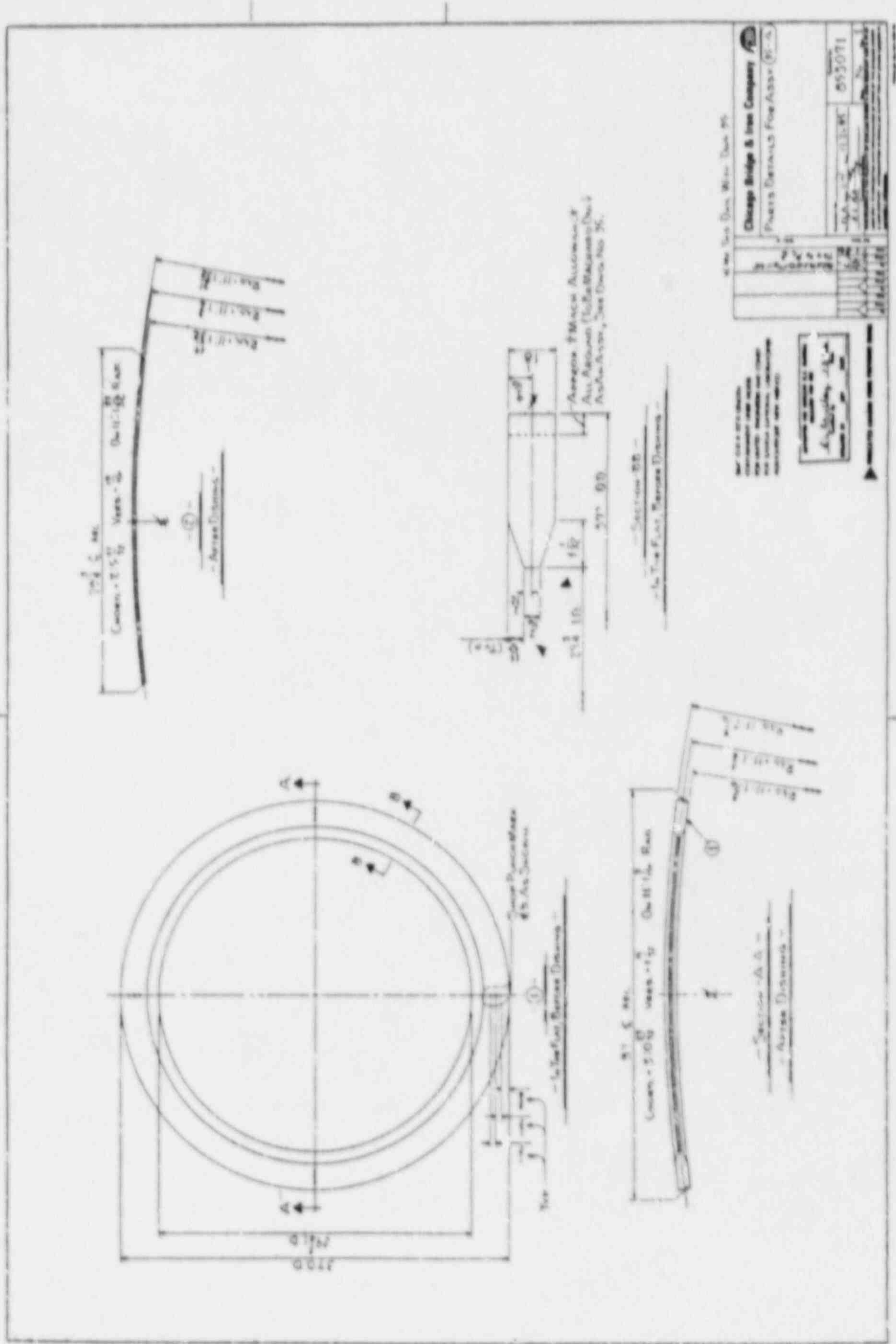

0°
270°
180°
48 SPA @ 6" 24'-0
30 SPA @ 6" 15'-0
17 SPA @ 6" 8'-6
28 SPA @ 6" 14'-0
10 SPA @ 6" 5'-0
16 SPA @ 6" 7'-0
24 SPA @ 2" 4'-0
SHELL STRETCHOUT & STUD SPACING
(OUTSIDE VIEW)
32 SPA @ 2" = 5'-4
2'-8
DETAIL "D"
NOTES
1. WORK THIS DWG WITH DWG 31.
2. FIELD VARY STUD SPACING TO CLEAR SEAMS.
13 SPA @ 2" 2'-2
1'-1
DETAIL "B"
22 SPA @ 2" 3'-8
1'-10
DETAIL "C"
Chicago Bridge & Iron Company
WELD STUD LOCATIONS
(FIELD INSTALLED)
853071

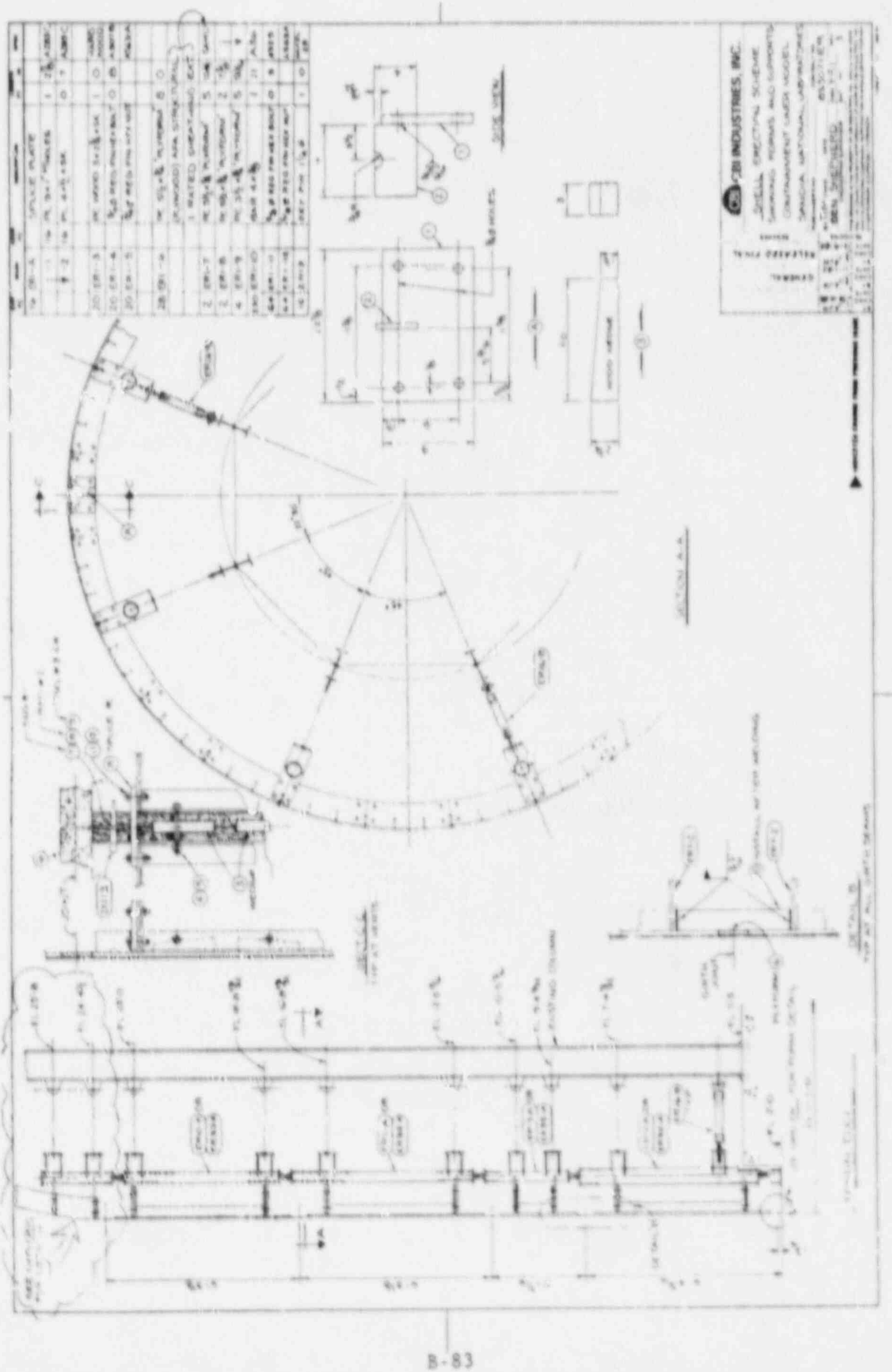

Chicago Bridge & Iron Company
E5507
ASSY - A
SECTION - B-B
PLAN

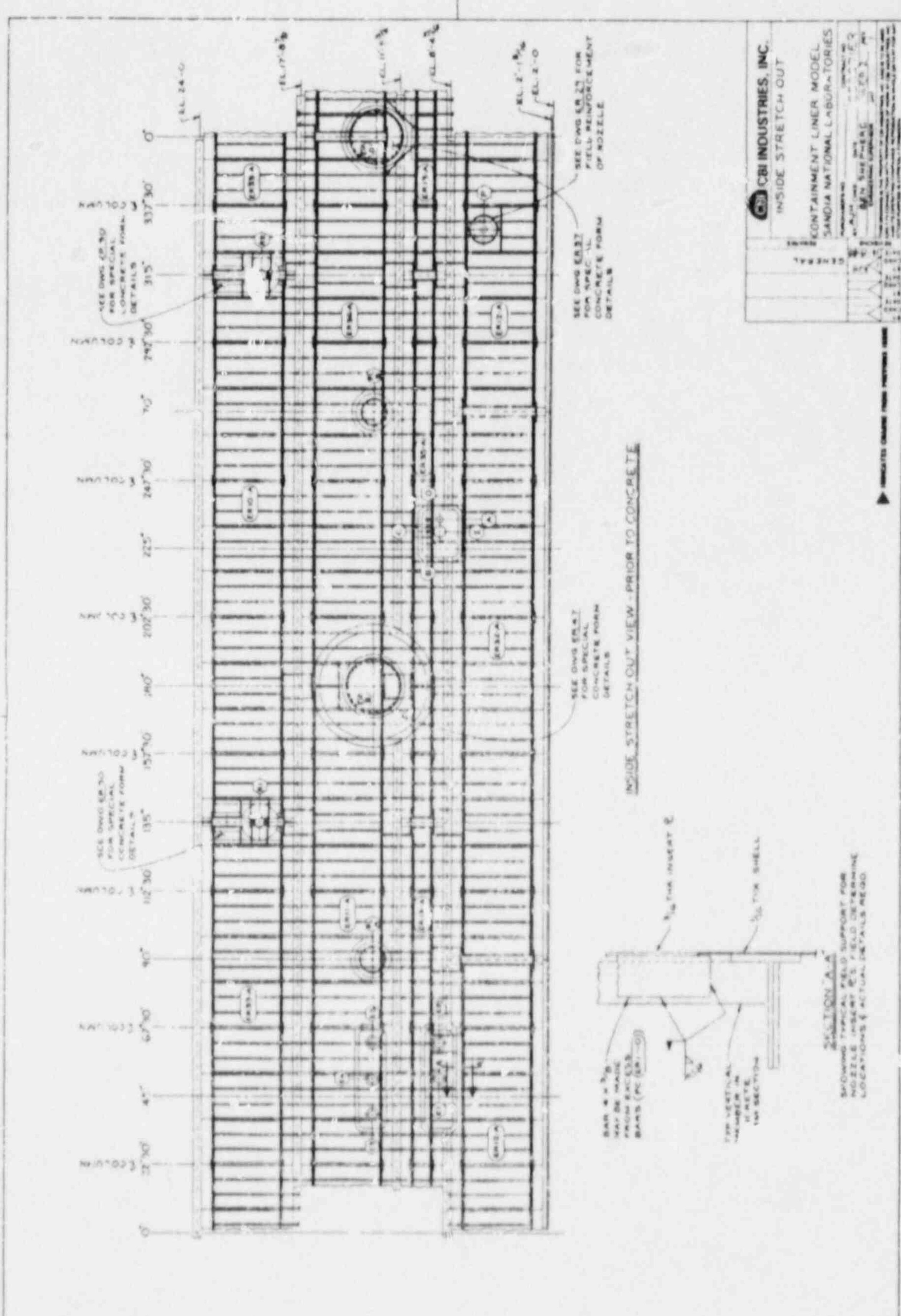

Chicago Bridge & Iron Company
- Section A-A -
- After Dishing -



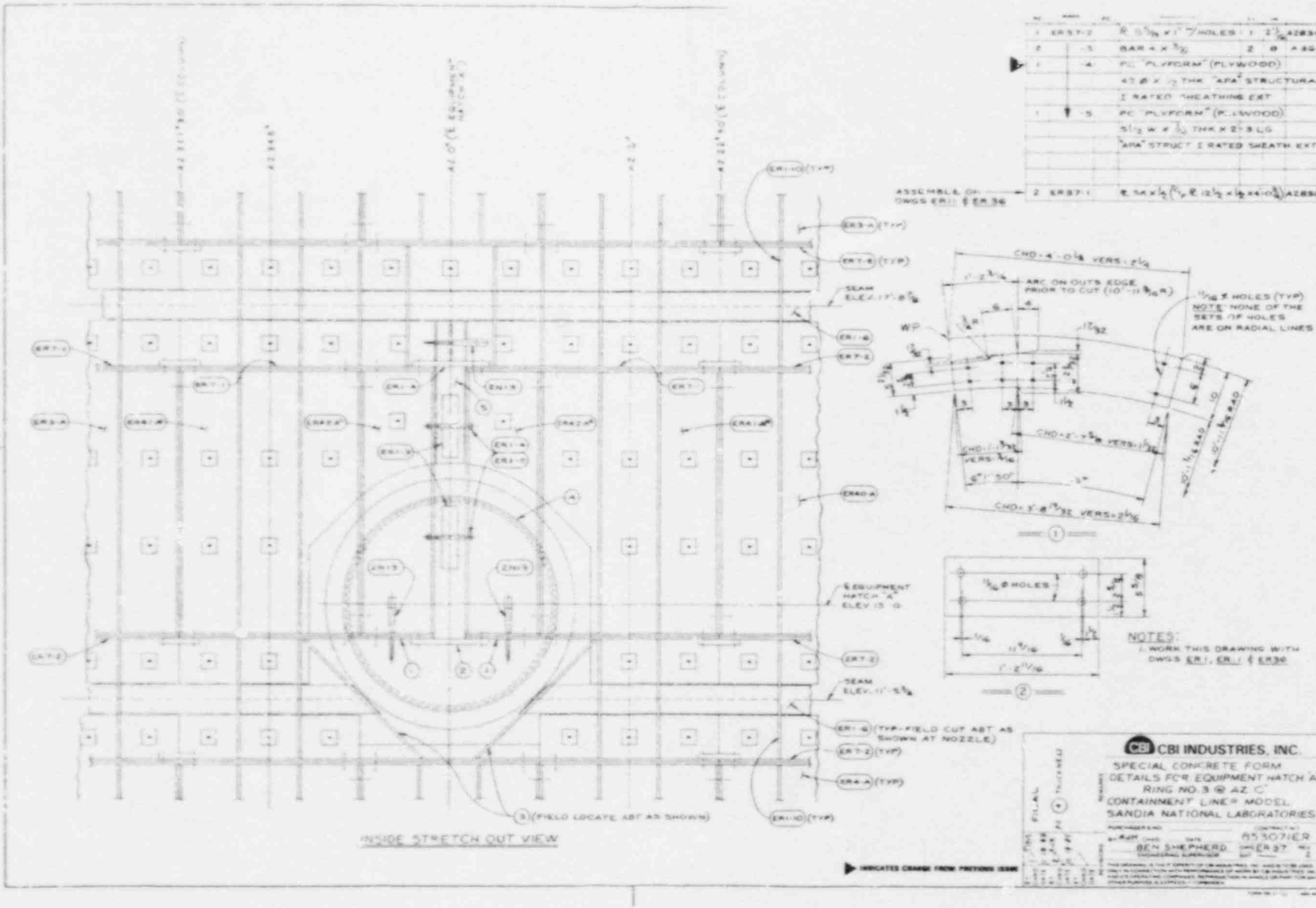
Section B-B
Assy A
Seam C
Weld Procedure
Tapping Instructions **
Plan
Assy A
* ASTM A516 Gr 60
** ASTM A516 GR 60 (NORMALIZED)
Chicago Bridge & Iron Company
Dome Vert Reinf Layer
Assy A
853071

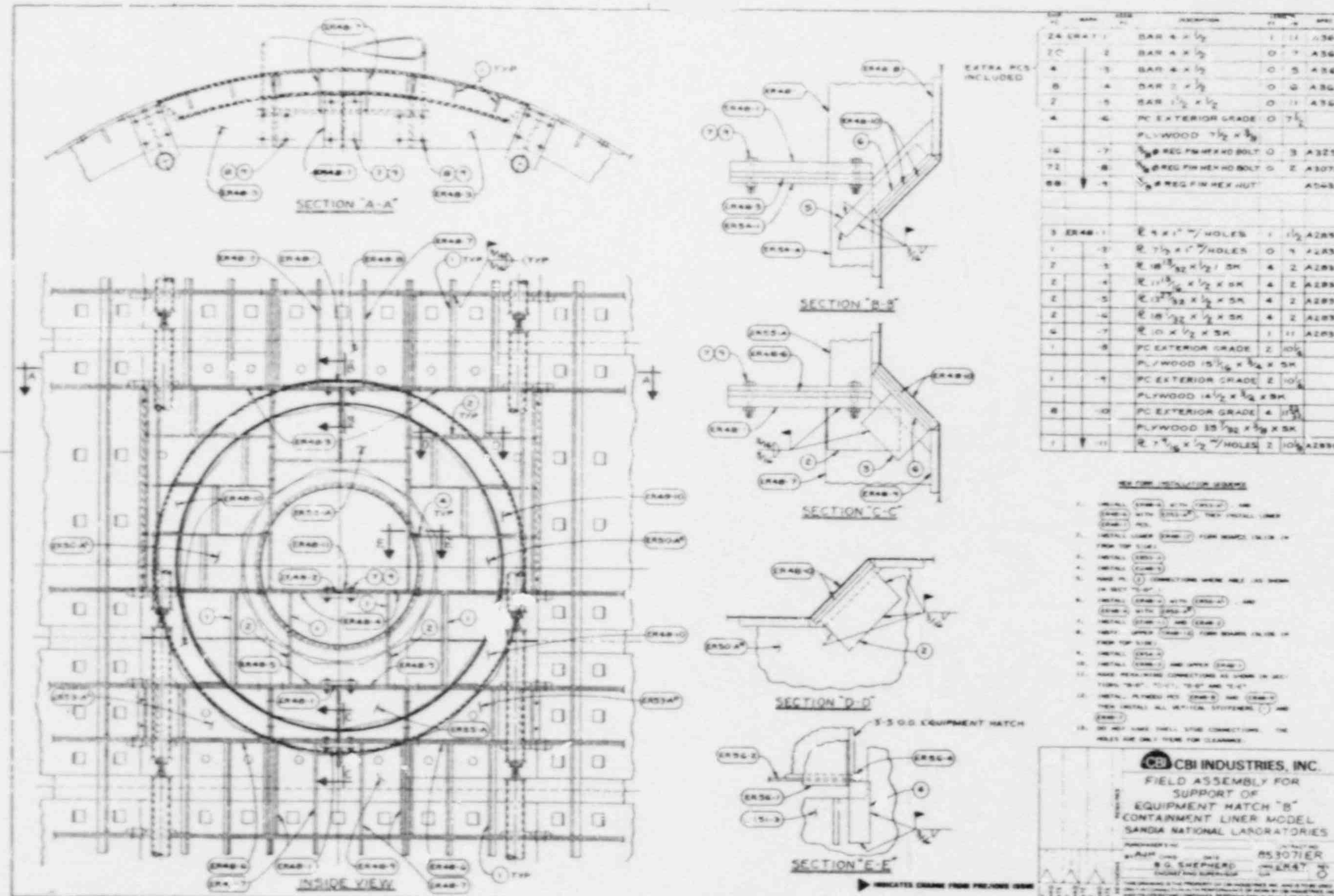

Chicago Bridge & Iron Company

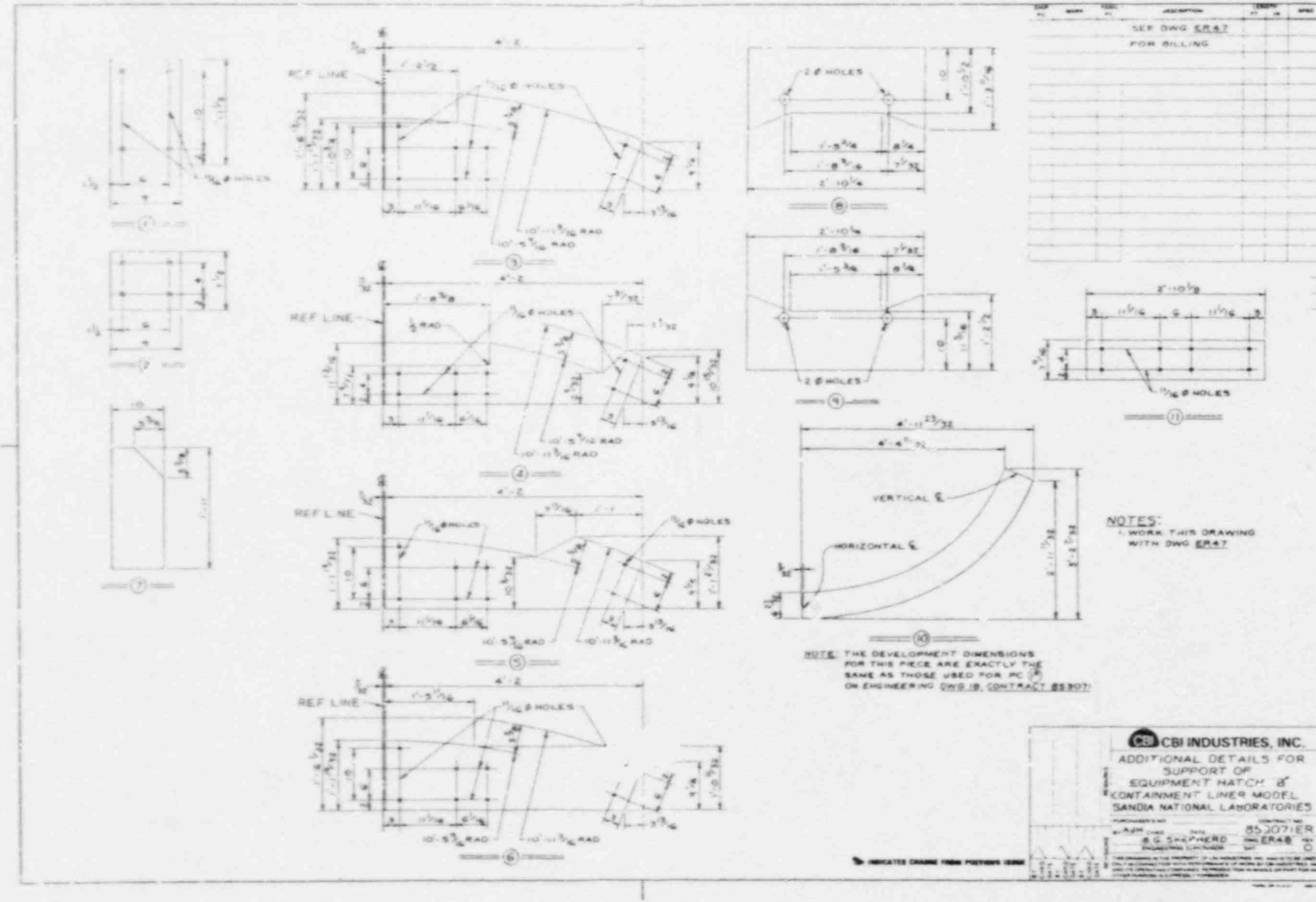


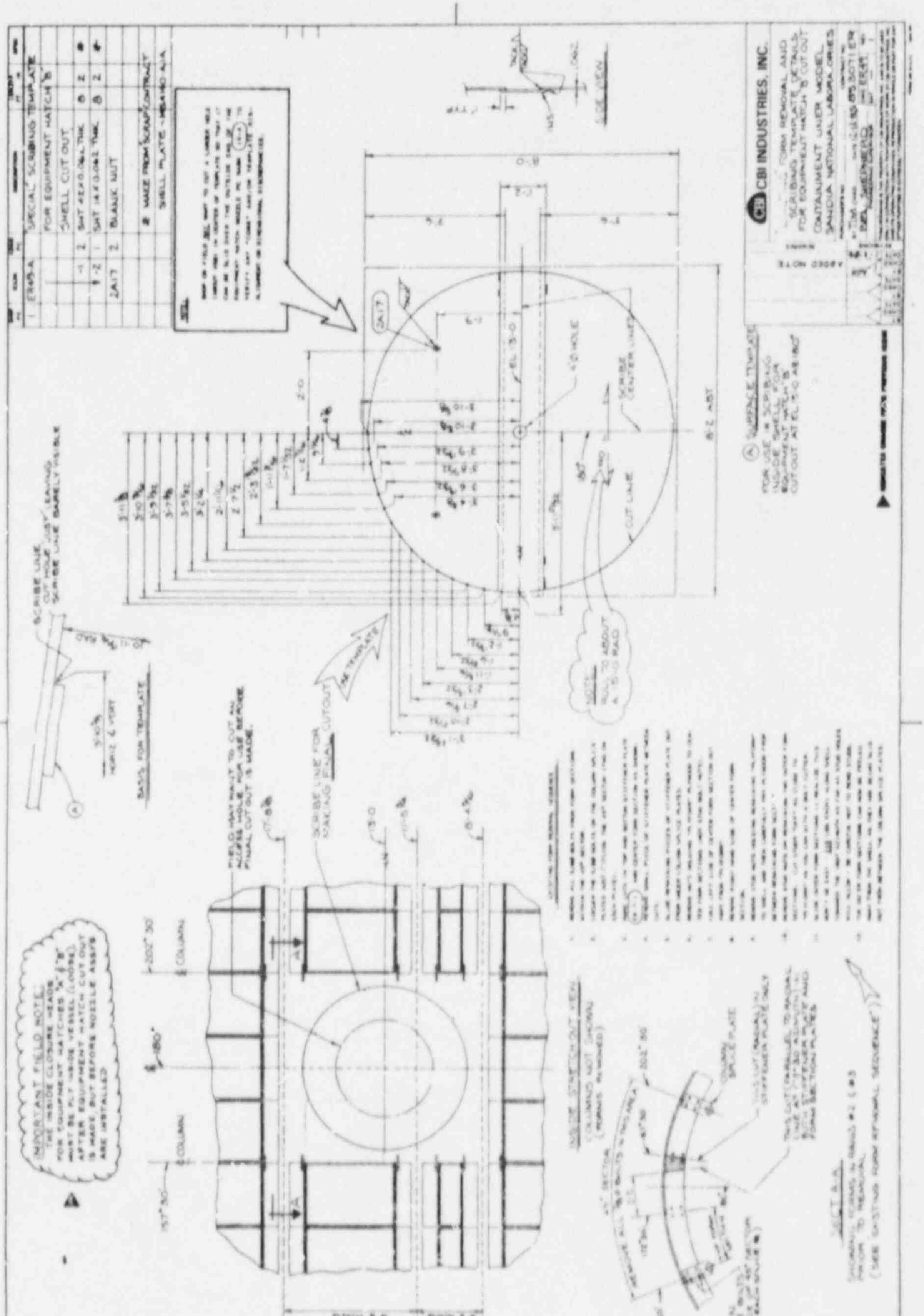


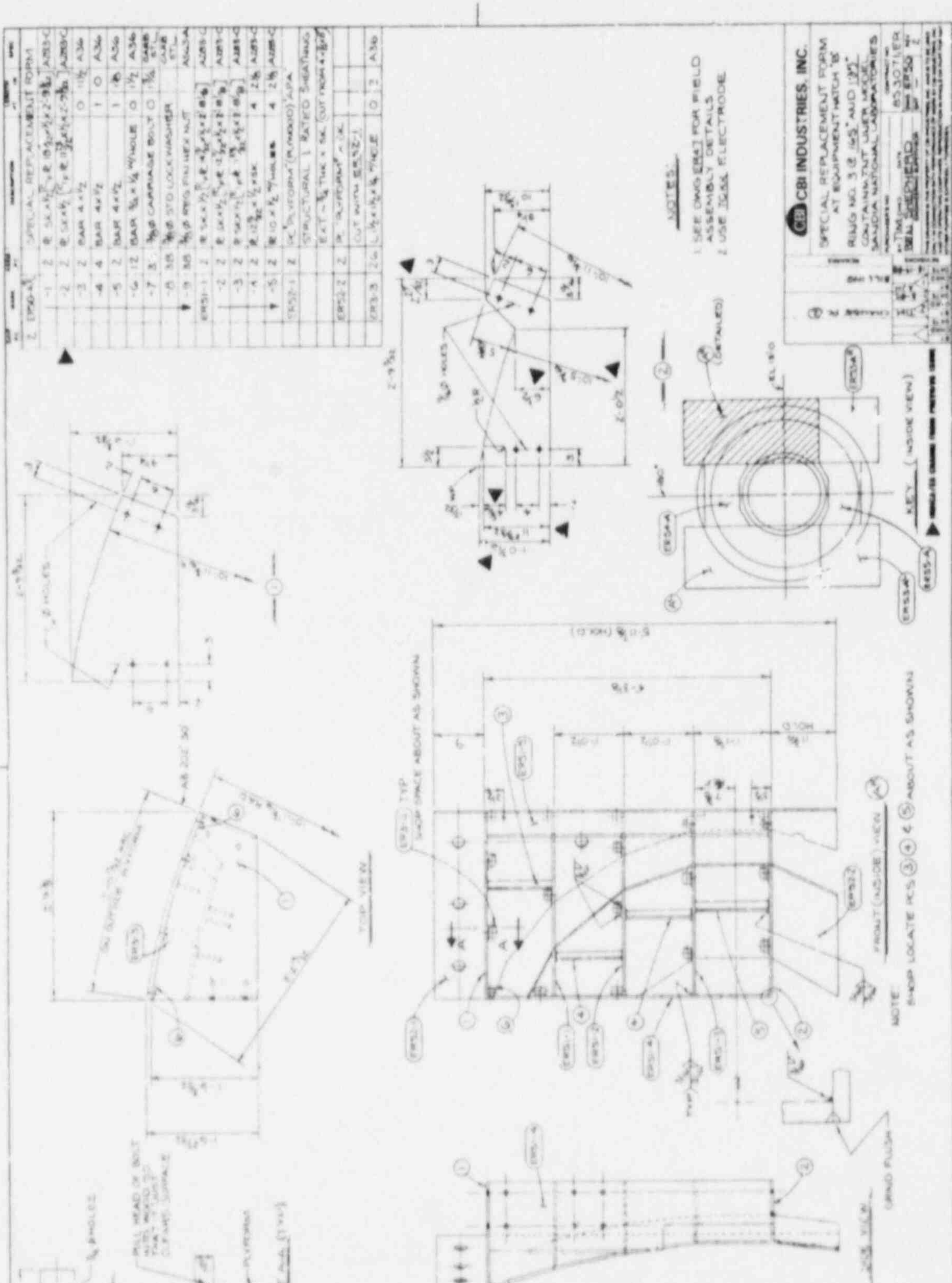
INSIDE STRETCH OUT VIEW - PRIOR TO CONCRETE
CBI INDUSTRIES, INC.
INSIDE STRETCH OUT
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
SECTION "A-A"

