BDM/A-81-426-TR

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SOLAR PROFILE INTENSITY GAUGE DESIGN AND OPERATION AND THERMAL RECEIVER TUBE OPTIMIZATION

(DRAFT)

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FOREWORD

This report was prepared by The BDM Corporation (BDM) for Sandia National Laboratories, Albuquerque, New Mexico, under contract number 62-0249. The design and operation of the Solar Profile Intensity Gauge (SPIG) is described, and a method for optimizing a thermal receiver tube subassembly for linear parabolic trough solar collectors is described.

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CHAPTER I
INTRODUCTION

A. BACKGROUND

Component and material optimization are important issues in developing optimal collectors for both solar thermal and photovoltaic applications. The optimization of linear parabolic troughs (LPT) was addressed by BDM in a DOE contract for the "Conceptual Design and Analysis of a 100 MWe Line Focus Solar Central Power Plant" (contract number ET-78-C-03-2073) where a large aperture trough with a D-shaped receiver tube subsystem (RTS) was determined to provide both improved performance and lower cost for large solar thermal electric power applications. Sandia National Laboratories in Albuquerque is currently developing the large aperture trough and has contracted The BDM Corporation to provide the necessary receiver tube subsystem optimization by expanding and completing the work performed in the above referenced contract. During the Line Focus Power Plant (LFPP) contract, BDM conservatively calculated that a total of four points (6 to 7 percent) improved net collector performance could be gained by utilizing a D-shaped receiver tube with a D-shaped glass annulus. This alternative geometry reduced thermal energy losses while maintaining the intercept integrity of the collector. Preliminary measurements performed at the BDM Solar Test Facility (STF) on a prototype of a D-shaped tube with a circular glass annulus showed about 5 percent improved performance using the same concentrating mirror. Other receiver tube geometries offer even greater thermal energy savings.

The same characteristics of light "crowding" in regions around the receiver tube in line focus troughs also will effect the photovoltaic system performance. BDM, under DOE contract for the "Commercial Application of a Photovoltaic Concentrating System" (contract number ET-78-C-04-5313), has demonstrated that more cost effective power can be produced with the use of smaller photovoltaic cells and larger LPTs. The optimization of the photovoltaic cell size and trough size promise significant cost reductions in the use of line focus photovoltaic systems.

B. PURPOSE AND SCOPE

The optimization of either a thermal or a photovoltaic RTS when used in line focusing concentrating solar collectors requires detailed definition of the positional intensity of concentrated insolation around the focal area of the concentrator. Once detailed empirical data concerning the intensity profile is provided, the optimal receiver can be designed with the use of detailed engineering design models and calculations. These models and calculations will, of course, determine the optimal geometry and dimensions of the RTS for any given solar concentrator. Thus, the purpose of this program was to:

(1) Design and develop a device which would measure the solar intensity about the focal region of a linear parabolic trough (LPT) collector.

(2) Develop a thermal model such that detailed design trade-offs could be made as functions of RTS size and shape.

1. Profile Measurements

BDM has designed and developed a solar profile intensity gage (SPIG) which will provide a detailed definition of the intensity about the focal region of a linear parabolic trough as a function of position. The SPIG will obtain an intensity profile by measuring the intensity incident upon an incremental area of a cylindrical surface. The surface may be circular, D-shaped, or triangular, and may vary in size to obtain a complete profile as a function of angle and distance from the focal line.

2. RTS Optimization

BDM has developed a non-linear thermal network model for the RTS used in an LPT solar collector for design optimization. The required input to the model includes environmental data, operational data for the thermal system being modeled, and insolation data. The model will calculate the thermal resistances and, using the NET-2 computer program, the thermal losses and gains of the system. The thermal performance of an LPT can be determined for various sized RTS's having circular, D-shaped, or triangular cross-sections.

C. GENERAL DESCRIPTION

1. SPIG Description and Capabilities

The current application of the SPIG is on linear parabolic troughs mounted on a 2-axis tracker. This SPIG configuration is shown in figure I-1. The basic components of the SPIG include:

(1) The collector mounting
(2) The SPIG structure
(3) Translators and controls
(4) Insolation sensor

The collector mount is designed to mount the SPIG structure on the collector and maintain the SPIG at a predetermined location during tracking. The mount is attached to the wings of the trough by tightening opposed leveling pads. These pads allow the mount to be used on various trough edge designs, and the pads can be loosened to allow repositioning of the SPIG to different axial locations down the collector. Carriage bolts are inserted in the top of the mount to prevent vertical movement of the structure when it is repositioned. All leveling pads and carriage bolts are adjustable to allow proper alignment on the collector. The cross-beam is 4-inch x 4-inch aluminum tubing upon which the SPIG structure is mounted. The cross-beam can be adjusted horizontally to position the SPIG in the center of the trough.

The SPIG structure consists of vertical unistrut bolted to the cross-beam. An aluminum plate is bolted to the unistrut and a commercially available aluminum extrusion normally used as an optical bench is

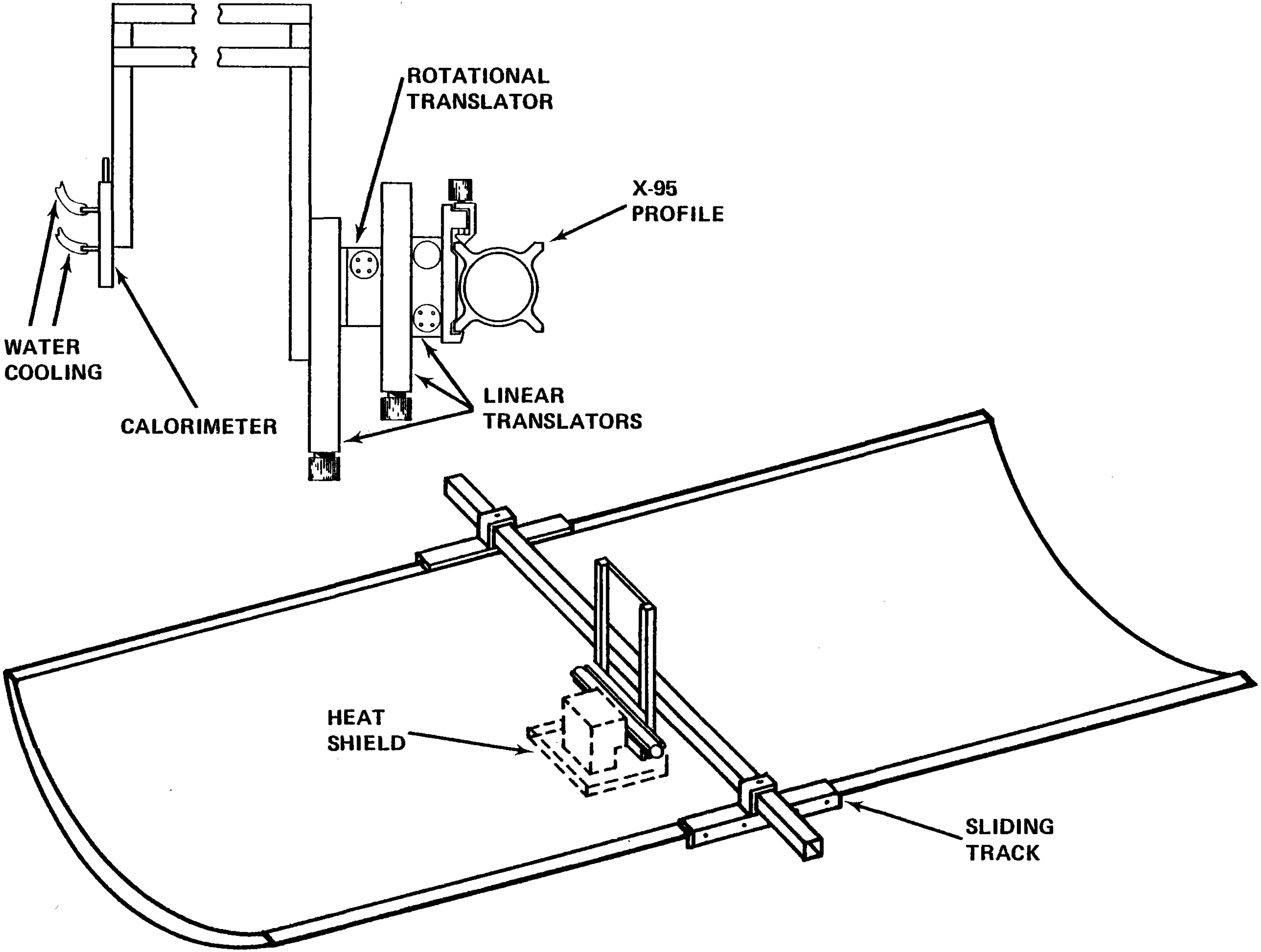


Figure I-1. SPIG Configuration for Linear Parabolic Troughs welded to the plate. The translators are attached to the extrusion with a commercially available sliding mount. The unistrut allows for gross vertical positioning of the SPIG, and the sliding mount is used to center the translators and energy sensor. A heat shield surrounds the bottom and sides of the translators to prevent concentrated radiation from burning the instrumentation cables. The collector mounts and cross-beam, and the SPIG structure provide a rigid solid base for the translators and intensity gage.

The solar intensity is measured over 360° of rotation. This is accomplished with a rotational translator driven by a reversible dc motor. A potentiometer is coupled with the translator to provide a measurement of angular displacement. To vary the radius of rotation, a linear translator is attached to the rotational translator. An effective diameter of up to 9 cm can be measured. To measure intensity about the axis centerline, linear translators are mounted to the cross structure and provide a 25 mm displacement in each direction. All linear translators have built-in potentiometers for displacement measurement. A constant current source provided by the HP-85 data acquisition system is used to measure the voltage drop across these potentiometers.

A calorimeter is mounted on a shaft which extends from the rotational translator. The diameter of the thermal sensing area is 3.2 mm (1/8-inch). Full scale output of 10 mV for 0-11.34 w/cm^2 (0-10 Btu/ft^2-sec) is provided by the sensor. The sensor has a threaded body for easy removal and replacement. A temperature sensor is provided on the calorimeter to protect against excess temperatures.

The HP-85 microprocessor and signal conditioning system is used for data acquisition and SPIG control. A schematic of the SPIG controls and measurements is provided in figure I-2. Each measurement process is preprogrammed on the HP-85 software and processed automatically producing complete solar intensity profile, integrated energy, and necessary digitized data and graphical output.

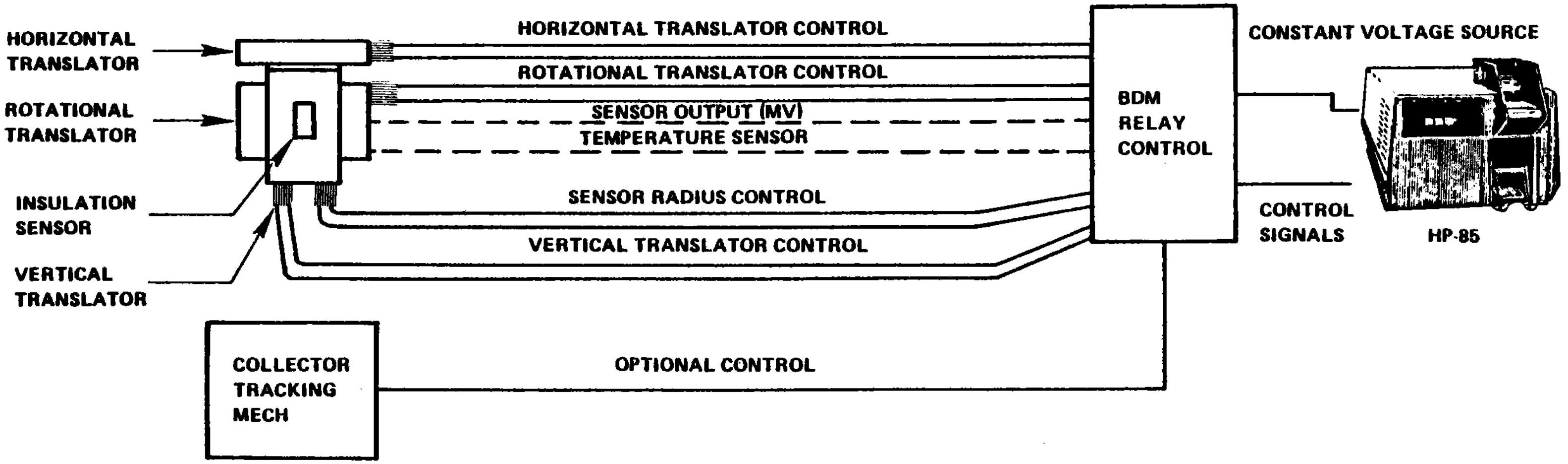


Figure I-2. Control and Measurement Schematic Diagram

2. SPIG/RTS Optimization Concept

The procedure for the optimization of the RTS involves separate measurement and modeling efforts as shown in figure I-3. First, the SPIG is used to map the solar intensity about the focal region of the concentrator. The flux density will be automatically integrated and digitized by microprocessor for use in the design model.

The BDM Solar Analysis Model is used to perform design tradeoffs for the RTS. The receiver tube model is an electrical network equivalent thermal grid model of the receiver tube and annulus. The insolation defined by the SPIG is entered as current sources, and the detailed resistive grid model provides nodal temperatures and heat flows defining the thermal characteristics of the solar thermal RTS.

Each candidate RTS geometry is modeled separately within the design computer model. The key trade-off between the collector intercept and thermal energy losses is performed within the design computer code, and the geometry and dimensions of the RTS that provide the maximum thermal energy gains are defined for each geometry. This process can be repeated quickly and efficiently for all line focus collectors.

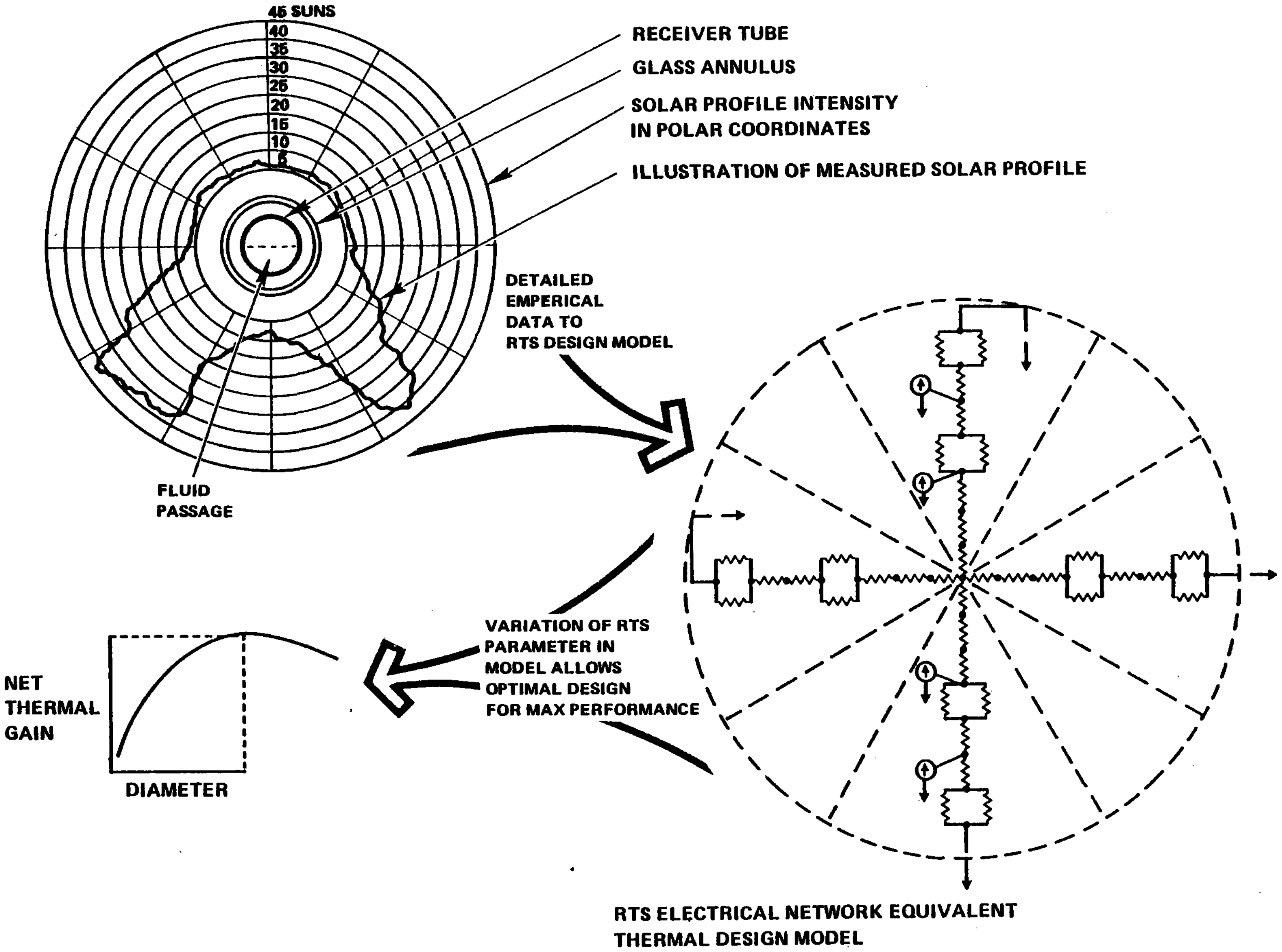


Figure I-3. Procedure for RTS Optimization

CHAPTER II
HARDWARE DESCRIPTION

The SPIG system consists of the following hardware subassemblies:

(1) SPIG Assembly
    (a) Collector Mount
    (b) SPIG Structure
    (c) Translators and Controls
    (d) Insolation Sensor
(2) Alignment Assembly
    (a) Collector Mount
    (b) Leveling Device

These portions of the SPIG system allow an operator to position and align the intensity gage on the collector and maintain the same alignment at all axial positions. The position at which the maximum incident intensity is obtained is determined automatically, and the intensity profiles for circular, D-shaped, and triangular RTS's are automatically obtained and stored on disc.

A. SPIG ASSEMBLY

1. Collector Mount

The collector mount consists of two adjustable mounting brackets and a cross-beam. The mounting brackets slip over the edges of the collector and are solidly attached to the collector by eight leveling pads on each mount (see drawing 02D001650). The leveling pads have swivel leads so the bracket can be attached to collectors having edges with different designs. Neoprene pads are attached to the leveling pads to provide additional friction for a solid grip on the mirror edge and to prevent damage to the mirror. This design allows the SPIG to be mounted on an LPT with any edge design and to be held in place during tracking of the sun.

Two carriage bolts are screwed through the top of each mounting bracket. These bolts prevent the bracket from slipping down onto the mirror surface, and prevents vertical movement of the structure when it is moved to a new axial position.

The top of the mounting bracket consists of a square bracket through which the cross-beam is inserted. The cross-beam is held in place by four bolts, two in each bracket. The bolts are screwed down to hold the cross-beam in place by friction. On initial set-up, this allows the beam to be adjusted to position the SPIG in the center of the trough.

The cross-beam is a 10-foot long, 4-inch x 4-inch aluminum tube upon which the SPIG structure is mounted. A vertical deflection of 0.011-inches for a 7-foot span with a 34 pound force centered on the beam has been calculated. The center of mass of the translators is about 4.2-inches from the edge of the beam; the torque on the beam produced by this cantilevered force causes an angular deflection of 0.015°. Thus, the collector mount produces a rigid, solid base for the SPIG structure.

The cross-beam also provides a channel for the instrumentation and control cables and the cooling line for the sensor. One end of the beam contains a plate on which is mounted connections for automatic translator control and data collection from the control room, manual translator control using a remote control box, and air to cool the tip of the insolation sensor. These cables exit the cross-beam through a hole in the middle of the beam. The instrumentation and control cables go directly to the translators and sensor, and the air line is attached to the top of the SPIG structure.

2. SPIG Structure

The SPIG structure consists of the assembly, which allows mounting of the translators, sensor, and other components to the cross-beam (see drawings 02D001650 and 02D001653). This structure consists of two sections of unistrut bolted to the cross-beam, an aluminum plate and support rail which bolts to the unistrut, and an upper structure to which the shadow box and air hose are attached.

A Klinger Scientific Corporation X-95 optical rail was cut lengthwise and welded to an aluminum plate to provide a support for the translators. The plate is bolted to the unistrut which allows vertical positioning of the SPIG in the trough. An aluminum strip is attached to the top of the SPIG structure such that it overhangs the insolation sensor. This provides a simulation of the shadow produced by a receiver tube on the center of the mirror.

Cooling air is provided to the sensor through a flexible air hose. This air hose is connected to the incoming air line at the top of the SPIG structure. The flexible hose allows cooling air to be provided to the sensor while the sensor is rotated through ± 180°.

The translators are mounted on the X-95 support rail with a Klinger Scientific Corporation clamping carriage which allows horizontal positioning of the translators and sensor. The translator configuration is shown in drawing 02D001651.

3. Translators and Controls

Four translators are used to position the sensor in the region of the focal line of the collector. These translators are manufactured by Klinger Scientific Corporation and are listed in table II-1.

TABLE II-1. TRANSLATOR DESCRIPTION

MODEL NUMBER	MAXIMUM DISPLACEMENT	DISPLACEMENT	ZERO POSITION	ERROR
UT100.50.CC.Pot	50 mm	HORIZONTAL	25 mm	± 0.2 mm
UT100.50.CC.Pot	50 mm	VERTICAL	25 mm	± 0.2 mm
UT100.100.CC.Pot	100 mm	RADIAL	5 mm	± 0.2 mm
UR80CC 10°/S	360°	ANGULAR	180°	± 5°

The two 50 mm translators are used to move the sensor horizontally and vertically (over an x-y grid) to position the sensor at the focal line of the mirror. The zero position of these translators is at the 25 mm mark so the range of motion is ± 22 mm. Near the end of the range, the potentiometer used to determine the position of the translators becomes non-linear, so the last 3 mm of the range is not used.

The sensor is set at the axis of rotation when the radius is zero; this occurs when the 100 mm translator is set to its zero position at the 5 mm mark. The 100 mm translator allows the sensor to be set at radii ranging from 0 to 90 mm. The last 3 mm at either end of the range is not used because of the non-linearity of the potentiometer in this region.

The three linear translators have limit switches which interrupt power to the drive motor when the translator stage reaches the end of travel. This provides electrical and mechanical protection to the motor and gear train. The rotator contains a continuous potentiometer and drive train such that there is no rotational limit except that provided in the controlling software. The software is written such that the motion of the rotator is limited to ± 160° so that the cables and air hose are not twisted and extended beyond their limit.

The rotator is set to zero at the 180° mark such that the sensor points toward the bottom of the trough. In the region of the 0° mark on the rotator (that is, when the index is within ± 10° from the 0° mark), the potentiometer is extremely non-linear. Thus, the angle of rotation is limited to ± 160° from the 180° mark.

Each translator is driven by a 24 V dc motor which develops 2.6 W of mechanical power for a 20 mA supply current. The linear translators use a single turn potentiometer to allow the position of the translators stage to be determined. These potentiometers have a weighted linearity of ± 0.25 percent, a total resistance of 10,000 ohms ± 10 percent, a uniformity of 0.1 percent, and a temperature coefficient of 0 to -400×10^{-6}/°C. These potentiometers extend from the translator body approximately 6-inches and are enclosed in plastic. An aluminum shield which surrounds each potentiometer has been bolted to the translator body to protect the potentiometers during handling and operation.

The rotator contains an internal, continuous potentiometer. It has essentially the same characteristics as the potentiometers in the linear translators except that it is not as uniform throughout its range. This causes a problem in controlling the position of the rotator. This will be discussed in more detail in a later section.

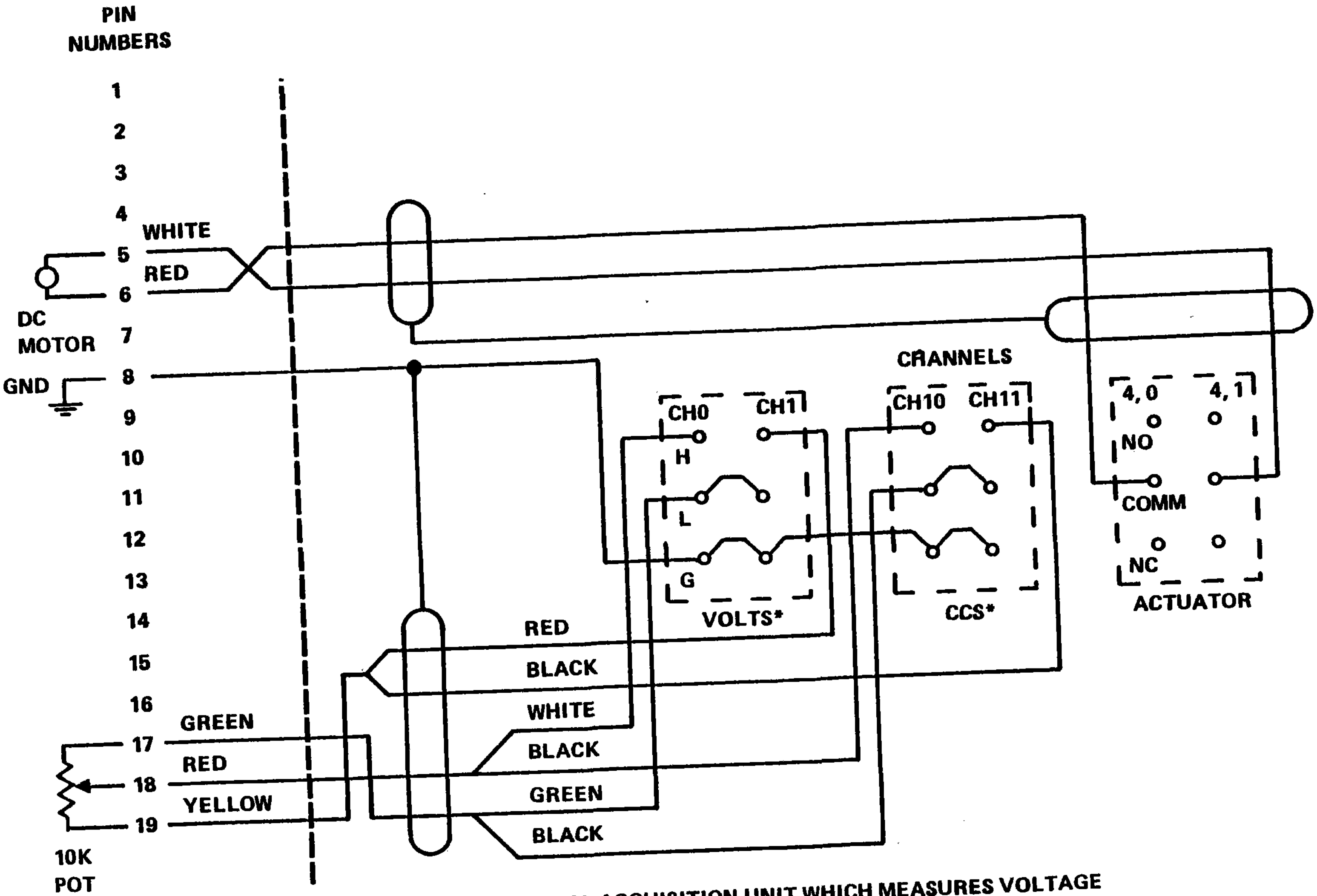
The connector pin configurations for the linear translators are shown in figures II-1, II-2, and II-3. The pin configuration for the rotator is identical to that for the vertical translator except that the voltmeter channels are 6 and 7, the constant current source channels are 16 and 17, and the actuator channels are 6 and 7. These channels are contained in the Hewlett-Packard 3497A Digital Acquisition/Control Unit, which is part of the SPIG control system. When the appropriate switches (or channels) are closed in the HP 3497A, a constant current is sent through the translator potentiometers and the voltage drops across the full potentiometer and the center tap are read into the HP 3497A. When the appropriate channels are closed in the actuator section of the HP 3497A, 24 V dc power is supplied to the translator motor to position the insolation sensor. The voltage reading provides a measurement of the position of the translators.

The control section of the SPIG system consists of the following:

(1) Hewlett-Package HP-85 Computer
(2) Hewlett-Packard 3497A Digital Acquisition/Control Unit
(3) Hewlett-Packard 9876A Thermal Graphics Printer
(4) Hewlett-Packard 92910M Flexible Disc Drive
(5) Power Supply
(6) Manual Control Unit

The software for controlling the position of the sensor, taking data, and storing the data on disc has been written for the HP-85 computer and will be discussed in the next section.

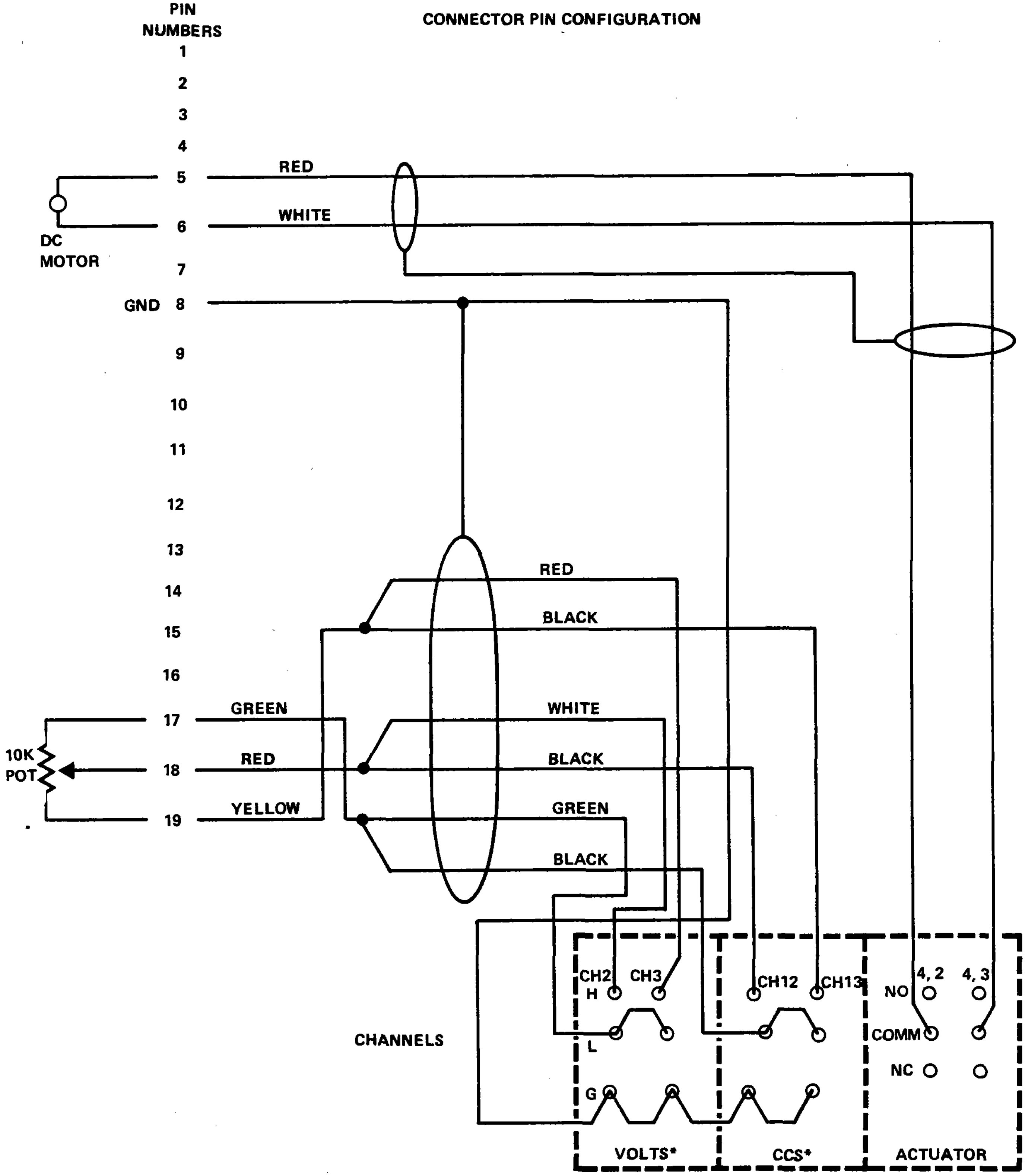
CONNECTOR PIN CONFIGURATION



*VOLTS: SECTION OF DATA ACQUISITION UNIT WHICH MEASURES VOLTAGE

CCS: CONSTANT CURRENT SOURCE

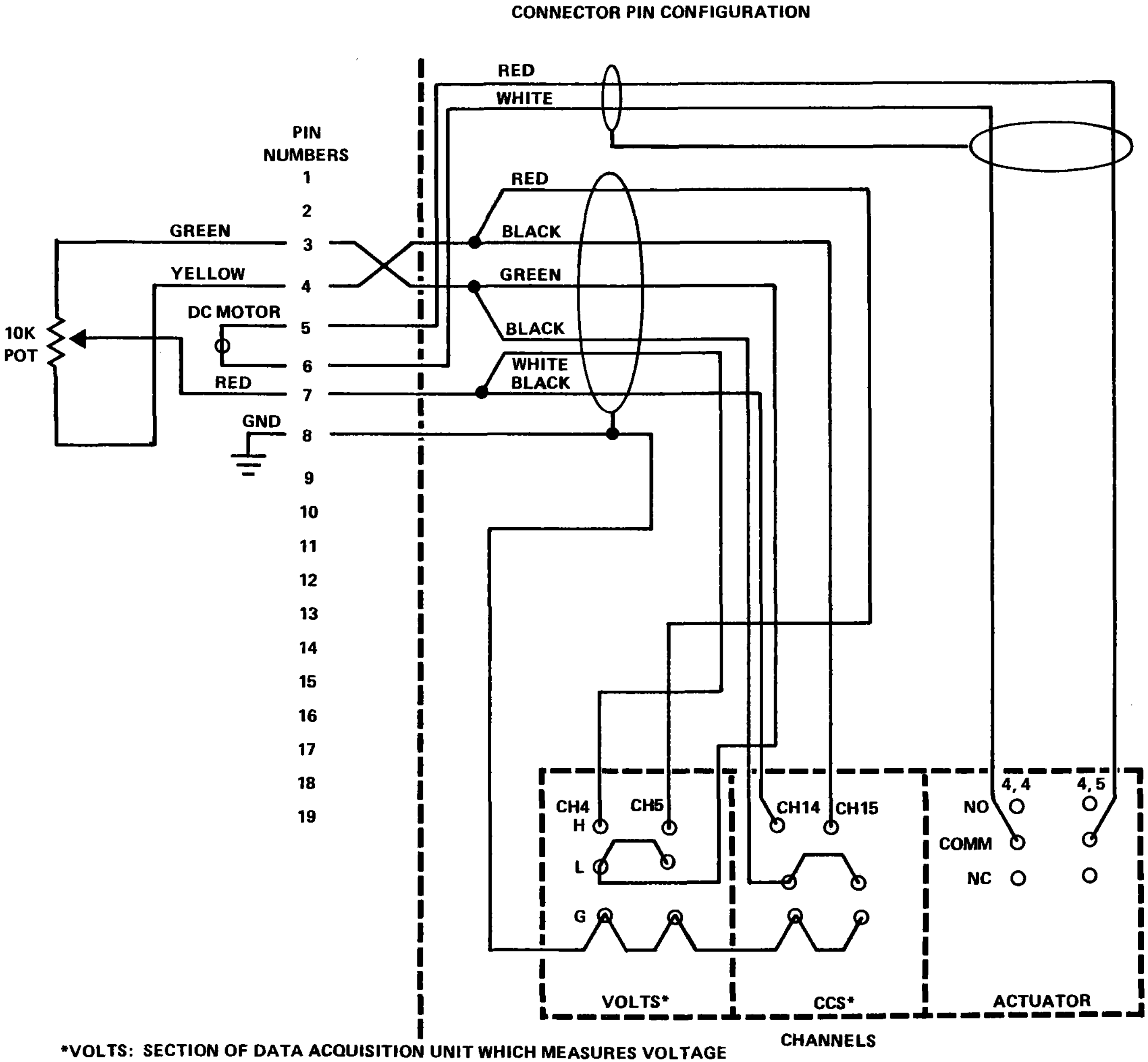
Figure II-1. 50 mm Horizontal Translator Connector Pin Configuration



*VOLTS: SECTION OF DATA ACQUISITION UNIT WHICH MEASURES VOLTAGE

CCS: CONSTANT CURRENT SOURCE

Figure II-2. 50 mm Vertical Translator Connector Pin Configuration



*VOLTS: SECTION OF DATA ACQUISITION UNIT WHICH MEASURES VOLTAGE
CCS: CONSTANT CURRENT SOURCE

Figure II-3. 100 mm Radial Translator Connector Pin Configuration

With appropriate commands from the HP-85, the HP 3497A provides a constant predetermined current to the translator potentiometers and temperature sensors which require 4-wire measurements. Voltage is measured with a digital voltmeter internal to the HP 3497A and transferred to the HP-85 where it is converted to position or temperature. Voltages are also measured directly and converted in the HP-85 to obtain wind speed and direction and intensity incident on the SPIG sensor, pyranometers, and pyrheliometer. This data is then stored on disc and/or printed out on the thermal printer.

Appropriate commands from the HP-85 close switches in the actuator section of the HP 3497A to allow 24 V dc from the power supply to be applied to selected translator motors to position the sensor. In addition, closing certain switches in the actuator section cause relays to close in the power supply allowing 115 V ac to be applied to collector drive pylons. The lines from the actuator to the power supply relays are denoted Logic 1 and 2 on the circuit diagrams. This allows collector tracking to be computer controlled during data collection.

The horizontal and vertical linear translators and the rotator can be controlled with a manual control unit located on a 40-foot cable at the solar collector. 24 V dc power lines are routed to the 52-pin connector on the end of the cross-beam and into the manual control. One set of power lines goes through the HP 3497A actuator section and the other set goes directly to the translator motors. When the manual control is set on "remote," power to the translator motors is controlled by the HP-85 and HP 3497A. When the manual control is set to "manual," the HP 3497A is disconnected from the translators which are now controlled manually from the control unit.

A wiring schematic from the 52-pin connector to the translators and sensor showing pin connections and channels is provided in drawing 02D001655. This drawing also has a schematic of the manual control unit and its pin connections. A list of the channels in the HP 3497A actuator used for control and data collection is given in table II-2. As indicated, the tracker is controlled with channels 8 and 9 with the various permutations of open and closed channels producing the indicated functions of stow, deadband, etc. These permutations are valid for the BDM Solar Kinetics, Inc. tracker and collector control system; however, they may require changing for other systems.

4. Insolation Sensor

The insolation sensor subassembly consists of the calorimeter, amplifier, and temperature sensor. The calorimeter is a circular foil heat flux gage manufactured by Thermogage, Inc. and shown in figure II-4. The sensing element is a 0.125-inch diameter foil of Constantan 5 mils thick placed in the center of the calorimeter face. The calorimeter is 1/2-inch in diameter and the face is coated with a material having an absorptivity of 0.98. The time constant of the gage is 0.070-seconds.

This type of heat rate sensor derives its output from a differential thermocouple circuit. The thermocouple measures the temperature gradient between the center and the periphery of the active sensor area, where the periphery consists of the body of the calorimeter which acts as a heat sink. This temperature gradient is directly proportional to the heating rate. The heat rate is given by

$$\dot{Q} = 4 \frac{Sk}{R^2} \Delta T$$

where

$\dot{Q}$ = heating rate
S = sensor thickness
k = sensor thermal conductivity
R = radius of active sensor
ΔT = temperature differential

The non-linearity of the thermal EMF curve is offset by the fact that the conductivity changes with temperature in the opposite direction by

TABLE II-2. CHANNEL FUNCTIONS FOR THE HP 3497A

ACTUATOR CHANNELS	SWITCH POSITION	FUNCTION
0	C	MOVE TRANSLATOR TO RIGHT
1	O	
0	O	MOVE TRANSLATOR TO LEFT
1	C	
2	C	MOVE TRANSLATOR UP
3	O	
2	O	MOVE TRANSLATOR DOWN
3	C	
4	C	INCREASE RADIUS
5	O	
4	O	DECREASE RADIUS
5	C	
6	C	ROTATE CLOCKWISE
7	O	
6	O	ROTATE COUNTER-CLOCKWISE
7	C	
8	O	STOW COLLECTOR
9	O	
8	C	PLACE TRACKER IN AUTOMATIC TRACKING MODE
9	O	
8	O	PLACE TRACKER IN DEADBAND
9	C	
8	C	BRING COLLECTOR OUT OF STOW
9	C	

C - CLOSED
O - OPEN

TABLE II-2. CHANNEL FUNCTIONS FOR THE HP 3497A (Continued)

VOLTMETER CHANNELS	DEVICE	FUNCTION
0 10	HORIZONTAL TRANSLATOR	MEASURE VOLTAGE ACROSS CENTER TAP PROVIDE CURRENT TO CENTER TAP
1 11	HORIZONTAL TRANSLATOR	MEASURE VOLTAGE ACROSS POTENTIOMETER PROVIDE CURRENT TO POTENTIOMETER
2 12	VERTICAL TRANSLATOR	MEASURE VOLTAGE ACROSS CENTER TAP PROVIDE CURRENT TO CENTER TAP
3 13	VERTICAL TRANSLATOR	MEASURE VOLTAGE ACROSS POTENTIOMETER PROVIDE CURRENT TO POTENTIOMETER
4 14	RADIAL TRANSLATOR	MEASURE VOLTAGE ACROSS CENTER TAP PROVIDE CURRENT TO CENTER TAP
5 15	RADIAL TRANSLATOR	MEASURE VOLTAGE ACROSS POTENTIOMETER PROVIDE CURRENT TO POTENTIOMETER
6 16	ROTATOR	MEASURE VOLTAGE ACROSS CENTER TAP PROVIDE CURRENT TO CENTER TAP
7 17	ROTATOR	MEASURE VOLTAGE ACROSS POTENTIOMETER PROVIDE CURRENT TO POTENTIOMETER
8 18	RTD*	MEASURE VOLTAGE ACROSS RTD PROVIDE CURRENT TO RTD
9	CALORIMETER & AMPLIFIER	MEASURE VOLTAGE OUTPUT
20 30	AMBIENT TEMPERATURE	MEASURE VOLTAGE PROVIDE CURRENT
21	WIND SPEED	MEASURE VOLTAGE OUTPUT
22	WIND DIRECTION	MEASURE VOLTAGE OUTPUT
23	PYRHELIOMETER	MEASURE VOLTAGE OUTPUT
24	PYRANOMETER	MEASURE VOLTAGE OUTPUT

* RESISTANCE THERMOMETER

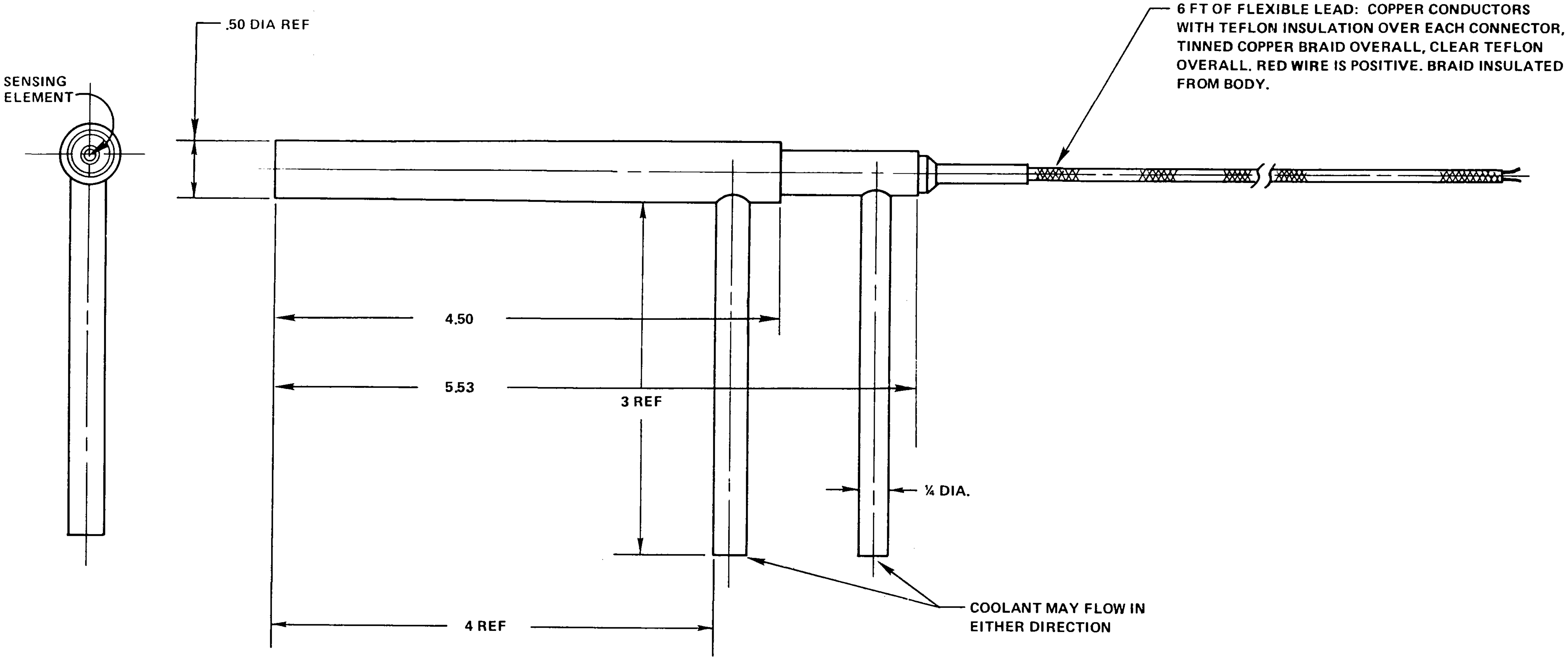


Figure II-4. SPIG Calorimeter

approximately the same ratio. Over limited ranges, a linear relation can be used and expressed as

$$\dot{Q} = CE$$

where

C = constant based on sensor design

E = the sensor output in mV

This linear relation is valid over a temperature range from ambient to 400°F. Two calorimeters were purchased for this project, and their linear calibration curves are shown in figures II-5 and II-6. The gages are linear up to 1700 mV (17 BTU/ft^2-sec in the 1000 gain mode of the amplifier and 170 BTU/ft^2-sec in the 100 gain mode).

