INSTRUCTION MANUAL

PART ONE

AERODYNAMIC THERMAL SIMULATION SYSTEM

RADIANT ARRAY

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812

(Reference: Contract Number NAS8-26416)

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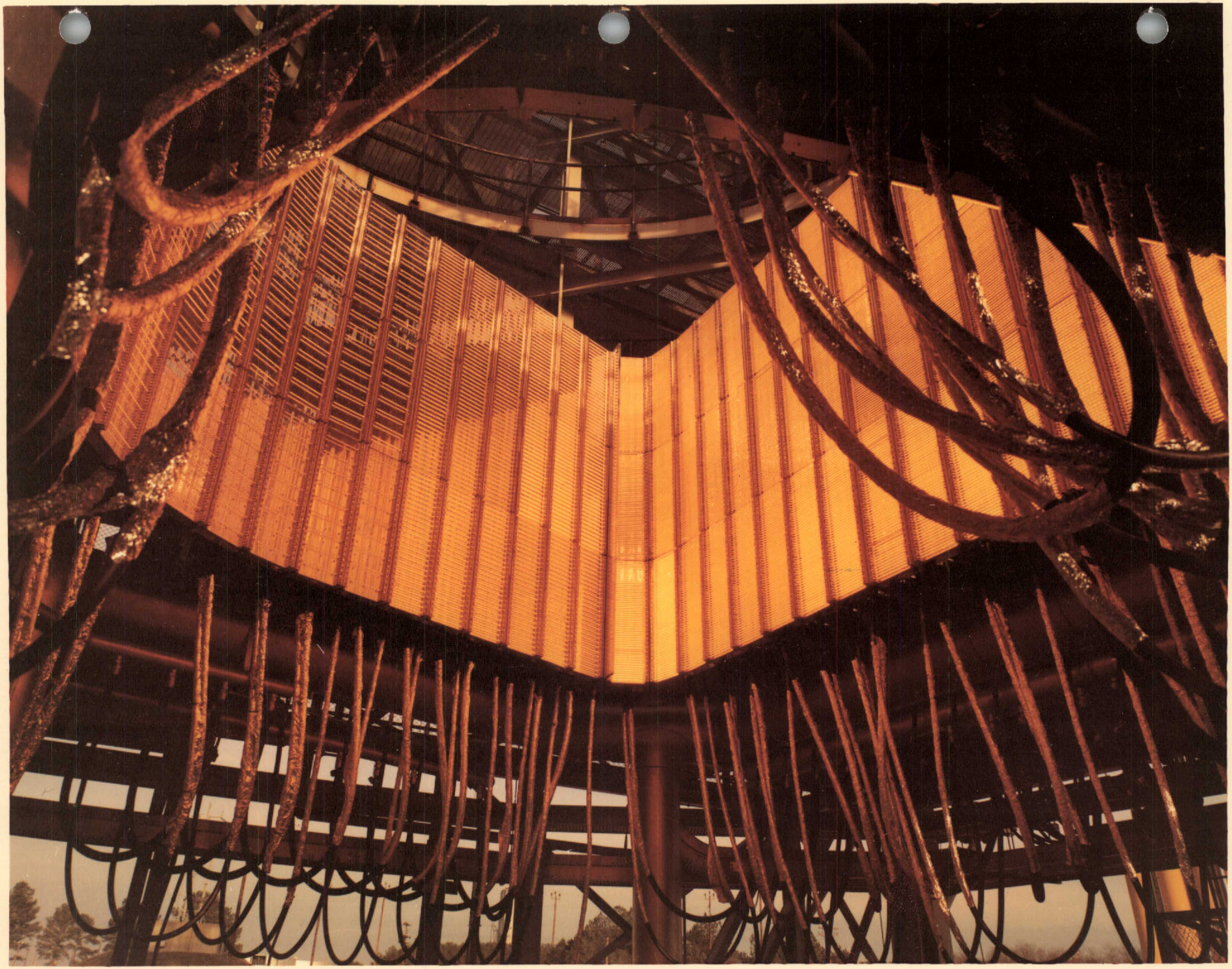

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Note: * indicates the preceding page number of text material.

SECTION 1 - INTRODUCTION

1-1 SCOPE

This manual pertains to an aerodynamic thermal simulation system located at the George C. Marshall Space Flight Center in Alabama. This system was designed and built by RESEARCH INC in Minneapolis, Minnesota under MSFC Contract Number NAS8-26416.

This manual describes the system construction, set up, maintenance, and operation. The system is divided into two major parts (a) the Radiant Array and (b) the Controls.

1-2 FORMAT

This manual is divided into three parts. Each part is contained in a separate book as follows:

TABLE 1-1 MANUAL PARTS

Part or Book	Title
ONE	Radiant Array
TWO	System Controls
THREE	Related Reference Material

Therefore, this book contains Part 1 of the manual, concerned with the radiant array.

Additional information concerning design philosophy and calculations can be found in a document titled "Final Report for the Preliminary Design of an Aerodynamic Thermal Simulation System", Revision A by A. F. Kitchar and R. L. Stuefen dated 13 September 1971.

1-3 BASIC REQUIREMENT

The aerodynamic thermal simulation system is primarily designed to subject various configurations of the Space Shuttle to the dynamic heating conditions it may encounter in ascent and reentry flight. This is done by irradiating the test article surface with dynamic radiant heat energy generated from an array of tubular quartz tungsten filament emitter sources in a surrounding radiant array as shown on the colored fore figure. The surrounding array is divided into many (i.e., up to 36) separate controllable zones in order to create the desired aerodynamic heat flux profile over a large surface area.

SECTION 2 - SYSTEM DESCRIPTION

2-1 GENERAL

This aerodynamic thermal simulation system is designed to test various scaled down versions of the Space Shuttle vehicle (i.e., test article) fuselage sections. It is designed to simulate both ascent and reentry aerodynamic heating conditions under the dynamic conditions such a vehicle will encounter in flight.

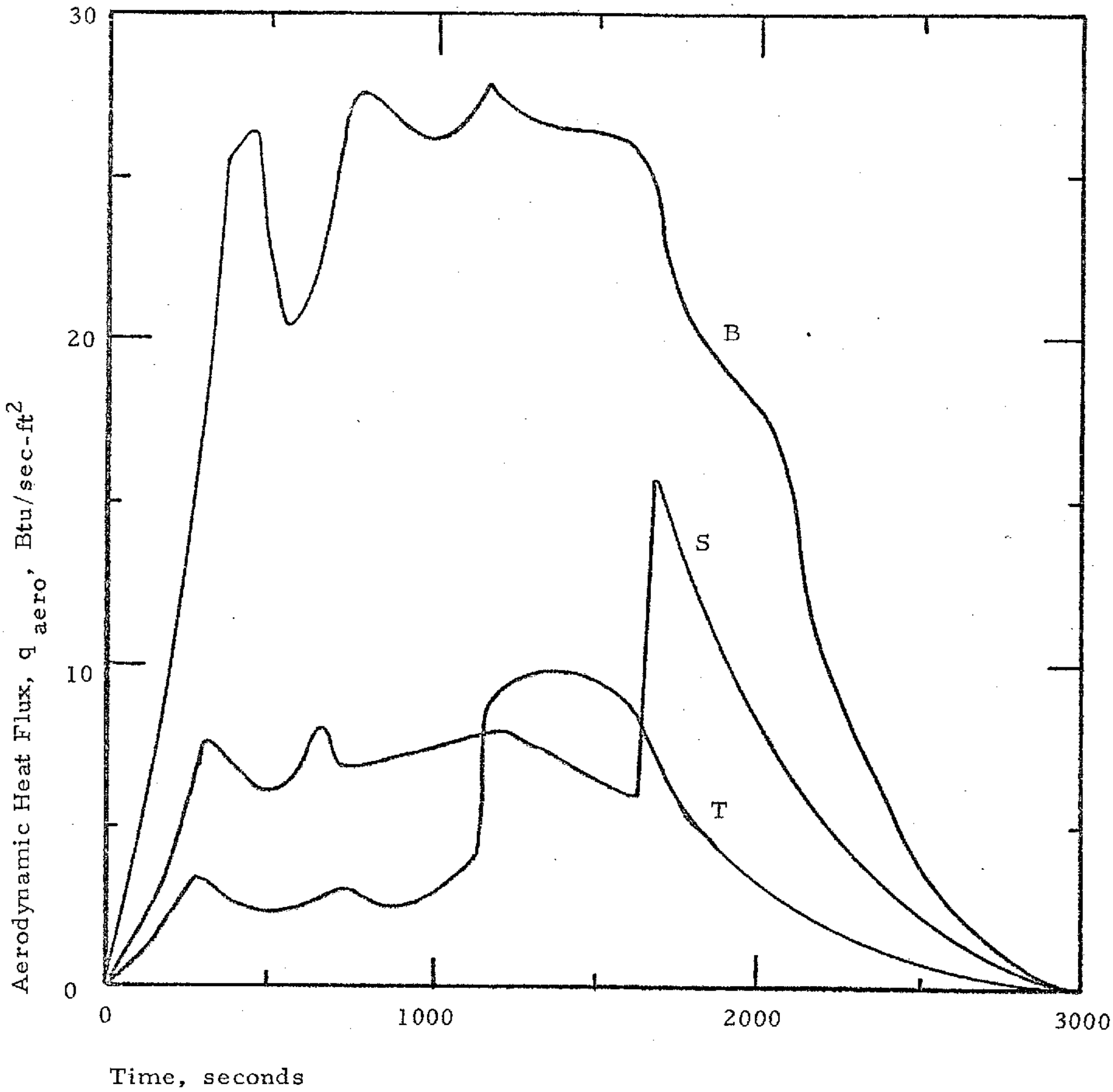
These aerodynamic heating conditions are simulated by irradiating the test article surface with dynamic responding radiant heat energy generated from rapid responding high density radiant heat sources. The test article is surrounded with an array of modular high density radiant heating units. These surrounding radiant heating units are divided into "regions" that represent a particular aerodynamic heat flux profile. There are basically three regions having aerodynamic heat flux profiles similar to those shown on Figure 2-1.

Since the regions can be quite large, depending upon article size, the region is divided into many separate controllable zones in order to insure that the entire area of the region is uniformly heated.

An output signal of a control sensor, representing temperature or heat flux, located on the test article near the center of each zone, is programmed according to the aerodynamic heating profile. The sensor signal from each zone is fed into a precision temperature controller that commands the distributed zero cross over solid state power regulators to provide the required radiant heating unit voltage. The surroudning radiant heating units provide the heat necessary to produce the desired control sensor signal. The conditions at the control sensor represent the test article surface condition over the entire zone.

The aerodynamic heat profile is realized by programming the setting of the precision temperature controller. There is a programmer for each region of the radiant array, (a) the Top, $1200^{\circ}F$ region, (b) the Side, $1800^{\circ}F$ region, and (c) the Bottom, $2500^{\circ}F$ region.

The reducing heat flux portion of the aerodynamic heating profiles is simulated by uniformly introducing gaseous nitrogen into the radiant chamber onto the test article surface. The required gaseous nitrogen is controlled by a proportional regulating valve for each region as controlled by the system controls.



B - Bottom Region; Body point 1 - 1792 mile cross range
S - Side Region; Body point 2 - 1792 mile cross range
T - Top Region; Body point 3 - 1792 mile cross range

FIGURE 2-1 TYPICAL AERODYNAMIC HEAT FLUX PROFILES

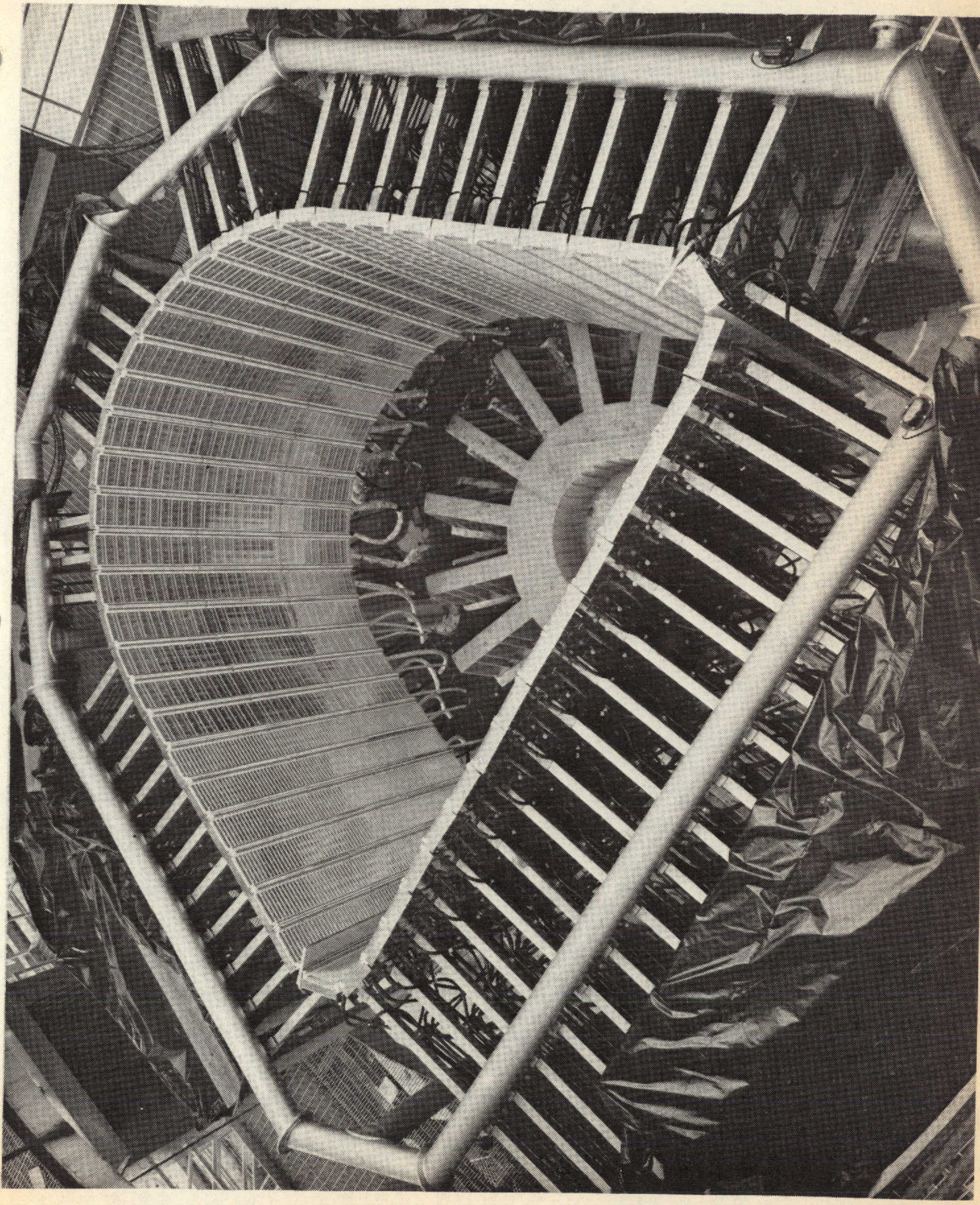


FIGURE 2-2 RADIANT ARRAY TOP VIEW

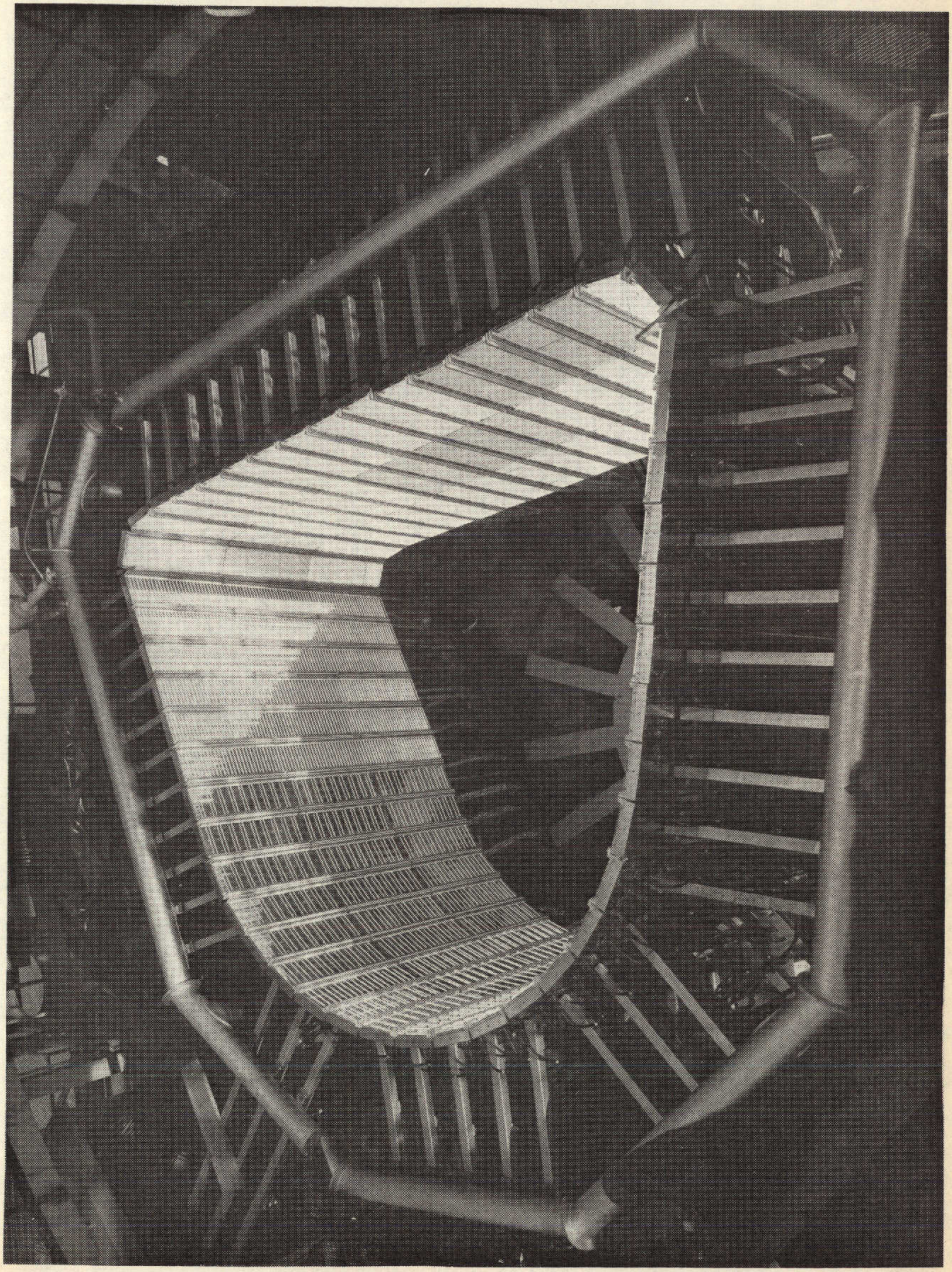


FIGURE 2-3 RADIANT ARRAY WITH LAMPS ENERGIZED

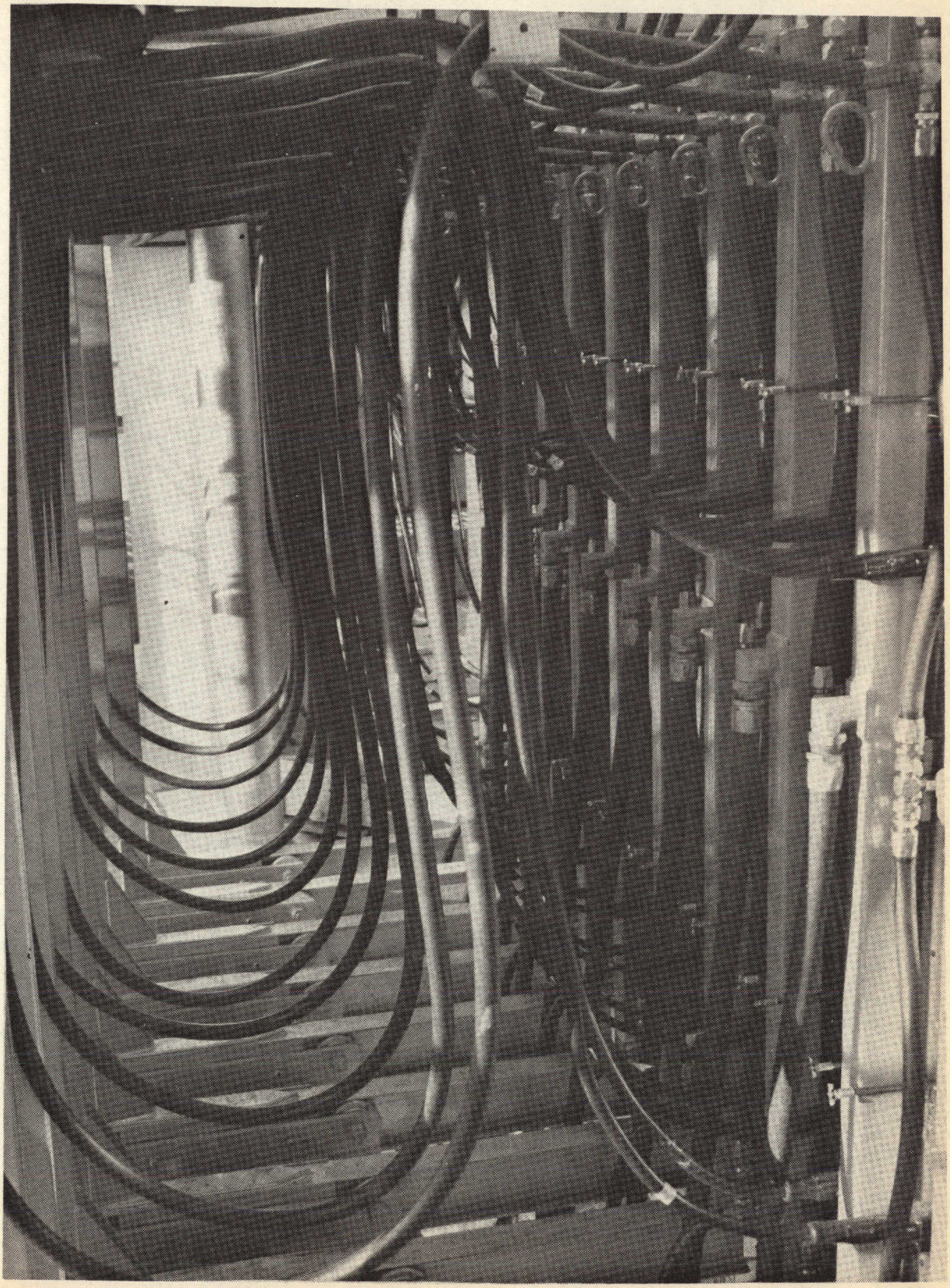


FIGURE 2-4   REAR VIEW OF MODULAR UNIT ROWS

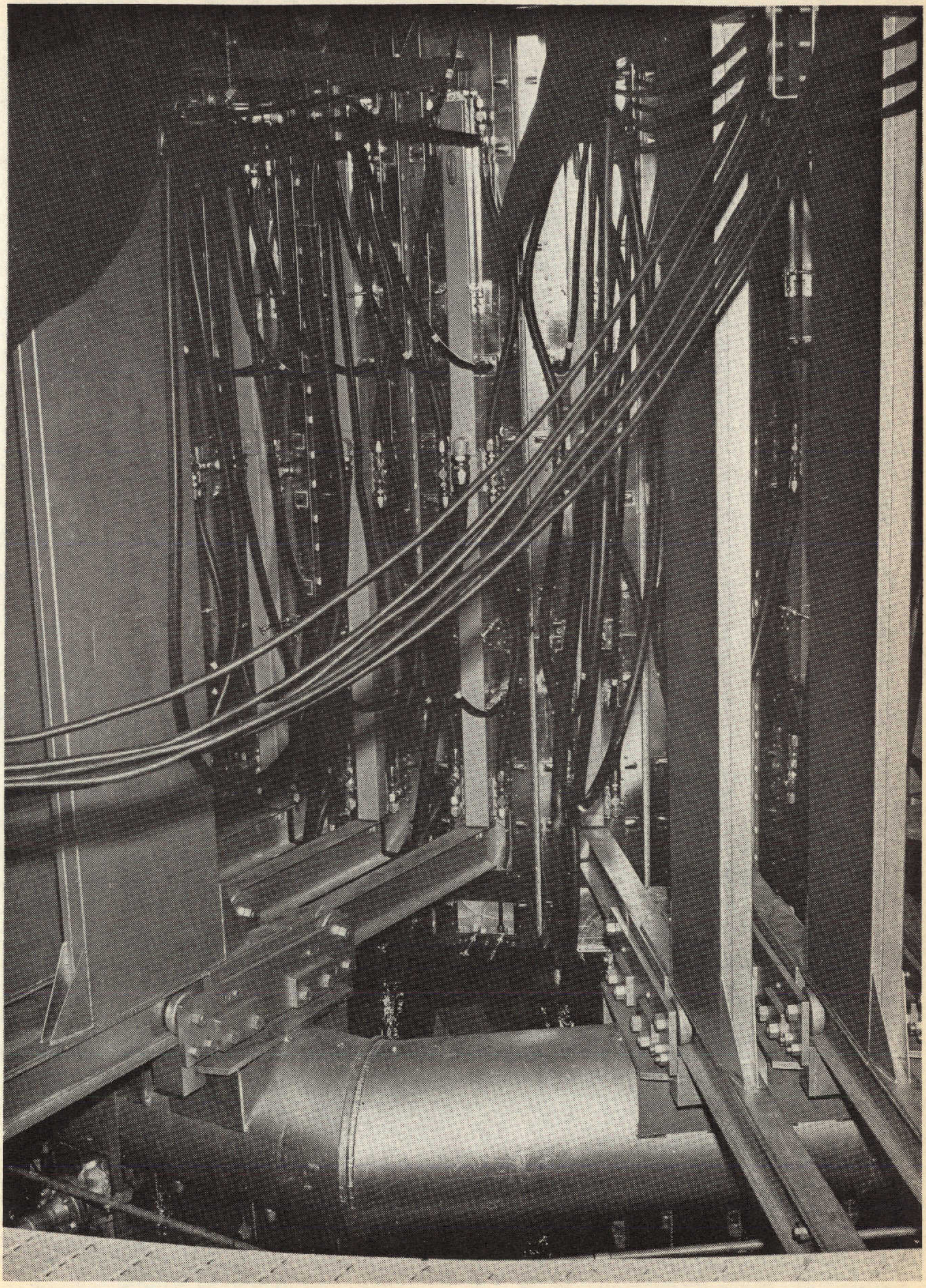


FIGURE 2-5 DETAIL STANCHION VIEW

The system is capable of producing the following test article skin equilibrium temperatures:

TABLE 2-1 EQUILIBRIUM TEMPERATURE CAPABILITY	
Region	Test Article Skin Equilibrium Temperature, ^{o}F
Top	1200
Side	1800
Bottom	2500

2-2 THE RADIANT ARRAY

The radiant array completely surrounds a test article with as many as 144 modular radiant heating units as shown in Figure 2-2. The test article would be placed inside this cavity and rest on the support spider base shown at the base.

Figure 2-3 shows the array energized at a low power level. The Top 1200°F region is at the left where the radiant emmiter density (i.e., lamp density) is sparse. The Side 1800°F region is at the top and bottom of the figure where the lamp density is greater. The Bottom 2500°F region is at the right where the lamp density is greatest. The modular radiant heating units are 13 inches wide and mounted in sets of three to comprise an individual adjustable row. They are supported on adjustable frames that are cantelevered from a peripheral main frame. The main frame is welded steel tube and also serves as a cooling water distribution manifold for the entire radiant array.

All services, such as (a) power, (b) cooling water, and (c) gaseous nitrogen connect to the radiant units at the rear side. Figure 2-4 shows these various flexible power leads, water lines, and GN_2 lines at the rear of the modular unit rows.

The cantelevered adjustable frame (i.e., stanchion frame) for supporting each individual modular unit row is supported by an adjustable ball bearing roller carriage assembly welded to a large peripheral steel structure tube of the main frame as shown on Figure 2-5.