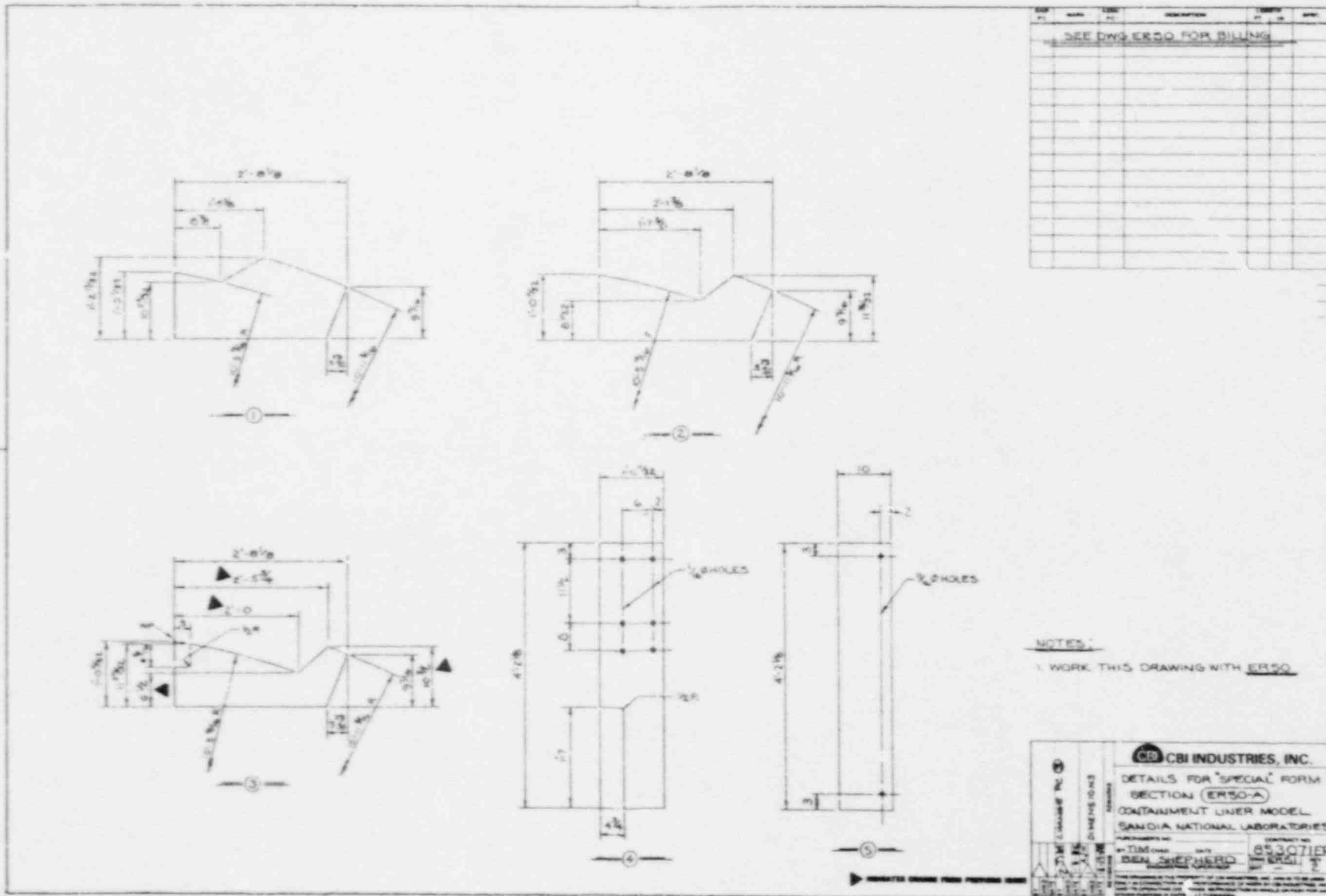

INSIDE STRETCH OUT VIEW
SEAM ELEV. 11'-8⅝
SEAM ELEV. 11'-5⅝
℄ EQUIPMENT HATCH "A" ELEV. 13'-0
ER1-6 (TYP-FIELD CUT ABT AS SHOWN AT NOZZLE)
ER7-2 (TYP)
ER4-A (TYP)
ER1-10 (TYP)
ER7-6 (TYP)
ER3-A (TYP)
5 (FIELD LOCATE ABT AS SHOWN)
ASSEMBLE ON DWGS ER11 & ER36
1 ER37-2 ℞ 5⅛ x 1' 7 HOLES 1 2⅞ A283C
2 -3 BAR 4 x ⅜ 2 0 A36
1 -4 PC "PLYFORM" (PLYWOOD)
4'-2 Ø x ½ THK "APA" STRUCTURAL
I RATED SHEATHING EXT
1 -5 PC "PLYFORM" (PLYWOOD)
5½ W x ½ THK x 2'-3 LG
"APA" STRUCT I RATED SHEATH EXT
2 ER37-1 ℞ 3/4 x ½ A283C
CHD=4'-0⅛ VERS=2¼
ARC ON OUTS EDGE PRIOR TO CUT (10'-11⅜ R)
11/16 Ø HOLES (TYP)
NOTE: NONE OF THE SETS OF HOLES ARE ON RADIAL LINES
WP
CHD=2'-7⅝ VERS=1⅜
CHD=1'-1⅛ VERS=3/16
CHD=3'-8 13/32 VERS=2 3/16
1
11/16 Ø HOLES
1'-2 11/16
2
NOTES:
1. WORK THIS DRAWING WITH DWGS ER1, ER11 & ER36
CBI INDUSTRIES, INC.
SPECIAL CONCRETE FORM DETAILS FOR EQUIPMENT HATCH "A" RING NO.3 @ AZ. C°
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
85307IER
BEN SHEPHERD
ER37
INDICATES CHANGE FROM PREVIOUS ISSUE


SECTION "A-A"
INSIDE VIEW
SECTION "B-B"
SECTION "C-C"
SECTION "D-D"
SECTION "E-E"
EXTRA PCS INCLUDED
3'-5" O.D. EQUIPMENT HATCH
CBI INDUSTRIES, INC.
FIELD ASSEMBLY FOR
SUPPORT OF
EQUIPMENT HATCH "B"
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
B.G. SHEPHERD
85307IER

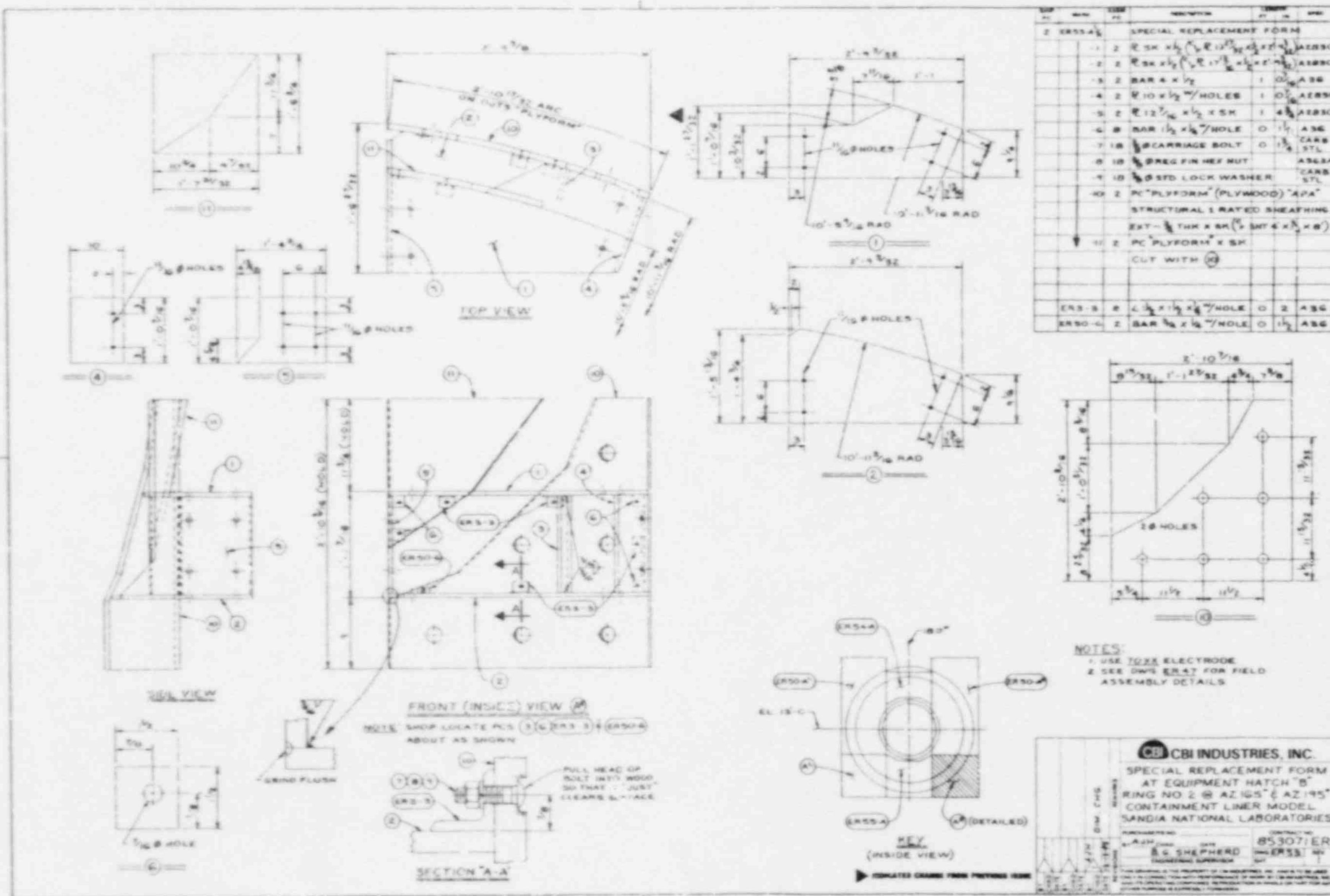

SEE DWG ER47
FOR BILLING
REF LINE
$^{11}/_{16}$ Ø HOLES
2 Ø HOLES
VERTICAL ℄
HORIZONTAL ℄
NOTES:
1. WORK THIS DRAWING WITH DWG ER47
NOTE: THE DEVELOPMENT DIMENSIONS FOR THIS PIECE ARE EXACTLY THE SAME AS THOSE USED FOR PC ⑧ ON ENGINEERING DWG 18, CONTRACT 85307!
CBI INDUSTRIES, INC.
ADDITIONAL DETAILS FOR SUPPORT OF EQUIPMENT HATCH & CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
85307IER
B.G. SHEPHERD
ER48
0

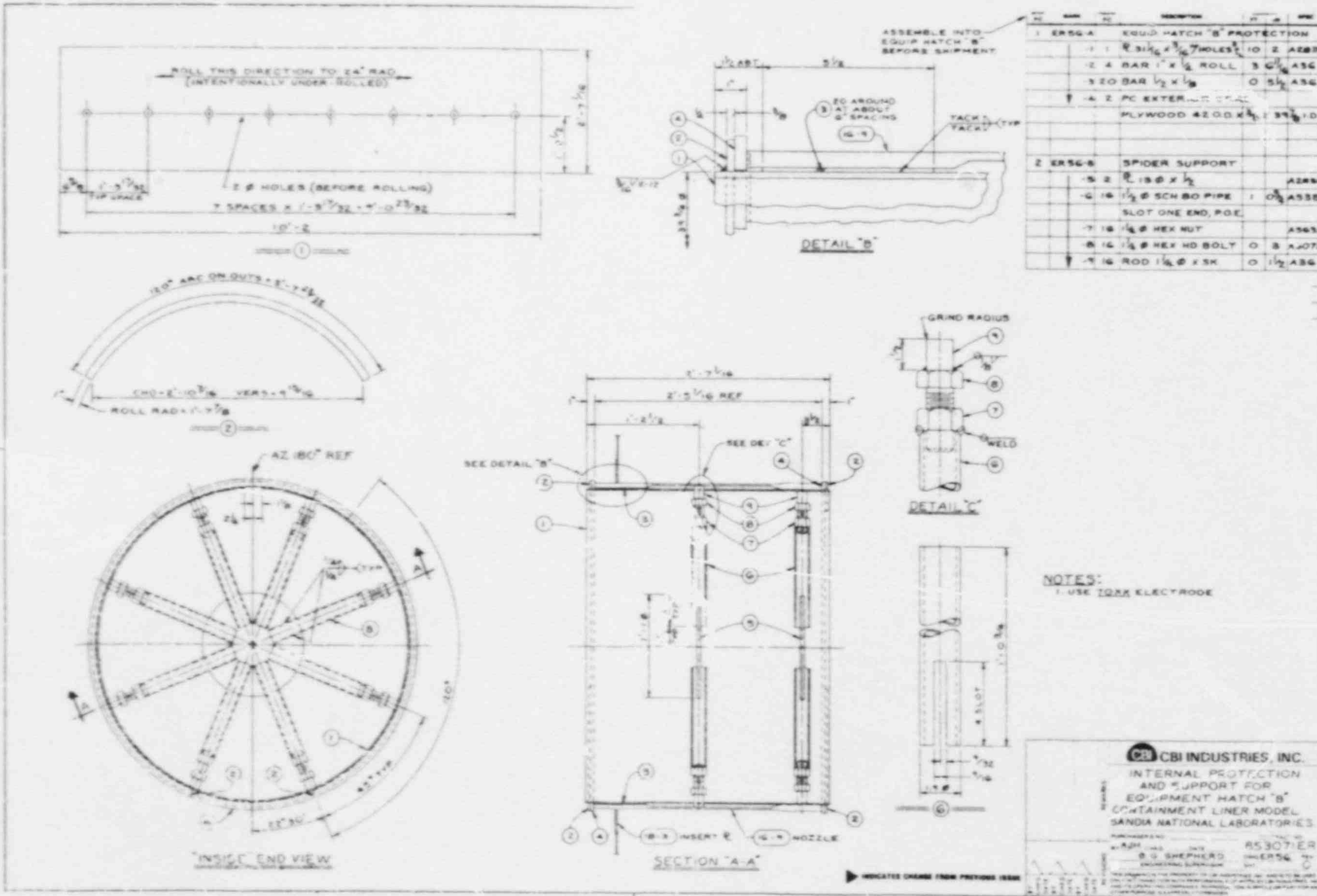

CBI INDUSTRIES, INC.
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES

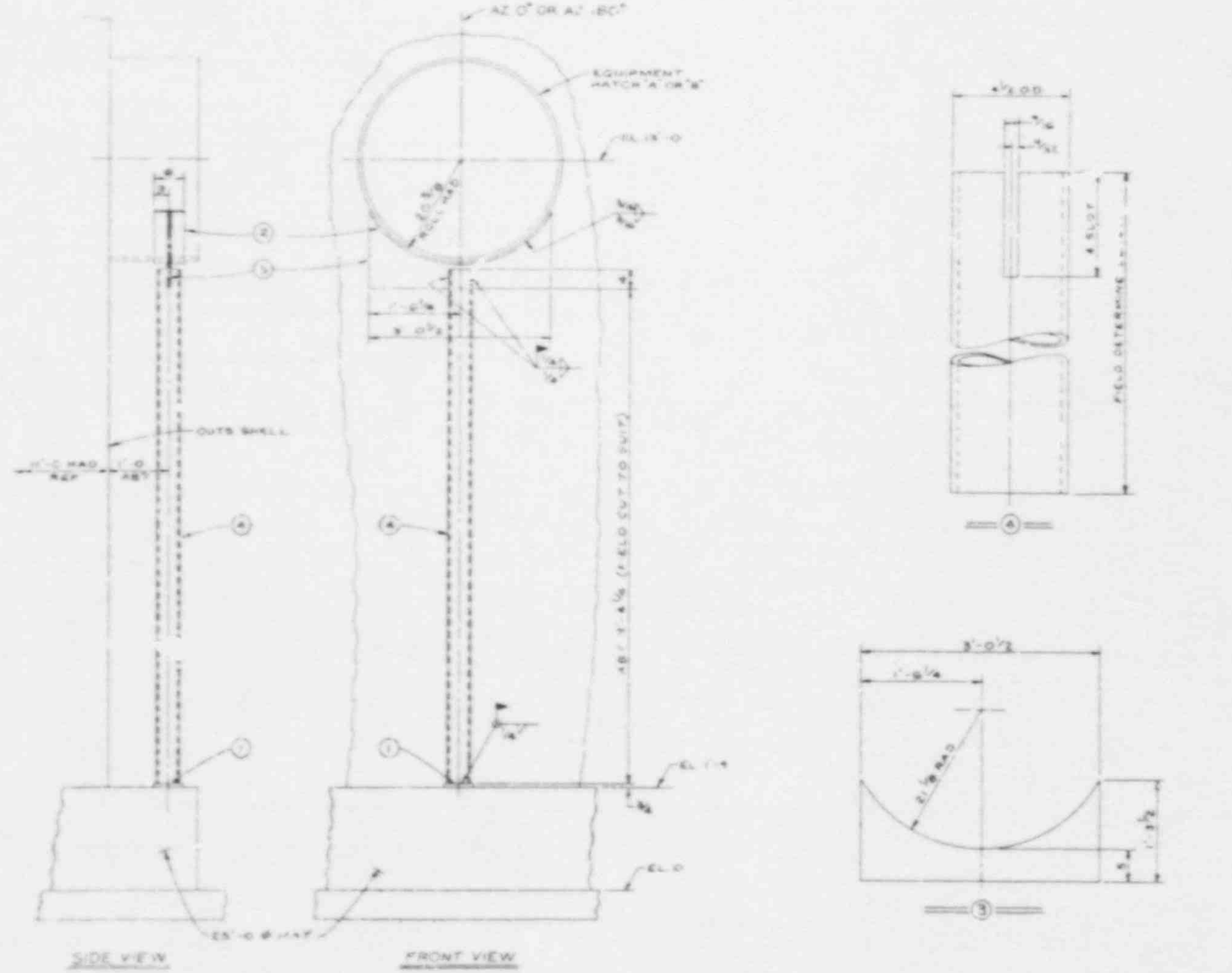

CBI INDUSTRIES, INC.
SPECIAL REPLACEMENT FORM AT EQUIPMENT HATCH
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
NOTES:
TOP VIEW
FRONT (INSIDE) VIEW
GRIND FLUSH
KEY (INSIDE VIEW)



SEE DWG ER50 FOR BILLING
2'-8 1/8
NOTES:
1. WORK THIS DRAWING WITH ER50
CBI INDUSTRIES, INC.
DETAILS FOR "SPECIAL" FORM
SECTION (ER50-A)
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
TIM
BEN SHEPHERD
853071ER


SPECIAL REPLACEMENT FORM
TOP VIEW
FRONT (INSIDE) VIEW
NOTE: SHOP LOCATE PCS ③ ⑥ ER3-3 & ER50-6 ABOUT AS SHOWN
SIDE VIEW
SECTION "A-A"
PULL HEAD OF BOLT INTO WOOD SO THAT IT JUST CLEARS SURFACE
GRIND FLUSH
KEY (INSIDE VIEW)
(DETAILED)
EL 13'-0"
NOTES:
1. USE 70XX ELECTRODE
2. SEE DWG ER47 FOR FIELD ASSEMBLY DETAILS
CBI INDUSTRIES, INC.
SPECIAL REPLACEMENT FORM
AT EQUIPMENT HATCH "B"
RING NO 2 @ AZ 165° & AZ 195°
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
85307 ER
ER55
B.G. SHEPHERD


ROLL THIS DIRECTION TO 24" RAD (INTENTIONALLY UNDER-ROLLED)
2 Ø HOLES (BEFORE ROLLING)
7 SPACES
10'-2
ROLL RAD
"INSIDE" END VIEW
AZ 180° REF
SECTION "A-A"
SEE DETAIL "B"
SEE DET "C"
INSERT ℞
NOZZLE
DETAIL "B"
ASSEMBLE INTO EQUIP HATCH "B" BEFORE SHIPMENT
ZG AROUND AT ABOUT 6" SPACING
TACK
DETAIL "C"
GRIND RADIUS
WELD
SLOT
EQUIP HATCH "B" PROTECTION
BAR 1" x 1/2 ROLL
PLYWOOD
SPIDER SUPPORT
SCH 80 PIPE
SLOT ONE END, P.O.E.
HEX NUT
HEX HD BOLT
ROD
NOTES:
1-USE 70XX ELECTRODE
CBI INDUSTRIES, INC.
INTERNAL PROTECTION AND SUPPORT FOR EQUIPMENT HATCH "B" CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
B.G. SHEPHERD
85307 ER
ER56
INDICATES CHANGE FROM PREVIOUS ISSUE



4	ER58-1		℞ 6 ⌀ × ¾			A233C
2		-2	℞ 6 × ½	5	7⅜	A283C
			ROLL TO 20⅝ RAD			
2		-3	℞ 15½ × ½ × 0K	3	0½	A283C
2		-4	4⌀ SCH 40 PIPE	10	0	A53B
			SLOT ONE END, P.O.E.			

NOTES:
1. USE 70XX ELECTRODE

CBI INDUSTRIES, INC.

TEMPORARY EXTERNAL SUPPORT FOR EQUIPMENT HATCHES "A" & "B"
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES

CONTRACT NO. 853071ER
B.G. SHEPHERD
ENGINEERING SUPERVISOR
DWG ER58 REV 0

▶ INDICATES CHANGE FROM PREVIOUS ISSUE

CBI SUMMARY SHEET

ERECTION DRAWINGS (ER) FOR CONTAINMENT LINER MODEL "UNITED ENGINEERS" LOCATION SANDIA NATIONAL LABORATORIES	# O-SHEET FOR CONST. SERVICES DEPT. ERECTION DRAWINGS	LIST OF BILLS AND MISC. FINAL BILL: 0 - 0-1 ER 1 THRU ER 33 W SHTS ____ STDS ____

DRAWINGS COMPLETE ☐ YES ☒ NO

FINAL BILLS COMPLETE ☐ YES ☒ NO

REMARKS:

LIST OF CONTRACT AND STANDARD DRAWINGS

BILLS	DWG OR STD	REV	DESCRIPTION	BILLS	DWG OR STD	REV	DESCRIPTION
ER16	ER 19	1	ROOF FORMS END SECT 2ND COURSE		ER 1	2	WALL FORMING CONCEPT
ER20 ER21	ER 20	3	ROOF DOLLAR PL FORM	—	ER 2	0	INSIDE STRETCH OUT
ER16 25,26	ER 21	3	1ST COURSE, COLUMN CLIPS & MISC. PL'S	ER1 ER4 ER5	ER 3	2	CONC FORM SECT
ER13	ER 22	1	ROOF SHIPPING ASSM	ER10	ER 4	2	CONC FORM SECT
ER17	ER 23	1	DETAILS FOR ROOF NORF SECT	ER1 ER4 ER5	ER 5	3	CONC FORM SECT
ER 22,19	ER 24	2	CENTER COLUMN SUPT	ER11	ER 6	3	CONC FORM SECT
ER 23	ER 25	2	CENTER COLUMN SUPT DETAILS	ER2,5 6,11	ER 7	2	CIRC STIFF DETAILS
	ER 26	1	MISC. DETAILS	ER2, 5,6,11	ER 8	3	COLUMN DETAILS
	ER 27	0	VOID	ER8 ER10	ER 9	3	COLUMN DETAILS
	ER 28	1	CONC. FORM SECT.	ER3	ER 10	3	SHELL AND CONC FORM SHIPPING ASSY
ER31	ER 29	0	FIELD REINF FOR NOZZ "P"	ER6	ER 11	2	SHELL AND CONC FORM SHIPPING ASSY
	ER 30	1	SPECIAL DETAILS FOR FORMS	ER9	ER 12	2	SHELL AND CONC FORM SHIPPING ASSY
	ER 31	1	CONC. FORM SECT.	ER12	ER 13	2	SHELL AND CONC FORM SHIPPING ASSY
	ER 32	1	SHELL & CONC. FORM SHIPPING ASSY				
	ER 33	1	SHELL & CONC. FORM SHIPPING ASSY	ER32	ER 15	3	ROOF ERECTION SCHEME
	ER 34	1	SPECIAL CONC. FORM RING # 3 90° & 270°	ER13	ER 16	1	ROOF FORMING MAIN SECT 1ST COURSE
	ER 35	1	SHELL & CONC FORM SHIPPING ASSY	ER14	ER 17	1	ROOF FORMING MAIN SECT 2ND COURSE
	ER 36	1	SHELL & CONC FORM SHIPPING ASSY	ER15	ER 18	1	ROOF FORMING END SECT 1ST COURSE
	ER 37	1	SPECIAL FORM SECT. RING NO. 3 @ 0°	← CONT ABOVE LEFT			

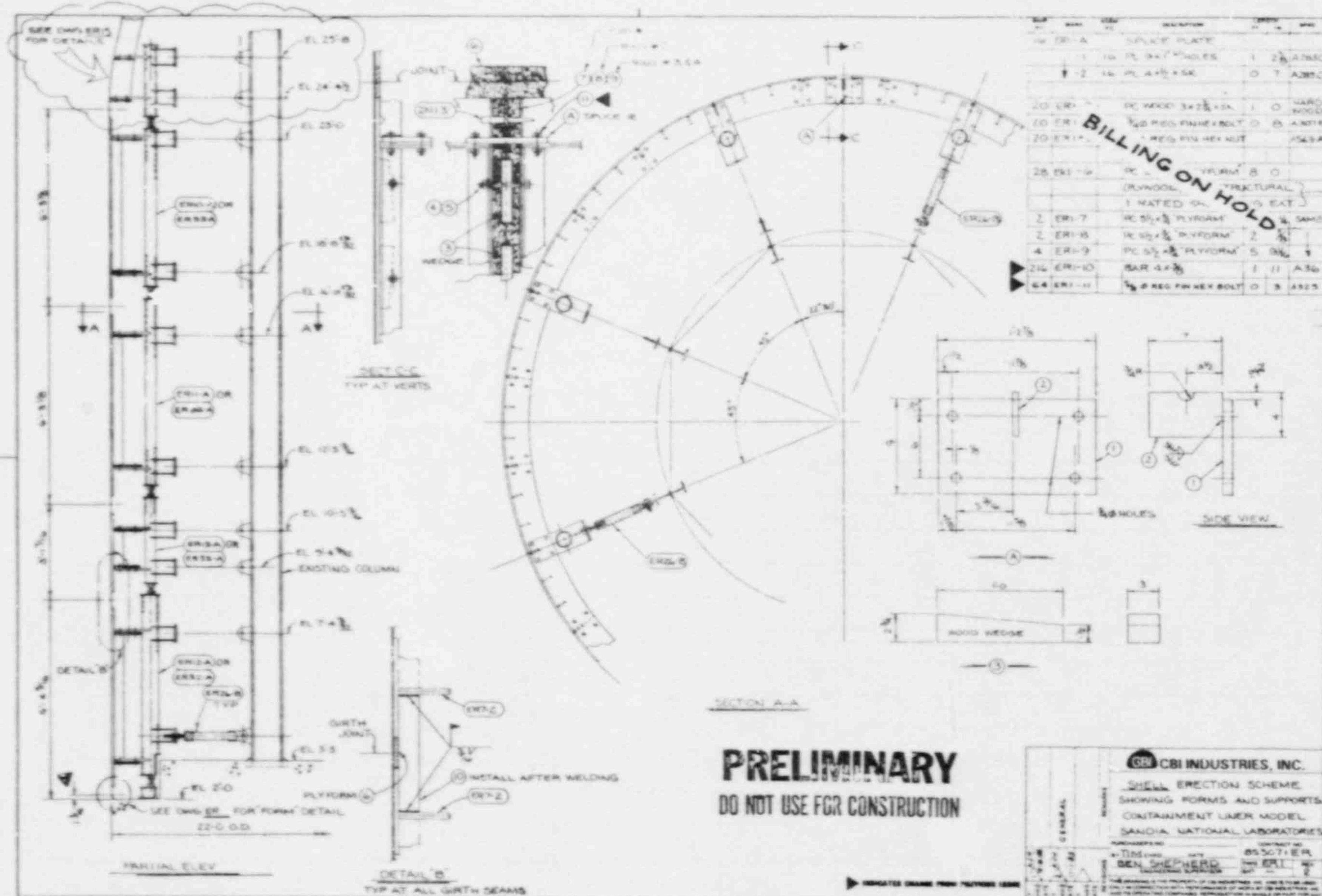
REV	10	11	9	ENG ASSIGNED	MFG ASSIGNED	CONSTR ASSIGNED	MADE BY	CHKD BY	ENG COORDINATOR	CONTRACT NO.	SHEET
NO. / CHKD	TIM ✓	TIM ✓	TIM ✓	CHG	CCC	HOUSTON	TWI		BEN Shepherd	853071 ER	0
DATE	12-10-85	12-12-85	12-9-85				DATE	DATE			