The temperature sensing element is a thin film detector (TFD) manufactured by Omega Engineering, Inc., model number Pt 100 FKG 3/10. It is a 100 ohm platinum resistance thermometer used to monitor the temperature at the tip of the calorimeter to insure that the temperature doesn't reach 400°F.

The amplifier is used to increase the output from the calorimeter. It is manufactured by Thermogage, Inc. and operates on four standard AA cells. The typical operating time is 1,000 hours before battery replacement. In order to achieve this operating time, the battery circuit must be opened by disconnecting the amplifier after use. The specifications for the amplifier are given in table II-3. The amplifier gain is currently set at 500.

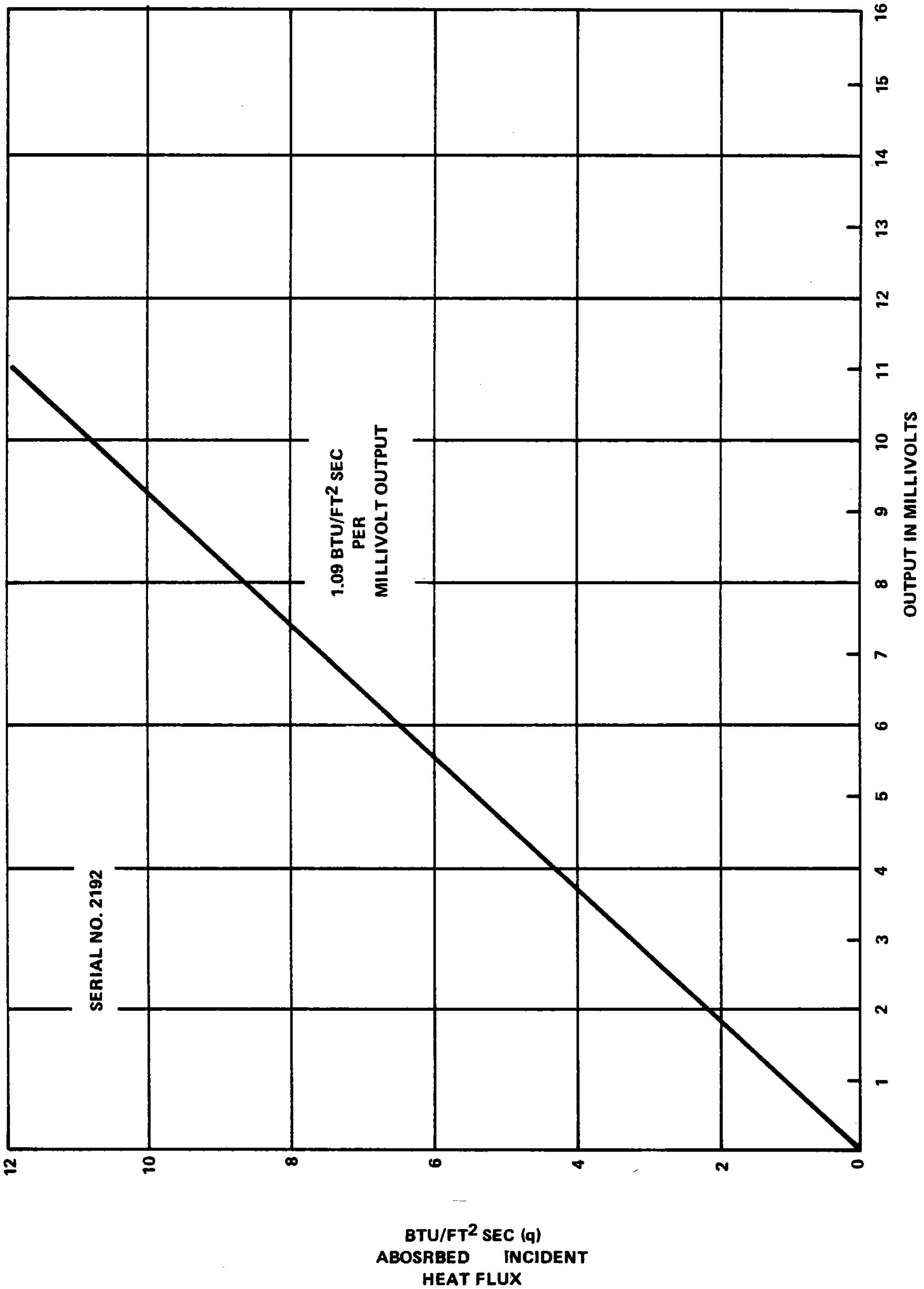


Figure II-5. Calibration Curve for Calorimeter Serial No. 2192

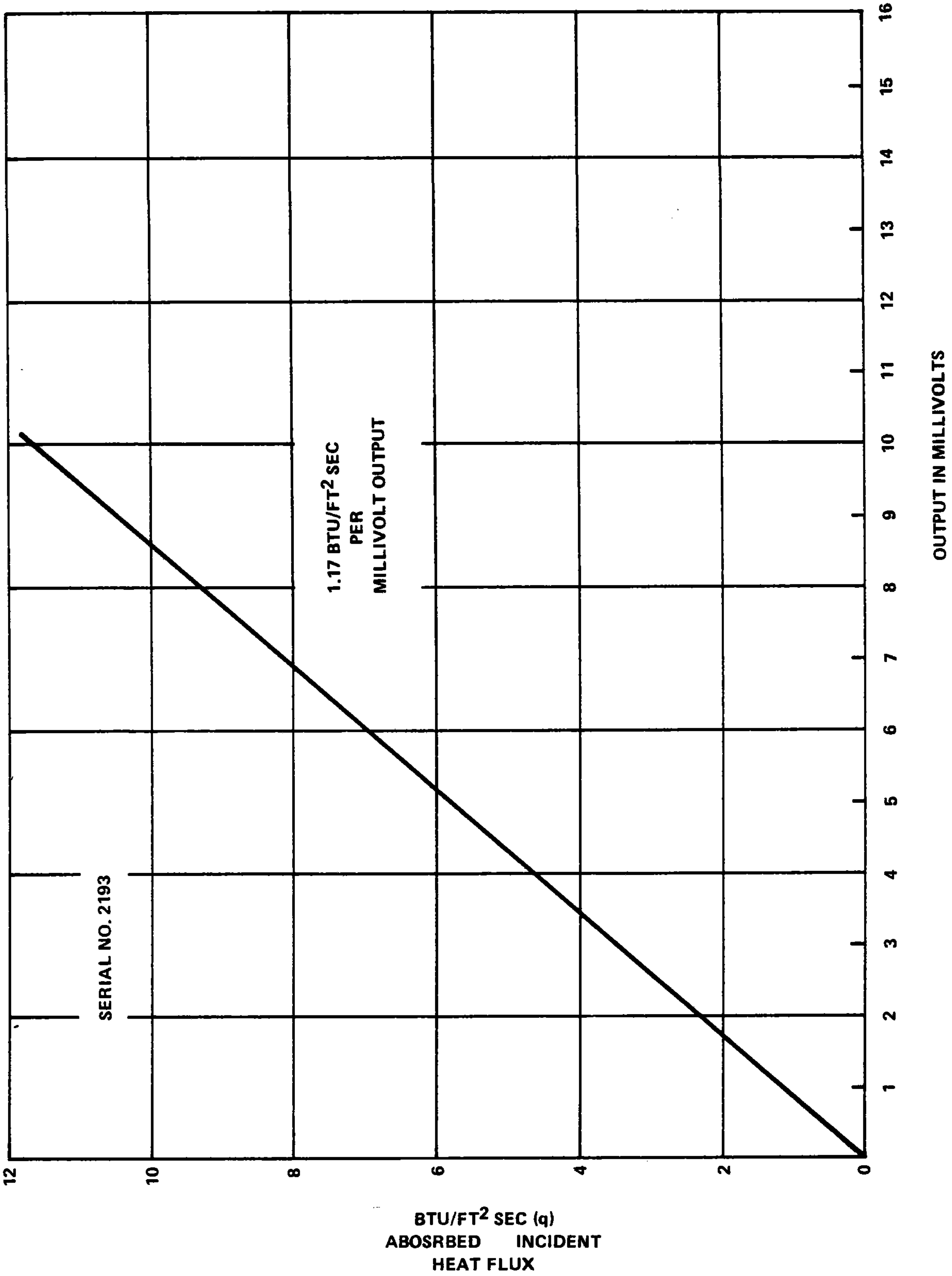


Figure II-6. Calibration Curve for Calorimeter Serial No. 2193

TABLE II-3. AMPLIFIER SPECIFICATIONS

1. GAIN EITHER 1000 OR 100 ADJUSTABLE ± 50 PERCENT
2. NOISE TYPICALLY ± 1/10 MICROVOLT
3. INPUT IMPEDANCE 2000 OHM; OUTPUT IMPEDANCE 1 OHM
4. FREQUENCY RESPONSE 1 KC
5. TIME CONSTANT 0.3 MILLISECONDS
6. RANGE - 1000 GAIN
    - INPUT 0 - 1700 MICROVOLTS
    - OUTPUT 0 - 1700 MILLIVOLTS

   RANGE - 100 GAIN
    - INPUT 0 - 17 MILLIVOLTS
    - OUTPUT 0 - 1700 MILLIVOLTS
7. ZERO TEMPERATURE STABILITY 1/3 MICROVOLT/°F

B. ALIGNMENT ASSEMBLY

1. Collector Mount

The collector mount consists of two adjustable mounting brackets and a cross-beam (see drawing 02D001654). The mounting brackets slip over the edges of the collector at the end opposite to the SPIG assembly and are attached to the collector with four leveling pads on each mount. A plate extends from the mount toward the side of the collector to allow attachment of the cross-beam.

The cross-beam is bolted to the mounting brackets through two slots, one in each end of the beam. Two sections of unistrut are welded to the beam to allow mounting a platform for the leveling device. The slots in the beam allow positioning of the leveling device in the center of the collector, and the unistrut allows for vertical adjustment. An 18-inch machine scale is attached to the beam on an assembly which allows side-to-side adjustment of the position of the scale. A machine slide is bolted to the platform to allow fine side-to-side adjustment of the leveling device.

2. Leveling Device

The leveling device consists of a Wild N01 Dumpy Level manufactured by Wild Heerbrugg Instruments, Inc. and a short focus lens. The level is a surveyors level and is mounted on the machine slide. By using the level, the machine scale on the collector mount, and the machine scales on the SPIG assembly, the SPIG can be positioned in the same orientation at each axial position on the collector.

C. OPERATIONAL DESCRIPTION

All channels in the HP 3497A are connected to the appropriate translators and SPIG sensors. As indicated in table II-2, the environmental data cables must be connected to the proper channels in the HP 3497A before the SPIG can be operated.

Prior to operation, the SPIG assembly is mounted at one end of a collector and the alignment assembly at the other end, with the SPIG sensor facing away from the alignment assembly. Electrical connections are made between the control units, the translators, and the insolation sensor, and an air supply is also connected to the calorimeter for cooling. The SPIG translators are then positioned at their zero points, and the sensor is centered in the middle of the trough with the face of the sensor at the focal line.

Once the SPIG has been positioned, the Dumpy level is aligned parallel to the collector focal line with the vertical cross-hair parallel to the machine scale on the SPIG assembly. The Dumpy level is left in this position and the SPIG positioned with respect to the level at subsequent axial positions. Thus, the initial position of the SPIG is its reference position for subsequent tests at new axial positions on a particular collector.

When the SPIG and Dumpy level are positioned, control can be passed to the HP-85 computer through the program MOVE. This program performs the following functions sequentially:

(1) Obtains an average intensity ratio* over a 5 x 5 grid centered about the original position of the tip of the calorimeter.

(2) Takes an intensity reading every 10° over a 320° arc and at ten different radii between 0 and 50 mm.

(3) Takes an intensity reading every 10° over a 180° arc, at ten different radii between 0 and 50 mm, and at positions of the center of rotation 5 mm below the focal line, at the focal line, and 5 mm above the focal line.

(4) Takes an intensity reading at ten equally spaced positions along each of two legs of an equilateral triangle with the vertex pointed toward the bottom of the trough. This is done for three different size triangles (leg lengths of 10, 20, and 30 mm) and for the horizontal leg 5 mm below the focal line, at the focal line, and 5 mm above the focal line.

At each radius (or size of triangle), the time of day and environmental data is recorded before and after each angular scan. The environmental data is then averaged for each radius and stored, along with intensity data, in the HP-85 computer. There are eight data sets at each axial position; one set for each of functions 1 and 2, and three sets for each of functions 3 and 4. For the latter, there is one data set at each of the three positions of the center of rotation. After each data set is taken and stored in the HP-85, it is then stored on disc and the data arrays initialized in the HP-85 to allow storage of the next data set.

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* Intensity ratio refers to the instantaneous intensity measured by the calorimeter divided by the pyrheliometer reading.

Prior to obtaining an intensity profile over a cylinder (function 2 above), the average intensity ratios over the 5 x 5 grid are printed out on the thermal printer. This allows the operator to determine where the optimum focal line is and to reposition the calorimeter (within limits) from the computer.

When all the data is obtained at the first axial position, the SPIG is moved to a new position and positioned using the Dumpy level. Another set of intensity profiles is then obtained at the new axial position.

D. CAPABILITIES AND LIMITATIONS

The SPIG is capable of measuring intensities from 0 to 17 BTU/ft^2-sec about the focal line of a linear parabolic trough collector. The assembly has been designed for a 2-axis tracker so that the incident intensity is perpendicular to the plane of the trough. Insolation incident at other angles may produce shadows which in turn would produce meaningless profiles. In addition, there is the danger of burning cables and/or translator covers by concentrated reflected radiation at off-normal incidence.

The SPIG is capable of obtaining intensity profiles for various geometries including circular, D-shaped, and triangular shapes with the axis of rotation at different positions about the focal line. The rotational scan is limited to ± 160° from the zero position due to the limits caused by the cables to the radial translator and the sensor, and due to the non-linearity of the rotator potentiometer about the zero mark.

The size of the triangle shape is limited to a 30 mm leg due to the vertical translator. This translator has a maximum travel of 25 mm from zero which limits the size triangle which can be traced out by the tip of the calorimeter.

The SPIG can determine the optimum focal line as that point having the maximum average intensity. When this point has been determined through use of the 5 x 5 grid of intensity ratios, the calorimeter can be positioned to the optimum location by entering the appropriate position into the HP-85 computer. However, the calorimeter must be positioned very close to the focal line during initial set-up and while the translators are at their zero position. If the calorimeter must be positioned more than 5 mm from the zero position in order to bring it to the optimum focal line, then the maximum size of a triangle which can be traced out is further reduced.

CHAPTER III
SOFTWARE DESCRIPTION

The software developed for this program has been divided into three computer programs. The first program, called MOVE, controls the positioning of the calorimeter, takes data from the calorimeter and environmental sensors, and stores the data on disc. The other two programs manipulate and display the data. Program AVGPRO produces an axially averaged intensity profile for a given collector for each of the geometries investigated. Program PRPL prints or plots the data stored on disc by MOVE and AVGPRO. Program listings are provided in the appendix.

A. OPERATIONAL

Program MOVE will perform the following functions:

(1) Control tracking of the collector, if desired
(2) Keep track of the time of day
(3) Position the calorimeter and take intensity data
(4) Monitor the calorimeter temperature
(5) Take environmental data including
    (a) Wind speed and direction
    (b) Ambient temperature
    (c) Pyrheliometer readings
    (d) Pyranometer readings
(6) Average the environmental data for each angular scan
(7) Convert voltage measurements to engineering units
(8) Store the following on disc
    (a) Calorimeter readings in terms of raw voltage data, intensity ratios, and intensity in engineering units
    (b) Average environmental data and beginning and ending times for each angular scan

(c) Conversion factors used in converting raw data to engineering units

(d) Angular orientation of the calorimeter at each axial position with respect to the initial orientation.

This program requires the time of day to be input at the beginning of the day. The correct time is then maintained by the HP 3497A. This unit is then queried by the HP-85 before and after each angular scan so the beginning and ending time for each angular scan at each radius is determined and subsequently stored on disc.

If the operator desires computer control of the tracking, he must specify the condition of the collector; either in stow, deadband, or auto-tracking. If the collector is in stow or deadband, it will be placed in auto-tracking. Immediately before each angular scan, the collector will be placed in deadband; the collector will be placed in auto-tracking after each scan.

The positions of the translators are then determined. If the position of the horizontal or vertical translators is more than ± 5 mm from the zero position, the SPIG assembly should be repositioned since subsequent repositioning of the calorimeter to the region of maximum intensity may limit the range of the translators such that the triangle cannot be traced out. If this is not of concern, then the translators should be within ± 10 mm from the zero point to allow the 5 x 5 grid of average intensity ratios to be obtained. The rotator should be within ± 10° from zero or else it will subsequently get too close to the nonlinear region of the potentiometer and possibly lose its position. When this occurs, computer control ceases, the rotator continues rotating, and damage to the cables may result. The radial translator should be at zero for the tip of the calorimeter to be initially at the center of rotation.

Data will be stored according to Julian date, axial position, and type of scan performed. Therefore, the operator must input the Julian date and an axial position number. These axial position numbers must be in ascending order for the program AVGPRO to read the data off the disc sequentially and obtain an average profile.

When the SPIG has been moved to within 2-feet of the alignment assembly, it must be turned around so the calorimeter faces the alignment assembly. This allows data to be obtained over the last 2-feet of trough. This also causes the left/right and rotational directions to be reversed from what they were for previous scans. The program accounts for this reversal; however, the operator must specify at each axial position whether or not the calorimeter is facing away from the leveling device.

Once these inputs are provided to the program, the SPIG radius will be extended to 10 mm, the SPIG will be positioned 10 mm left of center ($x = -10$ mm), and 10 mm above the focal line ($y = +10$ mm). It will then be rotated clockwise 150° and an intensity reading taken with the calorimeter and pyrheliometer. This ratio will be stored in an array. The SPIG will then rotate counter-clockwise through 300°, stopping every 30° to obtain intensity readings and calculate a ratio. The average intensity ratio at this position ($x = -10$, $y = +10$) is then determined by adding the ratios and dividing by 11. The SPIG is then moved to $x = -5$ mm and an average ratio is obtained at this position. This continues for $-10 \leqslant x \leqslant 10$ and $-10 \leqslant y \leqslant 10$ in 5 mm increments so that a 5 x 5 grid is produced showing average intensity ratios about the assumed focal line.

This information is printed on the thermal printer and the operator can determine if there is a more optimum position for the tip of the calorimeter. If a new 0, 0 point is desired, the operator simply enters the new x, y coordinates and the SPIG will be moved to this new position.

When this section of the program is finished, the data is stored on disc and the temperature of the calorimeter is monitored. If the temperature is greater than 350°F, the radial translator will extend the calorimeter to a radius of 90 mm to remove the tip from the focal region. If computer control of the tracker has been selected, the tracker is placed in deadband. The SPIG temperature will be displayed and the program terminated.

The next section of the program obtains an intensity profile for a cylindrical RTS. The initial radius is set to zero and the time is read from the HP 3497A. Environmental data is also obtained prior to the angular scan. The SPIG is then rotated clockwise 160°, readings are taken from the calorimeter and pyrheliometer, and an intensity ratio formed. The SPIG is then rotated counter-clockwise through 320°, stopping every 10° to obtain readings from the calorimeter and pyrheliometer. When the SPIG has obtained data at +160°, the time is noted, environmental data is obtained, and the SPIG is rotated back to zero. The environmental data, obtained before and after rotation, is then averaged for the scan at zero radius and stored along with the raw calorimeter voltages and intensity ratios obtained every 10°, and the beginning and ending times.

The SPIG temperature is then monitored and if it is less than 350°F the SPIG radius is increased to 5 mm and the process repeated. This is repeated for radii between 0 and 50 mm in 5 mm increments. When all the profiles have been obtained for all radii, the data is stored on disc and the SPIG returned to 0° and 0 radius.

The next part of the program obtains an intensity profile for a D-shaped RTS. This operates in essentially the same manner as for the cylindrical RTS except the range of the angular scan is from -90° to +90°. In addition, the profile at 11 radii is obtained for three positions of the center of rotation: $y = -5$ mm, 0, and +5 mm. The first set of profiles is obtained at $y = -5$ mm, the data is stored, and the temperature monitored. The vertical translator then moves the center of rotation to zero and another set of profiles is obtained. After three sets of profiles are obtained, the SPIG is returned to its zero position and the program then goes onto obtain data for a triangular RTS.

The same data is obtained for the triangular RTS as for the previous geometries. Data is obtained for three equilateral triangles with the length of the legs being 10, 20, and 30 mm. The triangles are oriented so that one vertex is pointed at the bottom of the trough and one leg is parallel to the plane of the collector aperture. Profiles are obtained with the horizontal leg of the triangle at 5 mm below, at, and 5 mm above the focal line as indicated in figure III-1. Data is taken at ten equally spaced points along each of two legs of the triangles.

The calorimeter is first rotated clockwise 60° and moved to the top left vertex to take a reading. It then moves down the leg of the triangle with the face of the calorimeter parallel to the leg. Data is taken every ten increments. When the bottom vertex is reached, the calorimeter rotates 120° counter-clockwise and is moved up parallel to the leg of the triangle. After the profiles are obtained in the first vertical position (y = -5 mm), the data is stored and the temperature is monitored. When the profiles are obtained for all size triangles and at the three vertical positions, the data is stored on disc and the SPIG is returned to its zero position and the program is terminated.

After each angular scan (or each scan around a triangle), the operator may elect to have the profile plotted on the CRT of the HP-85. If the profile does not appear correct, he may choose to retake data at the current radius.

The subroutines which may require modification by the user are those that contain the conversion factors for the measuring devices and which perform pyrheliometer and pyranometer temperature corrections. The conversion factors are contained in subroutine 8000, the environmental data is obtained in subroutines 9000 through 9210, and the temperature corrections are made in subroutines 9300 and 9520.

B. DATA REDUCTION

The program AVGPRO reads the intensity data from disc for each axial position, sums the intensities, and divides by the number of axial positions to produce an averaged intensity profile for the collector being studied.

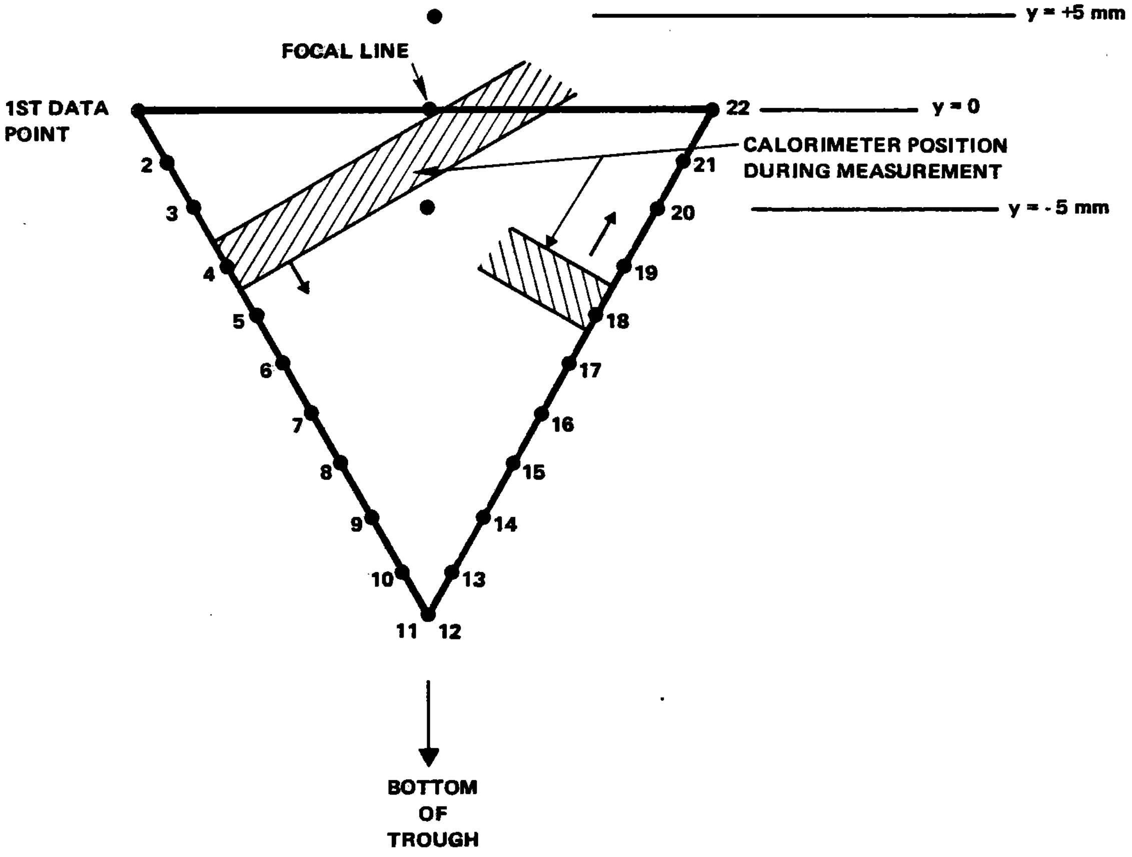

Figure III-1. Triangular RTS Measurements

If all the data described in the previous section were obtained, only that data from five axial positions would fit on a single disc. Thus, the operator must specify the number of discs to be used in the averaging process, the number of axial positions to be averaged, and the days (Julian date) on which the data was taken. The program will provide a catalog listing of the data files if desired.

This program will read an intensity ratio at a specific radius (or triangle size) and angle (or point on the leg of a triangle), and at a specific vertical position. This will be done for each axial position and the values averaged axially. The next angle is selected and the process repeated. This is done for all angles at a given radius and y position until an average profile is obtained at that radius. An average profile is then obtained for the next larger radius and so on until an average profile is obtained as a function of radius and angle for the collector. Average profiles are also obtained as functions of radius and angle at different vertical positions for the D-shaped and triangular RTS. These profiles are then stored on disc in files whose names are determined by the geometry, vertical position, a user specified identifier of the measurement series, and a collector identifier.

C. DATA MANIPULATION AND DISPLAY

Program PRPL reads data from the disc and displays the data as either a listing or in graphical form. This program will also provide a catalog listing of data files if desired. The user must specify the file name and the type of output desired.

Data obtained directly from the SPIG has a file name format given by XXX-ZZ-MN where:

XXX = Julian date on which data was taken
ZZ = axial position number specified by the user in program MOVE
M = 1: average intensities on a 5 x 5 grid
M = 2: data for a cylindrical RTS

M = 3: data for a D-shaped RTS

M = 4: data for a triangular RTS

N = 1: center of rotation 5 mm below axis

N = 2: center of rotation on asix

N = 3: center of rotation 5 axis

The files containing averaged intensities have names with the format A-X-BBB where:

A = CYL: cylindrical RTS

A = D1: D-shaped RTS 5 mm below axis

A = D2: D-Shaped RTS on axis

A = D3: D-shaped RTS 5 mm above axis

A = T1: triangular RTS 5 mm below axis

A = T2: triangular RTS on axis

A = T3: triangular RTS 5 mm above axis

X = measurement series identifier specified by the user in program AVGPRO

BBBB = collector identifier specified by the user in program AVGPRO.

This program will perform the following functions as specified by the user:

(1) Print average intensity profile
(2) Plot average intensity profile
(3) Print relative intensity profile at an axial position
(4) Plot relative intensity profile at an axial position
(5) Print intensity profile at an axial position
(6) Plot intensity profile at an axial position
(7) Print raw intensity data at an axial position
(8) Print conversion factors
(9) Print environmental data
(10) Print average intensities over a 5 x 5 grid
(11) Print SPIG angular orientation versus axial position relative to initial orientation.

The first two functions display data produced by AVGPRO, the rest of the functions display data obtained by MOVE.

The relative intensity refers to the intensity measured by the calorimeter divided by the intensity measured by the pyrheliometer at the same time. The intensity profile refers to the relative intensity multiplied by the pyrheliometer reading averaged over the period of the angular scan. Raw data refers to the voltage readings obtained from the calorimeter, and environmental data includes the following:

(1) Wind speed
(2) Wind direction
(3) Pyrheliometer reading
(4) Pyranometer reading
(5) Ambient temperature
(6) Start time for the angular scan at a particular radius
(7) End time for the angular scan at a particular radius.

The first four data items are averages taken from measurements performed before and after the angular scan at each radius (or triangle size).

CHAPTER IV
OPERATIONAL AND TEST PROCEDURES

The operational and test procedures can be divided into three operations: initial set-up and alignment; data collection; and relocation to a new axial position.

A. INITIAL SET-UP

The initial set-up procedure consists of installing the SPIG assembly and alignment assembly on opposite ends of a collector. The SPIG calorimeter is manually centered in the middle of the trough, and the tip of the calorimeter set at the focal line of the mirror. A reference point on the machine scale attached to the SPIG assembly is determined by measuring a distance y from the bottom of the trough.

The machine scale on the alignment assembly is then centered in the middle of the trough. A reference point on this scale is obtained by measuring a distance y from the center of the trough. The Dumpy level is than aligned such that its horizontal cross-hair lies on the two reference points; one on the SPIG assembly and one on the alignment assembly. When the level is lined up with these two reference points, it is parallel to the axis of the collector.

The Dumpy level is then rotated so that the vertical cross-hair is parallel to the machine scale on the SPIG assembly and lies along one edge of the scale. This allows realignment of the SPIG when moved to a new axial position.

C. DATA COLLECTION

Data is obtained simply by using the program MOVE. The operation of this program was described in the previous section.

D. RELOCATION

When all the data has been obtained at an axial position, the SPIG translators should be returned to their original zero position. The leveling pads should be loosened and the SPIG assembly moved to a new axial position. The carriage bolts in the top of the collector mounts should not be adjusted since these insure that the SPIG remains at the same vertical distance from the bottom of the trough.

When the SPIG assembly has been located at the desired axial position, and the leveling pads tightened, the SPIG may be adjusted such that it lies in the center of the collector. This is done by adjusting the horizontal position such that the edge of the machine scale on the SPIG assembly lies along the vertical cross-hair of the Dumpy level. Gross adjustments may be made by loosening the bolts holding the cross-beam in place and adjusting the position of the beam. Finer horizontal adjustments may be made using the manual control.

The manual control may also be used to rotate the SPIG such that the machine scale on the SPIG is parallel to the vertical cross-hair of the level. This orients the SPIG to its original position. Vertical adjustments are also made with the manual control so that the reference point on the SPIG machine scale lines up with the horizontal cross-hair of the level.

Once the SPIG has been oriented and positioned to its original orientation using the Dumpy level, it is ready to begin taking data at the new axial position.

CHAPTER V
RECEIVER TUBE THERMAL OPTIMIZATION

A. INTRODUCTION

The second task in this project was to develop a thermal model of a receiver tube subassembly (RTS). Using the intensity data obtained with the SPIG device, the size and shape of an RTS may be optimized using the thermal model to calculate heat loss and efficiencies.

The model makes use of the electrical and thermal network equivalents to relate the thermal system to an electrical circuit. The equations associated with the thermal network are solved using the steady-state portion of the NET-2 general purpose network analysis computer code. The model has been validated for a cylindrical receiver tube by comparing predicted efficiencies with measured efficiencies for the Solar Kinetics, Inc. (SKI) T-700 collector.

This section of the report describes in detail the thermal model and calculations of the resistance for a cylindrical RTS shown in figure V-1. Thermal resistance relations have also been derived for the D-shaped and triangular RTS, and are programmed into the computer program RESIST listed in the appendix.

This computer program has been written for the HP-85. The required inputs are the incident intensity obtained from SPIG; material properties such as absorptivity, emissivity, conductivity, etc.; collector properties such as size, reflectivity, intercept factor, etc.; and temperatures of the ambient air and heat transfer fluid at the RTS inlet. The output consists of resistances, currents (in terms of heat fluxes), and voltages (in terms of temperatures) in the exact format required for input to NET-2.

The NET-2 program will calculate temperatures at each node, and the heat flux between nodes. The useful energy gain of the collector is obtained by summing the energy transferred from nodes 7, 9, 15, and 21

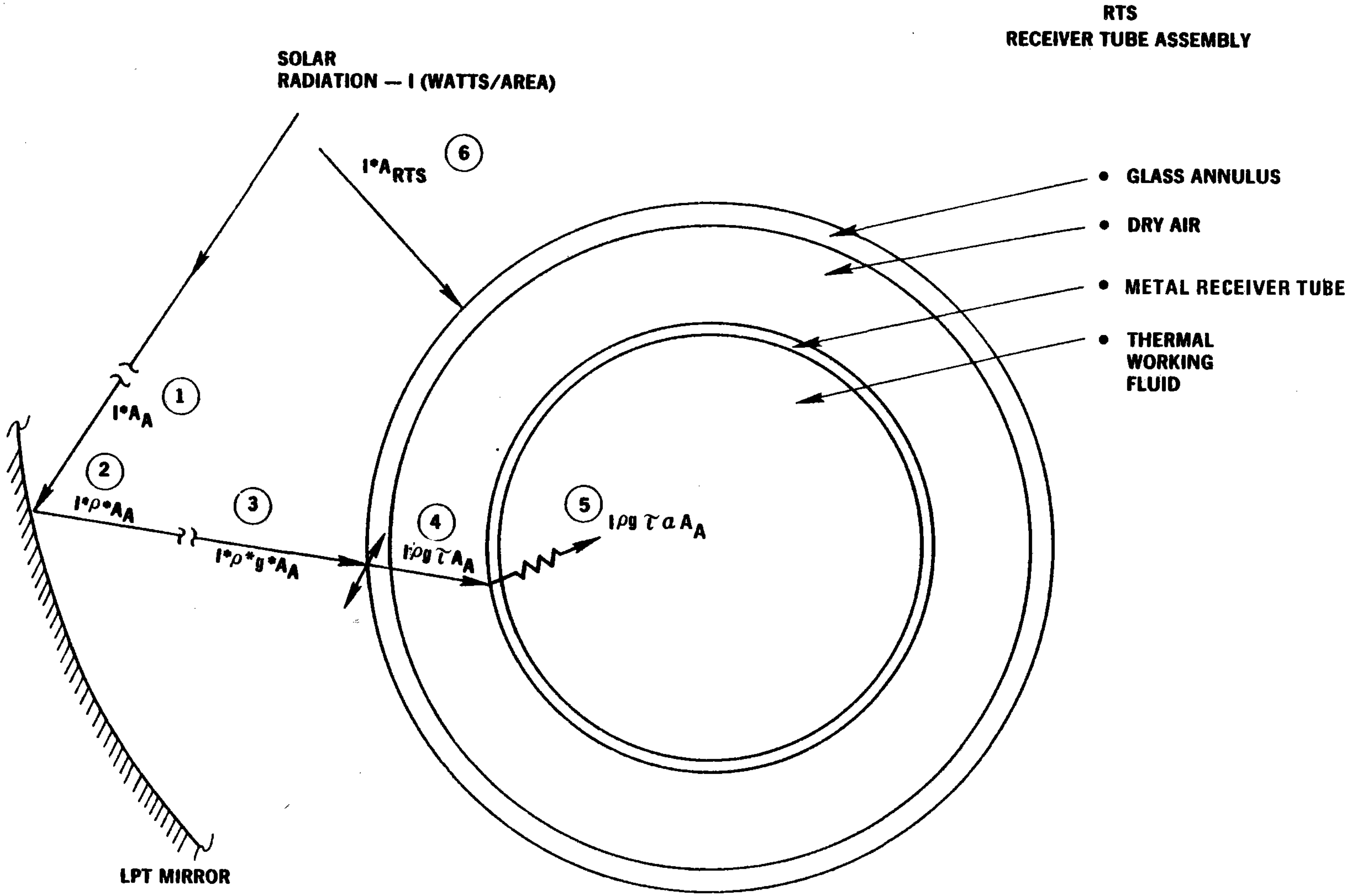

Figure V-1. RTS Receiver Tube Assembly

to node 8, where node 8 is the heat transfer fluid (see figure V-2). Knowing the useful energy gained and the insolation on the collector from SPIG pyrheliometer readings, the collector efficiency can be calculated for various sizes and shapes of receiver tubes.

B. HEAT TRANSFER MECHANISMS

The linear parabolic trough and receiver tube configuration consists of a parabolic reflective mirror which focuses incident solar radiation onto the RTS. As shown in figure V-1, the RTS consists of the metal receiver tube which carries the thermal working fluid and is coated with a spectrally selective absorber. The receiver tube is encapsulated within a glass annulus which is designed to minimize energy loss. The annulus spacing contains dry air at atmospheric pressure.

The energy gained by the collector system is entirely radiative in nature and is obtained from SPIG data. The thermal losses are due to convection, conduction, and radiation.

In determining the energy losses of the collector system, it is necessary to consider all the mechanisms and the different aspects of geometry. With reference to figure V-2, the RTS has been divided into four sections. Section A is the top 180° of the RTS and faces the open sky. The bottom of the RTS faces the mirror and is divided into three 60° sectors; B, C, and D as shown. The RTS has been divided into these four thermal sectors to better reflect the effect of the circumferentially variable incident solar flux. A qualitative representation of an expected solar flux distribution on a receiver tube is shown in figure V-3.