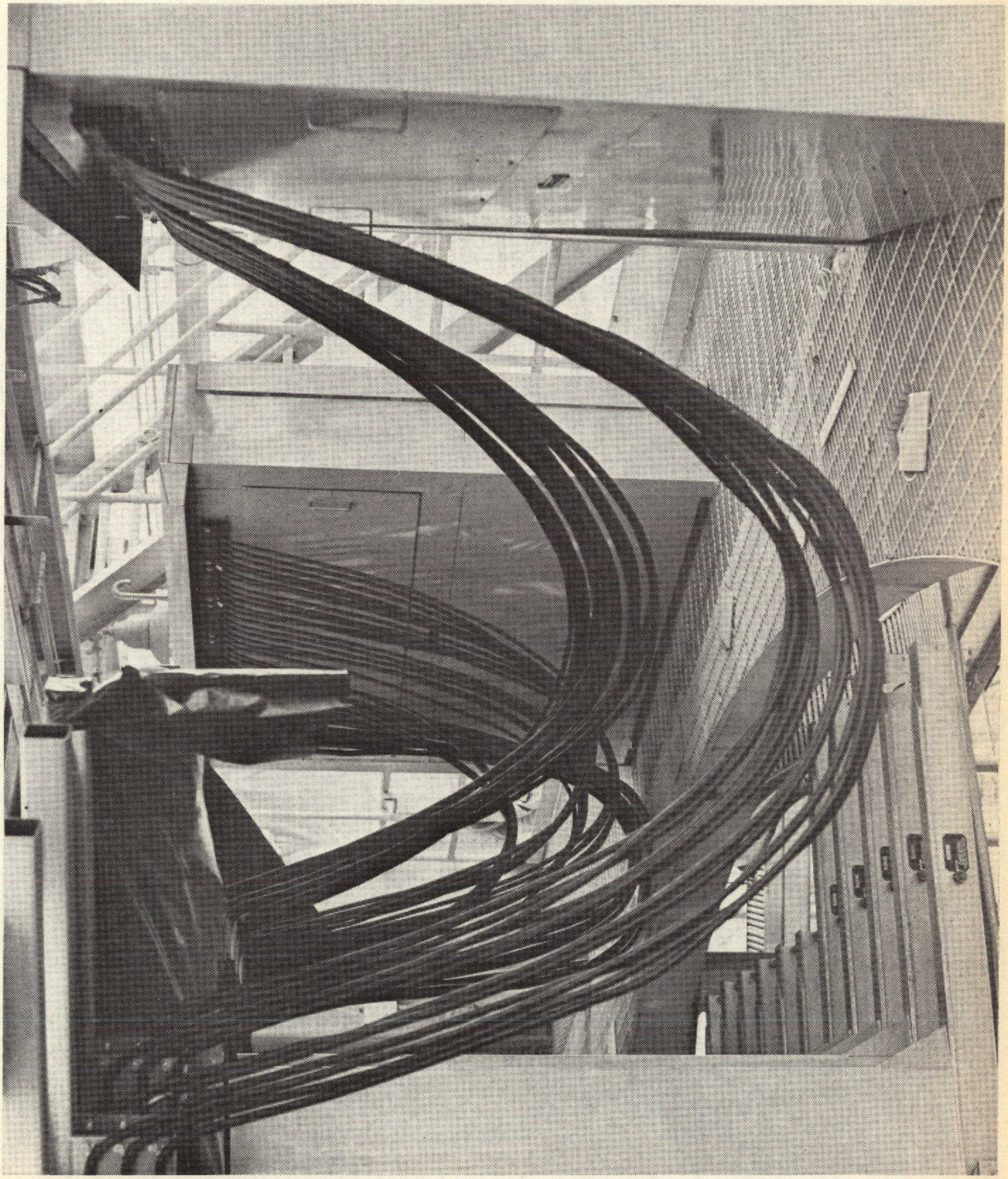


FIGURE 2-6   FLEXIBLE POWER LEADS FROM LINK PANEL CABINET

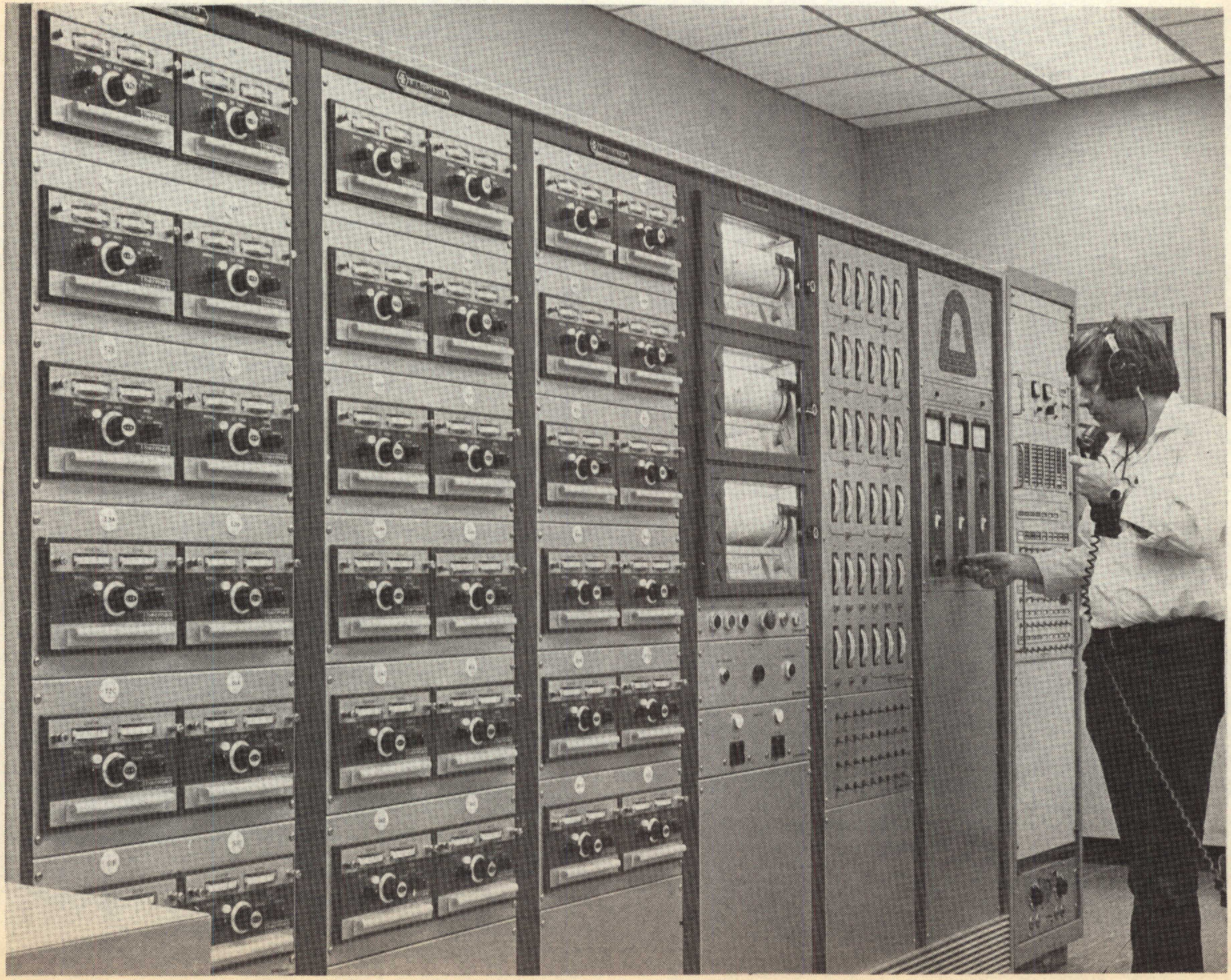


FIGURE 2-7   MASTER CONTROL CONSOLE

5-8

In order to provide for radiant array configuration adjustability, all service lines to the surrounding array of modular heater units are connected via flexible leads. Figure 2-6 shows the flexible power leads from ten power link panel cabinets located at the periphery of the entire array and draping to each of the adjustable stanchion frames. The power enters these link panel cabinets from a bus duct system under the floor grating.

2-3 THE CONTROLS

There are controls for each of the 36 zones in the radiant array. The system master control console is located in a remote block house. Figure 2-7 shows the control console layout. There are 36 precision solid state temperature controllers located in the first three racks from the left. The aerodynamic heating programmers (i.e., Data Traks) for each of the three regions, Top, Side, and Bottom are located in the fourth rack along with master start and stop buttons. The fifth rack contains an array of 36 load voltmeters and zone selector switches. The sixth rack is provided with radiant array cooling water flow indicator lights and manual gaseous nitrogen controls.

The controls are discussed in greater detail in Part 2 of the manual titled "System Controls".

2-4 BASIC SPECIFICATIONS

The following sections describe some of the basic specifications for the Test Article and Radiant Array.

2-4-1 Test Article

2-4-1-1 Irradiated Area: Up to 66,648 inches^2 = 462 ft^2 as is the case for the maximum envelope, test article number 1 shown on Figure 2-9.

2-4-1-2 Shape: A variety of shapes approximately cylindrical with vertical axis like those shown for the typical configurations shown on Figures 2-9 through 2-13.

2-4-1-3 Vertical Height: 120 inches = 10 feet, maximum, centered 185 inches from concrete slab of SII stand as shown on Figure 7-2.

2-4-1-4 Irradiated Regions: Top 1200°F, Side 1800°F, and Bottom 2500°F typically shown on Figure 2-9.

2-4-1-5 Surface Emittance: Ranging from .6 to .9

2-4-1-6 Heat Capacity: Negligible

2-4-1-7 Internal Heat Loss from Surface: Near zero.

2-4-1-8 Maximum Equilibrium Temperature: Top Region: 200 to 1200°F
Side Region: 200 to 1800°F
Bottom Region: 300 to 2500°F

2-4-1-9 Heating Rate: Depends upon test article heat capacity and internal heat loss of test article skin. Figure 2-8 shows an example for .035 inch thick oxidized stainless steel.

2-4-2 Radiant Array

2-4-2-1 Regions: There are three regions, one for each aerodynamic heating temperature profile. They are the Top, Side and Bottom.

2-4-2-2 Zones: Up to 36 zones located throughout the three regions as described in Sections 4-2-2 and 4-2-3.

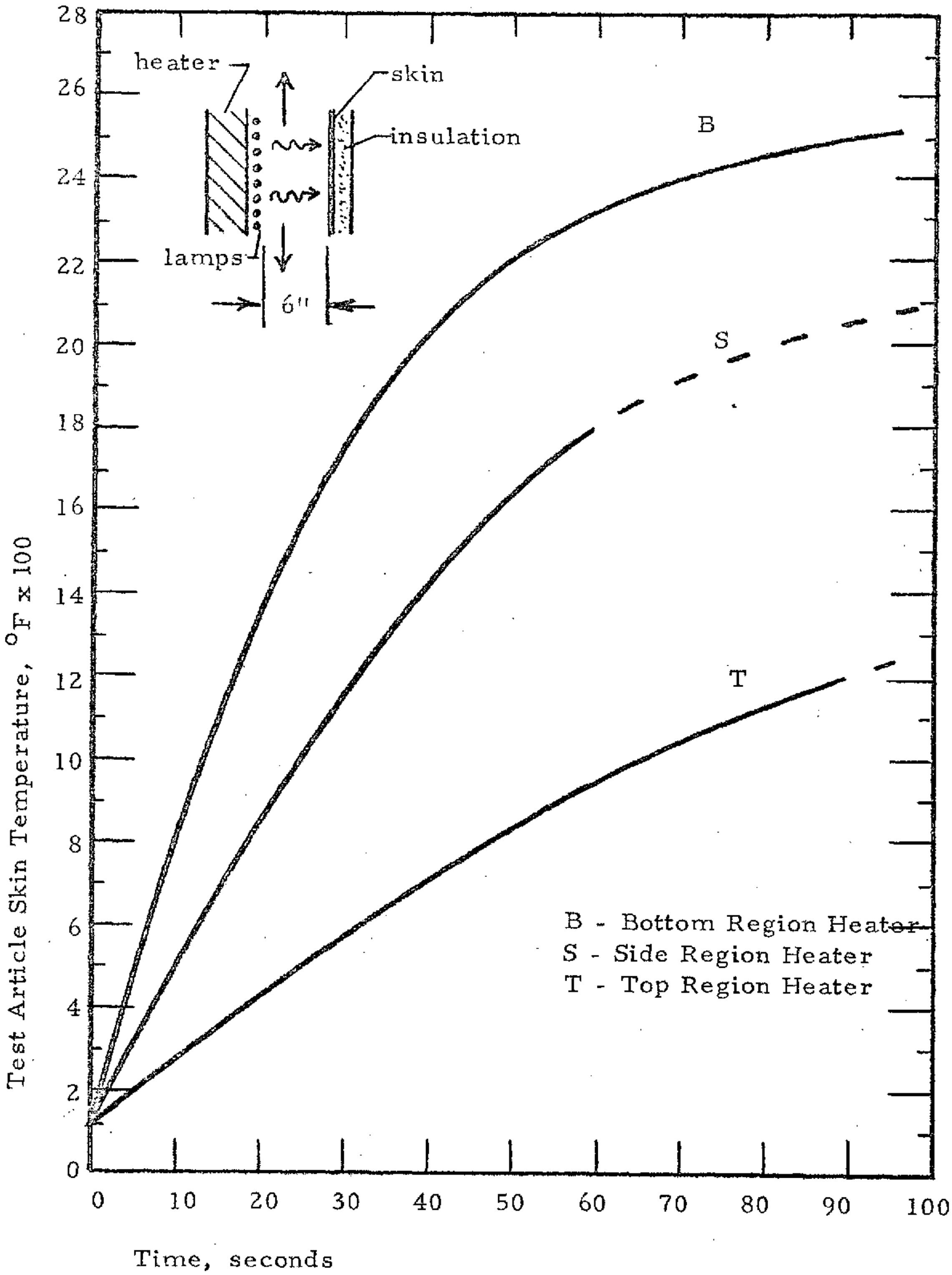
2-4-2-3 Modular Radiant Heat Units: Up to 144 modular radiant heating units can be configured to irradiate various test articles. Reference Section 4-2-2.

2-4-2-4 Configuration Adjustment: The radiant array frame is adjustable over a wide range to accommodate nearly any configuration such as those shown on Figures 2-9 through 2-13.

2-4-2-5 Radiant Heat Source: Rapid responding tubular filament radiant heat lamp number 1000 T3/CL/HT or Q3M T3/CL/HT as described in Section 3-1-6.

2-4-2-6 Response: Approximately one second as described in Section 3-1-6-2.

2-4-2-7 Reflector: Specular water cooled aluminum.



Heater: Number D40710
Lamp: #1000 T3/CL/HT
Lamp Voltage: 440 volts
Skin: oxidized, .035 inch thick stainless steel
Insulation: "Fiberfrax", 1.50 inches thick

FIGURE 2-8 HEATING RATE EXAMPLES

2-4-2-8 Array Cooling Provision: 65°F water at up to 20 psig inlet supply manifold pressure. Flow rate depends upon array configuration, as described in Section 3-4-2.

2-4-2-9 Test Article Cooling: Via gaseous nitrogen impingement from an array of nozzles throughout the array as described in Section 3-5.

2-4-2-10 Duty Cycle: A typical duty cycle for the radiant array is shown on Figure 2-1 at about 3000 seconds. However, the duty cycle depends upon the duration at temperature during a test. At maximum test article temperature for each region, the duty should be (a) less than 90 minutes, for the Top 1200°F region, (b) less than 25 minutes for the Side 1800°F region, and (c) less than 7 minutes for the Bottom 2500°F region.

2-4-2-11 Voltage: 450 to 460 volts, 60 Hz maximum to radiant array zones.

2-4-2-12 Power: Up to 11,537 KW for largest configuration.

2-4-2-13 Uniformity: $\pm$ 3 to $\pm$5% of the mean incident heat flux in an irradiated test article surface area.