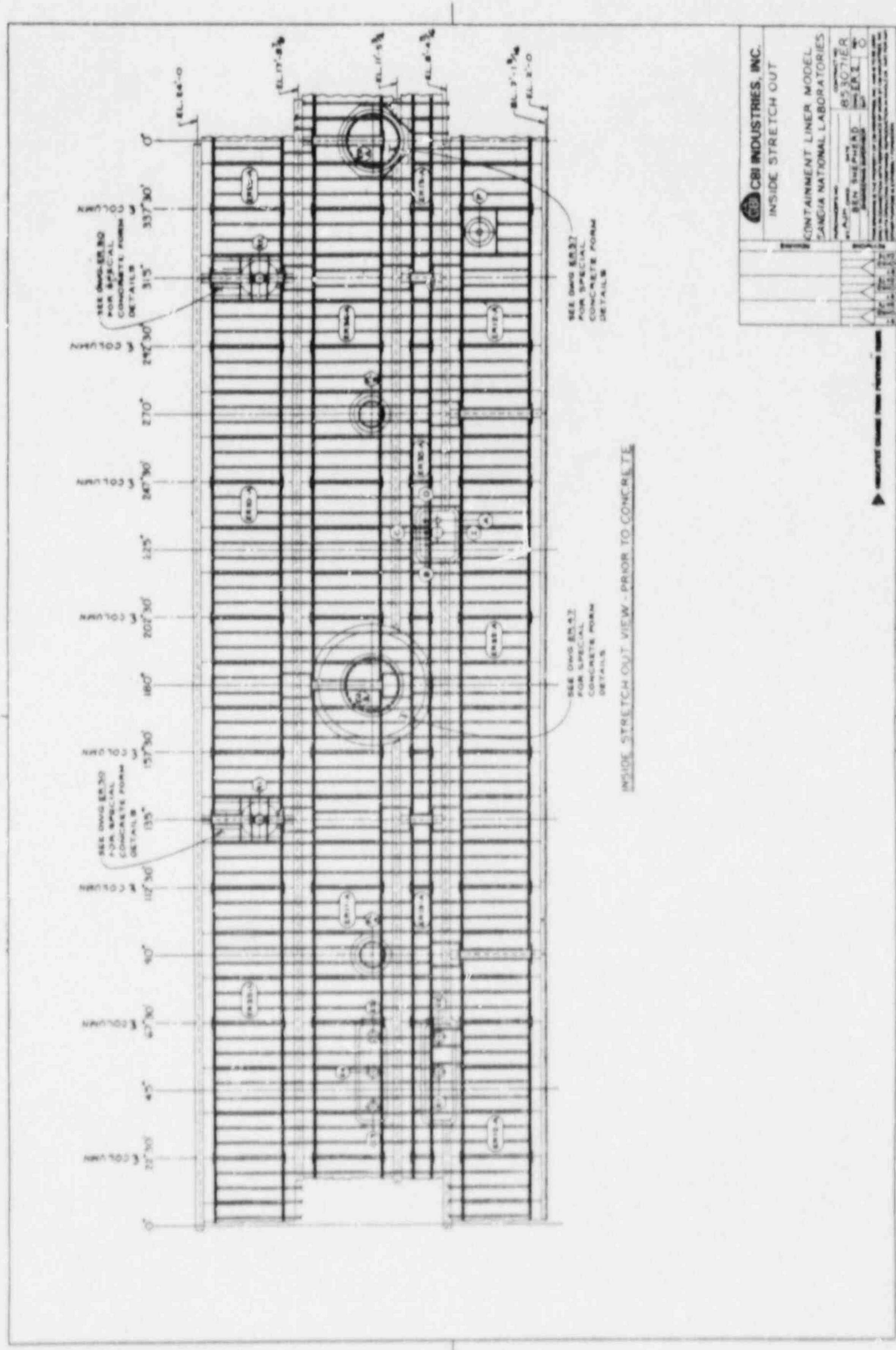
DE 13 (PAGE 2) REV 1-73

CBI LIST OF DRAWINGS AND BILLS

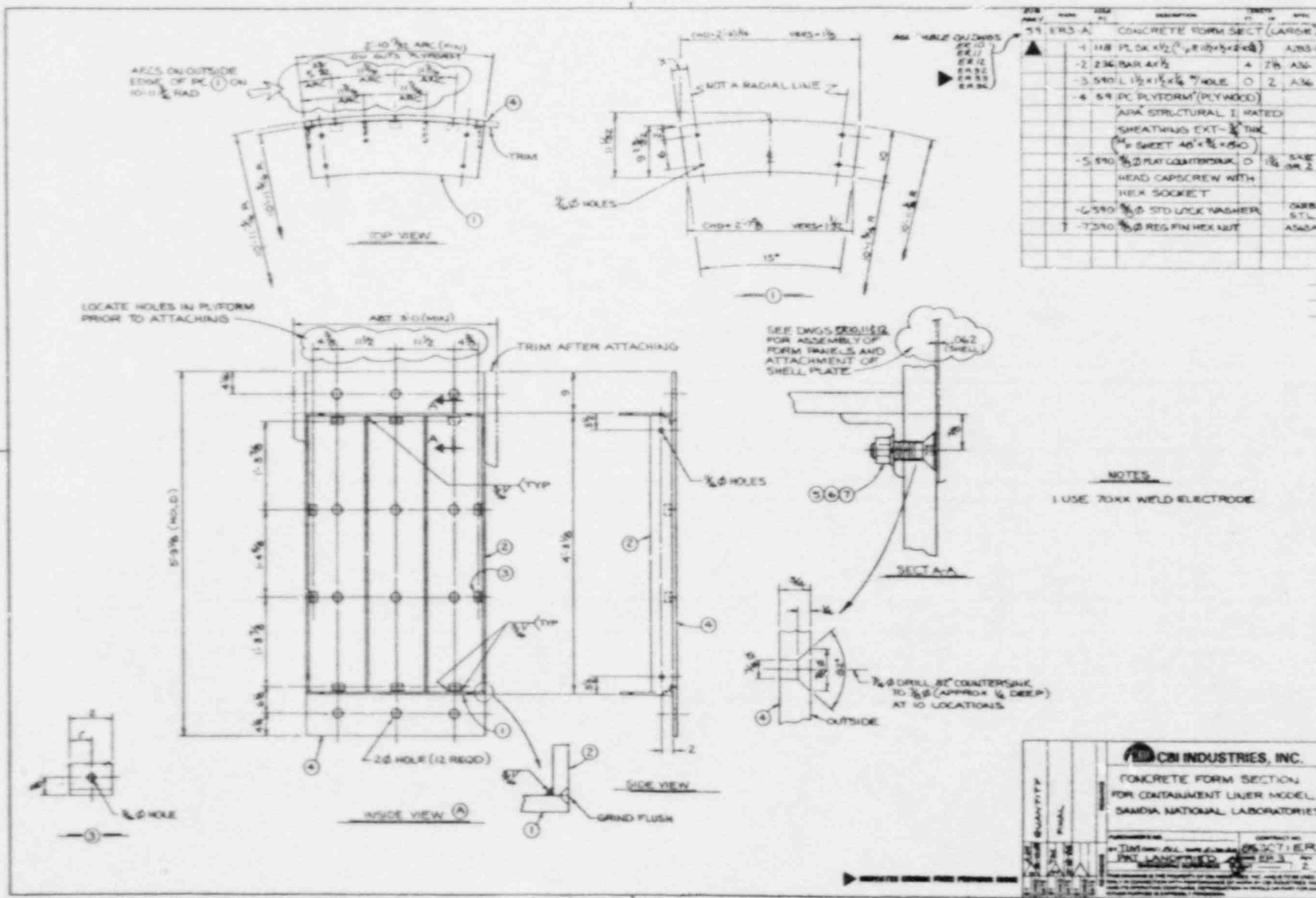
BILLS	DWG OR STD	REV	DESCRIPTION	BILLS	DWG OR STD	REV	DESCRIPTION
	ER38	1	CONC FORM SECT RING NO 3 @ 60°				
	ER39	1	CONC FORM SECT RING NO 3 @ 45°				
	ER40	1	CONC FORM SECT RING NO 3 @ 30°				
	ER41	1	CONC FORM SECT RING NO 3 @ 15° & 345°				
	ER42	1	CONC FORM SECT SPECIAL END				
	ER43	1	CONC. FORM SECT.				
	ER44	1	CONC. FORM SECT				
	ER45	1	CONC. FORM SECT				
	ER46		CONC FORM SECT				
ER28	ER50	0	SPECIAL REPLACEMENT FORM RING #3 165° & 195°				
ER28	ER51	0	" " " DETAILS				
ER28 & ER29	ER52	0	" " " "				
ER27	ER53	0	" " RING # 2 165° & 195° FORM				
ER29	ER54	0	" " FORM RING # 3 180°				
ER30	ER55	1	" " FORM RING #2 180°				
	ER60	0	TOP HEAD LIFT				
ER24	ER61	1	ROOF LIFT LUG AND SET UP DIMENSIONS				

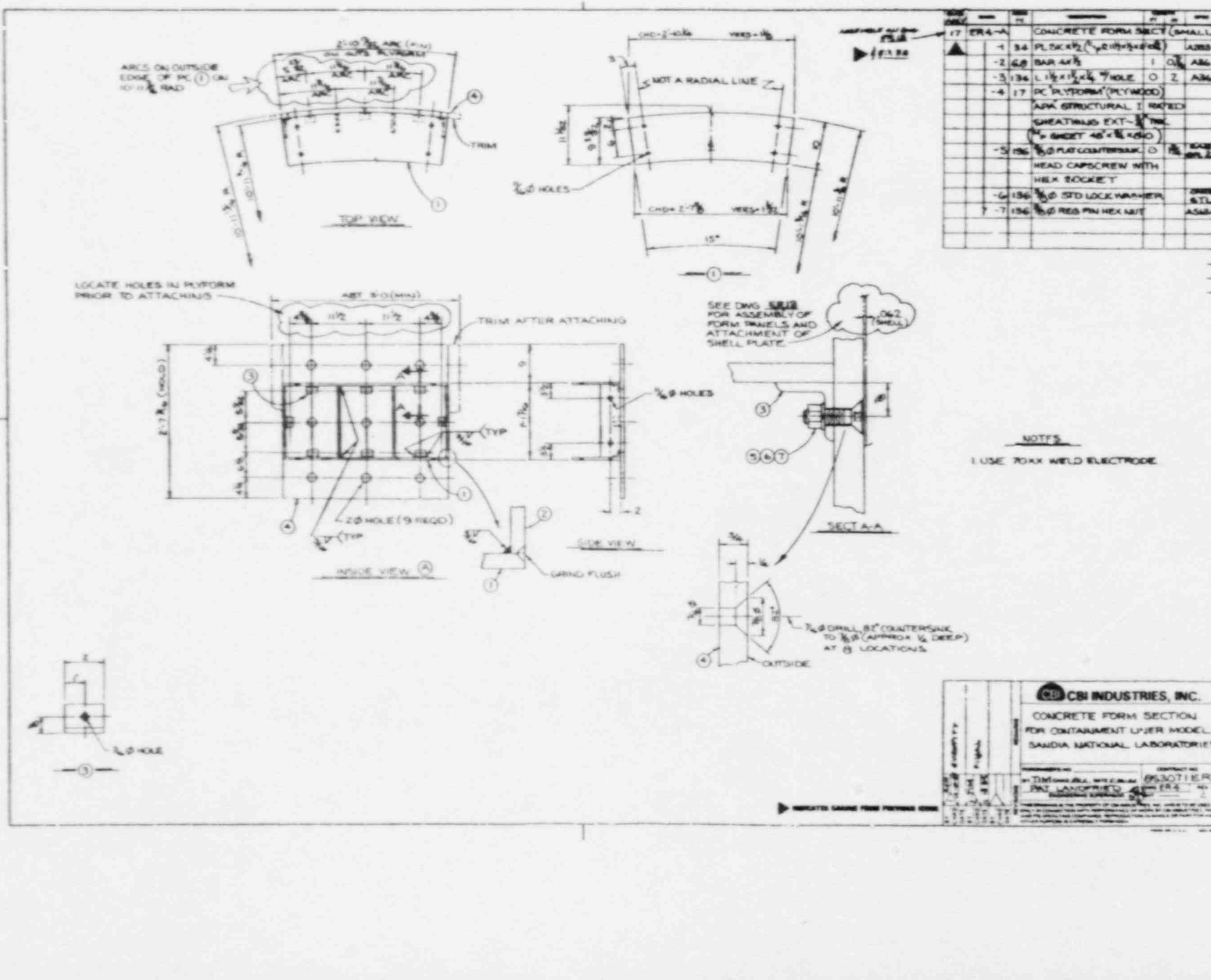
REV	5	6	3	4		ENG ASSIGNED	MADE BY	DATE	CHKD BY	DATE	CONTRACT NO.	SHEET
BY	TIM	TIM	TIM	TIM		CHG	AJH	10/10/85			85307IER	O-1
CHKD	✓											
DATE	12-6-85	12-9-85	11-18-85	11-22-85								


SEE DWG ER15 FOR DETAILS
PARTIAL ELEV
SECT C-C
TYP AT VERTS
DETAIL "B"
TYP AT ALL GIRTH SEAMS
GIRTH JOINT
PLYFORM
INSTALL AFTER WELDING
EXISTING COLUMN
22-0 O.D.
SECTION A-A
SIDE VIEW
WOOD WEDGE
BILLING ON HOLD
PRELIMINARY
DO NOT USE FOR CONSTRUCTION
CBI INDUSTRIES, INC.
SHELL ERECTION SCHEME
SHOWING FORMS AND SUPPORTS
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
BEN SHEPHERD

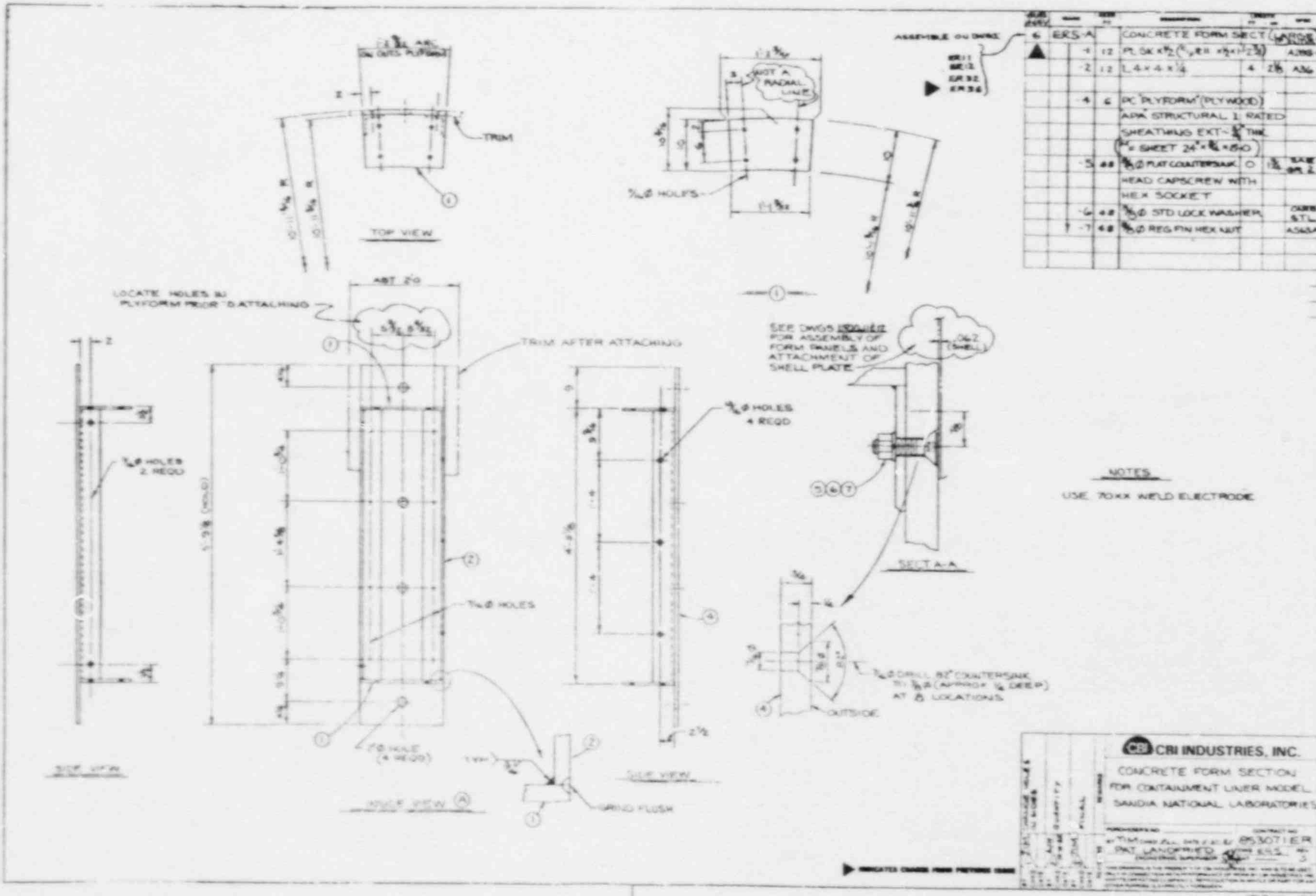


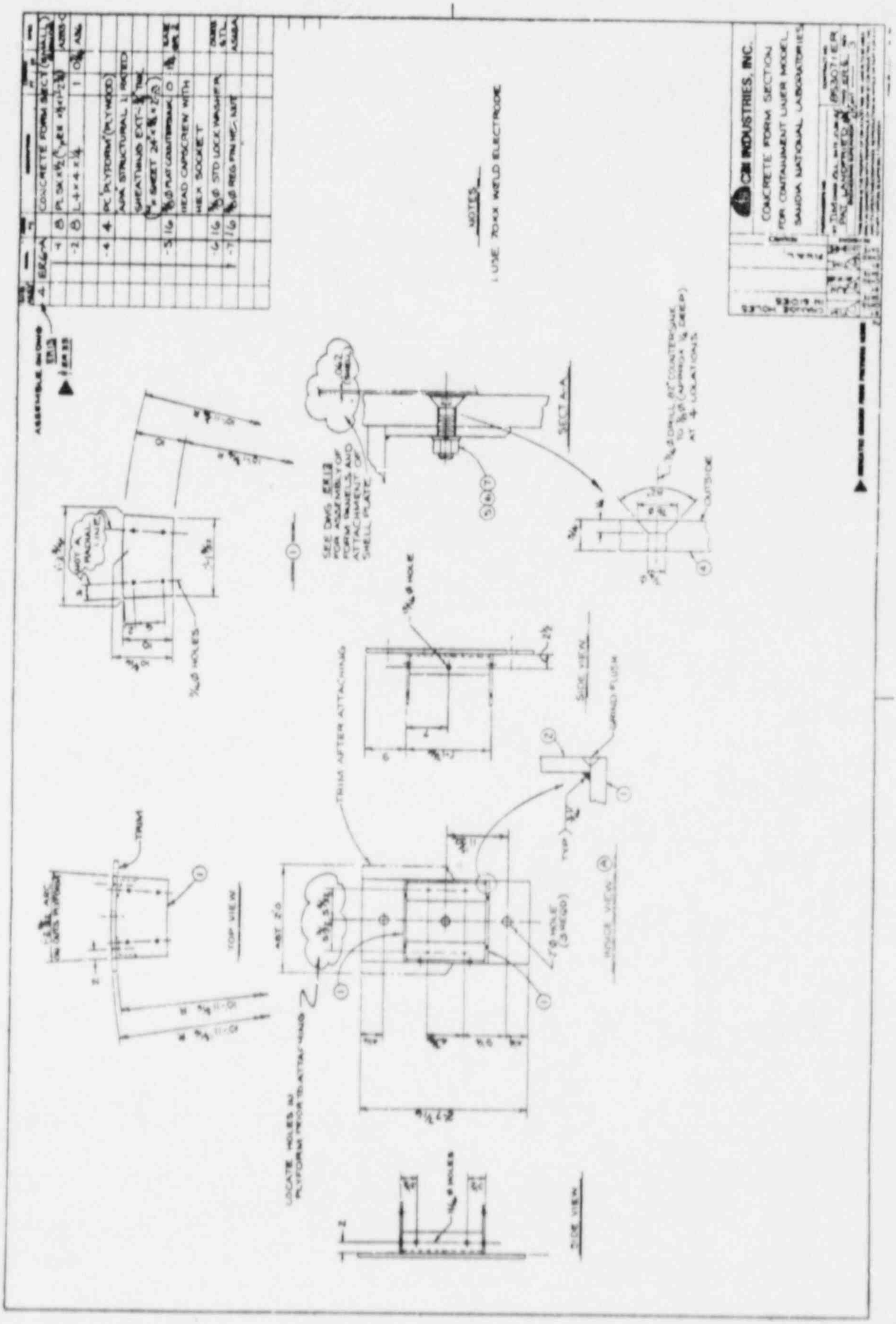
CBI INDUSTRIES, INC.
INSIDE STRETCH OUT
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
BEN SHEPHERD
85307IER
ER1
0
INSIDE STRETCH OUT VIEW - PRIOR TO CONCRETE
SEE DWG ER30 FOR SPECIAL CONCRETE FORM DETAILS
SEE DWG ER37 FOR SPECIAL CONCRETE FORM DETAILS
SEE DWG ER47 FOR SPECIAL CONCRETE FORM DETAILS
EL 24'-0
EL 2'-0
0°
22°30'
45°
67°30'
90°
112°30'
135°
157°30'
180°
202°30'
225°
247°30'
270°
292°30'
315°
337°30'
360°
℄ COLUMN

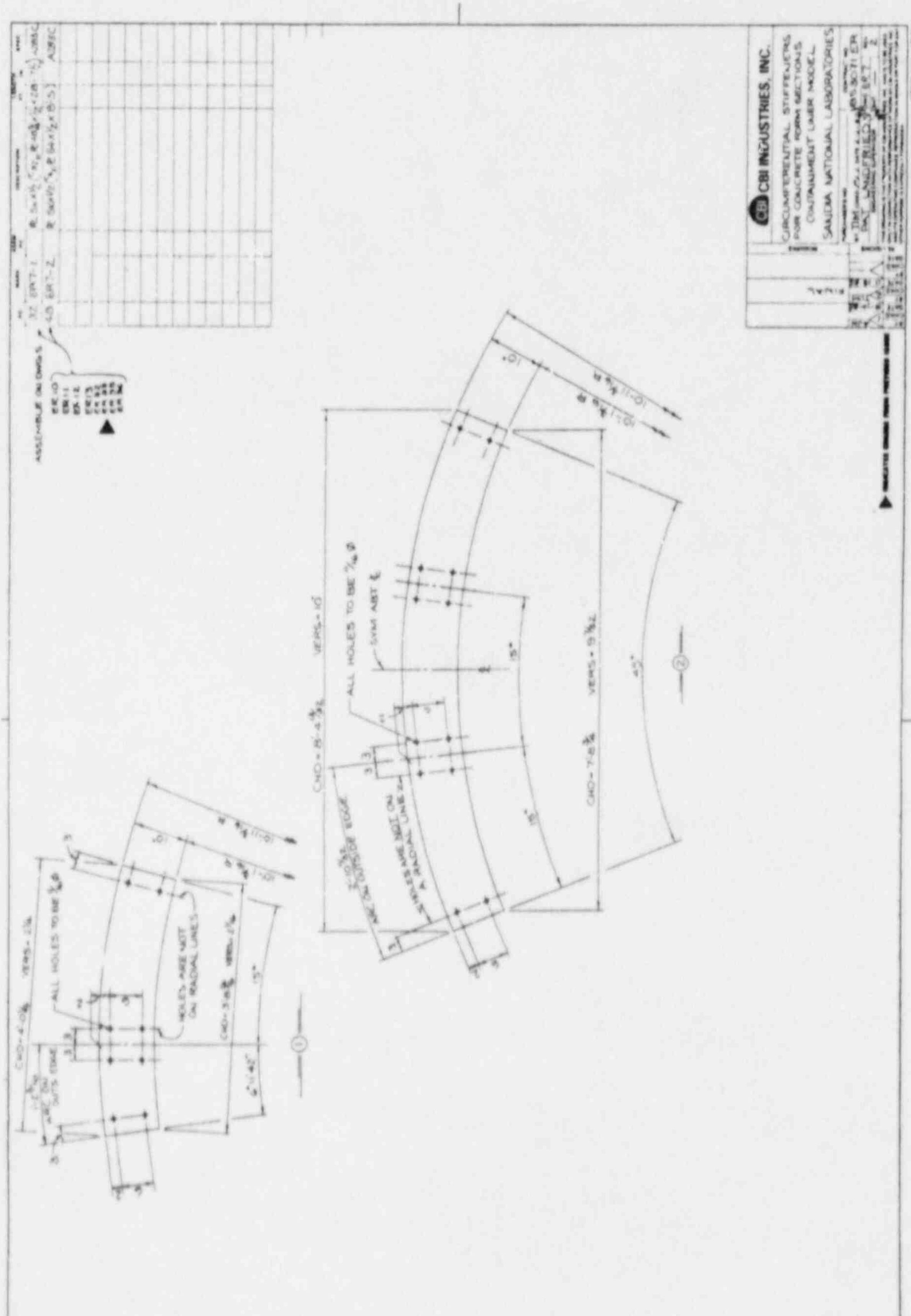

ARCS ON OUTSIDE EDGE OF PC (1) ON
TRIM
TOP VIEW
NOT A RADIAL LINE
HOLES
15"
LOCATE HOLES IN PLYFORM PRIOR TO ATTACHING
TRIM AFTER ATTACHING
5'-9 (HOLD)
TYP
HOLES
2Ø HOLE (12 REQD)
INSIDE VIEW (A)
SIDE VIEW
GRIND FLUSH
HOLE
SEE DWGS FOR ASSEMBLY OF FORM PANELS AND ATTACHMENT OF SHELL PLATE
.062 (SHELL)
SECT A-A
82° COUNTERSINK AT 10 LOCATIONS
OUTSIDE
NOTES
1. USE 70XX WELD ELECTRODE
CONCRETE FORM SECT (LARGE)
PL
BAR
PC PLYFORM (PLYWOOD)
APA STRUCTURAL I RATED
SHEATHING EXT
SHEET
FLAT COUNTERSUNK
HEAD CAPSCREW WITH
HEX SOCKET
STD LOCK WASHER
REG FIN HEX NUT
A36
CBI INDUSTRIES, INC.
CONCRETE FORM SECTION
FOR CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
QUANTITY
FINAL

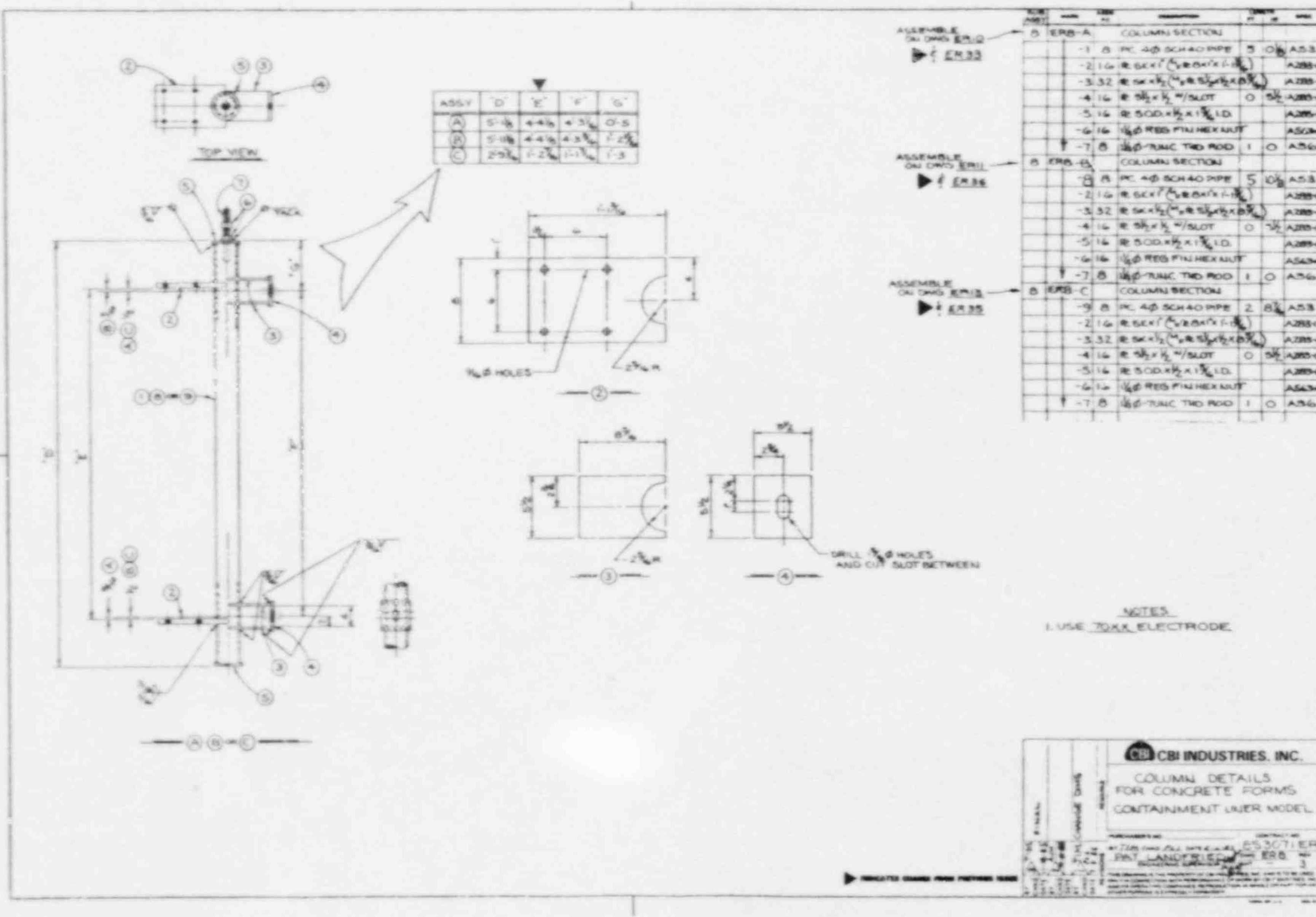


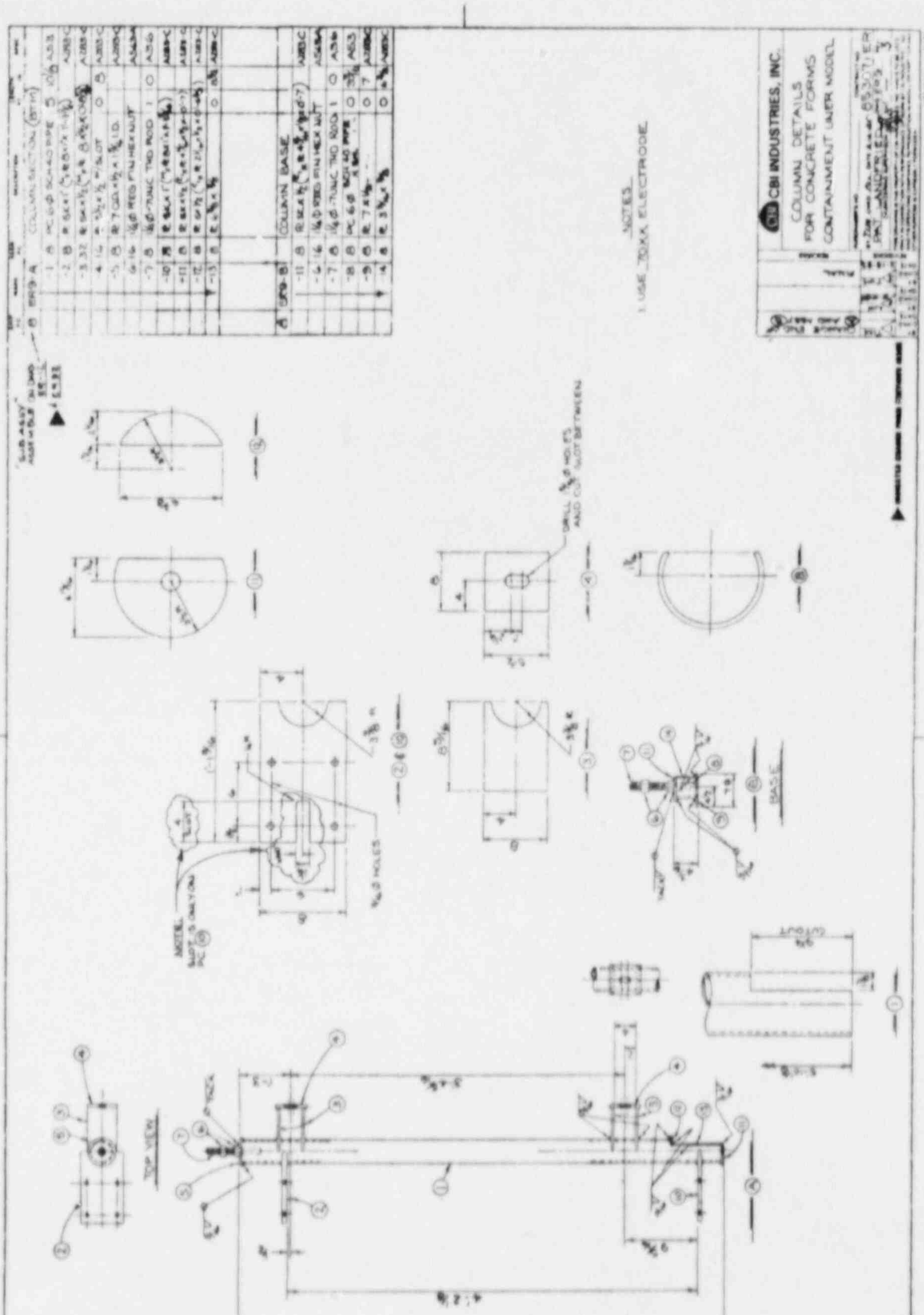
CBI INDUSTRIES, INC.
CONCRETE FORM SECTION
FOR CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
NOTES
1. USE 70XX WELD ELECTRODE
TOP VIEW
INSIDE VIEW A
SIDE VIEW
SECT A-A
ARCS ON OUTSIDE EDGE OF PC 1 ON 10'-11 RAD
NOT A RADIAL LINE
TRIM
LOCATE HOLES IN PLYFORM PRIOR TO ATTACHING
TRIM AFTER ATTACHING
2Ø HOLE (9 REQD)
GRIND FLUSH
SEE DWG FOR ASSEMBLY OF FORM PANELS AND ATTACHMENT OF SHELL PLATE
OUTSIDE
AT 8 LOCATIONS
CONCRETE FORM SECT (SMALL)
BAR
PC PLYFORM (PLYWOOD)
APA STRUCTURAL I RATED
HEAD CAPSCREW WITH
HEX SOCKET