The upper half of the receiver tube receives radiation directly from the sun, and the 180° sector will be adequate to model the relatively uniform radiation over this region. The lower half of the RTS receives radiation reflected from the mirror and concentrated into two lobes on either side of the bottom center of the tube. The minimum in

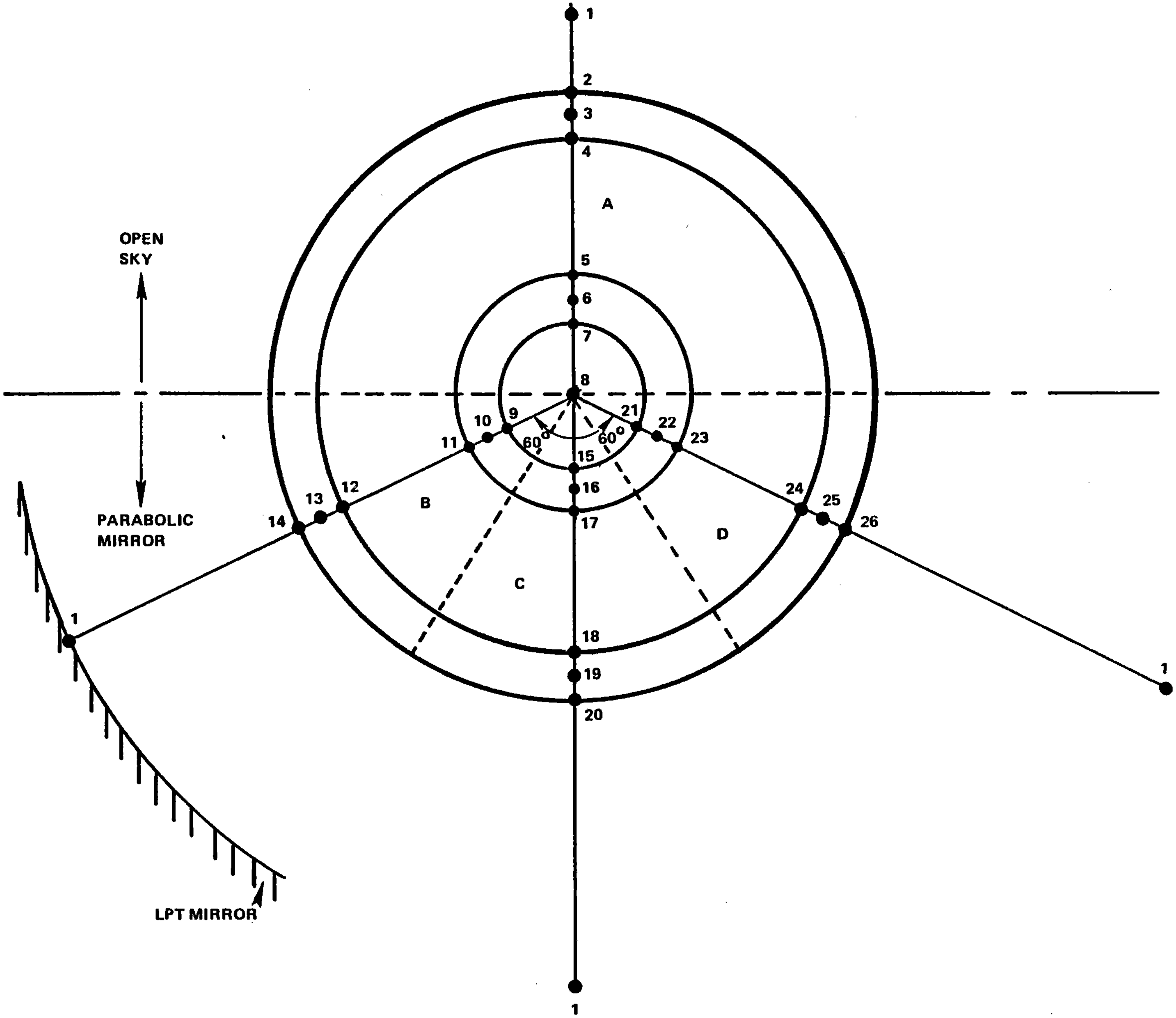

Figure V-2. Nodal Diagram of the Heat Transfer Network for the RTS

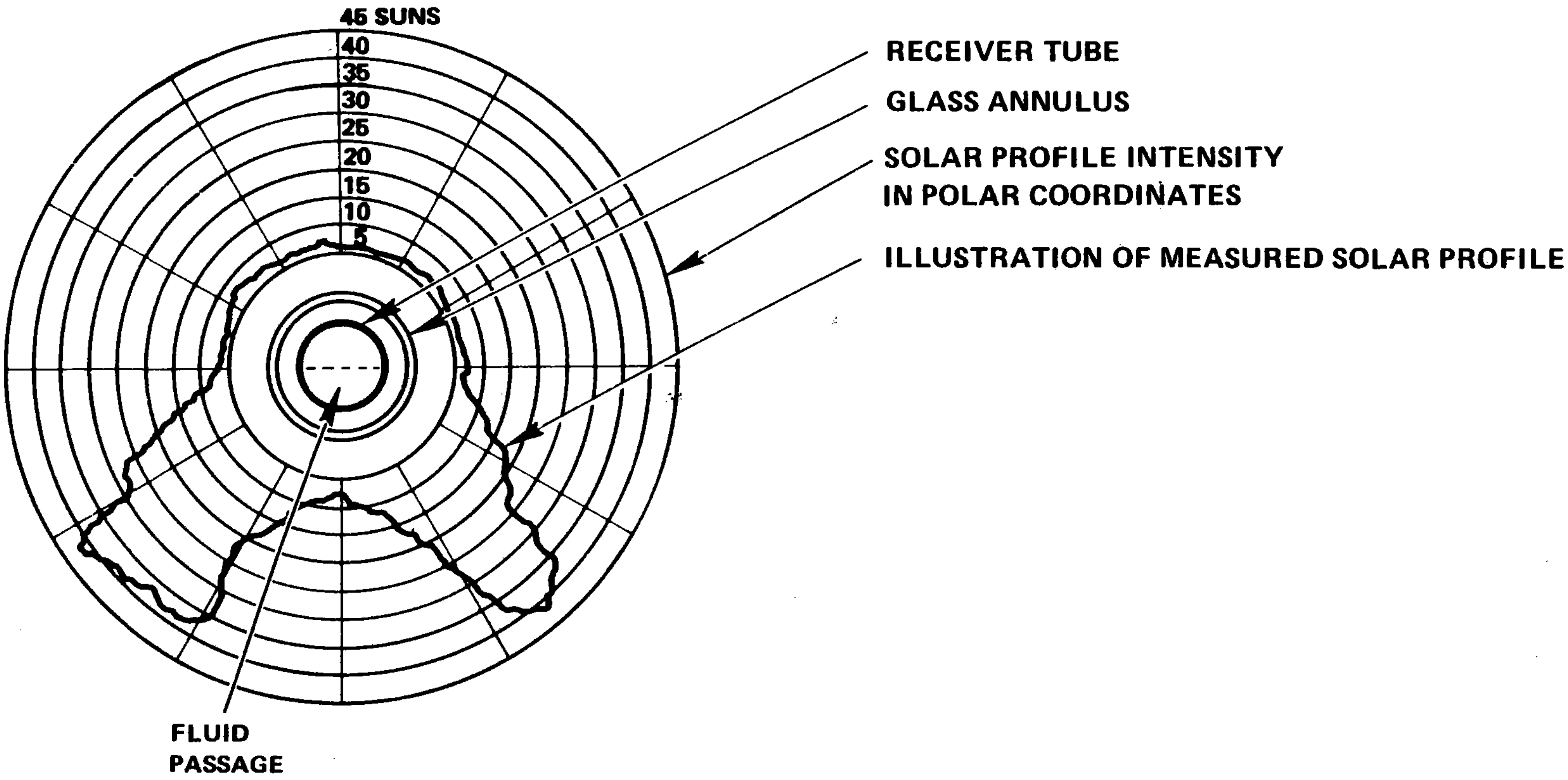

Figure V-3. Solar Flux Distribution on a Receiver Tube the incident condition is primarily due to the reflective properties and geometry of the mirror, and partly due to shadowing by the receiver tube subassembly.

Based on a previous study for the LFPP (reference 1) which used two sectors, this level of analysis using four sectors is considered adequate to model the indicated non-uniformities.

All three forms of heat transfer are present throughout the RTS thermal network. Radiation and convection occurs from the top and bottom of the glass cover to ambient conditions (where the four nodes denoted by 1 are ambient); however, the geometry of the mirror will affect radiation heat transfer from all four nodes on the outside of the glass cover. All of the energy lost from the RTS must be conducted through the glass cover as the glass is opaque to long wavelength radiation. Energy is also conducted to or from the thermal working fluid through the steel receiver tube. Also, since the radiation incident upon the cover and RT is non-uniform, the circumferential temperature distribution may be expected to be nonuniform so that circumferential heat conduction will occur within the cover and receiver tube.

The heat transfer between the glass cover and the RT involves all three forms of heat transfer. However, with the optimal spacing between the RT and glass cover (references 2 and 3), the Rayleigh number is maintained at a sufficiently low value to nearly eliminate convection and cause conduction to predominate. As a result, the equation for conduction is used with an effective conductivity. The effective conductivity is discussed in detail in reference 3. The result of using an effective conductivity is that only two paths of heat transfer across the annulus gap need be considered: radiation and conduction.

Heat is also transferred to the thermal working fluid by convection. The parameter governing this transfer is the convective heat transfer (or film) coefficient. Although the convective film coefficient varies with the heat flux to the fluid, the lowest film coefficient occurs in the region of highest heat flux (references 4 and 5). This should force circumferential conduction in the receiver tube from regions of high temperature to regions of lower temperature. In addition, the largest radiation heat loss will occur from the circumferential position at the highest temperature. These factors tend to even out the heat flux to the fluid. Thus, we have assumed a sufficiently uniform heat flux to the fluid so that an average film coefficient can be used to calculate convective heat transfer to the fluid (reference 6).

1. Radiation Heat Transfer

In developing the relations for thermal resistance to radiation heat transfer, the following assumptions were made:

(1) Each sector surface is isothermal.

(2) All surfaces are diffuse gray surfaces for thermal radiation.

(3) No radiation occurs between the inner surfaces of the glass cover (i.e., the temperature difference between glass surfaces is small compared to the temperature difference between the glass and the RT, and the annulus gap is small so the view factor is small between glass surfaces).

The general form of the equation is:

$$q_{1-2} = \sigma A_1 \, F_{1-2} \, (T_1^4 - T_2^4) = h_r \, A_1 \, (T_1 - T_2)$$

where

$T = 5.729 \times 10^{-12}$ watts/cm^2 K^4

A_1 = area of the hot surface

F_{1-2} = the gray-body shape factor

$$F_{1-2} = \frac{1}{\frac{1-\varepsilon_1}{\varepsilon_1} + \frac{1}{f_{1-2}} + \frac{A_1}{A_2} \frac{1-\varepsilon_2}{\varepsilon_2}}$$

f_{1-2} = black-body shape factor

$\varepsilon_1, \varepsilon_2$ = emissivities

A_2 = area of cold surface

The radiative resistance is then given by

$$R_r = \frac{1}{A_1 h_r} = \frac{T_1 - T_2}{\sigma A_1 \; F_{1-2} \; (T_1^4 - T_2^4)}$$

This radiative resistance is input to NET-2 as a function of temperature. NET-2 has the capability to iterate over the temperatures to obtain the appropriate heat transfer between radiation nodes.

a. Radiation from Receiver Tube to Glass Cover

Using Hottel's crossed-string method (reference 7), one can derive the black-body shape factor between a surface on the receiver tube and an opposite surface on the glass annulus. Referring to figure V-4a for the case in which $\alpha \leqslant \beta$ one has the relation

$$A_B \; f_{B-B'} = R_1 \; (\beta - \alpha) + x - (R_2 - R_1)$$

where

$\alpha = \cos^{-1} R_1/R_2$ in radians
$x = R_2 \sin \alpha$
$A_B = R_1 \beta$
R_1 = the outer radius of the receiver tube
R_2 = the inner radius of the glass annulus
β = the sector angle in radians

The above relation reduces to

$$f_{B-B'} = 1/\beta \; [R_2/R_1 \; (\sin\alpha - 1) + \beta - \alpha + 1]$$

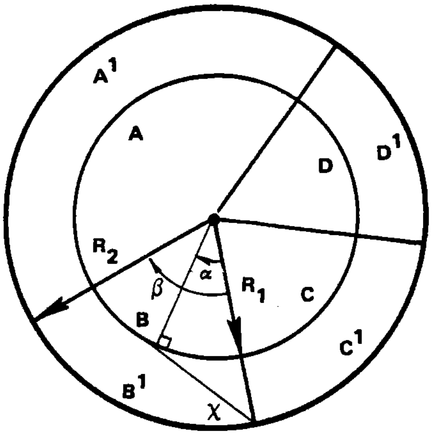

Figure V-4a. Geometry for the Derivation of the Shape Factor between Surfaces B and B' for the case where the Angle to the Point of Tangency (α) is less than the Sector Angle (β)

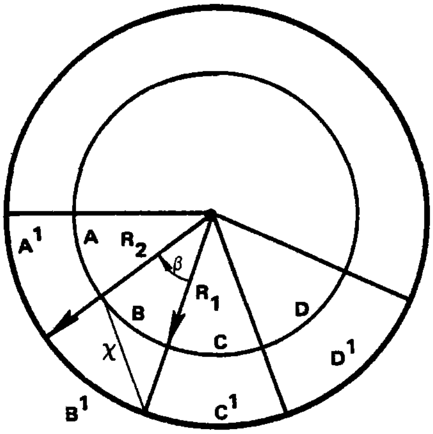

Figure V-4b. Geometry for the Derivation of the Shape Factor between Surfaces B and B' for the Case where there is no Point of Tangency within the Sector

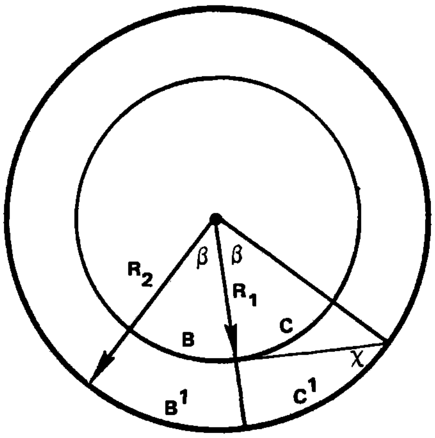

Figure V-4c. Limiting Case in which Surface B does not "see" beyond Adjacent Sectors

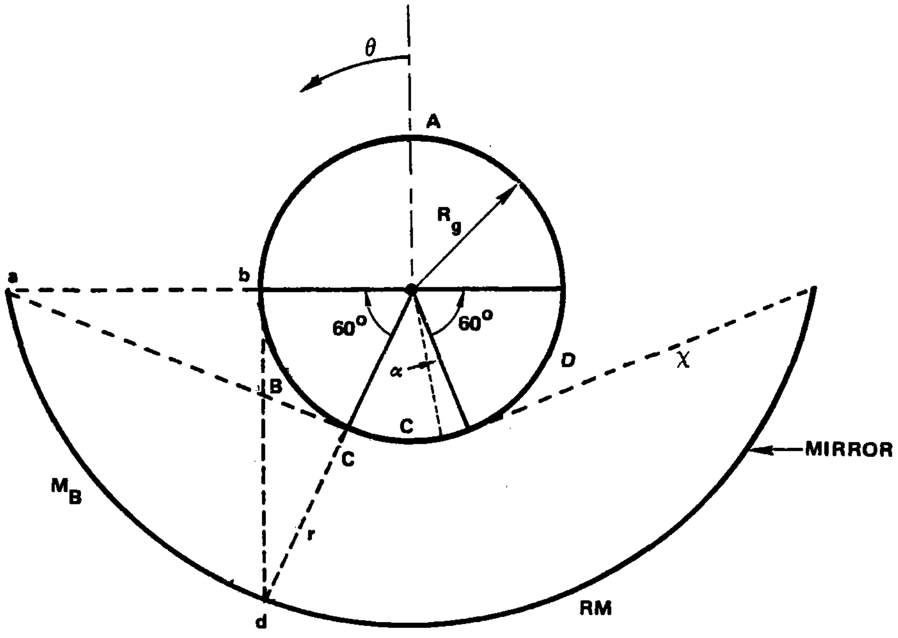

Figure V-4d. Geometry for Determining Shape Factors between the Glass Annulus and the Mirror

For the case in which the line x is not tangent to the inner surface within the sector, then from figure V-4b one obtains the relation

$$A_B\, f_{B-B'} = \left[R_1^2+R_2^2 - 2R_1R_2\cos\beta\right]^{1/2} - (R_2 - R_1)$$

which can be written as

$$f_{B-B'} = \frac{1}{\beta}\left\{\left[1 + \frac{R_2^2}{R_1^2} - 2\,\frac{R_2}{R_1}\cos\beta\right]^{1/2} - \left[\frac{R_2}{R_1} - 1\right]\right\}$$

If one can assume that surface B does not radiate to any surface beyond the adjacent sectors (i.e., surface B only radiates to surfaces A' and C' in figure V-4), then the shape factor to adjacent surfaces can be found from the following relations

$$f_{B-A'} + f_{B-B'} + f_{B-C'} = 1$$

but

$$f_{B-A'} = f_{B-C'}$$

so that

$$f_{B-A'} = f_{B-C'} = 1/2\left[1 - f_{B-B'}\right]$$

For the assumption that surface B does not radiate beyond the adjacent sector to be valid, the limiting tangent to surface B (line x in figure V-4c) must not extend beyond sector C. In the case shown in figure V-4c we have

$$\cos \beta = R_1/R_2$$

Thus, for surface B to radiate only to adjacent sectors we must have

$$\beta \geq \cos^{-1} \frac{R_1}{R_2}$$

For the situation shown in figure V-2 for 60° sectors, we must have $R_2/R_1 > 2$ in order for radiation to occur to sectors beyond the adjacent sector. We don't expect such a situation to occur since this will produce a geometry which will not minimize the combined conductive and convective heat transfer across the annular air gap.

b. Radiation from the Glass Cover

In calculating the view-factors from the outer surface of the glass cover, the crossed-string method is again used. Referring to figure V-4d, the view-factor from surface B to surface M_B on the mirror is given by

$$A_B \, f_{B-M_B} = 1/2 \left[A_{ac} + A_{bd} - A_{ab} - A_{cd}\right]$$

where

$A_B = \beta R_g$

R_g = outer radius of the glass

$A_{ab} = 2f - R_g$

$A_{cd} = r - R_g$

$A_{bd} = [R_g^2 + r^2 - 2R_g r \cos\beta]^{1/2}$

$A_{ac} = \left[R_g^2 + (2f)^2 - (2)(2f)R_g \cos\beta\right]^{1/2}$

and for a parabola with focal length f

$$r = \frac{2f}{1 - \cos\theta}$$

Thus, the view-factor for sector B to the portion of the mirror denoted by M_B is given by

$$f_{B-M_B} = \frac{1}{2\beta R_g}\left\{\left[R_g^2 + r^2 - 2rR_g\cos\beta\right]^{1/2} + \left[R_g^2 + (2f)^2 - 4R_g f\cos\beta\right]^{1/2} - (2f - R_g) - (r - R_g)\right\}$$

Sector B also radiates to the rest of the mirror (RM) and the sun (S) so that

$$f_{B-MB} + f_{B-S} + f_{B-RM} = 1$$

Also,

$$f_{B-RM} = \frac{1}{2\beta R_g}\left\{\frac{\pi}{3}R_g + (r - R_g) - \left[R_g^2 + r^2 - 2rR_g\cos\beta\right]^{1/2}\right\}$$

so that the view-factor from surface B to the entire mirror becomes

$$f_{B-M} = f_{B-M_B} + f_{B-RM}$$

By symmetry, this equals the view-factor from surface D to the mirror, so that

$$f_{D-M} = f_{B-M}$$

$$f_{D-S} = f_{B-S}$$

By similar reasoning, the view-factor for surface C to the mirror is given by

$$f_{C-M} = \frac{1}{\beta R_g} \left\{ R_g(2\beta-\alpha)+2f\sin\alpha - \left[R_g^2+(2f)^2-4fR_g \cos\beta \right]^{1/2} \right\}$$

$$f_{C-S} = 1 - f_{C-M}$$

For surface A (the top surface), using symmetry one can write

$$f_{A-S} = f_{(B+C+D)} - M$$

but

$$(A_B + A_B + A_C)\, f_{(B+C+D)} - M = A_B\, f_{B-M} + A_C\, f_{C-M} + A_D\, f_{D-M}$$

and

$$A_B = A_C = A_D$$

so that

$$f_{A-S} = 1/3 \left[f_{B-M} + f_{C-M} + f_{D-M} \right]$$

and

$$f_{A-M} = 1 = f_{A-S}$$

c. Radiation from a D-Shaped Receiver Tube

Since the top of a D-shaped RTS is flat, all the radiation goes to the sky so that

$$F_{A-S} = 1, \; F_{A-M} = 0$$

The view factors from the bottom cylindrical portion are the same as for the cylindrical RTS.

2. Conduction Heat Transfer

Thermal conduction will occur radially, from the outer surface of the RT to the inner surface, across the annular gap, and through the glass cover. In addition, azimuthal conduction will occur in the RT and the glass cover due to nonuniform heating. For radial conduction, the general equation is

$$q_{1-2} = \frac{k \, A_1 \, (T_1 - T_2)}{R_1 \, \ln(R_2/R_1)} = h_K \, A_1 \, (T_1 - T_2)$$

and for azimuthal conduction the general equation is

$$q_{1-2} = \frac{k \, A_1 \, (T_1 - T_2)}{R_{avg} \, (\vartheta_2 - \vartheta_1)} = h_K \, A_1 \, (T_1 - T_2)$$

where

$A_1 = R_{outer} - R_{inner}$ = thickness of RT or glass

$R_{avg}\ (\vartheta_2 - \vartheta_1)$ = distance between points where T_2 and T_1 are measured.

Heat transfer across the annular spacing is assumed to consist of only radiation and conduction (the convective contribution being contained in the effective conductivity). Emperical data for coaxial cylinders has been examined in reference 3 where it was concluded that the relation

$$q_{1-2} = \frac{2\pi\ k_e}{\ln R_{2}/R_{1}}\ (T_1 - T_2)$$

can be used to determine the heat transfer across a small annular gap. Here, k_e represents the effective conductivity for heat transfer by conduction and convection. Reference 3 gives the relation between k_e and k, the conductivity of dry air, as

$$k_e/k = 0.317\ Ra_{cc}^{*\ 1/4}$$

where

$$Ra_{cc}^{*} = \frac{8\left[\ln R_{2}/R_{1}\right]^4}{(R_{2}/R_{1} - 1)^3 \left[1 + (R_{1}/R_{2})^{3/5}\right]^5}\ Ra_b$$

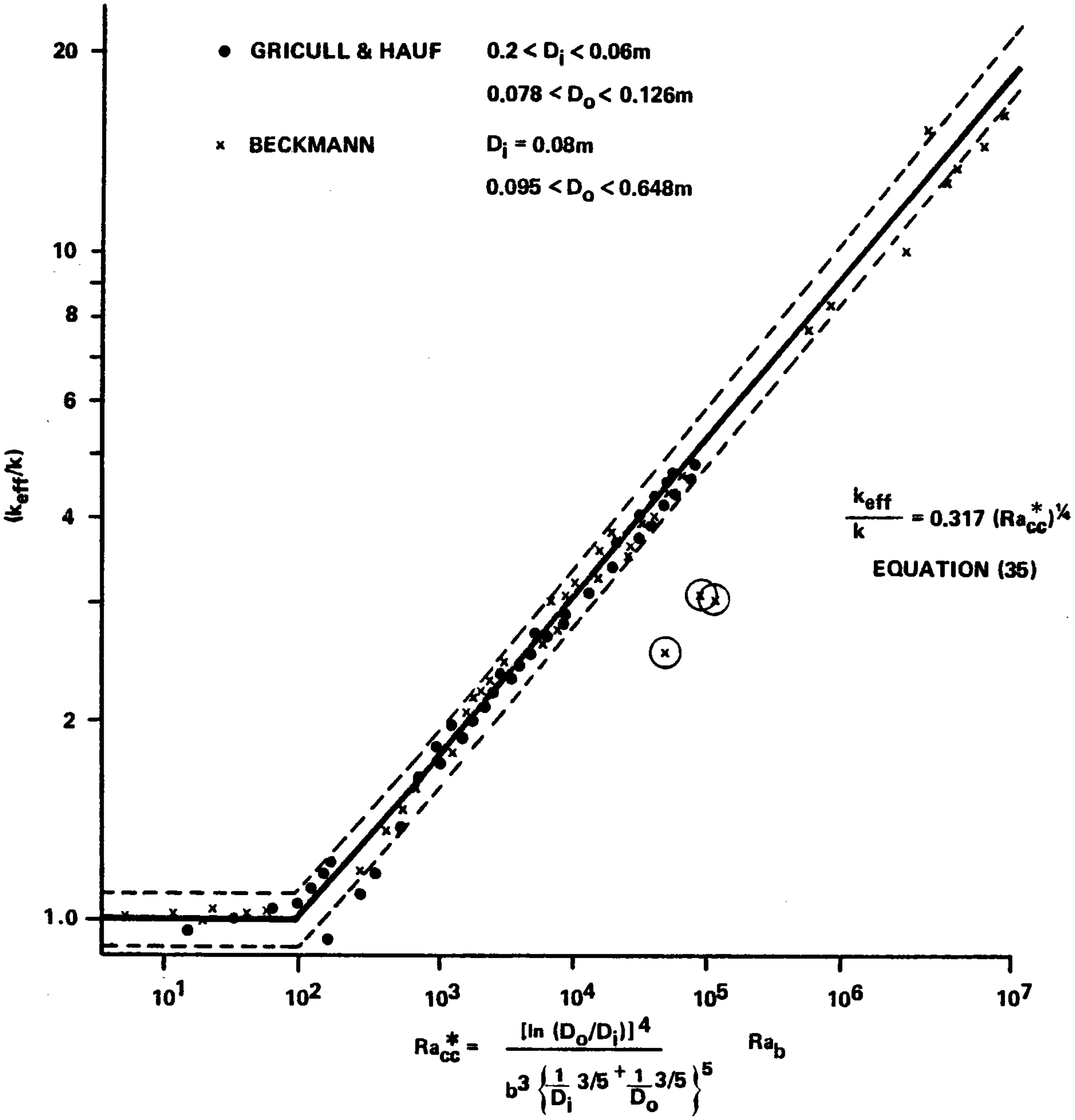

Figure V-5. Heat Transfer Across Concentric Cylindrical Annuli and

$$R_{ab} = \frac{g \beta (T_1 - T_2) b^3}{\nu\alpha}$$

is the Raleigh number and b is the gap spacing.

This correlation is shown in figure V-5 (obtained from reference 3) and shows that for $Ra^*_{cc} \leqslant 100$, $k_e = k$ and the convective contribution is suppressed. As an example, for $R_2/R_1 = 1.17$, $Ra^*_{cc} = 3.89 \times 10^{-2} Ra_b$. In order that $k_e = k$, then we must have

$$Ra^*_{cc} = 3.89 \times 10^{-9} Ra_b \leq 100$$

or

$$Ra_b \leq 2570$$

If one assumes the temperature of the glass cover is 140°F and the RT is 600°F, then the gap spacing is found to be 9 mm. This is approximately the optimal spacing of 10 mm found by Treadwell (reference 2).

The conductive resistance is given by

$$R_k = \frac{1}{h_k A_1}$$

For radial conduction

$$R_k = \frac{\ln R_{2/R_1})}{k \beta}$$

and for circumferential conduction

$$R_k = \frac{R_{avg} (\beta_1 + \beta_2)/2}{k(R_2 - R_1)}$$

For a D-shaped RTS, the conductive resistances through the bottom cylindrical portion are the same as for the cylindrical RT. For radial conduction through the top, the resistance is given by

$$R_k = \frac{R_2 - R_1}{2k\ R_1}$$

and for circumferential conduction from section A to adjacent sectors

$$R_k = \frac{R_1 + R_{avg}\ \beta/2}{k\ (R_2 - R_1)}$$

Heat transfer across the annular air gap in a D-shaped and triangular tube is assumed to obey the previous relations for a cylindrical RT except that the hydraulic diameter is used.

3. Convection Heat Transfer

The general form of the equation is

$$q_{1-2} = h_c\ A_1\ (T_1 - T_2)$$

where

h_c = Convective heat transfer (or film) coefficient

A_1 = Area of the hot surface

with the resistance given by

$$R_c = \frac{1}{h_c A_1}$$

since the Nusselt number is given by

$$Nu = \frac{h_c D}{k}$$

the resistance can be written as

$$R_c = \frac{D_1}{kA_1 Nu}$$

where D_1 is the diameter of the surface and k is the conductivity of the fluid.

For this study it will be assumed that the heat transfer to and from the fluid in the RT is governed by the average film coefficient. This assumption neglects the effect (if any) of the circumferential variation in heat flux to the fluid. The value of h_c for internal turbulent pipe flow can be calculated using the Seider-Tate type relation recommended by Monsanto, the manufacturers of therminol fluids (reference 8). Thus,

$$Nu = 0.022\ Re_b^{0.8}\ Pr_b^{0.4}\ \left(^{\mu_b}/_{\mu_s}\right)^{0.16}$$

where all properties are taken at the bulk temperature of the fluid except μ_s which is taken at the inside surface temperature of the RT. This relation is valid when significant differences between the bulk temperature of the fluid and the wall temperature occur such that appreciable changes in fluid properties may occur between the wall and the central flow.

In those situations where a helical type insert has been placed in the RT to enhance heat transfer to the fluid, there are empirical correlations available for the Nusselt number (reference 9). These relations have been obtained analytically and applied to empirical data for fluids such as ethylene glycol and water to obtain appropriate coefficients and exponents. It is assumed that these correlations are applicable to therminol for want of any better relations.

For fully developed laminar flow, the Nusselt number is given by (reference 10)

$$Nu = 5.172 \left\{ 1 + 5.484 \times 10^{-3} (Pr)^{0.7} (Re/n)^{1.25} \right\}^{1/2}$$

where Re and Nu are based on the inside diameter of the tube and n is the numbers of tube diameters per 180° tape twist. For fully developed turbulent flow, the relation is (reference 11)

$$Nu = 0.023 \left[1 + (\pi/2n)^2 \right]^{0.4} Re^{0.8} Pr^{0.4} + 0.193 \left[\frac{Re^2}{n} \beta(T_w - T_b) Pr \right]^{1/3}$$

where Re and Nu are based on the hydraulic diameter, β is the coefficient of thermal expansion, T_w is the wall temperature and T_b is the bulk fluid temperature. In these equations the fluid properties are evaluated at the bulk temperatures.

Several empirical correlations are provided in the literature for forced convection from a single cylinder in crossflow. The following correlation for the Nusselt number is given in reference 12:

$$Nu = C_1 Re^{n_1}$$

$C_1 = 0.583$, $n_1 = 0.471$ for $3.5 \leq Re \leq 5 \times 10^3$

$C_1 = 0.148$, $n_1 = 0.633$ for $5 \times 10^3 \leq Re \leq 5 \times 10^4$

$C_1 = 0.0208$, $n_1 = 0.814$ for $5 \times 10^4 \leq Re \leq 2 \times 10^5$

where the fluid properties are evaluated at the film temperature

$$T_f = \frac{1}{2} (T_s + T_\infty)$$

and T_s is the surface temperature of the cylinder.

If the wind is not perpendicular to the axis of the cylinder, the axial component increases the thickness of the boundary layer and reduces the convective heat transfer as shown in figure V-6. For a yawed cylinder, the following relation is provided for the Nusselt number ratio:

$$\frac{(Nu)_\psi}{(Nu)_{\psi=90°}} = (\sin^2 \psi + F^2 \cos^2 \psi)^{n_1/2}$$

where

$$F \sim 0.3 \exp (- {}^L/_{400D}) + (1 + 22\ Re)^{-1}$$

where L is the length of the cylinder and D is its diameter. For axial flow ($\Psi = 0$) the heat transfer is about 40 percent of that for cross-flow ($\psi = 90°$).

C. CIRCUIT ANALOG MODEL

The analysis performed in this project considers only the steady-state situation. The cross-section of the RTS and the appropriate nodes are shown in figure V-2. The appropriate electrical network consisting of resistors and current and voltage sources, is shown in figure V-7. Heat flux input (i.e., solar insolation) is specified as a current source, and known temperatures such as inlet fluid and ambient temperature are specified as voltage sources. The relations defining resistances between nodes are calculated from the previous relations in the computer program RESIST.

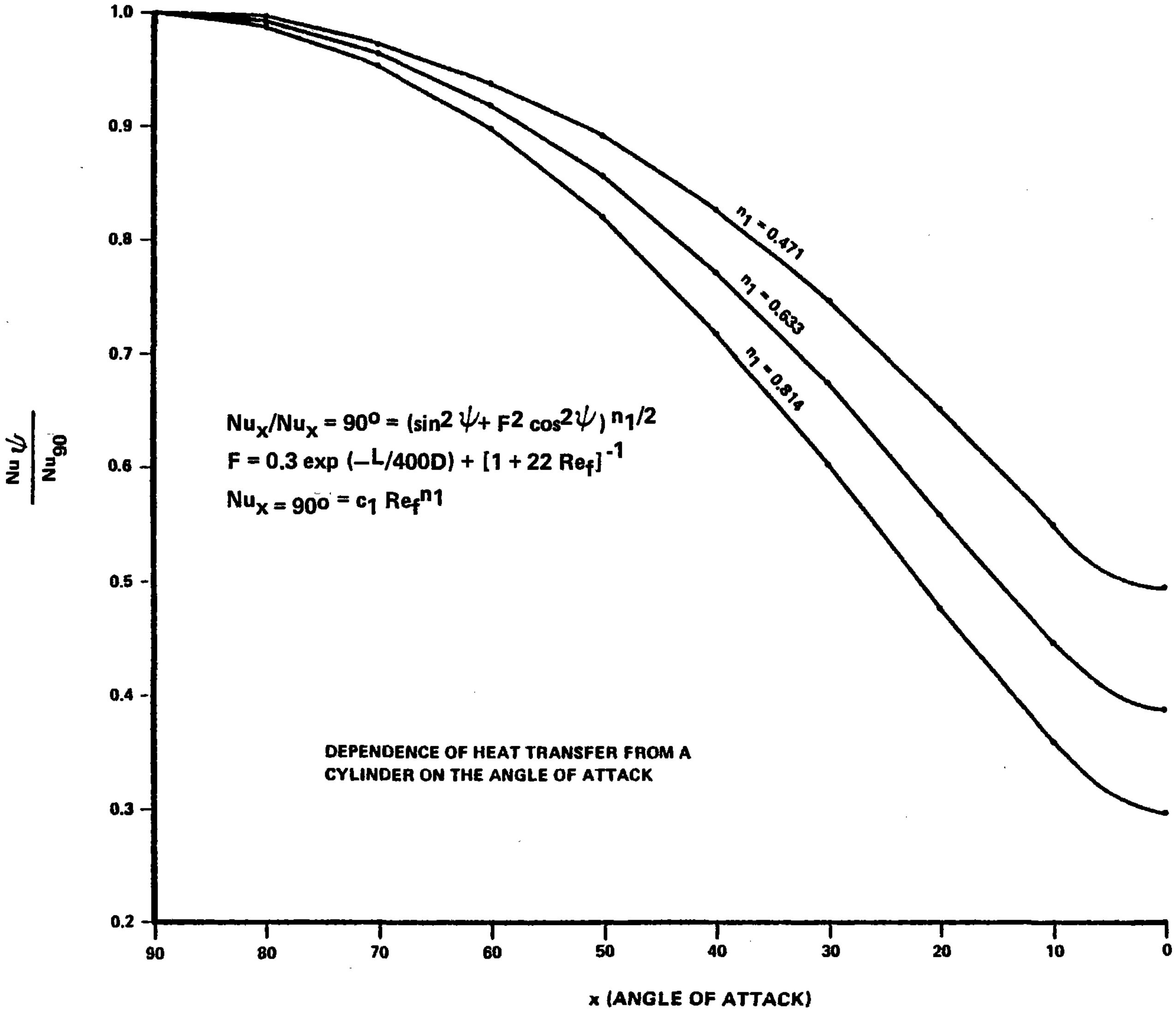

Figure V-6. Dependence of Heat Transfer from a Cylinder on the Angle of Attack

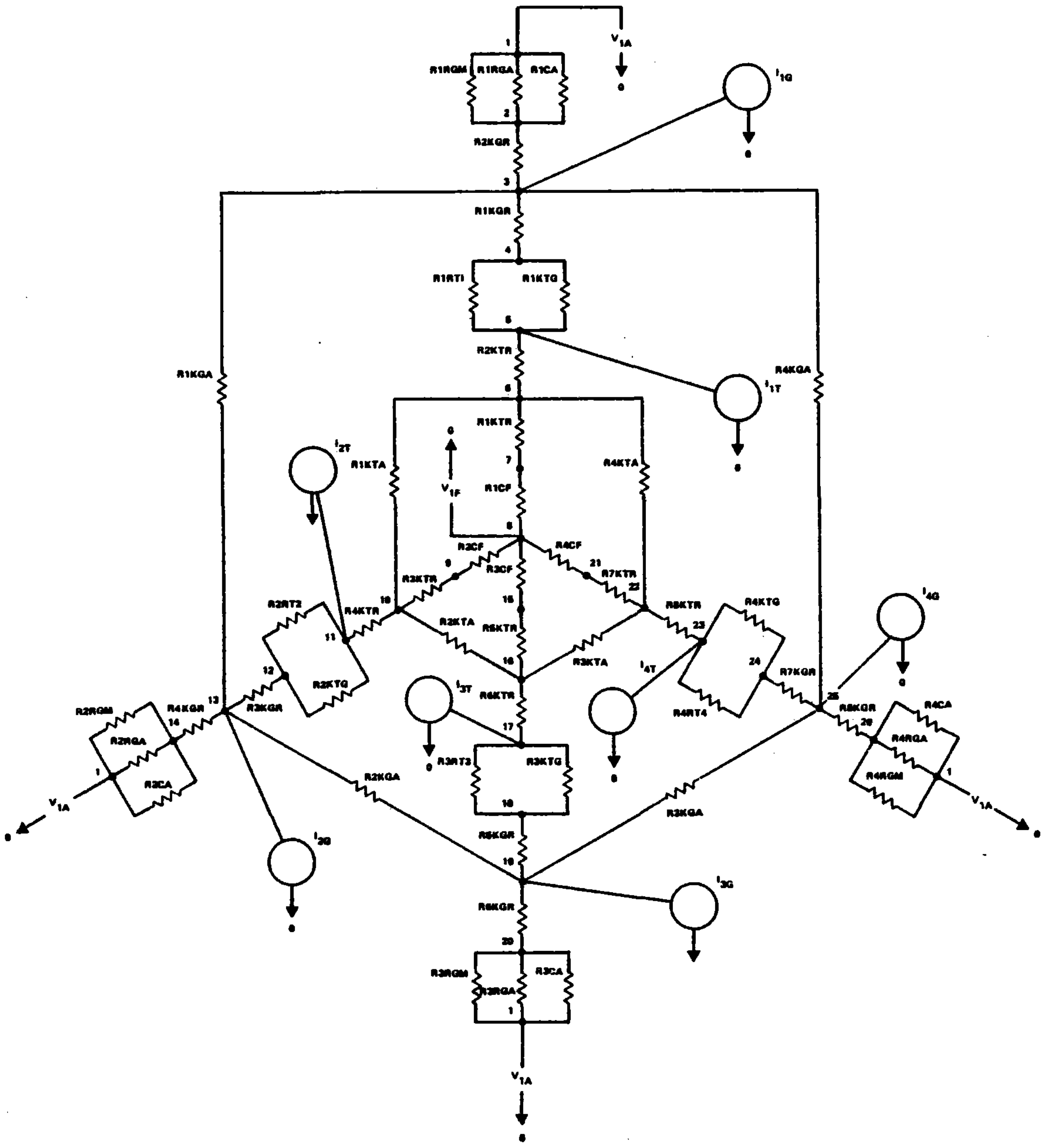

Figure V-7. RTS Heat Transfer Electrical Analogy

D. MODEL VALIDATION

Two sets of experimental data on the Solar Kinetics T-700 LPT were available for model validation. The first consisted of a series of tests in a small range of operating temperatures and insolations at the BDM STF in Albuquerque. A major feature of these tests was that surface temperatures of the RTS components were measured at points corresponding to some of the network node locations. The second set of data consists of comprehensive tests at the SNLA MTSTF over the useful range of temperatures and insolations. These results are in the form of a curve fit of empirical collector efficiencies with no component temperature data. There are slight differences between the two sets which can be accounted for by mirror soiling. The validation approach taken was to compare the network results using commonly accepted values for material properties of the RTS and comparing temperature and efficiency predictions with measured values.

Experiments on the SKI T-700 collector at the BDM solar test facility used a collector on a north-south axis mounted on a single axis tracker. Measurements were taken of the RT and glass cover temperatures at the inlet and outlet, facing the sun and facing the mirror. The inlet and outlet temperatures and flow rate of the heat transfer fluid were obtained along with wind speed and direction, air temperature, and direct normal insolation.

Measured efficiency was obtained using the relation

$$\eta = \frac{\dot{m}\, c_p\, (T_{out} - T_{in})}{(A_a)\, I_b \cos i}$$

where

$\dot{m}$ = the flow rate

C_p = the specific heat

I_b = the direct normal insolation obtained from the pyrheliometer measurement

A_a = the aperture area

i = the incidence angle

The measured efficiencies and predicted efficiencies using the thermal model are compared in table V-1 and the temperatures are compared in table V-2.

In validating the thermal model, it was assumed that the mirror reflectivity was 0.8 and the radiation incident upon the RTS was uniform since the expected non-uniformities could not be quantified. Efficiencies calculated assuming a distribution of 20 percent of the reflected radiation incident on the bottom center sector and 40 percent on each of the two side sectors showed negligible difference from the uniform intensity case in collector efficiency and sun-side temperatures. Mirror-side temperatures decreased about 4 percent below those for the uniform intensity case.

A comparison between efficiencies predicted with the thermal model and a relation derived empirically by SNLA (reference 13) is also shown in table V-1. A mirror reflectivity of 0.83 was assumed in the present model for comparison with SNLA data.

The predicted and measured efficiencies agree within 4.5 percent, and the efficiencies predicted by the present model agree within 2 percent with those predicted using the SNLA empirical relation. This agreement is within any differences which might be expected due to differences in material properties (particularly mirror reflectivity) and experimental errors. It is important to note that all values are for the steady-state. A large difference between measured efficiency and efficiency calculated using a steady-state model could occur due to

TABLE V-1. COMPARISON OF MEASURED AND CALCULATED EFFICIENCIES

CASE NO.	BDM DATA		CLEAN MIRROR	
	MEASURED η	PREDICTED η	SNLA MEASURED η	BDM PREDICTION
1	52.9%	54.3%	57.9%	56.5%
2	53.1%	54.3%	57.9%	56.5%
3	52.5%	54.0%	58.1%	56.2%
4	51.2%	55.1%	57.8%	57.4%
5	52.9%	55.1%	57.9%	57.3%
6	51.2%	54.9%	58.0%	57.2%
7	53.0%	54.2%	58.1%	56.5%
8	51.0%	54.6%	58.0%	56.9%
9	51.5%	55.0%	58.0%	58.7%
10	51.0%	55.6%	57.9%	57.5%

TABLE V-2. COMPARISON OF MEASURED AND CALCULATED RTS TEMPERATURES

CASE NO.	MEASURED GLASS TEMP (°F)	CALCULATED GLASS TEMP (°F)	MEASURED RT TEMP (°F)	CALCULATED RT TEMP (°F)
	TOWARD SUN TOWARD MIRROR	TOWARD SUN TOWARD MIRROR	TOWARD SUN TOWARD MIRROR	TOWARD SUN TOWARD MIRROR
1	170 265	189 253	402 467	413 494
2	181 268	189 252	404 469	413 494
3	190 268	181 238	407 471	415 496
4	187 273	217 291	408 471	417 498
5	178 271	213 286	408 472	418 500
6	179 270	205 276	411 475	420 503
7	190 270	180 237	412 474	420 502
8	176 276	190 252	412 472	421 503
9	184 281	198 266	413 473	422 505
10	183 280	210 282	413 474	422 505

a rapidly varying insolation. The pyrheliometer measures instantaneous efficiency, but the outlet temperature of the heat transfer fluid varies slowly due to thermal inertia.

In addition to the good agreement between efficiencies, predicted and measured receiver tube temperatures agreed to within 7 percent.