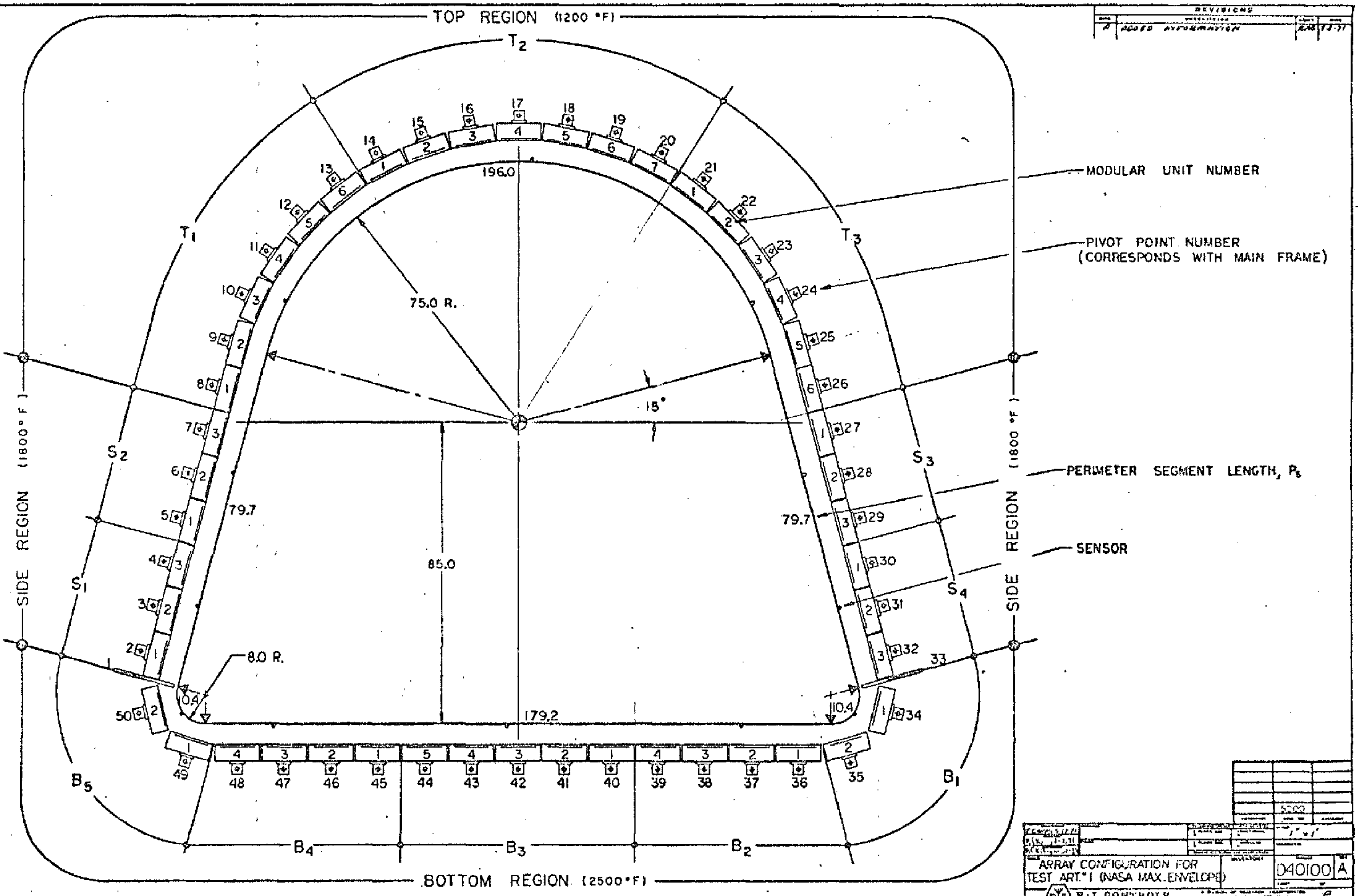


FIGURE 2-9: ARRAY CONFIGURATION FOR TEST ARTICLE NUMBER 1

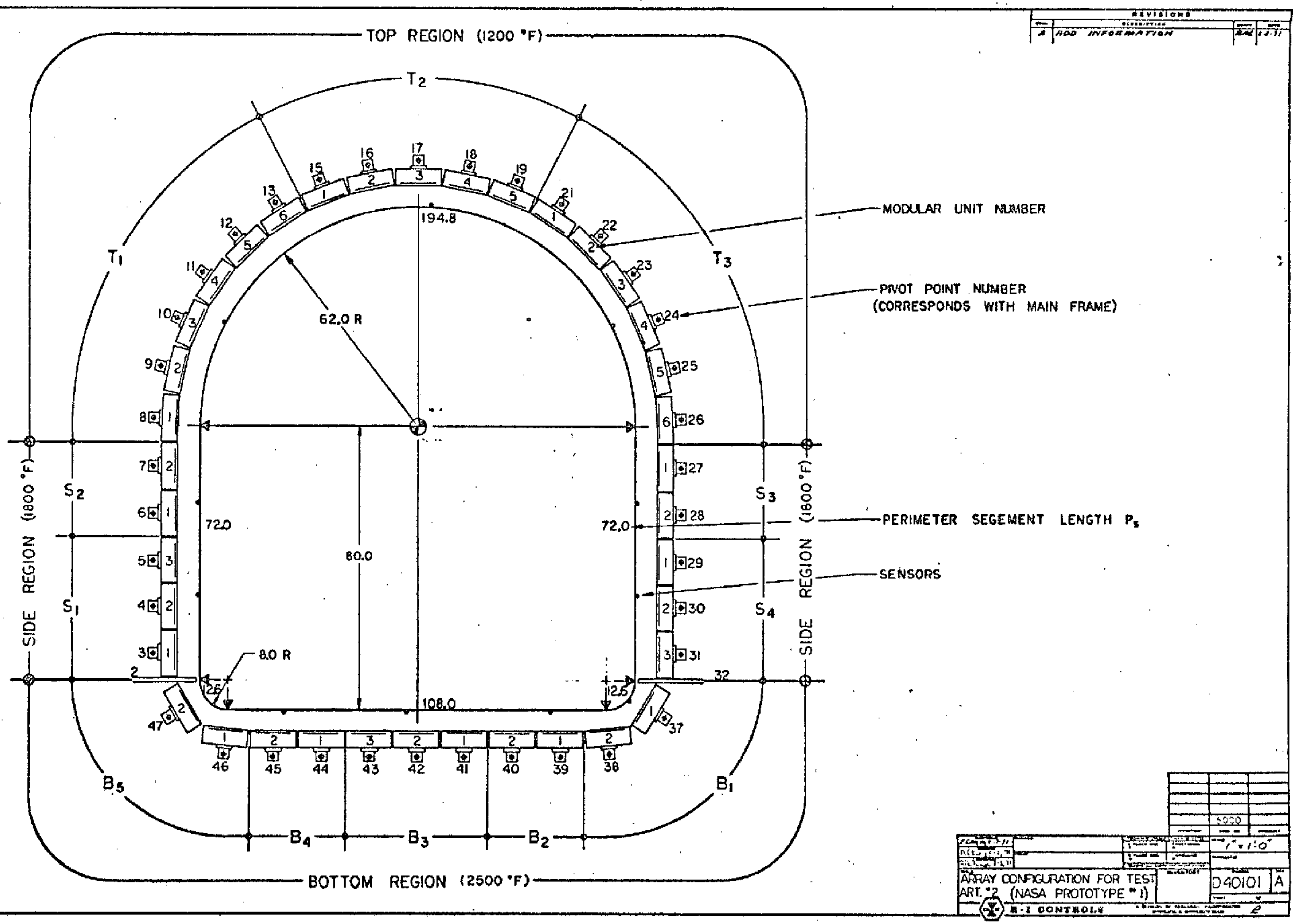


FIGURE 2-10: ARRAY CONFIGURATION FOR TEST ARTICLE NUMBER 2

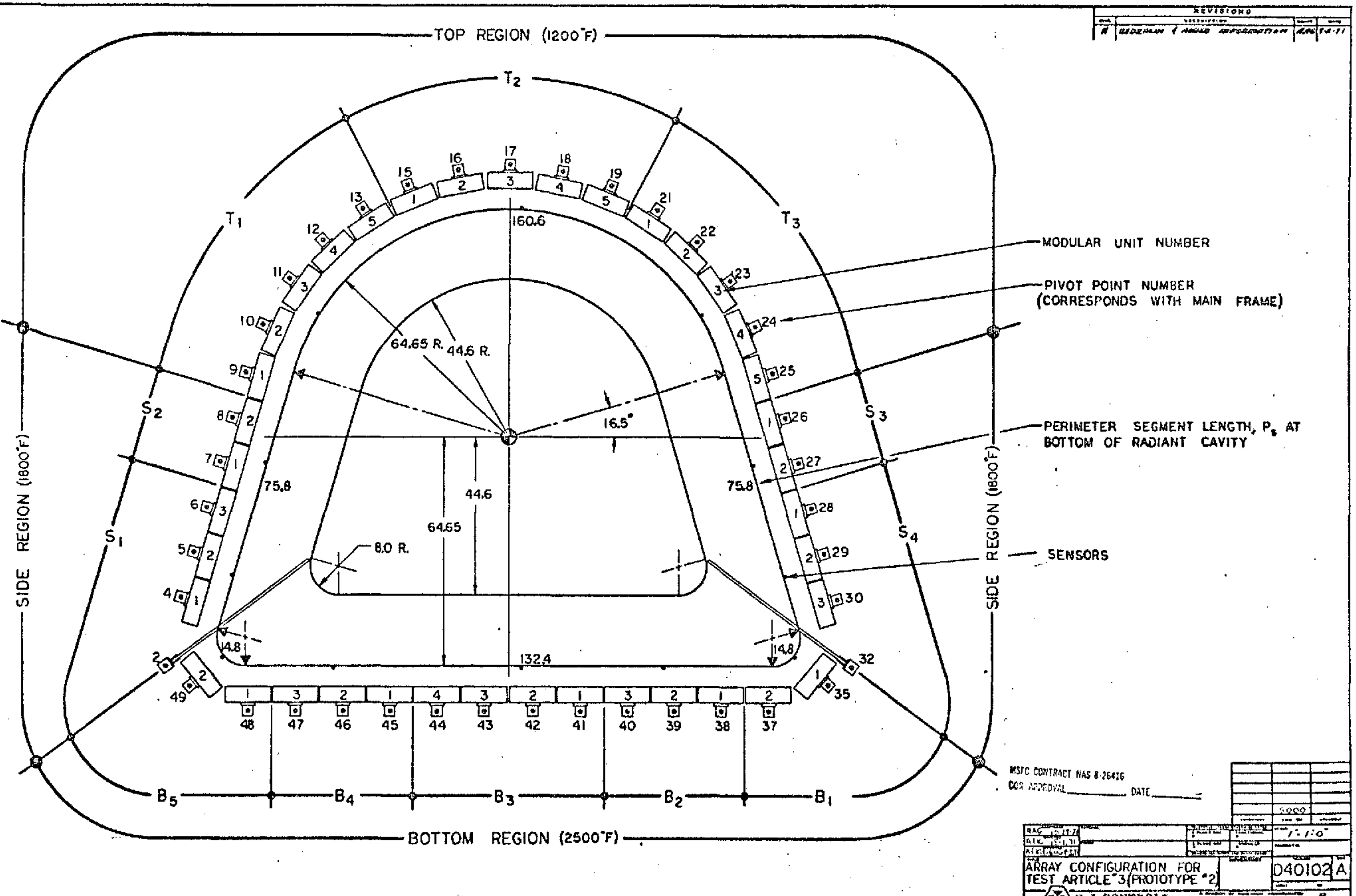


FIGURE 2-11: ARRAY CONFIGURATION FOR TEST ARTICLE NUMBER 3

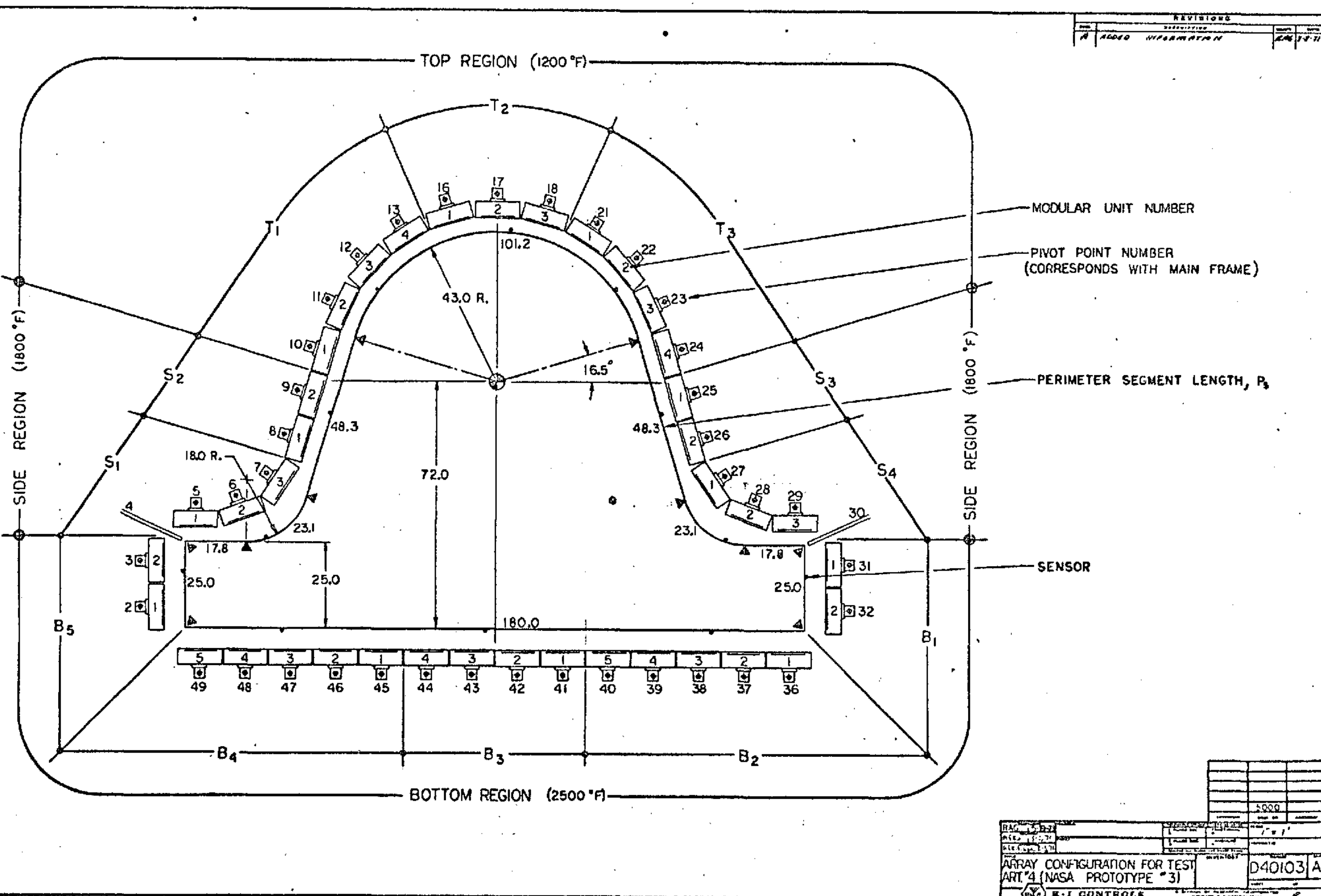
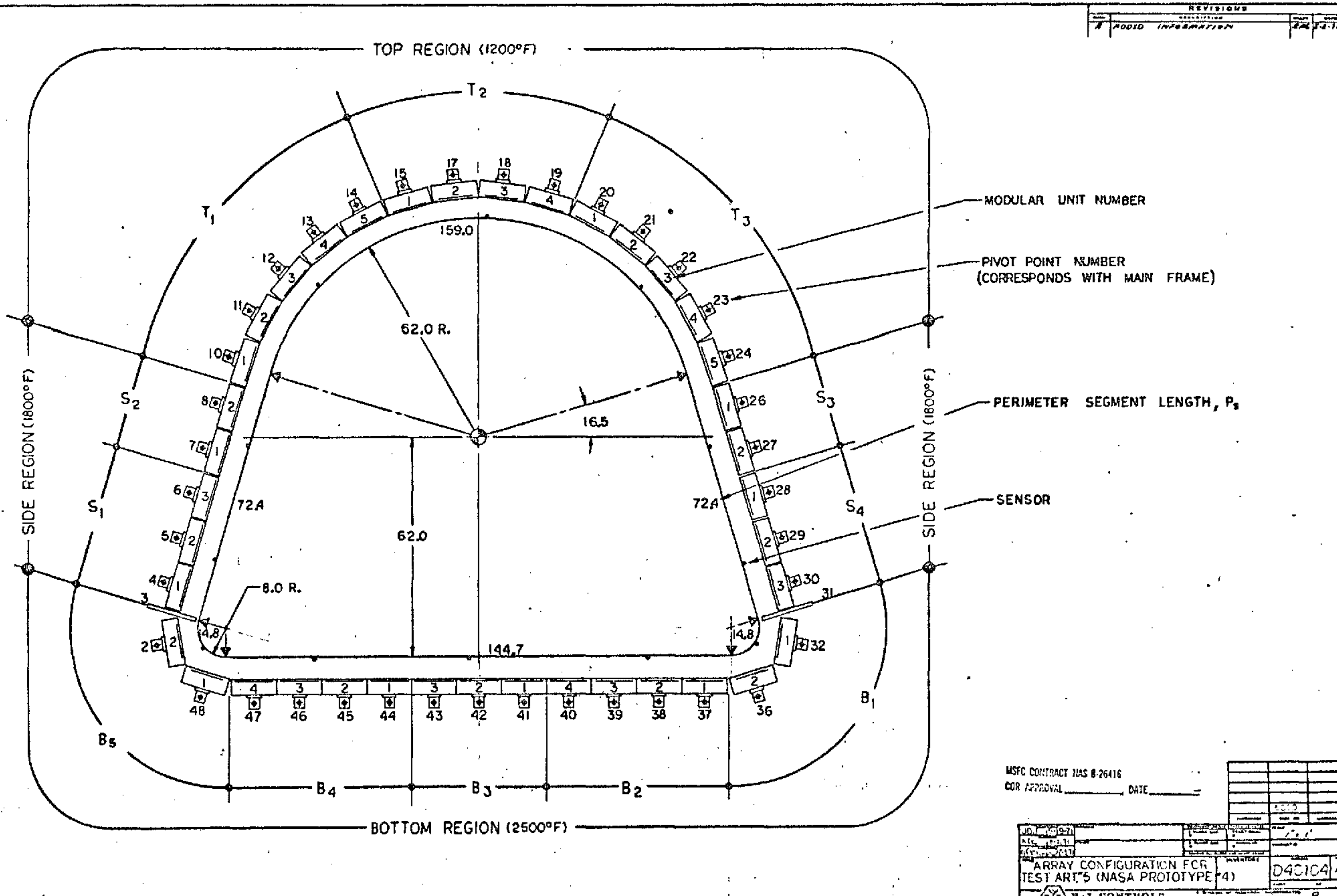


FIGURE 2-12: ARRAY CONFIGURATION FOR TEST ARTICLE NUMBER 4

FIGURE 2-13: ARRAY CONFIGURATION FOR TEST ARTICLE NUMBER 5



SECTION 3 - ARRAY SUBSYSTEMS

3-1 THE MODULAR RADIANT HEATING UNIT

The modular radiant heating unit serves to generate the radiant heat necessary to irradiate the test article surface and heat it to the desired equilibrium temperatures. The modular radiant units are small with respect to the entire radiant array so that they may be configured to accommodate a wide variety of test article shapes.

The heat is generated by resistance heated tungsten filament tubular quartz radiant heat lamps. These lamps are arrayed in the modular radiant heating unit as shown on Figures 3-1 through 3-5.

The radiant energy emitted from the lamp is directed toward the test article surface by a specular aluminum water cooled reflector. The lamps are supported in the radiant unit by individual sockets (i.e., grooves) in a water cooled aluminum bus bar, Item 29 of Figure 3-2. Lamp terminal connections are made under a screw, Item 2 of Figure 3-2 at the cooler rear side of the unit.

In addition to heating, the modular units also provide for cooling the test article surface. There is an integrated gaseous nitrogen cooling system in each modular unit. When test article cooling is required, the gaseous nitrogen is ejected from a manifold inside the reflector body through a multitue of nozzles (i.e., 33 nozzles) located between the lamps as shown by Item 35 on Figures 3-2 and 3-4.

3-1-1 Types of Modular Radiant Heating Units

There are three types of modular radiant heating units, one type for each region; Top, Side, and Bottom. They differ with respect to (a) the number of lamps installed, and (b) the size of the gaseous nitrogen cooling nozzles installed. In all other respects, the three types of modular heating units are alike. Therefore, it is possible to convert the modular unit types by installing the required lamps and nozzles. The following Table 3-1 shows the specification differences for these units.

TABLE 3-1 MODULAR RADIANT UNIT TYPES

Modular Unit Types	Modular Unit Number*	Test Article Equilibrium Temperature °F	Lamps			GN_2 Nozzles			W' Cooling Water Flow, GPM
			N' Qty	S' Spacing, inches	P_m Max Power, KW	Part Number	Orifice Diameter, inches	Gas Flow pounds per sec	
Top	40710-3	1200	9	4.50	24.3	B40728-1	.031	.0429	.95
Side	40710-2	1800	27	1.50	72.9	B40728-2	.043	.0845	2.86
Bottom	40710-1	2500	55	.75	148.5	B40728-3	.054	.1334	5.84

* Reference Figures 3-1 through 3-5

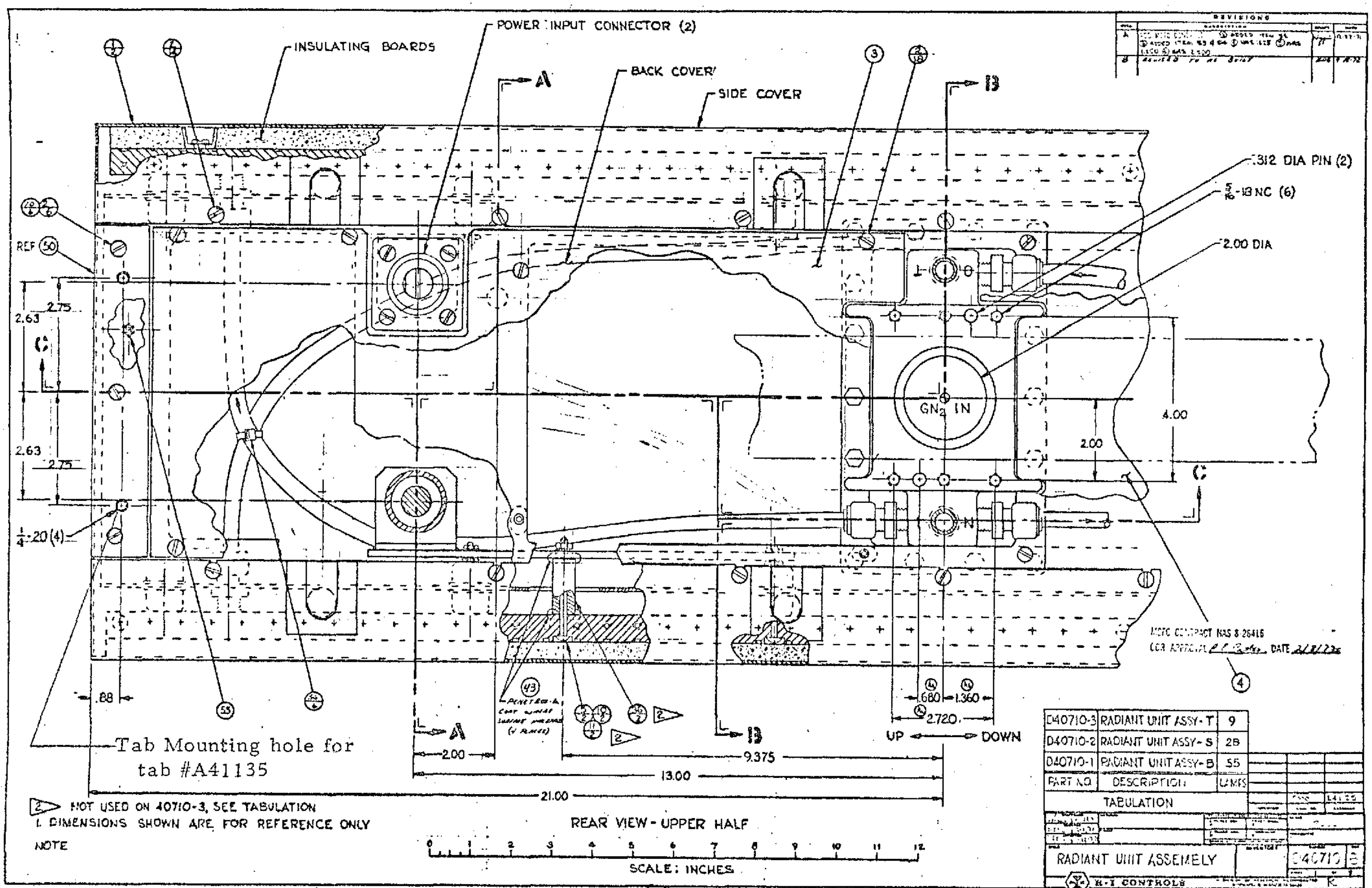


FIGURE 3-1: RADIANT UNIT ASSEMBLY, UPPER REAR

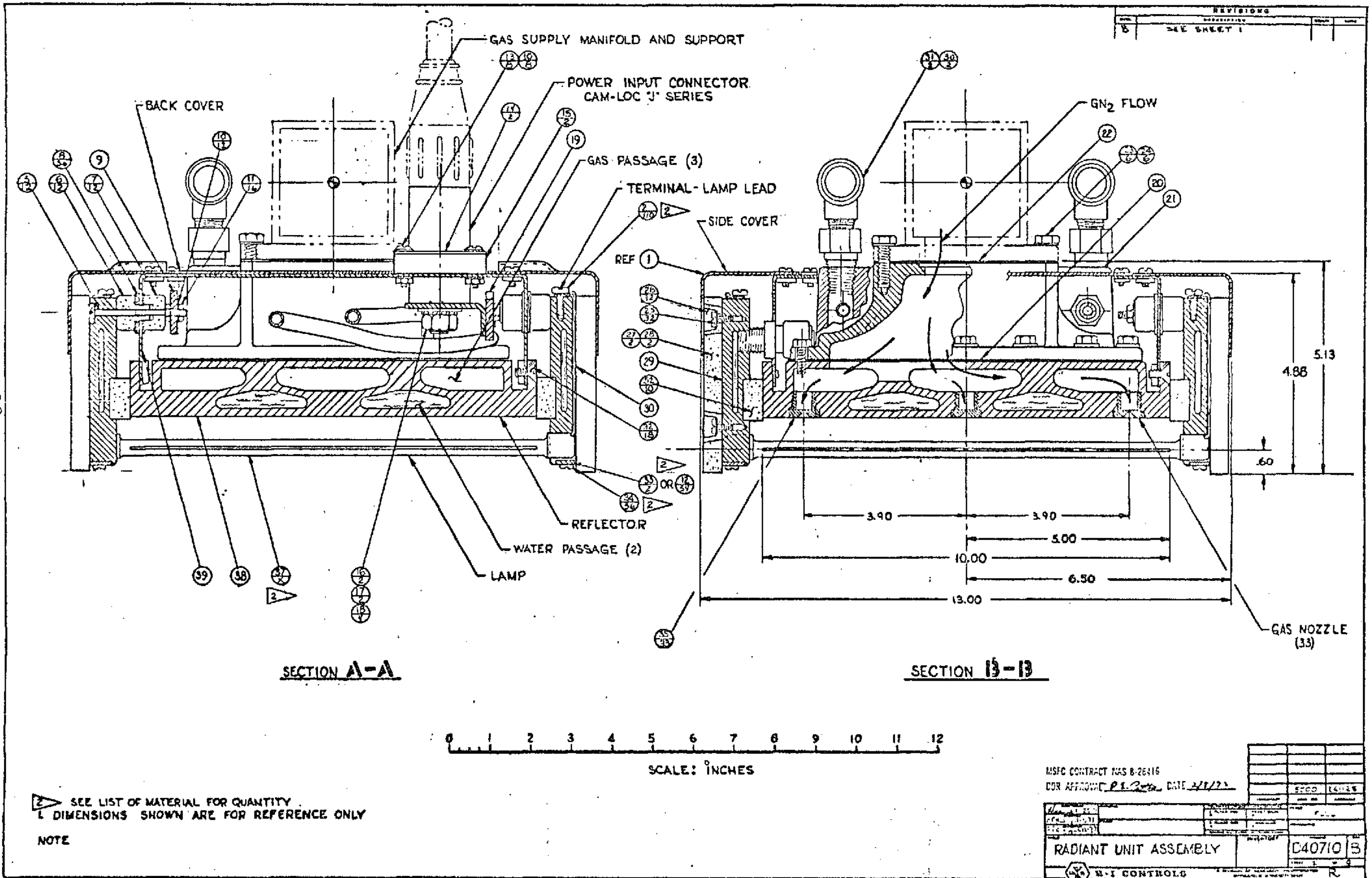


FIGURE 3-2: RADIANT UNIT ASSEMBLY, SECTIONS

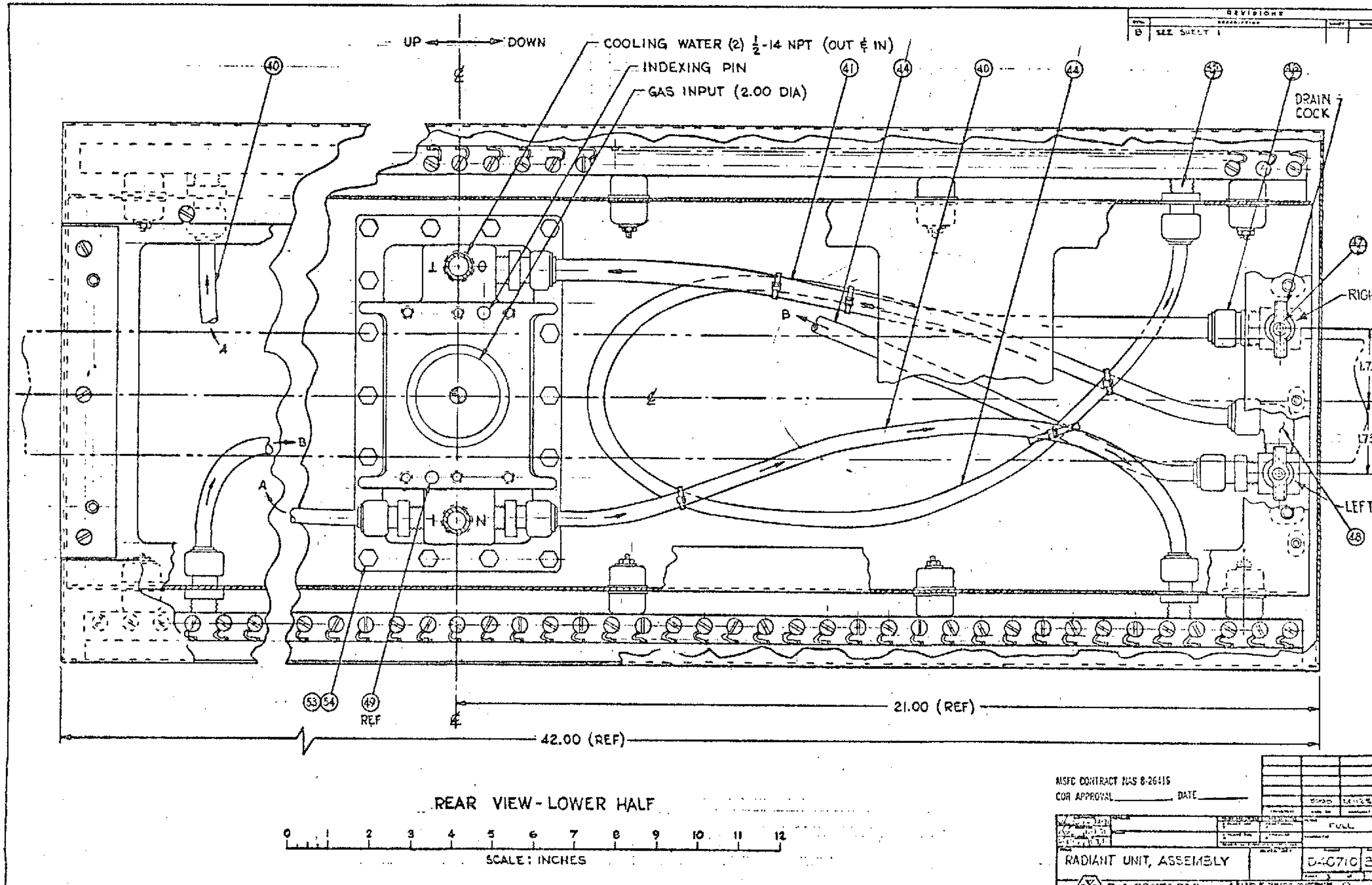


FIGURE 3-3: RADIANT UNIT ASSEMBLY, LOWER REAR

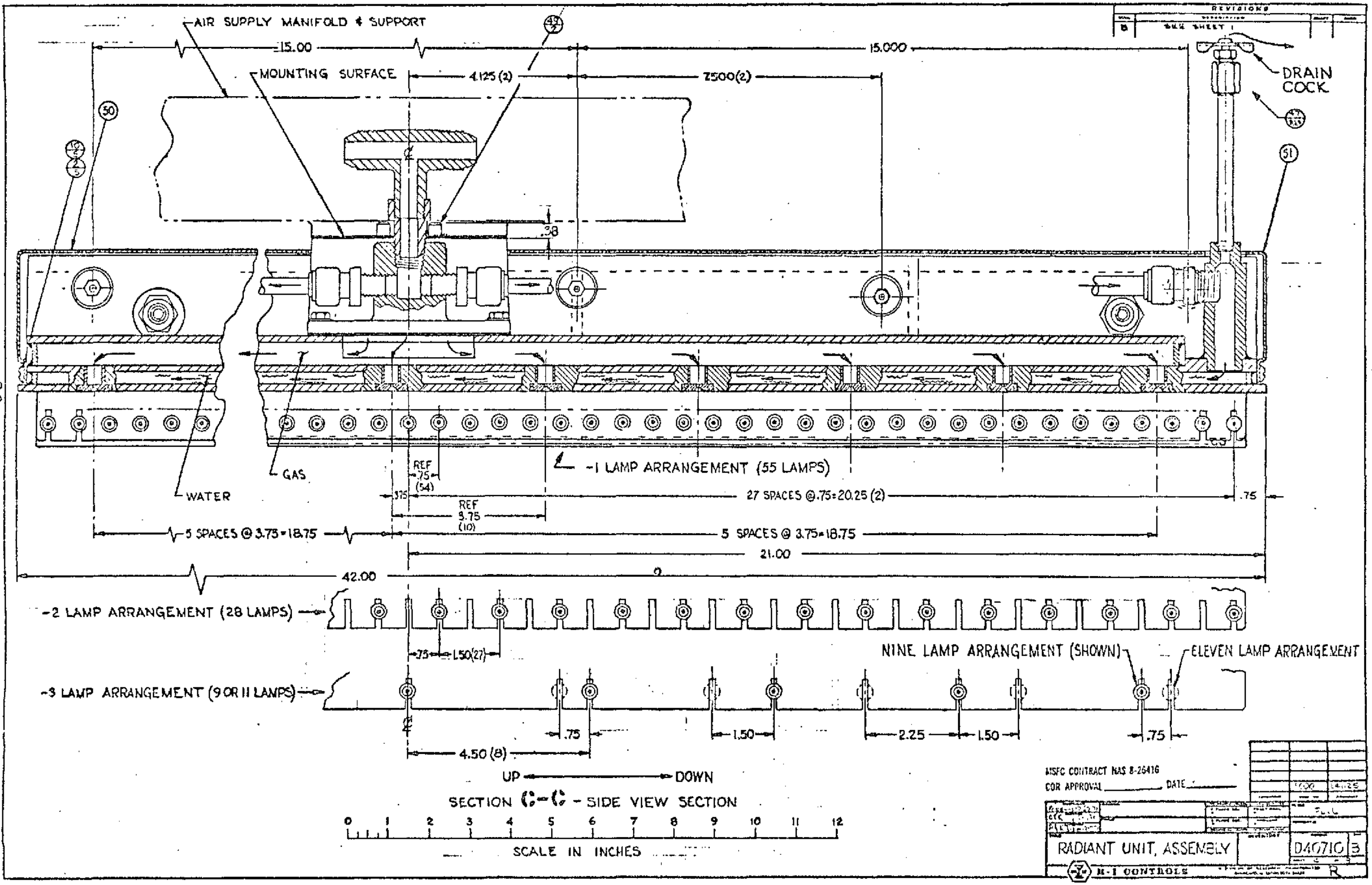


FIGURE 3-4: RADIANT UNIT ASSEMBLY, SIDE SECTION

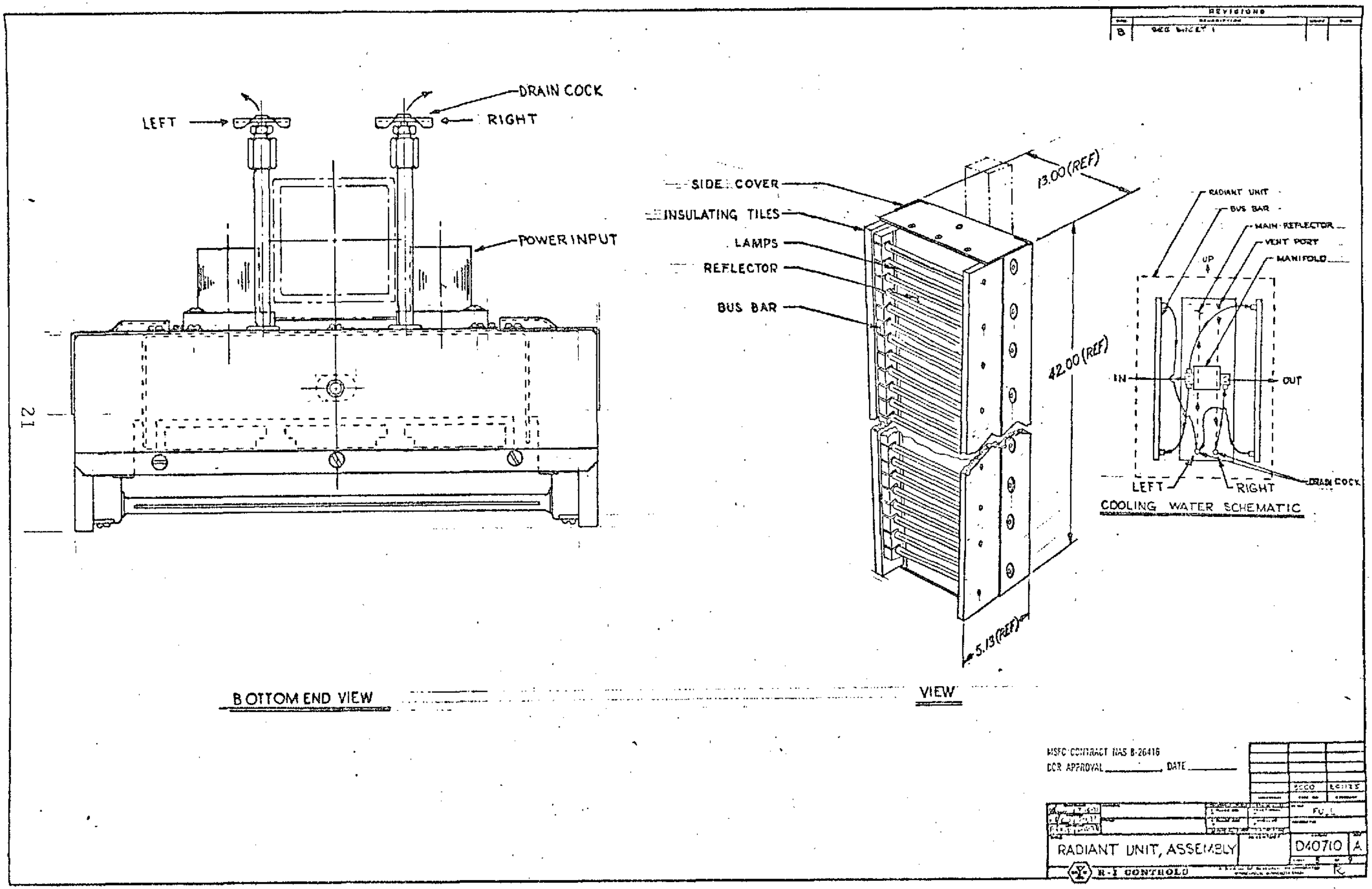


FIGURE 3-5: RADIANT UNIT ASSEMBLY, END

3-1-2 Mounting

The modular heating unit has a machined surface pad at the center rear side of the unit as shown on Figure 3-1. There are six 5/16-18NC threaded holes on the pad for hex bolt fasteners. There are two .312 inch diameter index pins projecting from its surface to align the unit with respect to a mounting pad on the adjustable stanchion pivot tube while inserting the fasteners.

This mounting pad also serves as the gaseous nitrogen input port and a gasket, Item 22 shown on Figure 3-2 is required to seal this connection.

There are also two 1/4-20 NC holes at each end of the modular unit for joining adjacent modular units of a modular unit row.

3-1-3 GN_2 Input Connection

Gaseous nitrogen input to the modular heating unit is through a 2.00 inch diameter port located on the mounting pad at the center rear of the unit as shown on Figure 3-1. This connection is made to the stanchion frame pivot tube manifold when the unit is mounted.

The gas enters the unit into a gas passage plenum chamber within the main body of the reflector as shown on Figure 3-2. The 33 nozzles, Item 35, screw into the plenum.

3-1-4 Water Input

The cooling water for removing heat gained by the radiant unit, enters the left rear side at the center of the unit through the port labeled "IN" and exits the right side through a port labeled "OUT" as shown on Figure 3-3. Figure 3-5 shows a schematic of the water circuit within the unit.

The units should be mounted so that the drain cocks, Items 47 and 48 of Figure 3-3, are at the bottom.

The water flow requirements are given in Section 3-4.

3-1-5 Power Input

Electrical power enters the modular radiant unit at the upper rear side through two male Cam-Lock Number JRR-1040M weather-proof connectors as shown on Figure 3-1. This connector mates with a female Cam-Lock connector Number XCJ-12F for Top and Side regions and number XCJ-40F for the Bottom region.

Each of these two connectors are connected to the lamp support bus bar via a copper bus, Item 19 shown on Figure 3-2. Therefore, all lamps are in parallel.

The power requirement hook-up procedure is described in Section 4-2-7.

The lamp installation procedure is described in Section 5-1.