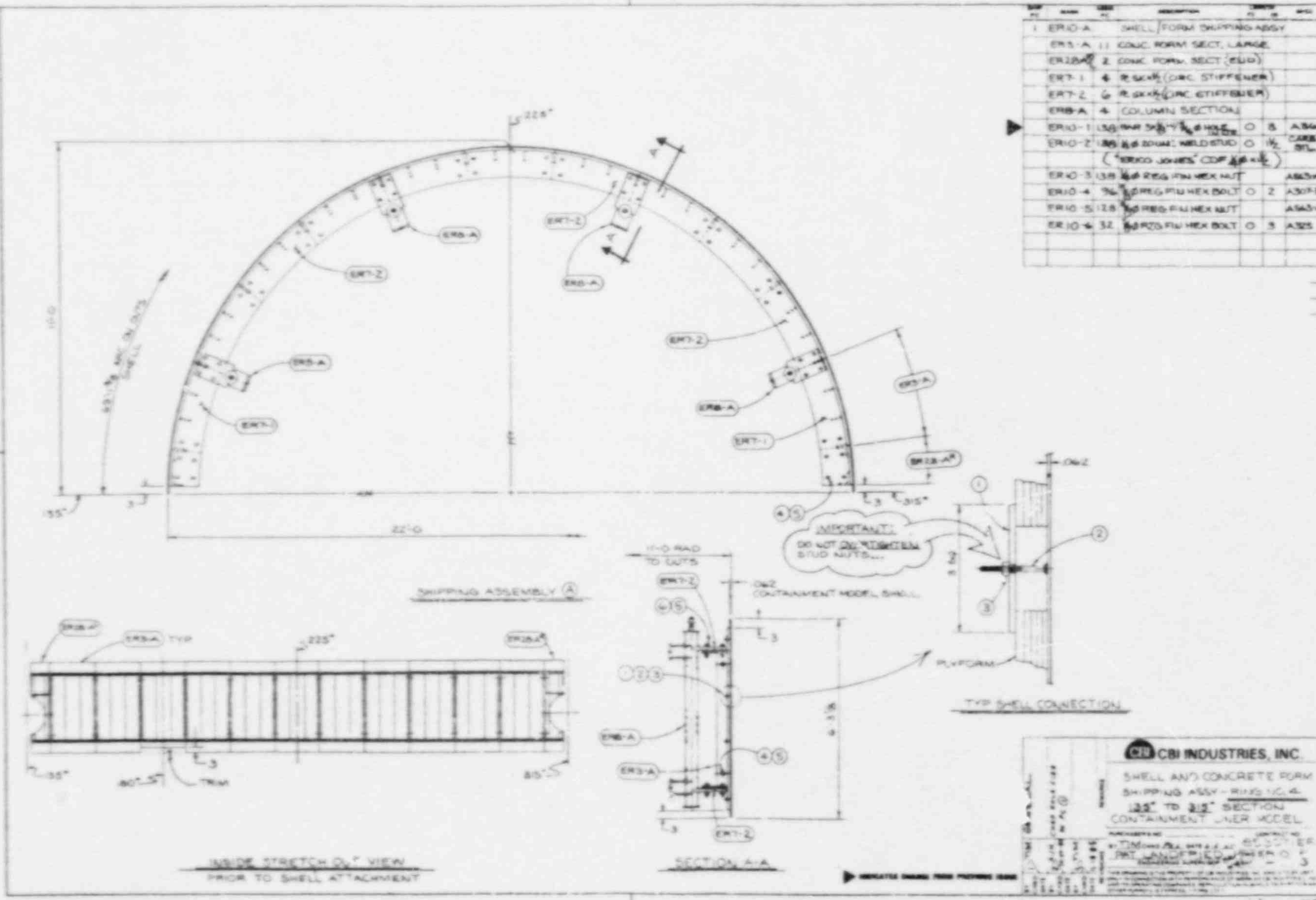

TOP VIEW
TRIM
NOT A RADIAL LINE
LOCATE HOLES IN PLYFORM PRIOR TO ATTACHING
TRIM AFTER ATTACHING
SEE DWGS FOR ASSEMBLY OF FORM PANELS AND ATTACHMENT OF SHELL PLATE
SIDE VIEW
SECT A-A
OUTSIDE
GRIND FLUSH
NOTES
USE 70XX WELD ELECTRODE
CONCRETE FORM SECT
HEAD CAPSCREW WITH
HEX SOCKET
CBI INDUSTRIES, INC.
CONCRETE FORM SECTION
FOR CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES

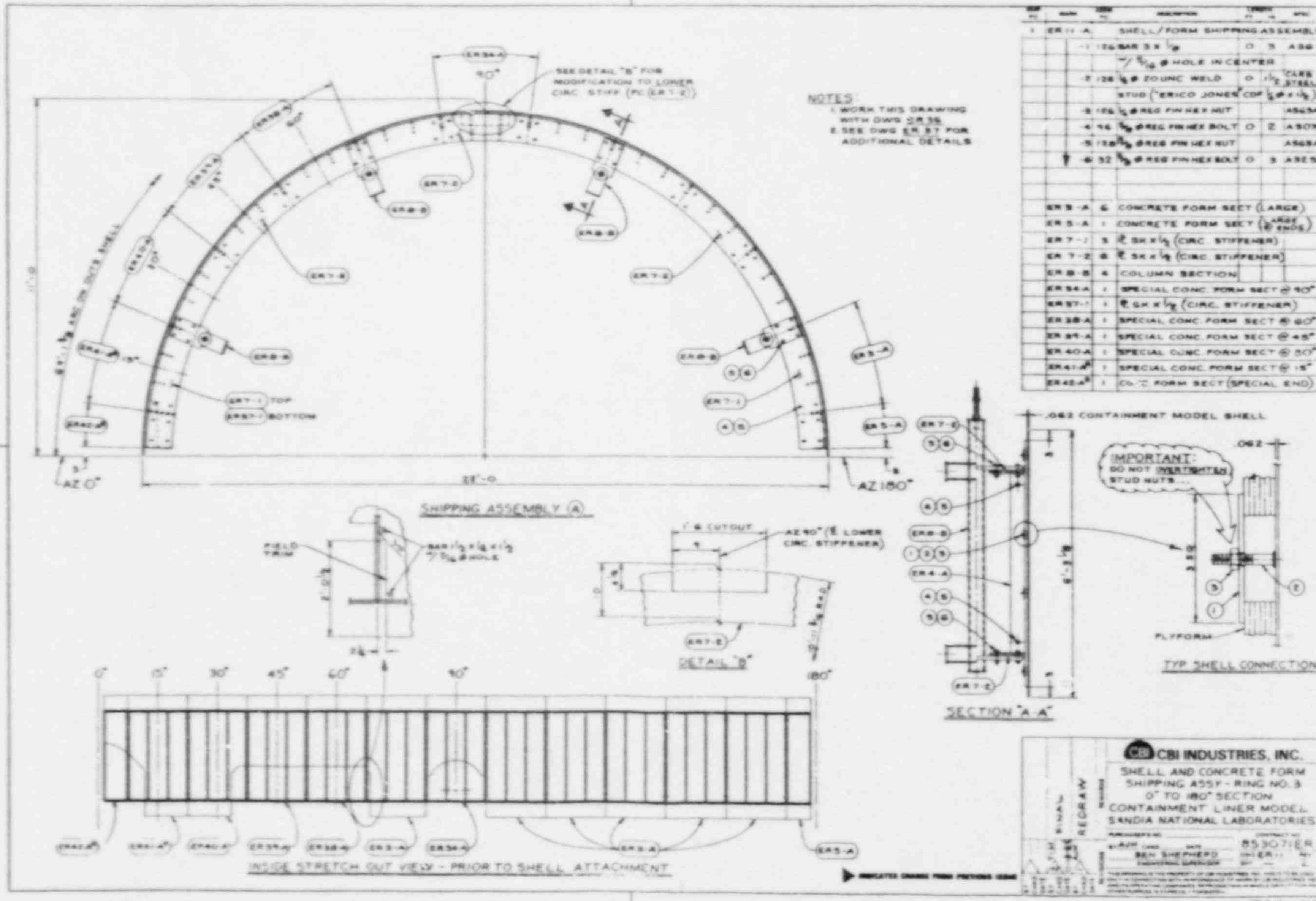

CBI INDUSTRIES, INC.
CONCRETE FORM SECTION
FOR CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
NOTES
1. USE 70XX WELD ELECTRODE
TOP VIEW
SIDE VIEW
INSIDE VIEW
SECT A-A

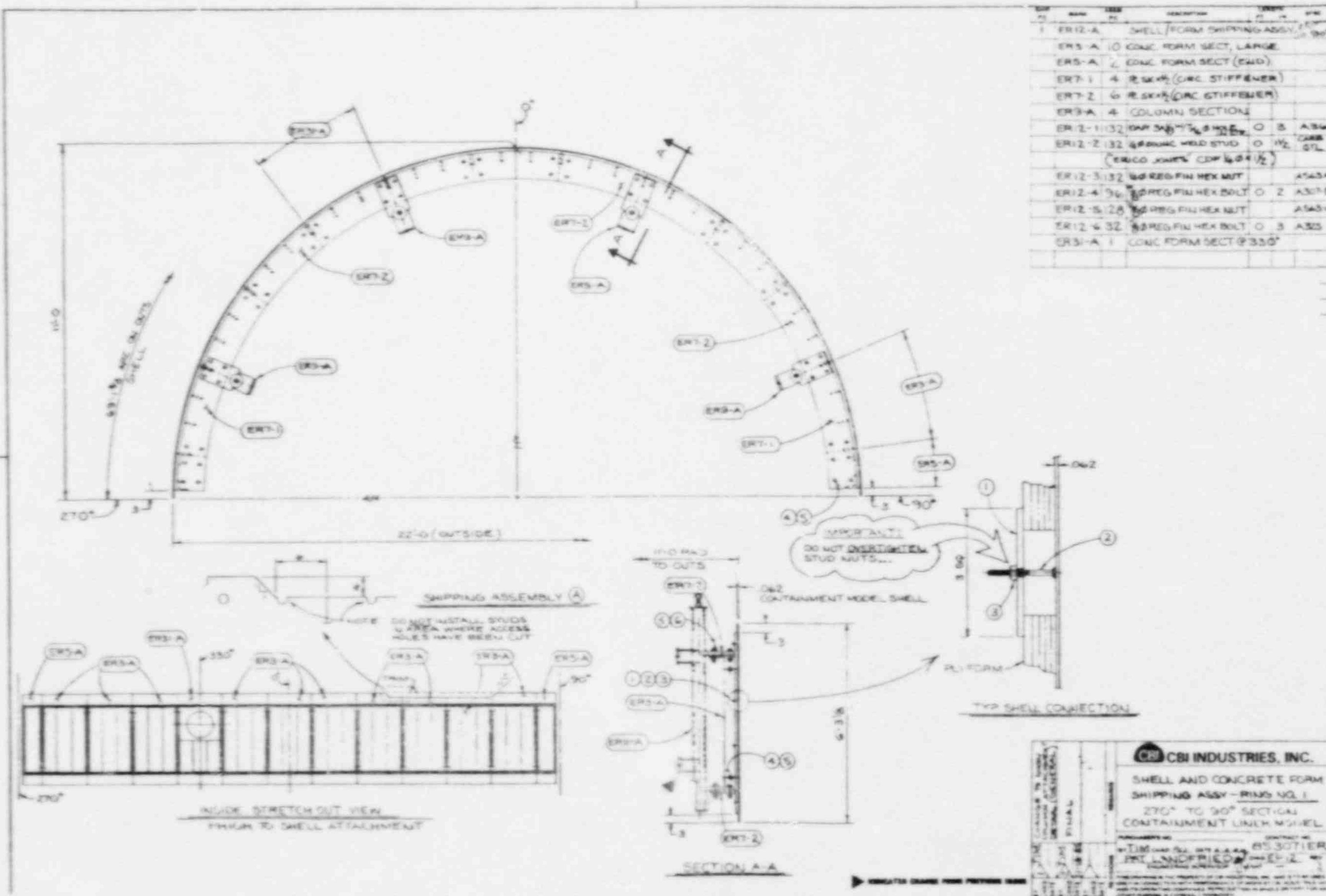

CBI INDUSTRIES, INC.
CIRCUMFERENTIAL STIFFENERS FOR CONCRETE FORM SECTIONS
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
ALL HOLES TO BE
HOLES ARE NOT ON RADIAL LINES
ASSEMBLE ON DWGS


TOP VIEW
ASSY 'D' 'E' 'F' 'G'
A 5-1/8 4-4 1/8 4-3 1/8 0-5
B 5-1 1/8 4-4 1/8 4-3 3/16 1-2 3/8
C 2-9 3/4 1-2 3/4 1-1 3/16 1-3
5/8 Ø HOLES
2 5/16 R
DRILL 5/8 Ø HOLES AND CUT SLOT BETWEEN
ASSEMBLE ON DWG ER10
ASSEMBLE ON DWG ER11
ASSEMBLE ON DWG ER12
8 ERB-A COLUMN SECTION
-1 8 PC. 4Ø SCH 40 PIPE A53
-4 16 PL 5 1/2 x 1/2 W/SLOT A283-C
-5 16 PL 5 O.D. x 1/2 x 1 1/8 I.D. A283-C
-6 16 1 1/8 Ø REG FIN HEX NUT A563-A
-7 8 1 1/8 Ø-7UNC THD ROD A36
8 ERB-B COLUMN SECTION
8 ERB-C COLUMN SECTION
NOTES
1. USE 70XX ELECTRODE
CBI INDUSTRIES, INC.
COLUMN DETAILS FOR CONCRETE FORMS
CONTAINMENT LINER MODEL
853071 ER
ERB
3
INDICATES CHANGE FROM PREVIOUS ISSUE

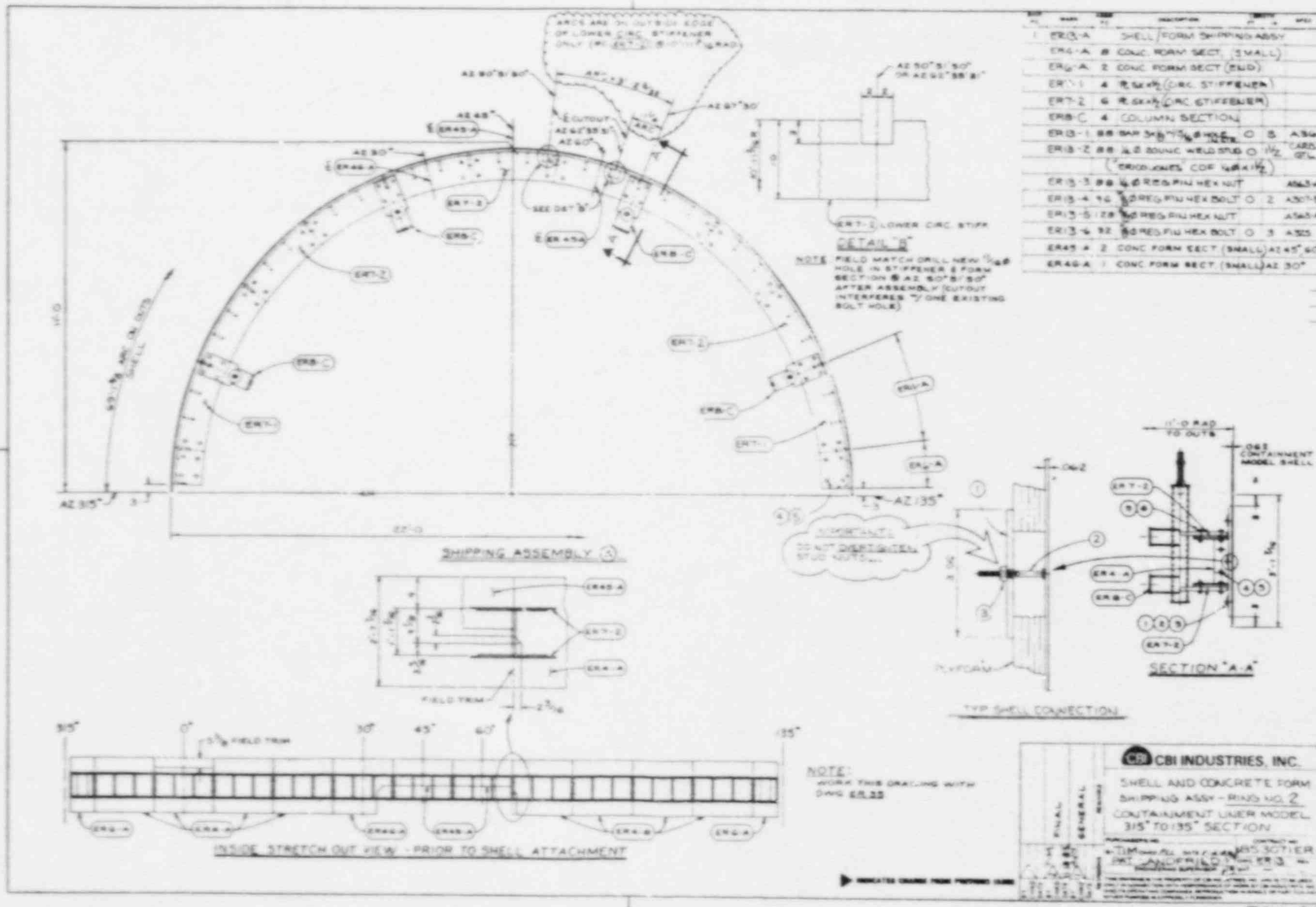

CBI INDUSTRIES, INC.
COLUMN DETAILS FOR CONCRETE FORMS CONTAINMENT LINER MODEL
NOTES
1. USE 70XX ELECTRODE
COLUMN SECTION
COLUMN BASE
TOP VIEW
BASE
DRILL 1⁄8 Ø HOLES AND CUT SLOT BETWEEN

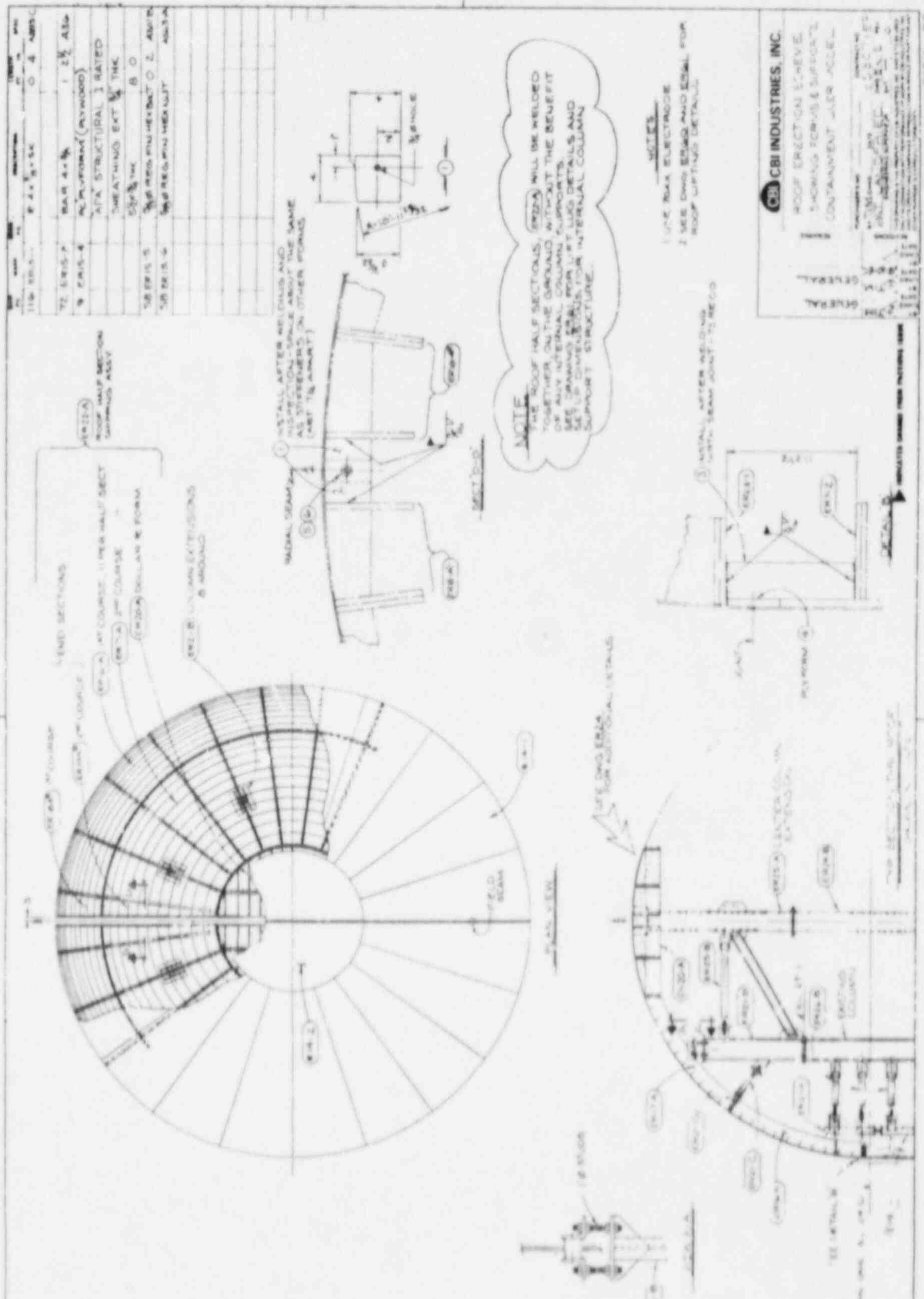

ER10-A SHELL FORM SHIPPING ASSY
ER5-A 11 CONC. FORM SECT. LARGE
ER7-1 4 (CIRC. STIFFENER)
ER7-2 6 (CIRC. STIFFENER)
ER8-A 4 COLUMN SECTION
ER10-3 REG FIN HEX NUT
ER10-4 REG FIN HEX BOLT
ER10-5 REG FIN HEX NUT
ER10-6 32 FIN HEX BOLT
SHIPPING ASSEMBLY A
22'-0
IMPORTANT! DO NOT OVERTIGHTEN STUD NUTS...
CONTAINMENT MODEL SHELL
PLYFORM
TYP SHELL CONNECTION
INSIDE STRETCH OUT VIEW
PRIOR TO SHELL ATTACHMENT
SECTION A-A
TRIM
CBI INDUSTRIES, INC.
SHELL AND CONCRETE FORM
SHIPPING ASSY - RING NO. 4
135° TO 315° SECTION
CONTAINMENT LINER MODEL

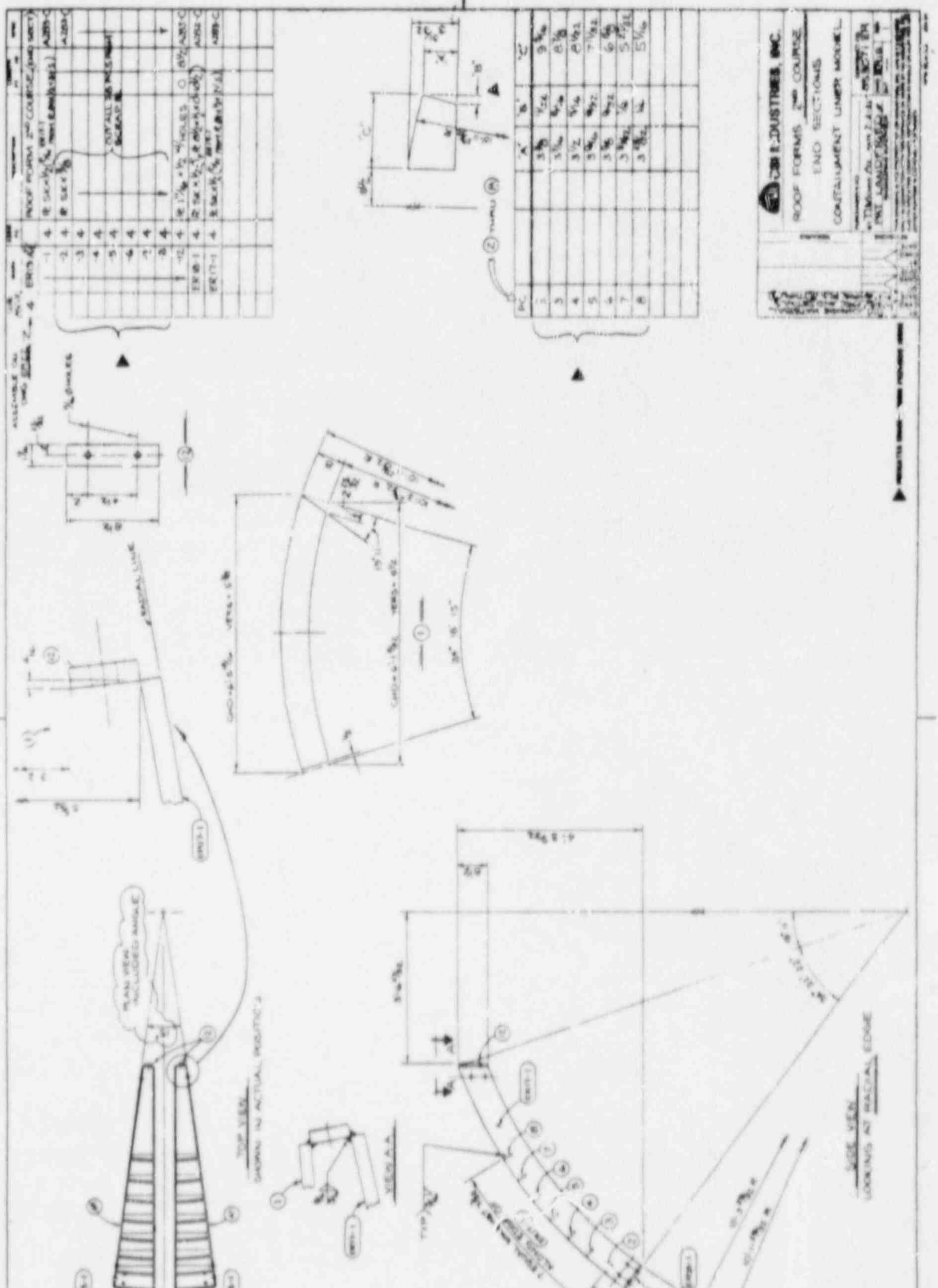

SHIPPING ASSEMBLY (A)
NOTES:
1. WORK THIS DRAWING WITH DWG ER 36
2. SEE DWG ER 37 FOR ADDITIONAL DETAILS
SEE DETAIL "B" FOR MODIFICATION TO LOWER CIRC. STIFF (PC ER 7-2)
AZ 0°
AZ 180°
22'-0
DETAIL "B"
1'-6 CUTOUT
AZ 90° (℄ LOWER CIRC. STIFFENER)
FIELD TRIM
SECTION "A-A"
.062 CONTAINMENT MODEL SHELL
IMPORTANT: DO NOT OVERTIGHTEN STUD NUTS...
PLYFORM
TYP SHELL CONNECTION
INSIDE STRETCH OUT VIEW - PRIOR TO SHELL ATTACHMENT
SHELL/FORM SHIPPING ASSEMBLY
CONCRETE FORM SECT (LARGE)
COLUMN SECTION
SPECIAL CONC. FORM SECT @ 90°
SPECIAL CONC. FORM SECT @ 60°
SPECIAL CONC. FORM SECT @ 45°
SPECIAL CONC. FORM SECT @ 30°
SPECIAL CONC. FORM SECT @ 15°
CONC FORM SECT (SPECIAL END)
CBI INDUSTRIES, INC.
SHELL AND CONCRETE FORM SHIPPING ASSY - RING NO. 3 0° TO 180° SECTION
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
BEN SHEPHERD
85307 1ER
FINAL
REDRAW