The same validation procedure was accomplished for a D-shaped receiver tube that was tested at BDM. Predictions of efficiency using the present model fell within 5 percent of the measured efficiencies.

It can be concluded that the network model predicts with acceptable accuracy the behavior of both circular and D-shaped RTS configurations, and can be used as a design and evaluation tool. The availability of measured solar intensity profile data together with the model will allow evaluation of variously shaped receiver tubes, determination of the effects of different RTS sizing, and locations with respect to the "true" focal line.

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CHAPTER VI
SUGGESTED IMPROVEMENTS

BDM has operated the SPIG on its SKI T-700 collector mounted on a single axis tracker. After having operated the SPIG, there are a few improvements we feel should be made in the electrical and mechanical design of the system. These are as follows:

<u>Rotator Potentiometer</u>: The position of the rotator is determined by reading the potentiometer voltage, both full scale and center tap, and taking a ratio. Thus,

$$P = 360\ (1 - V1/V2) + H - 180$$

where

P = position in degrees
V1 = center tap voltage drop
V2 = full potentiometer voltage drop
H = offset
180° = zero position of the rotator.

All the potentiometers were calibrated to determine the position as a function of the voltage ratio. They all required a correction factor to be added to or subtracted from the voltage ratio to obtain the position in millimeters or degrees. For the linear translators, this offset was consistent to within a few percent through the range of the translator. However, the rotator potentiometer has an offset which varies from 4° to 10° depending on position.

We recommend that a different potentiometer be attached to the timing belt drive recessed in the edge of the rotator body. The drive shaft rotates 35 turns for 360° rotation of the rotator stage. The center of the new potentiometer must be determined so that the center tap is positioned at the middle when the rotator stage is at the 180°

mark. The new potentiometer must then be connected to the same pins as the old potentiometer and calibrated to determine the offset required to convert voltage ratio to degrees.

SPIG Positioning: The positioning of the tip of the calorimeter at the focal line of the collector can be quite tedious and time consuming using the unistrut. We would recommend designing an assembly on which worm gears can be installed in order to precisely position the calorimeter with either a hand crank or a motor controlled by the operator through the HP-85. This would allow rapid, precise horizontal and vertical positioning of the SPIG at the point of maximum intensity.

APPENDIX A
EQUIPMENT LIST

A. HEWLETT-PACKARD EQUIPMENT

	DESCRIPTION	MODEL NUMBER
1.	Computer with HP-TR Module	HP-85F
a.	IO ROM	
b.	16 K Memory Module	82903A
c.	HP-IB IM Cable	10833A
d.	Plotter/Printer ROM	00085-15002
e.	Mass Storage ROM	00085-15001
f.	Carrying Case	82933A
2.	Thermal Graphics Printer	9876A
3.	Scanner (Data Acquisition/Control Unit)	3497A
a.	Option 231 Clock Format	
b.	Power Option 326	
c.	Option 010 (5 1/2 DVM and A/O 20 Channel MUX Assembly)	
d.	Option 110 (16 Channel Actuator/ Digital Output Assembly)	
4.	Dual Master Flexible Disc Drive	92910M
	5 1/4-inch Flexible Discs	

B. KLINGER SCIENTIFIC CORPORATION EQUIPMENT

	DESCRIPTION	MODEL NUMBER
1.	Two 50 mm Translators w/Potentiometer	UT100.50CC w/pot
2.	100 mm Translator w/Potentiometer	UT100.100CC w/pot
3.	Rotation Stage w/Potentiometer	UR80CC w/pot
4.	X-95 Rail	
5.	Clamping Carriage	026403

C. MISCELLANEOUS

	DESCRIPTION AND MODEL NUMBER	MANUFACTURER
1.	24 Volt Power Supply #B24GT110	Acopian
2.	Amplifier (X1000)	Thermogage, Inc.
3.	Two Heat Flux Gages #1000-30	Thermogage, Inc.
4.	Power Supply and Relay Box	BDM
5.	Manual Control Box	BDM
6.	Wild Dumpy Level and Close Focus Lens	Wild Heerburg Instruments, Inc.
7.	Machine Slide #R-345L	Milwaukee Machine Manufacturing Co.
8.	Thin Film RTD #PT100FKG	Omega Engineering, Inc.

APPENDIX B
COMPUTER PROGRAM LISTINGS

1. Program "MOVE"

```
10 OPTION BASE 1
15 DEG
20 I5=.0001
30 DIM P0(4),Y(5),X(5),B(5),C(7),A(11,35),R(11),A2(11,35),E1(5),E2(5),E(11,5),T0
(11),T9(11)
40 DIM P4(20),M1$[28],M2$[28],M3$[34],M$[112],M1(4),M2(4)
50 DIM W4(6),W5(6),W1(6),W2(6),P1(4),A5(5,5),H(4),M8$[71],M9$[39]
70 SHORT R3,Y3
80 CLEAR 709
90 MASS STORAGE IS ":D700"
100 PRINTER IS 703,80
110 DISP "DO YOU WANT TO SET THE TIME? (Y OR N)"
120 INPUT S1$
130 CLEAR
140 IF S1$="N" THEN 210
150 T1$="TD"
160 DISP "INPUT MONTH,DAY,HOUR,MIN,SEC IN THE FORMAT MMDDHHMMSS"
170 INPUT T$
180 CLEAR
190 T$=T1$&T$
200 OUTPUT 709 ;T$
210 OUTPUT 709 ;"TD"
220 ENTER 709 ; T2$
230 DISP "CURRENT TIME IS_",T2$
240 DISP "IS THE DISPLAYED TIME CORRECT? (Y OR N)"
250 INPUT S2$
260 IF S2$="N" THEN 150
270 OUTPUT 709 ;"SD0"
280 REM **GO TO SUBROUTINE TO DEFINE TRANSFER FUNCTIONS AND CORRECTION FACTORS
290 GOSUB 8000
300 M9=1
310 M8=0
360 DISP "IS COMPUTER CONTROL OF THE TRACKER REQUIRED?(Y OR N)"
370 INPUT C$
380 IF C$="N" THEN 530
390 CLEAR
400 DISP "INPUT CONDITION OF TRACKER"
410 DISP "___1.STOW"
420 DISP "___2.DEADBAND"
430 DISP "___3. AUTO-TRACKING"
440 INPUT C9
450 CLEAR
460 ON C9 GOTO 470,520,510
470 OUTPUT 709 ;"DC4,8DC4,9"
480 WAIT 2000
490 OUTPUT 709 ;"DO4,8DC4,9"
500 GOTO 520
510 OUTPUT 709 ;"DO4,8DC4,9"
520 DISP "TRACKER IS NOW IN DEADBAND FOR POSITIONING OF SPIG"
530 OUTPUT 709 ;"VR5VT4VC2"
640 DISP "PROGRAM IS IN PAUSE, WHEN SPIG HAS BEEN POSITIONED PRESS CONTINUE"
650 BEEP
660 PAUSE
670 CLEAR
```

```
680 REM **DETERMINE 0 POSITION OF TRANSLATORS
690 GOSUB 7000
700 DISP "ARE THE ZERO POSITIONS WITHIN RANGE? (Y OR N)"
710 INPUT S5$
720 IF S5$="N" THEN 640
730 IF C$="Y" THEN GOSUB 5000 ELSE 750
740 WAIT 5000
750 DISP "INPUT 3 DIGIT JULIAN DATE"
760 INPUT D$
770 DISP "INPUT AXIAL POSITION IN FEET"
780 INPUT Z
790 DISP "INPUT TWO DIGIT AXIAL POSITION NUMBERIN ASCENDING ORDER"
800 INPUT Z5$
820 CLEAR
830 H$="-"
840 DISP "INPUT TYPE OF COLLECTOR (15 DIGITS MAXIMUM)"
850 INPUT F2$
860 CLEAR
920 F1$=D$&H$&Z5$
930 DISP "IS SPIG FACING AWAY FROM LEVEL? (Y OR N)"
940 INPUT S6$
950 CLEAR
960 REM **SET TRACKER TO DEADBAND
970 IF C$="Y" THEN GOSUB 5030
980 REM **SET RADIUS TO 10MM
990 E9=.04
1000 L=3
1010 GOSUB 7200
1020 K3=P0(L)+10
1030 GOSUB 7500
1040 DISP "RADIUS IS _";P-P0(L)
1050 REM **INCREMENT X,Y,AND THETA
1055 M=1
1060 IF S6$="Y" THEN I1=10 ELSE I1=-10
1070 IF S6$="Y" THEN S1=5 ELSE S1=-5
1080 IF S6$="Y" THEN I4=150 ELSE I4=-150
1090 IF S6$="Y" THEN S4=-30 ELSE S4=30
1100 N2=0
1110 FOR K2=P0(2)+10 TO P0(2)-10 STEP -5
1120 L=2
1130 GOSUB 7200
1140 GOSUB 7500
1150 N2=N2+1
1160 N1=0
1165 Y(N2)=P
1170 FOR K1=P0(1)-I1 TO P0(1)+I1 STEP S1
1180 L=1
1190 GOSUB 7200
1200 GOSUB 7500
1210 N1=N1+1
1220 N4=0
1230 A3=0
1235 IF S6$="Y" THEN X(N1)=P ELSE X(N1)=-P
1236 I6=0 @ N9=0
1237 L=4
1238 GOSUB 7200
1240 FOR K4=P0(4)+I4 TO P0(4)-I4 STEP S4
1245 I6=I6+3
1250 N9=0
1270 GOSUB 7500
1280 N4=N4+1
1290 REM **READ PYROHELIOMETER DATA
1300 GOSUB 9150
1310 I=B(4)
1315 WAIT 1000
1320 REM **READ CALORIMETER DATA
```

```
1325 OUTPUT 709 ;"AI9"
1330 ENTER 709 ; A1
1335 A1=-A1
1340 A4=A1/I*C(1)
1350 A3=A3+A4
1360 NEXT K4
1370 A5(N1,N2)=A3/N4
1380 REM **SET TRACKER TO AUTOMATIC
1390 IF C$="Y" THEN GOSUB 5000
1400 REM **SET ROTATOR BACK TO ZERO
1410 K4=P0(4) @ N9=0
1415 I6=18
1420 GOSUB 7500
1430 REM **MONITOR SPIG TEMPERATURE
1440 GOSUB 5260
1450 IF N=0 THEN 1510
1460 DISP "SPIG TEMP TOO HIGH-COLLECTOR IN DEADBAND, SPIG MOVED TO MAX RADIUS-TE
ST ABORTED"
1470 REM **STORE DATA OBTAINED UPTO NOW
1480 GOSUB 5700
1490 BEEP
1500 END
1510 REM **SET TRACKER TO DEADBAND
1520 IF C$="Y" THEN GOSUB 5030
1530 NEXT K1
1540 NEXT K2
1550 REM **STORE AVERAGE NORMALIZED INTENSITY AND POSITIONS
1560 GOSUB 5700
1570 REM **SET TRACKER TO AUTOMATIC
1580 IF C$="Y" THEN GOSUB 5000
1590 REM **PRINT OUT NORMALIZED INTENSITY AND POSITION
1600 GOSUB 5500
1610 REM **RETURN SPIG TO X=Y=0 AND R=0
1620 K1=0 @ L=1
1630 GOSUB 7200
1640 GOSUB 7500
1650 K2=0 @ L=2
1660 GOSUB 7200
1670 GOSUB 7500
1680 K3=0 @ L=3
1690 GOSUB 7200
1700 GOSUB 7500
1710 REM **HALT PROGRAM UNTIL 0,0 POINT IS DETERMINED
1720 DISP "PROGRAM IS IN PAUSE, WHEN POSITION FOR MAX AVERAGE"
1725 DISP "INTENSITY IS DETERMINED PRESS CONTINUE"
1730 BEEP
1740 PAUSE
1750 REM **INPUT NEW POSITION FOR X AND Y
1760 DISP "ENTER THE DESIRED X AND Y POSITIONS"
1770 INPUT K1,K2
1780 REM **MOVE SPIG TO NEW POSITION
1790 L=1
1800 GOSUB 7200
1810 GOSUB 7500
1820 L=2
1830 GOSUB 7200
1840 GOSUB 7500
1850 GOSUB 7000
1860 IF S6$="Y" THEN I4=160 ELSE I4=-160
1870 IF S6$="Y" THEN S4=-10 ELSE S4=10
1880 I3=50
1890 S3=5
1900 N3=0
1910 N4=0
1915 GOSUB 9750 ! ZERO ARRAYS FOR NEXT SERIES
1920 REM **PERFORM R-THETA SCAN FOR CYLINDRICAL PROFILE
```

```
1930 M=2
1940 FOR K3=P0(3) TO P0(3)+I3 STEP S3
1945 N4=0
1950 L=3
1960 IF C$="Y" THEN GOSUB 5030
1970 GOSUB 7200
1980 GOSUB 7500
1990 N3=N3+1
2000 GOSUB 5060
2010 T0$=T2$
2020 J=0
2030 GOSUB 5100
2040 R(N3)=P
2050 L=4
2060 GOSUB 7200
2065 I6=0 @ N9=0
2070 FOR K4=P0(4)+I4 TO P0(4)-I4 STEP S4
2075 I6=I6+1
2080 GOSUB 7500
2090 N4=N4+1
2100 GOSUB 9150
2110 I=B(4)
2130 WAIT 1000
2140 OUTPUT 709 ;"AI9"
2150 ENTER 709 ; A2(N3,N4)
2155 A2(N3,N4)=-A2(N3,N4)
2160 A(N3,N4)=A2(N3,N4)/I*C(1)
2170 NEXT K4
2180 GOSUB 5060
2190 T9$=T2$
2195 J=1
2200 GOSUB 5100
2210 FOR E0=1 TO 5
2220 E(N3,E0)=(E1(E0)+E2(E0))/2
2230 NEXT E0
2240 REM **RESET THETA TO ZERO
2250 K4=P0(4) @ N9=0
2256 I6=18
2260 GOSUB 7500
2270 IF C$="Y" THEN GOSUB 5000 ELSE 2290
2280 WAIT 5000
2290 GOSUB 5260
2300 IF N=0 THEN 2360
2310 DISP "SPIG TEMP TOO HIGH -COLLECTOR IN DEADBAND, SPIG MOVED TO MAX RADIUS-T
EST ABORTED"
2320 REM **STORE DATA OBTAINED UP TO NOW
2330 GOSUB 5700
2340 BEEP
2350 END
2360 DISP "IS AN INTENSITY VS. THETA PLOT DESIRED? (Y OR N)"
2370 INPUT P$
2380 IF P$="N" THEN 2500
2390 DISP "PRESS CONTINUE TO CLEAR THE PLOT FROM THE SCREEN"
2395 WAIT 5000
2400 GOSUB 6300
2410 PAUSE
2420 GCLEAR
2430 ALPHA
2440 DISP "ARE NEW MEASUREMENTS DESIRED AT THIS RADIUS? (Y OR N)"
2450 INPUT R$
2455 CLEAR
2460 IF R$="N" THEN 2500
2470 J=0
2480 N4=0 @ N9=0
2490 GOTO 2070
2500 T0(N3)=VAL(T0$)
```

```
2510 T9(N3)=VAL(T9$)
2520 NEXT K3
2530 GOSUB 5700
2540 REM **RETURN SPIG TO R=0
2550 K3=0
2560 L=3
2570 GOSUB 7200
2580 GOSUB 7500
2590 N2=0
2600 N3=0
2610 N4=0
2620 IF S6$="Y" THEN I4=90 ELSE I4=-90
2630 IF S6$="Y" THEN S4=-10 ELSE S4=10
2635 GOSUB 9750 ! ZERO ARRAYS FOR NEXT SERIES
2640 REM **PERFORM SCAN FOR D-SHAPED PROFILE
2645 M=3
2650 FOR K2=P0(2)-5 TO P0(2)+5 STEP 5
2660 L=2
2670 IF C$="Y" THEN GOSUB 5030
2680 GOSUB 7200
2690 GOSUB 7500
2700 N2=N2+1
2710 Y(N2)=P
2715 N3=0
2720 FOR K3=P0(3) TO P0(3)+I3 STEP S3
2725 N4=0
2730 L=3
2740 GOSUB 7200
2750 GOSUB 7500
2760 N3=N3+1
2770 GOSUB 5060
2780 T0$=T2$
2790 J=0
2800 GOSUB 5100
2810 R(N3)=P
2820 L=4
2830 GOSUB 7200
2835 I6=8 @ N9=0
2840 FOR K4=P0(4)+I4 TO P0(4)-I4 STEP S4
2845 I6=I6+1
2850 GOSUB 7500
2860 N4=N4+1
2870 GOSUB 9150
2880 I=B(4)
2890 WAIT 1000
2900 OUTPUT 709 ;"AI9"
2910 ENTER 709 ; A2(N3,N4)
2915 A2(N3,N4)=-A2(N3,N4)
2920 A(N3,N4)=A2(N3,N4)/I*C(1)
2930 NEXT K4
2940 GOSUB 5060
2950 T9$=T2$
2955 J=1
2960 GOSUB 5100
2970 FOR E0=1 TO 5
2980 E(N3,E0)=(E1(E0)+E2(E0))/2
2990 NEXT E0
3000 REM **RESET THETA TO ZERO
3010 K4=P0(4) @ N9=0
3015 I6=18
3020 GOSUB 7500
3030 IF C$="Y" THEN GOSUB 5000 ELSE 3050
3040 WAIT 5000
3050 GOSUB 5260
3060 IF N=0 THEN 3120
3070 DISP "SPIG TEMP TOO HIGH-COLLECTOR IN DEADBAND,SPIG MOVED TO MAX RADIUS-TES
```

```
T ABORTED"
3080 REM **STORE DATA OBTAINED UP TO NOW
3090 GOSUB 5700
3100 BEEP
3110 END
3120 DISP "IS AN INTENSITY VS. THETA PLOT DESIRED? ( Y OR N)"
3130 INPUT P$
3140 IF P$="N" THEN 3270
3150 DISP "PRESS CONTINUE TO CLEAR THE PLOT FROM THE SCREEN"
3155 WAIT 5000
3160 GOSUB 6300
3170 PAUSE
3180 GCLEAR
3190 ALPHA
3200 DISP "ARE NEW MEASUREMENTS DESIRED AT THIS RADIUS? (Y OR N)"
3210 INPUT R$
3220 CLEAR
3230 IF R$="N" THEN 3270
3240 J=0
3250 N4=0 @ N9=0
3260 GOTO 2840
3270 T0(N3)=VAL(T0$)
3280 T9(N3)=VAL(T9$)
3290 NEXT K3
3295 GOSUB 5700
3300 NEXT K2
3310 REM **RETURN SPIG TO Y=R=0
3320 L=3 @ K3=0
3330 GOSUB 7200
3340 GOSUB 7500
3350 L=2 @ K2=P0(2)
3360 GOSUB 7200
3370 GOSUB 7500
3375 GOSUB 9750 ! ZERO ARRAYS FOR NEXT SERIES
3380 REM **PERFORM SCAN FOR TRIANGLE
3390 IF S6$="Y" THEN I4=60 ELSE I4=-60
3400 N2=0
3405 M=4
3410 FOR Y2=P0(2)-5 TO P0(2)+5 STEP 5
3415 K2=Y2
3420 L=2
3430 IF C$="Y" THEN GOSUB 5030
3440 GOSUB 7200
3450 GOSUB 7500
3460 N2=N2+1
3470 Y(N2)=P
3480 N3=0
3490 FOR L8=5 TO 15 STEP 5
3500 R1=L8/COS(30)
3510 D9=L8/SIN(30)
3520 D2=D9/9
3530 N3=N3+1
3540 X0=P0(1)
3550 Y0=Y(N2)+L8*TAN(30)
3560 R(N3)=2*L8
3561 K3=R1
3562 L=3
3563 GOSUB 7200
3564 GOSUB 7500
3570 K4=P0(4)+I4
3580 L=4 @ N9=0
3585 IF I4=60 THEN I6=6 ELSE I6=22
3590 GOSUB 7200
3600 GOSUB 7500
3610 N4=0
3620 GOSUB 5060
```

```
3630 T0$=T2$
3640 J=0
3650 GOSUB 5100
3655 N4=0
3660 FOR D=0 TO D9 STEP D2
3670 IF S6$="Y" THEN D1=D ELSE D1=-D
3680 N4=N4+1
3690 K1=X0+D1*SIN(30)
3700 L=1
3710 GOSUB 7200
3720 GOSUB 7500
3730 K2=Y0-D*COS(30)
3740 L=2
3750 GOSUB 7200
3760 GOSUB 7500
3770 P4(N4)=D-D9
3780 GOSUB 9150
3790 I=B(4)
3800 WAIT 1000
3810 OUTPUT 709 ;"AI9"
3820 ENTER 709 ; A2(N3,N4)
3825 A2(N3,N4)=-A2(N3,N4)
3830 A(N3,N4)=A2(N3,N4)/I*C(1)
3840 NEXT D
3850 K4=P0(4)-I4
3860 L=4 @ N9=0
3865 IF I4=60 THEN I6=22 ELSE I6=6
3870 GOSUB 7200
3880 GOSUB 7500
3890 FOR D=D9 TO 0 STEP -D2
3900 IF S6$="Y" THEN D1=D ELSE D1=-D
3910 N4=N4+1
3920 K1=X0-D1*SIN(30)
3930 L=1
3940 GOSUB 7200
3950 GOSUB 7500
3960 K2=Y0-D*COS(30)
3970 L=2
3980 GOSUB 7200
3990 GOSUB 7500
4000 P4(N4)=D9-D
4010 GOSUB 9150
4020 I=B(4)
4030 WAIT 1000
4040 OUTPUT 709 ;"AI9"
4050 ENTER 709 ; A2(N3,N4)
4055 A2(N3,N4)=-A2(N3,N4)
4060 A(N3,N4)=A2(N3,N4)/I*C(1)
4070 NEXT D
4080 GOSUB 5060
4090 T9$=T2$
4095 J=1
4100 GOSUB 5100
4110 FOR E0=1 TO 5
4120 E(N3,E0)=(E1(E0)+E2(E0))/2
4130 NEXT E0
4140 REM **RESET THETA TO ZERO
4150 L=4 @ N9=0
4160 K4=P0(4)
4165 I6=18
4170 GOSUB 7200
4180 GOSUB 7500
4190 IF C$="Y" THEN GOSUB 5000 ELSE 4210
4200 WAIT 5000
4210 GOSUB 5260
4220 IF N=0 THEN 4280
```

```
4230 DISP "SPIG TEMP TOO HIGH-COLLECTOR IN DEADBAND,SPIG MOVED TO MAX RADIUS-TES
T ABORTED"
4240 REM **STORE DATA OBTAINED UP TO NOW
4250 GOSUB 5700
4260 BEEP
4270 END
4280 DISP "IS AN INTENSITY POSITION PLOT DESIRED? (Y OR N)"
4290 INPUT P$
4300 IF P$="N" THEN 4420
4310 DISP "PRESS CONTINUE TO CLEAR PLOT FROM SCREEN"
4315 WAIT 5000
4320 GOSUB 6300
4330 PAUSE
4340 GCLEAR
4350 ALPHA
4360 DISP "ARE NEW MEASUREMENTS DESIRED FOR  THIS SIZE TRIANGLE? (Y OR N)"
4370 INPUT R$
4380 CLEAR
4390 IF R$="N" THEN 4420
4400 J=0 @ N9=0
4410 GOTO 3570
4420 T0(N3)=VAL(T0$)
4430 T9(N3)=VAL(T9$)
4440 NEXT L8
4450 GOSUB 5700
4460 NEXT Y2
4470 REM **RETURN SPIG TO ZERO POSITION
4480 L=3 @ K3=0
4490 GOSUB 7200
4500 GOSUB 7500
4510 L=4 @ K4=P1(4)
4515 I6=18 @ N9=0
4520 GOSUB 7200
4530 GOSUB 7500
4540 L=1 @ K1=P0(1)
4550 GOSUB 7200
4560 GOSUB 7500
4570 L=2 @ K2=P0(2)
4580 GOSUB 7200
4590 GOSUB 7500
4600 DISP "ARE NEW MEASUREMENTS DESIRED AT NEW AXIAL POSITION? (Y OR N)"
4610 INPUT A$
4615 CLEAR
4620 IF A$="N" THEN 4660
4630 GOSUB 9750 ! ZERO ARRAYS FOR NEXT SERIES
4640 M9=M9+1
4641 M8=M8+1
4642 IF M8<5 THEN 4650
4643 DISP "DATA AT 5 AXIAL POSITIONS ARE STORED ON ONE DISC. INSERT NEW DISC IN
DRIVE 0."
4644 DISP "WHEN NEW DISC IS INSERTED IN DRIVE0 PRESS CONTINUE"
4645 BEEP
4646 PAUSE
4647 M8=0
4648 CLEAR
4650 IF C$="Y" THEN 510 ELSE 640
4660 END
5000 REM **INITIATE AUTOMATIC TRACKING
5010 OUTPUT 709 ;"DC4,8D04,9"
5020 RETURN
5030 REM **PLACE TRACKER IN DEADBAND
5040 OUTPUT 709 ;"D04,8DC4,9"
5050 RETURN
5060 REM **READ TIME
5070 OUTPUT 709 ;"TD"
5080 ENTER 709 ; T2$
```

```
5081 T3$=T2$[1,2]
5082 T4$=T2$[4,5]
5083 T5$=T2$[7,8]
5084 T6$=T2$[10,11]
5085 T7$=T2$[13,14]
5086 T2$=T3$&T4$&T5$&T6$&T7$
5090 RETURN
5100 REM **READ ENVIRONMENTAL DATA
5110 GOSUB 9000 ! READ AMBIENT TEMP
5120 GOSUB 9050 ! READ WIND SPEED
5130 GOSUB 9100 ! READ WIND DIRECTION
5140 GOSUB 9150 ! READ PYRHELIOMETER DATA
5150 GOSUB 9210 ! READ PYRANOMETER DATA
5160 FOR E0=1 TO 5
5170 IF J=1 THEN 5200
5180 E1(E0)=B(E0)
5190 GOTO 5210
5200 E2(E0)=B(E0)
5210 NEXT E0
5220 RETURN
5260 REM **MONITOR CALORIMETER TEMP
5270 N=0
5280 OUTPUT 709 ;"AC8,18 VT1"
5290 ENTER 709 ; T1
5300 T2=FNC4(T1)
5310 IF T2>40 THEN 5370
5320 DISP "CALORIMETER TEMP IS_",T2,"_DEG-F"
5330 BEEP
5340 DISP "DO YU WISH TO CONTINUE THE TEST? (Y OR N)"
5350 INPUT S7$
5360 IF S7$="Y" THEN 5470
5370 IF T2<370 THEN 5470
5380 DISP "CALORIMETER TEMP IS TOO HIGH -INCREASE FLOW RATE"
5390 DISP "TEMPERATURE IS_",T2,"_DEG-F"
5400 BEEP
5410 GOSUB 5030
5420 L=3
5430 K3=P0(3)+90
5440 GOSUB 7200
5450 GOSUB 7500
5460 N=1
5470 RETURN
5500 REM **PRINT NORMALIZED INTENSITY AND POSITION
5510 PRINT USING "#,12X"
5520 FOR J1=1 TO 5
5530 PRINT USING 5540 ; X(J1)
5540 IMAGE #,SDD.DD,5X
5550 NEXT J1
5560 PRINT
5570 PRINT USING "2/"
5580 FOR J2=1 TO 5
5590 PRINT USING 5600 ; Y(J2)
5600 IMAGE #,2X,SDD.DD,4X
5610 FOR J1=1 TO 5
5620 PRINT USING 5630 ; A5(J1,J2)
5630 IMAGE #,MDDD.DD,4X
5640 NEXT J1
5650 PRINT
5660 PRINT USING "2/"
5670 NEXT J2
5680 RETURN
5700 REM **STORE DATA ON DISC 0
5710 M1$="COLLECTOR IS_"&F2$
5720 M2$="SPIG AXIAL POSITION IS_"&VAL$(Z)
5730 M3$="PROGRAM ABORTED DUE TO EXCESS TEMP"
5740 ON M GOTO 5750,5850,5950,6090
```

```
5750 F$=F1$&H$&VAL$(M)
5760 M9$="THIS FILE STORES THE X-Y GRID POSITIONS"
5765 M8$="THE AVERAGE NORMALIZEDINTENSITY AT EACH POSITION AND THE ZERO POSITION
"
5766 M$=M9$&M8$
5770 CREATE F$,1,1000
5780 ASSIGN# 1 TO F$
5790 IF N=0 THEN 5820
5800 PRINT# 1 ; N,M$,M1$,M2$,M3$,X(),Y(),A5(,),P0(),P1()
5810 GOTO 5830
5820 PRINT# 1 ; N,M$,M1$,M2$,X(),Y(),A5(,),P0(),P1()
5830 ASSIGN# 1 TO *
5840 RETURN
5850 F$=F1$&H$&VAL$(M)
5860 M$="THIS FILE STORES THE INTENSITY PROFILE FOR A CYLINDER AND ENVIRONMENTAL
 DATA"
5870 CREATE F$,1,7500
5880 ASSIGN# 1 TO F$
5890 IF N=0 THEN 5920
5900 PRINT# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),R(),A(,),A2(,)
5910 GOTO 5930
5920 PRINT# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),R(),A(,),A2(,)
5930 ASSIGN# 1 TO *
5940 RETURN
5950 F$=F1$&H$&VAL$(M)&VAL$(N2)
5960 ON N2 GOTO 5970,5980,5990
5970 Y1=-5 @ GOTO 6000
5980 Y1=0 @ GOTO 6000
5990 Y1=5
6000 M8$="THIS FILE STORES THE INTENSITY PROFILE FOR A D-SHAPED RTS LOCATED_"
6005 M9$=VAL$(Y1)&" MM RELATIVE TO AXIS"
6006 M$=M8$&M9$
6010 CREATE F$,1,7500
6020 ASSIGN# 1 TO F$
6030 IF N=0 THEN 6060
6040 PRINT# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),Y(N2),R(),A(,),A2(,)
6050 GOTO 6070
6060 PRINT# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),Y(N2),R(),A(,),A2(,)
6070 ASSIGN# 1 TO *
6080 RETURN
6090 F$=F1$&H$&VAL$(M)&VAL$(N2)
6100 ON N2 GOTO 6110,6120,6130
6110 Y1=-5 @ GOTO 6150
6120 Y1=0 @ GOTO 6150
6130 Y1=5
6140 M8$="THIS FILE STORES THE INTENSITY PROFILE FOR A TRIANGULAR RTS LOCATED "
6141 M9$=VAL$(Y1)&" MM RELATIVE TO AXIS"
6142 M$=M8$&M9$
6150 CREATE F$,1,7500
6160 ASSIGN# 1 TO F$
6170 IF N=0 THEN 6200
6180 PRINT# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),Y(N2),R(),A(,),A2(,),P4()
6190 GOTO 6210
6200 PRINT# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),Y(N2),R(),A(,),A2(,),P4()
6210 ASSIGN# 1 TO *
6220 RETURN
6300 REM **PRODUCE I VS. THETA PLOT ON DISPLAY
6310 GCLEAR
6320 ON M GOTO 6330,6330,6390,6460
6330 Z1=-240 @ Z2=180
6340 X1=20 @ X2=-180
6350 X3=180
6360 R3=R(N3)
6370 W$="RADIUS= "&VAL$(R3)
6380 GOTO 6520
6390 Z1=-130 @ Z2=90
```

```
6400 X1=30 @ X2=-90
6410 X3=90
6420 R3=R(N3) @ Y3=Y(N2)
6430 W$="RADIUS= "&VAL$(R3)
6440 W1$="CENTER= "&VAL$(Y3)
6450 GOTO 6520
6460 Z1=-(D9+2*D9/6) @ Z2=D9
6470 X1=D9/2 @ X2=-D9
6480 X3=D9
6490 R3=R(N3) @ Y3=Y(N2)
6500 W$="LEG= "&VAL$(R3)
6510 W1$="CENTER= "&VAL$(Y3)
6520 SCALE Z1,Z2,-30,200
6530 XAXIS 0,X1,X2,X3
6540 YAXIS X2,20,0,200
6550 LDIR 0
6555 IF M=4 THEN 6566
6560 FOR X=X2 TO X3 STEP 3*X1
6565 GOTO 6570
6566 FOR X=X2 TO X3 STEP X1
6570 MOVE X,-20
6580 LABEL VAL$(X)
6590 NEXT X
6600 MOVE X2,-30
6610 IF M=4 THEN 6640
6620 LABEL "AZIMUTHAL POSITION"
6630 GOTO 6650
6640 LABEL "POSITION ON TRIANGLE"
6650 FOR Y=0 TO 200 STEP 20
6660 MOVE X2-.2*X3,Y-5
6670 LABEL VAL$(Y)
6680 NEXT Y
6690 LDIR 90
6700 MOVE X2-.22*X3,20
6710 LABEL "INTENSITY RATIO"
6720 LDIR 0
6730 MOVE X2+Z2/2,10
6740 LABEL W$
6750 IF M=2 THEN 6780
6760 MOVE X2+Z2/2,20
6770 LABEL W1$
6780 ON M GOTO 6790,6790,6850,6910
6790 MOVE X2+10,A(N3,1)
6800 FOR J2=1 TO N4
6810 J3=(J2-1)*10
6820 DRAW X2+10+J3,A(N3,J2)
6830 NEXT J2
6840 RETURN
6850 MOVE X2,A(N3,1)
6860 FOR J2=1 TO N4
6870 J3=(J2-1)*10
6880 DRAW X2+J3,A(N3,J2)
6890 NEXT J2
6900 RETURN
6910 MOVE X2,A(N3,1)
6920 FOR J2=1 TO N4
6930 DRAW P4(J2),A(N3,J2)
6940 NEXT J2
6950 RETURN
7000 REM ** DETERMINE POSITION OF TRANSLATORS
7010 DISP "THE ZERO POSITIONS ARE"
7020 FOR L=1 TO 4
7030 GOSUB 7200
7040 OUTPUT 709 ;"AC";L2;",";L4;"VT1"
7050 ENTER 709 ; V1
7060 OUTPUT 709 ;"AC";L3;",";L5;"VT1"
```

```
7070 ENTER 709 ; V2
7071 ON L GOTO 7072,7072,7080,7082
7072 P0(L)=-(M2(L)*V1/V2-H(L)-M1(L))
7073 GOTO 7090
7080 P0(L)=M2(L)*V1/V2-H(L)-M1(L)
7081 GOTO 7090
7082 P0(L)=M2(L)*(1-V1/V2)+H(L)-M1(L)
7090 DISP USING 7100 ; L,P0(L)
7100 IMAGE 2D,4X,3D.3D
7110 IF M9=1 THEN P1(L)=P0(L)
7120 NEXT L
7130 RETURN
7200 REM **DEFINE CHANNELS
7210 L1=L-1
7220 L2=L1*2
7230 L3=L2+1
7240 L4=L2+10
7250 L5=L2+11
7260 RETURN
7300 REM **INCREASE FAST
7310 OUTPUT 709 ;"DO4,";L2;"DC4,";L3
7320 RETURN
7330 REM **DECREASE FAST
7340 OUTPUT 709 ;"DO4,";L3;"DC4,";L2
7350 RETURN
7360 REM **INCREASE SLOW
7370 OUTPUT 709 ;"DO4,";L2;"DC4,";L3 @ OUTPUT 709 ;"DO4,";L3
7380 RETURN
7390 REM **DECREASE SLOW
7400 OUTPUT 709 ;"DO4,";L3;"DC4,";L2 @ OUTPUT 709 ;"DO4,";L2
7410 RETURN
7500 REM **MOVE TRANSLATORS
7510 ON L GOTO 7520,7540,7560,7580
7520 K=K1
7530 GOTO 7590
7540 K=K2
7550 GOTO 7590
7560 K=K3
7570 GOTO 7590
7580 K=K4
7590 OUTPUT 709 ;"AC";L2;",";L4;"VT1"
7600 ENTER 709 ; V1
7610 OUTPUT 709 ;"AC";L3;",";L5;"VT1"
7620 ENTER 709 ; V2
7621 K9=2 @ E9=.04
7622 ON L GOTO 7633,7623,7633,7730
7623 P=-(M2(L)*V1/V2-H(L)-M1(L))
7624 IF P<K-K9 THEN GOSUB 7330 ELSE 7626 ! INCREASE FAST
7625 GOTO 7590
7626 IF P>K+K9 THEN GOSUB 7300 ELSE 7628 ! DECREASE FAST
7627 GOTO 7590
7628 IF P<K-E9 THEN GOSUB 7390 ELSE 7630 ! INCREASE SLOW
7629 GOTO 7590
7630 IF P>K+E9 THEN GOSUB 7360 ELSE 7632 ! DECREASE SLOW
7631 GOTO 7590
7632 RETURN
7633 P=M2(L)*V1/V2-H(L)-M1(L)
7634 IF L=1 THEN P=-P
7640 IF P<K-K9 THEN GOSUB 7300 ELSE 7660 ! INCREASE FAST
7650 GOTO 7590
7660 IF P>K+K9 THEN GOSUB 7330 ELSE 7680 ! DECREASE FAST
7670 GOTO 7590
7680 IF P<K-E9 THEN GOSUB 7360 ELSE 7700 ! INCREASE SLOW
7690 GOTO 7590
7700 IF P>K+E9 THEN GOSUB 7390 ELSE 7720 ! DECREASE SLOW
7710 GOTO 7590
```

```
7720 RETURN
7730 P=M2(L)*(1-V1/V2)+H(L)-180
7740 K9=10 @ E9=.5
7750 IF N9=4 THEN GOTO 7810
7760 IF P<K-K9 THEN GOSUB 7330 ELSE 7780 ! CW FAST
7770 GOTO 7590
7780 IF P>K+K9 THEN GOSUB 7300 ELSE 7800 ! CCW FAST
7790 GOTO 7590
7800 N9=4
7810 IF P<K-E9 THEN GOSUB 7390 ELSE 7830 ! CW SLOW
7820 GOTO 7590
7830 IF P>K+E9 THEN GOSUB 7360 ELSE 7850 ! CCW SLOW
7840 GOTO 7590
7850 RETURN
8000 REM **DEFINE TRANSFER FUNCTIONS
8010 ! X-TRANSLATOR (NO.1)
8020 H(1)=.6 ! OFFSET
8030 M2(1)=50 ! TOTAL RANGE
8040 M1(1)=25 ! ZERO POINT
8050 ! Y-TRANSLATOR (NO. 2)
8060 H(2)=1.1 ! OFFSET
8070 M2(2)=50 ! TOTAL RANGE
8080 M1(2)=25 ! ZERO POINT
8090 ! RADIAL TRANSLATOR
8100 H(3)=-.2 ! OFFSET
8110 M2(3)=100 ! TOTAL RANGE
8120 M1(3)=5 ! ZERO POINT
8130 ! ROTATOR
8140 H(4)=7.6
8150 M2(4)=360 ! TOTAL RANGE
8160 M1(4)=180 ! ZERO POINT
8170 ! TEMPERATURE PROBE
8180 C1=2.5805 ! SLOPE IN DEG-C/OHM
8190 C2=-258 ! INTERCEPT IN DEG-C
8200 ! CALORIMETER
8210 C(1)=1.17*11350*2 ! WATTS/M**2/VOLT
8220 ! AMBIENT TEMPERATURE
8230 C(2)=-2.5805 ! SLOPE IN DEG-C/OHM
8240 C(3)=-258 ! INTERCEPT IN DEG-C
8250 ! WIND SPEED
8260 C(4)=21 ! MPH/VOLT
8270 ! WIND DIRECTION
8280 C(5)=360/2.335 ! RADIANS/VOLT
8290 ! PYRHELIOMETER
8300 C(6)=110619.5 ! WATTS/M**2/VOLT
8310 ! PYRANOMETER
8320 C(7)=99206.35 ! WATTS/M**2/VOLT
8330 DEF FNC4(W9) = (C1*W9/I5+C2)*1.8+32
8350 RETURN
9000 REM **AMBIENT TEMPERATURE MEASUREMENT
9010 OUTPUT 709 ;"AC20,30 VT1"
9020 ENTER 709 ; B(1)
9030 B(1)=C(2)*B(1)/I5+C(3) ! DEGREES CENTIGRADE
9040 RETURN
9050 REM **WIND SPEED MEASUREMENTS
9060 OUTPUT 709 ;"AI21"
9070 ENTER 709 ; B(2)
9080 B(2)=B(2)*C(4) ! MILES/HOUR
9090 RETURN
9100 REM **WIND DIRECTION MEASUREMENT
9110 OUTPUT 709 ;"AI22"
9120 ENTER 709 ; B(3)
9130 B(3)=B(3)*C(5) ! DEGREES CW FROM NORTH
9140 RETURN
9150 REM ** PRYHELIOMETER MEASUREMENT
9160 OUTPUT 709 ;"AI23"
```

```
9170 ENTER 709 ; B(4)
9180 GOSUB 9300
9190 B(4)=B(4)*W6*C(6) ! WATTS/M**2
9200 RETURN
9210 REM **PYRANOMETER MEASUREMENT
9220 OUTPUT 709 ;"AI24"
9230 ENTER 709 ; B(5)
9240 GOSUB 9520
9250 B(5)=B(5)*W3*C(7) ! WATTS/M**2
9260 RETURN
9300 REM **PYRHELIOMETER TEMP CORRECTION
9310 GOSUB 9000 ! READ AMBIENT TEMP
9320 IF B(1)<-20 THEN 9350
9330 IF B(1)>50 THEN 9350
9340 GOTO 9410
9350 DISP "AMBIENT TEMP OUT OF RANGE FOR"
9360 DISP "PYRHELIOMETER TEMP CORRECTION"
9370 DISP "SUBROUTINE"
9380 DISP
9390 DISP "THE PROGRAM IS TERMINATED"
9400 END
9410 RESTORE 9450
9420 FOR W=1 TO 6
9430 READ W4(W),W5(W)
9440 NEXT W
9450 DATA -20,.993,-5,.999,10,1.003,25,1.004,40,.997,50,.997
9460 W=1
9470 IF B(1)<W4(W) THEN 9500
9480 W=W+1
9490 GOTO 9470
9500 W6=W5(W)+(B(1)-W4(W-1))/(W4(W)-W4(W-1))*(W5(W)-W5(W-1))
9510 RETURN
9520 REM **PYRANOMETER TEMP CORRECTION
9530 GOSUB 9000 ! READ AMBIENT TEMP
9540 IF B(1)<-20 THEN 9570
9550 IF B(1)>50 THEN 9570
9560 GOTO 9630
9570 DISP "AMBIENT TEMP OUT OF RANGE FOR"
9580 DISP "PYRANOMETER TEMP CORRECTION"
9590 DISP "SUBROUTINE"
9600 DISP
9610 DISP "THE PROGRAM IS TERMINATED"
9620 END
9630 RESTORE 9670
9640 FOR W=1 TO 6
9650 READ W1(W),W2(W)
9660 NEXT W
9670 DATA -20,.998,-5,1.002,10,1.004,20,1.003,40,.995,50,.995
9680 W=1
9690 IF B(1)<W1(W) THEN 9720
9700 W=W+1
9710 GOTO 9690
9720 W3=W2(W)+(B(1)-W1(W-1))/(W1(W)-W1(W-1))*(W2(W)-W2(W-1))
9730 RETURN
9750 REM **ZERO ARRAYS FOR NEXT SERIES OF MEASUREMENTS
9760 FOR O2=1 TO 9
9770 R(O2)=0
9780 T0(O2)=0
9790 T9(O2)=0
9800 FOR O3=1 TO 35
9810 A(O2,O3)=0
9820 A2(O2,O3)=0
9830 NEXT O3
9840 FOR O3=1 TO 5
9850 E(O2,O3)=0
9860 NEXT O3
```