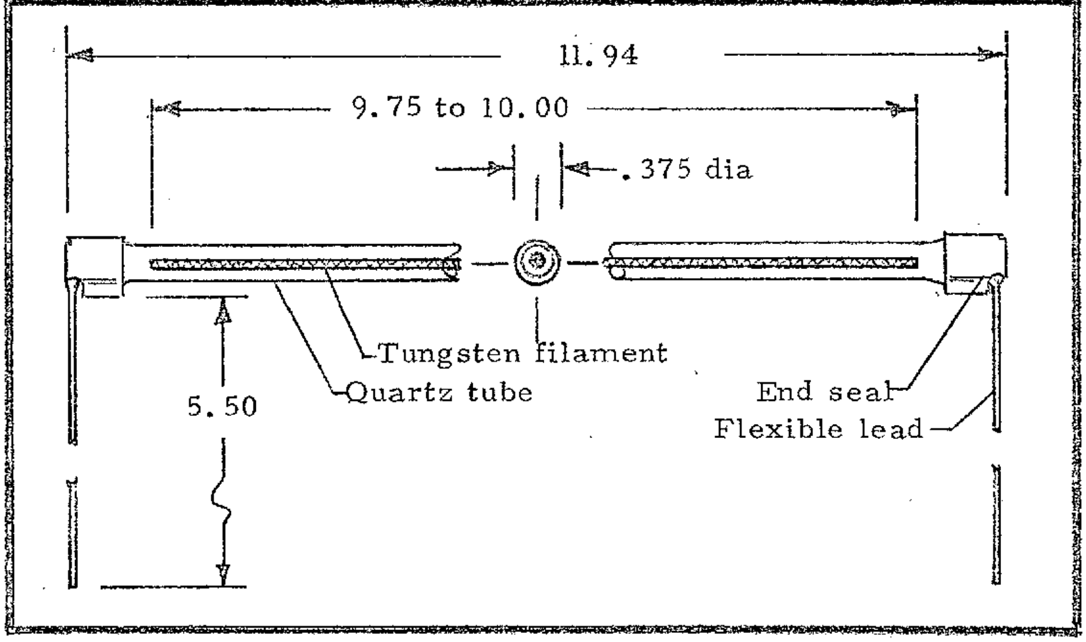
3-1-6 The Radiant Heat Lamp

The modular radiant heating units use standard tubular quartz tungsten filament radiant heat lamps as the radiant heat source. These lamps are supported in sockets (i.e., grooves) in the lamp support bus bar of the radiant unit.

3-1-6-1 Type: There are two types of lamps that can be used as shown in the following table:

TABLE 3-2 LAMP TYPES

Type	Lamp Number	Rated Voltage, Volts	Rated Power, KW	Power at 240 Volts, KW	Power at 460 Volts, KW	Gas Fill
1	1000T3/CL/HT	240	1.0	1.0	2.7	Argon
2	Q3MT3/CL/HT	480	3.0	1.0	2.7	Halogen



Both types are alike in geometry and radiant energy output. Type number 1, the 1000 T3/CL/HT is more common and is available from Westinghouse, General Electric and Sylvania. Type number 2, Q3MT3/CL/HT is less common and may be difficult to obtain. Type 2 can be obtained from General Electric Company.

Type 1, 1000 T3/CL/HT lamp is operated to near twice its rated voltage to attain the required heat flux levels. This is commonly done in aerodynamic heat simulation applications because of the relatively short duty cycle with respect to an industrial application. However, lamp life is degraded because the filament is required to operate at a very high temperature (i.e., about 3250°K, 5391°F) as compared to its rated long term operating temperature(i.e., 2500°K, 4041°F). At these elevated operating temperatures, tungsten is emitted from the filament and is eventually deposited on the inside surface of the tubular quartz lamp envelope, causing it to darken and reduce its radiant energy transmission.

The type 2, Q3MT3/CL/HT lamp is filled with a halogen agent such as iodine or bromine which helps prevent tungsten accumulation on the quartz envelope wall. When tungsten particles evaporate from the lamp filament, they combine with the halogen gas and together the combination migrates back to the hot filament and separates. The tungsten is redeposited onto the filament in this cycle. The result is longer lamp life due to the effects of reduced tungsten particle accumulation on the quartz envelope. There have been claims that the life of the halogen cycle lamp due to this effect may be about ten times that of the more standard type 1, 1000 T3/CL/HT lamp.

3-1-6-2 Response

The response of the lamp depends upon the heating rate of the tungsten filament when energized. The following Figure 3-6 shows the response at various applied voltages.

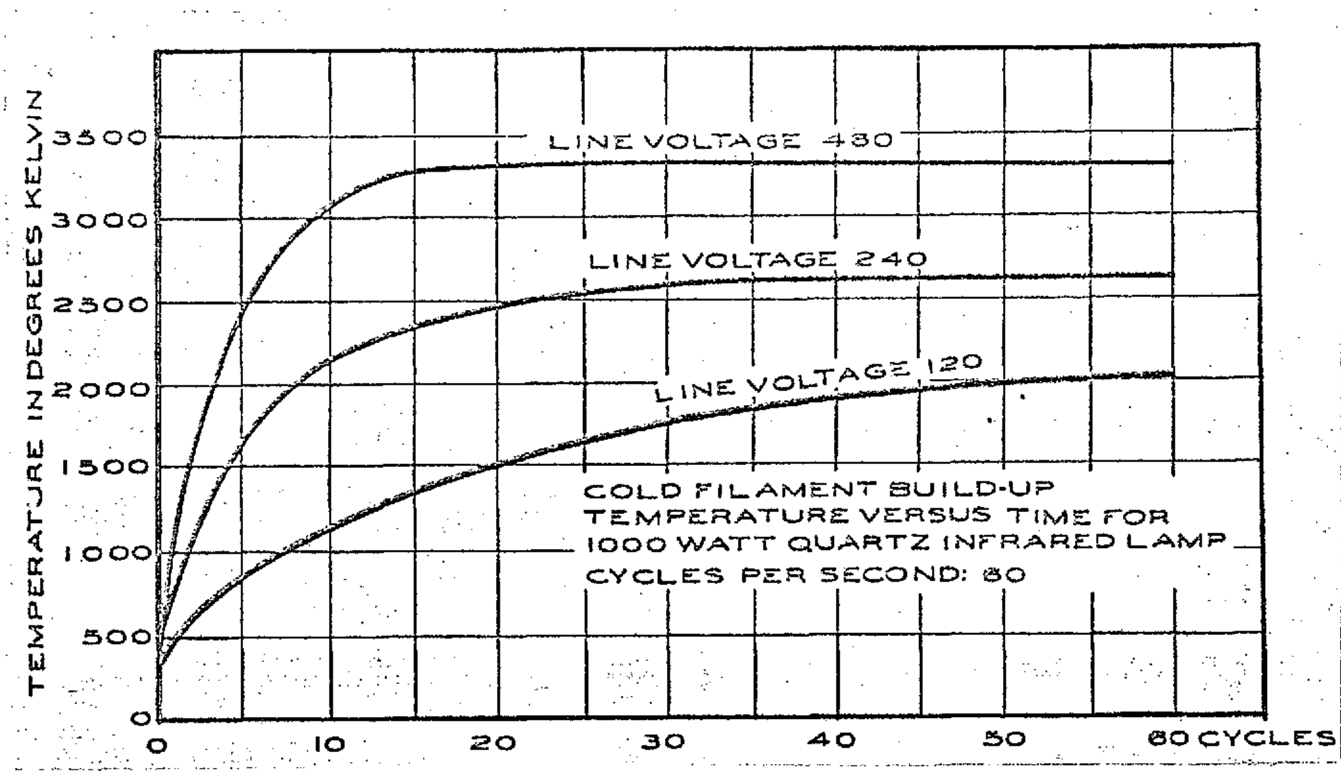


FIGURE 3-6 LAMP FILAMENT RESPONSE

3-1-6-3 Spectral Characteristics

The spectrum of the lamp depends upon the tungsten emitter temperature which also depends upon the applied voltage. The following Figure 3-7 shows the spectral response curve for the Type 1, 1000 T3/CL/HT lamp at (a) 240 volts (i.e., 100%), (b) 360 volts (i.e., 150%), and (c) 480 volts (i.e., 200%). For the Type 2, Q3MT3/CL/HT lamp, 200% represents the rated voltage.

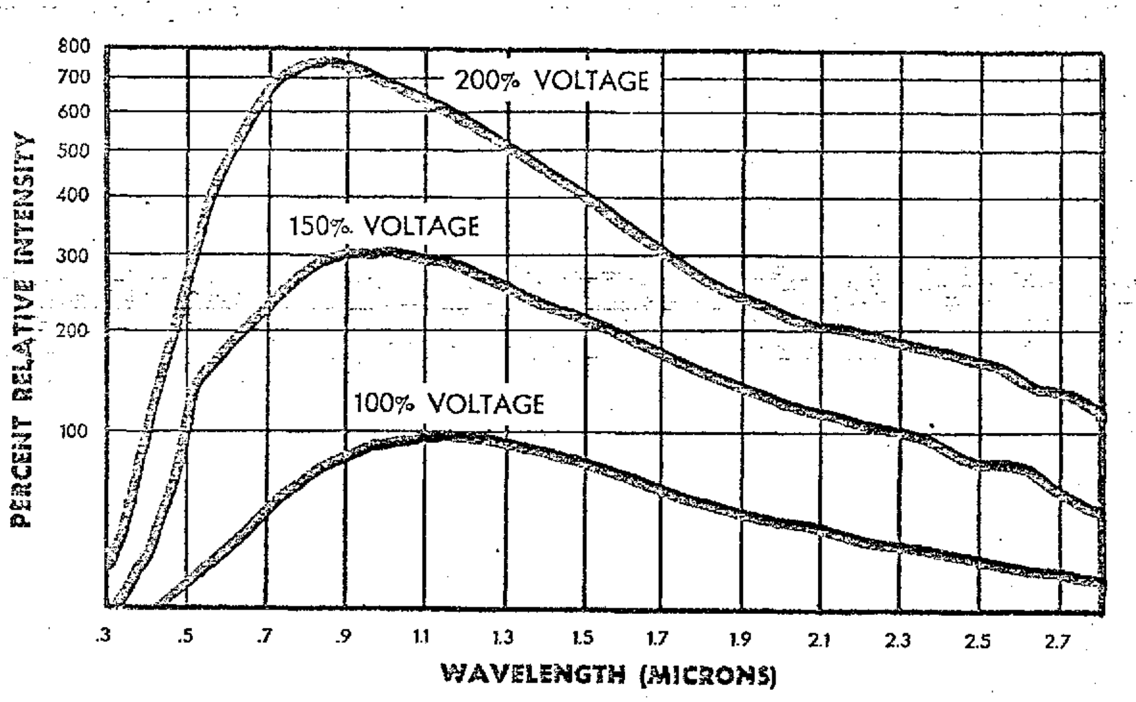


FIGURE 3-7 LAMP SPECTRUM

3-1-6-4 Power Dissipation

The energy dissipated by the lamp depends upon the applied voltage. The following Figure 3-8 shows the energy dissipated by the lamp in % of rated wattage vs. a % of the rated lamp voltage. For example, if the type 1, 1000 T3/CL/HT lamp were operated at 1/2 its rated voltage (i.e., 240/2 = 120 volts), it would dissipate 33.3% of its rated power (i.e., .333 x 1000 = 333 watts).

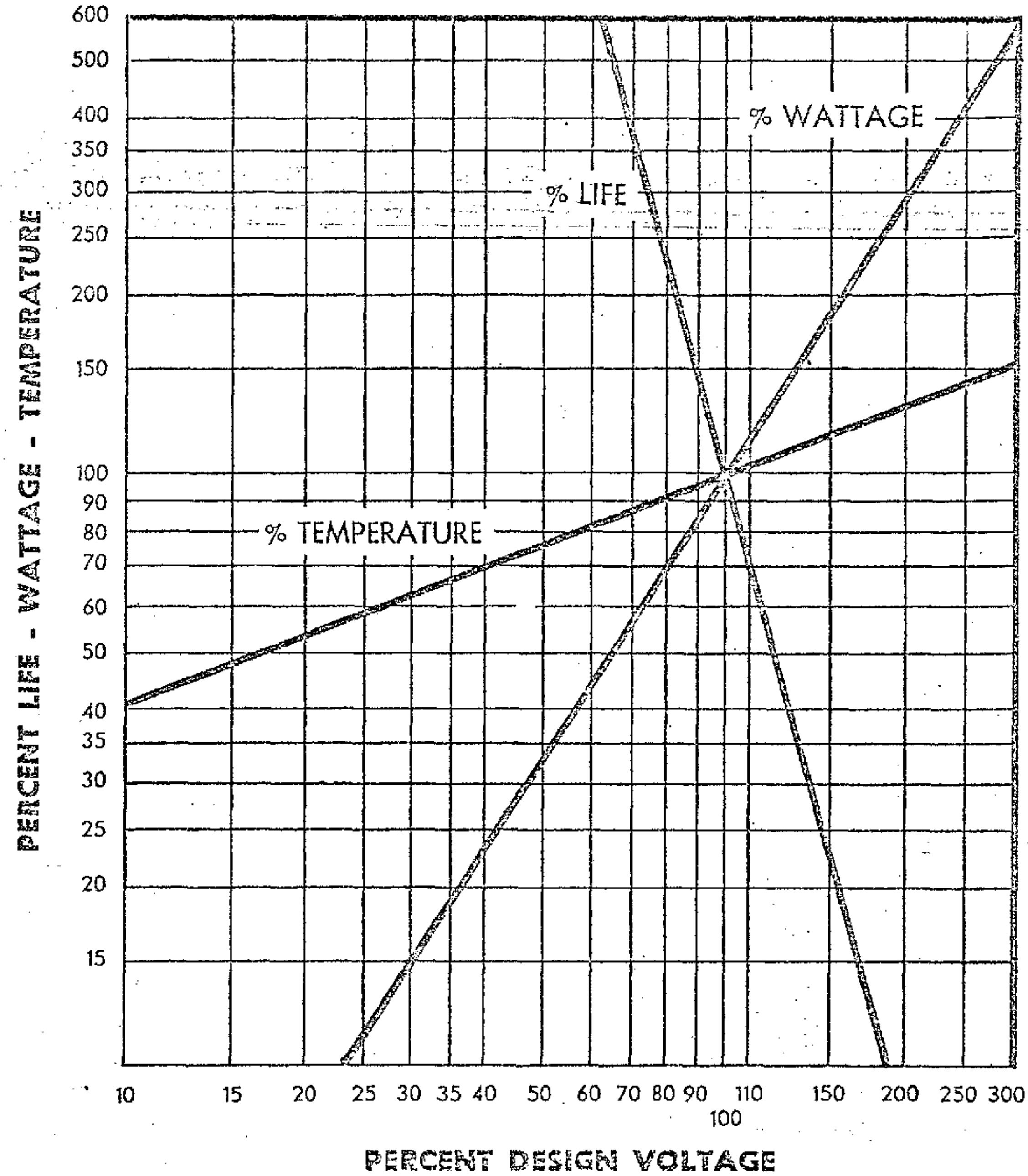


FIGURE 3-8 LAMP POWER DISSIPATION

3-2 THE ADJUSTABLE STANCHION FRAME

The adjustable stanchion frame serves to support the modular radiant heating units in a wide variety of radiant array configurations. Some of these configurations are shown in Figures 2-9 through 2-13. There are provisions for 50 adjustable stanchions around the periphery of the radiant array as shown on Figure 7-1.

The stanchion is a rigid steel frame weldment as shown on Figure 3-9. It is attached to the main frame via carriage assembly shown on Figure 3-10. The stanchion is cantelevered from the carriage assembly at various distances from the radiant array center depending upon the shape of the radiant chamber. There are two types of stanchions, "short and long". Their location in the array and adjustment range with respect to the main frame attachment points is given on Figure 4-1. The procedure for adjusting the stanchion is given in Section 4-2-7

3-3 THE MAIN FRAME

The main frame of the radiant array serves to support all subsystems of the array. They are (a) the 50 adjustable stanchion frames with three modular radiant units on each, (b) the integrated water cooling system, and (c) the gaseous nitrogen cooling system. Item 1 of Figure 7-1 and 7-2 shows the main frame with respect to these subsystems.

The main frame is a tubular steel weldment. It rests on the concrete pad of the SII stand on four 16 inch diameter tubular steel legs. These four legs taper to near point contact and set on 3 inch diameter steel pins projecting from an anchored base plate on the concrete slab.

A 16 inch diameter tubular steel peripheral ring is supported by the four legs. This peripheral steel ring supports the downward and twisting load of all the adjustable stanchions. There is a welded 1.00 inch thick steel mounting plate at each of the 50 stanchion attachment points to support the cantelevered stanchions.

The frame extends upward to another peripheral ring to support the lateral forces of the adjustable stanchion frames. This section of the main frame is of 8.00 inch diameter welded steel tube, and is supported on four 8.00 inch diameter steel columns. There is a Unistrut track below the upper frame peripheral ring to attach the stanchion guide assembly shown on Figure 3-11 for each of the stanchion frames.

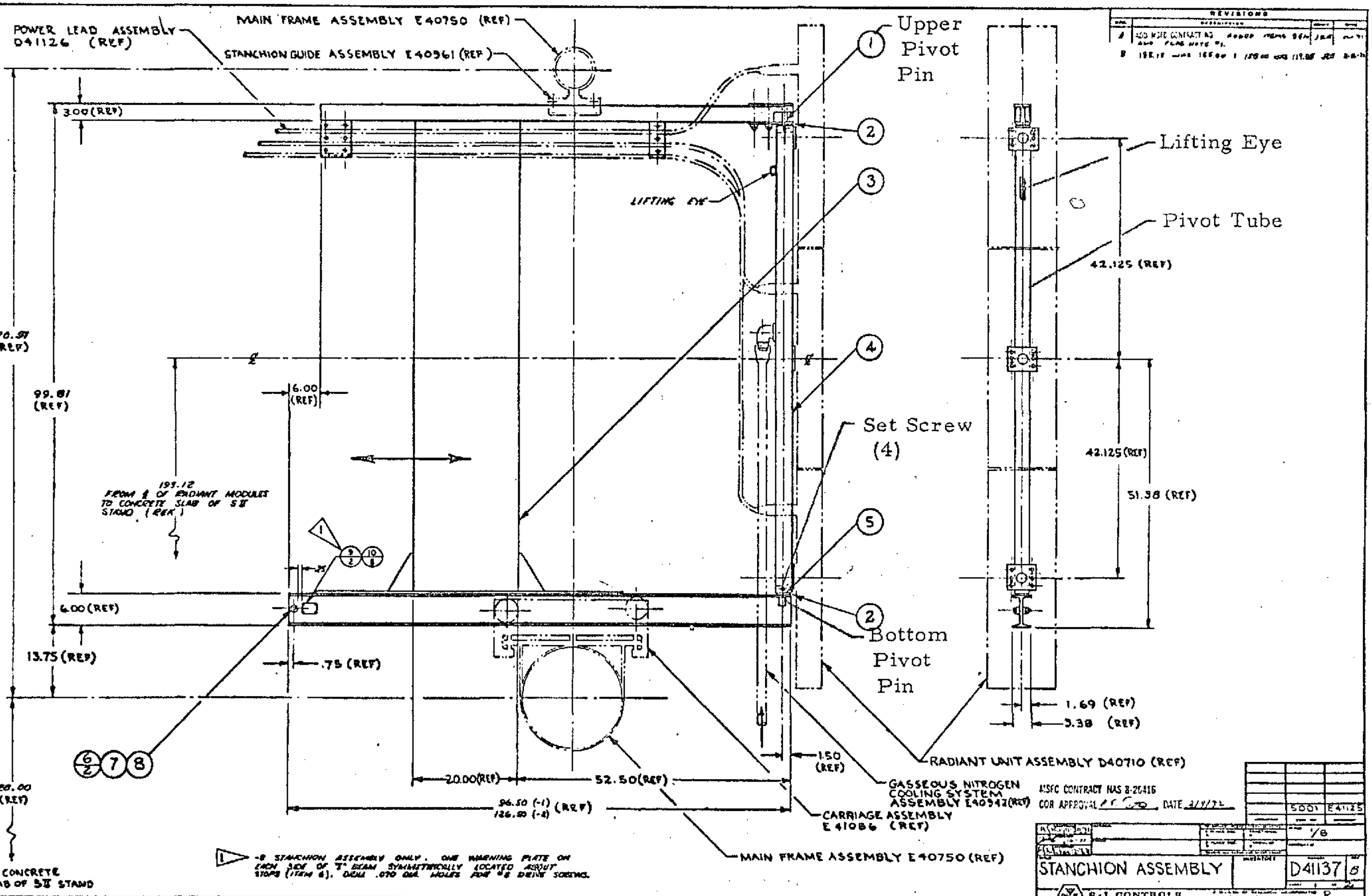


FIGURE 3-9: STANCHION ASSEMBLY

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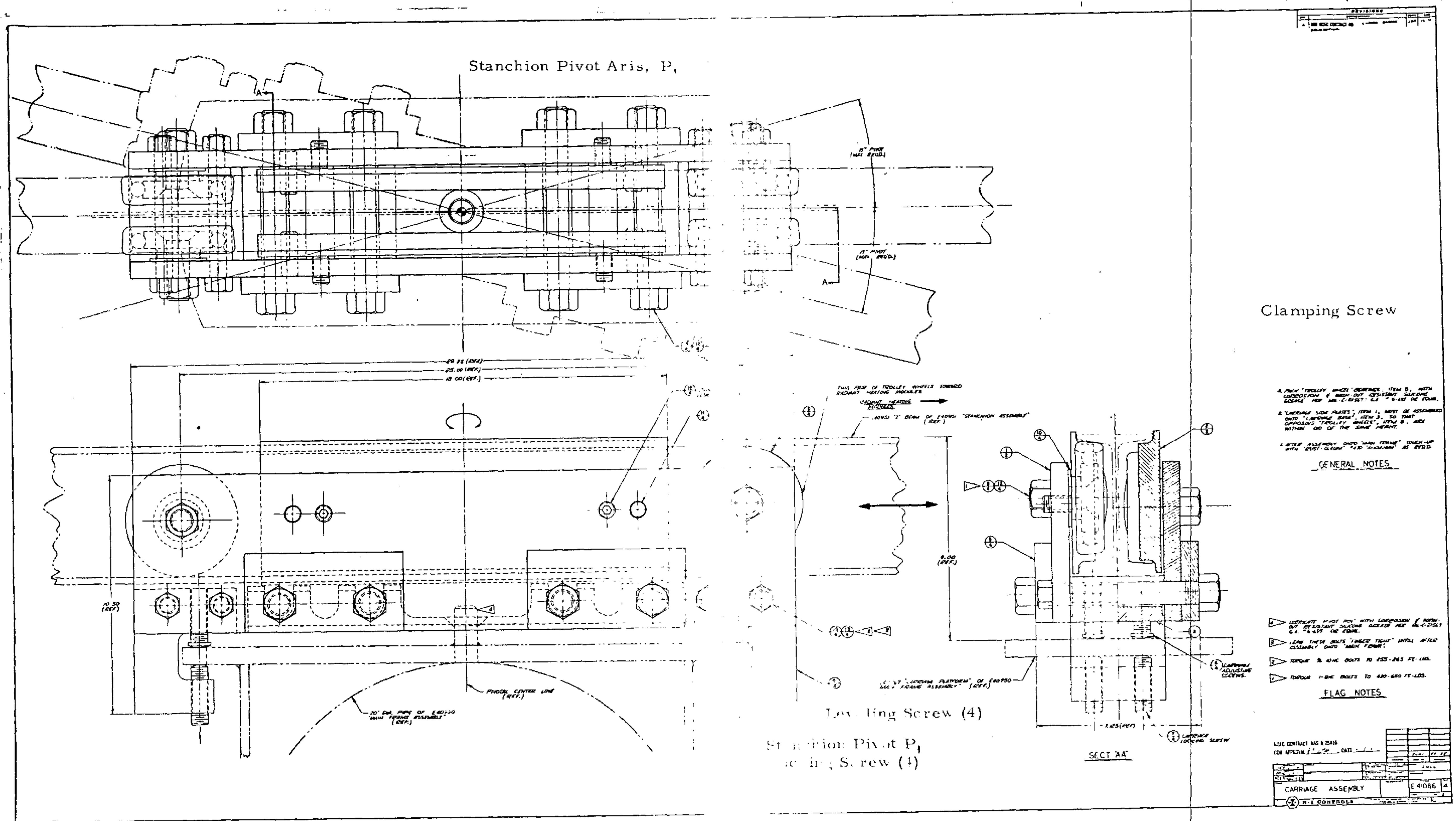


FIGURE 3-10
CARRIAGE ASSEMBLY

FOLDOUT FRAME 1

FOLDOUT FRAME 2

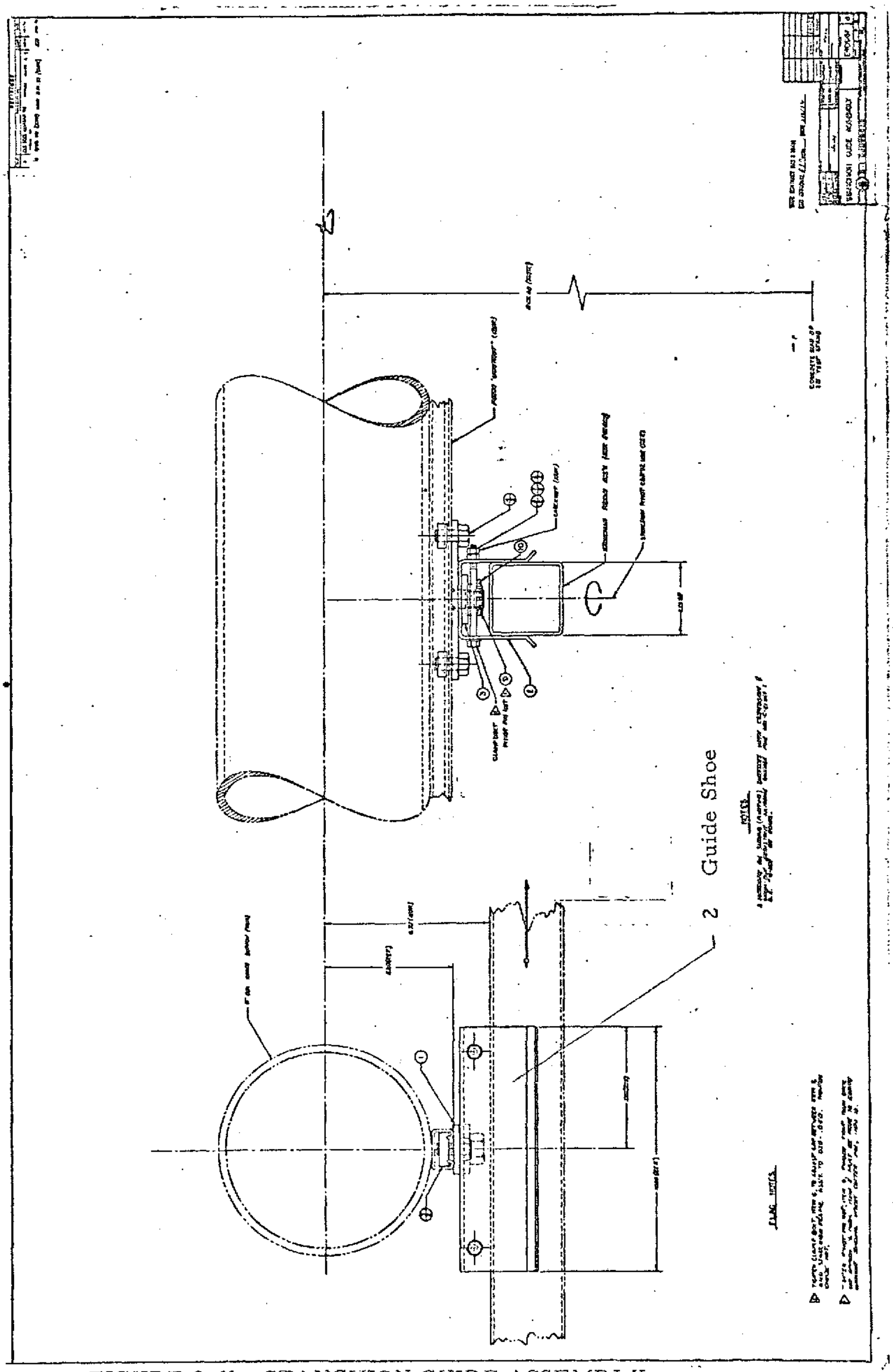


FIGURE 3-11: STANCHION GUIDE ASSEMBLY

In addition to serving as the main structural support for the radiant array, the main frame also serves as the radiant array cooling water manifold. The upper peripheral ring serves as a water supply distribution manifold for all the stanchions. It is divided into two passages, one for the Top and Side regions and another straight section for the Bottom region. There is a welded water exit port associated with each of the adjustable stanchions.

The bottom peripheral ring serves as a water drain manifold for each of the adjustable stanchion frames. There is also a drain port provided for each of the stanchions. The spent water then drains down on leg of the main frame to a 8.00 inch diameter flanged exhaust port as shown on Figure 3-12.

3-4 THE COOLING WATER SYSTEM

The water cooling system of the radiant array serves to cool all array components subjected to the radiant heat of the radiant chamber cavity. Primarily, these are (a) the modular radiant heating units, (b) the inner region shields, and (c) the end reflectors. The water cooling system for the radiant array is shown on Figure 3-12.

3-4-1 Water Circuit

The radiant array cooling water originates from a large reservoir at the site and is pumped to a standpipe at the SII stand. The water leaves the stand-pipe through a manual operated gate valve and divides to two compressed air operated shut off valves, one for the Bottom region and the other for the Side and Top regions of the radiant array.