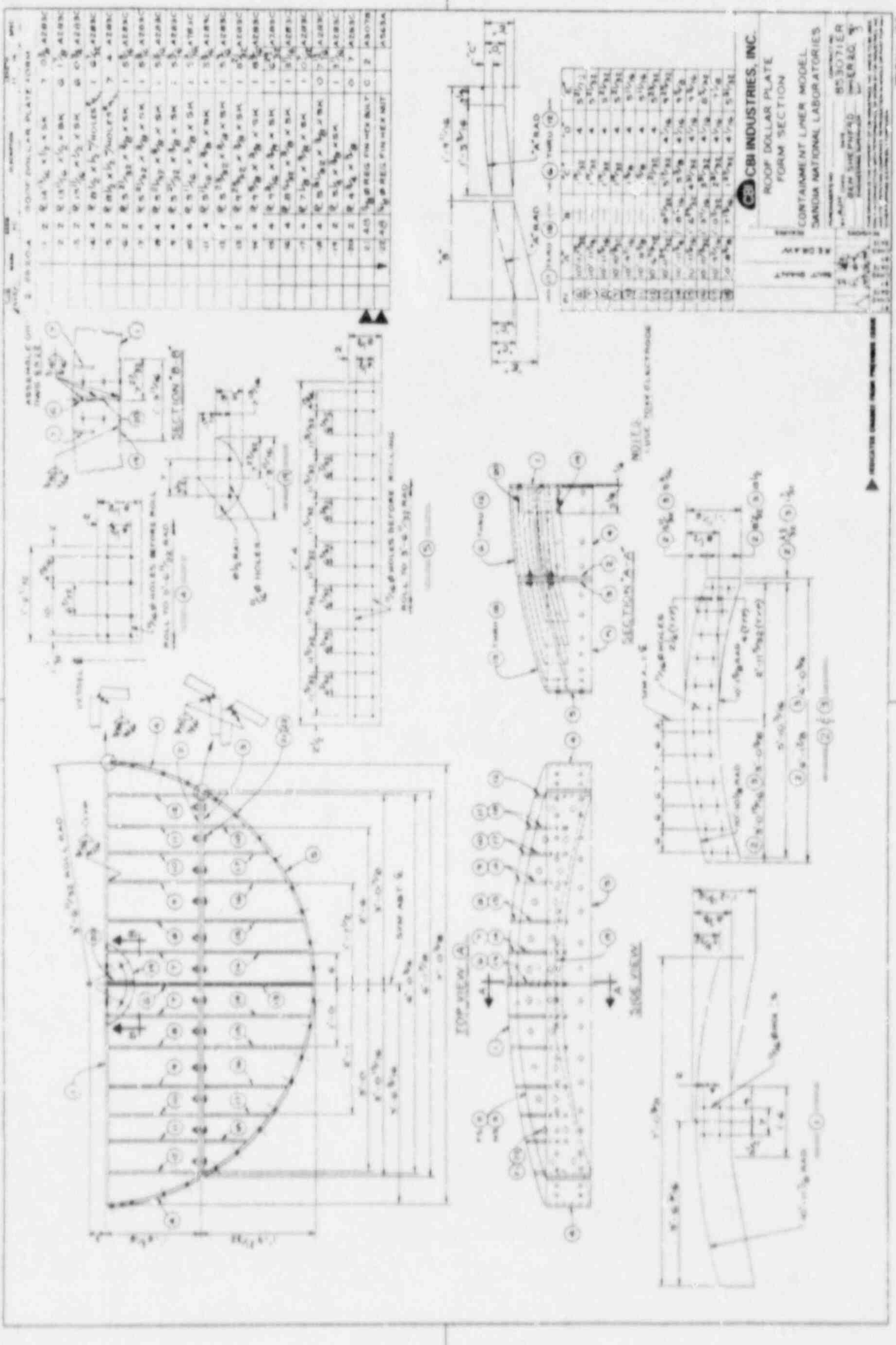


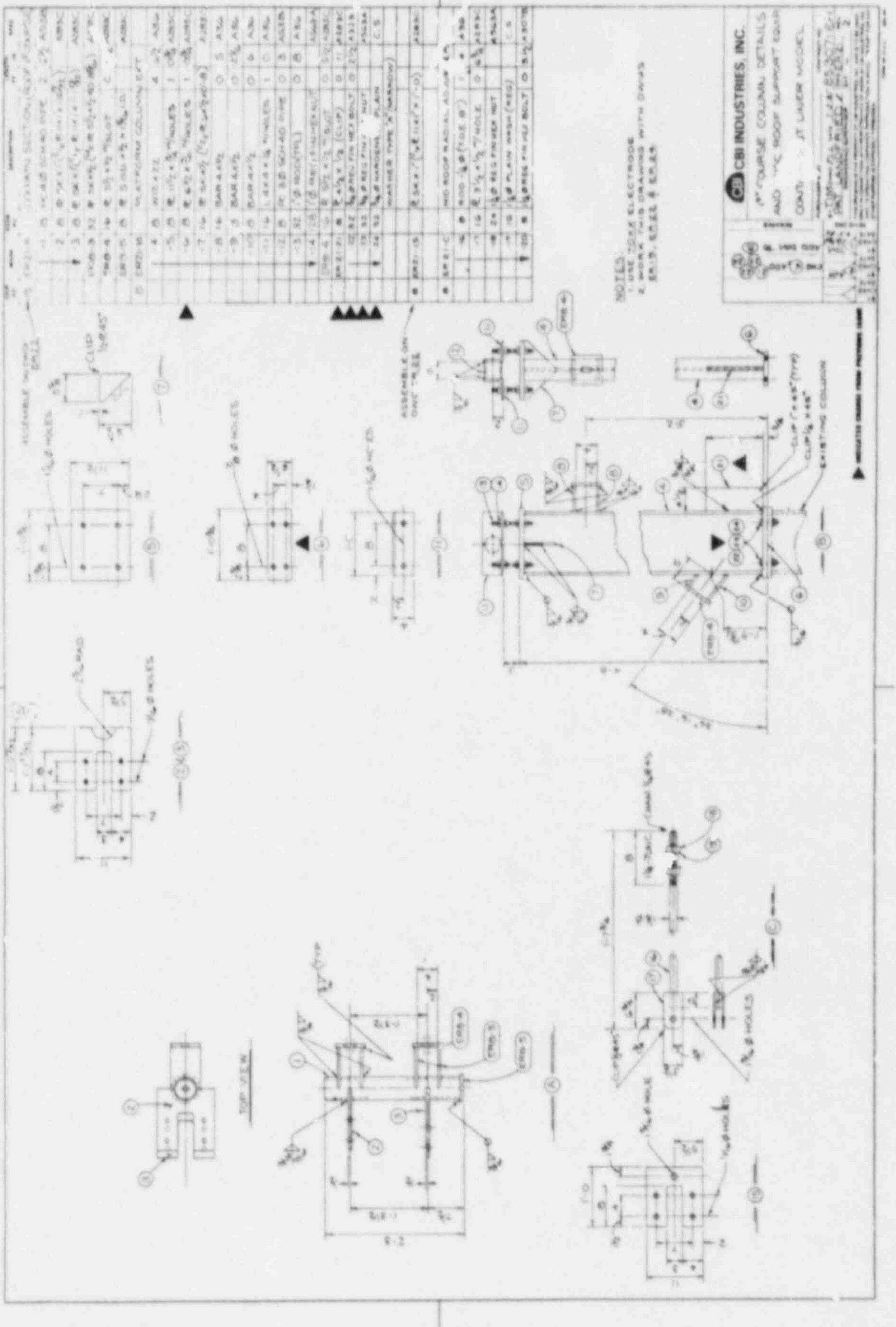
ER12-A SHELL/FORM SHIPPING ASSY.
ER5-A 10 CONC. FORM SECT, LARGE
ER5-A 2 CONC. FORM SECT (END)
ER7-1 4 (CIRC. STIFFENER)
ER7-2 6 (CIRC. STIFFENER)
ER3-A 4 COLUMN SECTION
ER12-3 132 REG FIN HEX NUT A563A
ER12-4 REG FIN HEX BOLT A307-B
ER12-5 28 REG FIN HEX NUT A563A
ER12-6 32 REG FIN HEX BOLT A325
ER31-A 1 CONC FORM SECT @ 330°
22'-0 (OUTSIDE)
270°
90°
SHIPPING ASSEMBLY A
NOTE DO NOT INSTALL STUDS IN AREA WHERE ACCESS HOLES HAVE BEEN CUT
INSIDE STRETCH OUT VIEW
PRIOR TO SHELL ATTACHMENT
.062 CONTAINMENT MODEL SHELL
SECTION A-A
IMPORTANT!
DO NOT OVERTIGHTEN STUD NUTS...
PLY FORM
TYP SHELL CONNECTION
CBI INDUSTRIES, INC.
SHELL AND CONCRETE FORM
SHIPPING ASSY - RING NO. 1
270° TO 90° SECTION
CONTAINMENT LINER MODEL
85307IER

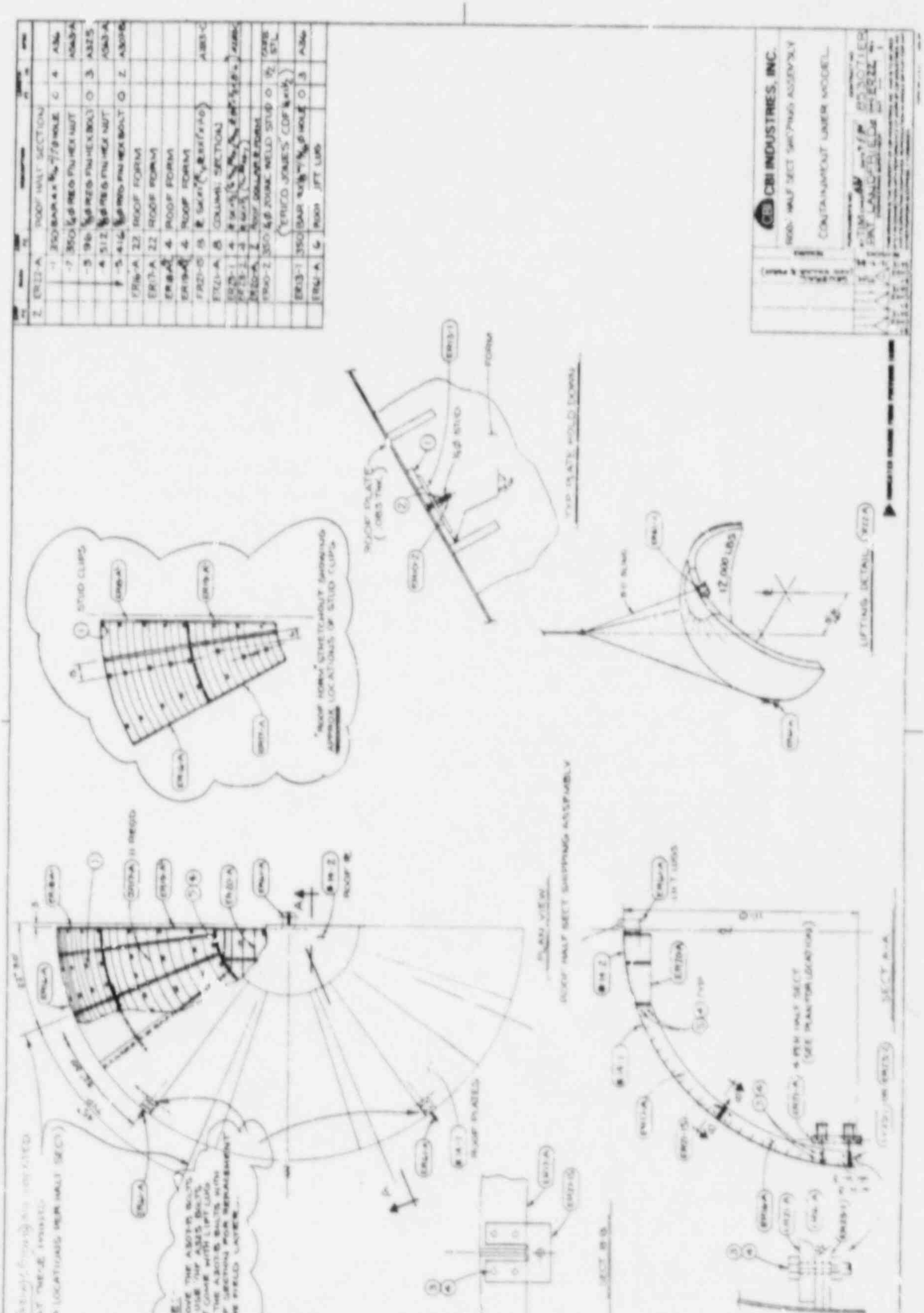

CBI INDUSTRIES, INC.
SHELL AND CONCRETE FORM
SHIPPING ASSY - RING NO. 2
CONTAINMENT LINER MODEL
315° TO 135° SECTION
SHIPPING ASSEMBLY ③
INSIDE STRETCH OUT VIEW - PRIOR TO SHELL ATTACHMENT
SECTION "A-A"
TYP SHELL CONNECTION
DETAIL "B"
NOTE: WORK THIS DRAWING WITH DWG ER.35
AZ 315°
AZ 135°
22'-0
11'-0
FIELD TRIM

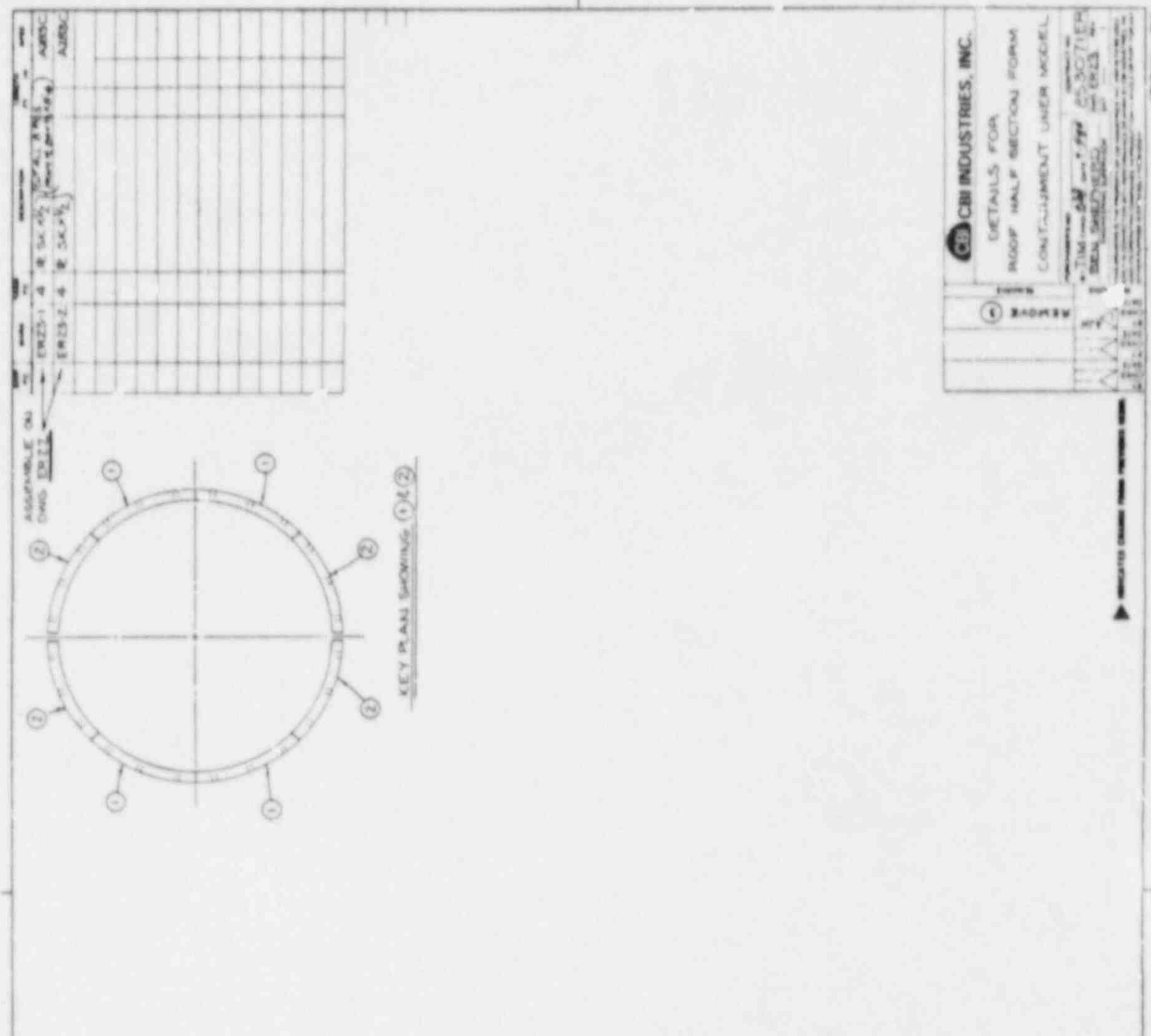

CBI INDUSTRIES, INC.
PLAN VIEW
NOTE
NOTES

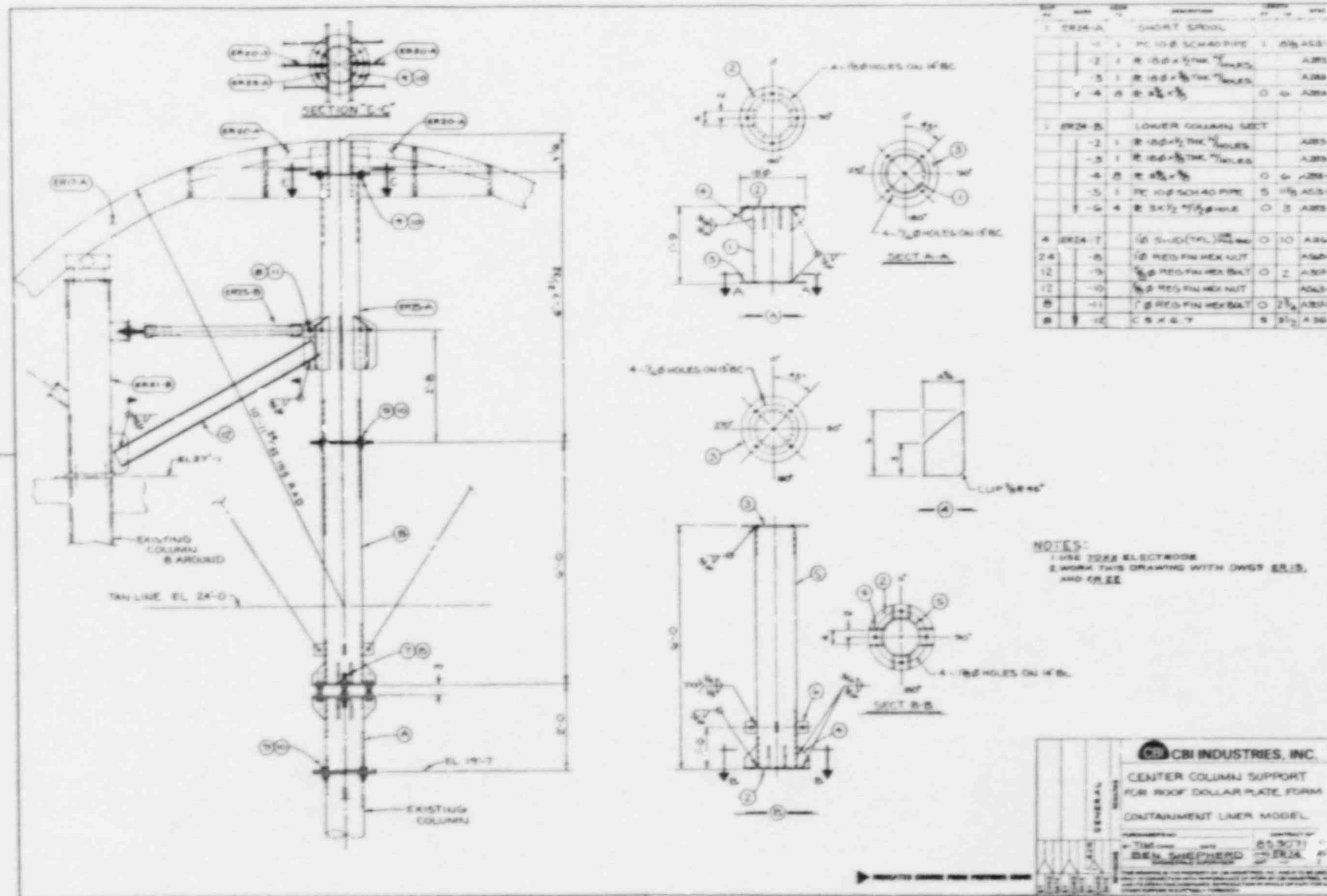

CBI INDUSTRIES, INC.
ROOF FORMS 2ND COURSE
END SECTIONS
CONTAINMENT LINER MODEL
TOP VIEW
SHOWN IN ACTUAL POSITION
SIDE VIEW
LOOKING AT RADIAL EDGE
VIEW A-A
PLAN VIEW INCLUDED ANGLE
RADIAL LINE


CBI INDUSTRIES, INC.
ROOF DOLLAR PLATE
FORM SECTION
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
TOP VIEW
SIDE VIEW
SECTION "A-A"
SECTION "B-B"

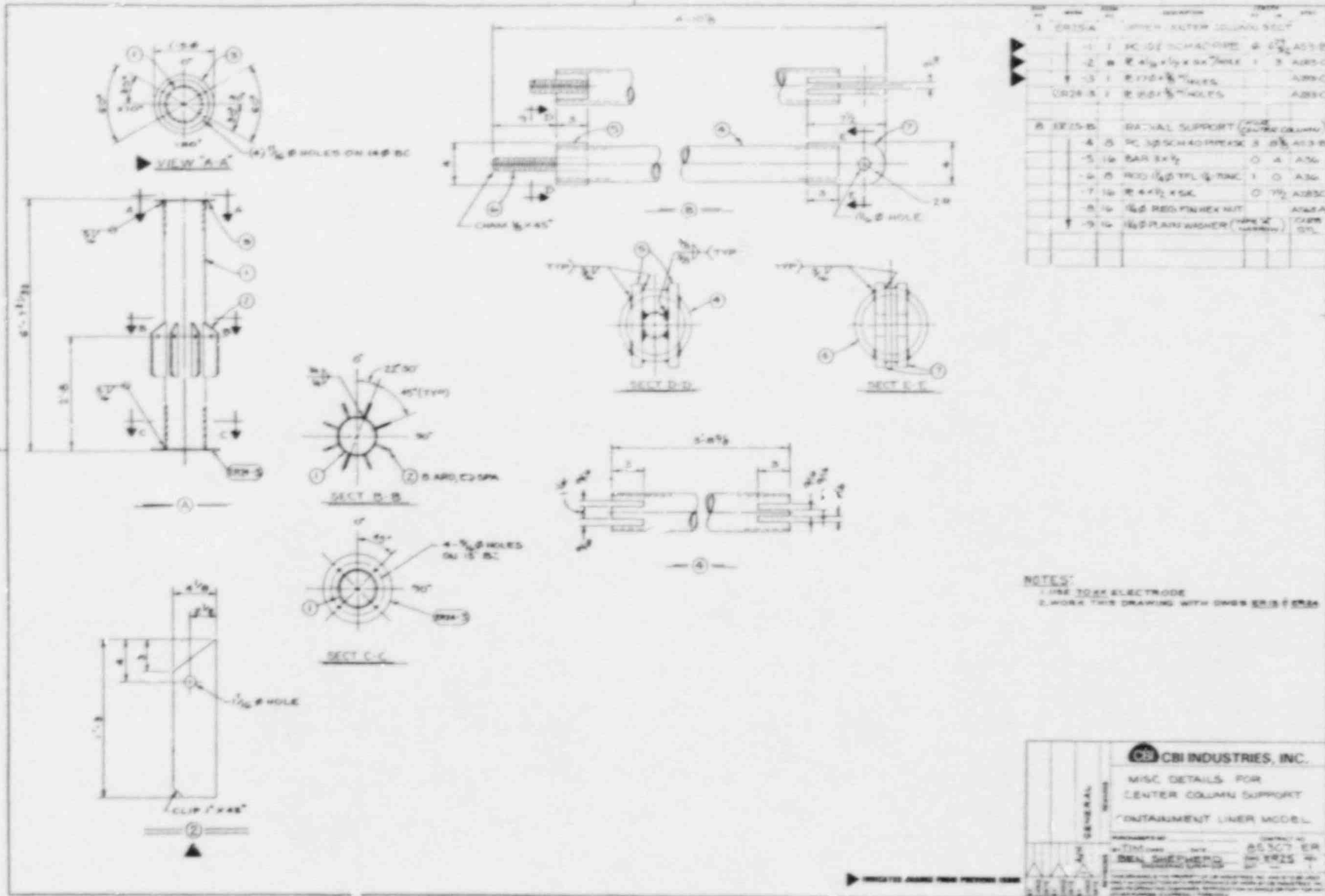

CBI INDUSTRIES, INC.
TOP VIEW
EXISTING COLUMN


CBI INDUSTRIES, INC.
PLAN VIEW
SECT. A-A


CBI INDUSTRIES, INC.
DETAILS FOR
ROOF HALF SECTION FORM
CONTAINMENT LINER MODEL
KEY PLAN SHOWING 1 & 2
ALL HOLES

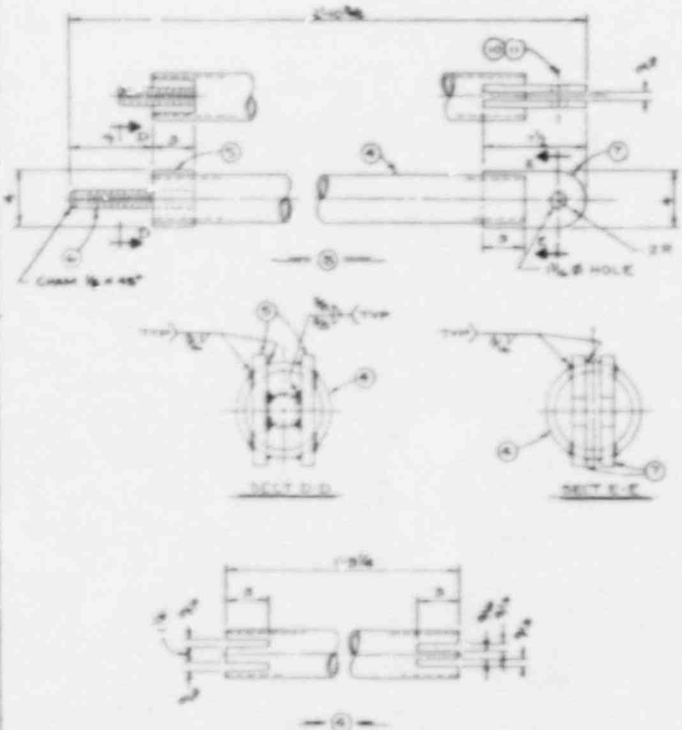


SECTION "C-C"
SHORT SPOOL
LOWER COLUMN SECT
SECT A-A
SECT B-B
TAN LINE EL 24'-0
EL 19'-7
EXISTING COLUMN
EXISTING COLUMN 8 AROUND
NOTES:
1. USE 70XX ELECTRODE
2. WORK THIS DRAWING WITH DWGS ER15 AND ER22
CBI INDUSTRIES, INC.
CENTER COLUMN SUPPORT FOR ROOF DOLLAR PLATE FORM
CONTAINMENT LINER MODEL
BEN SHEPHERD
GENERAL



VIEW "A-A"
SECT B-B
SECT C-C
SECT D-D
SECT E-E
CHAM 1/8 x 45°
1 1/16 Ø HOLE
CLIP 1" x 45°
RADIAL SUPPORT
BAR 3 x 1/2
NOTES:
1. USE 7018 ELECTRODE
2. WORK THIS DRAWING WITH DWGS ER13 & ER24
CBI INDUSTRIES, INC.
MISC DETAILS FOR
CENTER COLUMN SUPPORT
CONTAINMENT LINER MODEL
BEN SHEPHERD
ER25

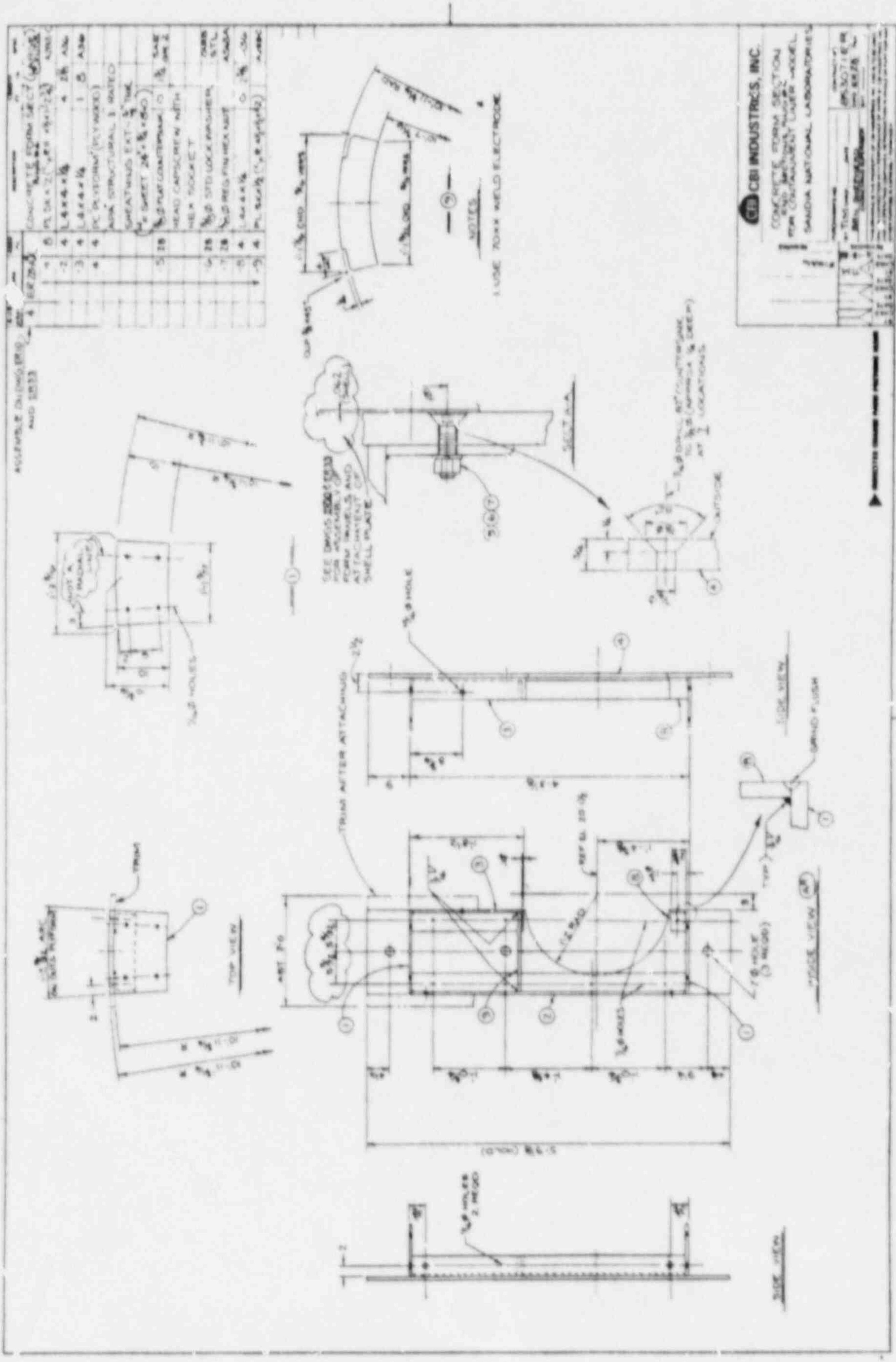
BO ER26-B		SHORT RADIAL ADJUSTER			
-4	80	PC 5/8 SCH40 PIPE	1	9/16	A53-B
		× SK			
-5	160	BAR 3×1/2	0	4	A36
-6	80	ROD 1 1/8Ø TH'L 1 1/8-7UNC	1	0	A36
-7	160	PL 4×1/2×SK	0	7 1/2	A285-C
-8	160	1 1/8Ø REG FIN HEX NUT			A563-A
-9	160	1 1/8Ø PLAIN WASHER (TYPE A NARROW)			CARB STL
-10	80	1"Ø REG FIN HEX BOLT	0	2 3/4	A307B
-11	80	1"Ø REG FIN HEX NUT			A563A