2. Program "AVGPRO"

```
10 OPTION BASE 1
20 MASS STORAGE IS ":D700"
30 DIM M$[112],M1$[28],M2$[28],M3$[28],A(11,35),A2(11,35)
40 DIM R(11),E(11,5),T0(11),T9(11)
50 DIM C(7),A3(11,35),P3(20),C1(11),D1(11),D2(11),D3(11),T1(11),T2(11),T3(11),P4
(20)
60 DISP "THIS PROGRAM CALCULATES THE AVERAGE INTENSITY PROFILE FOR A COLLECTOR"
65 DISP "AND STORES THE AVERAGE"
70 DISP "PROFILES ON A DISC IN DRIVE 1."
80 DISP
90 DISP "THE INPUT REQUIRED IS:"
100 DISP "A. THE NUMBER OF DISCS TO BE USED IN THE AVERAGING PROCESS"
110 DISP "B. THE JULIAN DATE ON WHICH DATA WAS TAKEN"
111 DISP "C. THE NUMBER OF AXIAL POSITIONS TO BE AVERAGED"
112 DISP "DO YOU WANT A CATALOG LISTING OF DATA FILES? (Y OR N)"
120 INPUT C$
130 CLEAR
140 IF C$="N" THEN 440
150 DISP "INPUT NUMBER OF DISCS TO BE LISTED"
160 INPUT D9
170 CLEAR
180 DISP "WHEN DISC IS INSERTED IN DRIVE 0, PRESS CONTINUE"
185 PAUSE
190 PRINTER IS 703,80
200 FOR D=1 TO D9
210 CRT IS 703,80
220 PRINT "DISC #_",D
230 PRINT
240 CAT
250 PRINT
260 CRT IS 1
270 IF D=D9 THEN 320
280 DISP "INSERT NEW DISC INTO DRIVE 0 AND PRESS CONTINUE"
290 BEEP
300 PAUSE
310 CLEAR
320 NEXT D
330 OUTPUT 703 ;CHR$(12)
340 PRINT "THE FILE NAME HAS THE FORMAT XXX-ZZ-MN"
350 PRINT "XXX=JULIAN DATE"
360 PRINT "ZZ=AXIAL POSITION NUMBER"
370 PRINT "M=1: INTENSITY ON 5X5 GRID"
380 PRINT "M=2: CYLINDRICAL RTS"
390 PRINT "M=3: D-SHAPED RTS"
400 PRINT "M=4: TRIANGLE"
410 PRINT "N=1: 5MM BELOW AXIS"
420 PRINT "N=2: ON AXIS"
430 PRINT "N=3: 5MM ABOVE AXIS"
440 OUTPUT 703 ;CHR$(12)
450 DISP "INPUT NUMBER OF DISCS TO BE USED"
460 INPUT D9
470 DISP "INPUT NUMBER OF AXIAL POSITIONS TO BE AVERAGED"
480 INPUT Z9
490 DISP "INPUT NUMBER OF DAYS ON WHICH DATA TO BE AVERAGED WAS TAKEN"
500 INPUT J9
510 CLEAR
520 DISP "INSERT DISCS IN DRIVE0 IN THE SAME SEQUENCE AS DATA WAS TAKEN"
530 DISP "(THAT IS POSITION NUMBERS MUST BE IN ASCENDING SEQUENCE)"
540 DISP
550 DISP "WHEN DISCS ARE INSERTED IN DRIVES 0 AND 1, PRESS CONTINUE"
560 BEEP
```

```
570 PAUSE
580 CLEAR
590 DISP "INPUT A ONE DIGIT NUMBER TO IDENTIFY THE SERIES"
600 DISP "OF MEASUREMENTS WHICH MAKE UP THIS AVERAGE"
620 DISP "INTENSITY"
630 INPUT T
640 CLEAR
650 DISP "INPUT A 4 CHARACTER IDENTIFIER FOR THE COLLECTOR"
660 INPUT C1$
670 CLEAR
680 DISP "INPUT FIRST JULIAN DATE ON WHICH DATA WAS TAKEN"
690 INPUT J$
700 J=1
710 FOR I=1 TO 11
720 C1(I)=0 @ P3(I)=0
730 D1(I)=0 @ D2(I)=0 @ D3(I)=0
740 T1(I)=0 @ T2(I)=0 @ T3(I)=0
750 FOR K1=1 TO 35
760 A3(K,K1)=0
770 NEXT K1
780 NEXT I
790 FOR D=1 TO D9
800 Z1=D*5-4
810 IF Z9<D*5 THEN Z2=Z9 ELSE Z2=D*5
820 Z3=0
830 FOR Z=Z1 TO Z2
840 IF Z<10 THEN Z$="0"&VAL$(Z) ELSE Z$=VAL$(Z)
850 Z3=Z3+1
860 FOR M=2 TO 4
870 IF M=2 THEN 940
880 FOR M1=1 TO 3
890 F$=J$&"-"&Z$&"-"&VAL$(M)&VAL$(M1)
900 GOSUB 1500
910 GOSUB 2500
920 NEXT M1
930 GOTO 970
940 F$=J$&"-"&Z$&"-"&VAL$(M)
950 GOSUB 1500
960 GOSUB 2500
970 NEXT M
980 NEXT Z
990 IF D=D9 THEN 1050
1000 DISP Z3,"_POSITIONS HAVE BEEN READ FROM THIS DISC"
1010 DISP "INSERT NEW DISC INTO DRIVE 0 AND PRESS CONTINUE"
1020 BEEP
1030 PAUSE
1040 CLEAR
1050 NEXT D
1070 DISP Z3,"_POSITIONS HAVE BEEN READ OFF THE LAST DISC"
1080 MASS STORAGE IS ":D701"
1090 FOR M9=1 TO 3
1100 IF M9=1 THEN GOSUB 3100
1110 IF M9=1 THEN 1150
1120 FOR M1=1 TO 3
1130 GOSUB 3200
1140 NEXT M1
1150 NEXT M9
1160 MASS STORAGE IS ":D700"
1170 END
1500 REM **SUBROUTINE TO READ DATA FROM FILE
1505 FOR K=1 TO 11
1510 R(K)=0
1520 FOR K1=1 TO 35
1530 A2(K,K1)=0
1540 NEXT K1
1550 FOR E0=1 TO 5
```

```
1551 E(K,E0)=0
1552 NEXT E0
1553 NEXT K
1554 FOR K1=1 TO 20
1555 P4(K1)=0
1556 NEXT K1
1560 ASSIGN# 1 TO F$
1570 ON ERROR GOTO 2060
1580 OFF ERROR
1590 READ# 1 ; N
1600 ASSIGN# 1 TO *
1610 M9=M-1
1620 ON M9 GOTO 1630,1740,1900
1630 IF N=0 THEN 1710
1635 ASSIGN# 1 TO F$
1640 READ# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),R(),A(,),A2(,)
1650 ASSIGN# 1 TO *
1660 FOR I=1 TO 11
1670 R1=R(I)
1680 IF R1=0 THEN C1(I)=C1(I)+1
1690 NEXT I
1700 GOTO 1730
1710 ASSIGN# 1 TO F$
1715 READ# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),R(),A(,),A2(,)
1720 ASSIGN# 1 TO *
1730 RETURN
1740 IF N=0 THEN 1870
1745 ASSIGN# 1 TO F$
1750 READ# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),Y1,R(),A(,),A2(,)
1760 ASSIGN# 1 TO *
1770 FOR I=1 TO 11
1780 R1=R(I)
1790 ON M1 GOTO 1800,1820,1840
1800 IF R1=0 THEN D1(I)=D1(I)+1
1810 GOTO 1850
1820 IF R1=0 THEN D2(I)=D2(I)+1
1830 GOTO 1850
1840 IF R1=0 THEN D3(I)=D3(I)+1
1850 NEXT I
1860 GOTO 1890
1870 ASSIGN# 1 TO F$
1875 READ# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),Y1,R(),A(,),A2(,)
1880 ASSIGN# 1 TO *
1890 RETURN
1900 IF N=0 THEN 2030
1905 ASSIGN# 1 TO F$
1910 READ# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),Y1,R(),A(,),A2(,),P4()
1920 ASSIGN# 1 TO *
1930 FOR I=1 TO 11
1940 R1=R(I)
1950 ON M1 GOTO 1960,1980,2000
1960 IF R1=0 THEN T1(I)=T1(I)+1
1970 GOTO 2010
1980 IF R1=0 THEN T2(I)=T2(I)+1
1990 GOTO 2010
2000 IF R1=0 THEN T3(I)=T3(I)+1
2010 NEXT I
2020 GOTO 2050
2030 ASSIGN# 1 TO F$
2035 READ# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),Y1,R(),A(,),A2(,),P4()
2040 ASSIGN# 1 TO *
2050 RETURN
2060 OFF ERROR
2070 IF ERRN=67 THEN 2110
2080 DISP "ERRN=_";ERRN
2090 DISP "ERRL=_";ERRL
```

```
2100 PAUSE
2110 DISP "THE PROGRAM IS TRYING TO FIND FILE_"&F$
2120 IF D=D9 THEN 2250
2130 DISP
2140 DISP "THE NUMBER OF DISCS USED IS LESS THAN_";D9
2150 DISP "THE NUMBER OF AXIAL POSITIONS READ FROM THIS DISC IS LESS THAN 5"
2160 DISP
2170 DISP "INPUT NEW JULIAN DATE"
2180 INPUT J$
2190 IF M=2 THEN 2220
2200 F$=J$&"-"&Z$&"-"&VAL$(M)&VAL$(M1)
2210 GOTO 2230
2220 F$=J$&"-"&Z$&"-"&VAL$(M)
2230 CLEAR
2240 GOTO 1560
2250 DISP "THIS IS THE LAST DISC"
2260 DISP "LESS THAN_",Z9,"_POSITIONS HAVE BEEN FOUND"
2270 DISP
2280 DISP "INPUT NEW JULIAN DATE"
2290 INPUT J$
2300 IF M=2 THEN 2330
2310 F$=J$&"-"&Z$&"-"&VAL$(M)&VAL$(M1)
2320 GOTO 2340
2330 F$=J$&"-"&Z$&"-"&VAL$(M)
2340 CLEAR
2350 GOTO 1560
2500 REM **SUBROUTINE TO SUM AND STORE SUMMED INTENSITIES
2510 MASS STORAGE IS ":D701"
2520 IF Z>1 THEN 2710
2530 T$=VAL$(T)&"-"&C1$
2540 F1$="CYL-"&T$
2550 F2$="D1-"&T$
2560 F3$="D2-"&T$
2570 F4$="D3-"&T$
2580 F5$="T1-"&T$
2590 F6$="T2-"&T$
2600 F7$="T3-"&T$
2610 FOR I=1 TO 7
2620 A$="F"&VAL$(I)&"$"
2630 CREATE A$,1,3500
2640 ASSIGN# 1 TO A$
2650 IF M9=3 THEN 2680
2660 PRINT# 1 ; A3(,)
2670 GOTO 2690
2680 PRINT# 1 ; A3(,),P3()
2690 ASSIGN# 1 TO *
2700 NEXT I
2710 ON M9 GOTO 2720,2740,2810
2720 A$=F1$
2730 GOTO 2870
2740 ON M1 GOTO 2750,2770,2790
2750 A$=F2$
2760 GOTO 2870
2770 A$=F3$
2780 GOTO 2870
2790 A$=F4$
2800 GOTO 2870
2810 ON M1 GOTO 2820,2840,2860
2820 A$=F5$
2830 GOTO 2870
2840 A$=F6$
2850 GOTO 2870
2860 A$=F7$
2870 ASSIGN# 1 TO A$
2880 IF M9=3 THEN 2910
2890 READ# 1 ; A3(,)
```

```
2900 GOTO 2920
2910 READ# 1 ; A3(,),P3()
2920 ASSIGN# 1 TO *
2930 ON M9 GOTO 2940,2960,2980
2940 K8=11 @ K9=35
2950 GOTO 2990
2960 K8=11 @ K9=19
2970 GOTO 2990
2980 K8=4 @ K9=20
2990 FOR K=1 TO K8
3000 FOR K1=1 TO K9
3010 A3(K,K1)=A3(K,K1)+A(K,K1)*E(K,4)
3020 IF M9<3 THEN 3040
3030 P3(K1)=P3(K1)+P4(K1)
3040 NEXT K1
3050 NEXT K
3060 PURGE A$ @ PACK
3070 CREATE A$,1,3500
3080 ASSIGN# 1 TO A$
3090 IF M9=3 THEN 3120
3100 PRINT# 1 ; A3(,)
3110 GOTO 3130
3120 PRINT# 1 ; A3(,),P3()
3130 ASSIGN# 1 TO *
3140 MASS STORAGE IS ":D700"
3150 RETURN
3200 REM **IDENTIFY FILES FOR AVERAGED INTENSITIES
3210 ON M9 GOTO 3220,3260,3390
3220 A$=F1$
3230 GOSUB 3600
3240 PRINT "AVERAGE INTENSITY FOR CYLINDER STORED IN FILE-",F1$
3250 RETURN
3260 ON M1 GOTO 3270,3310,3350
3270 A$=F2$
3280 GOSUB 3600
3290 PRINT "AVERAGE INTENSITY FOR D-SHAPED RTS AT -5MM OFF AXIS STORED IN FILE_"
,F2$
3300 RETURN
3310 A$=F3$
3320 GOSUB 3600
3330 PRINT "AVERAGE INTENSITY FOR D-SHAPED RTS ON AXIS STORED IN FILE_",F3$
3340 RETURN
3350 A$=F4$
3360 GOSUB 3600
3370 PRINT "AVERAGE INTENSITY FOR D-SHAPED RTS AT +5MM OFF AXIS STORED IN FILE_"
,F4$
3380 RETURN
3390 ON M1 GOTO 3400,3440,3480
3400 A$=F5$
3410 GOSUB 3600
3420 PRINT "AVERAGE INTENSITY FOR TRIANGLE AT -5MM OFF AXIS STORED IN FILE_",F5$

3430 RETURN
3440 A$=F6$
3450 GOSUB 3600
3460 PRINT "AVERAGE INTENSITY FOR TRIANGLE ON AXIS STORED IN FILE_",F6$
3470 RETURN
3480 A$=F6$
3490 GOSUB 3600
3500 PRINT "AVERAGE INTENSITY FOR TRIANGLE AT +5MM OFF AXIS STORED IN FILE_",F7$

3510 RETURN
3600 REM ** CALCULATE AND STORE AVERAGE INTENSITIES
3610 ASSIGN# 1 TO A$
3620 IF M9=3 THEN 3650
3630 READ# 1 ; A3(,)
```

```
3640 GOTO 3660
3650 READ# 1 ; A3(,),P3()
3660 ASSIGN# 1 TO *
3670 ON M9 GOTO 3680,3710,3790
3680 K8=11 @ K9=35
3690 M$[1,112]="AVERAGE INTENSITY PROFILE FOR CYLINDER"
3700 GOTO 3860
3710 K8=11 @ K9=19
3720 ON M1 GOTO 3730,3750,3770
3730 M$[1,112]="AVERAGE INTENSITY PROFILE FOR D-SHAPED RTS AT -5MM OFF AXIS"
3740 GOTO 3860
3750 M$[1,112]="AVERAGE INTENSITY PROFILE FOR D-SHAPED RTS ON AXIS"
3760 GOTO 3860
3770 M$[1,112]="AVERAGE INTENSITY PROFILE FOR D-SHAPED RTS AT +5MM OFF AXIS"
3780 GOTO 3860
3790 K8=4 @ K9=20
3800 ON M1 GOTO 3810,3830,3850
3810 M$[1,112]="AVERAGE INTENSITY PROFILE FOR TRIANGLE AT -5MM OFF AXIS"
3820 GOTO 3860
3830 M$[1,112]="AVERAGE INTENSITY PROFILE FOR TRIANGLE ON AXIS"
3840 GOTO 3860
3850 M$[1,112]="AVERAGE INTENSITY PROFILE FOR TRIANGLE AT +5MM OFF AXIS"
3860 FOR K1=1 TO K8
3870 FOR K1=1 TO K9
3880 ON M9 GOTO 3890,3910,3980
3890 A3(K,K1)=A3(K,K1)/(Z9-C1(K))
3900 GOTO 4050
3910 ON M1 GOTO 3920,3940,3960
3920 A3(K,K1)=A3(K,K1)/(Z9-D1(K))
3930 GOTO 4050
3940 A3(K,K1)=A3(K,K1)/(Z9-D2(K))
3950 GOTO 4050
3960 A3(K,K1)=A3(K,K1)/(Z9-D3(K))
3970 GOTO 4050
3980 ON M1 GOTO 3990,4010,4030
3990 A3(K,K1)=A3(K,K1)/(Z9-T1(K))
4000 GOTO 4050
4010 A3(K,K1)=A3(K,K1)/(Z9-T2(K))
4020 GOTO 4050
4030 A3(K,K1)=A3(K,K1)/(Z9-T3(K))
4040 P3(K1)=P3(K1)/Z9
4050 NEXT K1
4060 NEXT K
4070 PURGE A$
4080 PACK
4090 CREATE A$,1,3500
4100 ASSIGN# 1 TO A$
4110 IF M9=3 THEN 4150
4120 PRINT# 1 ; A3(,),M$,M1$
4130 GOTO 4160
4140 PRINT# 1 ; A3(,),P3(),M$,M1$
4150 ASSIGN# 1 TO *
4160 RETURN
4170 END
```

3. Program "PRPL"

```
10 OPTION BASE 1
20 MASS STORAGE IS ":D700"
30 DIM M$[112],M1$[28],M2$[28],M3$[28],A(11,35)
40 DIM A2(11,35),E(11,5),R(11),T0(11),T9(11),C(7)
50 DIM A5(5,5),X(5),Y(5),P0(4),P1(4),A3(11,35),R2$[37],Q1$[512],Q2$[64],Q3$[6],Q
4$[32]
51 INTEGER Q4
52 REAL Q1,Q2,Q3
55 PRINTER IS 703,80
60 DISP "THIS PROGRAM RETRIEVES AND DISPLAYS SPIG DATA"
70 DISP "STORED ON DISC IN DRIVE0. SINCE DATA FOR ONLY"
80 DISP "5 AXIAL POSITIONS WILL FIT ON A SINGLE DISC, SEVERAL"
90 DISP "DISCS MAY BE REQUIRED TO OBTAIN ALL THE DATA"
100 DISP "FOR A GIVEN COLLECTOR"
110 DISP
120 DISP "DO YOU WANT A CATALOG LISTING OF FILES STORED ON DISC?(Y OR N)"
130 INPUT C$
140 CLEAR
150 IF C$="N" THEN 490
160 DISP "INPUT NUMBER OF DISCS TO BE LISTED"
170 INPUT D9
180 CLEAR
190 DISP "WHEN DISC IS INSERTED IN DRIVE0 PRESS CONTINUE"
200 BEEP
210 PAUSE
220 CLEAR
230 PRINTER IS 703,80
240 FOR D=1 TO D9
250 CRT IS 703,80
260 PRINT "DISC #_",D
270 PRINT
280 CAT
290 PRINT
300 CRT IS 1
310 IF D=D9 THEN 360
320 DISP "INSERT NEW DISC INTO DRIVE 0 AND PRESS CONTINUE"
330 BEEP
340 PAUSE
350 CLEAR
360 NEXT D
370 OUTPUT 703 ;CHR$(12)
380 PRINT "THE FILE NAME HAS THE FORMAT XXX-ZZ-MN"
390 PRINT "XXX=JULIAN DATE"
400 PRINT "ZZ=AXIAL POSITION NUMBER"
410 PRINT "M=1: INTENSITY ON 5X5 GRID"
420 PRINT "M=2: CYLINDRICAL RTS"
430 PRINT "M=3: D-SHAPED RTS"
440 PRINT "M=4: TRIANGULAR RTS"
450 PRINT "N=1:5MM BELOW AXIS"
460 PRINT "N=2: ON AXIS"
470 PRINT "N=3: 5MM ABOVE AXIS"
471 PRINT
472 PRINT "FILES CONTAINING AVERAGED INTENSITIES HAVE NAMES WITH THE FORMAT A-X-
BBBB"
473 PRINT "A=CYL: CYLINDRICAL PROFILE"
```

```
474 PRINT "A=D1: D-SHAPED PROFILE AT -5MM OFF AXIS"
475 PRINT " A=D2: D-SHAPED PROFILE ON AXIS"
476 PRINT "A=D3: D-SHAPED PROFILE AT +5MM OFF AXIS"
477 PRINT "A=T1: TRIANGULAR PROFILE AT -5MM OFF AXIS"
478 PRINT "A=T2: TRIANGULAR PROFILE ON AXIS"
479 PRINT "A=T3 TRIANGULAR PROFILE AT +5MM OFF AXIS"
480 PRINT "X=MEASUREMENT SERIES IDENTIFIER"
481 PRINT " BBBB=COLLECTOR IDENTIFIER"
482 OUTPUT 703 ;CHR$(12)
490 DISP "INPUT NUMBER (N) CORRESPONDING TO THE OPERATION"
500 DISP "OR OUTPUT DESIRED. MENU IS ON PRINTER"
510 PRINT "1. PRINT AVERAGE INTENSITY PROFILE"
520 PRINT "2. PLOT AVERAGE INTENSITY PROFILE"
530 PRINT "3. PRINT RELATIVE INTENSITY PROFILE AT AN AXIAL POSITION"
540 PRINT "4. PLOT RELATIVE INTENSITY PROFILE AT AN AXIAL POSITION"
550 PRINT "5. PRINT INTENSITY PROFILE AT AN AXIAL POSITION"
560 PRINT "6. PLOT INTENSITY PROFILE AT AN AXIAL POSITION"
570 PRINT "7. PRINT RAW INTENSITY DATA AT AN AXIAL POSITION"
580 PRINT "8. PRINT CONVERSION FACTORS"
590 PRINT "9. PRINT ENVIRONMENTAL DATA"
600 PRINT "10. PRINT AVERAGE INTENSITIES OVER 5X5 GRID"
610 PRINT "11.PRINT SPIG ANGULAR ORIENTATION VS. AXIAL POSITION"
615 PRINT "RELATIVE TO INITIAL ORIENTATION"
630 INPUT J
640 CLEAR
650 OUTPUT 703 ;CHR$(12)
660 DISP "INPUT DISIRED FILE NAME"
670 INPUT F$
680 CLEAR
690 DISP "WHEN APPROPRIATE DISC IS INSERTED IN DRIVE 0 PRESS CONTINUE"
700 BEEP
710 PAUSE
720 CLEAR
730 IF J>2 THEN 890
740 ASSIGN# 1 TO F$
750 ON ERROR GOSUB 1500
760 OFF ERROR
770 IF ERRN=67 THEN GOTO 660
780 OFF ERROR
790 N$=F$[1,1] @ N=0
800 IF N$="C" THEN M=2
810 IF N$="D" THEN M=3
820 IF N$="T" THEN M=4
830 IF M=4 THEN 860
840 READ# 1 ; A3(,),M$,M1$
850 GOTO 870
860 READ# 1 ; A3(,),P3(),M$,M1$
870 ASSIGN# 1 TO *
880 GOTO 1150
890 M=VAL(F$[8,8])
900 ASSIGN# 1 TO F$
910 ON ERROR GOSUB 1500
920 OFF ERROR
930 IF ERRN=67 THEN GOTO 660
940 OFF ERROR
950 ON M GOTO 960,1010,1060,1110
960 READ# 1 ; N
970 ASSIGN# 1 TO *
980 N1=N+1
990 GOSUB 1600
1000 GOTO 1150
1010 READ# 1 ; N
1020 ASSIGN# 1 TO *
1030 N1=N+1
1040 GOSUB 1700
1050 GOTO 1150
```

```
1060 READ# 1 ; N
1070 ASSIGN# 1 TO *
1080 N1=N+1
1090 GOSUB 1800
1100 GOTO 1150
1110 READ# 1 ; N
1120 ASSIGN# 1 TO *
1130 N1=N+1
1140 GOSUB 1900
1150 IF J>6 THEN GOTO 1180
1160 ON J GOSUB 2000,2600,2000,2600,2000,2600
1170 GOTO 1200
1180 J1=J-6
1190 ON J1 GOSUB 2000,8600,8900,9300,9600
1200 CLEAR
1210 DISP "IS ANOTHER FILE OUTPUT DESIRED?(Y OR N)"
1220 INPUT B1$
1230 IF B1$="Y" THEN GOTO 490
1240 END
1500 REM **SUBROUTINE RETURNS ERROR MESSAGE
1510 OFF ERROR
1520 DISP "ERROR NUMBER_";ERRN
1530 DISP "ON LINE_";ERRL
1540 IF ERRN=67 THEN 1570
1550 DISP "ERROR IN PROGRAM OTHER THAN WRONG FILE NAME"
1560 PAUSE
1570 DISP "CANNOT FIND SPECIFIED FILE NAME, EITHER FILE NAME WAS INCORRECT OR WR
ONG DISC"
1580 DISP "INSERTED"
1590 RETURN
1600 REM **READ FILES
1610 ASSIGN# 1 TO F$
1620 ON N1 GOTO 1630,1650
1630 READ# 1 ; N,M$,M1$,M2$,X(),Y(),A5(,),P0(),P1()
1640 GOTO 1660
1650 READ# 1 ; N,M$,M1$,M2$,M3$,X(),Y(),A5(,),P0(),P1()
1660 ASSIGN# 1 TO *
1670 RETURN
1700 REM **READ FILES
1710 ASSIGN# 1 TO F$
1720 ON N1 GOTO 1730,1750
1730 READ# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),R(),A(,),A2(,)
1740 GOTO 1760
1750 READ# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),R(),A(,),A2(,)
1760 ASSIGN# 1 TO *
1770 RETURN
1800 REM **READ FILES
1810 ASSIGN# 1 TO F$
1820 ON N1 GOTO 1830,1850
1830 READ# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),Y1,R(),A(,),A2(,)
1840 GOTO 1860
1850 READ# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),Y1,R(),A(,),A2(,)
1860 ASSIGN# 1 TO *
1870 RETURN
1900 REM **READ FILES
1910 ASSIGN# 1 TO F$
1920 ON N1 GOTO 1930,1950
1930 READ# 1 ; N,M$,M1$,M2$,C(),T0(),T9(),E(,),Y1,R(),A(,),A2(,),P4()
1940 GOTO 1960
1950 READ# 1 ; N,M$,M1$,M2$,M3$,C(),T0(),T9(),E(,),Y1,R(),A(,),A2(,),P4()
1960 ASSIGN# 1 TO *
1970 RETURN
2000 REM **PRINT INTENSITY PROFILE
2010 IF M=2 THEN K8=11 @ K9=33 @ A9=160
2020 IF M=3 THEN K8=11 @ K9=19 @ A9=90
2030 IF M=4 THEN K8=3 @ K9=20
```

```
2040 PRINTER IS 703,80
2050 PRINT M$
2060 PRINT M1$
2070 IF J>2 THEN PRINT M2$
2080 IF N=1 THEN PRINT M3$
2090 PRINT
2100 ON M GOTO 2110,2110,2110,2160
2110 R$="ELEVEN RADII"
2120 R1$="ANGLE"
2130 R2$="RADIUS IN MILLIMETERS"
2140 R3$="THETA" @ K7=6
2150 GOTO 2200
2160 R$="FOUR TRIANGLES"
2170 R1$="POSITION ON LEG"
2180 R2$="LENGTH OF TRIANGLE LEG IN MILLIMETERS"
2190 R3$="POS__" @ K7=4
2200 IF J=1 THEN J2=1
2210 IF J=3 THEN J2=2
2220 IF J=5 THEN J2=3
2230 IF J=7 THEN J2=4
2240 ON J2 GOTO 2250,2330,2420,2510
2250 PRINT "THIS PRINTS THE AVERAGE INTENSITY IN WATTS/M^2 FOR_",R$,"_AS A FUNCT
ION OF _",R1$
2260 FOR K=1 TO K8
2270 IF M=4 THEN 2300
2280 R(K)=(K-1)*5
2290 GOTO 2310
2300 R(K)=K*10
2310 NEXT K
2320 GOSUB 8200
2325 RETURN
2330 PRINT "THIS PRINTS THE RATIO OF SPIG/PYRHELIOMETER MEASUREMENTS FOR_",R$
2335 PRINT "_AS A FUNCTION OF _",R1$
2340 FOR K=1 TO K8
2350 FOR K1=1 TO K9
2360 A3(K,K1)=A(K,K1)
2370 IF M<4 THEN 2390
2380 P3(K1)=P4(K1)
2390 NEXT K1
2400 NEXT K
2410 GOSUB 8200
2415 RETURN
2420 PRINT "THIS PRINTS THE INTENSITY IN WATTS/M^2 FOR_",R$
2425 PRINT "_AS A FUNCTION OF_",R1$
2430 FOR K=1 TO K8
2440 FOR K1=1 TO K9
2450 A3(K,K1)=A(K,K1)*E(K,4)
2460 IF M<4 THEN 2480
2470 P3(K1)=P4(K1)
2480 NEXT K1
2490 NEXT K
2500 GOSUB 8200
2505 RETURN
2510 PRINT "THIS PRINTS THE RAW SPIG INTENSITIES IN VOLTS FOR_",R$
2515 PRINT "_AS A FUNCTION OF_",R1$
2520 FOR K=1 TO K8
2530 FOR K1=1 TO K9
2540 A3(K,K1)=A2(K,K1)
2550 IF M<4 THEN 2570
2560 P3(K1)=P4(K1)
2570 NEXT K1
2580 NEXT K
2590 GOSUB 8200
2595 RETURN
2600 REM **PLOT INTENSITIES
2610 DISP "DO YOU WANT A:"
```

```
2620 DISP "1. SCREEN SIZE PLOT?"
2630 DISP "2.FULL SIZE PLOT?"
2640 DISP "INPUT 1 OR 2"
2650 INPUT P1
2660 CLEAR
2670 PRINTER IS 703,80
2680 IF M=2 THEN K8=11 @ K9=33
2690 IF M=3 THEN K8=11 @ K9=19
2700 IF M=4 THEN K8=3 @ K9=20
2710 PRINT M$
2720 PRINT M1$
2730 IF J>2 THEN PRINT M2$
2740 IF N=1 THEN PRINT M3$
2750 PRINT
2760 IF J=2 THEN J2=1
2770 IF J=4 THEN J2=2
2780 IF J=6 THEN J2=3
2790 ON J2 GOTO 2800,2980,3170
2800 FOR K=1 TO K8
2810 IF M=4 THEN 2840
2820 R(K)=(K-1)*5
2830 GOTO 2850
2840 R(K)=K*10
2850 NEXT K
2860 FOR K=1 TO K8
2870 PRINT "THIS PLOTS AVERAGE INTENSITY IN 1000 WATTS/M^2"
2880 IF M=4 THEN 2910
2890 PRINT "FOR RADIUS R=_",R(K),"_MILLIMETERS"
2900 GOTO 2920
2910 PRINT "FOR TRIANGLE LEG=_",R(K),"_MILLIMETERS"
2920 PRINT
2930 GOSUB 7000
2940 ON P1 GOSUB 7600,7800
2950 OUTPUT 703 ;CHR$(12)
2960 NEXT K
2970 RETURN
2980 FOR K=1 TO K8
2990 FOR K1=1 TO K9
3000 A3(K,K1)=A(K,K1)
3010 IF M<4 THEN 3030
3020 P3(K1)=P4(K1)
3030 NEXT K1
3040 NEXT K
3050 FOR K=1 TO K8
3060 PRINT "THIS PLOTS THE RATIO OF SPIG/PYRHELIOMETER MEASUREMENTS"
3070 IF M=4 THEN 3100
3080 PRINT "FOR RADIUS R=_",R(K),"_MILLIMETERS"
3090 GOTO 3110
3100 PRINT "FOR TRIANGLE LEG=_",R(K),"_MILLIMETERS"
3110 PRINT
3120 GOSUB 7000
3130 ON P1 GOSUB 7600,7800
3140 OUTPUT 703 ;CHR$(12)
3150 NEXT K
3160 RETURN
3170 FOR K=1 TO K8
3180 FOR K1=1 TO K9
3190 A3(K,K1)=A(K,K1)*E(K,4)/1000
3200 IF M<4 THEN 3220
3210 P3(K1)=P4(K1)
3220 NEXT K1
3230 NEXT K
3240 FOR K=1 TO K8
3250 PRINT "THIS PLOTS THE INTENSITY IN 1000 WATTS/M^2"
3260 IF M=4 THEN 3290
3270 PRINT "FOR RADIUS R=_",R(K),"_MILLIMETERS"
```

```
3280 GOTO 3300
3290 PRINT "FOR TRIANGLE LEG=_",R(K),"_MILLIMETERS"
3300 PRINT
3310 GOSUB 7000
3320 ON P1 GOSUB 7600,7800
3330 OUTPUT 703 ;CHR$(12)
3340 NEXT K
3350 RETURN
7000 REM **PLOT ROUTINE
7010 GCLEAR
7020 ON M GOTO 7030,7030,7070,7110
7030 Z1=-240 @ Z2=180
7040 X1=20 @ X2=-180
7050 X3=180
7060 GOTO 7150
7070 Z1=-130 @ Z2=90
7080 X1=30 @ X2=-90
7090 X3=90
7100 GOTO 7150
7110 D9=R(K)/SIN(30)
7120 Z1=-(D9+2*D9/6) @ Z2=D9
7130 X1=D9/2 @ X2=-D9
7140 X3=D9
7150 SCALE Z1,Z2,-30,200
7160 XAXIS 0,X1,X2,X3
7170 YAXIS X2,20,0,200
7180 LDIR 0
7185 IF M=4 THEN 7196
7190 FOR X=X2 TO X3 STEP 3*X1
7195 GOTO 7200
7196 FOR X=X2 TO X3 STEP X1
7200 MOVE X,-20
7210 LABEL VAL$(X)
7220 NEXT X
7230 MOVE X2,-30
7240 IF M=4 THEN 7270
7250 LABEL "AZIMUTHAL POSITION"
7260 GOTO 7280
7270 LABEL "POSITION ON TRIANGLE"
7280 FOR Y=0 TO 200 STEP 20
7290 MOVE X2-.2*X3,Y-5
7300 LABEL VAL$(Y)
7310 NEXT Y
7320 LDIR 90
7330 MOVE X2-.22*X3,20
7335 IF J=6 THEN GOTO 7340
7336 LABEL "RELATIVE INTENSITY"
7337 GOTO 7350
7340 LABEL "INTENSITY IN SUNS"
7350 LDIR 0
7360 ON M GOTO 7370,7370,7430,7490
7370 MOVE X2+10,A3(K,1)
7380 FOR J2=1 TO 33
7390 J3=(J2-1)*10
7400 DRAW X2+10+J3,A3(K,J2)
7410 NEXT J2
7420 RETURN
7430 MOVE X2,A3(K,1)
7440 FOR J2=1 TO 19
7450 J3=(J2-1)*10
7460 DRAW X2+J3,A3(K,J2)
7470 NEXT J2
7480 RETURN
7490 MOVE X2,A3(K,1)
7500 FOR J2=1 TO 20
7510 DRAW P3(J2),A3(K,J2)
```

```
7520 NEXT J2
7530 RETURN
7600 REM ** SAME SIZE IMAGE
7630 PRINTER IS 703,80
7640 SET I/O 7,16,1
7650 SETGU @ MOVE 0,100
7660 FOR Q4=1 TO 192
7670 BREAD Q4$,32
7680 PRINT USING "K,K" ; CHR$(27)&"*b32W",Q4$
7690 NEXT Q4
7700 SET I/O 7,16,2
7710 SETUU
7720 RETURN
7800 REM **LARGE IMAGE
7830 PRINTER IS 703,80
7840 SET I/O 7,16,1
7850 SETGU @ MOVE 0,100
7860 Q3$=CHR$(27)&"*b64W"
7870 Q1$[1,1]=CHR$(0) @ IF LEN(Q1$)=512 THEN 7980
7880 RESTORE 7890
7890 DATA 0,3,12,15,48,51,60,63,192,195,204,207,240,243,252,255
7900 FOR Q1=1 TO 16
7910 READ Q2@ Q2$[Q1]=CHR$(Q2)
7920 NEXT Q1
7930 FOR Q1=1 TO 16
7940 FOR Q2=1 TO 16
7950 Q1$[2*((Q1-1)*16+(Q2-1))+1]=Q2$[Q1,Q1]&Q2$[Q2,Q2]
7960 NEXT Q2
7970 NEXT Q1
7980 FOR Q1=1 TO 192
7990 BREAD Q2$[1,32],32
8000 FOR Q2=32 TO 1 STEP -1
8010 Q3=NUM(Q2$[Q2])*2+1
8020 Q2$[Q2*2-1,Q2*2]=Q1$[Q3,Q3+1]
8030 NEXT Q2
8040 FOR Q2=1 TO 2
8050 PRINT USING "K,K" ; Q3$,Q2$
8060 NEXT Q2
8070 NEXT Q1
8080 SET I/O 7,16,2
8090 SETUU
8100 RETURN
8200 REM **PRINT INTENSITIES
8210 PRINT
8220 PRINT
8230 P=0 @ K6=1
8240 PRINT USING "25X,K" ; R2$
8250 PRINT USING "#,5A,4X" ; R3$
8260 FOR K=K6 TO K7
8270 PRINT USING 8280 ; R(K)
8280 IMAGE #    ,DD.D,7X
8310 NEXT K
8320 PRINT
8330 FOR K1=1 TO K9
8340 IF M=4 THEN 8370
8350 PRINT USING "#,SDDD,2X" ; -A9+(K1-1)*10
8360 GOTO 8380
8370 PRINT USING "#,DD.D,2X" ; P3(K1)
8380 FOR K=K6 TO K7
8390 PRINT USING 8400 ; A3(K,K1)
8400 IMAGE #,D.DDE,2X
8410 NEXT K
8420 PRINT
8430 NEXT K1
8440 PRINT
8450 IF M=4 THEN 8530
```

```
8460 P=P+1
8470 PRINT
8480 PRINT
8490 PRINT
8500 IF P>1 THEN 8530
8510 K6=7 @ K7=11
8520 GOTO 8240
8530 OUTPUT 703 ;CHR$(12)
8540 RETURN
8600 REM **PRINT CONVERSION FACTORS
8610 PRINTER IS 703,80
8620 Z=VAL(F$[5,6])
8630 PRINT "THIS PRINTS THE CONVERSION FACTORS AT AXIAL POSITION_",Z,"_FEET"
8640 PRINT
8650 PRINT USING 8660 ; C(1)
8660 IMAGE "CALORIMETER",2X,SD.DDDD,"_WATTS/M^2/VOLTS"
8670 PRINT "AMBIENT TEMP RTD"
8680 PRINT USING 8690 ; C(2)
8690 IMAGE 5X,"SLOPE",2X,SD.DDDD,"_DEG-C/OHM"
8700 PRINT USING 8710 ; C(3)
8710 IMAGE 5X,"INTERCEPT",2X,SDDD.DDD,"_DEG-C"
8720 PRINT USING 8730 ; C(4)
8730 IMAGE "WIND SPEED",2X,DD.D,"_MPH/VOLT"
8740 PRINT USING 8750 ; C(5)
8750 IMAGE "WIND DIRECTION",2X,DDD.DD,"_RADIANS/VOLT"
8760 PRINT USING 8770 ; C(6)
8770 IMAGE "PYRHELIOMETER",2X,D.DDDE,"_WATTS/M^2/VOLT"
8780 PRINT USING 8790 ; C(7)
8790 IMAGE "PYRANOMETER",2X,D.DDDE,"_WATTS/M^2/VOLT"
8800 OUTPUT 703 ;CHR$(12)
8810 RETURN
8900 REM **PRINT ENVIRONMENTAL DATA
8910 PRINTER IS 703,80
8920 Z=VAL(F$[5,6])
8930 PRINT "ENVIRONMENTAL DATA AT AXIAL POSITION_",Z,"_FEET"
8940 PRINT "DATA GIVEN AS A FUNCTION OF RADIUS IN MILLIMETERS"
8950 PRINT " THE DATA IS IN COLUMNS WHERE"
8960 PRINT "1=AMBIENT TEMP(DEG-C)"
8970 PRINT "2=WIND SPEED (MPH)"
8980 PRINT "3=WIND DIRECTION (DEG CW FROM NORTH)"
8990 PRINT " 4=PYRHELIOMETER (WATTS/M^2)"
9000 PRINT "5=PYRANOMETER (WATTS/M^2)"
9010 PRINT "6=START TIME"
9020 PRINT "7=END TIME"
9030 PRINT
9040 PRINT M$
9050 PRINT
9060 IF M=4 THEN K8=4 ELSE K8=11
9070 PRINT
9080 IF M=4 THEN 9110
9090 PRINT USING "#,6A,5X" ; "RADIUS"
9100 GOTO 9120
9110 PRINT USING "#,6A,5X," ; "SIZE_"
9120 PRINT USING 9130 ; 1,2,3,4,5,6,7
9130 IMAGE D,7X,D,7X,D,7X,D,7X,D,13X,D,14X,D
9140 FOR K=1 TO K8
9150 PRINT USING "#,DD.D,4X" ; R(K)
9160 FOR K1=1 TO 5
9170 PRINT USING 9180 ; E(K,K1)
9180 IMAGE #,3D.D,3X,2D.D,3X,3D.D,3X,4D.D,3X,4D.D,3X
9190 NEXT K1
9195 PRINT USING 9196 ; T0(K),T9(K)
9196 IMAGE #,10D,3X,10D
9197 PRINT
9200 NEXT K
9210 OUTPUT 703 ;CHR$(12)
```

```
9220 RETURN
9300 REM **PRINT NORMALIZED INTENSITY OVER 5X5 GRID
9310 PRINTER IS 703,80
9320 PRINT M$
9330 PRINT M1$
9340 PRINT M2$
9350 IF N=1 THEN PRINT M3$
9360 PRINT USING "#,12X"
9370 FOR K1=1 TO 5
9380 PRINT USING 9390 ; X(K1)
9390 IMAGE #,SDD.DD,5X
9400 NEXT K1
9410 PRINT
9420 PRINT USING "2/"
9430 FOR K2=1 TO 5
9440 PRINT USING 9450 ; Y(K2)
9450 IMAGE #,2X,SDD.DD,4X
9460 FOR K1=1 TO 5
9470 PRINT USING 9480 ; A5(K1,K2)
9480 IMAGE #,MDDD.DD,4X
9490 NEXT K1
9500 PRINT
9510 PRINT USING "2/"
9520 NEXT K2
9530 OUTPUT 703 ;CHR$(12)
9540 RETURN
9600 REM **PRINT ANGULAR ORIENTATION
9610 PRINTER IS 703,80
9615 IF J=12 THEN 9650
9620 PRINT M$
9630 PRINT M1$
9640 PRINT M2$
9650 PRINT "THE INITIAL ORIENTATION IS_",P1(4)
9660 PRINT
9670 Z=VAL(F$[5,6])
9680 PRINT "THE ORIENTATION AT_",Z,"_FEET IS _",P0(4)
9690 OUTPUT 703 ;CHR$(12)
9700 RETURN
9710 END
```