The water enters the radiant array at two locations through 3.5 inch diameter flanged fittings located on the supply manifold which is also the upper portion of the main frame as shown on Figure 3-12. Water is then distributed around the upper periphery of the array through a 8.0 inch diameter manifold. This manifold is divided into two parts, one for cooling array components in the Bottom region and the other for cooling components in the Side and Top regions. There is a paddle type flow switch near the water entrance of the manifolds to illuminate lights on the master control panel when water is not flowing. The flow switch data is given in Part 3 of this manual under Section labeled "Purchased Parts Radiant Array".

The water is then distributed from the supply manifold to each of the modular unit rows of the radiant array through J1C type swivel fittings located adjacent to each of the adjustable stanchion frames. The water passes through .75 inch diameter flexible draped hoses from the supply manifold to the J1C swivel fitting near the top rear of each modular unit row. At the rear of the modular unit row, it divides to enter each of the three modular radiant units as shown on Figure 3-13.

The water enters the modular radiant unit near the center rear of each unit and then divides to flow through each of the two lamp support bus bars, as shown on Figure 3-5. After cooling the lamp support bus bars, the water is passed through the main reflector body and out of the modular heating unit.

At the rear of the modular unit row, the water is combined from all three heaters into a .75 inch diameter flexible hose running to the peripheral exit 18.0 inch diameter exit drain manifold. The peripheral exit drain manifold is also the lower part of the main structure and is provided with J1C swivel type connector input ports located adjacent to each of the stanchion frames.

The water in the exit drain manifold flows down one leg of the main frame structure into a 8.0 inch diameter flanged fitting with another paddle type flow switch. The exit flow switch illuminates a light on the master control console at the "no flow" condition.

The water is then discharged from the radiant array through a 8.0 inch pipe to a nearby drainage ditch.

There are two other secondary parallel flow passages for (a) the inner region shields, and (b) the end reflectors that are not described above. These two secondary flow passages occur between the radiant array upper peripheral supply manifold and the lower peripheral exit manifold. The flow circuit for these two secondary passages is described in Section 4-2-11.

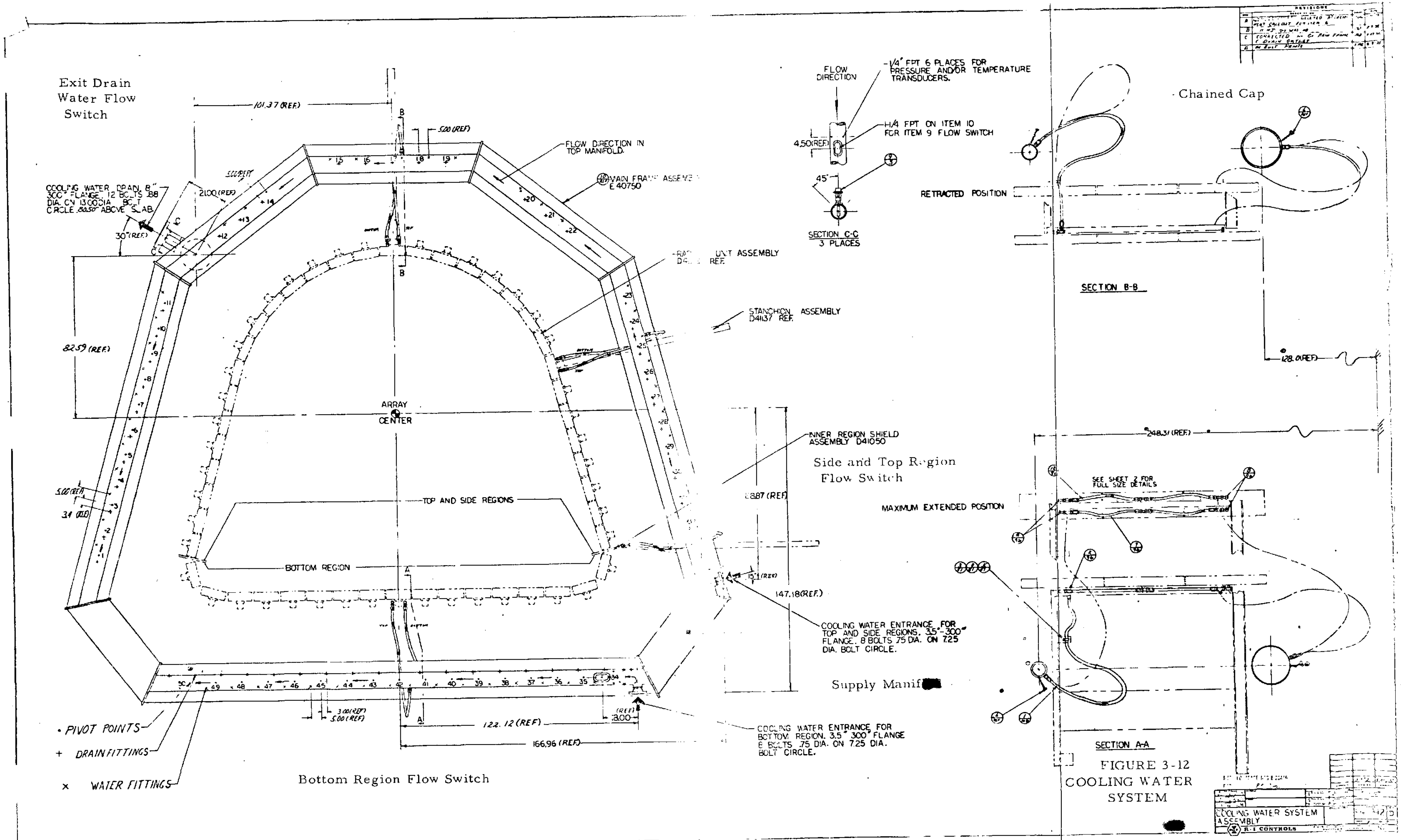


FIGURE 3-12
COOLING WATER SYSTEM

FOLDOUT FRAME

FOLDOUT FRAME 2

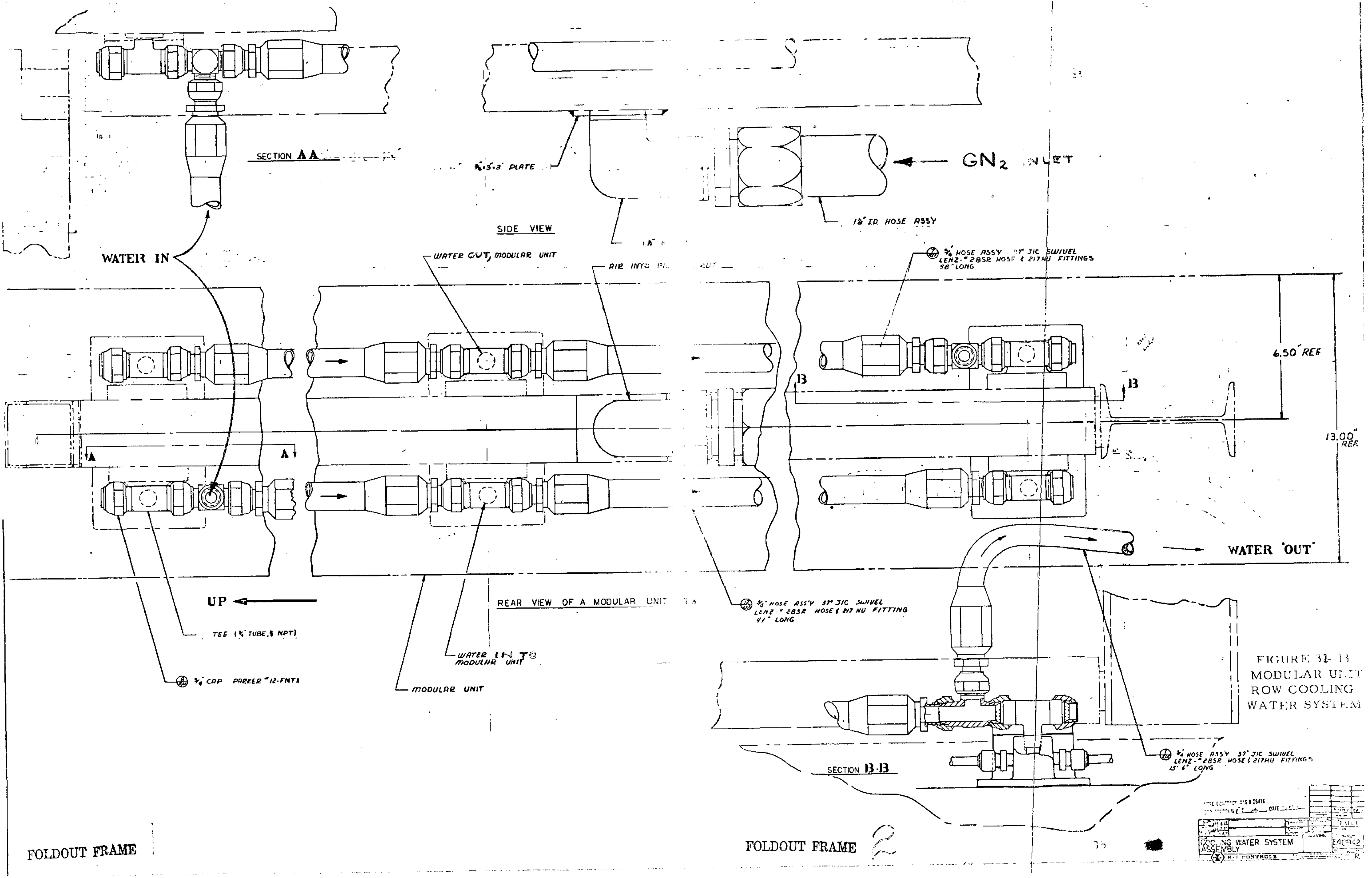


FIGURE 31-13
MODULAR UNIT
ROW COOLING
WATER SYSTEM

FOLDOUT FRAME

FOLDOUT FRAME 2

3-4-2 Water Flow Requirement

The cooling water flow rate requirements are based on the most extreme operating condition that may be encountered. This condition may exist when nearly all the energy dissipated by the radiant array is eventually absorbed by the radiant array (i. e., about 80%). Therefore, if enough cooling water is provided to remove this energy, the radiant array will be reasonably protected for nearly all unforeseen conditions. Some of the unusual conditions that may require near maximum dissipation power removal are:

a. The radiant array rêflector surface becomes contaminated during a test run due to something emitted from the heated test article. The reflector efficiency will drop and the power required to maintain the test program will increase, possibly to maximum. Thus most of this energy will be absorbed by the radiant array.

b. Test article absorptance drops very low such that incident energy is not effectively absorbed by the test article but instead by the radiant array.

c. Test article has high heat capacity and is heated to contribute excessive heat to surrounding radiant array with contaminated reflector. The heat energy absorbed by the array could be near exceeding the maximum dissipated power depending upon the heat capacity of such a test article.

d. Radiant array is operated at full power without a test article but with complete radiant cavity closure end reflectors. In such an empty enclosed cavity, nearly all radiant energy, except for natural convection losses, is absorbed by the cavity walls.

The energy to be absorbed by the water depends upon the kind and number of modular radiant units employed. Since all the energy dissipated is from the modular radiant units, the energy, P_a, that is to be absorbed by the water passing through a modular radiant unit is:

$$P_a = .80\, P_m,\ \text{KW}$$

where:

P_a = Energy to be absorbed by the water passing through the modular unit, KW

P_m = Maximum power dissipated by the modular radiant unit, KW

In this radiant array, the inlet water temperature, T_i is to be about 65°F and the outlet water temperature, T_o is allowed to attain 205°F. Therefore, the required water flow, W, per modular radiant heating unit is:

$$W = \frac{P_a}{1.054\ C_p(T_o - T_i)} = \frac{P_a}{147.6}\text{, pounds per second}$$

where:

W = Water flow per modular radiant heat unit, pounds per second.

P_a = Energy to be absorbed by water in modular heating unit, KW

C_p = Specific heat of coolant = 1 for water

T_o = Outlet water temperature, °F = 205°F

T_i = Inlet water temperature, °F = 65°F

On this basis the following table shows the resultant water flow rates required for each type of modular radiant heating unit (i.e., Top, Side and Bottom)

TABLE 3-3 WATER FLOW REQUIREMENT

Type of Modular Heating Unit, Region	P_m Maximum power dissipated per modular unit, KW	P_a Absorbed energy = .85 P_m KW	W Water flow rate per modular unit, pounds per second	W' Water flow rate per modular unit= 7.21 W gallons per minute
Top	24.3	19.4	.132	.95
Side	72.9	58.3	.396	2.86
Bottom	148.5	118.8	.810	5.84

However, since the water supply manifold is common for the Top and Side regions, and both Top region and Side region heater rows are in parallel, it is necessary to pass the same water flow rates through the heaters in both those regions. The required water flow rate must be that for the modular radiant heater requiring the greatest flow (i.e., the Side region heater) at W = .396 pounds per second or W' = 2.86 gallons per minute. The following Table 3-4 shows the total required flow rates W_T under these conditions for all five test article configurations.

TABLE 3-4 WATER FLOW PER REGION SUPPLY MANIFOLD

Test Article	Water Supply Manifold Region	W' Required water flow rate per modular unit gallons per min.	M_m Number of modular units per supply manifold	W_m Water flow rate per supply manifold = $W'M_m$ gallons per minute	W_T Total water flow rate gallons per minute
1	Top & Side	2.86	93	265	563
	Bottom	5.84	51	298	
2	Top & Side	2.86	81	232	424
	Bottom	5.84	33	192	
3	Top & Side	2.86	75	215	478
	Bottom	5.84	45	263	
4	Top & Side	2.86	63	180	495
	Bottom	5.84	54	315	
5	Top & Side	2.86	72	206	469
	Bottom	5.84	45	263	
Max.	Top & Side	2.86	93	265	NA
	Bottom	5.84	54	315	

3-4-3 Water Pressure

The cooling water supply manifold pressure required to yield the required flow rates given in the preceding section 3-4-2 are shown in the following Table 3-5 and Figure 3-14. The two dots represent date points taken during the preliminary check out of the system for test article configuration number 1 (i. e., maximum envelope). It indicates that the supply manifold pressure for the Top and Side region heaters should be 7.0 to 8.5 psig and 16.5 to 20.0 for the Bottom region. Apparently a supply manifold pressure of approximately 20.0 psig will satisfy all the water flow conditions in the radiant array. It is recommended that the supply manifold pressure be limited to 20.0 psig to reduce the risk of a leak in the water passages during operation.

3-4-4 Water Shut Down

The radiant array water cooling system should be drained for (a) radiant array configuring, (b) long term inactive periods, and (c) freezing conditions.

For configuring the array, it is not necessary to drain all water out of the passages. Most of the water may be drained by shutting water off at manual gate valve and venting the two supply manifolds. The supply manifolds may be vented by disconnecting one or two of the flexible water lines.

3-4-4-1 Inactive Period Water Shut Down

For long term inactive periods or freezing conditions, the system should be well drained. Simply turning off the water and venting the supply manifolds as described above will not drain all the water from the passages since some will not drain completely. The trap like passages in the modular radiant units are of greatest concern because the plastic tube connection, Item 46 on Figure 3-3 will not hold expanding freexing water. For this reason, the water should be drained in the following manner.

a. Shut water off at manual gate valve and allow water to drain out array exit port.
b. Pressurize supply manifolds with air or GN_2 at 20 psig (i.e., about 200 SCFM or more) and continue draining.
c. Shut off purging air or GN_2 and plug array water exit port.
d. Pressurize the supply manifold for Top and Side region with air or GN_2 at 20 psig and open left drain cocks at rear of modular radiant heating units for upper heaters "a" only as shown on Figures 3-3 and 3-5.

TABLE 3-5:	WATER PRESSURE	
Type of Modular Heat Unit, Region	W' Water Flow Rate per Unit, GPM	Supply Manifold Pressure (approx) psig
TOP	.95	2.0 to 2.5
SIDE	2.86	7.0 to 8.5
BOTTOM	5.84	16.5 to 20.0

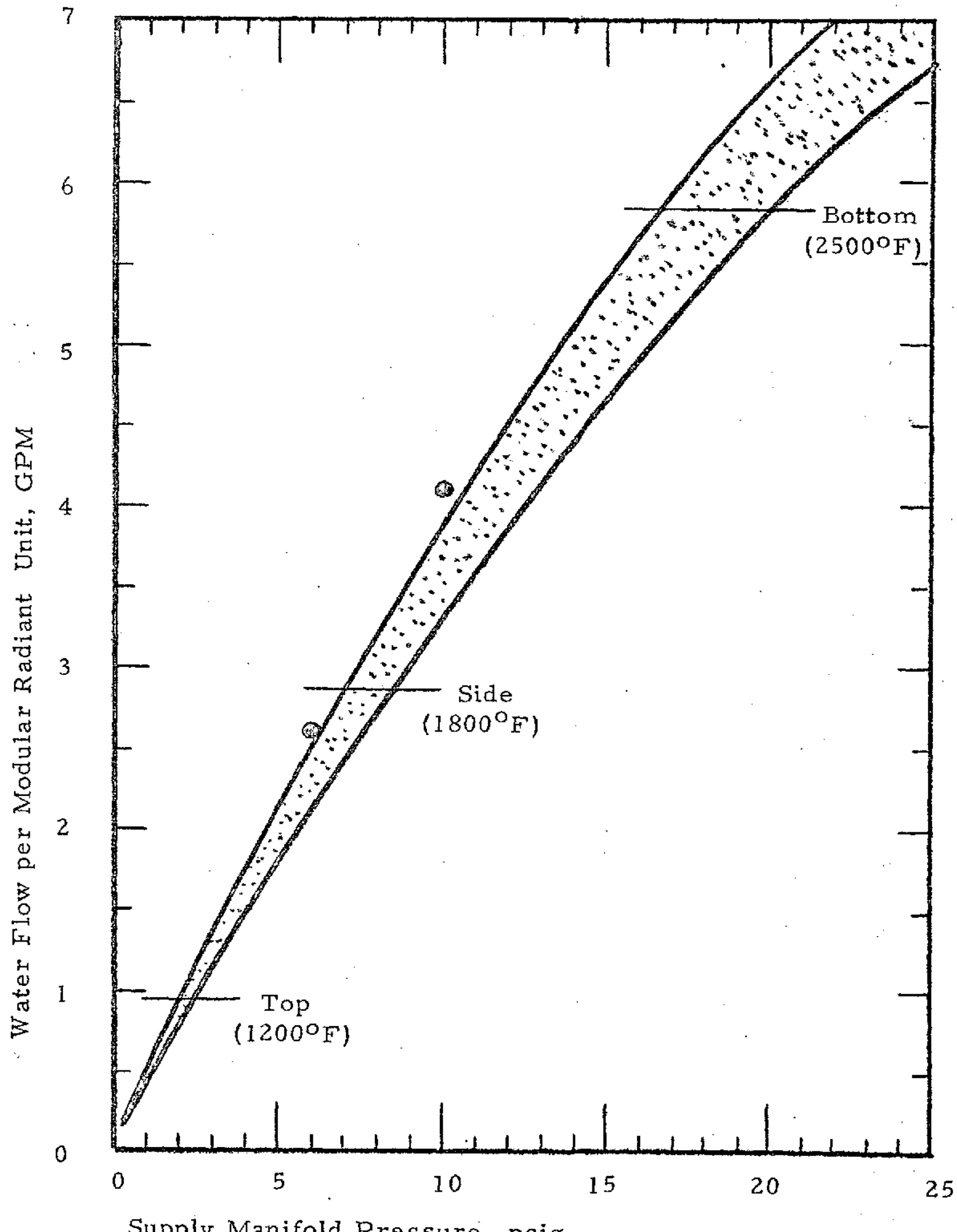


FIGURE 3-14: WATER PRESSURE VS FLOW

e. After water is purged from the left drain cocks, open the right drain cocks, and continue purging water.

f. After water is purged from the open drain cocks of the upper heaters "a", close the drain cocks and then open the left drain cocks for the center heaters "b" of the Top and Side region.

g. After water is purged from the left drain cocks, open the right drain cocks.

h. After water is purged from the open drain cocks of the center heaters "b", close the drain cocks and then open the left drain cocks for the lower heaters "c" of the Top and Side region.

i. After water is purged from the left drain cocks, open the right drain cocks.

j. After water is purged from the open drain cocks of the lower heaters "c" open all drain cocks of the Top and Side region and continue purging.

k. Repeat Steps (d) through (j) for modular heater of the Bottom region supply manifold.

l. Shut off purging gas and remove exit water plug

3-5 THE GASEOUS NITROGEN COOLING SYSTEM

The gaseous nitrogen cooling system serves to remove heat from the test article skin during reducing absorbed heat flux prôfiles. The heat is removed by injecting gaseous nitrogen into the radiant chamber through a multitude of nozzles such that the gaseous nitrogen impinges upon the test article surface. After removing test artcile heat energy the gas exhausts through the spaces between the modular unit rows to the ambient environment.

3-5-1 Cooling Requirement

During an aerodynamic heat cycle program, the test article experiences both increasing and decreasing absorbed heat flux as shown on drawing Figure 2-1. The energy generated by the array of tubular quartz tungsten filament lamps will satisfy the conditions of increasing heat flux. However, reducing the absorbed heat flux from the maximum to the minimum (i. e., near zero), requires that all contributing heat sources in the radiant array drop to near zero output. The absorbed heat flux can be substantially reduced by extinguishing the power to the radiant heat lamps. In fact, if the test article skin has zero thermal capacity, it will immediately cool to the temperature of the surrounding radiant array environment and the absorbed heat flux will likewise drop to near zero when lamp power is extinguished. However, if the test article has thermal capacity, it will remain heated and cool at a reduced rate.

If the test article with thermal capacity attains a high equilibrium surface temperature, its image in the surrounding radiant array acts as a second radiant heat source; therefore, when low absorbed heat flux densities are required during the aerodynamic heat cycle program, the contribution from the test article image may contribute excessive heat flux.

The forced GN_2 cooling system must be capable of removing the test article image heat q_m so the q_{aero} can approach zero as it would in free space. So, the maximum forced GN_2 cooling requirement is:

$$q_{fc} = q'_{aero} - q_n \text{ Btu/second-ft}^2$$

where

q_{fc} = Forced GN_2 cooling requirement, Btu/second-ft^2
q'_{aero} = Aerodynamic heating rate, Btu/second-ft^2
q_n = Net loss of test article in thermal simulator (i.e., radiant array(, Btu/second-ft^2

Table 3-6 shows the heat loss of the test article surface in the thermal simulator q_n for $\epsilon_s = .6$ to $.9$

The table also shows the maximum forced GN_2 cooling requirement $q_{fc} = q_{aero} - q$. We see that the maximum cooling requirement occurs for the high test article surface emittance $\epsilon_s = .9$. This means that the forced GN_2 cooling system is designed to remove up to 1.33 KW/ft^2 in the Top region, 5.97 KW/ft^2 in the Side region and 18.99 KW/ft^2 in the Bottom region.

For example, consider the case where the test article surface with thermal capacity in the Bottom region is at 2500°F equilibrium temperature and the aerodynamic heat flux program call for $q_{aero} = 0$. The lamps will extinguish and q_{aero} will drop to 18.99 KW/ft^2 since it is absorbing heat from its image in the surrounding radiant array. Then the forced GN_2 is introduced through an array of nozzles between the lamps to remove the 18.99 KW/ft^2 so q_{aero} - 0.

On this basis, Table 3-7 shows the gaseous nitrogen system parameters for the Top, Side and Bottom regions.

The gaseous nitrogen system is designed to accept a total of 12.69 pounds per second of gaseous nitrogen at a pressure of 500 psig at the inlet of the three region flow regulating valves, as shown on Figure 3-15. This flow is divided into two main entrance locations. The Bottom region inlet will take 7.02 pounds per second at an upstream orifice pressure of 90 psia, while the Top and Side region inlet will take 5.49 pounds per second.

TABLE 3-6: FORCED GN_2 COOLING REQUIREMENTS IN VARIOUS TEST ARTICLE REGIONS AT VARIOUS TEST ARTICLE EMITTANCES

Test Article Region	ϵ_s Emissivity of test article surface	q_{aero} Aerodynamic Heat Rate		q_n Heat Loss to Surrounding Radiant Array		q_{fc} Maximum Forced GN_2 Cooling Requirement = $q_{aero} - q_n$	
		Btu/sec/ft^2	KW/ft^2	Btu/sec/ft^2	KW/ft^2	Btu/sec/ft^2	KW/ft^2
Top (1200°F)	.6	2.10	2.21	1.65	1.73	.45	.48
	.7	2.47	2.59	1.73	1.82	.74	.77
	.8	2.82	2.96	1.83	1.92	.99	1.04
	.9	3.17	3.33	1.91	2.00	1.26	1.33*
	1.0	3.53	3.70	1.96	2.06	1.56	1.64
Side (1800°F)	.6	7.39	7.75	4.59	4.81	2.80	2.94
	.7	8.61	9.07	4.83	5.08	3.78	3.99
	.8	9.86	10.34	5.18	5.43	4.68	4.91
	.9	11.11	11.64	5.49	5.67	5.62	5.97*
	1.0	12.30	12.90	5.59	5.86	6.71	7.04
Bottom (2500°F)	.6	21.80	22.90	12.28	12.92	9.52	9.98
	.7	25.10	26.30	13.05	13.71	12.05	12.59
	.8	29.20	30.60	13.95	14.61	15.25	15.99
	.9	32.80	34.40	14.72	15.41	18.08	18.99*
	1.0	36.40	38.20	15.30	16.01	21.10	22.19

Note: * indicates maximum q_{fc} required for each region.

TABLE 3-7:

GASEOUS NITROGEN FLOW PARAMETERS

	Item	Region Top	Side	Bottom
T_s:	Maximum test article surface temperature, °F	1200	1800	2500
q_{fc}:	Forced convection heat flux, Btu/second/foot^2	1.3	5.7	18.0
T_ℓ :	Upstream orifice gas temperature, °F	80	80	80
C_{ov}:	Area covered by one jet nozzle, inches^2	15.6	15.6	15.6
h_o :	Distance of nozzle orifice to test article surface, inches	7	7	7
w :	Gas flow per area, pounds/foot^2/second	.0120	.0236	.0373
T_e:	Exhaust gas from array temperature, °F	500	1040	2010
w_n:	Gas flow per nozzle, pounds/second	.00130	.00256	.00404
w_m:	Gas flow per modular unit (i.e., 33 nozzles), pounds/second	.0429	.0845	.1334
M_r:	Number of modular units per region (maximum)	57	36	54
w_t:	Gas flow per region, pounds/second	2.45	3.04	7.20 *
P_ℓ :	Upstream nozzle gas pressure, psia	90	90	90
D_o:	Nozzle orifice diameter, inches	.031	.043	.054

*Therefore: Total maximum gas flow rate for entire system is $w_T = \sum w_t = 2.45 + 3.04 + 7.20 = 12.69$ pounds per second.

3-5-2 Gaseous Nitrogen Flow Passage

The gaseous nitrogen test article cooling system is divided into three similar parallel passages (i.e., circuits) as shown on Figure 3-15. There is a passage for each region, Top region, Side region and Bottom region.

The gaseous nitrogen flow through a typical passage starts with the 500 psig gas entering a flow regulator valve shown on Figure 3-16 and described in the "Purchased Parts - Radiant Array" Section of Part 3 of this manual. The quantity of gas flowing through the valve is controlled to maintain a given pressure in the primary manifold that is immediately downstream from the flow regulator valve as shown in Figure 3-17. The pressure is sensed by a 0-500 psia metal diaphram strain gage pressure transducer on the end of the primary manifold. The control loop between the pressure transducer and the control velve is completed at the master control console and through the control computer.

The nitrogen flow through the control valve, entering the valve at 500 psig and leaving the valve into the primary manifold at a controlled pressure of approximately 90 psia. From the primary manifold the GN_2 (gaseous nitrogen) flows through the distribution hoses into the pivot tubes. The pivot tube is a manifold for a modular unit row. The GN_2 then flows out of the pivot tube into passages in the modular radiant heating unit. Each modular unit has 33 orifices through which the GN_2 passes to impinge uniformly on the surface of the test article. After flowing over a portion of the test article surface and removing heat from it, the GN_2 leaves the radiant chamber via narrow gaps between the modular unit row and is dispersed into the surrounding atmosphere at elevated temperatures. Table 3-7 shows the various system parameters related to the gaseous nitrogen cooling system.