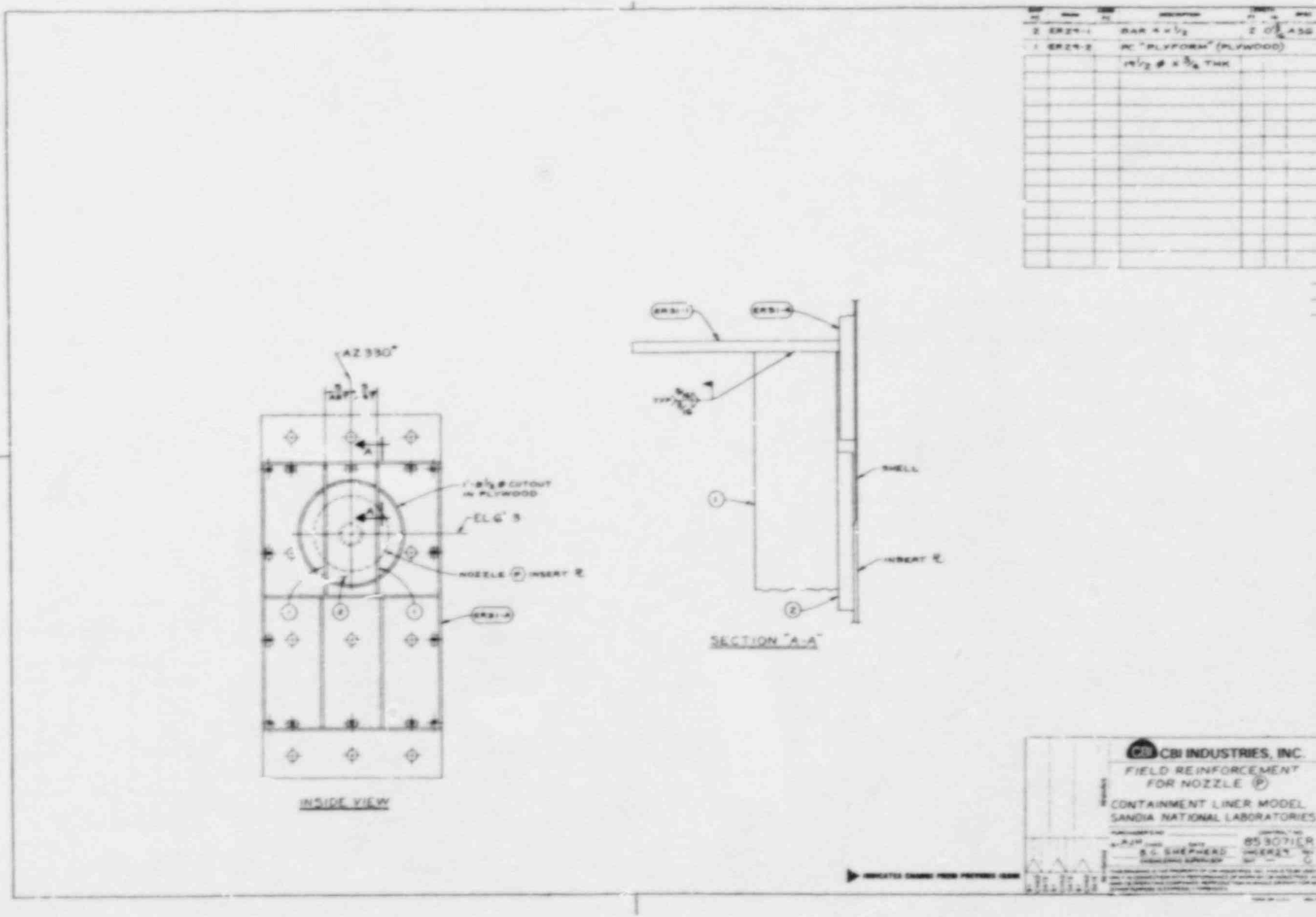


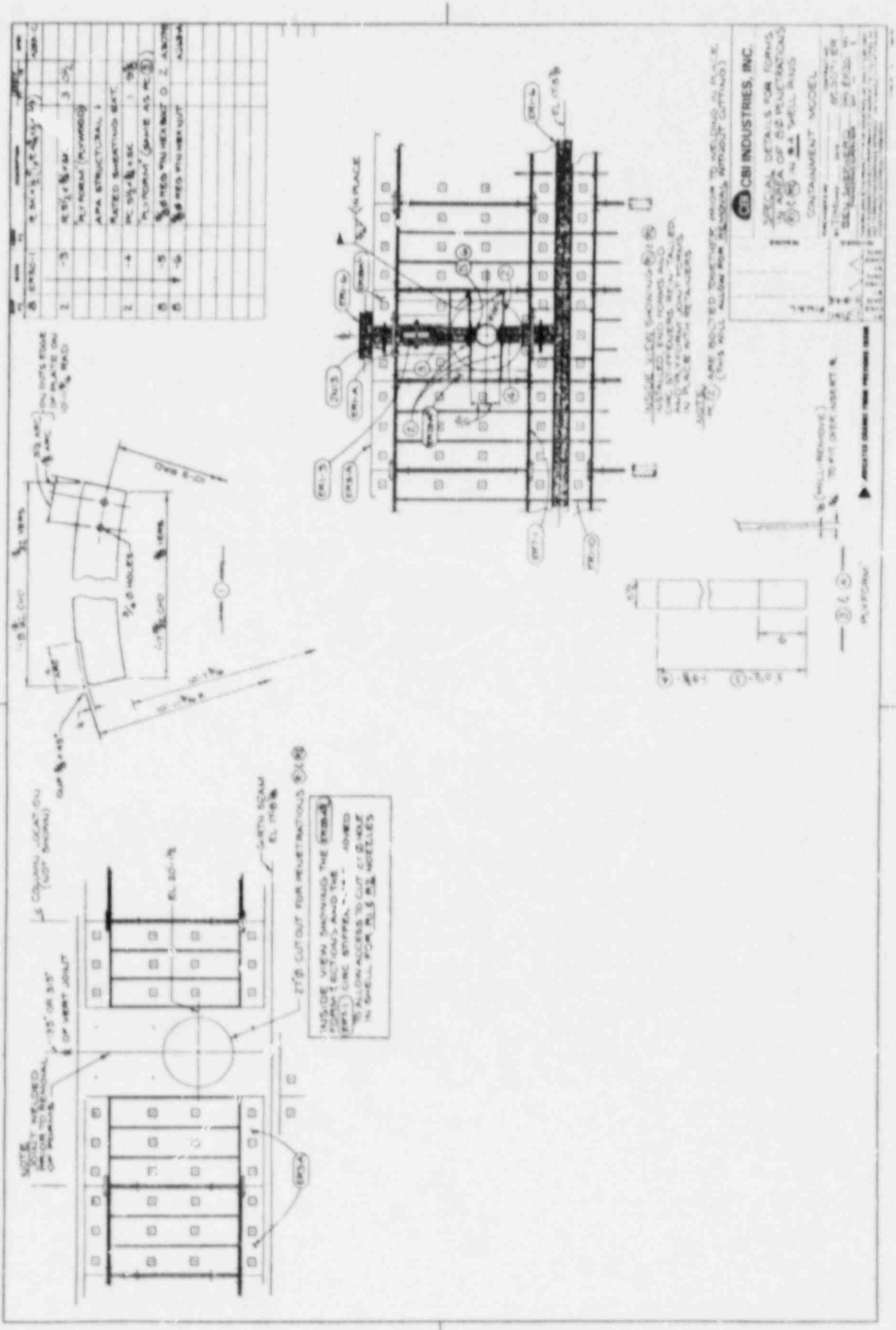
NOTES:
1. USE 7018 ELECTRODE
2. WORK THIS DRAWING WITH DWGS ER1 & ER18

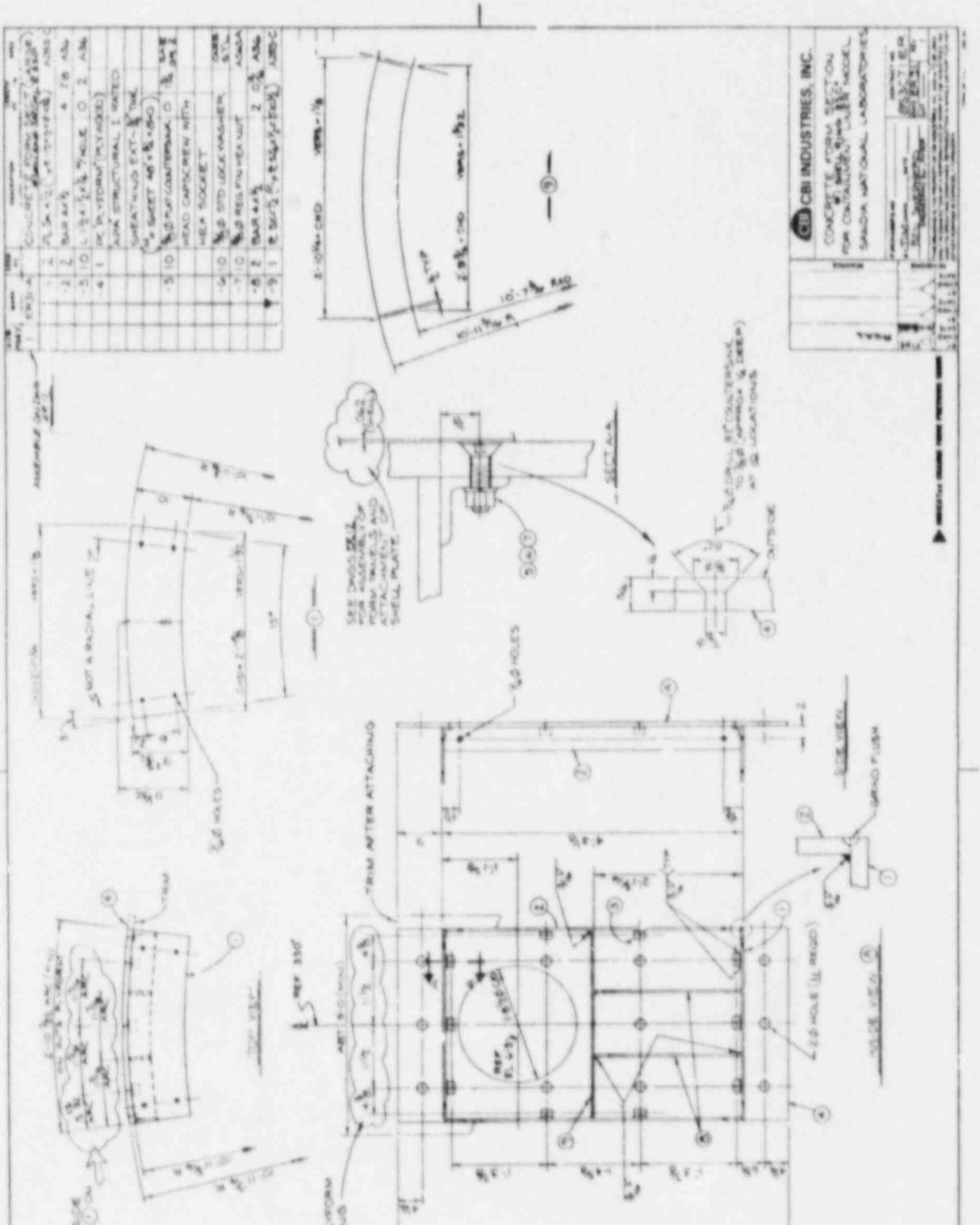
CBI INDUSTRIES, INC.
MISC DETAILS
CONTAINMENT LINER MODEL
GENERAL
TIM
BEN SHEPHERD
85-3CT1ER
ER26

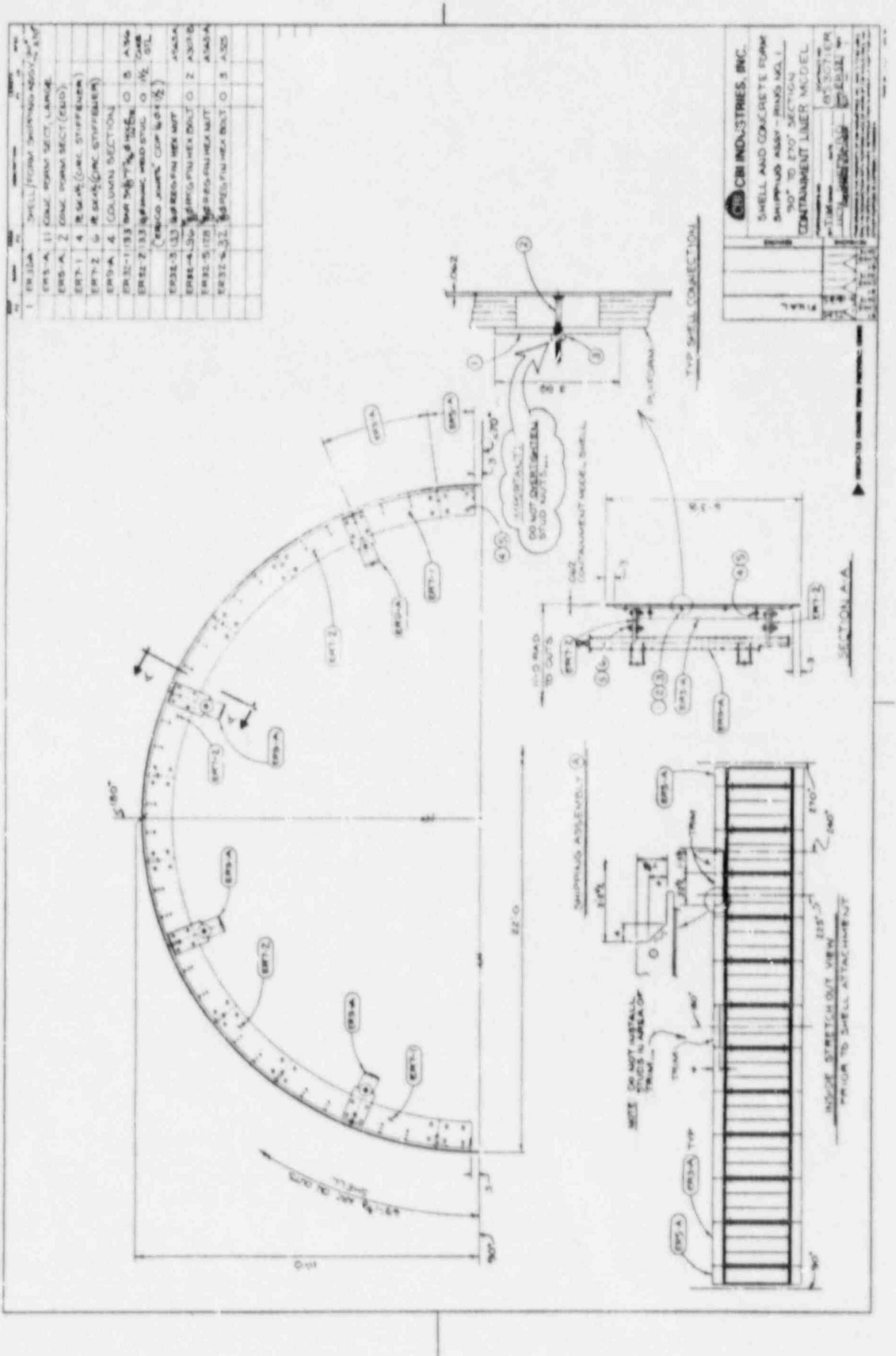
▶ INDICATES CHANGE FROM PREVIOUS ISSUE

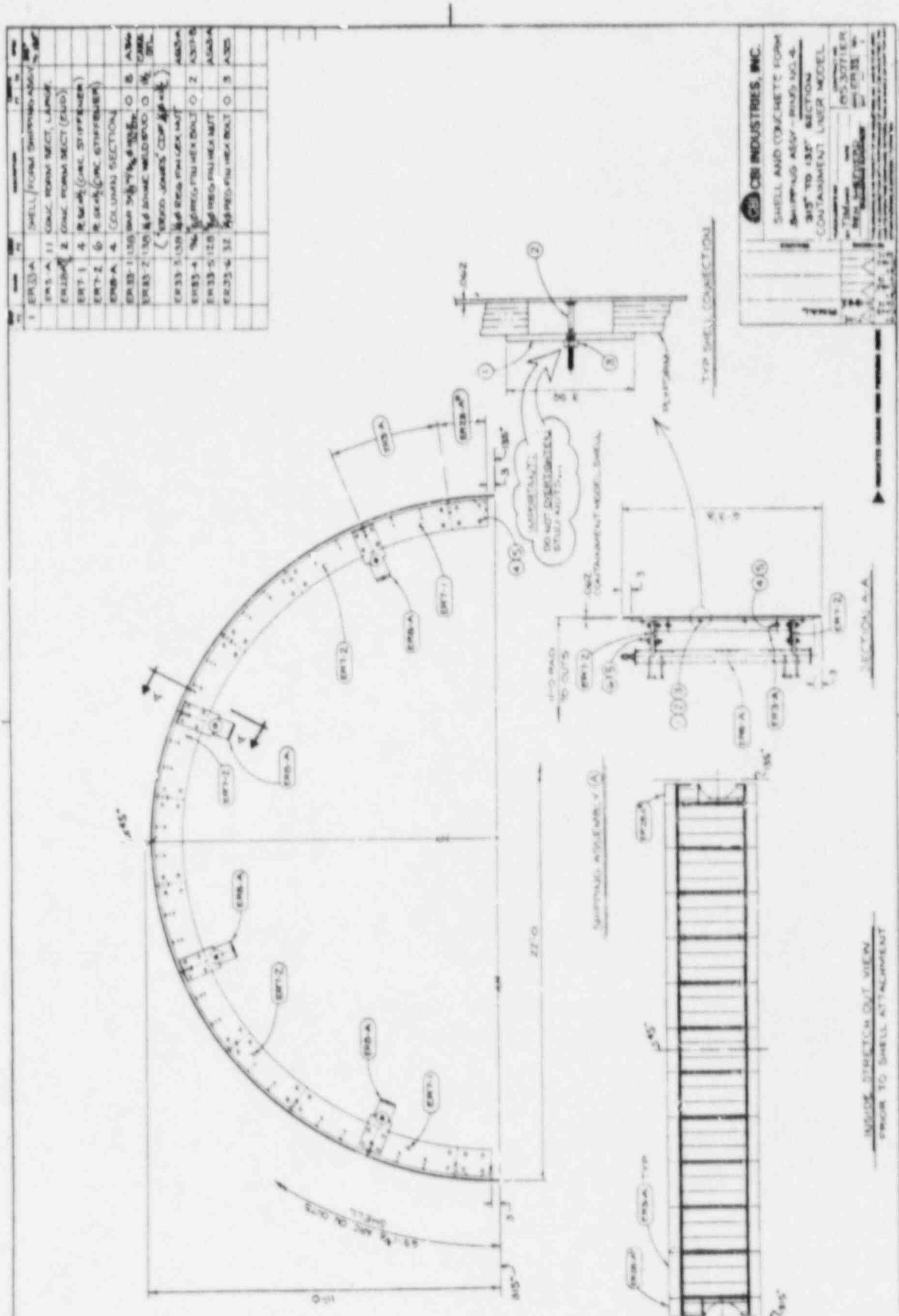

CBI INDUSTRIES, INC.
SANDIA NATIONAL LABORATORIES
NOTES:
SIDE VIEW
TOP VIEW
INSIDE VIEW
TRIM AFTER ATTACHING
GRIND FLUSH

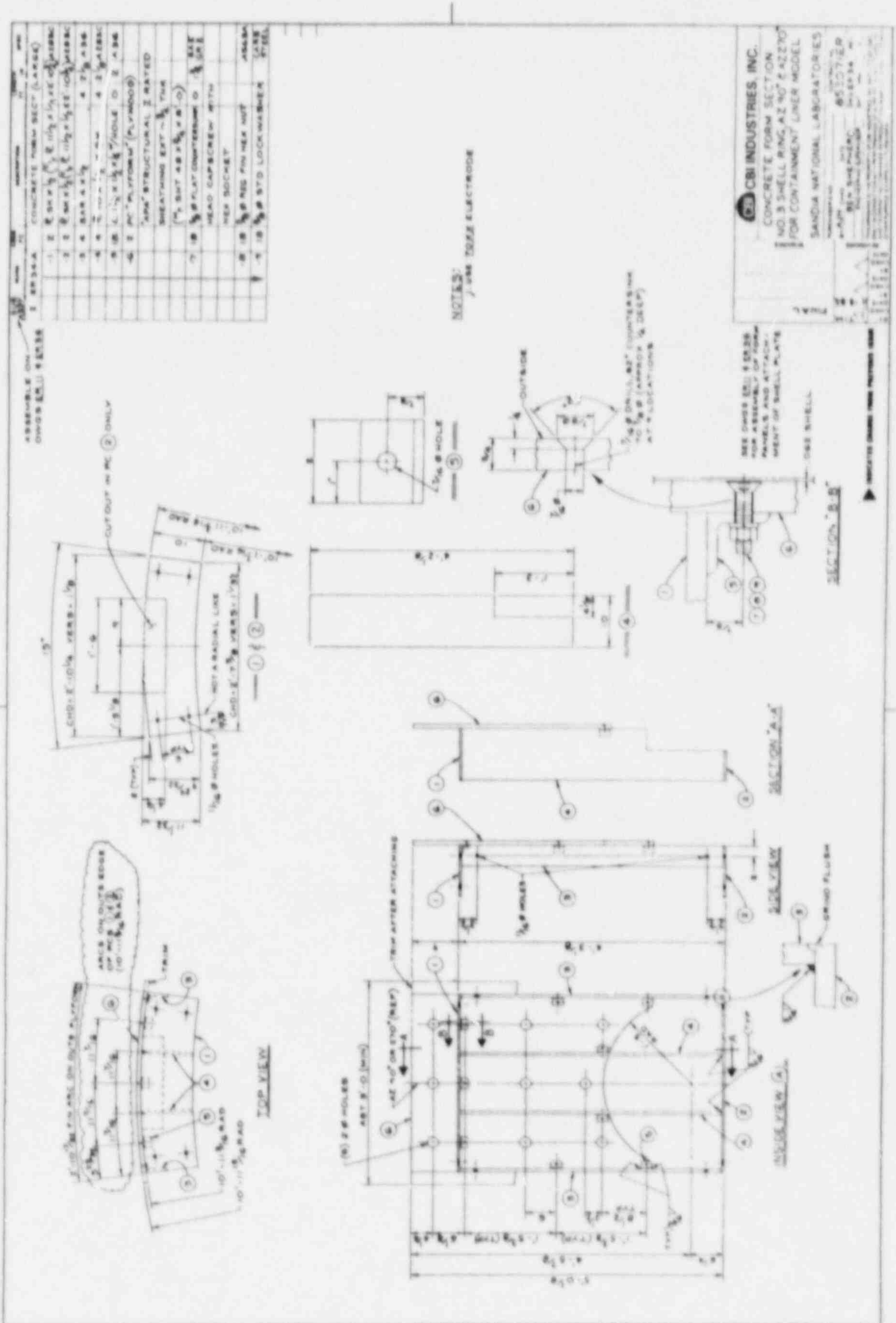

2 ER29-1 BAR 4 x 1/2
1 ER29-2 PC "PLYFORM" (PLYWOOD)
19 1/2 Ø x 3/4 THK
AZ 330°
1'-8 1/2 Ø CUTOUT IN PLYWOOD
EL 6' 3
NOZZLE (P) INSERT PL
ER31-4
INSIDE VIEW
ER31-1
SHELL
INSERT PL
SECTION "A-A"
CBI INDUSTRIES, INC.
FIELD REINFORCEMENT FOR NOZZLE (P)
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
B.C. SHEPHERD
85 3071CR

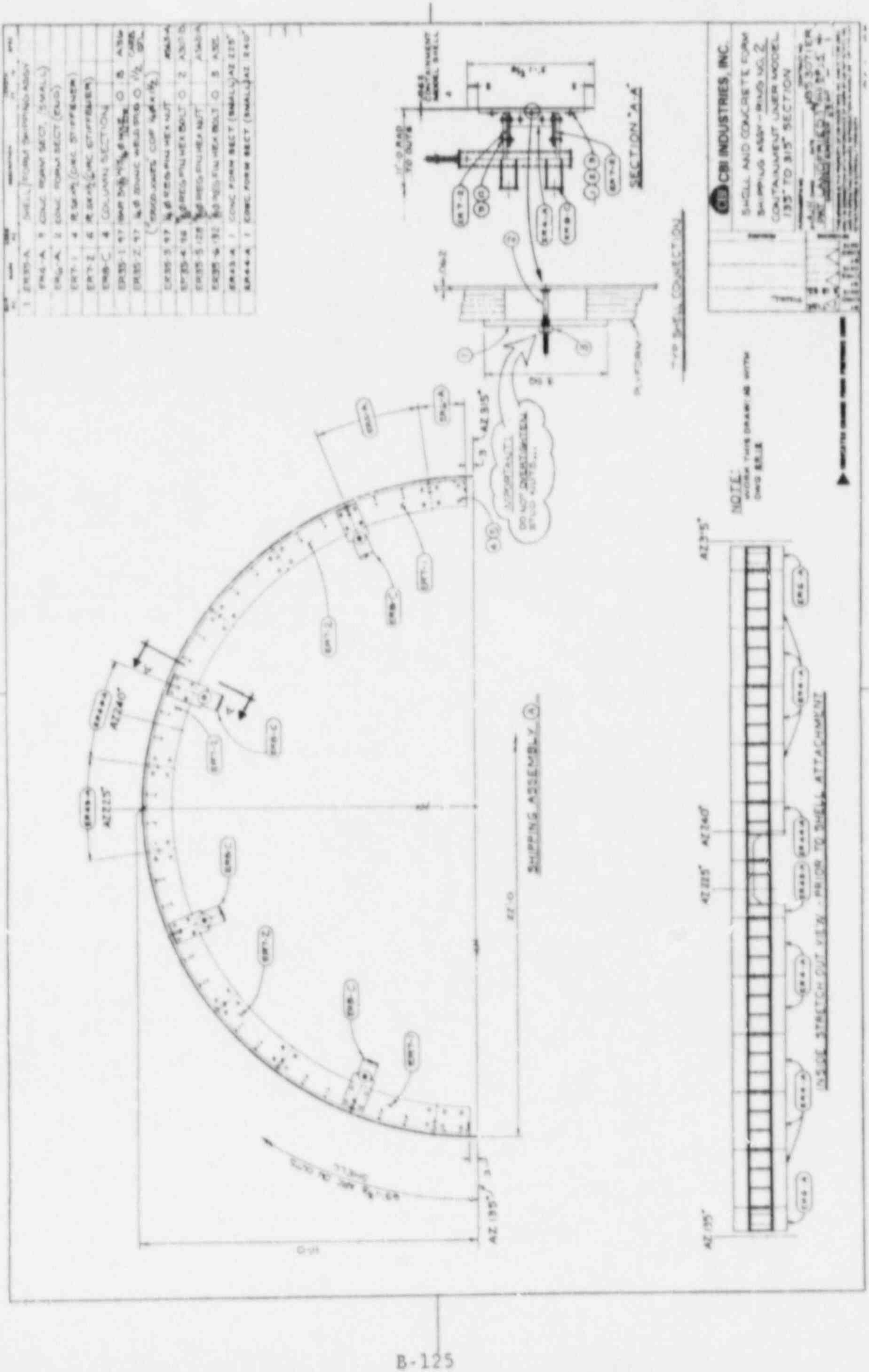

CBI INDUSTRIES, INC.
CONTAINMENT MODEL

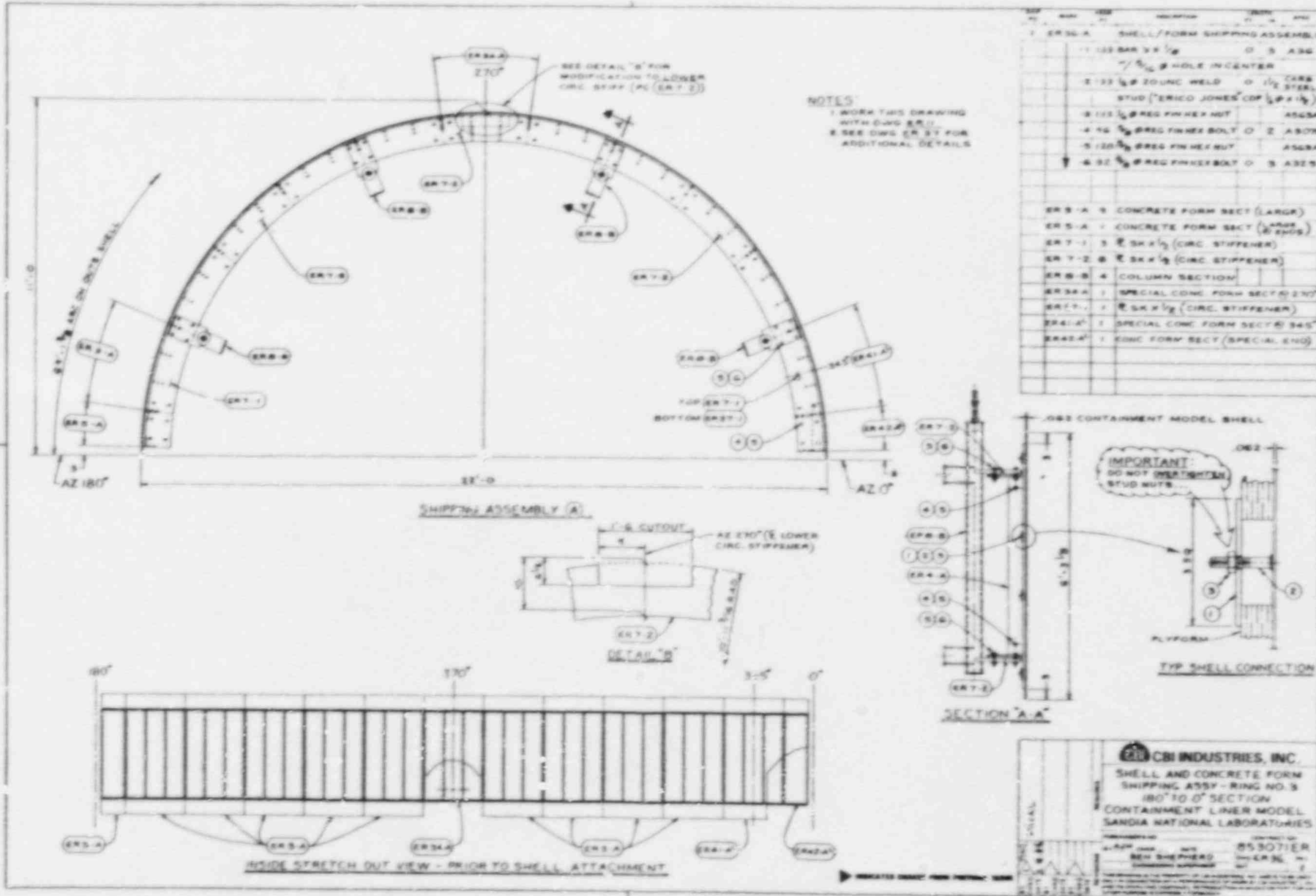

CBI INDUSTRIES, INC.
SANDIA NATIONAL LABORATORIES
TOP VIEW
INSIDE VIEW
SIDE VIEW
SECT A-A
TRIM AFTER ATTACHING
LOCATE HOLES IN PLATFORM PRIOR TO ATTACHING
GRIND FLUSH
OUTSIDE