4. Program "RESIST"

```
10 OPTION BASE 1
20 M=0
30 DIM R7(20),R8(28),B(5),F(20),W1(8),V(2),R9(8)
40 DISP "CHOOSE THE RTS GEOMETRY"
50 DISP "   1.CONCENTRIC CYLINDERS"
60 DISP "   2.D-SHAPED"
80 DISP "    3. 60-DEGREE TRIANGULAR RECEIVER TUBE AND COVER"
90 INPUT N
91 CLEAR
100 DISP "DOES THE RT CONTAIN A HELICAL TAPE INSERT?(Y OR N)"
101 DISP "THIS OPTION VALID ONLY FOR CYLINDER RT"
110 INPUT T$
120 IF T$="Y" THEN 130 ELSE 170
130 DISP "INPUT THE NUMBER OF 360-DEG TWISTS PER FOOT"
140 INPUT Y9
150 DISP "INPUT THICKNESS OF TAPE INSERT"
160 INPUT D9
170 IF N<3 THEN 300
180 DISP "INPUT OUTSIDE LENGTH OF LEG OF TRIANGULAR RT"
190 INPUT R2
200 DISP "INPUT THICKNESS OF RT"
210 INPUT L9
220 DISP "INPUT GAP SPACING"
230 INPUT L8
240 DISP "INPUT THICKNESS OF GLASS"
250 INPUT L7
260 R3=2*(.5*R2+L8*(TAN(30)+1/COS(30)))
270 R4=2*(.5*R2+(L7+L8)*(TAN(30)+1/COS(30)))
290 GOTO 380
300 DISP "INPUT INNER RADIUS OF RECEIVER TUBE IN INCHES"
310 INPUT R1
320 DISP "INPUT OUTER RADIUS OF RECEIVER TUBE IN INCHES"
330 INPUT R2
340 DISP "INPUT INNER RADIUS OF GLASS COVER IN INCHES"
350 INPUT R3
360 DISP "INPUT OUTER RADIUS OF GLASS COVER IN INCHES"
370 INPUT R4
380 DISP "INPUT LENGTH AND FOCAL LENGTH OF MIRROR IN INCHES"
390 INPUT L,L1
400 IF M=1 THEN 880
410 DISP "INPUT EMISSIVITY AND ABSORPTIVITY OF RECEIVER TUBE"
420 INPUT E1,A1
430 DISP "INPUT EMISSIVITY AND ABSORPTIVITY OF GLASS"
440 INPUT E2,A2
450 DISP "INPUT EMISSIVITY AND REFLECTIVITY OF MIRROR"
460 INPUT E3,P3
470 DISP "INPUT TRANSMISSIVITY OF GLASS FOR NORMAL AND NON-NORMAL SUN"
480 INPUT G2,G3
490 DISP "INPUT CONDUCTIVITY OF RT AND GLASS IN BTU/HR-FT-F"
500 INPUT K1,K2
510 IF M=2 THEN 880
```

```
560 DISP "INPUT WIND SPEED IN MPH AND ANGLE WITH RT AXIS IN DEG"
570 INPUT U,P9
580 DISP "INPUT FLUID FLOW RATE IN GAL/MIN"
590 INPUT G
600 DISP "INPUT PYRH READING IN WATTS/M^2"
610 INPUT P1
620 DISP "INPUT TEMPERATURE IN DEGREE F FOR"
630 DISP "RECEIVER TUBE"
640 INPUT Q2
650 DISP "GLASS COVER"
660 INPUT Q3
790 DISP "BULK FLUID"
800 INPUT Q1
810 DISP "INPUT AIR TEMP IN DEG F"
820 INPUT T0
830 IF M=3 THEN 880
840 CLEAR
845 DISP "INPUT INTENSITY ON RECEIVER TUBE SECTORS IN WATTS/M^2"
850 DISP "IF INTENSITY ON SECTOR 1 IS UNKNOWN, INPUT 0 AND"
855 DISP "THE DEFAULT VALUE WILL BE THE PYRHELIOMETER READING"
860 DISP "__ INPUT INTENSITY ON SECTOR 1"
861 INPUT W2(1)
862 IF W2(1)=0 THEN W2(1)=P1
863 DISP "__INPUT INTENSITY ON SECTOR 2"
864 INPUT W2(2)
865 DISP "__INPUT INTENSITY ON SECTOR 3"
870 INPUT W2(3)
871 DISP "INPUT INTENSITY ON SECTOR 4"
872 INPUT W2(4)
873 CLEAR
880 S1=.000000005729
885 IF P9>180 THEN P=ABS(270-P9)*PI/180 ELSE P=ABS(90-P9)*PI/180
890 B(1)=PI
900 FOR S=2 TO 4
910 B(S)=PI/3
920 NEXT S
930 B(5)=PI
940 W=4*L1*1.1417
950 REM **CALCULATE AVERAGE TEMPERATURES
990 Q0=.5*(T0+Q3)
1000 Q4=.5*(Q2+Q1)
1010 Q5=.5*(Q2+Q3)
1020 Q6=Q2-Q3
1030 REM **CALCULATE AIR PROPERTIES
1040 DEF FNB(Z) = 1/(Z+460)
1050 DEF FNP(Z) = 39.68/(Z+460)
1060 DEF FNU(Z) = .000000731*(Z+460)^1.5/(Z+658.7)
1070 DEF FNK(Z)
1080 K8=.00114*SQR(Z+460)
1090 E9=-21.6/(Z+460)
1100 K9=1+441.7/(Z+460)*.1^E9
1110 FNK=K8/K9
1120 FN END
1130 DEF FNC(Z) = .2238+.00002533*(Z+460)
1140 DEF FNV(Z) = FNU(Z)/FNP(Z)
1150 DEF FNA(Z) = FNK(Z)/(FNP(Z)*FNC(Z)*3600)
1160 DEF FNR1 = 32.2*FNB(Q5)*Q6/(FNV(Q5)*FNA(Q5))
1170 REM **CALCULATE FLUID PROPERTIES
1180 DEF FNP1(Z) = .907-.000372*Z
1190 DEF FNP2(Z) = 56.62-.0232*Z
1200 DEF FNP3(Z) = 7.569-.0031*Z
1210 DEF FNC1(Z) = .431+.000449*Z
1220 DEF FNC2(Z) = .00614*(961-Z)^.367
1230 DEF FNV1(Z) = 10^(10^(11.048212-3.962629*LGT(Z+459.7)))-.8
1240 DEF FNU1(Z) = 2.41901*FNV1(Z)*FNP1(Z)
1250 DEF FNB1 = .00049
```

```
1260 DEF FNP0(Z) = FNU1(Z)*FNC1(Z)/FNC2(Z)
1270 DEF FNR0(D) = G*FNP3(Q1)*60*12*D/(A5*FNU1(Q1))
1280 DEF FNR8(D) = G*FNP3(Q1)*60*4/(PI*D/12*FNU1(Q1))
1290 DEF FNR9(D) = FNP(Q0)*U*5280*D/(12*3600)/FNU(Q0)
1300 DEF FNG6(Z) = (SIN(P)^2+(G5*COS(P))^2)^(Z/2)
1310 REM **CALCULATE RESISTANCES BY SECTOR
1320 REM **CALL SUBROUTINE TO CALCULATE VIEW FACTORS
1330 ON N GOSUB 2000,2000,2320
1340 I1=0
1350 I=0
1360 J2=0
1370 FOR S=1 TO 4
1380 REM **CALCULATE RADIATIVE RESISTANCES
1390 FOR J=1 TO 5
1400 J1=J2+J
1410 GOSUB 2620
1420 IF J<4 THEN R5=R2 ELSE R5=R4
1421 IF N=3 THEN GOTO 1432
1430 IF F(J1)=0 THEN R7(J1)=0 ELSE R7(J1)=FNR(R5)
1431 GOTO 1440
1432 IF F(J1)=0 THEN R7(J1)=0 ELSE R7(J1)=FNR2(R5)
1440 NEXT J
1450 J2=5*S
1460 REM **CALCULATE CONDUCTIVE RESISTANCES
1470 REM **DEFINE HYDRAULIC RADII
1480 ON N GOTO 1490,1520,1580
1490 H2=R2
1500 H3=R3
1510 GOTO 1600
1520 H2=PI*R2/(PI+2)
1530 H3=PI*R3/(PI+2)
1540 GOTO 1600
1580 H2=SQR(3)*R2/6
1590 H3=SQR(H2+2*L8)/3
1600 GOSUB 2740
1610 ON N GOSUB 2960,3050,3550
1620 I=7*S
1630 REM **CALCULATE CONVECTIVE RESISTANCES
1631 IF T$="Y" THEN 1640 ELSE 1650
1640 Y8=3/(R1*Y9)
1650 ON N GOSUB 3600,3950,4580
1660 I1=2*S
1670 NEXT S
1680 REM **CALCULATE ABSORBED RADIATION
1800 GOSUB 4920
1920 V(1)=(T0+460)/1.8
1930 V(2)=(Q1+460)/1.8
1940 REM **PRINT RESULTS
1950 GOSUB 5240
1960 DISP "CHOOSE ONE OF THE FOLLOWING SETS OF NEW VARIABLES"
1961 DISP "  1.RTS RADII AND MIRROR SIZE"
1962 DISP "  2.MATERIAL PROPERTIES"
1963 DISP "  3.DAY,HOUR,TEMP,ETC"
1964 DISP "  4.OPTICAL INTERCEPT FRACTIONS"
1965 DISP "  5.ALL VARIABLES"
1966 DISP "  6 NONE"
1967 INPUT M
1968 ON M GOTO 40,410,840,40,1969
1969 END
2000 REM **SUBROUTINE FOR BLACK BODY CYLINDRICAL AND D-SHAPED RTSVIEW FACTORS
2020 A=ACS(R2/R3)
2030 F(1)=1/PI*(R3/R2*(SIN(A)-1)+PI-A+1)
2040 IF N=2 THEN F(1)=1
2050 F(2)=.5*(1-F(1))
2060 F(3)=F(2)
2070 F(6)=3/PI*(R3/R2*(SIN(A)-1)+PI/3-A+1)
```

```
2080 F(7)=.5*(1-F(6))
2090 F(8)=F(7)
2100 F(11)=F(6)
2110 F(12)=F(7)
2120 F(13)=F(7)
2130 F(16)=F(6)
2140 F(17)=F(7)
2150 F(18)=F(7)
2170 Z7=2*L1/(1-COS(PI/2+B(2)))
2180 X1=SQR(R4^2+Z7^2-2*R4*Z7*COS(B(2)))
2190 X2=SQR(R4^2+(2*L1)^2-4*R4*L1*COS(B(2)))
2200 X3=.5/(R4*B(2))*(X1+X2-(2*L1-R4)-(Z7-R4))
2205 X4=.5/(R4*B(2))*(PI/3*R4+(Z7-R4)-X1)
2210 F(10)=X3+X4
2220 F(9)=1-F(10)
2230 A0=ACS(R4/(2*L1))
2240 F(15)=(R4*(2*B(2)-A0)+2*L1*SIN(A0)-X2)/(R4*B(2))
2250 F(14)=1-F(15)
2260 F(19)=F(9)
2270 F(20)=F(10)
2280 F(4)=(F(10)+F(15)+F(20))/3
2290 IF N=2 THEN F(4)=1
2300 F(5)=1-F(4)
2310 RETURN
2320 REM **SUBROUTINE FOR BLACK BODY VIEW-FACTORS FOR TRIANGULAR RTS
2340 F(1)=1
2350 F(2)=0
2360 F(3)=0
2370 F(4)=1
2380 F(5)=0
2390 F(6)=2/R2*(SQR(R2^2/4+L8^2/COS(30)^2-R2*L8*COS(120)/COS(30))-L8/COS(30))
2410 F(7)=.5*(1-F(6))
2420 F(8)=F(7)
2430 F(11)=.5+1/R2*SQR(R2^2/4+L8^2/COS(30)^2-R2*L8*COS(60)/COS(30))-L8/(R2*COS(3
0))
2450 F(12)=.5*(1-F(11))
2460 F(13)=F(12)
2470 F(16)=F(6)
2480 F(17)=F(7)
2490 F(18)=F(7)
2500 X1=.5*R2+2*(L7+L8)/COS(30)
2510 X2=2*L1/(1-COS(150))-(.5*R2+(L7+L8)/COS(30))
2520 X3=2*L1-(.5*R2+(L7+L8)*(TAN(30)+1/COS(30)))
2530 X4=SQR(X3^2+X1^2-2*X3*X1*COS(120))
2540 X5=SQR(X1^2+X2^2-2*X1*X2*COS(120))
2550 X6=1/(2*X1)*(X5+X4-X3-X2)
2560 X7=1/(2*X1)*(X1+X2-X5)
2570 F(10)=X6+X7
2580 F(9)=1-F(10)
2590 X8=R4-((L7+L8)/COS(30)*(1+2*SIN(30))+R2*SIN(30))
2600 X9=SQR(4*L1^2+R4*SQR(3)/2)
2610 F(15)=1/X8*(X8+X9-X4)
2611 F(14)=1-F(15)
2612 F(20)=F(10)
2613 F(19)=F(9)
2614 RETURN
2620 REM **SUBROUTINE FOR GRAY BODY VIEW-FACTORS
2630 ON J GOTO 2640,2640,2640,2680,2700
2640 F1=(1-E1)/E1
2650 F2=(1-E2)/E2
2660 IF F(J1)=0 THEN F3=0 ELSE F3=1/(F1+1/F(J1)+R2/R3*F2)
2670 RETURN
2680 F3=1/(F2+1/F(J1))
2690 RETURN
2700 F1=(1-E3)/E3
2701 IF N=3 THEN GOTO 2712
```

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2710 IF F(J1)=0 THEN F3=0 ELSE F3=1/(F2+1/F(J1)+B(S)*R4*F1/W)
2711 GOTO 2720
2712 IF J1=20 THEN B1=2*X8 ELSE B1=X1
2713 F3=1/(F2+1/F(J1)+B1*F1/W)
2720 RETURN
2730 DEF FNR(Z) = 1/(S1*B(S)*Z*L*F3*2.54^2)
2735 DEF FNR2(Z) = 1/(S1*Z*F3*2.54^2)
2740 REM **SUBROUTINE FOR EFFECTIVE CONDUCTIVITY
2750 D=H2*(H3/H2-1)/12
2760 C1=FNR1*D^3
2770 C2=8*LOG(H3/H2)^4
2780 C3=(12*D/H2)^3
2790 C4=(1+(H2/H3)^(3/5))^5
2800 C5=C2*C1/(C3*C4)
2810 IF C5<=100 THEN K3=FNK(Q5) ELSE K3=.317*FNK(Q5)*C5^.25
2820 RETURN
2830 REM **FUNCTIONS FOR CONDUCTIVE RESISTANCES
2840 DEF FNK1(Z) = LOG((R2+R1)/(2*R1))/(B(S)*Z*L*43.96)
2850 DEF FNK2(Z) = LOG(2*R2/(R2+R1))/(B(S)*Z*L*43.96)
2860 DEF FNK3(Z) = .5*(R2+R1)*.5*(B(S)+B(S+1))/((R2-R1)*Z*L*43.96)
2870 DEF FNK4(Z) = LOG(R3/R2)/(B(S)*Z*L*43.96)
2880 DEF FNK5(Z) = LOG((R4+R3)/(2*R3))/(B(S)*Z*L*43.96)
2890 DEF FNK6(Z) = LOG(2*R4/(R4+R3))/(B(S)*Z*L*43.96)
2900 DEF FNK7(Z) = .5*(R4+R3)*.5*(B(S)+B(S+1))/((R4-R3)*Z*L*43.96)
2910 DEF FNH1(Z) = .5*(R2-R1)/(2*R2*Z*L*43.96)
2920 DEF FNH2(Z) = (R1+.5*(R2-R1)+.5*(R2+R1)*PI/6)/(Z*(R2-R1)*L*43.96)
2930 DEF FNH3(Z) = (R3-R2)/(2*R3*Z*L*43.96)
2940 DEF FNH4(Z) = .5*(R4-R3)/(2*R4*Z*L*43.96)
2950 DEF FNH5(Z) = (R3+.5*(R4-R3)+.5*(R4+R3)*PI/6)/(Z*(R4-R3)*L*43.96)
2960 REM **SUBROUTINES TO CALCULATE CONDUCTIVE RESISTANCES
2970 R8(I+1)=FNK1(K1)
2980 R8(I+2)=FNK2(K1)
2990 R8(I+3)=FNK3(K1)
3000 R8(I+4)=FNK4(K3)
3010 R8(I+5)=FNK5(K2)
3020 R8(I+6)=FNK6(K2)
3030 R8(I+7)=FNK7(K2)
3040 RETURN
3050 IF S=1 THEN 3060 ELSE 3140
3060 R8(I+1)=FNH1(K1)
3070 R8(I+2)=FNH1(K1)
3080 R8(I+3)=FNH2(K1)
3090 R8(I+4)=FNH3(K3)
3100 R8(I+5)=FNH4(K2)
3110 R8(I+6)=FNH5(K2)
3120 R8(I+7)=FNH5(K2)
3130 RETURN
3140 R8(I+1)=FNK1(K1)
3150 R8(I+2)=FNK2(K1)
3160 IF S=4 THEN R8(I+3)=FNH2(K1) ELSE R8(I+3)=FNK3(K1)
3170 R8(I+4)=FNK4(K3)
3180 R8(I+5)=FNK5(K2)
3190 R8(I+6)=FNK6(K2)
3200 IF S=4 THEN R8(I+7)=FNH5(K2) ELSE R8(I+7)=FNK7(K2)
3210 RETURN
3380 REM **FUNCTIONS FOR CONDUCTIVE RESISTANCES FOR TRIANGLE
3390 DEF FNT1(Z) = L9/(2*Z*R2*L*43.96)
3400 DEF FNT3(Z) = .5*(R2-L9)*(1+SIN(30))/(L9*Z*L*43.96)
3410 DEF FNT4(Z) = L8/(.5*(R2+2*L8/COS(30)+R3)*Z*L*43.96)
3420 DEF FNT5(Z) = L7/(2*Z*R4*L*43.96)
3430 DEF FNT7(Z) = .5*(R4-L7)*(X1-(.5*R2*COS(30)+L8+L7)*TAN(30))/(L7*Z*L*43.96)
3440 DEF FNS1(Z) = L9/(Z*R2*L*43.96)
3450 DEF FNS3(Z) = (R2*(1+SIN(30))-L9*SIN(30))/(2*Z*L9*L*43.96)
3460 DEF FNS4(Z) = L8/(.5*(.5*R2+.5*R2+L8/COS(30))*Z*L*43.96)
3470 DEF FNS5(Z) = L7/(.5*Z*X1*L*43.96)
3480 DEF FNS7(Z) = (X8+(.5*R2*COS(30)+L8+L7)*TAN(30))/(L7*A*L*43.96)
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3490 DEF FNQ4(Z) = L8/(.5*(R2+2*X8)*Z*L*43.96)
3500 DEF FNQ5(Z) = L7/(X8*Z*L*43.96)
3550 REM **CONDUCTIVE RESISTANCES FOR TRIANGLE
3560 ON S GOTO 3561,3569,3577,3585
3561 R8(I+1)=FNT1(K1)
3562 R8(I+2)=FNT1(K1)
3563 R8(I+3)=FNT3(K1)
3564 R8(I+4)=FNT4(K3)
3565 R8(I+5)=FNT5(K2)
3566 R8(I+6)=FNT6(K2)
3567 R8(I+7)=FNT7(K2)
3568 RETURN
3569 R8(I+1)=FNS1(K1)
3570 R8(I+2)=FNS1(K1)
3571 R8(I+3)=FNS3(K1)
3572 R8(I+4)=FNS4(K3)
3573 R8(I+5)=FNS5(K2)
3574 R8(I+6)=FNS5(K2)
3575 R8(I+7)=FNS7(K2)
3576 RETURN
3577 R8(I+1)=FNT1(K1)
3578 R8(I+2)=FNT1(K1)
3579 R8(I+3)=FNS3(K1)
3580 R8(I+4)=FNQ4(K3)
3581 R8(I+5)=FNQ5(K2)
3582 R8(I+6)=FNQ5(K2)
3583 R8(I+7)=FNQ7(K2)
3584 RETURN
3585 R8(I+1)=FNS1(K1)
3586 R8(I+2)=FNS1(K1)
3587 R8(I+3)=FNT3(K1)
3588 R8(I+4)=FNS4(K3)
3589 R8(I+5)=FNS5(K2)
3590 R8(I+6)=FNS5(K2)
3591 R8(I+7)=FNT7(K2)
3592 RETURN
3600 REM **SUBROUTINE FOR CONVECTIVE RESISTANCES
3610 D1=2*R1
3620 IF T$="Y" THEN 3630 ELSE 3730
3630 IF FNR8(D1)<2100 THEN 3640 ELSE 3660
3640 N0=5.172*SQR(1+.005484*FNP0(Q1)^.7*(FNR8(D1)/Y8)^1.25)*(FNU1(Q1)/FNU1(Q2))^
.16
3650 GOTO 3780
3660 A5=PI*R1^2-2*D9*R1
3670 P5=(PI+2)*D1-2*D9
3680 D5=4*A5/P5
3690 N2=.023*(1+(PI/(2*Y8))^.4)
3700 N3=.193*((FNR0(D5)/Y8)^2*FNB1*(Q2-Q1)*FNP0(Q1))^(1/3)
3710 N0=N2*FNR0(D5)^.8*FNP0(Q1)^.4*N3*(FNU1(Q1)/FNU1(Q2))^.16
3720 GOTO 3780
3730 IF FNR8(D1)<2100 THEN 3740 ELSE 3760
3740 N0=1.86*(FNR8(D1)*FNP0(Q1))^(1/3)*(D1/L)^(1/3)*(FNU1(Q1)/FNU1(Q2))^.14
3750 GOTO 3780
3760 N0=.022*FNR8(D1)^.8*FNP0(Q1)^.4*(FNU1(Q1)/FNU1(Q2))^.16
3780 R9(I1+1)=2/(B(S)*FNC2(Q1)*N0*L*43.96)
3790 D4=2*R4
3800 A4=PI*R4^2
3810 G5=.3*EXP(-L/(400*D4))+1/(1+22*FNR9(D4))
3820 IF FNR9(D4)<5000 AND FNR9(D4)>35 THEN 3830 ELSE 3860
3830 G6=.471
3840 N1=.583*FNR9(D4)^G6*FNG6(G6)
3850 GOTO 3920
3860 IF FNR9(D4)<50000 AND FNR9(D4)>5000 THEN 3870 ELSE 3900
3870 G6=.633
3880 N1=.148*FNR9(D4)*G6*FNG6(G6)
3890 GOTO 3920
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3900 G6=.814
3910 N1=.0208*FNR9(D4)^G6*FNG6(G6)
3920 R9(I1+2)=2/(B(S)*FNK(Q0)*N1*L*43.96)
3930 RETURN
3950 REM **CONVECTIVE RESISTANCES FOR D-SHAPED RT
3960 A5=PI*R1^2/2
3970 P5=(PI+2)*R1
3980 D5=4*A5/P5
3990 IF FNR8(D5)<2100 THEN 4000 ELSE 4020
4000 N0=1.86*(FNR8(D5)*FNP0(Q1))^(1/3)*(D5/L)^(1/3)*(FNU1(Q1)/FNU1(Q2))^.14
4010 GOTO 4030
4020 N0=.022*FNR8(D5)^.8*FNP0(Q1)^.4*(FNU1(Q1)/FNU1(Q2))^.16
4030 IF S=1 THEN 4040 ELSE 4060
4040 R9(I1+1)=D5/(2*R1*FNC2(Q1)*L*N0*43.96)
4050 GOTO 4070
4060 R9(I1+1)=D5/(R1*B(S)*FNC2(Q1)*L*N0*43.96)
4070 A4=PI*R4^2/2
4080 P4=(PI+2)*R4
4090 D4=4*A4/P4
4100 G5=.3*EXP(-L/(400*D4))+1/(1+22*FNR9(D4))
4110 IF FNR9(D4)<5000 AND FNR9(D4)>35 THEN 4120 ELSE 4150
4120 G6=.471
4130 N1=.583*FNR9(D4)^G6*FNG6(G6)
4140 GOTO 4210
4150 IF FNR9(D4)<50000 AND FNR9(D4)>5000 THEN 4160 ELSE 4190
4160 G6=.633
4170 N1=.148*FNR9(D4)^G6*FNG6(G6)
4180 GOTO 4210
4190 G6=.814
4200 N1=.0208*FNR9(D4)^G6*FNG6(G6)
4210 IF S=1 THEN 4220 ELSE 4240
4220 R9(I1+2)=D4/(2*R4*FNK(Q0)*N1*L*43.96)
4230 GOTO 4250
4240 R9(I1+2)=D4/(R1*B(S)*FNK(Q0)*N1*L*43.96)
4250 RETURN
4580 REM **CONVECTIVE RESISTANCES FOR TRIANGLE
4590 R1=R2-2*(L9/COS(30)+L9*TAN(30))
4600 A5=.25*SQR(3)*R1^2
4610 P5=3*R1
4620 D5=4*A5/P5
4630 IF FNR8(D5)>2100 THEN 4660
4640 N0=1.86*(FNR8(D5)*FNP0(Q1))^(1/3)*(D5/L)^(1/3)*(FNU1(Q1)/FNU1(Q2))^.14
4650 GOTO 4670
4660 N0=.022*FNR8(D5)^.8*FNP0(Q1)^.4*(FNU1(Q1)/FNU1(Q2))^.16
4670 ON S GOTO 4680,4700,4680,4700
4680 R9(I1+1)=D5/(R1*FNC2(Q1)*L*N0*43.96)
4690 GOTO 4710
4700 R9(I1+1)=D/(.5*R1*FNC2(Q1)*L*N0*43.96)
4710 A4=.25*SQR(3)*R4
4720 P4=3*R4
4730 D4=4*A4/P4
4740 G5=.3*EXP(-L/(400*D4))+1/(1+22*FNR9(D4))
4750 IF FNR9(D4)<5000 AND FNR9(D4)>35 THEN 4760 ELSE 4790
4760 G6=.471
4770 N1=.583*FNR9(D4)^G6*FNG6(G6)
4780 GOTO 4850
4790 IF FNR9(D4)<50000 AND FNR9(D4)>5000 THEN 4800 ELSE 4830
4800 G6=.633
4810 N1=.148*FNR9(D4)^G6*FNG6(G6)
4820 GOTO 4850
4830 G6=.814
4840 N1=.0208*FNR9(D4)^G6*FNG6(G6)
4850 ON S GOTO 4860,4880,4900,4880
4860 R9(I1+2)=D4/(R4*FNK(Q0)*N1*L*43.96)
4870 GOTO 4910
4880 R9(I1+2)=D4/(X1*FNK(Q0)*N1*L*43.96)
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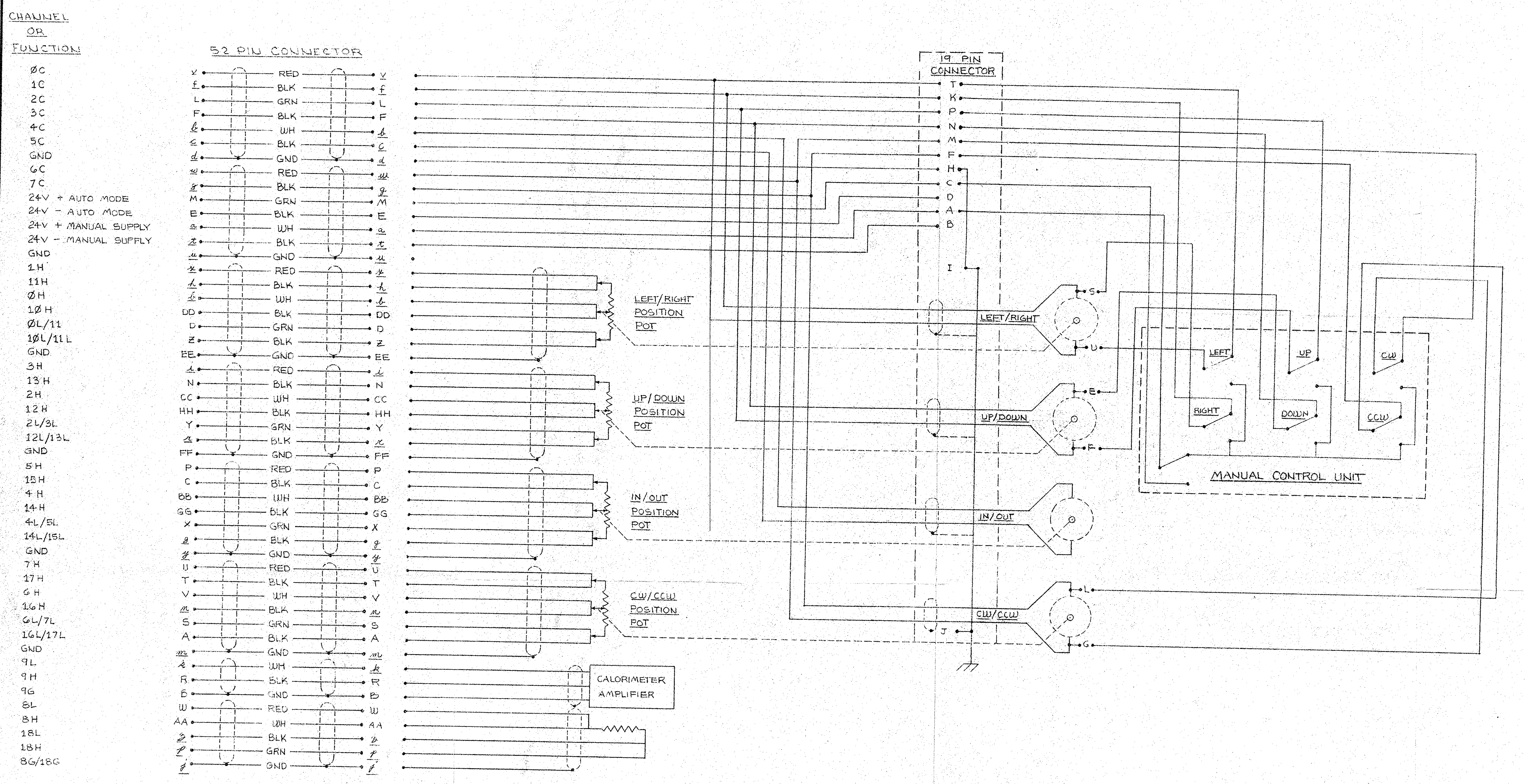
4890 GOTO 4910
4900 R9(I1+2)=D4/(2*X8*FNK(Q0)*N1*L*43.96)
4910 RETURN
4920 REM **CALCULATE HEAT FLUX
4930 ON N GOTO 4940,4970,5060
4940 W1(1)=W2(1)*P1*R4*A2*L/(144*.98)
4950 W1(2)=W2(1)*PI*R2*G3*A1*L/(144*.98)
4960 GOTO 4990
4970 W1(1)=W2(1)*2*R4*A2*L/(144*.98)
4980 W1(2)=W2(1)*2*R2*G2*A1*L/(144*.98)
4990 W1(3)=W2(2)*PI/3*A2*R2*L/(144*.98)
5000 W1(4)=W2(2)*PI/3*R2*G2*A1*L/(144*.98)
5010 W1(5)=W2(3)*PI/3*A2*R2*L/(144*.98)
5020 W1(6)=W2(3)*PI/3*R2*G2*A1*L/(144*.98)
5030 W1(7)=W2(4)*PI/3*A2*R2*L/(144*.98)
5040 W1(8)=W2(4)*PI/3*R2*G2*A1*L/(144*.98)
5050 RETURN
5060 W1(1)=W2(1)*R4*A2*L/(144*.98)
5070 W1(2)=W2(1)*R2*G2*A1*L/(144*.98)
5080 W1(3)=W2(2)*.5*R2*A2*L/(144*.98)
5090 W1(4)=W2(2)*.5*R2*G2*A1*L/(144*.98)
5100 W1(5)=W2(3)*.5*R2*A2*L/(144*.98)
5110 W1(6)=W2(3)*.5*R2*G2*A1*L/(144*.98)
5120 W1(7)=W2(4)*.5*R2*A2*L/(14*.98)
5130 W1(8)=W2(4)*.5*R2*G2*A1*L/(144*.98)
5140 RETURN
5240 PRINT "RESIST";TAB(9);"NODES";TAB(17);"VALUE"
5250 PRINT
5260 IMAGE X,K,2X,K,2X,K,2X,K,D.DDDE,/,K
5270 PRINT USING 5260 ; "R1RT1",5,4,"F1(",R7(1),",N(5),N(4))"
5275 IF R7(2)=0 THEN GOTO 5300
5280 PRINT USING 5260 ; "R1RTB",5,12,"F1(",R7(2),",N(5),N(12))"
5290 PRINT USING 5260 ; "R1RTD",5,24,"F1(",R7(3),",N(5),N(24))"
5300 PRINT USING 5260 ; "R1RGA",2,1,"F1(",R7(4),",N(2),N(1))"
5305 IF R7(5)=0 THEN GOTO 5320
5310 PRINT USING 5260 ; "R1RGM",2,1,"F1(",R7(5),",N(2),N(1))"
5320 PRINT USING 5260 ; "R2RT2",11,12,"F1(",R7(6),",N(11),N(12))"
5330 PRINT USING 5260 ; "R2RTA",11,4,"F1(",R7(7),",N(11),N(4))"
5340 PRINT USING 5260 ; "R2RTC",11,18,"F1(",R7(8),",N(11),N(18))"
5350 PRINT USING 5260 ; "R2RGA",14,1,"F1(",R7(9),",N(14),N(1))"
5360 PRINT USING 5260 ; "R2RGM",14,1,"F1(",R7(10),",N(14),N(1))"
5370 PRINT USING 5260 ; "R3RT3",17,18,"F1(",R7(11),",N(17),N(18))"
5380 PRINT USING 5260 ; "R3RTB",17,12,"F1(",R7(12),",N(17),N(12))"
5390 PRINT USING 5260 ; "R3RTD",17,24,"F1(",R7(13),",N(17),N(24))"
5400 PRINT USING 5260 ; "R3RGA",20,1,"F1(",R7(14),",N(20),N(1))"
5410 PRINT USING 5260 ; "R3RGM",20,1,"F1(",R7(15),",N(20),N(1))"
5420 PRINT USING 5260 ; "R4RT4",23,24,"F1(",R7(16),",N(23),N(24))"
5430 PRINT USING 5260 ; "R4RTC",23,18,"F1(",R7(17),",N(23),N(18))"
5440 PRINT USING 5260 ; "R4RTA",23,4,"F1(",R7(18),",N(23),N(4))"
5450 PRINT USING 5260 ; "R4RGA",26,1,"F1(",R7(19),",N(26),N(1))"
5460 PRINT USING 5260 ; "R4RGM",26,1,"F1(",R7(20),",N(26),N(1))"
5470 PRINT
5480 IMAGE X,K,2X,K,2X,K,2X,D.DDDE
5490 PRINT USING 5480 ; "R1KTR",7,6,R8(1)
5500 PRINT USING 5480 ; "R2KTR",6,5,R8(2)
5510 PRINT USING 5480 ; "R1KTA",6,10,R8(3)
5520 PRINT USING 5480 ; "R1KTG",5,4,R8(4)
5530 PRINT USING 5480 ; "R1KGR",4,3,R8(5)
5540 PRINT USING 5480 ; "R2KGR",3,2,R8(6)
5550 PRINT USING 5480 ; "R1KGA",3,13,R8(7)
5560 PRINT USING 5480 ; "R3KTR",9,10,R8(8)
5570 PRINT USING 5480 ; "R4KTR",10,11,R8(9)
5580 PRINT USING 5480 ; "R2KTA",10,16,R8(10)
5590 PRINT USING 5480 ; "R2KTG",11,12,R8(11)
5600 PRINT USING 5480 ; "R3KGR",12,13,R8(12)
5610 PRINT USING 5480 ; "R4KGR",13,14,R8(13)
```