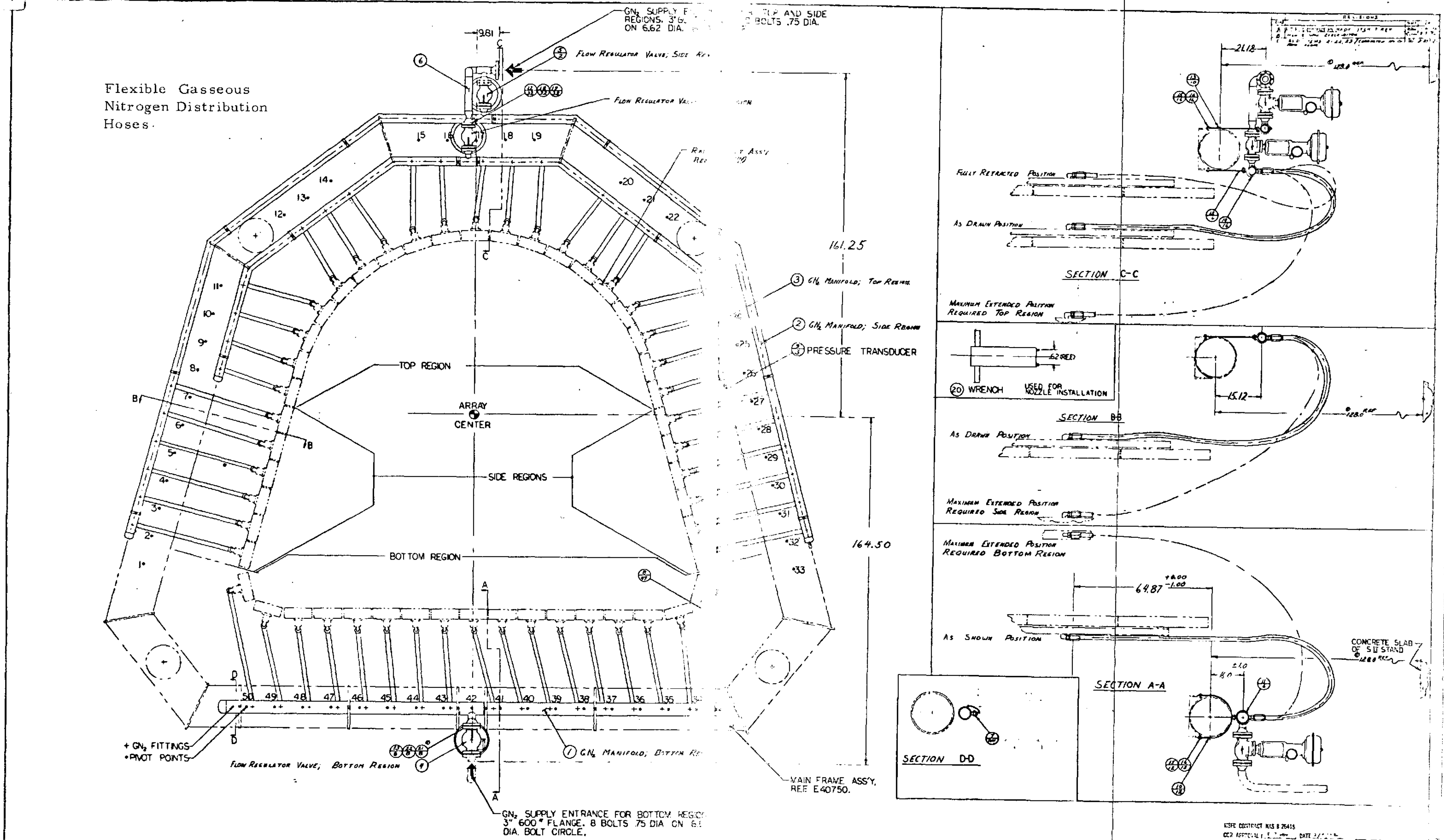


FIGURE 3-15
GASSEOUS NITROGEN COOLING

FOLDOUT FRAME

FOLDOUT FRAME 2

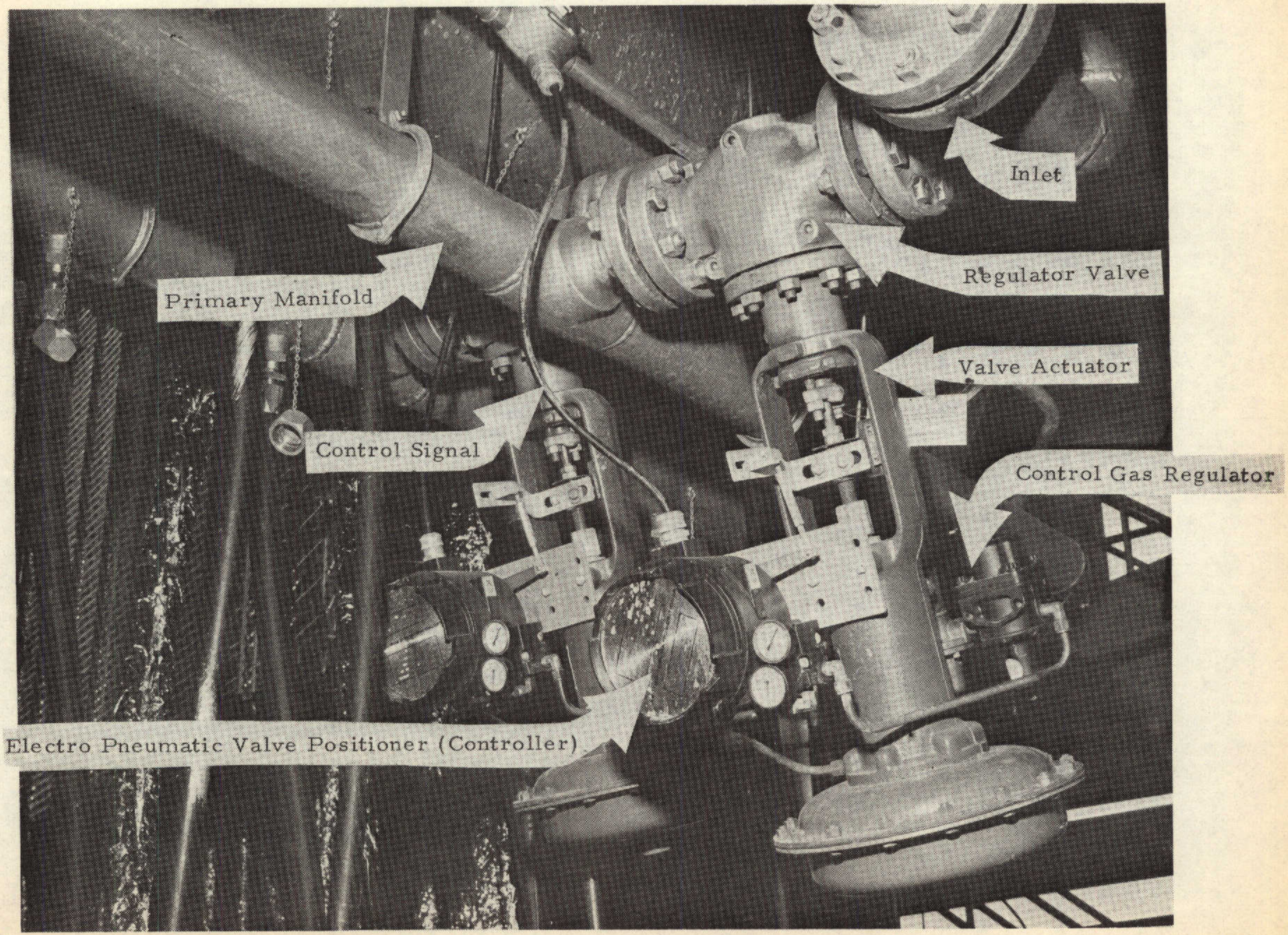


FIGURE 3-16 DETAIL OF GASEOUS NITROGEN CONTROL VALVE

46-A

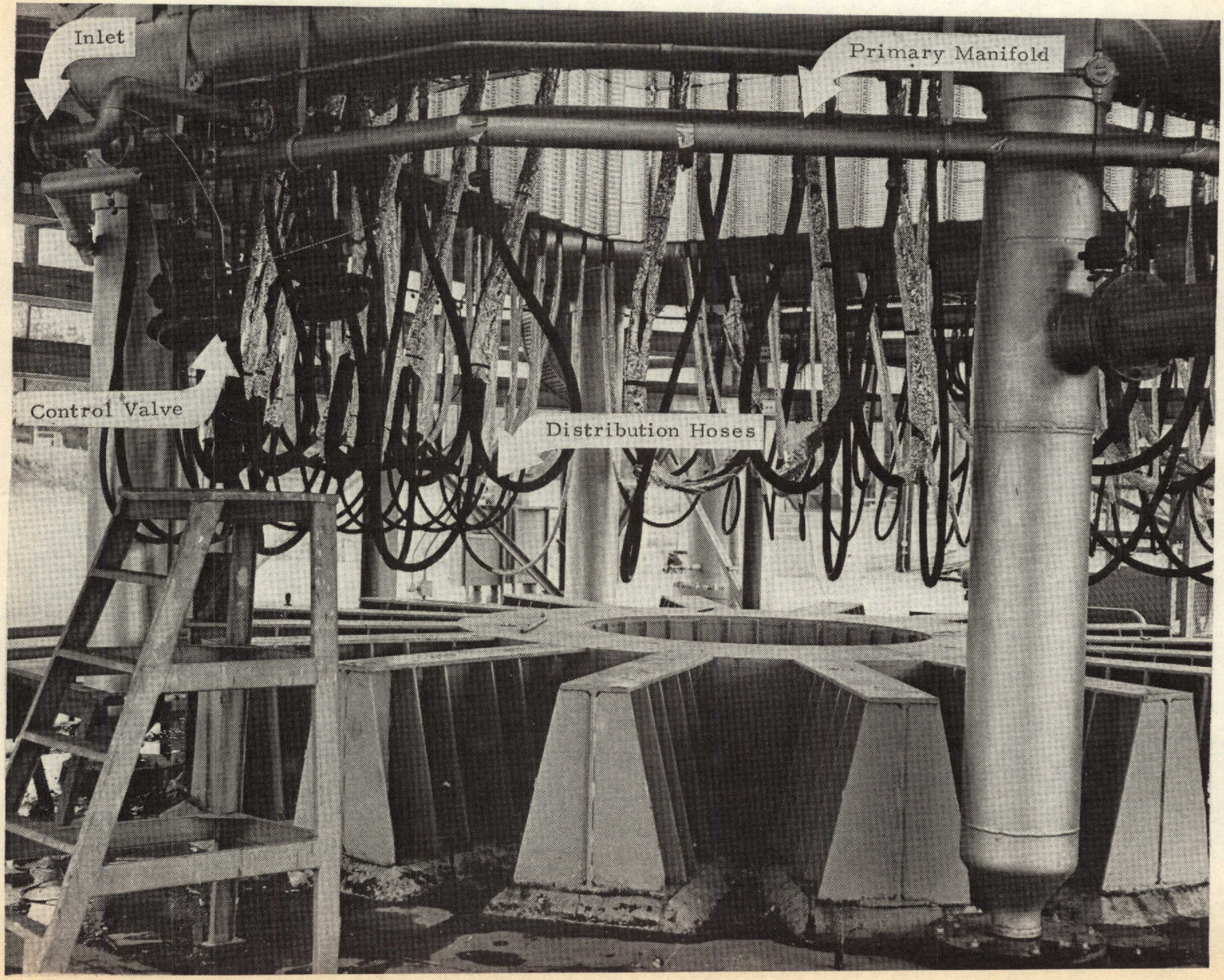


FIGURE 3-17 RADIANT ARRAY: BOTTOM VIEW

46-B

SECTION 4 - SET UP AND START UP

4-1 GENERAL

The radiant array can be configured to accommodate a wide variety of test article configurations. Some of these configurations are shown on Figures 2-9 through 2-13. Figure 7-1 shows the radiant array set up for the largest of these (i.e., Array Configuration for Test Article Number 1: NASA Maximum Envelope, ref Figure 2-9) and the shaded area shows the smallest test article envelope of these combined configurations. However, due to the adjustable features, the array is capable of accommodating many other configurations.

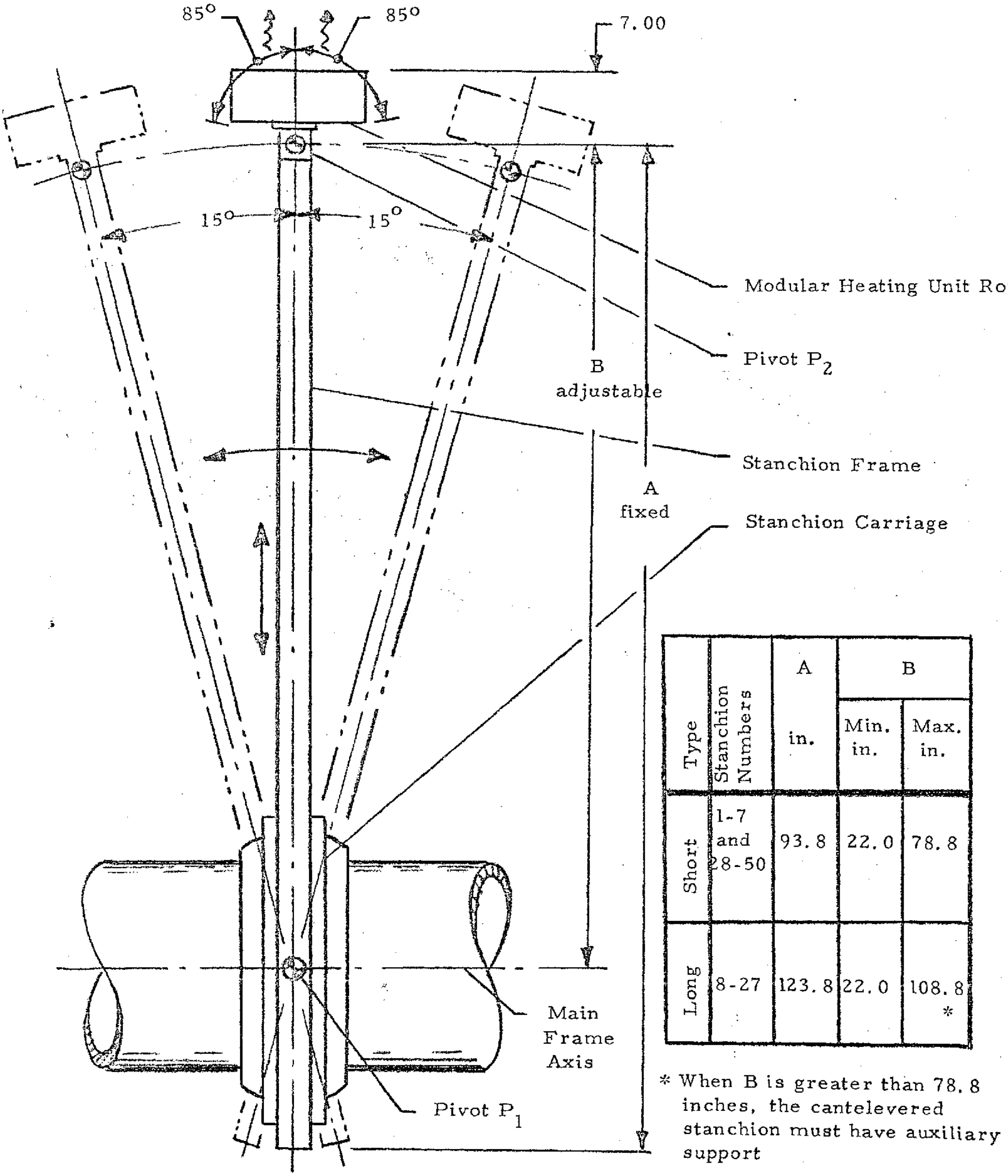
A test artcile can be irradted by surrounding it with an array of modular radiant heating units shown on Figures 3-1 through 3-5. These modular radiant heating units are mounted to an adjustable stanchion frame. One adjustable stanchion frame supports three modular radiant heating units. Each adjustable stanchion is individually supported from a peripheral main frame as shown on Figures 7-1 and 7-2. Therefore, by properly adjusting the required stanchions and modular unit rows, nearly any radiant cavity can be created.

There are two types of adjustable stanchion frames; the "short" and the "long". The short stanchions are located on the straight sections of the main support frame, at points 1 through 7 and 28 through 50 as shown on Figure 7-1 (i.e., In the Bottom and Side regions). The long stanchions are located on the near circular portion of the main frame, at points 8 through 27 as shown on Figure 7-1 (i.e., In the Top region). The long stanchion will provide support for heaters located very near the geometric center of the array (i.e., as near as 16.00 inches).

The range of radiant array configuration adjustment is, therefore dependent upon the stanchion adjustment range with respect to the main frame as shown on Figure 4-1.

There are four modes of adjustment for the stanchion.

1. Stanchion Pivot: The entire stanchion may be pivoted $\pm 15^{\circ}$ about pivot point P_1 to aim the support structure toward the test article surface.



Type	Stanchion Numbers	A	B	
		in.	Min. in.	Max. in.
Short	1-7 and 28-50	93.8	22.0	78.8
Long	8-27	123.8	22.0	108.8 *

* When B is greater than 78.8 inches, the cantelevered stanchion must have auxiliary support

FIGURE 4-1:
STANCHION ADJUSTMENT RANGE

2. Modular Unit Row Pivot: The modular unit row mounted at the cantelevered end of the stanchion may be pivoted $\pm 85^{\circ}$ about point P_2 to aim the modular unit toward the test article surface.

3. Stanchion Extension: The entire stanchion can be extended from pivot point P_I as shown on the table in Figure 4-1 to place radiant unit in proximity of the test article surface.

4-2 ARRAY CONFIGURATION PROCEDURE

The following procedure can be used to set up and reconfigure the radiant array. For illustration, assume that the array is to be configured to accommodate the test article shape shown on Figure 2-10. Here, the shape and the desired surface equilibrium temperature are given.

4-2-1 Layout Array

Layout Test Article Configuration. Make a scaled layout of the test article with the three temperature region boundaries defined (i.e., Top, Side, and Bottom region). A "region" is an area of the test article that is to be subjected to one particular aerodynamic heating profile. That is, the aerodynamic heating conditions are the same throughout the region.

4-2-2 Fit Heating Units

Fit modular radiant unit rows into each region such as the distance from the test article surface to the modular radiant unit is 6 to 8 inches. In this case, 6 to 8 inches spacing is required to attain good radiant heat flux uniformity between adjacent modular unit rows. If radiant units are very near the test article surface, the uniformity will be degraded but system efficiency will be high. If radiant units are far from the test article surface, the uniformity will be good but the system efficiency will be degraded.

Where there is to be a sharp transition in heat flux between adjacent regions, such as between the Bottom and Side region, provide an inner region shield to separate the two. An inner region shield prevents the radiant heat from one region irradiating another region. The inner region shield is shown on Figure 4-2

Also, allow a .13 to .50 inch gap between adjacent modular radiant unit rows so that gaseous nitrogen cooling gas can escape from the radiant cavity during the cooling periods of the test program.

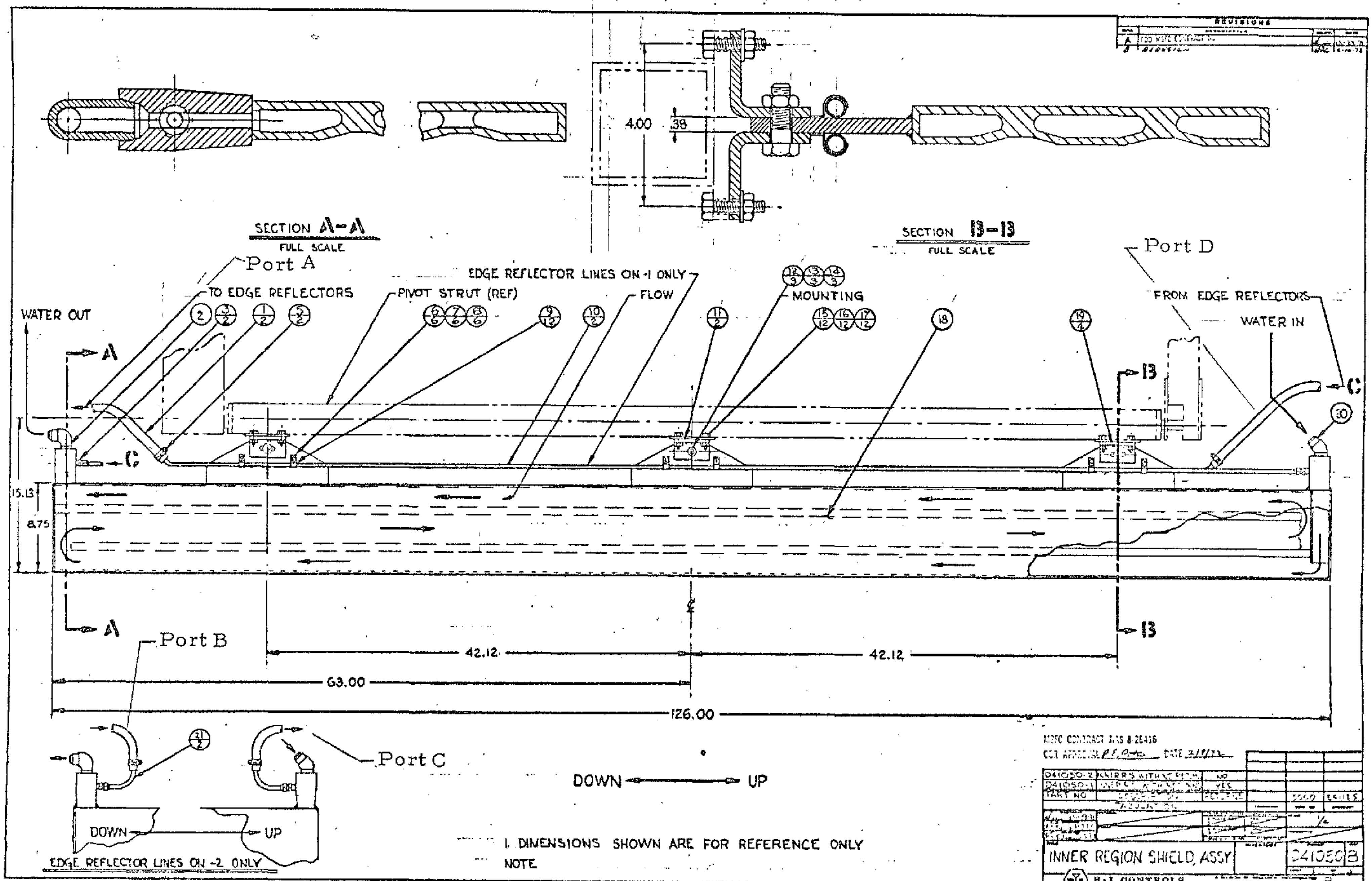


FIGURE 4-2: INNER REGION SHIELD ASSEMBLY

4-2-3 Establish Zones

Divide the regions into zones in order to insure that the entire region is heated in like manner. Even though conditions appear to be the same over the entire region, there are still subtle differences. Some are:

a. Variation in natural convection test article surface heat loss on a vertical surface.

b. Variations in test article surface emittance and absorptance (i. e., surface conditions).

c. Variations in radiant cavity efficiency near the edge boundaries with respect to the center of the region.

d. Possible variations in test article construction such as skin thickness, thermal insulation, etc.

The effect of these variations can be reduced by dividing the region into elemental areas (i. e., zones) and controlling each independently. Many divisions will provide best control. The smallest division possible is equal to the size of one modular radiant unit which covers an area 13.00 inches wide x 42 inches high. However, so small a division is normally not required.

In the example, the Bottom region of the test article configuration shown on Figure 2-10 is divided into 15 zones thus:

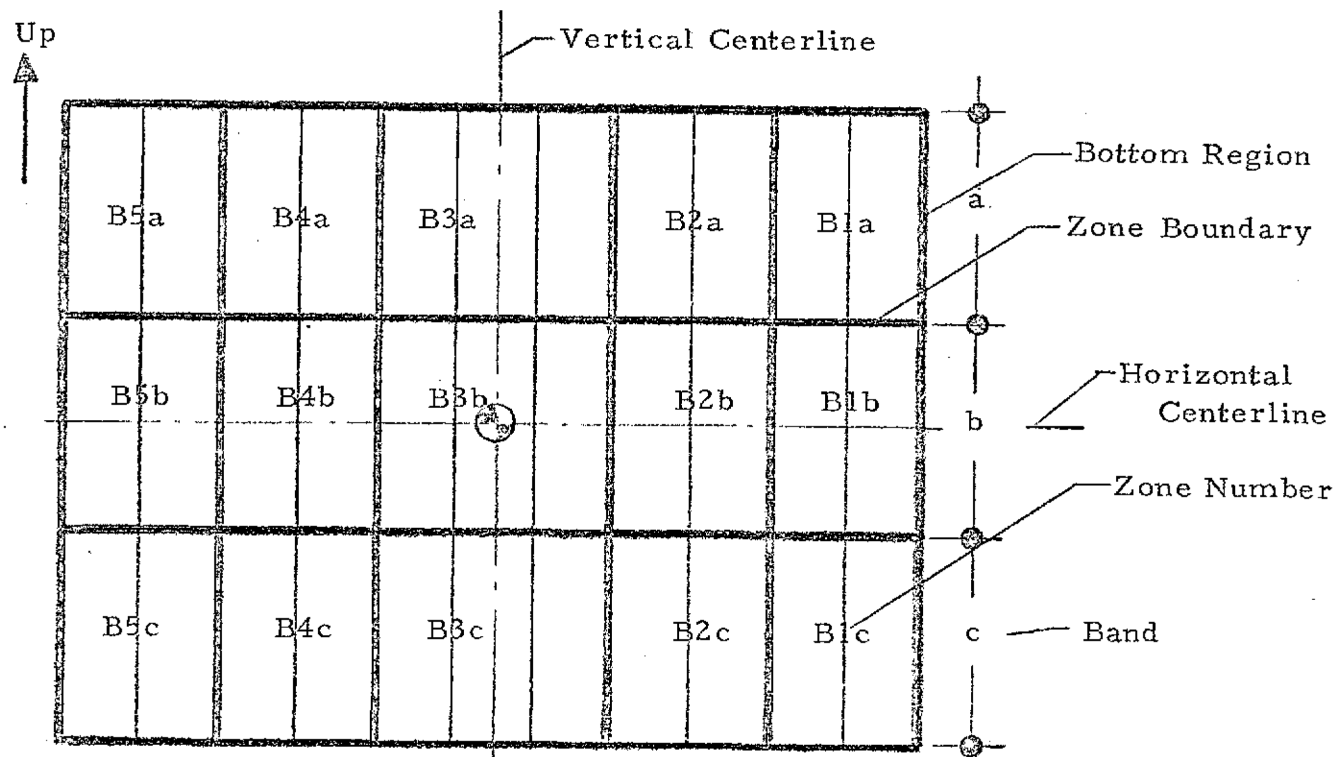


FIGURE 4-3 EXAMPLE OF BOTTOM REGION ZONES

In this case, the effects of vertical variation in convection heat loss are accommodated by dividing the region into three equal bands a, b, and c. The effects due to the 8.0 inch radius corners of the test article are accommodated by providing zones.B1a, B1b, B1c, and B5a, B5b, B5c at these locations. The effects of horizontal condition variations over the large flat area of the test article are accommodated by the remaining zones.

4-2-4 Select Power Control Channels

Assign a power/control channel for each zone. The maximum power demand for a zone must not exceed the power rating for its assigned power/control channel.

The system is provided with 36 power/control channels as shown on Table 4-1.

The power required per zone P_z depends upon the maximum power dissipation capability per modular unit, P_m and the number of modular units to be employed for than zone, thus:

$$P_z = M_z P_m$$

where:

P_z = Power required for the zone, KW
M_z = Number of modular heater units in a zone, KW
P_m = Maximum power dissipation capability per modular heating unit, KW

The maximum power dissipation capability for each of the three types of modular radiant heating units is shown in the following Table 4 2.

TABLE 4-1: POWER/CONTROL CHANNEL RATINGS

	Item	Channel or Zone Number	Power/Control Rating at 460 volts	
			Power, KW	Current, amperes
TOP REGION: 1200°F	1	T1a	170	370
	2	T1b	170	370
	3	T1c	170	370
	4	T2a	170	370
	5	T2b	170	370
	6	T2c	170	370
	7	T3a	170	370
	8	T3b	170	370
	9	T3c	170	370
SIDE REGION: 1800°F	10	S1a	297	645
	11	S1b	297	645
	12	S1c	297	645
	13	S2a	297	645
	14	S2b	297	645
	15	S2c	297	645
	16	S3a	297	645
	17	S3b	297	645
	18	S3c	297	645
	19	S4a	297	645
	20	S4b	297	645
	21	S4c	297	645
BOTTOM REGION: 2500°F	22	B1a	297	645
	23	B1b	297	645
	24	B1c	297	645
	25	B2a*	891	1935
	36	B2b*	891	1935
	27	B2c*	891	1935
	28	B3a*	891	1935
	29	B3b*	891	1935
	30	B3c*	891	1935
	31	B4a*	891	1935
	32	B4b*	891	1935
	33	B4c*	891	1935
	34	B5a	297	645
	35	B5b	297	645
	36	B5c	297	645
TOTAL	—	—	14,895	32,355

* Each of the channels/zones from B2a through B4c are divided into three equal subzones. Each subzone can dissipate up to 297 KW 645 amperes

TABLE 4-2 MODULAR HEATING UNIT POWER						
Region	Modular heating unit number	N'_ℓ Number of lamps per modular unit	S_ℓ On center lamp spacing inches	P_ℓ Power dissipation per lamp KW	P_m Max power dissipation per modular unit	I_m Max current at full power amperes
Top 1200°F	40710-3	9	4.50	2.7	24.3	53
Side 1800°F	40710-2	27	1.50	2.7	72.9	158
Bottom 2500°F	40710-1	55	.75	2.7	148.5	323

Therefore, the power per zone for the Bottom region of the example configuration is as shown in the following Table 4-3.