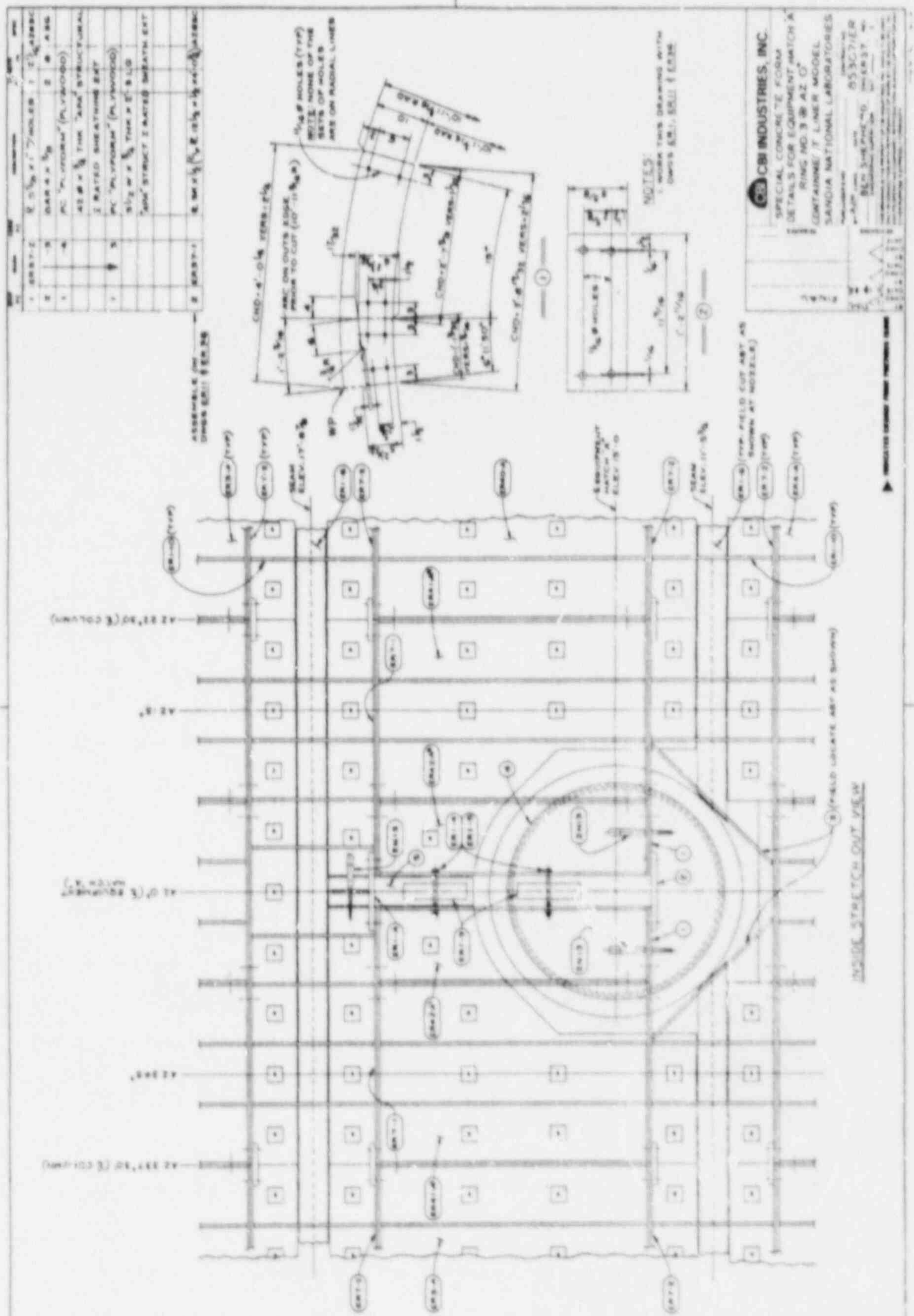

CBI INDUSTRIES, INC.
SHELL AND CONCRETE FORM SHIPPING ASSY - RING NO. 1 90° TO 270° SECTION
CONTAINMENT LINER MODEL
TYP SHELL CONNECTION
SECTION A-A
SHIPPING ASSEMBLY A
IMPORTANT: DO NOT OVERTIGHTEN STUD NUTS
INSIDE STRETCHOUT VIEW PRIOR TO SHELL ATTACHMENT

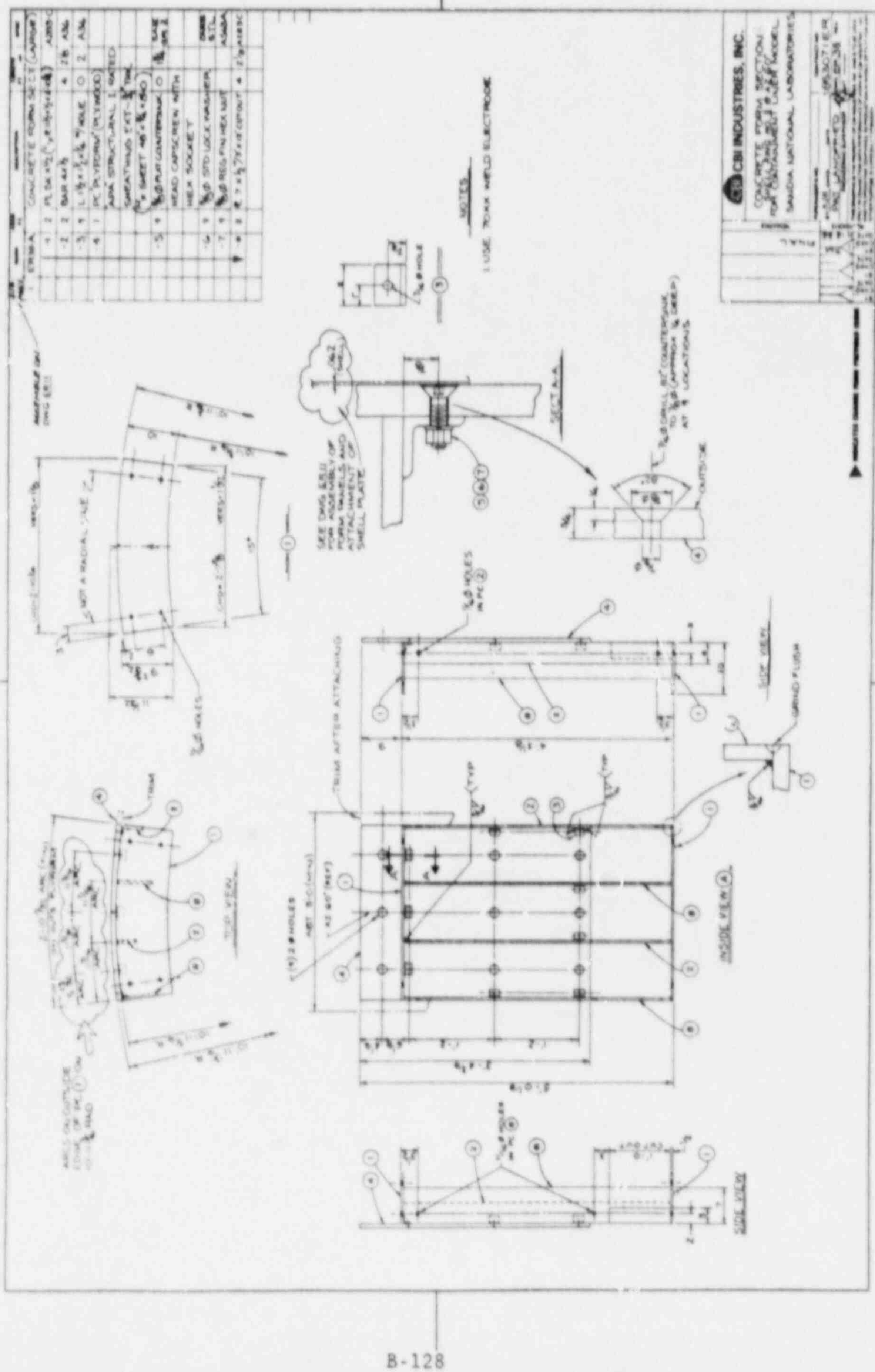

CBI INDUSTRIES, INC.
SHELL AND CONCRETE FORM
SHIPPING ASSY - RING NO. 4
315° TO 135° SECTION
CONTAINMENT LINER MODEL
85307 ER
SHIPPING ASSEMBLY A
SECTION A-A
TYP SHELL CONNECTION
INSIDE STRETCH OUT VIEW
PRIOR TO SHELL ATTACHMENT
IMPORTANT!: DO NOT OVERTIGHTEN STUD NUTS...
CONTAINMENT MODEL SHELL
22'-0
11'-0
ER33-A SHELL/FORM SHIPPING ASSY
ER5-A 11 CONC. FORM SECT, LARGE
ER7-1 4 (CIRC. STIFFENER)
ER7-2 6 (CIRC. STIFFENER)
ER8-A 4 COLUMN SECTION

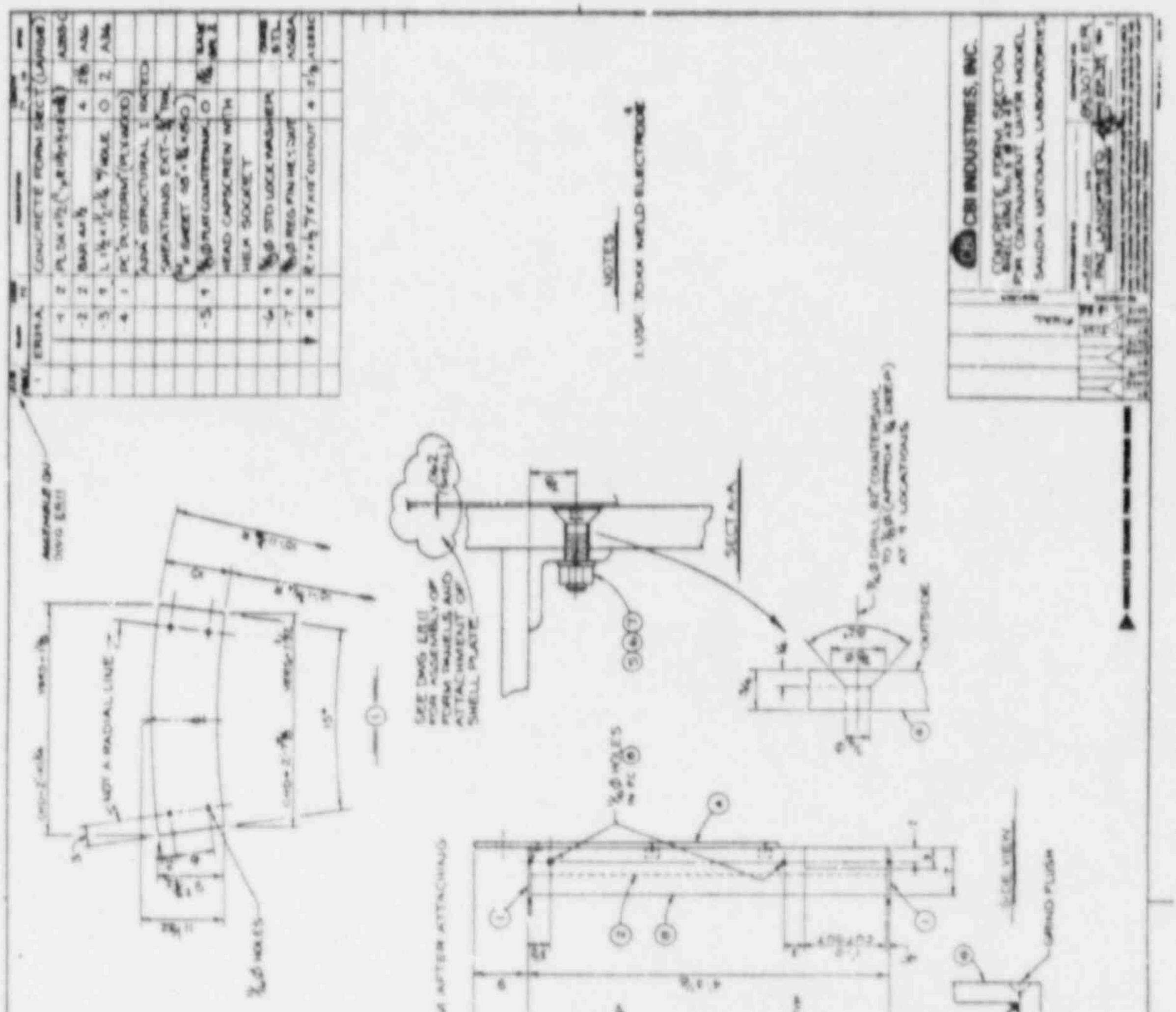

CBI INDUSTRIES, INC.
CONCRETE FORM SECTION
NO. 3 SHELL RING AZ 90° & 270°
FOR CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
TOP VIEW
INSIDE VIEW (A)
SIDE VIEW
SECTION "A-A"
SECTION "B-B"
NOTES:


CBI INDUSTRIES, INC.
SHELL AND CONCRETE FORM SHIPPING ASSY - RING NO. 2 CONTAINMENT LINER MODEL 135° TO 315° SECTION
SHIPPING ASSEMBLY A
SECTION "A-A"
INSIDE STRETCH OUT VIEW - PRIOR TO SHELL ATTACHMENT
AZ 135°
AZ 225°
AZ 240°
AZ 315°

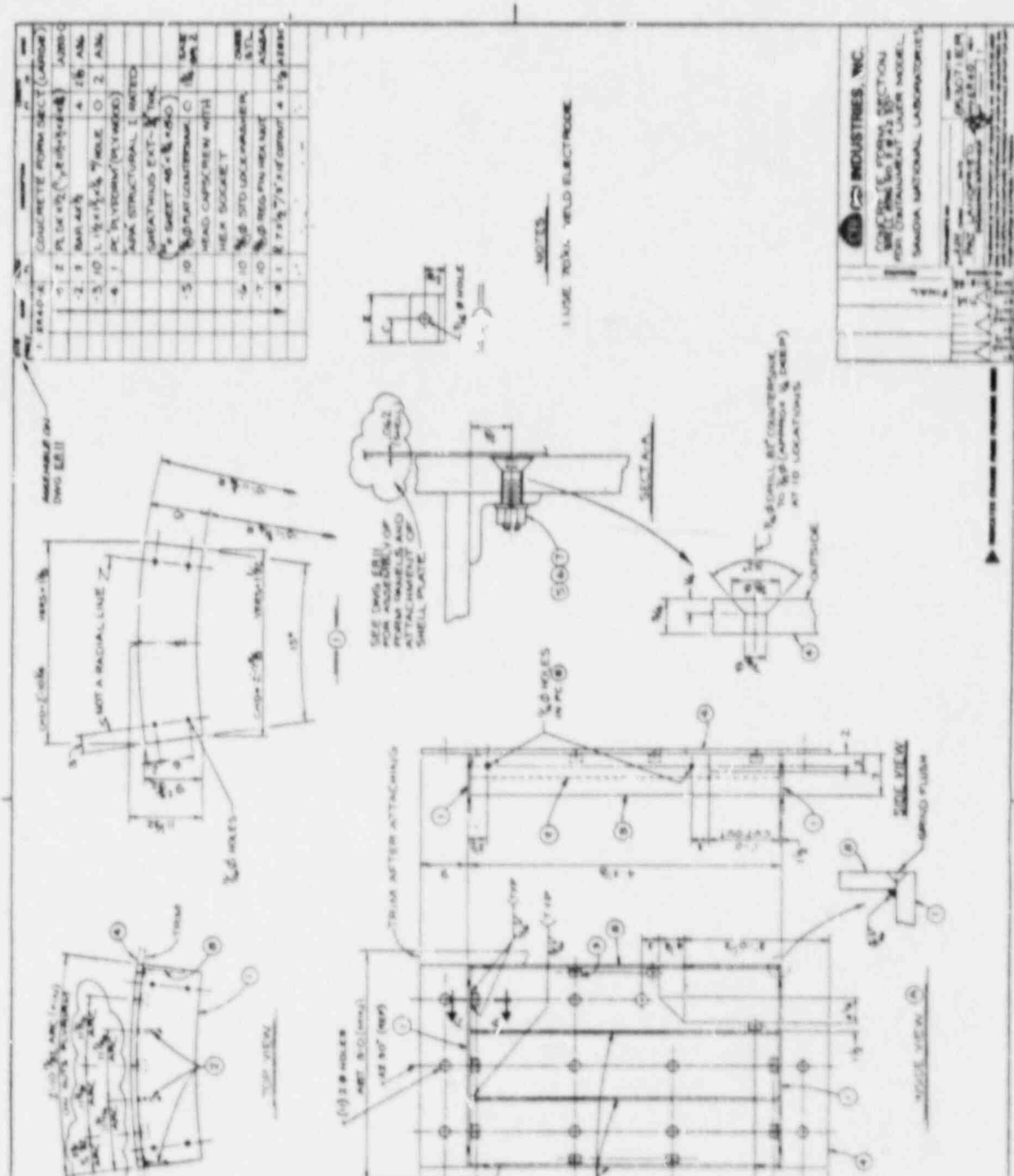

NOTES:
1. WORK THIS DRAWING WITH DWG ER11
2. SEE DWG ER 37 FOR ADDITIONAL DETAILS
SEE DETAIL "B" FOR MODIFICATION TO LOWER CIRC. STIFF (PC ER 7-2)
270°
AZ 180°
AZ 0°
SHIPPING ASSEMBLY (A)
C-6 CUTOUT
AZ 270° (℄ LOWER CIRC. STIFFENER)
DETAIL "B"
SECTION "A-A"
.062 CONTAINMENT MODEL SHELL
IMPORTANT: DO NOT OVERTIGHTEN STUD NUTS
PLYFORM
TYP SHELL CONNECTION
INSIDE STRETCH OUT VIEW - PRIOR TO SHELL ATTACHMENT
ER 36-A SHELL/FORM SHIPPING ASSEMBLY
CONCRETE FORM SECT (LARGE)
COLUMN SECTION
SPECIAL CONC. FORM SECT @ 270°
SPECIAL CONC. FORM SECT @ 345°
CONC FORM SECT (SPECIAL END)
CBI INDUSTRIES, INC.
SHELL AND CONCRETE FORM
SHIPPING ASSY - RING NO. 3
180° TO 0° SECTION
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
BEN SHEPHERD
85307IER

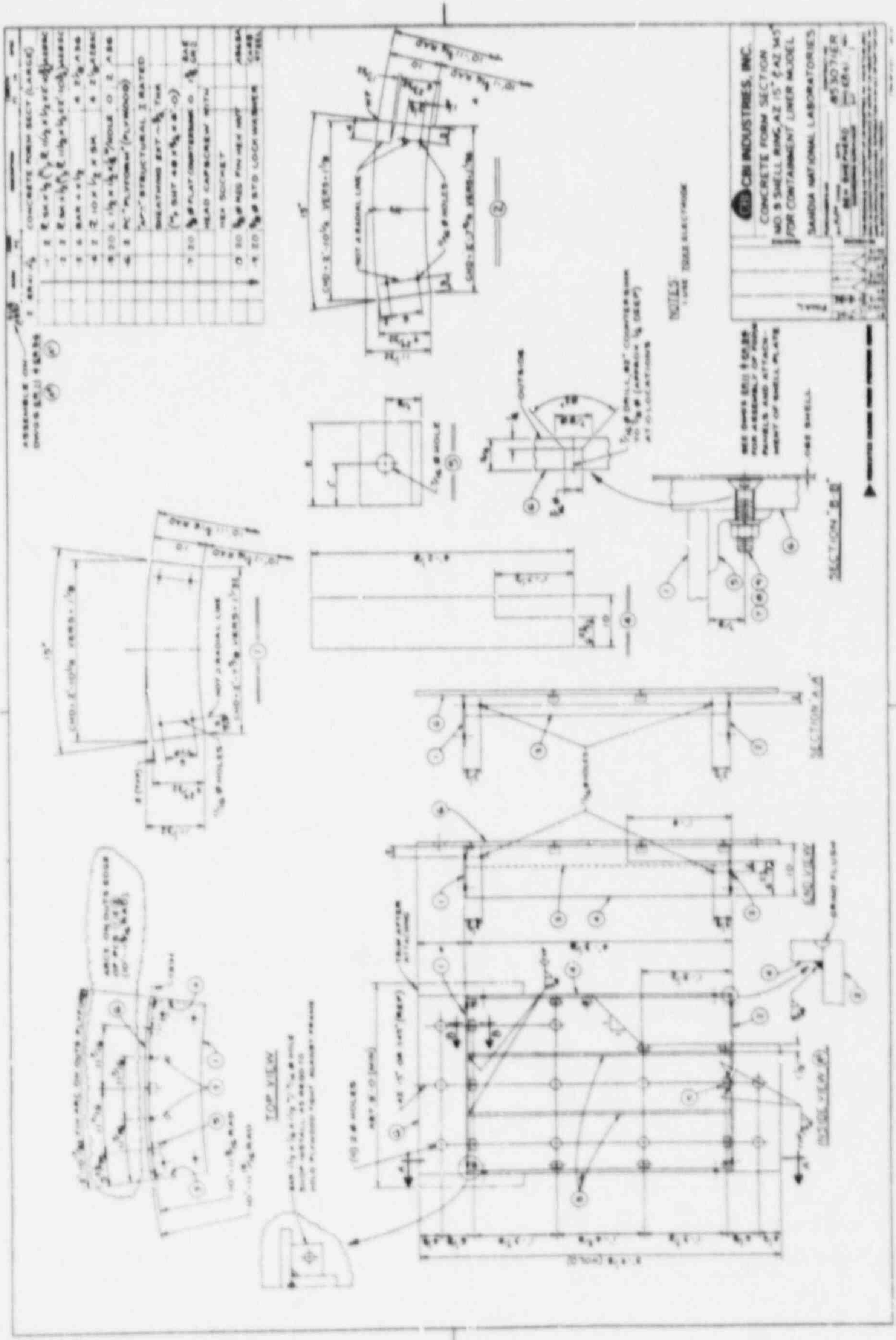

CBI INDUSTRIES, INC.
SPECIAL CONCRETE FORM DETAILS FOR EQUIPMENT HATCH A
CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
INSIDE STRETCH OUT VIEW
NOTES:


CBI INDUSTRIES, INC.
CONCRETE FORM SECTION
SANDIA NATIONAL LABORATORIES
NOTES
1 USE 7018 WELD ELECTRODE
INSIDE VIEW
SIDE VIEW
TOP VIEW
SECT A-A
TRIM AFTER ATTACHING
GRIND FLUSH

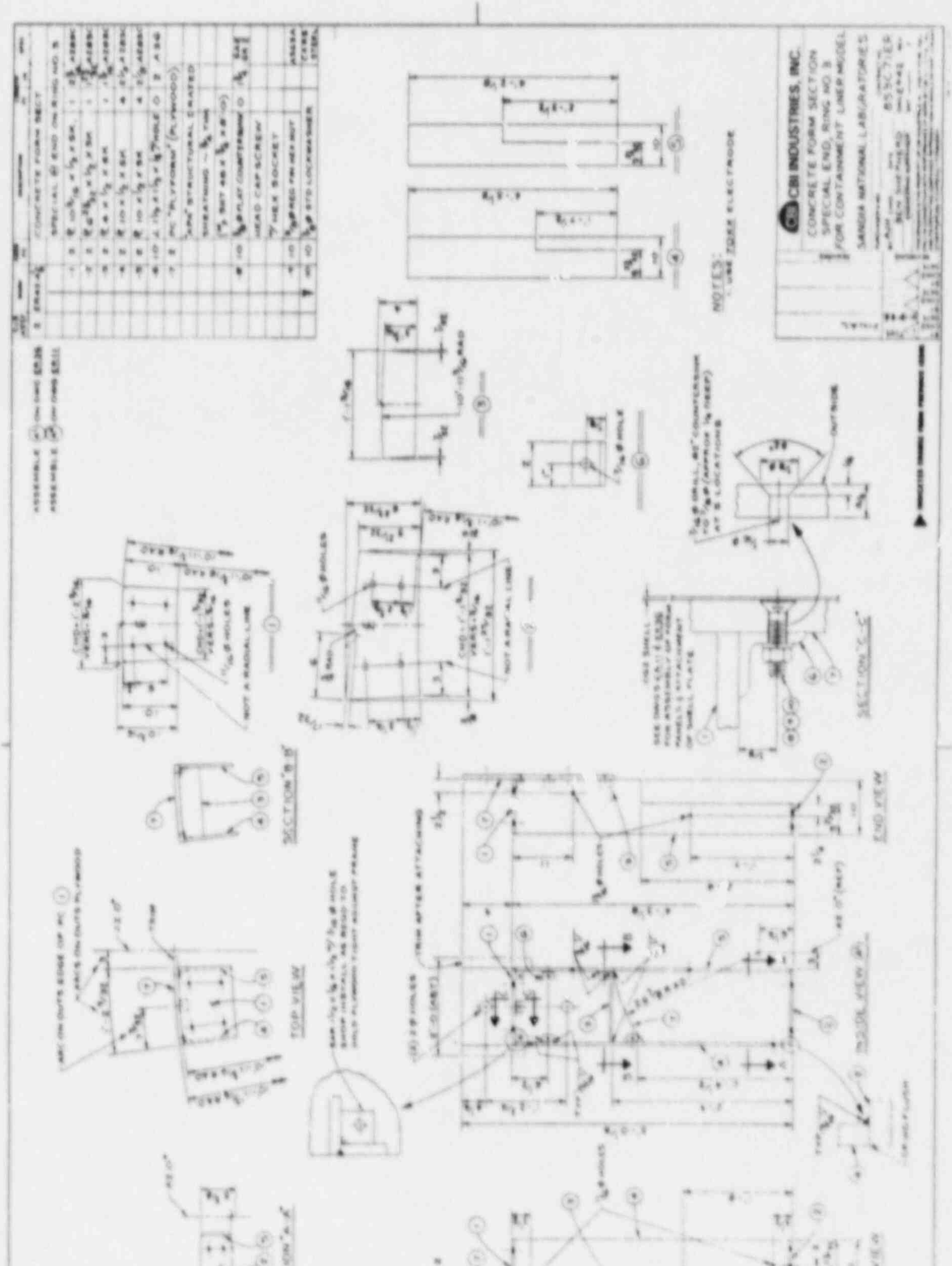


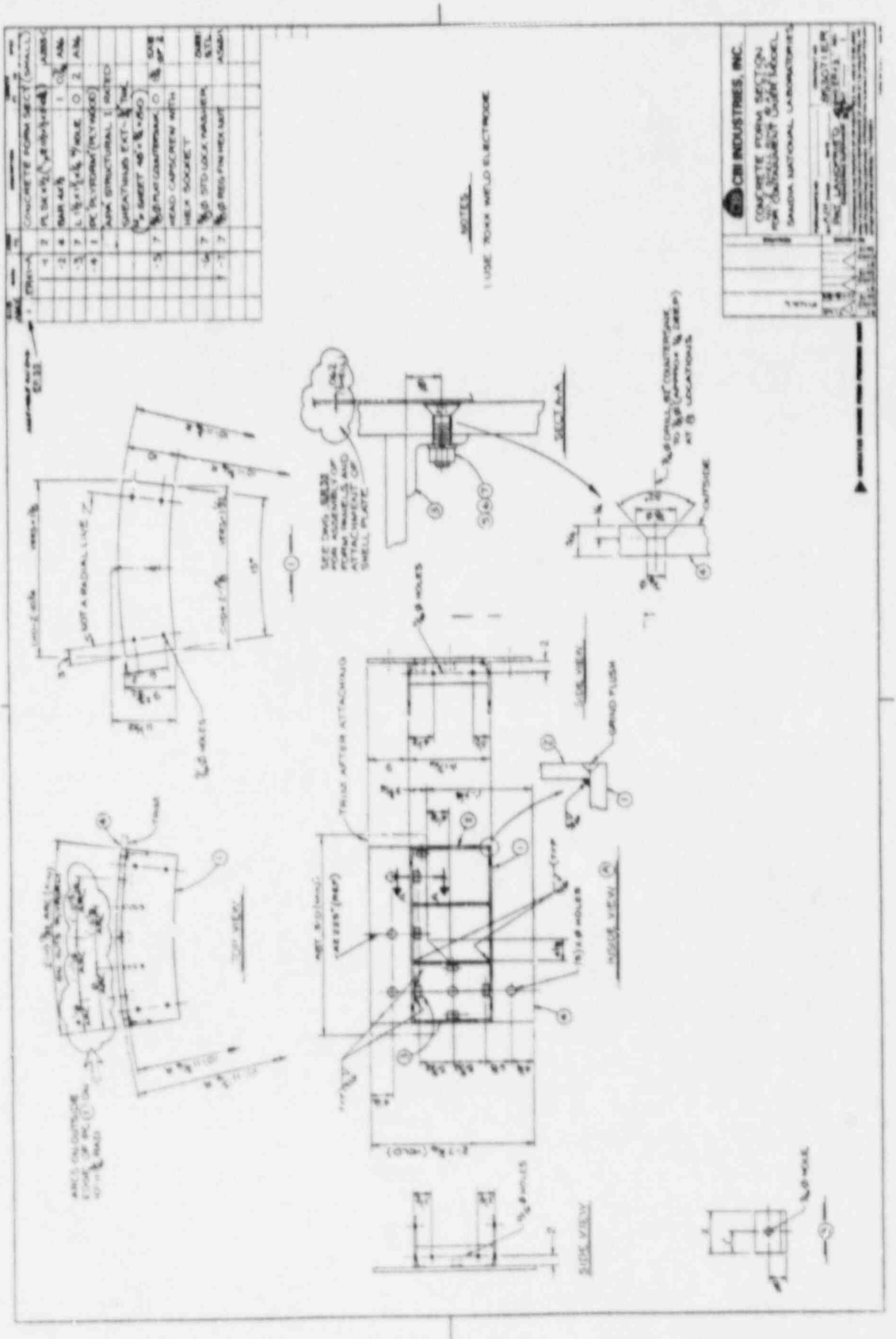
CBI INDUSTRIES, INC.
SANDIA NATIONAL LABORATORIES
NOTES
1. USE 70XX WELD ELECTRODE
SECTION A-A
SIDE VIEW
TOP VIEW
INSIDE VIEW (A)