```
5620 PRINT USING 5480 ; "R2KGA",13,19,R8(14)
5630 PRINT USING 5480 ; "R5KTR",15,16,R8(15)
5640 PRINT USING 5480 ; "R6KTR",16,17,R8(16)
5650 PRINT USING 5480 ; "R3KTA",16,22,R8(17)
5660 PRINT USING 5480 ; "R3KTG",17,18,R8(18)
5670 PRINT USING 5480 ; "R5KGR",18,19,R8(19)
5680 PRINT USING 5480 ; "R6KGR",19,20,R8(20)
5690 PRINT USING 5480 ; "R3KGA",19,25,R8(21)
5700 PRINT USING 5480 ; "R7KTR",21,22,R8(22)
5710 PRINT USING 5480 ; "R8KTR",22,23,R8(23)
5720 PRINT USING 5480 ; "R4KTA",22,6,R8(24)
5730 PRINT USING 5480 ; "R4KTG",23,24,R8(25)
5740 PRINT USING 5480 ; "R7KGR",24,25,R8(26)
5750 PRINT USING 5480 ; "R8KGR",25,26,R8(27)
5760 PRINT USING 5480 ; "R4KGA",25,3,R8(28)
5770 PRINT
5780 PRINT USING 5480 ; "R1CFT",8,7,R9(1)
5790 PRINT USING 5480 ; "R1CGA",2,1,R9(2)
5800 PRINT USING 5480 ; "R2CFT",8,9,R9(3)
5810 PRINT USING 5480 ; "R2CGA",14,1,R9(4)
5820 PRINT USING 5480 ; "R3CFT",8,15,R9(5)
5830 PRINT USING 5480 ; "R3CGA",20,1,R9(6)
5840 PRINT USING 5480 ; "R4CFT",8,21,R9(7)
5850 PRINT USING 5480 ; "R4CGA",26,1,R9(8)
5860 PRINT USING "5/"
5870 PRINT "VOLTAGE";TAB(10);"NODES";TAB(18);"VALUE"
5880 PRINT
5890 IMAGE X,K, 6X,K,2X,K,2X,D.DDDE
5900 PRINT USING 5890 ; "V1A",1,0,V(1)
5910 PRINT USING 5890 ; "V1F",8,0,V(2)
5920 PRINT USING "5/"
5930 PRINT "CURRENT";TAB(10);"NODES";TAB(18),"VALUE"
5940 PRINT
5950 PRINT USING 5890 ; "I1G",3,0,W1(1)
5960 PRINT USING 5890 ; "I1T",5,0,W1(2)
5970 PRINT USING 5890 ; "I2G",13,0,W1(3)
5980 PRINT USING 5890 ; "I2T",11,0,W1(4)
5990 PRINT USING 5890 ; "I3G",19,0,W1(5)
6000 PRINT USING 5890 ; "I3T",17,0,W1(6)
6010 PRINT USING 5890 ; "I4G",25,0,W1(7)
6020 PRINT USING 5890 ; "I4T",23,0,W1(8)
6030 RETURN
```



NO. REQ'D	PART NO.	MATERIAL	DESCRIPTION	ITEM NO

LIST OF MATERIAL

DRAWN: K COX
DATE: 7/27/81
CHECKED:
ENGINEER
PROJ. ENGR.
PROGRAM MANAGER
MATERIAL:
FINISH:
TOLERANCES:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
CONTRACT OR COST CENTER
NEXT ASS'Y.
APPLICATION

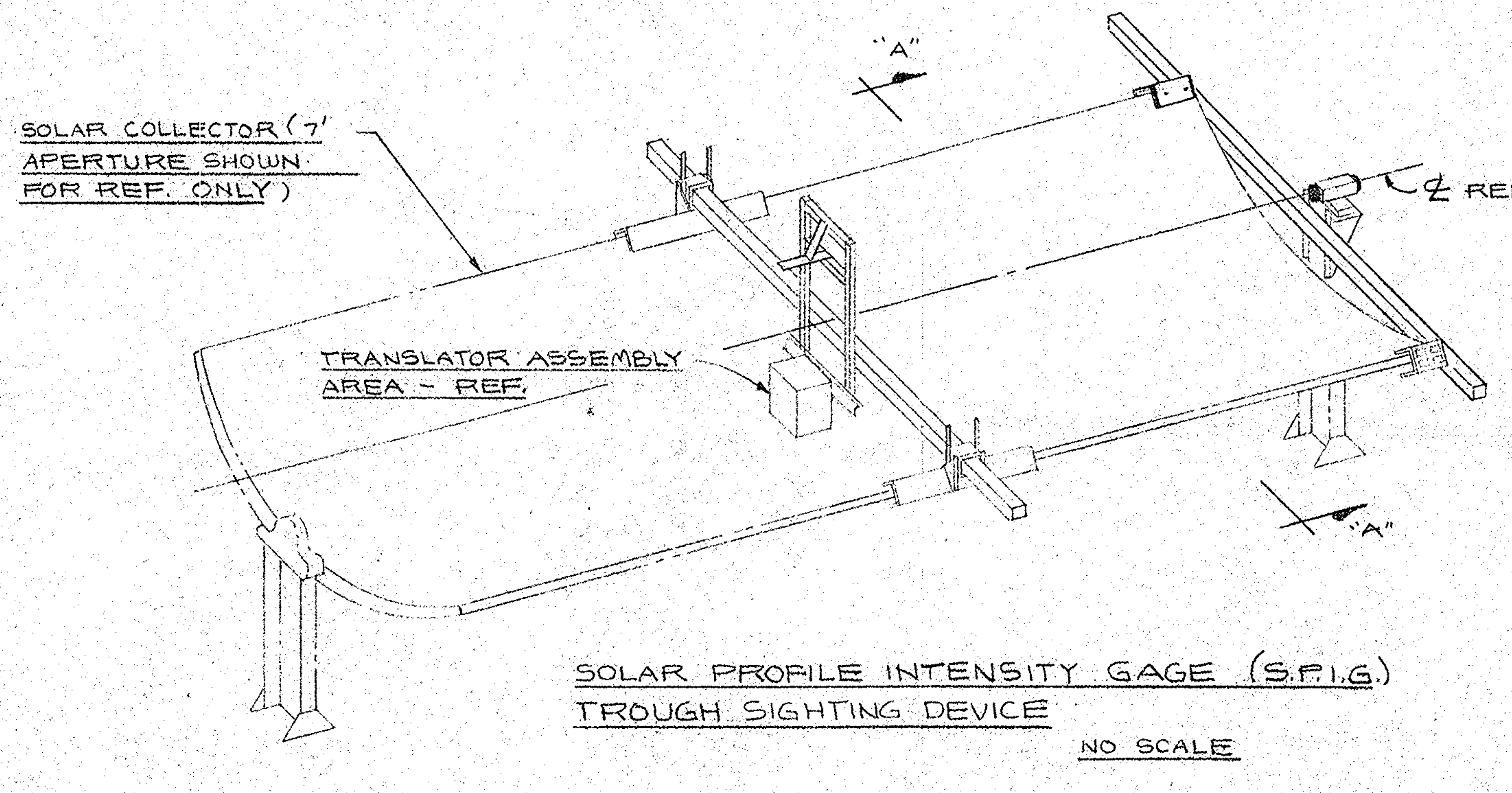
THE BDM CORPORATION
2600 YALE BLVD., S.E., ALBUQUERQUE, NM 87106

JUL 27 1981

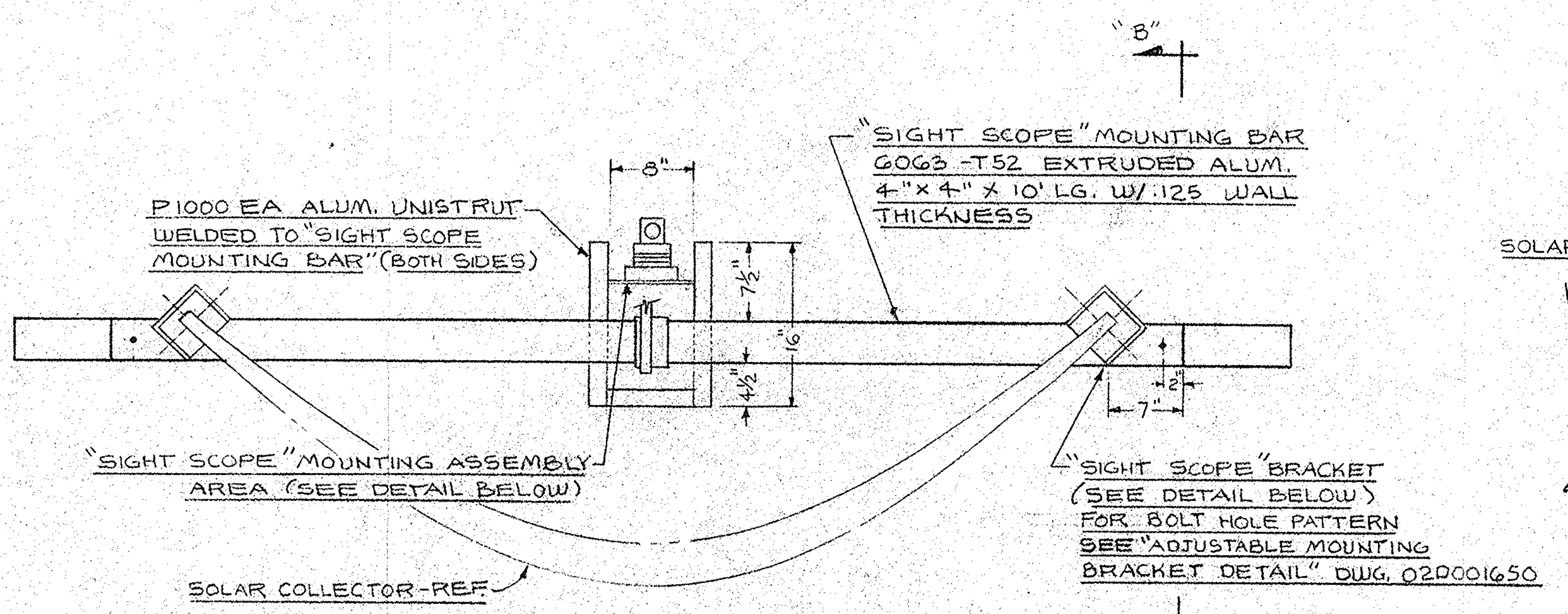
TITLE:
CONTROL SYSTEM
WIRING DIAGRAM
(S.P.I.G.)

CODE IDENT. 52308
SIZE D
DWG. NO. 02D001655
REV.
SCALE: NONE
SHEET 1 OF 1

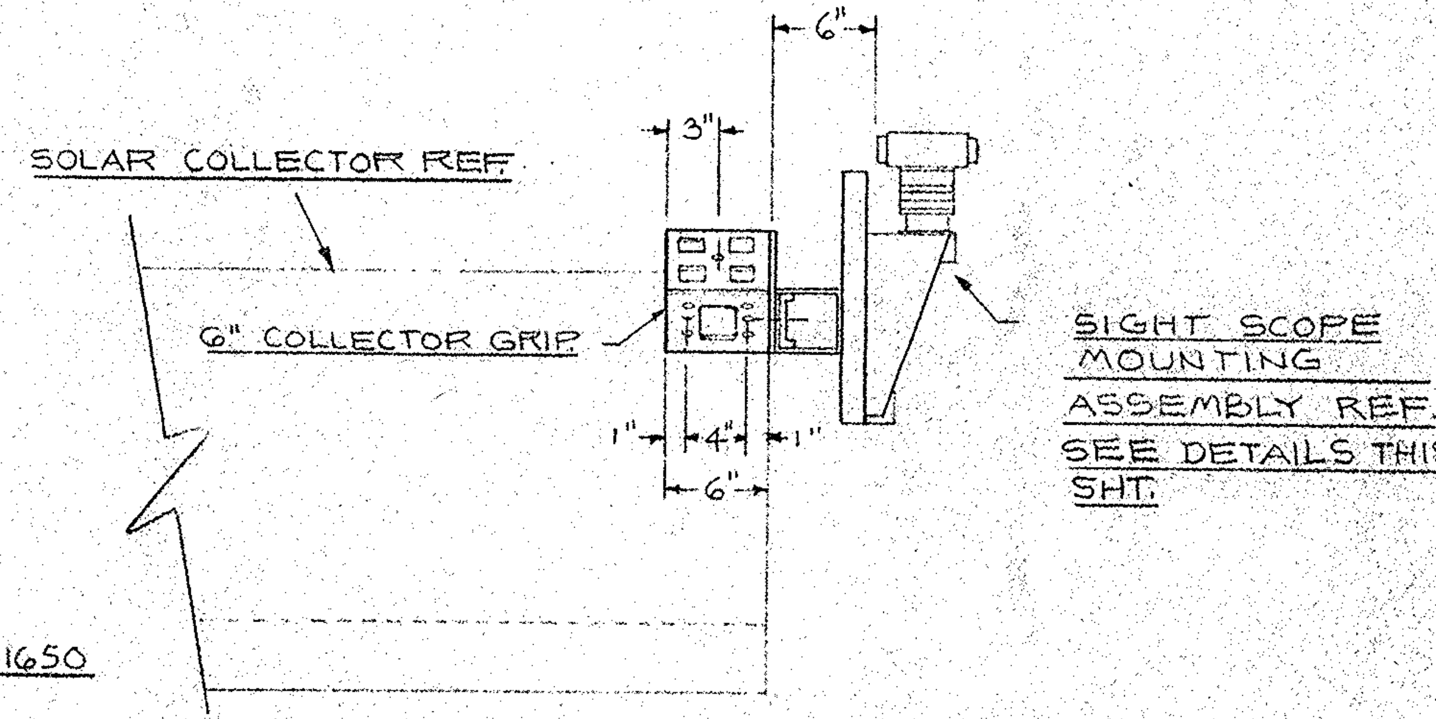
BRUNING 40-105



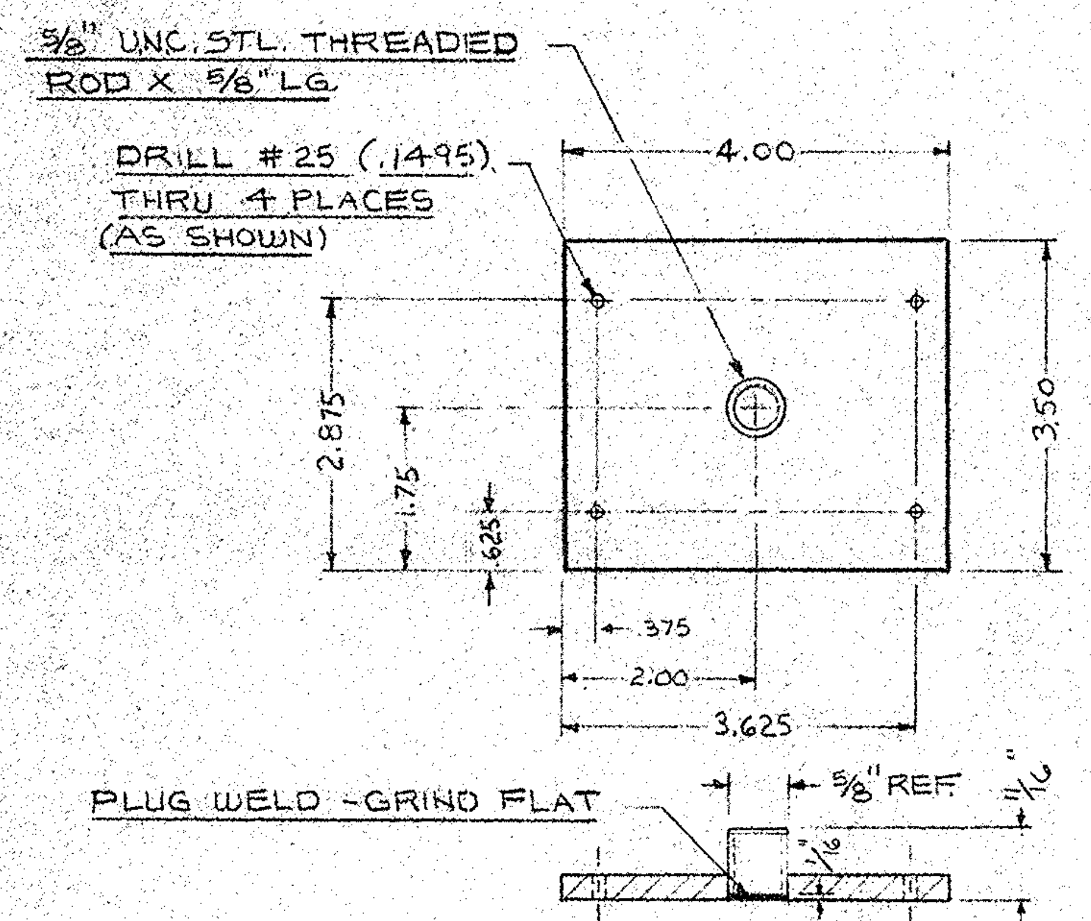
SOLAR PROFILE INTENSITY GAGE (S.P.I.G.)
TROUGH SIGHTING DEVICE
NO SCALE



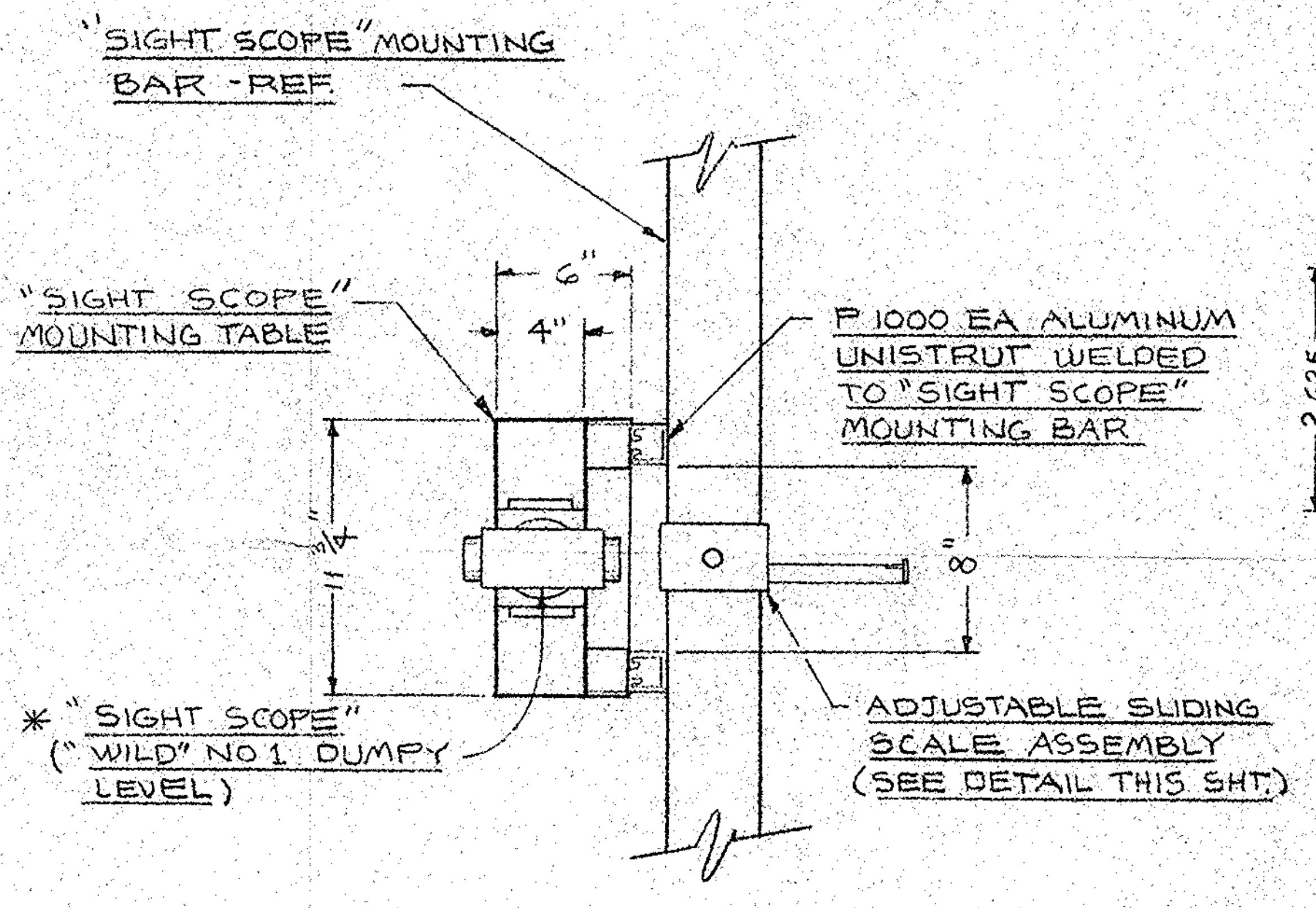
VIEW "A-A"
SCALE: 1"=1'-0"



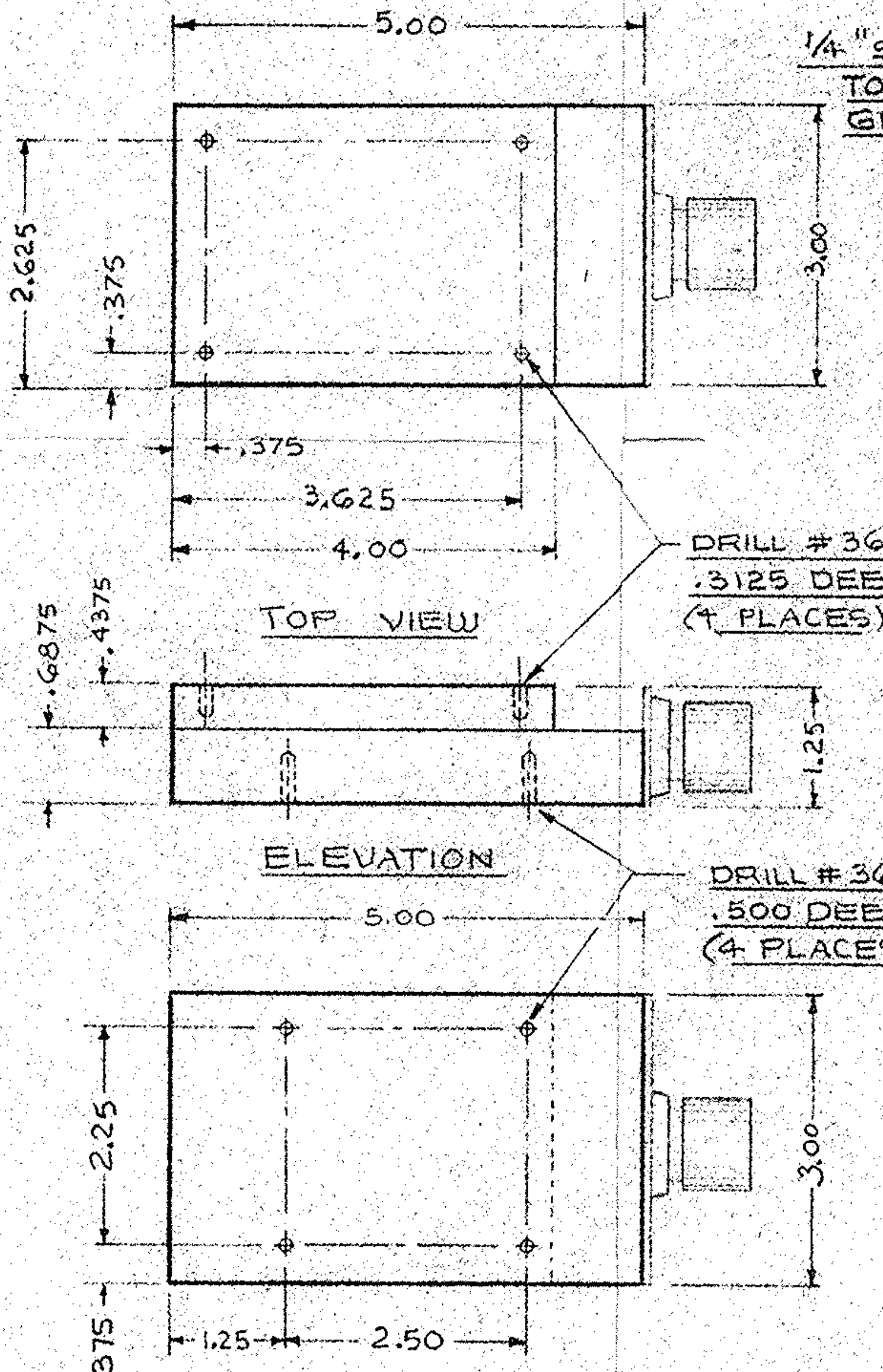
VIEW "B-B"
SCALE: 1"=1'-0"



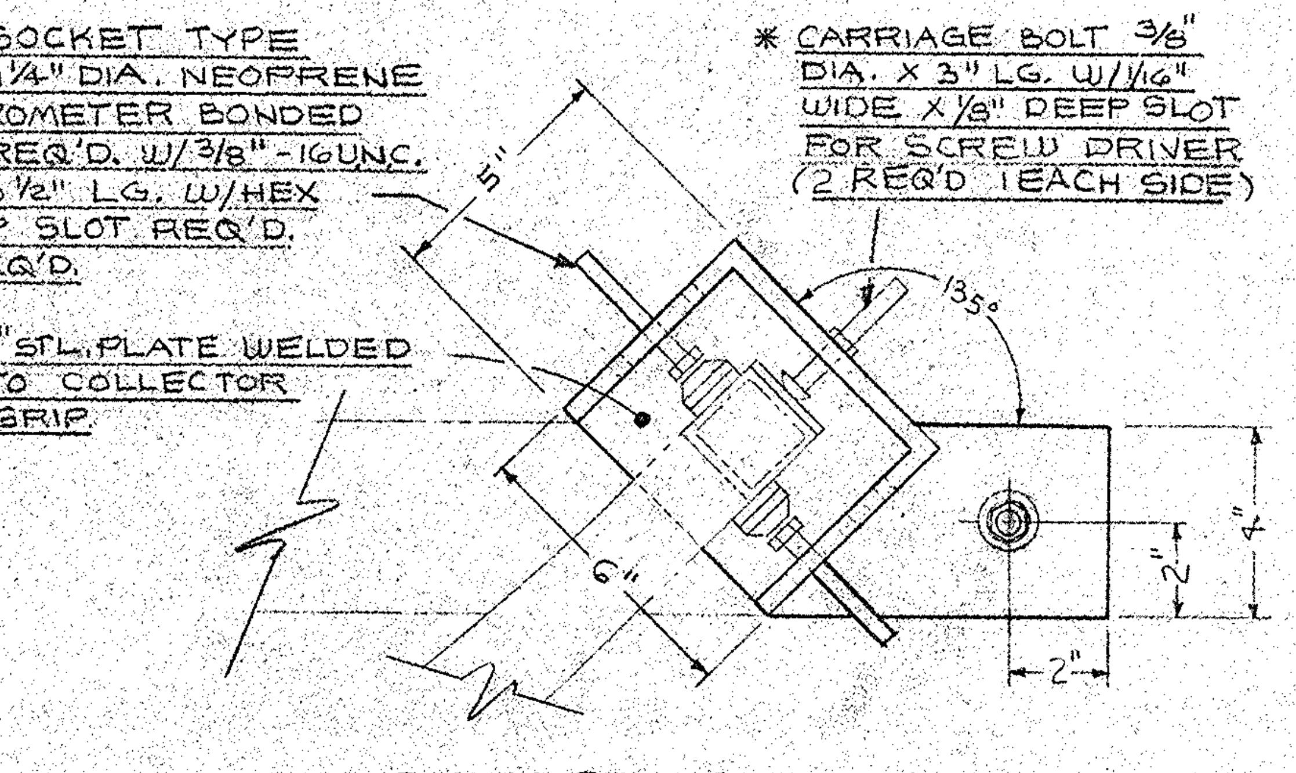
"SIGHT SCOPE" TO MACHINE SLIDE ADAPTER PLATE (MAKE FROM ¼" STL. STOCK)
SCALE: ½ SIZE



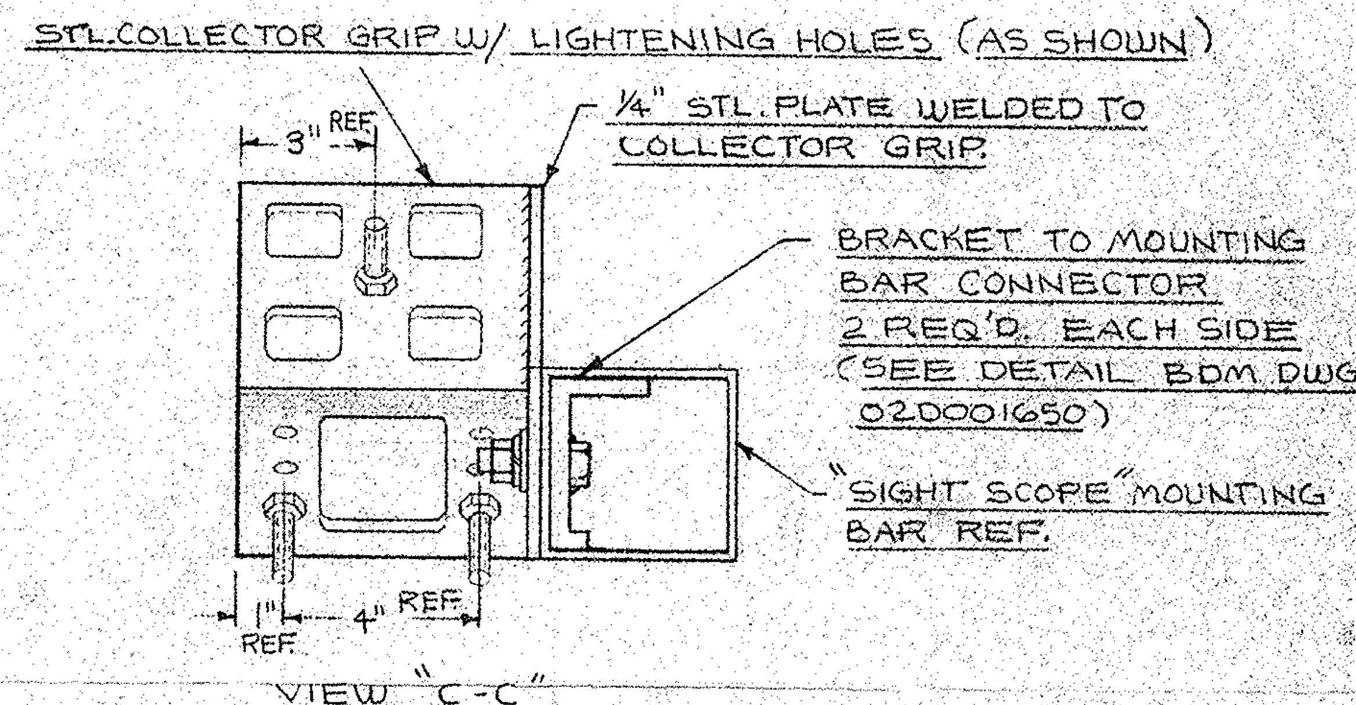
PLAN VIEW
"SIGHT SCOPE" MOUNT
SCALE: 1½"=1'-0"



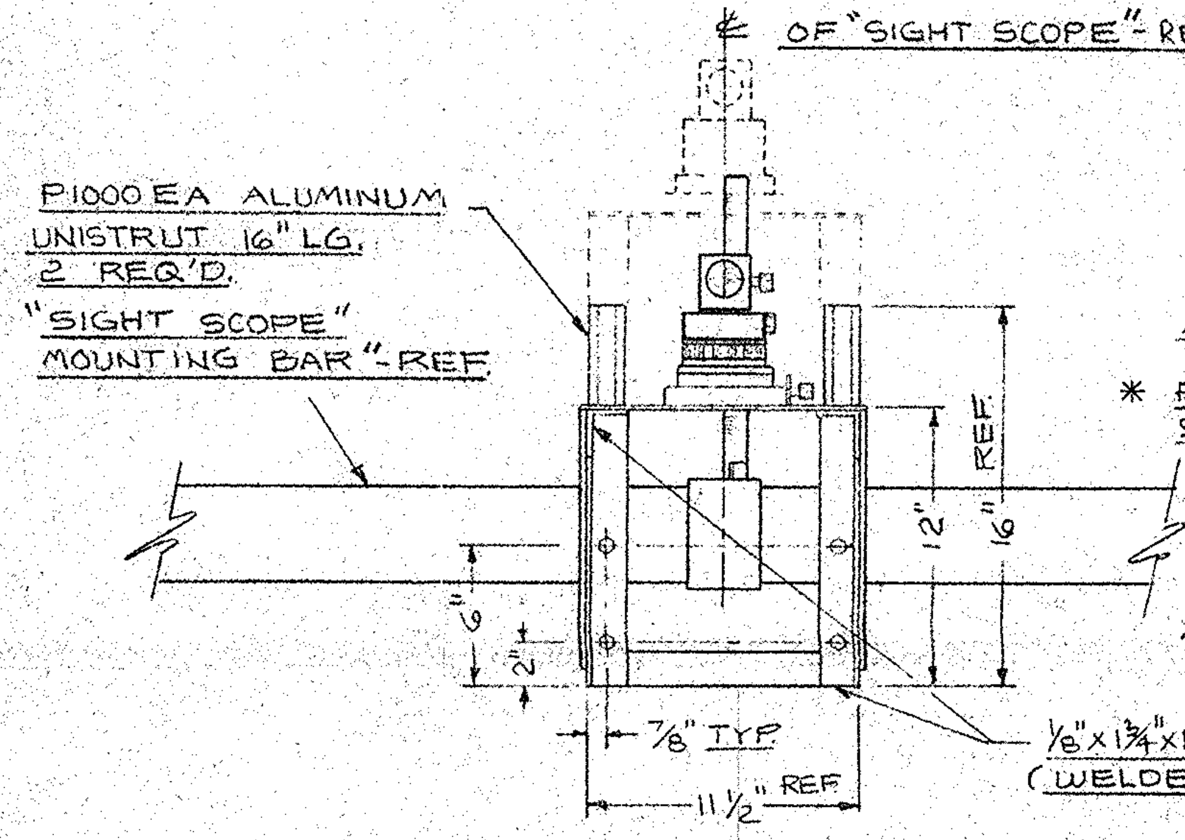
BOTTOM VIEW
* REGULAR DUTY LEAD SCREW # R-334L MILWAUKEE MACHINE SLIDE
SCALE: ½ SIZE



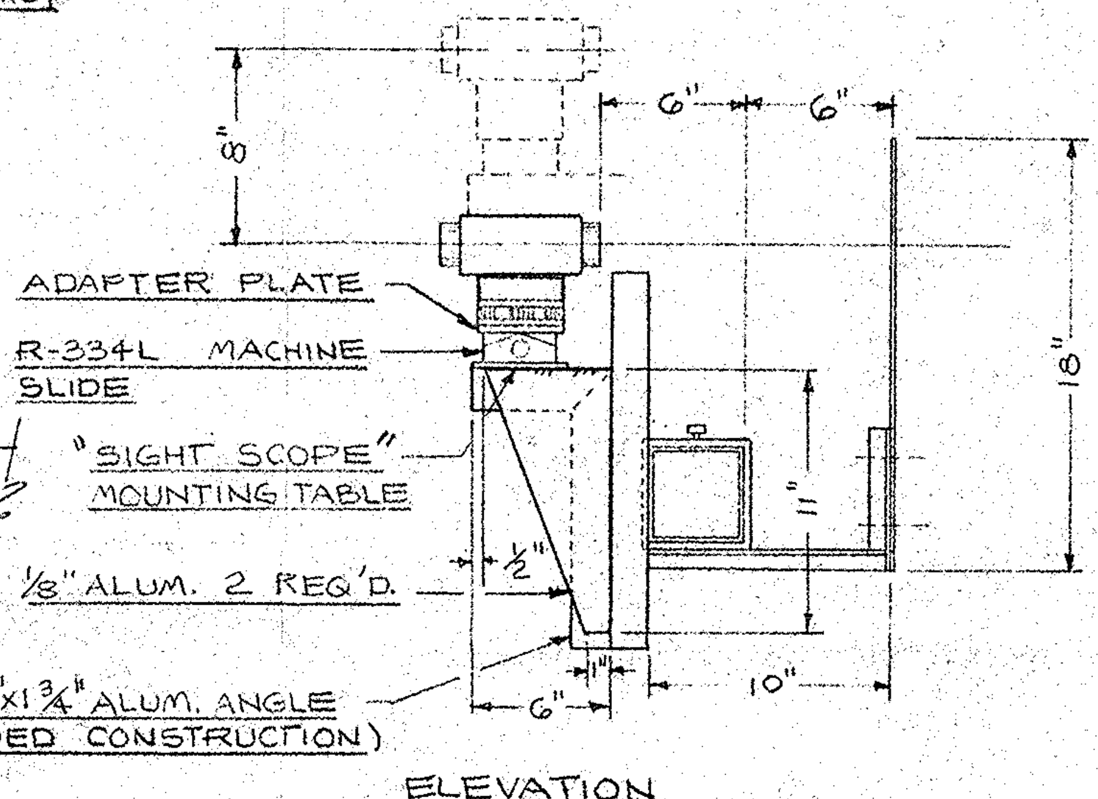
SIGHT SCOPE MOUNTING BRACKET DETAIL
SCALE: ¼ SIZE



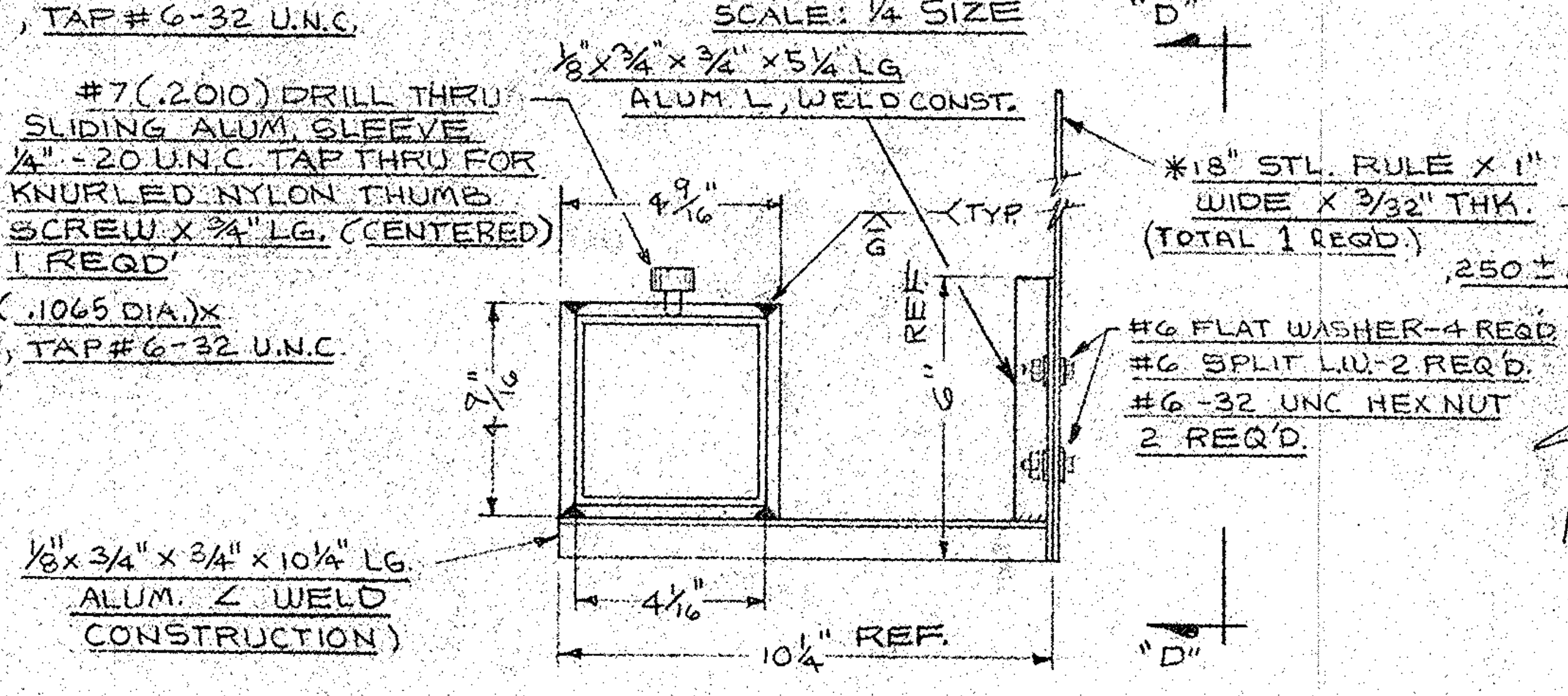
VIEW "C-C"
SCALE: ¼ SIZE



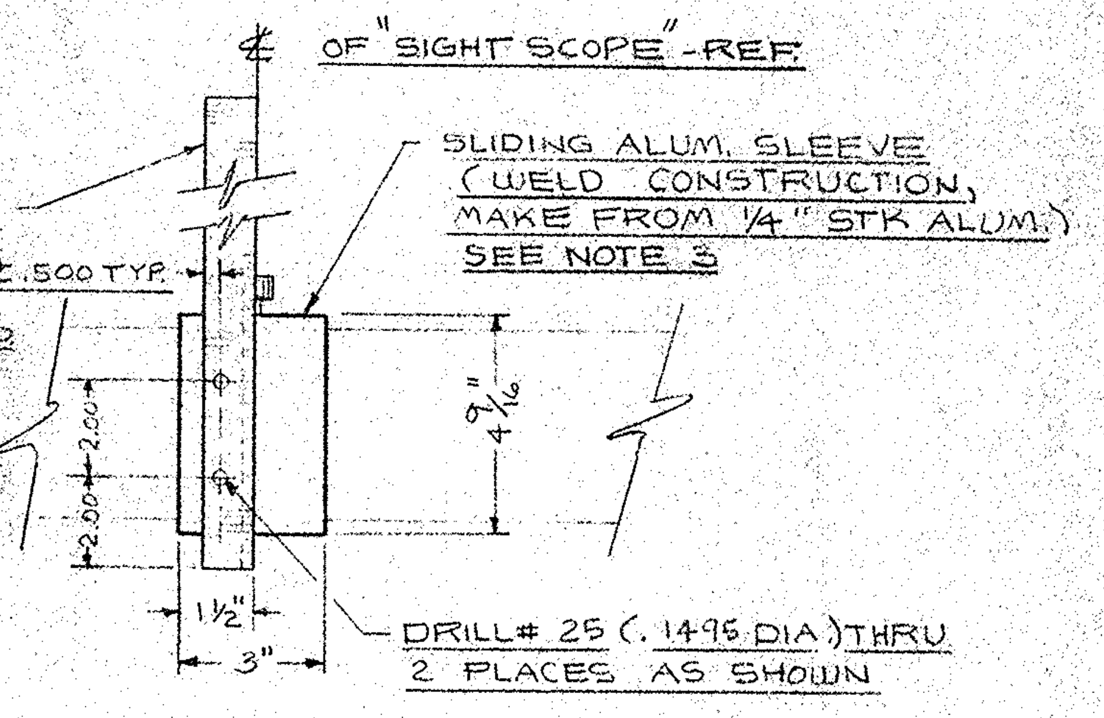
END VIEW
SCALE: 1½"=1'-0"



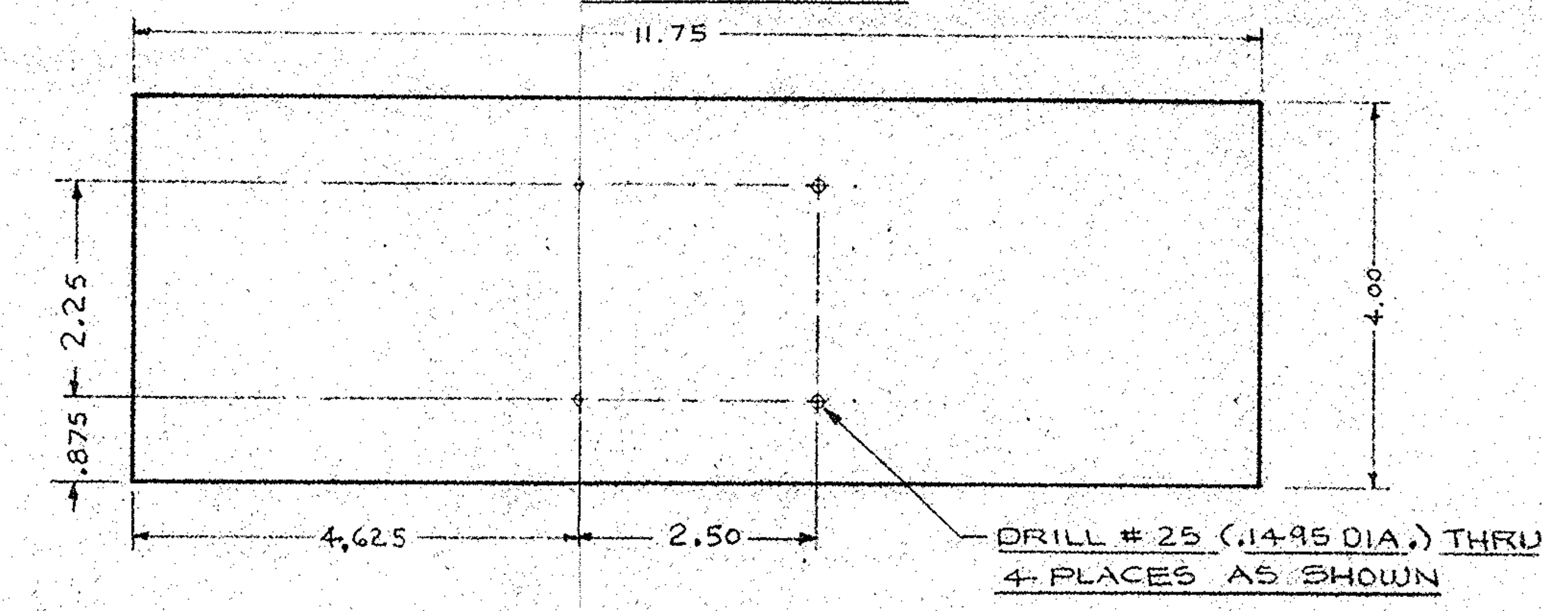
ELEVATION
SCALE: 1½"=1'-0"



ADJUSTABLE SLIDING SCALE DETAIL
(MAINTAIN 4 1/16" INSIDE DIM. OF ALUM. SLEEVE)
SCALE: ¼ SIZE



VIEW "D-D"
(HARDWARE NOT SHOWN THIS VIEW FOR CLARITY)
SCALE ¼ SIZE



"SIGHT SCOPE MOUNTING TABLE"
(MAKE FROM ⅛" STK ALUMINUM)
SCALE: ½ SIZE

NOTES:

1. THIS DWG. TO BE USED IN CONJUNCTION WITH DWG. 02D00 1450
2. ALL HARDWARE SHOWN THIS DWG. TO BE CADMIUM PLATED UNLESS OTHERWISE SPECIFIED.
3. ALL ALUMINUM ASSEMBLIES TO BE STRUCTURAL 6061 T6
4. * DENOTES FURNISHED BY BDM.

NO. REQ'D	PART NO.	MATERIAL	DESCRIPTION	ITEM N

LIST OF MATERIAL

DRAWN: K. COX	DATE: 1/4/81	MATERIAL:	
CHECKED:	2-12-81	FINISH:	
ENGINEER W			
PROJ. ENGR.			