TABLE 4-3 POWER DISSIPATION CAPABILITIES FOR TEST ARTICLE NUMBER 2*

Zone	M_z Number of Modular Heaters	P_m Max Power Dissipation per Modular Unit, KW	P_z Power Required per Zone KW	Power/ Control Channel Rating KW
B1a	2	148.5	297.0	297
B1b	2	148.5	297.0	297
B1c	2	148.5	297.0	297
B2a	2	148.5	297.0	891
B2b	2	148.5	297.0	891
B2c	2	148.5	297.0	891
B3a	3	148.5	445.5	891
B3b	3	148.5	445.5	891
B3c	3	148.5	445.5	891
B4a	2	148.5	297.0	891
B4b	2	148.5	297.0	891
B4c	2	148.5	297.0	891
B5a	2	148.5	297.0	297
B5b	2	148.5	297.0	297
B5c	2	148.5	297.0	297
Total	33	—	4900.5	9811

* Reference Figure 2-10

TABLE 4-4: POWER PER ZONE FOR TEST ARTICLE NO. 1

TOP REGION - 1200°F				
M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
6	T1a	6	145.8	
	T1b	6	145.8	
	T1c	6	145.8	
7	T2a	7	170.1	
	T2b	7	170.1	
	T2c	7	170.1	
6	T3a	6	145.8	
	T3b	6	145.8	
	T3c	6	145.8	
19		57	1385.1	

SIDE REGION - 1800°F				
3	S1a	3	218.7	
	S1b	3	218.7	
	S1c	3	218.7	
3	S2a	3	218.7	
	S2b	3	218.7	
	S2c	3	218.7	
3	S3a	3	218.7	
	S3b	3	218.7	
	S3c	3	218.7	
3	S4a	3	218.7	
	S4b	3	218.7	
	S4c	3	218.7	
12		36	2614.4	

BOTTOM REGION - 2500°F				
M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
2	B1a	2	297.0	
	B1b	2	297.0	
	B1c	2	297.0	
4	B2a	4	594.0	
	B2b	4	594.0	
	B2c	4	594.0	
5	B3a	5	742.5	
	B3b	5	742.5	
	B3c	5	742.5	
4	B4a	4	594.0	
	B4b	4	594.0	
	B4c	4	594.0	
2	B5a	2	297.0	
	B5b	2	297.0	
	B5c	2	297.0	
17		51	7573.5	

GRAND TOTAL				
48		144	11,573.0	

Ref. Figure 2-9

TABLE 4-5: POWER PER ZONE FOR TEST ARTICLE NO. 2

TOP REGION - 1200°F

M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
6	T1a	6	145.8	
	T1b	6	145.8	
	T1c	6	145.8	
5	T2a	5	121.5	
	T2b	5	121.5	
	T2c	5	121.5	
6	T3a	6	145.8	
	T3b	6	145.8	
	T3c	6	145.8	
17		51	1239.3	

SIDE REGION - 1800°F

M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
3	S1a	3	218.7	
	S1b	3	218.7	
	S1c	3	218.7	
2	S2a	2	145.8	
	S2b	2	145.8	
	S2c	2	145.8	
2	S3a	2	145.8	
	S3b	2	145.8	
	S3c	2	145.8	
3	S4a	3	218.7	
	S4b	3	218.7	
	S4c	3	218.7	
10		30	2187.0	

BOTTOM REGION - 2500°F

M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
2	B1a	2	297.0	
	B1b	2	297.0	
	B1c	2	297.0	
2	B2a	2	297.0	
	B2b	2	297.0	
	B2c	2	297.0	
3	B3a	3	445.5	
	B3b	3	445.5	
	B3c	3	445.4	
2	B4a	2	297.0	
	B4b	2	297.0	
	B4c	2	297.0	
2	B5a	2	297.0	
	B5b	2	297.0	
	B5c	2	297.0	
11		33	4900.5	

GRAND TOTAL

38		114	8326.8	

Ref Figure 2-10

TABLE 4-6: POWER PER ZONE FOR TEST ARTICLE NO. 3

TOP REGION - 1200°F				
M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
5	T1a	5	121.5	
	T1b	5	121.5	
	T1c	5	121.5	
5	T2a	5	121.5	
	T2b	5	121.5	
	T2c	5	121.5	
5	T3a	5	121.5	
	T3b	5	121.5	
	T3c	5	121.5	
15		45	1093.5	

SIDE REGION - 1800°F				
3	S1a	3	218.7	
	S1b	3	218.7	
	S1c	3	218.7	
2	S2a	2	145.8	
	S2b	2	145.8	
	S2c	2	145.8	
2	S3a	2	145.8	
	S3b	2	145.8	
	S3c	2	145.8	
3	S4a	3	218.7	
	S4b	3	218.7	
	S4c	3	218.7	
10		30	2187.0	

BOTTOM REGION - 2500°F				
M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
2	B1a	2	297.0	
	B1b	2	297.0	
	B1c	2	297.0	
4	B2a	3	445.5	
	B2b	3	445.5	
	B2c	3	445.5	
3	B3a	4	594.0	
	B3b	4	594.0	
	B3c	4	594.0	
4	B4a	3	445.5	
	B4b	3	445.5	
	B4c	3	445.5	
2	B5a	2	297.0	
	B5b	2	297.0	
	B5c	2	297.0	
15		45	6237.0	

GRAND TOTAL				
40		120	9517.5	

Ref Figure 2-11

TABLE 4-7: POWER PER ZONE FOR TEST ARTICLE NO. 4

TOP REGION - 1200° F				
M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
4	T1a	4	97.2	
	T1b	4	97.2	
	T1c	4	97.2	
3	T2a	3	72.9	
	T2b	3	72.9	
	T2c	3	72.9	
4	T3a	4	97.2	
	T3b	4	97.2	
	T3c	4	97.2	
11		33	801.9	

SIDE REGION - 1800° F				
3	S1a	3	218.7	
	S1b	3	218.7	
	S1c	3	218.7	
2	S2a	2	145.8	
	S2b	2	145.8	
	S2c	2	145.8	
2	S3a	2	145.8	
	S3b	2	145.8	
	S3c	2	145.8	
3	S4a	3	218.7	
	S4b	3	218.7	
	S4c	3	218.7	
10		30	2187.0	

BOTTOM REGION - 2500° F				
M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
2	B1a	2	297.0	
	B1b	2	297.0	
	B1c	2	297.0	
5	B2a	5	742.5	
	B2b	5	742.5	
	B2c	5	742.5	
4	B3a	4	594.0	
	B3b	4	594.0	
	B3c	4	594.0	
5	B4a	5	742.5	
	B4b	5	742.5	
	B4c	5	742.5	
2	B5a	2	297.0	
	B5b	2	297.0	
	B5c	2	297.0	
18		54	8019.0	

GRAND TOTAL				
39		117	11,007.9	

Ref. Figure 2-12

TABLE 4-8: POWER PER ZONE FOR TEST ARTICLE NO. 5

TOP REGION - 1200°F

M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
5	T1a	5	121.5	
	T1b	5	121.5	
	T1c	5	121.5	
4	T2a	4	97.2	
	T2b	4	97.2	
	T2c	4	97.2	
5	T3a	5	121.5	
	T3b	5	121.5	
	T3c	5	121.5	
14		42	1020.6	

SIDE REGION - 1800°F

M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
3	S1a	3	218.7	
	S1b	3	218.7	
	S1c	3	218.7	
2	S2a	2	145.8	
	S2b	2	145.8	
	S2c	2	145.8	
2	S3a	2	145.8	
	S3b	2	145.8	
	S3c	2	145.8	
3	S4a	3	218.7	
	S4b	3	218.7	
	S4c	3	218.7	
10		30	2187.0	

BOTTOM REGION - 2500°F

M_r Modular Unit Rows	Zone Number	M_z Modular Units per Zone	P_z Max. Power per Zone, KW	
2	B1a	2	297.0	
	B1b	2	297.0	
	B1c	2	297.0	
4	B2a	4	594.0	
	B2b	4	594.0	
	B2c	4	594.0	
3	B3a	3	445.5	
	B3b	3	445.5	
	B3c	3	445.5	
4	B4a	4	594.0	
	B4b	4	594.0	
	B4c	4	594.0	
2	B5a	2	297.0	
	B5b	2	297.0	
	B5c	2	297.0	
15		45	6682.5	

GRAND TOTAL

39		117	9870.1	

Ref. Figure 2-13

Since the power required, P_z, for each zone is equal to or less than the rating of the assigned power/control channel, the established zoning arrangement is satisfactory.

The arrangement and number of modular units, M_z, of each test article array configuration is shown on Figures 2-9 through 2-13.

The maximum power dissipation capability for each zone, each region and each radiant configuration is shown in Tables 4-4 through 4-8.

The power control channels for each of the test article configurations 1 through 5 are sized for the extreme condition. Table 4-1 summarizes the maximum power capabilities for each of these zones. So, each zone power control channel is capable of controlling the maximum power; however, this quantity of power will not be required for any one of the five array configurations.

The maximum power dissipation may occur for test article number 1 (ref: Table 4-4) at 11,573 KW.

4-2-5 Locate Control Sensors

At least one control sensor is required per zone. Each zone operates in closed loop control from the sensor signal. The sensor signal represents the dynamic control parameter (i.e., temperature, incident heat flux) of the test article surface. Therefore, the control sensor should be located to represent the test article surface condition in that zone. That is, we say that all points on the test article surface in that zone are like the point where the sensor is located.

The criteria for locating the control sensor is that it be located on the test article surface having a major influence from the corresponding radiant heat sources. Major influence occurs near the center of the zone area; therefore, they should be located near the center of the zone However, in some zones the modular unit row boundary or an air jet cooling nozzle occurs at the center. In order to avoid the slight disturbing effects of these localized radiant array conditions, the seonsors should be located slightly off center.

If the sensor is located opposite a modular unit row boundary, the incident heat flux is at a minimum because there are no radiant heat sources there. If it is located opposite the center of a modular unit row, the incident heat flux is at a maximum because radiant heat sources are directly opposite. However, if it is located between the modular unit row boundary and the center of the modular unit row, the incident heat flux will be between these two extremes and represent the mean condition for the entire zone.

The same argument holds for locating the sensor opposite or centered between air jet nozzles. It should be located neither opposite or centered between them but instead, between these two maximum and minimum positions.

Therefore, sensors are located <u>near</u> the center of the zone on the following basis:

a. If the zone center occurs at a modular unit row boundary like that of zone B2 shown on Figure 2-10, locate sensor right or left 3.5 $\pm$ .5 inches.

b. If the zone center occurs at the center of a modular unit row, like that of zone B3 shown on Figure 2-10, locate sensor right or left 3.0 $\pm$ .5 inches.

c. If a GN_2 jet nozzle occurs opposite the above sensor locations, locate the sensor .88 $\pm$ .3 inch upward or downward, to avoid direct gaseous nitrogen impingement from the nozzle.

The type of sensor to be employed will depend upon the desired control parameter; in this case, temperature or incident heat flux. To be compatible with the controls, the sensor signal must be conditioned to yield a 0 to 1.0 volt DC input to the controls.

Consideration must be given to the sensor attachment and the sensor leads. It is, therefore, recommended that the attachment be designed to withstand the anticipated environment and the sensor leads be protected from failure due to overheating. Where possible, the sensor leads should be located within the test article where the temperature is lower during the heating cycle. If the leads were attached on the outside surface of the test article, they will be directly exposed to the incident radiant heat energy and can be expected to exceed the temperature of the test article skin during heating due to their relatively low thermal capacity.

Perhaps these considerations and provisions should be made during the design of the test article.

4-2-6 Install Modular Heat Units

At this point, it is assured that (a) the test article is not installed, (b) the desired stanchions are mounted to the main frame, and (c) the modular unit rows are assembled onto the pivot tube and are lamped.

a. Ready stanchion by removing upper pivot pin item 1 and pin alignment plate, item 2 on Figure 3-9.
b. Lift assembled modular unit row via the lifting eye on the pivot tube and place the lower end of the pivot tube onto the bottom pivot pin shown on Figure 3-9. The lifting device must support the weight of a 800 pound modular unit row.
c. Insert upper pivot pin, item 1, with alignment plate, item 2 as shown on Figure 3-9.
d. Retract stanchion toward main frame to be out of the way for proceeding modular unit row installation.

4-2-7 Adjust Modular Unit Rows

If the test article is not installed, the recommended method to adjust the modular unit rows to the array configuration is the following "template" method. A template is used as an index to precisely locate each modular unit row.

4-2-7-1 Make Template

Make a full scale template of the radiant array horizontal cross section. Use 3/8 to 1/2 inch thick plywood with surface painted white for applying legible layout markings. Layout the test article surface cross section and the location of each modular radiant heating unit row front surface (i.e., the surface on which the modular unit rows will be located). Mark the peripheral location of each modular unit row on the surface they will be located and label their respective stanchion numbers. Then cut the template at the surface where the modular unit rows will be located.

4-2-7-2 Install Template

Install the cut and marked template at some convenient location where the test article will be located. A temporary wood frame should be sufficient for this purpose.

4-2-7-3 Position Modular Unit Rows

Extend the contelevered stanchion frames from the main frame toward the template until the front face of the radiant heating unit is indexed against the template.

If the stanchion frame is not level or the modular unit rows are not vertical, the stanchion carriage assembly shown on Figure 3-10 may be slightly tipped by adjusting the four leveling screw jacks. A thin 1-1/8 inch open end box wrench is required for this adjustment.

4-2-7-4 Lock Adjustment Frame

After the modular unit row positions have been established and the array is configured, lock all adjustments of the adjustable frame as follows. There are three adjustments to be locked as shown on Figures 4-1.

a. Lock Stanchion Pivot P_1: Tighten the four stanchion pivot P_1 locking screws with a 3/8 inch "allen" socket wrench. This will clamp the stanchion carriage assembly to the support plate on the main frame.

b. Lock Stanchion Extension Position: Tighten the four stanchion locking screws item 16 on Figure 3-10. First tighten the two screws on one side of the stanchion until the clamping shoe item 2 on Figure 3-10 is in contact with the stanchion structure I beam. Then tighten the two screws on the other side to clamp the stanchion I beam between the two clamping shoes. Use a 3/8 inch allen socket wrench.

c. Lock Modular Unit Tow Pivot P_2: Tighten the upper and lower set screws located at the ends of the modular unit row pivot tube. the set screw clamps against a recessed surface on the pivot pins.

4-2-7-5 Remove Template

Dismantle the template from inside the radiant array. Avoid damage to the lamps and reflector surface.

4-2-8 Connect Services

Connect power, cooling water, and gaseous nitrogen leads to the modular radiant heating units as follows:

4-2-8-1 Connect Power

Flexible power leads are provided on each stanchion for each of the three modular radiant heating units. These leads originate from the link panel junction cabinets located on the periphery of the array as shown on Figures 2-6, 4-4, and 7-2. A coded terminal board is located inside the cabinet labeling the power/control channel. A water-proof rubber twist lock connector is provided at the output ends of the flexible cable. Push the female connector at the end of the cable onto the male connector located at the rear of each of the modular radiant heat units and then twist clockwise to lock as shown on Figure 4-4.

4-2-8-2 Connect Water

Flexible water lines (i.e., hoses) are provided from the water manifolds to the rear of the modular radiant unit rows. J1C swivel type connectors are used for the connections. A 1-1/4 inch open end wrench can be used to tighten these connections.

a. Connect input supply water to upper left input fitting located at the rear of the modular unit row as shown on Figure 3-13.
b. Connect output water from the modular unit row at the lower right fitting located at the rear of the modular unit row as shown on Figure 3-13.
c. Close drain cocks located at the bottom rear of each modular radiant unit. There are two drain cocks per modular radiant unit.
d. Connect water in and out of the inner region shields(i.e. "in" on fitting item 20 and "out" on fitting item 2 as shown on Figure 4-2.
e. Cap unused water manifold connections. Screw on the chained cap item 6 on Figure 3-12 located on both the supply manifold and exit drain manifold.

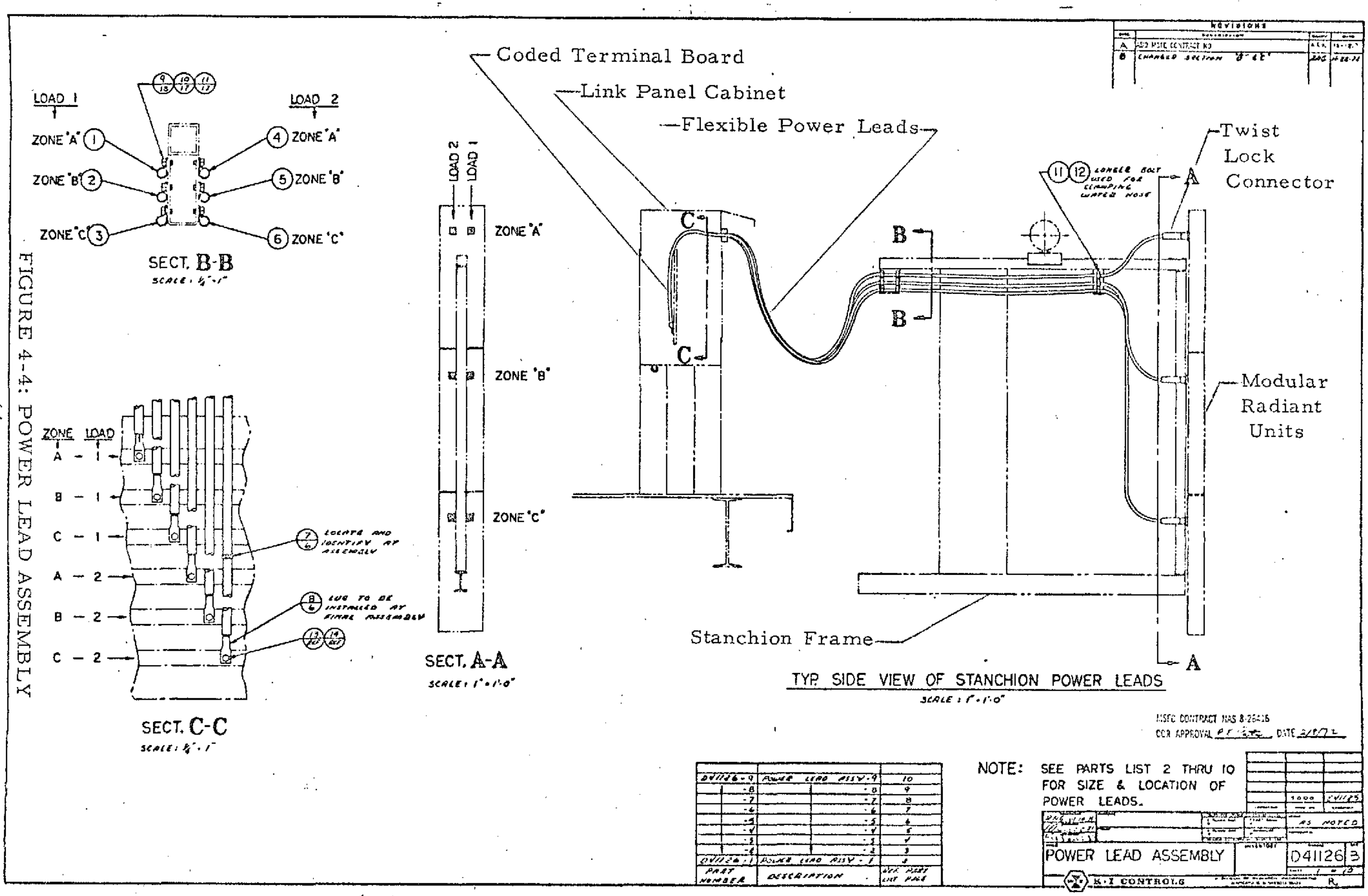


FIGURE 4-4: POWER LEAD ASSEMBLY

4-2-8-3 Connect Gaseous Nitrogen

Gaseous nitrogen for test article cooling periods is supplied to the modular radiant units via a flexible 1-1/8 inch diameter hose. This hose is provided with a J1C swivel type fitting and is connected to a elbow fitting located at the center of the modular unit row pivot tube as shown on Figure 3-13.

4-2-9 Preliminary Check

At this point in the set up, the radiant array should be subjected to a few preliminary checks so that inadvertent corrections can be made with minimum effort. During these checks, the system will be operated in open loop "manual" mode since there is no test article or control sensors available. The following preliminary checks should be made.

4-2-9-1 Water Check

Introduce cooling water into the system by opening the supply manual gate valve located on the SII stand and the two air operated valves for water into the Bottom region manifold and the Side/Top region manifold. The manifold pressure should not be permitted to exceed 20 psig to insure that fittings inside the modular radiant units are not over pressured. Note that the following is true.

a. There is adequate water flow through the radiant array (reference Section 3-4-2 for required flow rates). ____________ c
b. There is water flow through each of the modular radiant heating units as determined by opening each of the two drain cocks located at the bottom rear of each modular radiant unit. ____________ c
c. There are no observable water leaks throughout the array water passage system as determined by observation. ____________ c

4-2-9-2 Check Wiring

Check the power wiring by energizing each zone independently. However, prior to energizing the array it is important that the electrical insulation surfaces of the modular radiant units are dry. Therefore, check insulator tiles, items 27 and 28 and also insulation strip, item 52 shown on Figure 3-2 for dryness. If these items are excessively wet, as may be the case if the array were subjected to rain or water leaks, they will conduct electrical current to ground. Note the following to be true.

a. The radiant array zones are connected to the proper assigned power/control channel as determined by observation when the zone is energuzed at low power ___________ c

b. All zones can operate at full power (i.e., when voltage is maximized) without mishap. ___________ c

4-2-9-3 Lamp Check

Check all lamps in the radiant array for possible burn outs, leakers, and defects by energizing the array at low power (i.e., about 3 cycles out of 63) and observing defective lamp locations. A burned out lamp will not illuminate. A leaking lamp will discolor. Replace the defective lamps and note that all lamps in the array function. ___________ c

4-2-9-4 Gaseous Nitrogen Check

Check the manual mode operation of the gaseous nitrogen system and note the following to be true.

a. The modular radiant units have the correct nozzle installation as per the following Table 4-9. ___________ c

TABLE 4-9 GASEOUS NITROGEN NOZZLES

Modular Heater in Region	Nozzle Part Number	Nozzle Opening Diameter, inches
Top	B40728-1	.031
Side	B40728-2	.043
Bottom	B40728-3	.054

b. The GN_2 control valves for the Top, Side, and Bottom region function via manual control. ___________ c

c. GN_2 does exit the modular radiant heating unit nozzles toward the test article surface as observed when the control valve is manually opened. ___________ c

d. There is a .13 to .50 inch gap between adjacent modular unit rows for the exit of gaseous nitrogen from the radiant cavity. ___________ c

4-2-10 Test Article Installation

Install test article into the radiant array from above. Considerable care is required to prevent damage to the array or test article since there is only 6 to 8 inches peripheral clearance between the test article and the radiant array.

4-2-11 Attach End Reflectors

The upper and lower end reflectors enclose the radiant cavity. They attach to the top and the bottom of a modular radiant unit row as shown for items 14 and 15 of Figures 7-1 and 7-2. Each end reflector is adjustable to fill the gap between the modular and within about .50 inch from the test article. Each overlaps the adjacent panel as shown on Figures 4-5 and 4-6 to accommodate most any test article shape.

There are two kinds of end reflectors for use in the following locations (reference: Table 4-10).

TABLE 4-10 END REFLECTOR

Type of End Reflector	Part Number	Shown on Figure	Where Used	
			Region	Radiant Cavity End
Water-cooled	D41011	4-5	Bottom	Upper and Lower
			Side	Upper
Uncooled	D41012	4-6	Side	Lower
			Top	Upper and Lower

Attach the proper end reflector panel to each end of the modular unit row via the wing nut fastener, item 2 shown on Figures 4-5 and 4-6. Plumb water lines for the water cooled types using push-on hose and clamp connections as shown on Figures 7-1 and 4-5. All end reflectors for a region are plumbed in series.

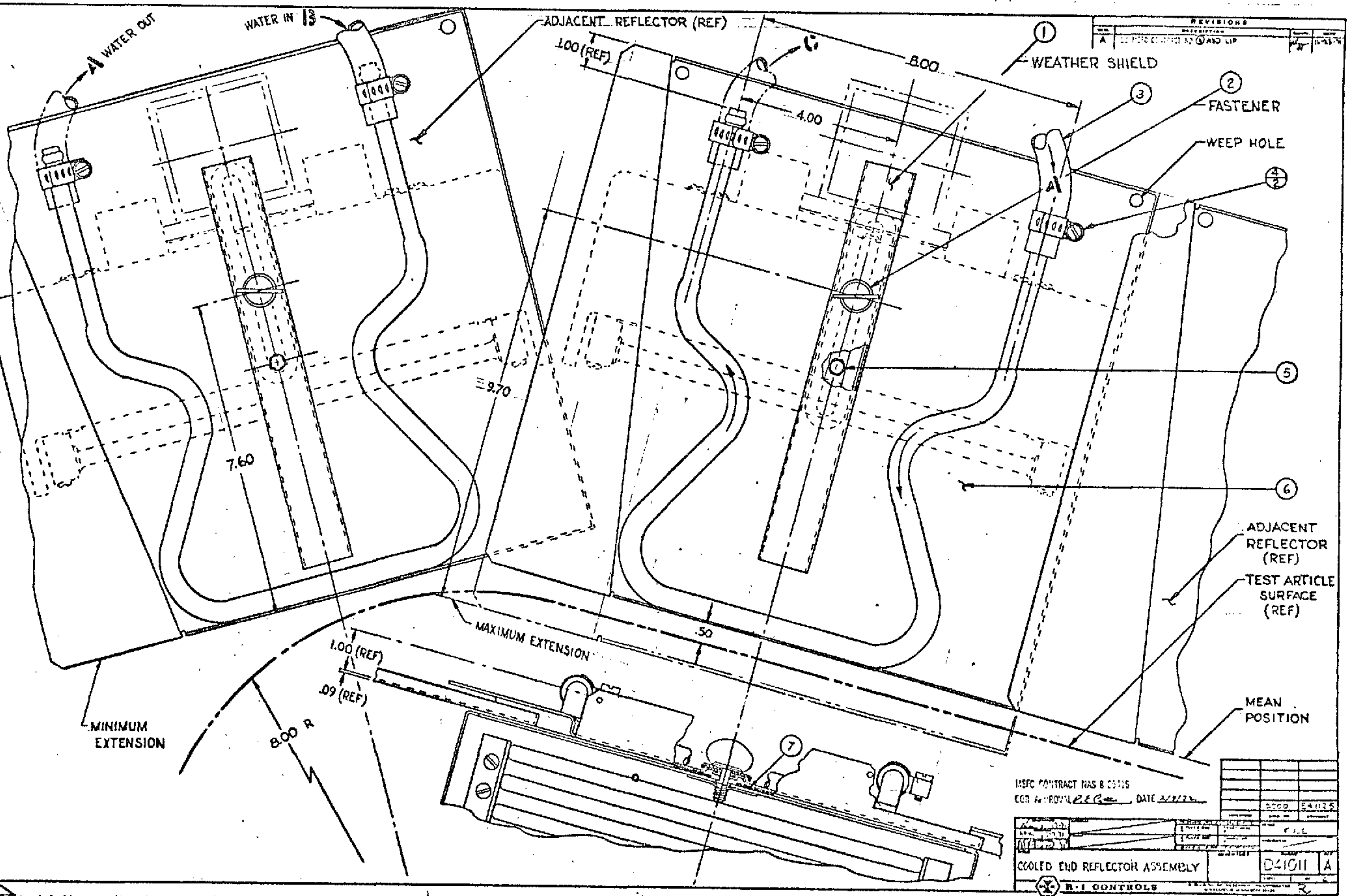


FIGURE 4-5: COOLED END REFLECTOR

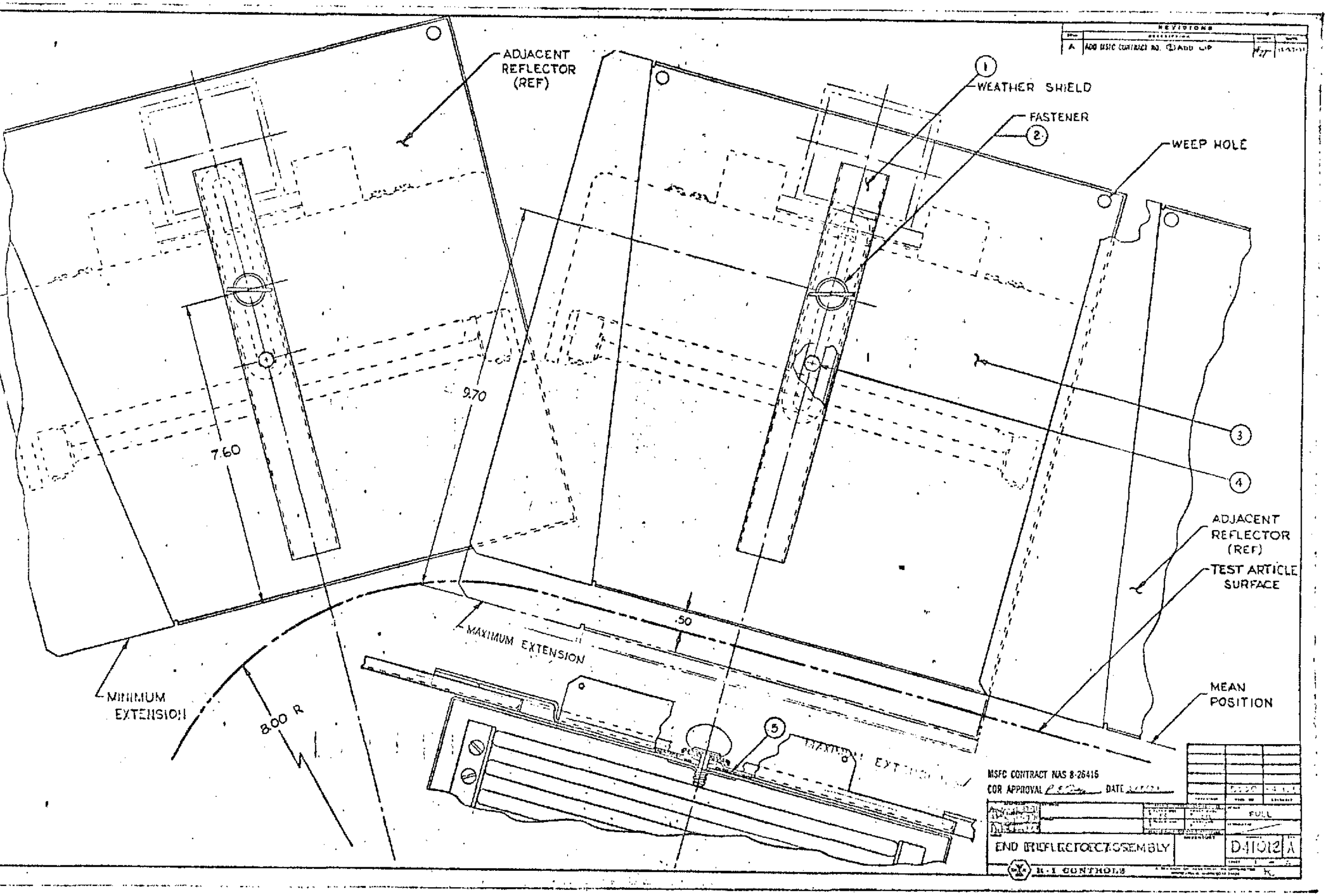


FIGURE 4-6: END REFLECTOR

For the lower end of the Bottom region, water is supplied from port A of the inner region shield and after passing through the end reflectors it exits to port B of the second inner region shield as shown on Figure 4-2.