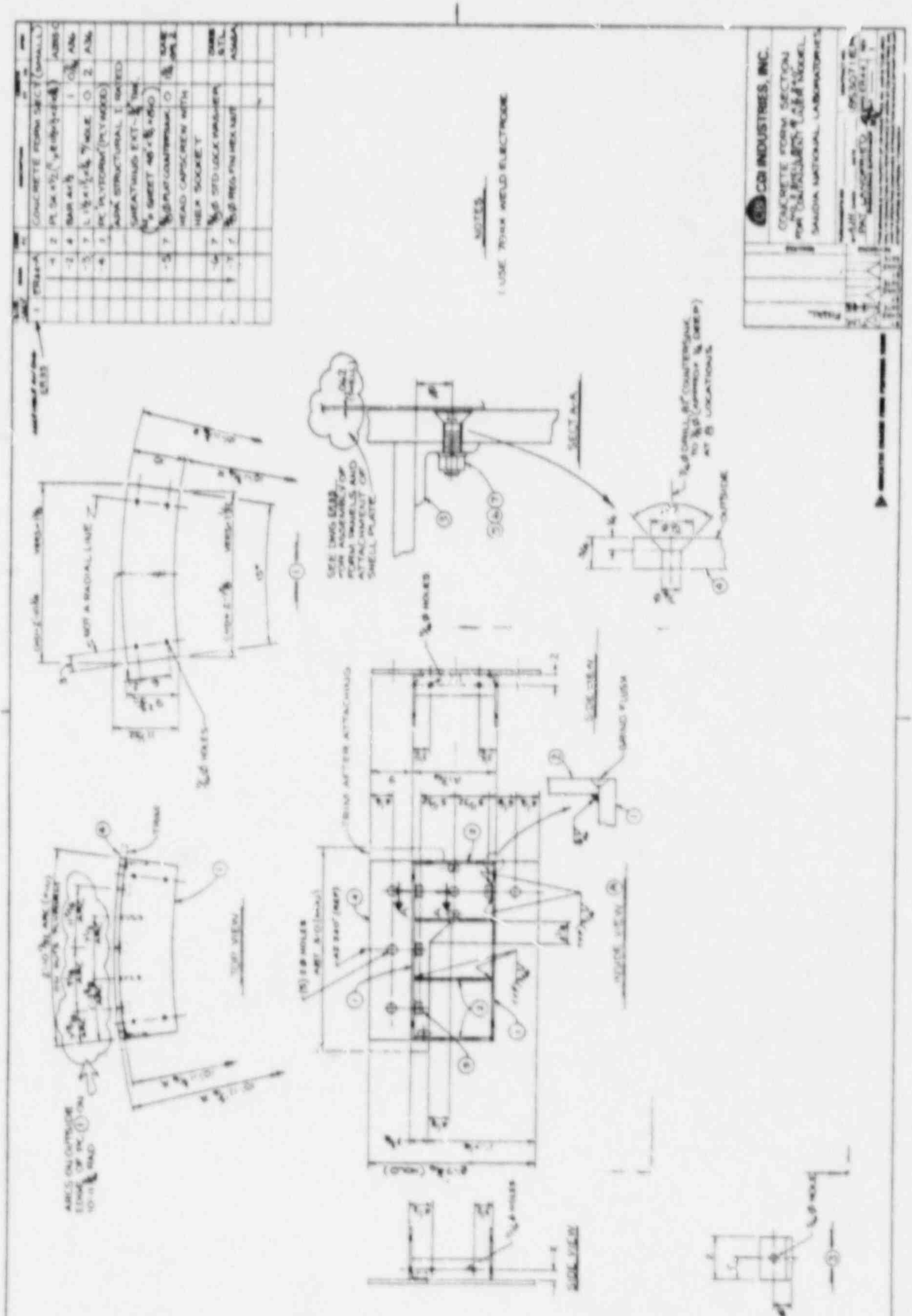


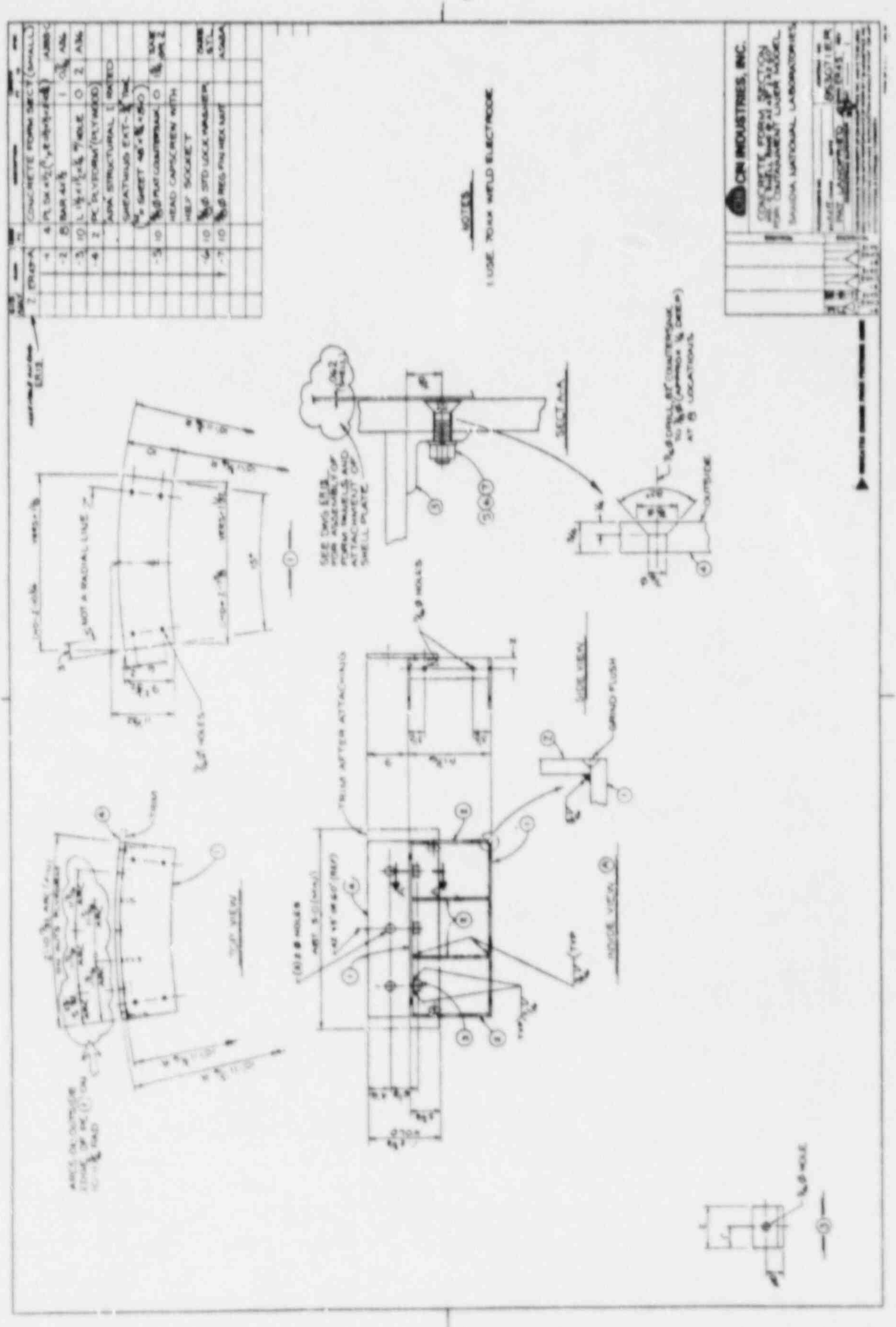


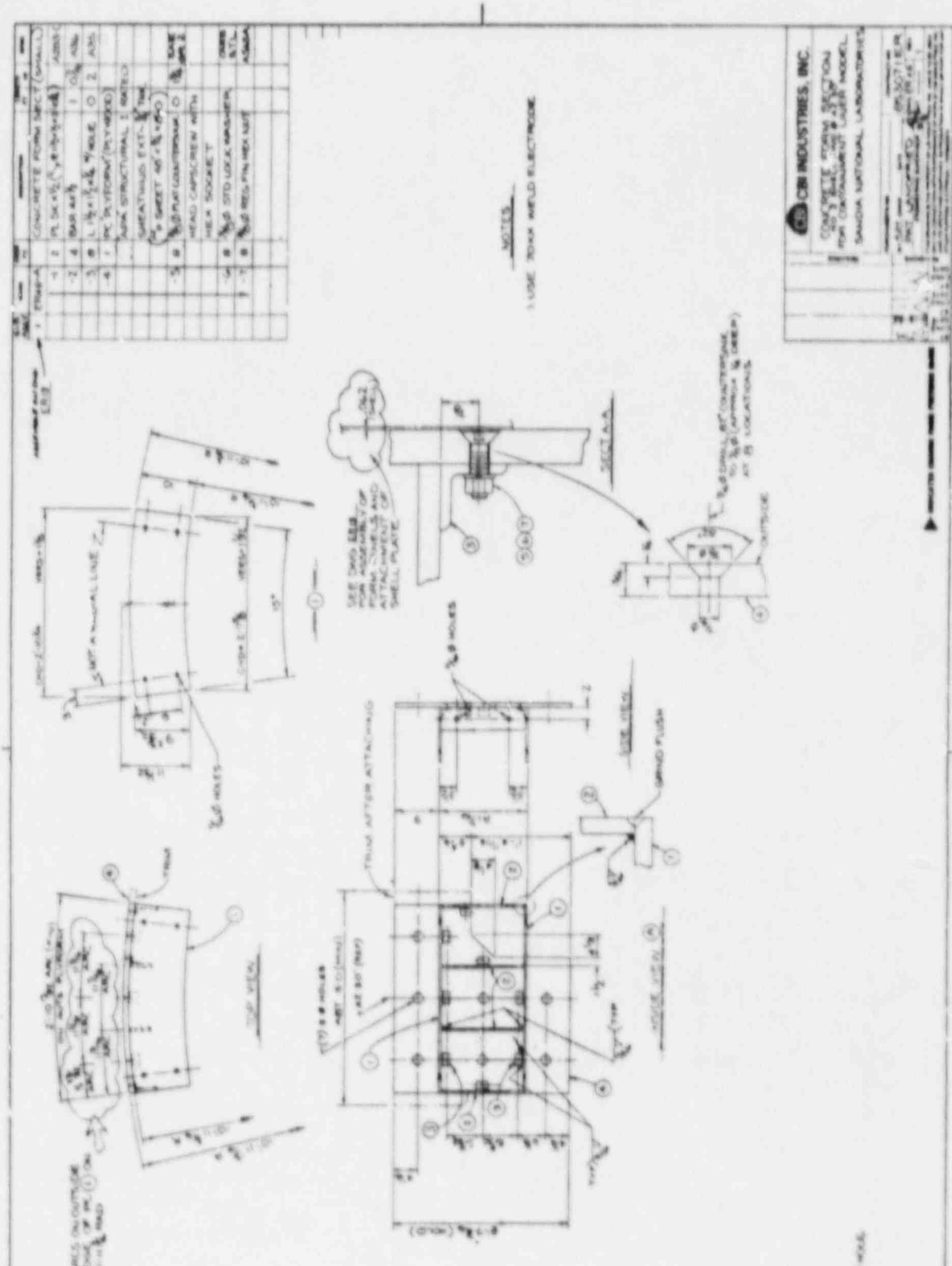
CBI INDUSTRIES, INC.
CONCRETE FORM SECTION
NO 9 SHELL RING, AZ 15° & AZ 345°
FOR CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
TOP VIEW
END VIEW
SECTION "A-A"
SECTION "B-B"
NOTES:

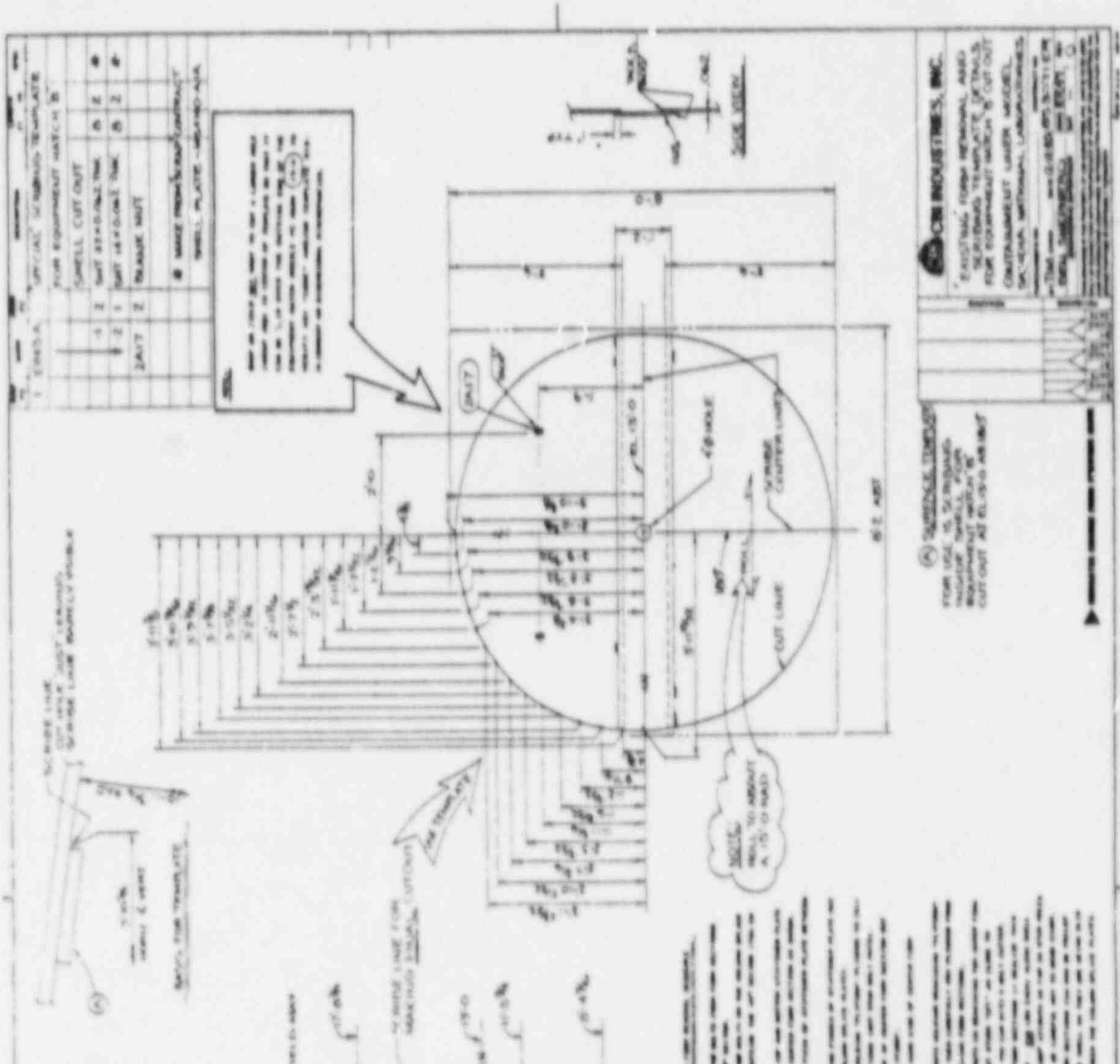

CBI INDUSTRIES, INC.
CONCRETE FORM SECTION
SPECIAL END, RING NO 3
FOR CONTAINMENT LINER MODEL
SANDIA NATIONAL LABORATORIES
NOTES:
SECTION "A-A"
TOP VIEW
SECTION "B-B"
SECTION "C-C"
END VIEW
INSIDE VIEW

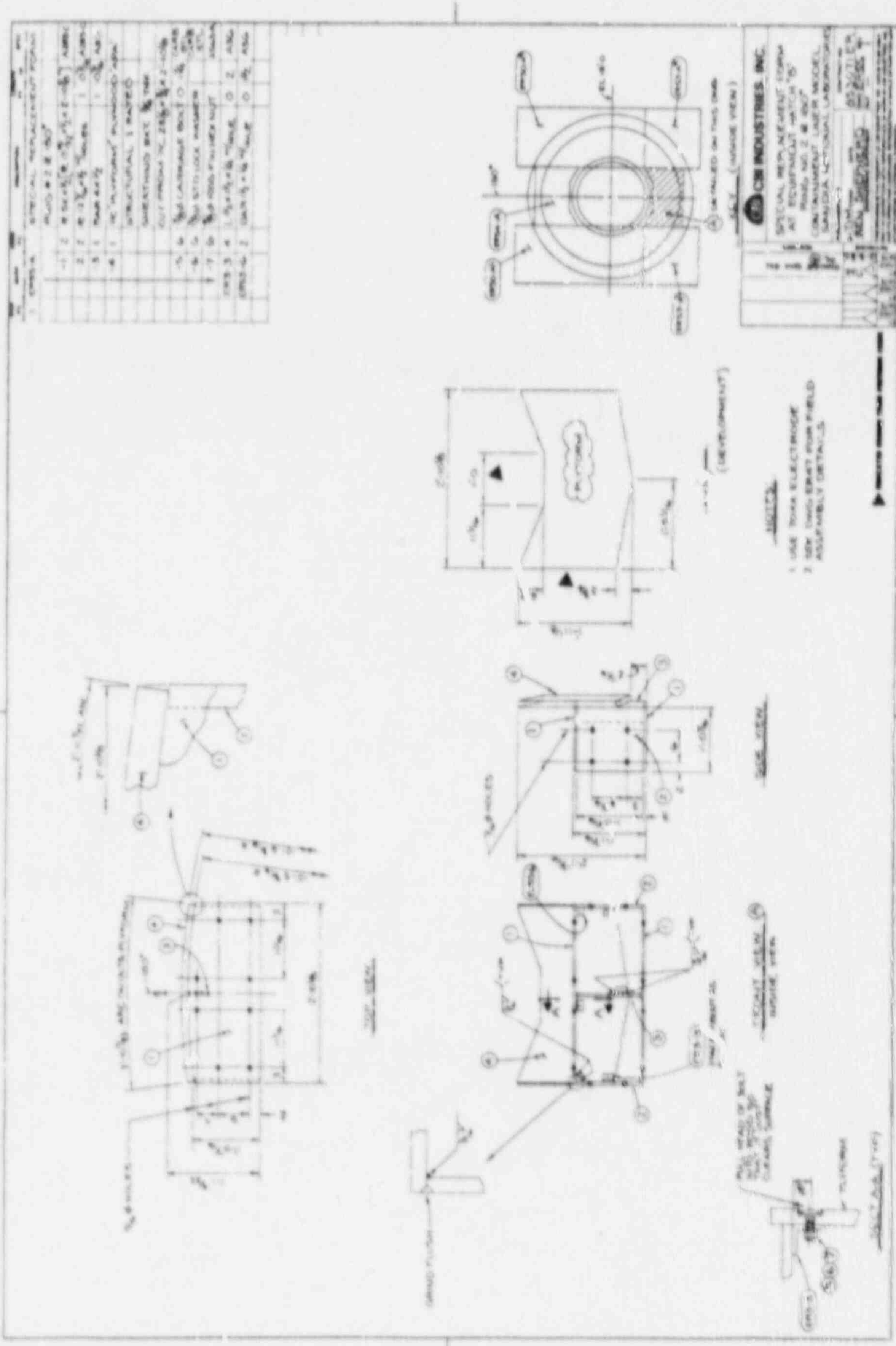

CBI INDUSTRIES, INC.
SANDIA NATIONAL LABORATORIES
NOTES:
1. USE 7018X WELD ELECTRODE
TOP VIEW
INSIDE VIEW
SIDE VIEW
SECT A-A
GRIND FLUSH
TRIM AFTER ATTACHING

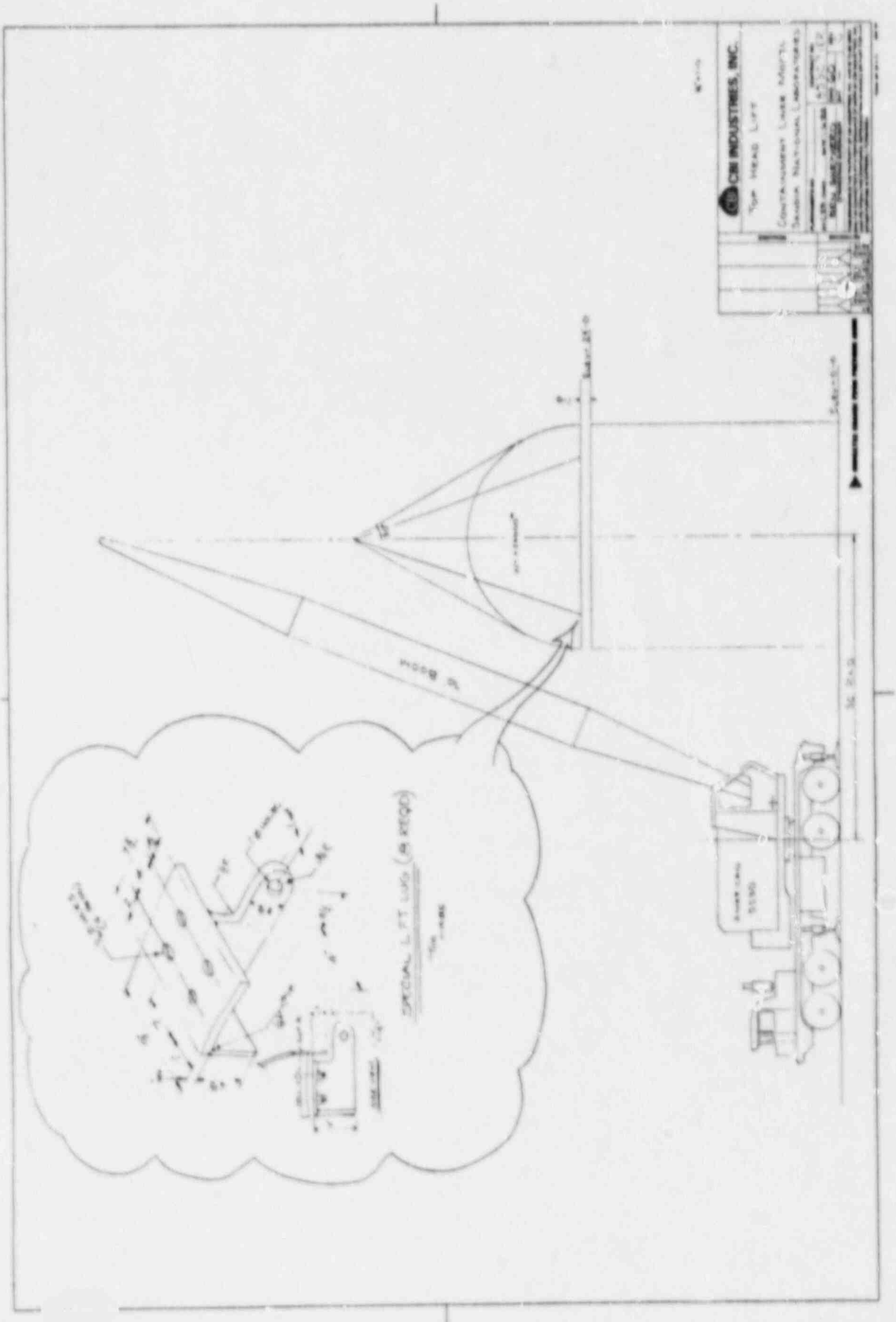


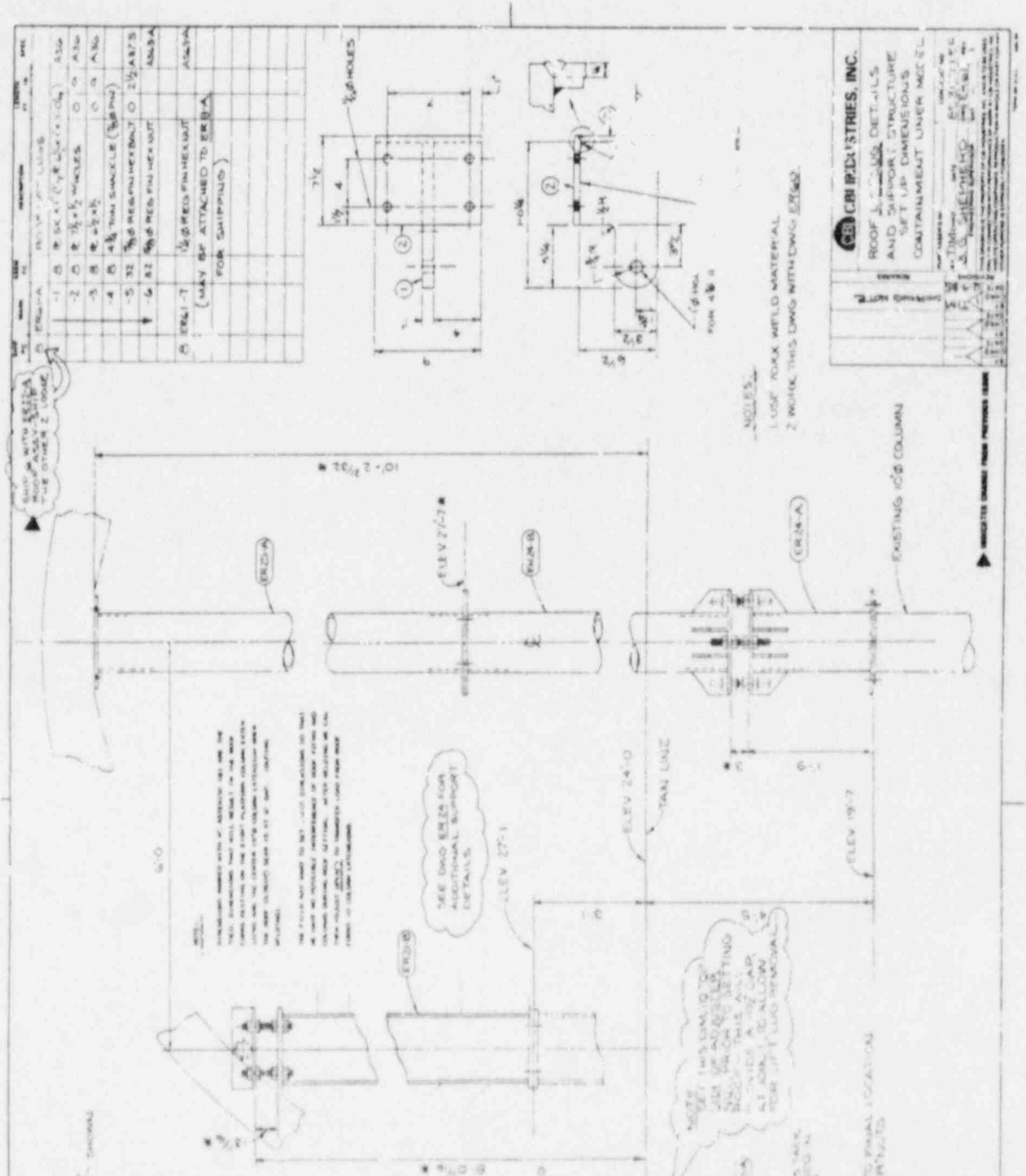

CBI INDUSTRIES, INC.
SANDIA NATIONAL LABORATORIES
TOP VIEW
INSIDE VIEW
SIDE VIEW
SECT A-A
NOTES
1 USE 70XX WELD ELECTRODE
TRIM AFTER ATTACHING
GRIND FLUSH
OUTSIDE


CBI INDUSTRIES, INC.
SANDIA NATIONAL LABORATORIES
NOTES
1. USE 70XX WELD ELECTRODE
TOP VIEW
SIDE VIEW
SECT A-A
TRIM AFTER ATTACHING
GRIND FLUSH
OUTSIDE




CBI INDUSTRIES INC.
TOP VIEW
SIDE VIEW
NOTES
(DEVELOPMENT)


CBI INDUSTRIES, INC.
TOP HEAD LIFT
SANDIA NATIONAL LABORATORIES
SPECIAL LIFT LUG (4 REQD)
AMERICAN 5530


CBI INDUSTRIES, INC.
ROOF LIFTING DETAILS AND SUPPORT STRUCTURE SET UP DIMENSIONS CONTAINMENT LINER MODEL
NOTES:
ELEV 24'-0
TAN LINE
ELEV 19'-7
ELEV 27'-1
EXISTING 10'Ø COLUMN
SEE DWG ER23 FOR ADDITIONAL SUPPORT DETAILS
ROOF ASSY
KEY PLAN
(MAY BE ATTACHED TO ER8-A FOR SHIPPING)

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE

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SAND88-0030

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Design, Construction, and Instrumentation of a 1/6-Scale Reinforced Concrete Containment Building

3. LEAVE BLANK

4. DATE REPORT COMPLETED

MONTH	YEAR
June	1988

5. AUTHOR(S)
D. S. Horschel

6. DATE REPORT ISSUED

MONTH	YEAR
August	1988

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Albuquerque, NM 87185

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Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

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Topical

b. PERIOD COVERED (Inclusive dates)

12. SUPPLEMENTARY NOTES

13. ABSTRACT (200 words or less)

This report describes the design, construction, and instrumentation of a 1/6-scale reinforced concrete containment building that has been built at Sandia National Laboratories in Albuquerque, New Mexico. The model Light Water Reactor (LWR) containment building was designed and built to the American Society of Mechanical Engineers (ASME) Code by United Engineers and Constructors, Inc. The containment model will be tested to failure to determine its response to static internal overpressurization. The results from testing the heavily instrumented containment will be used to assess the capability of analytical methods for predicting the performance of containments subject to severe accident loads as part of the U.S. Nuclear Regulatory Commission's program on containment integrity.

The scaled dimensions of the cylindrical wall and hemispherical dome are typical of a full-size containment. Features representative of a prototypical containment and included in the heavily reinforced model are equipment hatches, personnel airlocks, several small piping penetrations, and a thin steel liner attached to the concrete by headed studs.

Over 1200 channels of instrumentation will be used to assess the model's behavior during testing. Several video and still camera stations are also used during testing of the containment for both data gathering purposes and for support in conducting the test.

14. DOCUMENT ANALYSIS - a. KEYWORDS/DESCRIPTORS

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concrete

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