For the upper end of the Bottom region, water is supplied from port C of the inner region shield and after passing through the end reflectors, it exits to port D of the other inner region shield as shown on Figure 4-2.

For the upper end of the Side region, water is supplied directly from the Side/Top region manifold via a port located between stanchion pivots 7 and 8 and also 26 and 27. After passing through the end reflectors, the water exits to a port provided in the main exit manifold near stanchion pivot points number 1 and 33 as shown on Figure 7-1.

4-2-12 Preliminary Dynamic Heat Test

At this point, the radiant array is ready to function under dynamic test article heating conditions. The purpose of this test is to determine if all subsystems function under controlled dynamic heating conditions. For this test, a low level dynamic radiant heating program that will not degrade the test article prior to the final test should be written. Perhaps such a program would not exceed 400-500^{o}F test article temperatures.

5-1 LAMP MAINTENANCE

The lamp is an expendable component. Its operating life will depend upon the particular operating conditions encountered during the test runs.

In general, for such a system, lamp failure would be due to an overheated lamp endseal terminal or quartz envelope. In this system we may expect a lamp to fail for one of these reasons, depending upon test article region and operating duration.

TABLE 5-1 LAMP FAILURE MODES

Region	Probable Cause of Failure
Top	Endseal
Side	Endseal
Bottom	Quartz Envelope

However, the above type of failures do not preclude others, such as (a) old age, and (b) overvoltage. Old age is characterized by a darkening of the quartz lamp envelope due to tungsten deposits as discussed in Section 3-1-6-2. Overvoltage is often characterized by violent bursting due to rapid vaporization of the tungsten filament. The voltage should not be permitted to exceed 460 volts.

A defective radiant heating lamp may be replaced in the following manner.

5-1-1 Modular Unit Row Retraction

Retract modular unit row in which defective lamp appears in order to gain access to the front and rear sides of the modular heater as follows.

a. Detach upper and lower edge reflector from modular unit row by removing wing nut fastener -2 shown on Figure 4-5 or 4-6.

b. Release stanchion carriage break plate by loosening two of the stanchion locking screws, -16 shown on Figure 3-10 with a 3/8 inch allen sock wrench. The two locking screws on one side of the stanchion carriage assembly will release one of the break shoes plates. The other break shoe plate should not be loosened because it acts as a reference surface when the stanchion is returned and relocked into position.

c. Pull entire stanchion assembly together with the modular unit row rearward (i.e., radially outward from array center) about 12 inches. The stanchion frame "I" beam is supported on ball bearing trolley wheels as shown on Figure 3-10 and the upper portion of the stanchion frame is guided in a shoe, -2 as shown on Figure 3-11.

5-1-2 Lamp Removal

a. Remove the two covers, -1 as shown on Figure 3-2 by loosening attachment screws, -2 shown on Figure 3-1; thus, exposing the lamp lead terminals.

b. Disconnect defective lamp leads from terminal screw, -2 on Figure 3-2.

c. Slide lamp socket clip to one side by loosening screw, -34 on Figure 3-2 located on reflector side of unit.

d. Pull defective lamp out of grooved socket from reflector side of unit.

5-1-3 Lamp Installation

a. Select lamp. Use standard tubular quartz tungsten filament lamp number 1000 T3/CL/HT or Q3M T3/CL/HT. Both lamps dissipate the same power; however, the Q3M T3/CL/HT lamp is a halogen cycle lamp having longer potential life for operation above 240 volts.

b. Remove new lamp from carton. It is recommended that the lamp be handled by the metallic endseals and flexible leads rather than by the quartz lamp envelope, since quartz contamination due to body oils and etc. will degrade lamp envelope life.

c. Straighten flexible lamp leads to be perpendicular to filament axis.

d. Insert ends of flexible lamp leads into lamp socket and feed them through the slot provided. They will project out the rear side of the radiant unit adjacent to the lamp lead terminal screw.

e. Place lamp enseal into socket groove. The lamp should be loose and not bind in the groove.

f. Connect flexible lamp to terminal screw, -2 shown on Figure 3-2 at rear of unit.
CAUTION: Lamp lead should not be in tension after tightening lamp lead terminal screw.

g. Slide lamp socket clip, -33 over lamp socket and tighten screw, -34 shown on Figure 3-2.

h. Check installation:, The lamp should be loose in the socket and free to move $\pm$ .03 inch or more in all directions.
If not check (a) lamp lead tension and (b) the lamp for twisted endseal.

i. Trim excess lamp lead from under lamp terminal screw, if required, to prevent shorting to the case cover.

j. Replace modular heater unit side covers, -1 as shown on Figure 3-2 and tighten attachment screws.

5-1-4 Replace Modular Unit Row

a. Push stanchion frame assembly together with modular radiant units into psotiion (i.e., radially inward toward center of array). The proper position may be determined by lining it up with respect to the adjacent modular unit rows of the radiant array. There should be an equal vertical clearance gap of about .13 to .50 inches between adjacent modular unit rows.

b. Lock stancion in final adjusted position by tightening the same two stanchion locking screws (ref: item 5-1-1 (b) above) used to release it.

c. Inspect flexible service leads (i.e., (a) power, (b) water in, (c) water out, and (d) GN_2 in). They should drape like those of adjacent units.

d. Attach upper and lower edge reflector to the modular unit row via wing nut fastener, -2 shown on Figure 4-5 or 4-6.

5-2 REFLECTOR MAINTENANCE

The reflector surface should be maintained in a clean specular condition to obtain desired performance. If these surfaces become contaminated due to test article outgassing or improper inactive environmental protection, they may be cleaned in the following manner.

5-2-1 Dust

Particles of atmospheric dust that adhere lightly to the reflector and lamp envelope surface may be removed in the following manner.

a. Vacuum with fine brush attachment.
b. Dust with feather duster or fine bristle brush.
c. Dust with fine cheese cloth.
d. Blow with clean forced air from vacuum cleaner output.

5-2-2 Film

A contaminating film such as smoke may be removed from the reflector surface and lamp envelopes by washing the surfaces with a warm solution of 10% household ammonia and water. A soft cloth should be used to prevent scratching the reflector. After washing, the surfaces should be wiped dry with a soft cloth.

5-2-3 Coating

If there is an adhesive coating on the surfaces and none of the above methods will remove it, various compatible solvents may be tried. However, if unsuccessful, the contaminated area should be scoured and repolished as follows.

a. Small Areas: Scour area with fine abrasive such as "Brillo pad" or "Scotch Brite pad" until contamination is removed. Then polish to a specular finish.
b. Large Areas: Remove lamps and, if necessary, disassemble modular radiant unit and have surfaces repolished to specular finish according to fabrication drawings.

5-3 WEATHER PROTECTION

Since the radiant array is exposed to the weather, inside the SII test stand, it can gradually deteriorate. It is, therefore, recommended that the radiant array be covered during periods of non-use.

A protective cover of canvas, or plastic film should be placed over the radiant heat units when ever adverse weather conditions such as rain, snow, dust storms, are anticipated.

C2

SECTION 6 - SPARE PARTS

6-1 LIST

The recommended spare parts for the radiant array is based on the expendable nature of some of the components. The following list describes the item and reason for the recommended quantity.

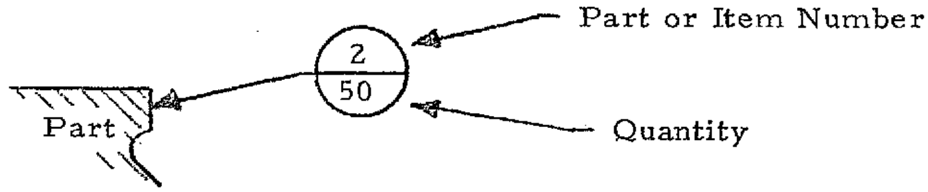
1. Lamp, Item 37 of drawing D40701 (Shown on Figure 3-2) — The lamp is the most expandable item of the radiant array. The number of spares should be enough to relamp the region having the greatest number of lamps, in this case, the Bottom region of test article configuration number 4 shown on Figure 2-12. Therefore, 2970 spare lamps are recommended.
2. Cooled End Reflector, item 14 of drawing E41125 (shown on Figures 7-1 and 4-5). — Since this item is subject to failure due to excessive heating caused by possible test article outgassing contamination that may rise up inside the radiant cavity and coat the reflector, there should be at least enough spares for the upper portion of the largest region in which they are used. The largest region is the Bottom region of test article number 4 shown on Figure 2-12. Therefore, 18 spares are recommended.
3. End Reflector Assembly, item 15 of drawing E41125 (shown on Figures 7-1 and 4-6) — The uncooled end reflectors for the lower temperature regions of the radiant array are also subject to failure as described in Item 2 above. The greatest number required in the upper portion of a region is that for the Top region of test article number 1 shown on Figure 2-9. Therefore, 19 spares should be provided.
4. Radiant Unit Assembly, number D40710 (shown on Figure 3-1) — In case it is necessary to quickly service a modular radiant unit in the array, it may be desirable to have one assembled modular row of heaters available for quick change. Therefore, three modular radiant unit spares are recommended.

5. Pivot Tube Assembly, item 4 of drawing D41137(shown on Figure 3-9) ———

The three modular radiant units described in item 4 above could be preassembled onto the modular unit row pivot tube in readiness for a quick change. Therefore, one spare pivot tube assembly is recommended.

7-1 DRAWING CODE

The radiant array is defined on a set of "as built" drawings located in the MSFC files. The top assembly drawing for the entire radiant array is drawing number E41125 as shown on Figures 7-1 and 7-2. This drawing shows all major subassemblies of the radiant array. Each subassembly and component of an assembly drawing is given a number (i.e., item number) in a baloon, thus:



There is a separate parts list, in tabular form, associated with each assembly drawing. The associated parts list carries the same number as that of the assembly drawing and shows the description, manufacturer's part number, and quantity of each item. For example the following Table 7-1 shows the parts for the top Radiant Array Assembly drawing number E41125 (reference: Figures 7-1 and 7-2).

The following Section 7-2 lists all drawings located in MSFC files for the radiant array.

TABLE 7-1 RADIANT ARRAY ASSEMBLY PARTS LIST

J.O.	DUE	QTY.	STOCK

ITEM	DESCRIPTION	MFR.	PART NO.	QTY.	P	FULL	INVENTORY
21							
20	LINK PANEL ENCLOSURE ASSEMBLY-1 (REF. D41247)						
19	LINK PANEL ENCLOSURE ASSEMBLY-2 (REF. D41247)						
18	LINK PANEL ENCLOSURE ASSEMBLY-3 (REF. D41247)						
17	SCREW-HEX HD; #1/4-20 NC x 1/2 LONG, STAINLESS STEEL			384			
16	TIE TAB	RI	A41135	192			
15	END REFLECTOR ASSEMBLY	RI	D41012	50			
14	COOLED END REFLECTOR ASSEMBLY	RI	D41011	48			
13	POWER LEAD ASSEMBLY (SEE D41126 FOR VARIATIONS)	RI	D41126	48			
12	INNER REGION SHIELD ASSEMBLY WITHOUT RETURNS	RI	D41050-2	1			
11	INNER REGION SHIELD ASSEMBLY WITH RETURNS	RI	D41050-1	1			
10	RADIANT UNIT ASSEMBLY - T	RI	D40710-3	57			
9	RADIANT UNIT ASSEMBLY - S	RI	D40710-2	36			
8	RADIANT UNIT ASSEMBLY - B	RI	D40710-1	54			
7	GASEOUS NITROGEN COOLING SYSTEM ASSEMBLY	RI	E40929	1			
6	COOLING WATER SYSTEM ASSEMBLY	RI	E40942	1			
5	STANCHION ASSEMBLY - 94 INCH TRAVEL	RI	D41137-2	21			
4	STANCHION ASSEMBLY - 64 INCH TRAVEL	RI	D41137-1	29			
3	STANCHION GUIDE ASSEMBLY	RI	E40961	50			
2	CARRIAGE ASSEMBLY	RI	E41086	50			
1	MAIN FRAME ASSEMBLY	RI	E40750	1			

DRAFTSMAN		USED ON	TITLE	INVENTORY	NUMBER	REV
AFR, 1248-7	500X	FINAL	RADIANT ARRAY ASSEMBLY		E41125	A

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LIST OF MATERIALS — SHEET 3 OF 3

7-2 DRAWING INDENTURE LIST

DRAWING INDENTURE LIST
FOR AN
AERODYNAMIC THERMAL SIMULATOR
RADIANT HEATING ARRAY

Reference: George C. Marshall Space Flight Center
Contract NAS8-26416

The following list of drawings represents the entire list of "as built" drawings for the radiant array. The dash number indicates the revision level.

- E41125-A Radiant Array Assembly
    - D40710-B Radiant Unit Assembly
        - D40711-B Side Cover
        - D40712-B Back Cover - Top
        - D40713-B Back Cover - Bottom
        - A40714-A Washer
        - C40715-A Bus Bar Assembly
            - B40716-B Bus Bar
            - A40717-B Connector Tab
        - A40718-B Tab - Long
        - B40719-A Gasket, Internal
        - D40720-A Entrance Manifold
            - D40721-A Manifold Casting
        - B40722-A Gasket - External
        - B40723-B Tile
        - D40724-B Lamp Support
            - B40725-A Extrusion
            - A41542-A Fitting
        - B40726-A Filler Bar
        - A40727-B Tab - Short
        - B40728-A Nozzle
        - A41940 Plug Stiffener
        - A40729-A Connector
        - D40730-B Main Reflector Body Assembly
            - C40731-B Reflector Extrusion
            - B40732-B Fitting - Single Port
            - B40733-B Fitting - Double Port
            - A40734-B Plug Plate - Water
            - A40735-B Plug Plate - Gas
            - A40736-B Plug Plate - Edge - Gas
        - D40737-B Frame Assembly

- D40738-C End Cover Assembly
- A42499 Heater Drain Cock Assembly

E40750-E Main Frame Assembly

- C40751-A Floor Plate Assembly
  - C40752-A Floor Plate
  - C40753-A Pin
- C40757-1-A Bulkhead for 8" Dia. Pipe
- C40757-2-A Bulkhead for 8" Dia. Pipe
- C40766-A Carriage Platform Support
- C41095-A Carriage Platform Assembly
  - C40767-A Carriage Platform
  - A40969-A Carriage Pivot
- C40875-B Stanchion Support Channel
- C41096-A Drain Cap
- B40967-A Plate
- B41098-A 8" Dia. Nipple
- A40765-A Water Fitting
- A40939-2-A Tube Cap Assembly
- D40754-A Base Plate
- D40755-1-C 16" Dia. Pipe Leg
- D40755-2-C 16" Dia. Pipe Leg (Top Left Corner)
- D40756-A 8" Dia. Pipe Leg
- D40758-A Top Corner - Water Supply
- D40759-A Bottom Corner - Water Supply
- D40760-A Circular Bulkhead
- D40761-A Elliptical Bulkhead
- D40762-A Bottom Corner - Structure
- D40763-A Heavy-wall - Top Right Corner - Structure
- D40764-1-A Thin-Wall - Top Left Corner - Structure
- D40764-2-A Thin-Wall - Top Right Corner - Structure
- D40768-A Bottom - Structure
- D40769-1-A Left Side - Structure
- D40769-2-A Right Side - Structure
- D40770-A Top - Structure
- D40771-A Bottom - Water Supply
- D40772-A Left Side - Water Supply
- D40773-A Right Side - Water Supply
- D40774-A Top - Water Supply
- D41097-A Heavy-wall - Top Left Corner - Structure
- C41485 16" Dia. Pipe Nipple

E40929-C Gaseous Nitrogen Cooling System Assembly

- E40930-A Manifold Assembly GN_2 - Bottom Region
  - D40931-B Manifold Pipe Bottom
  - A40932-A GN_2 Fitting
  - C40933-1-A Cap Instrumentation

- A40939-1-A Tube Cap Assembly

- E40934-B Manifold Assembly - GN_2 - Side Region
  - A40932-A GN_2 Fitting
  - C40933-2-A Cap Instrumentation
  - E40936-3-A Manifold Tube - N. E.
  - E40936-4 Manifold Tube - S. W.
  - D40937-C Manifold Tube - Side Region
  - A40939-1-A Tube Cap Assembly
- E40935-A Manifold Assembly - Top Region
  - A40932-A GN_2 Fitting
  - C40933-2-A Cap Instrumentation
  - C40936-1-A Manifold Tube N. E.
  - E40936-2-A Manifold Tube S. W.
  - A40939-1-A Tube Cap Assembly
- D40938-A Incoming GN_2 Divider Assembly
- C40940-A Strap Curved
- B40941-1-A Strap Straight - Short
- D40941-2-A Strap Straight - Long
- A41148-A Valve Flow Proportioning 3"
- A41149-A Valve Flow Proportioning 2"
- A41180-B Transducer Pressure
- B41185-A Wrench Assembly

E40942-D Cooling Water System Assembly
- B41347 Adapter Assembly

E40961-B Stanchion Guide Assembly
- B40962-A Mounting Plate Assembly
  - B40963-A Mounting Plate
  - A40964-A Mounting Plate Pivot
- A40966-B Pivot Washer
- C40974-A Guide Assembly
  - C40965-A Stanchion Guide

D41011-A Cooled End Reflector Assembly
- B41013 Weather Shield
- A41014-A Hose
- A41015-B Stop Pin
- D41016-A Cooled Reflector Assembly
  - D41017-A Tube
  - D41018-1-B Reflector, Thick
- A41019-A Spacer

D41012-A End Reflector Assembly
- B41013 Weather Shield
- A41015-B Stop Pin
- D41018-2-B Reflector, Thin
- A41019-A Spacer

D41050-B Inner Region Shield Assembly
- D41051-B Shield Weldment Assembly
  - B41052-C Special Fitting
  - B41055-B Tab
- B41060-B Long Tube
- B41061-A Bracket
- B41062-B Elbow
- A41014-A Hose

E41086-A Carriage Assembly
- D41087-A Carriage Side Plate
- D41088-A Carriage Locking Plate
- D41090-A Carriage Base - Machining
  - D41098-A Carriage Base - Casting
- C41091-C Carriage Clamp
- A41092-B Adjustment Screw
- A41093-B Locking Set Screw
- C41094-A Carriage Bolster Plate

D41126-B Power Lead Assembly
- C41127-A Load Cable Assembly for 4/0 Wire
- C41128-A Load Cable Assembly for #2 Wire
- A41129-A Tag

A41135-B Tie Tab

D41137-B Stanchion Assembly
- D40972-A Top Pivot Assembly
  - B40956-A Top Pivot Plate Assembly
    - A40957-B Top Pivot Pin
    - B40958-A Top Pivot Plate
  - B40973-A Bottom Pivot Plate

E40950-A Stanchion Frame Assembly
- C40951-A "I" Beam
- A40952-B Bottom Pivot Pin
- C40953-C Square Tube
- B40954-B Gusset
- C40955-B Half Shell
- C40959-A Rear Cable Hanger
- C40960-A Front Cable Hanger
- C40968-B "I" Beam Stiffener

E41075-A Pivot Tube Assembly
- D41076-A Tube - Pivot
- B41077-B GN_2 Fitting
- B41078-A Adapter Plate - GN_2 Fitting
- B41079-B Pivot Block

B41080-B	Module Attachment Plate
A40970-A	Stop
B41099-A	Waring Plate

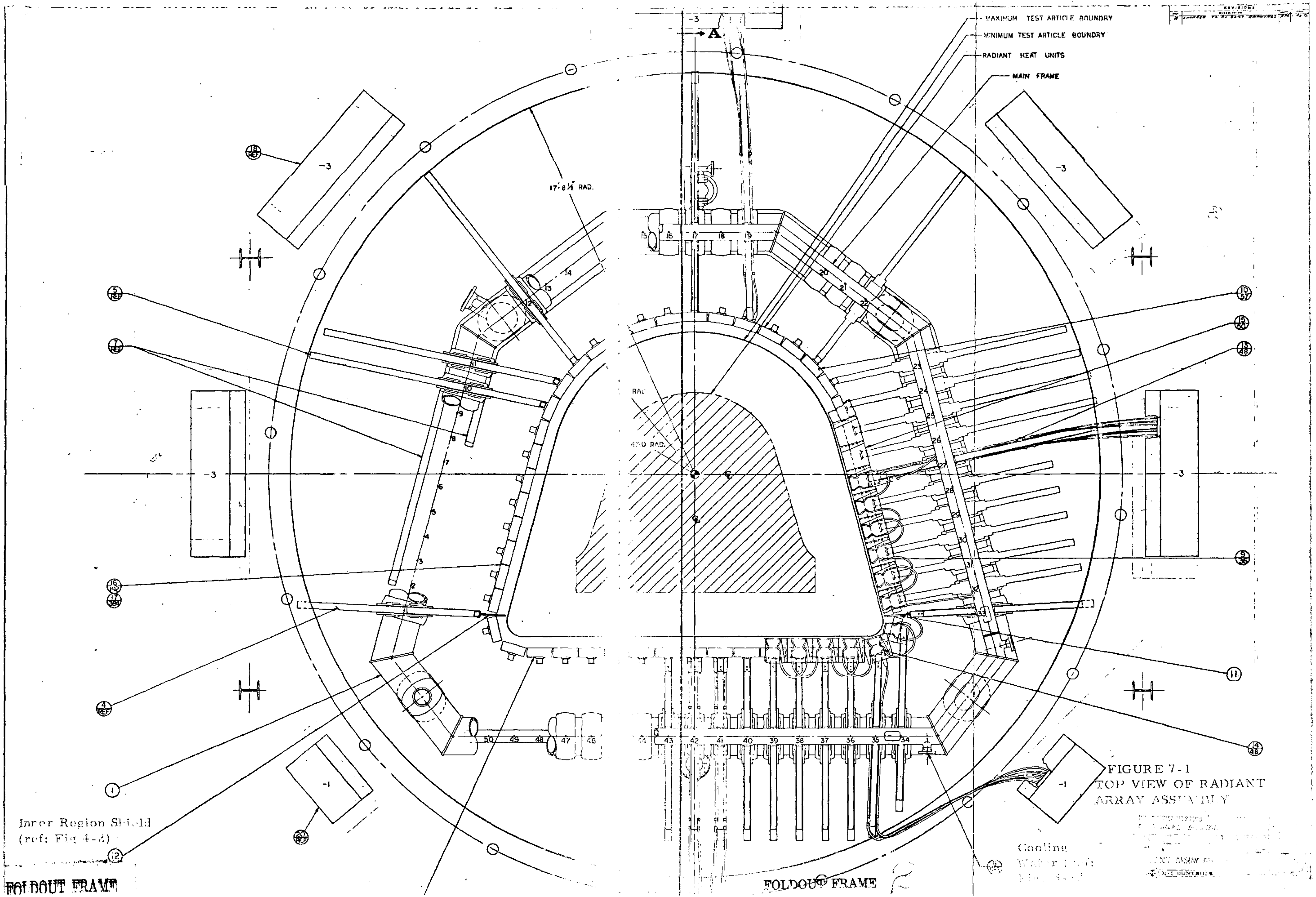

FIGURE 7-1
TOP VIEW OF RADIANT ARRAY ASSEMBLY

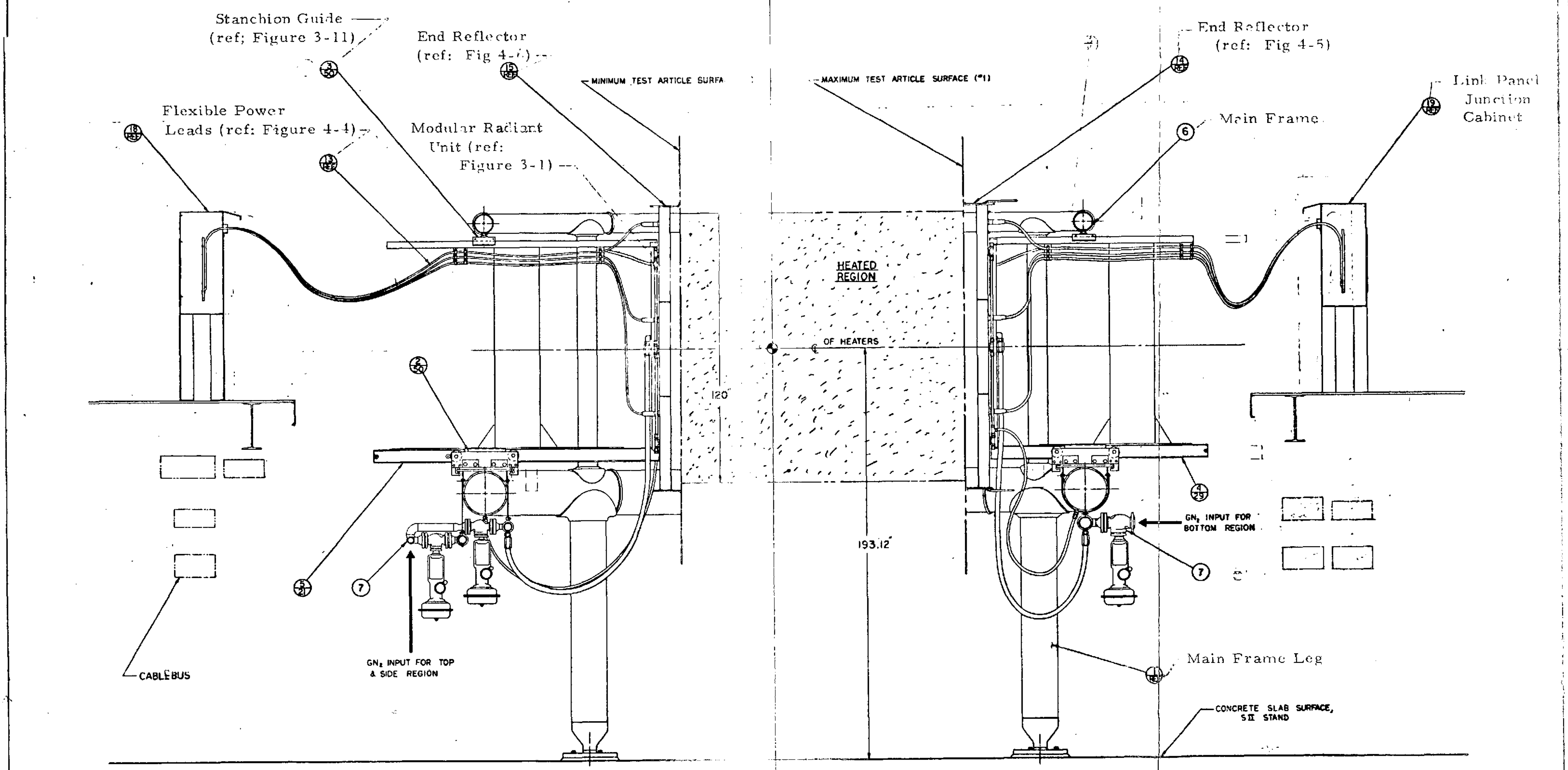

FIGURE 7-2
ELEVATION SECTION VIEW OF RADIANT ASSEMBLY

FOLDOUT FRAME

FOLDOUT FRAME 2