PROGRAM MANAGER Wayne K. Kauffman	2/20/81	TOLERANCES: xx ± .03 xxx ± .010 UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	
		CONTRACT OR COST CENTER	

NEXT ASS'Y.

APPLICATION

THE BDM CORPORATION
2600 YALE BLVD., S.E., ALBUQUERQUE, NM 87106

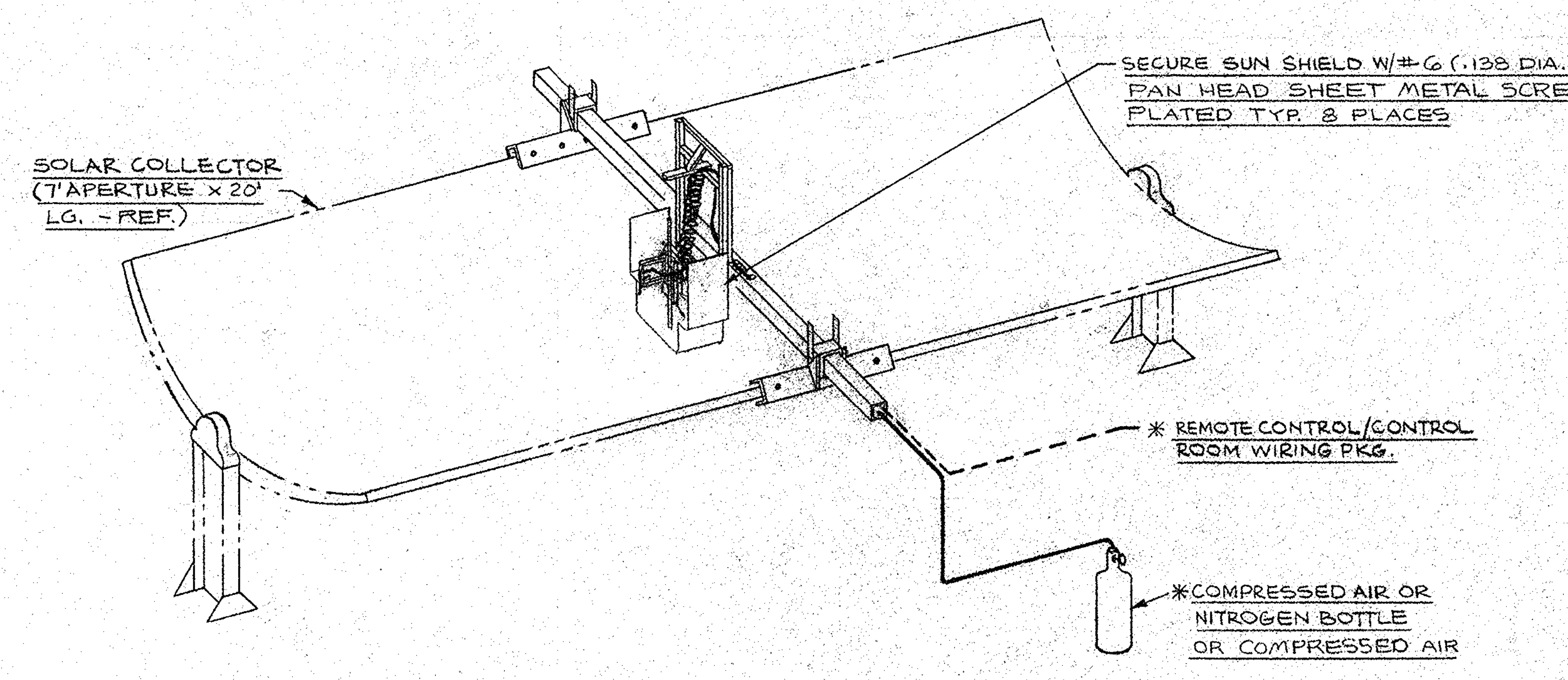
JUL 27 1981

TITLE: TROUGH SIGHTING DEVICE

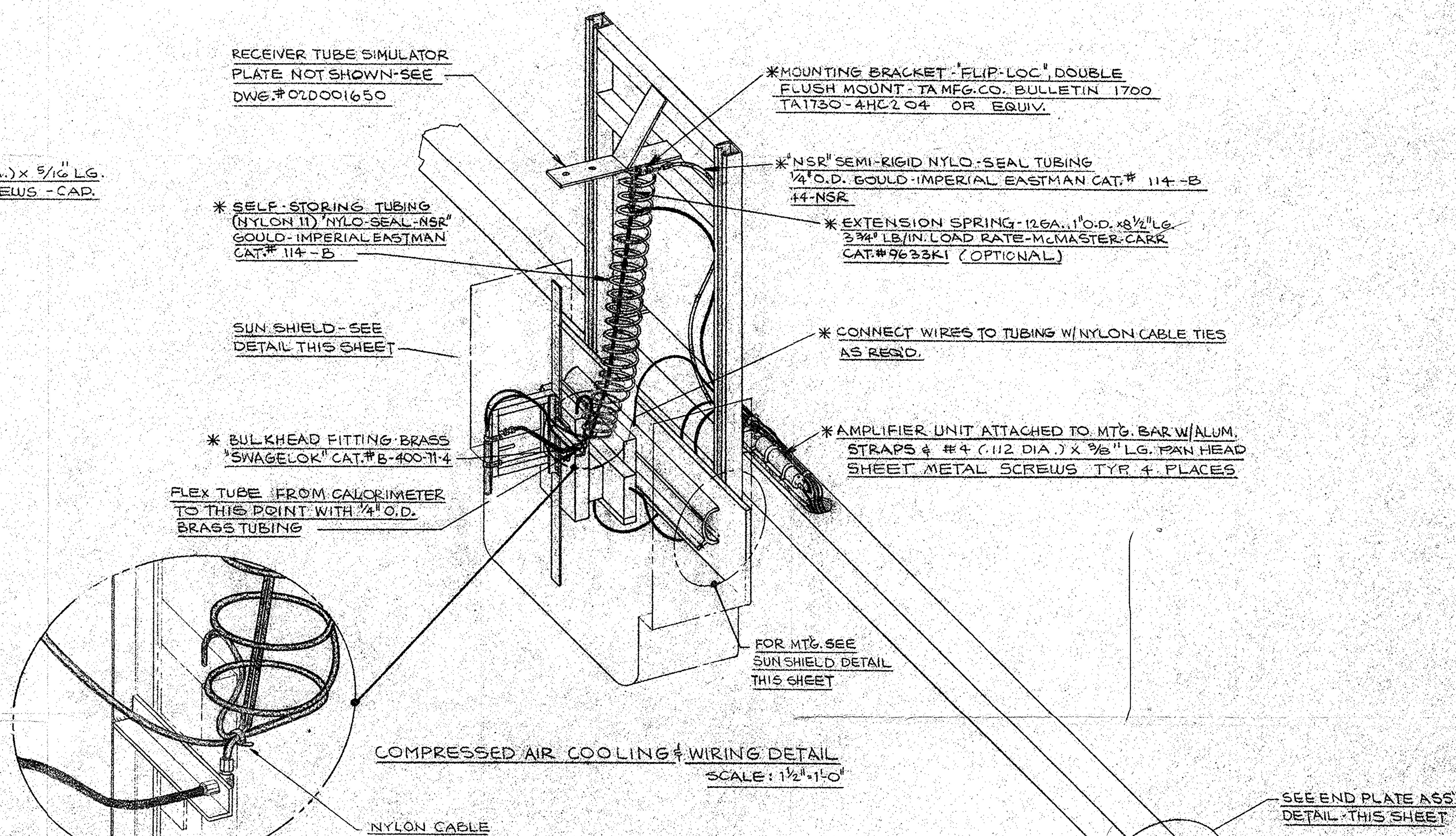
(S.P.I.G.)

CODE IDENT. 52308
SIZE D
DWG. NO. 02D001654
REV
SCALE: AS NOTED
SHEET 1 OF 1

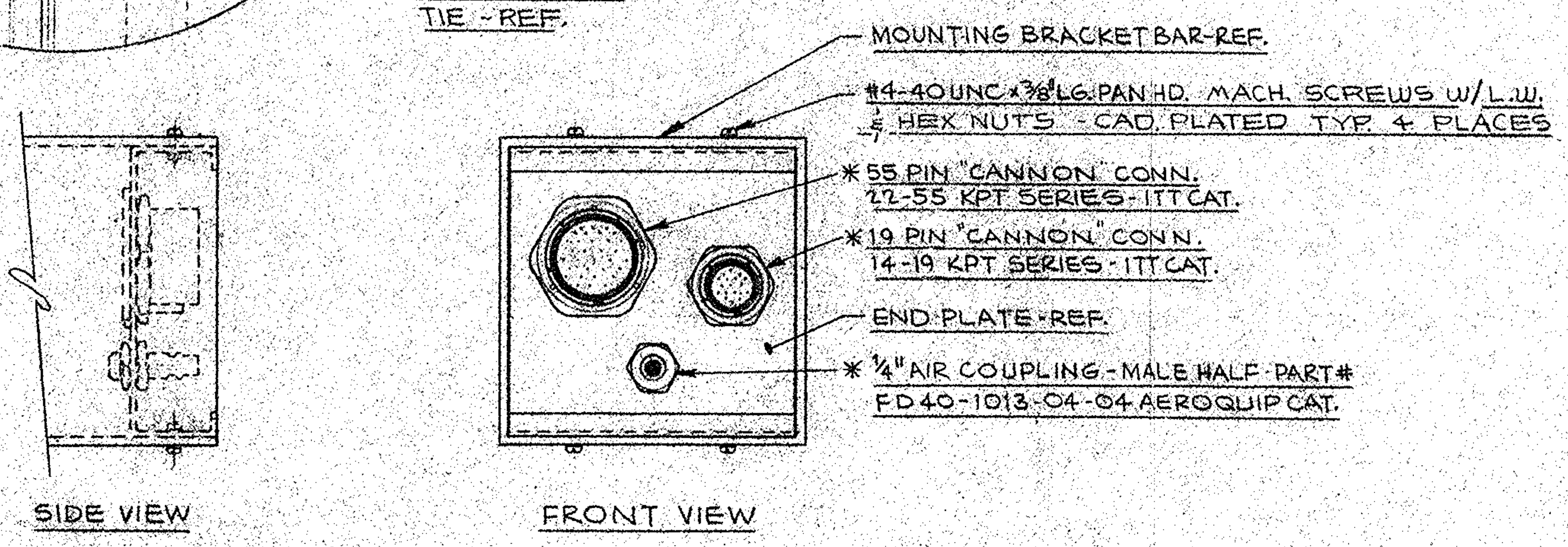
BRUNING 40-105



SOLAR PROFILE INTENSITY GAUGE (S.P.I.G)
COMPRESSED AIR COOLING SYSTEM
NOT TO SCALE



COMPRESSED AIR COOLING & WIRING DETAIL
SCALE: 1 1/2" = 1'-0"



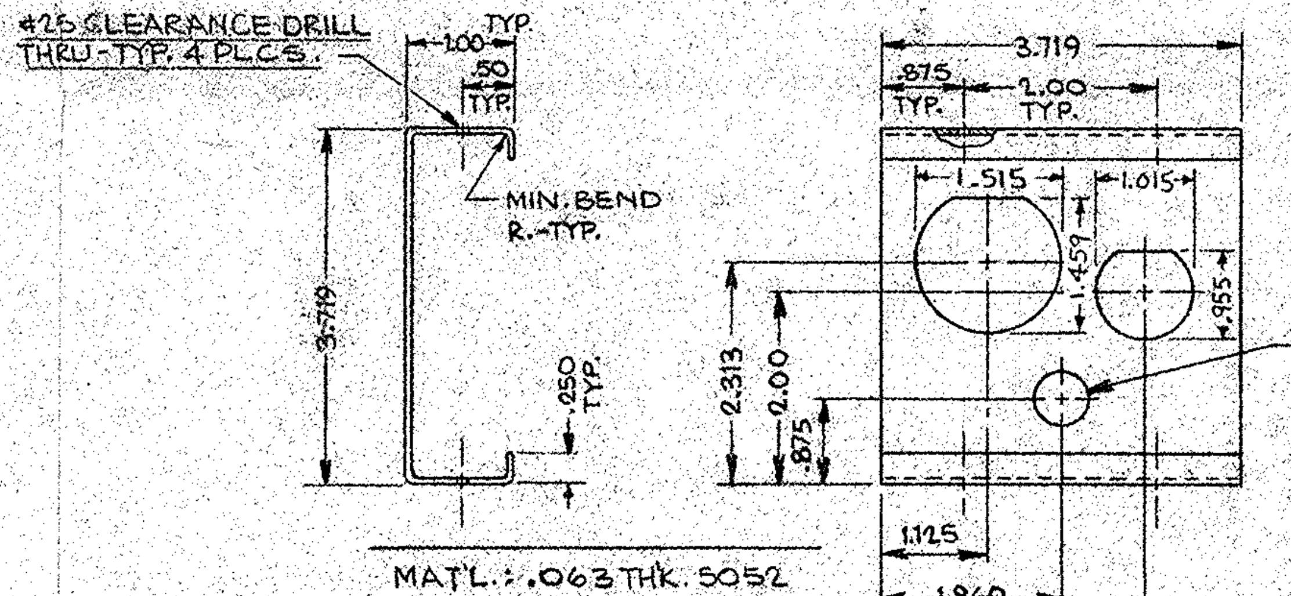
SIDE VIEW

FRONT VIEW

NOTES:

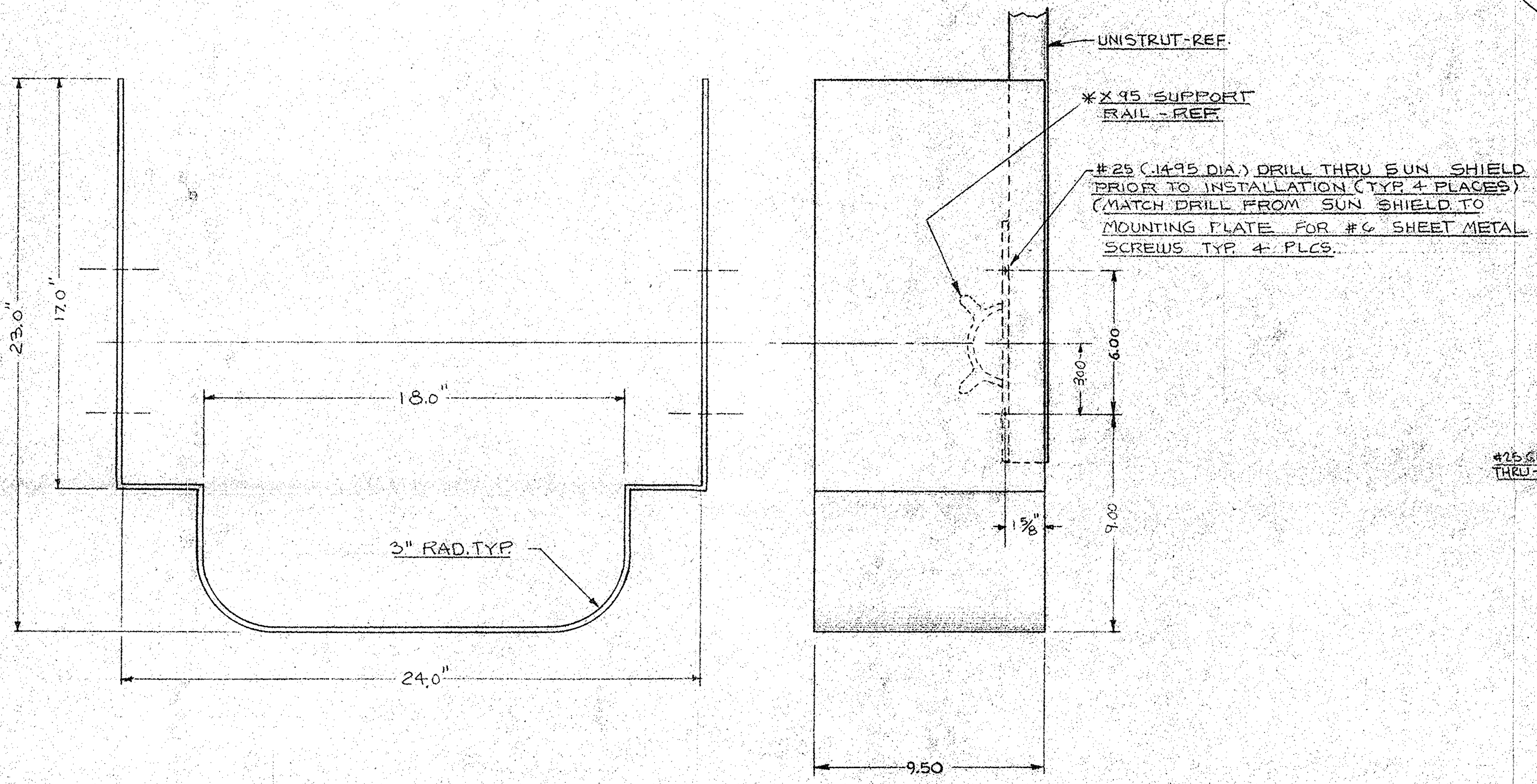
1. ALL CONNECTORS IN END PLATE ARE "QUICK-DISCONNECT" TYPE.
2. * DENOTES FURNISHED BY BDM.

END PLATE ASSEMBLY DETAIL
SCALE: HALF SIZE



MAT'L.: .063 THK. 5052 ALUM. STK.

END PLATE
SCALE: HALF SIZE



S.P.I.G. SUN SHIELD DETAIL
SCALE: 1/4 SIZE

MAT'L.: 3/32" (.094) THK. 6061-T6 ALUM.
FINISH: BLACK ANODIZED

NO. REQ'D	PART NO.	MATERIAL	DESCRIPTION	IT

LIST OF MATERIAL

DRAWN: B. SHRAKE — DATE: 2-12-81
CHECKED: — 2-12-81
ENGINEER W — 2/12/81
PROJ. ENGR.
PROGRAM MANAGER Wayne — 2/20/81
MATERIAL:
FINISH:
TOLERANCES:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
CONTRACT OR COST CENTER

NEXT ASS'Y.
APPLICATION

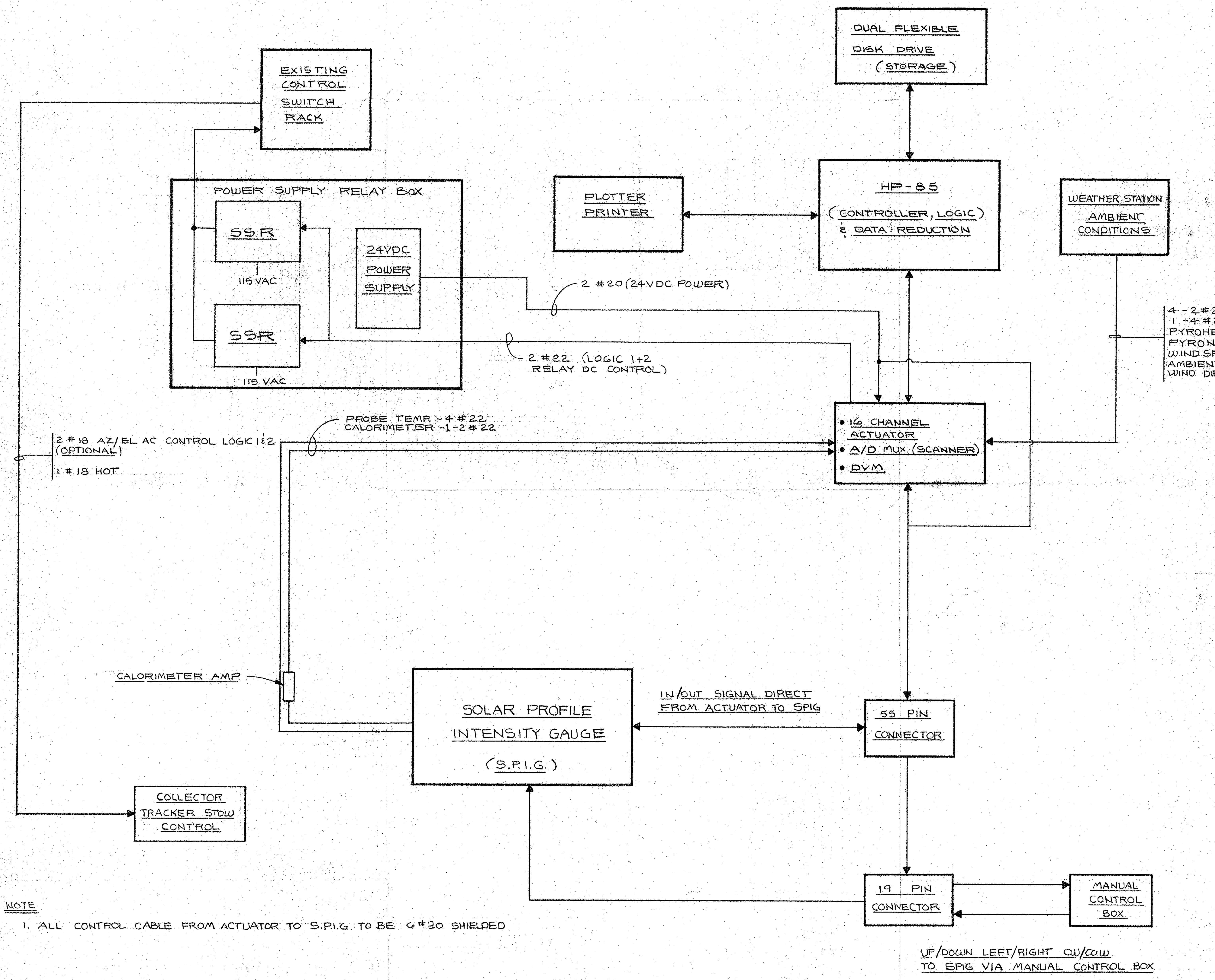
THE BDM CORPORATION
2600 YALE BLVD., S.E., ALBUQUERQUE, NM 87106

JUL 27 1981

TITLE:
SOLAR PROFILE INTENSITY GAUGE
WATER COOLING & WIRING ASSEMBLY
(SPIG)

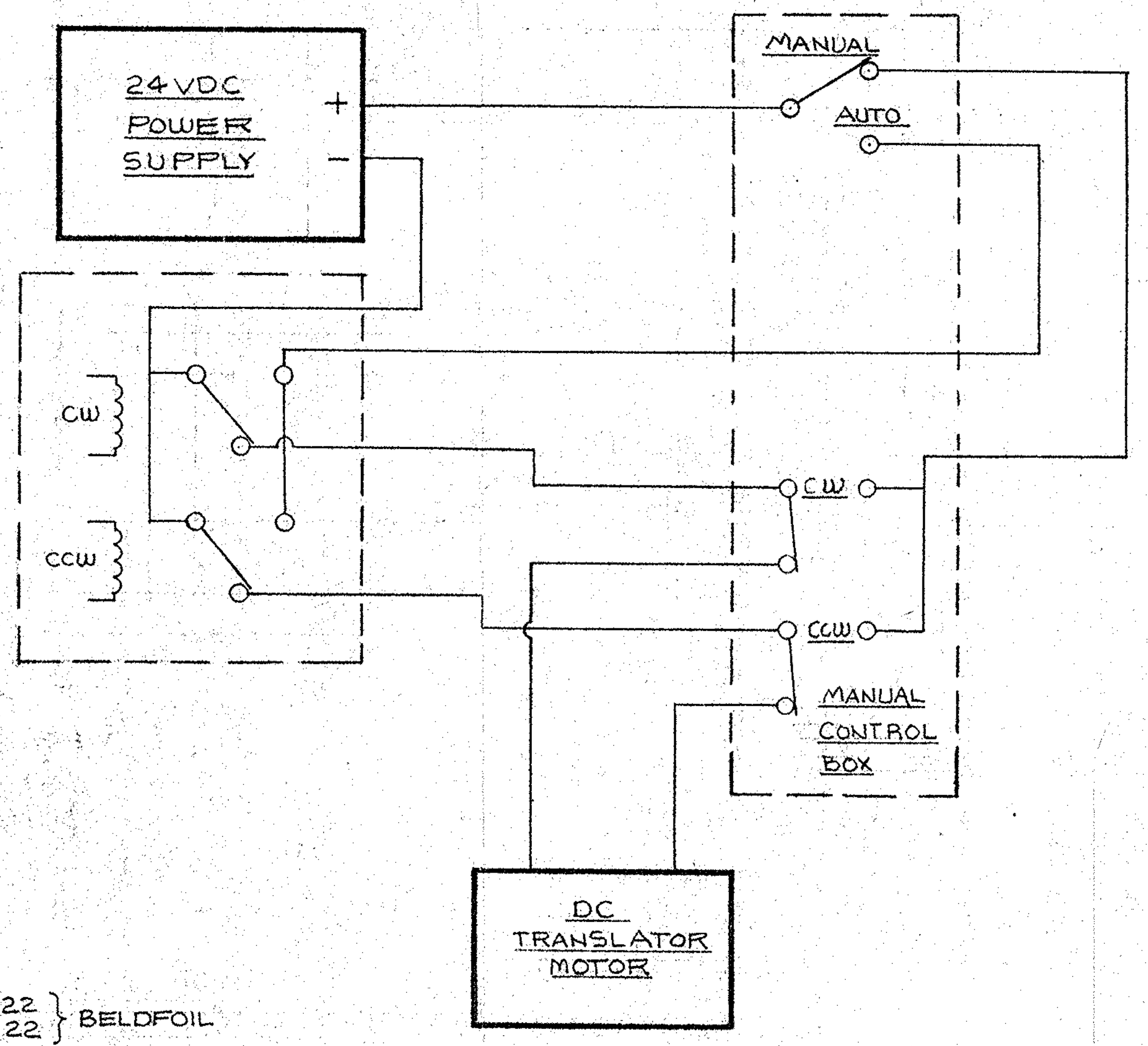
CODE IDENT. 52308
SIZE D
DWG. NO. 02D001653
SCALE: AS NOTED
SHEET 1 OF 1

BRUNING 40-105



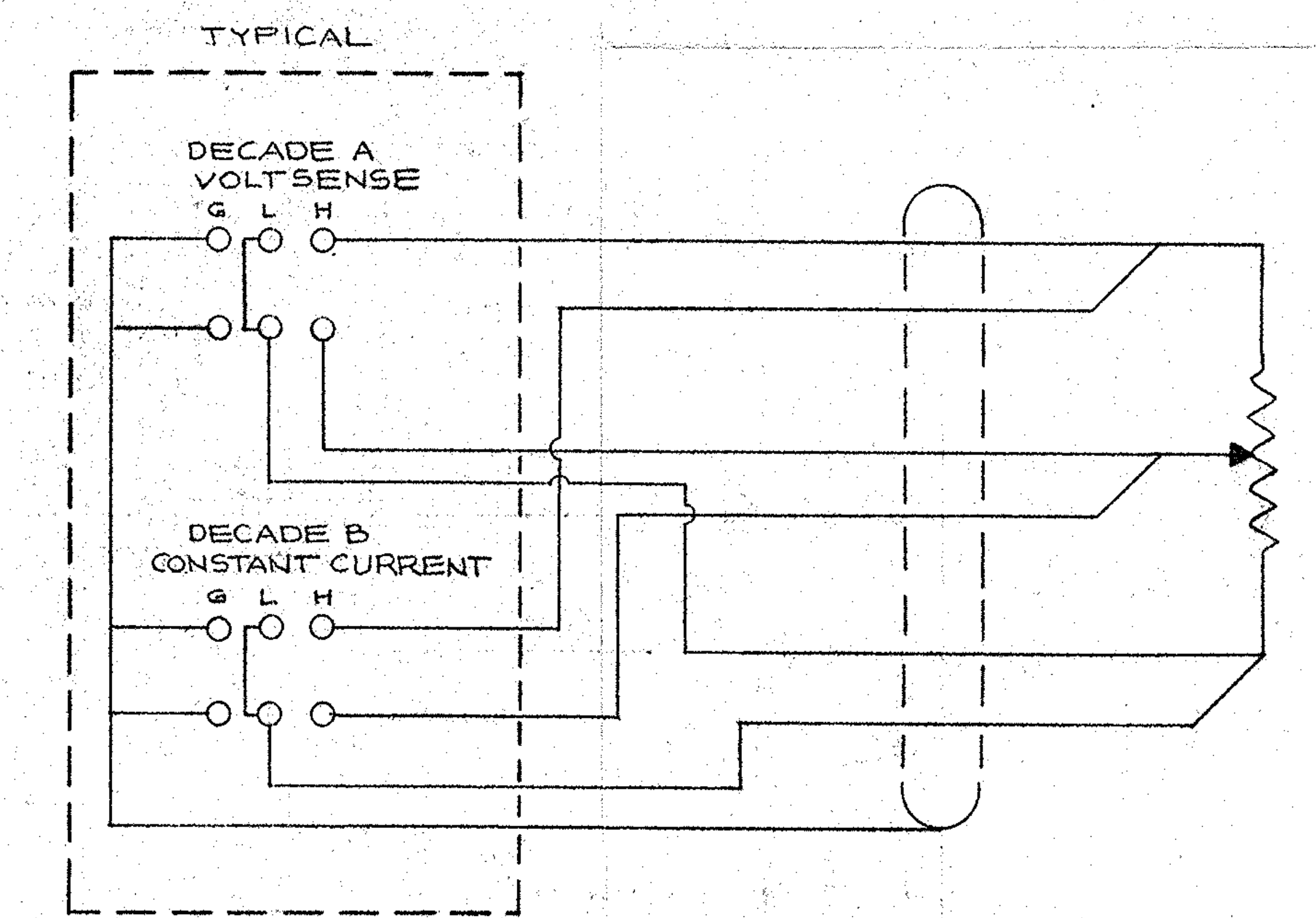
NOTE

1. ALL CONTROL CABLE FROM ACTUATOR TO S.P.I.G. TO BE 6 #20 SHIELDED



DETAIL A

NOTE: TYPICAL EACH TRANSLATOR DRIVE



TRANSLATOR POSITION POTENTIOMETER 4 WIRE WIRING CONNECTION

NOTE: FOR 4 WIRE POTENTIOMETER MEASUREMENTS, 20 CHANNEL A/D CARD IN SCANNER MUST BE SUBDIVIDED INTO SEPERATE DECADE A (VOLTSENSE) AND DECADE B (CONSTANT CURRENT SOURCE).

NO. REQ'D	PART NO.	MATERIAL	DESCRIPTION	ITEM N

LIST OF MATERIAL

DRAWN: K COX DATE: 10/17/80
CHECKED: Q 9-12-81
ENGINEER
PROJ. ENGR.
PROGRAM MANAGER
MATERIAL:
FINISH:
TOLERANCES:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
CONTRACT OR COST CENTER
NEXT ASS'Y.
APPLICATION

THE BDM CORPORATION
2600 YALE BLVD., S.E., ALBUQUERQUE, NM 87106

JUL 27 1981

TITLE:
CONTROLLER & DATA AQUISITION
SYSTEM BLOCK DIAGRAM
(S.P.I.G.)

CODE IDENT. 52308
SIZE D
DWG. NO. 02D001652
REV
SCALE: NO SCALE
SHEET 1 OF 1

BRUNING 40-105

NOTES:

1. THIS DWG. TO BE USED IN CONJUNCTION WITH BDM DWGS. 02D001650 & 02D001653
2. ADAPTER PLATE DRILLING TO MATCH EXISTING TRANSLATOR HOLES
3. ALL REFERENCE TO "KLINGER SCIENTIFIC CORP." CATALOG NUMBERS ARE KLINGER CATOLOG # 4-09 & SYSTEM X 95 CATALOG.
4. 6063-T5 3/4" x 3/4" EXTRUDED ALUMINUM TUBING W/ .062 WALL THICKNESS. (WELD CONSTRUCTION AS SHOWN)
5. ALL WIRING & COOLING CONNECTIONS NOT SHOWN THIS DW SEE BDM DWG. 02D001653.
6. 12" STEEL RULES TO BE "COMBINATION SQUARE" REMOVABLE 12" GROOVED STEEL BLADE OR EQUIVALENT.
7. * DENOTES FURNISHED BY BDM.

NO. REQ'D	PART NO.	MATERIAL	DESCRIPTION	ITEM

LIST OF MATERIAL

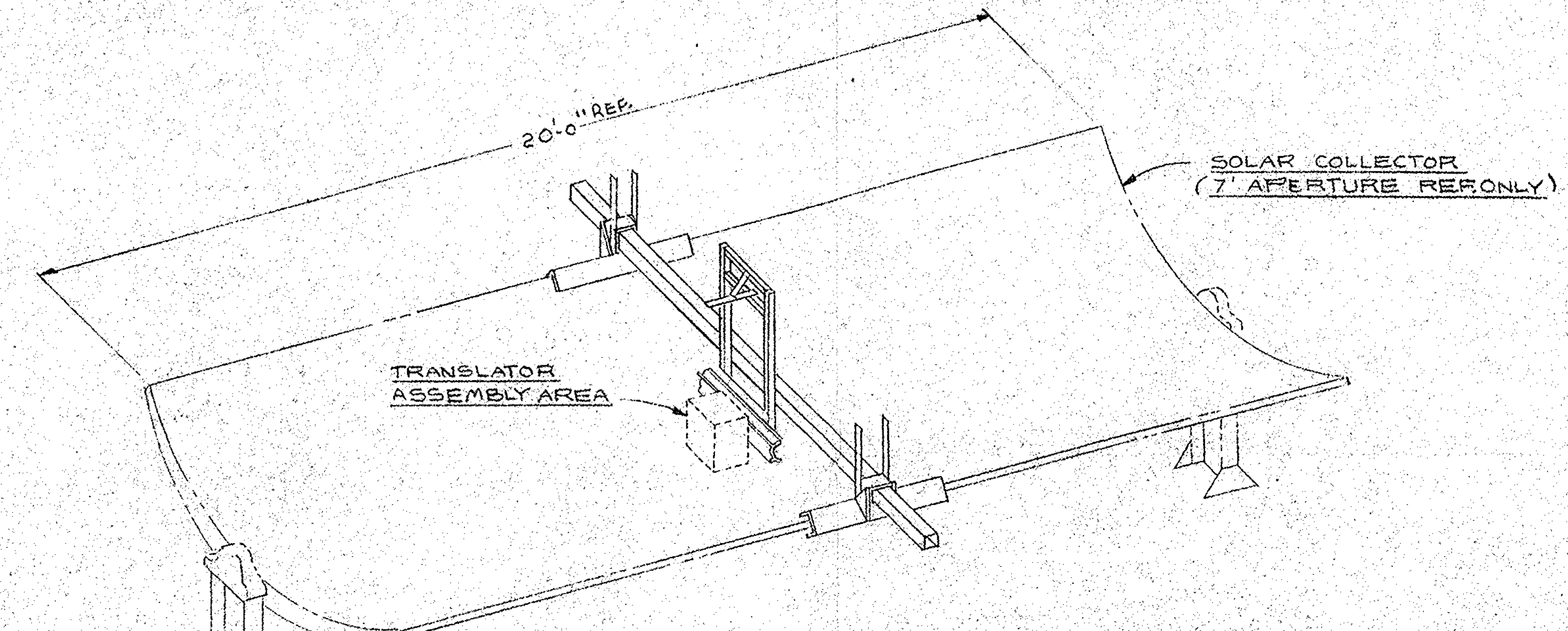
DRAWN: K COX DATE: 1/5/81
CHECKED: D. 2-12-81
ENGINEER W E 2/18/81
PROJ. ENGR.
PROGRAM MANAGER Wayne K. 2/20/81
MATERIAL:
FINISH:
TOLERANCES:
XX ± .03
XXX ± .010
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
CONTRACT OR COST CENTER
NEXT ASS'Y.
APPLICATION

THE BDM CORPORATION
2600 YALE BLVD., S.E., ALBUQUERQUE, NM 87106
JUL 27 1981

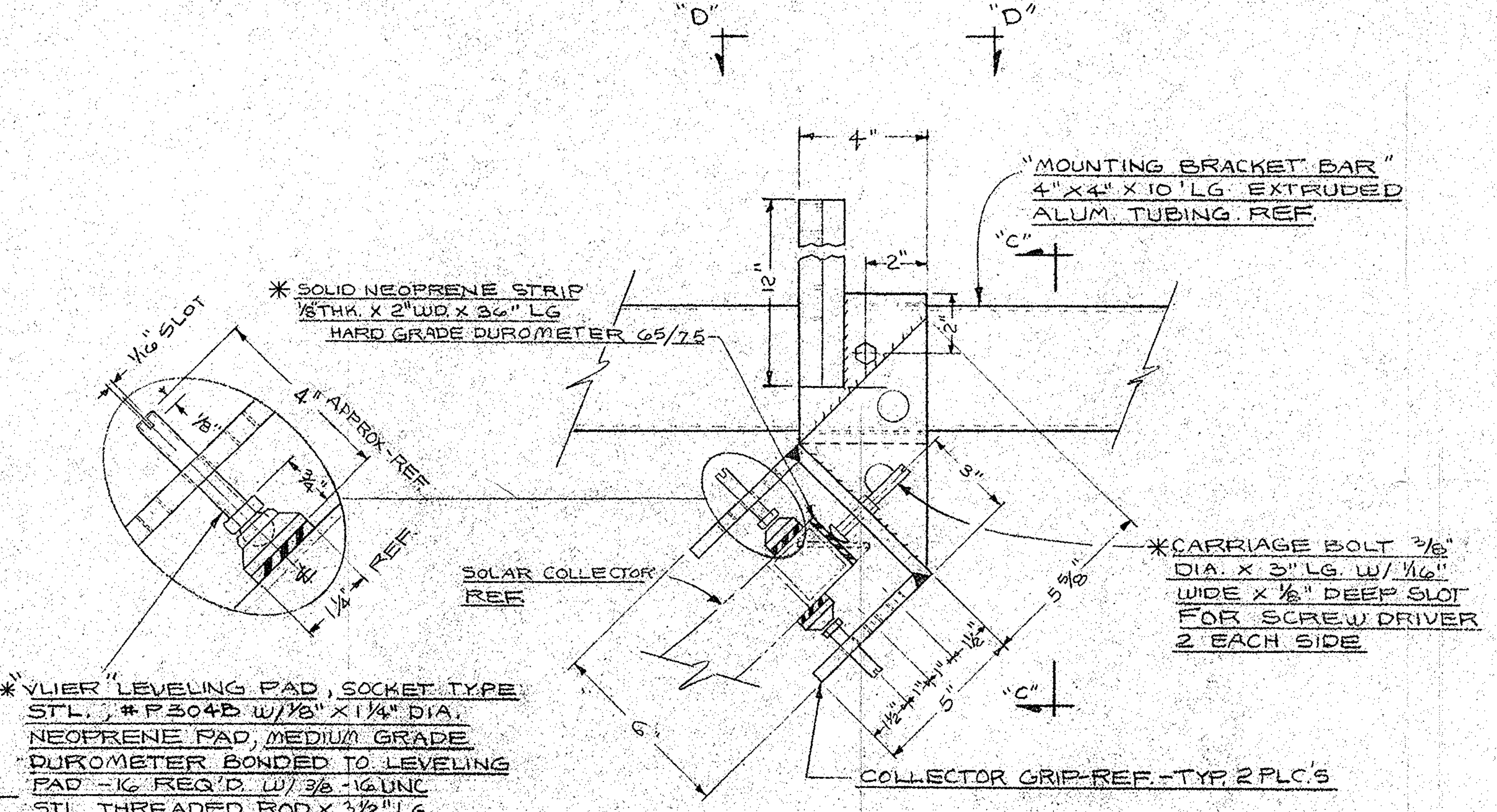
TITLE:
TRANSLATOR ASSEMBLY & PROBE
MOUNTING
(SPIG)

CODE IDENT. 52308
SIZE D
DWG. NO. 02D001651
RE
SCALE: AS NOTED
SHEET 1 OF 1

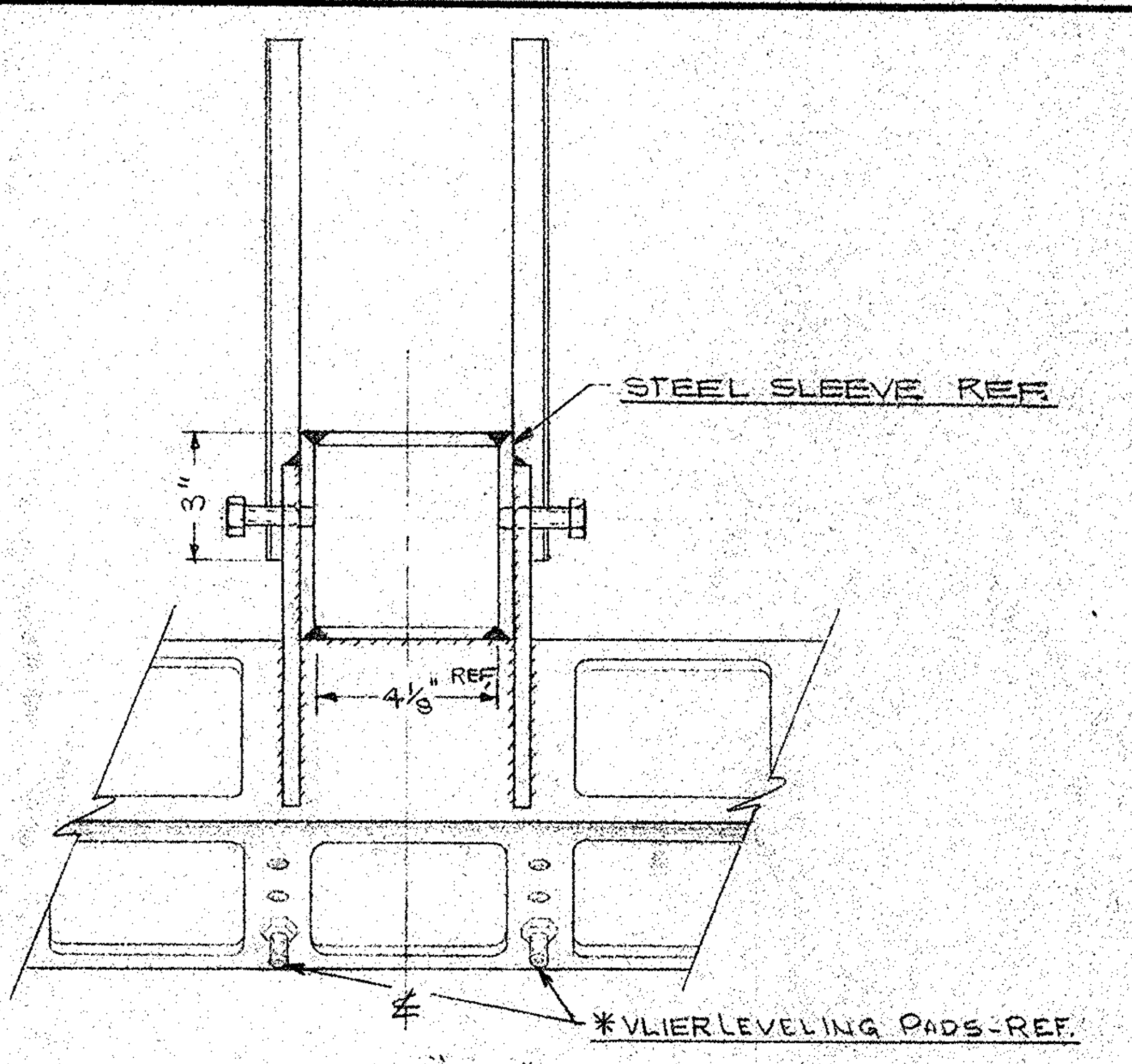
BRUNING 40-105



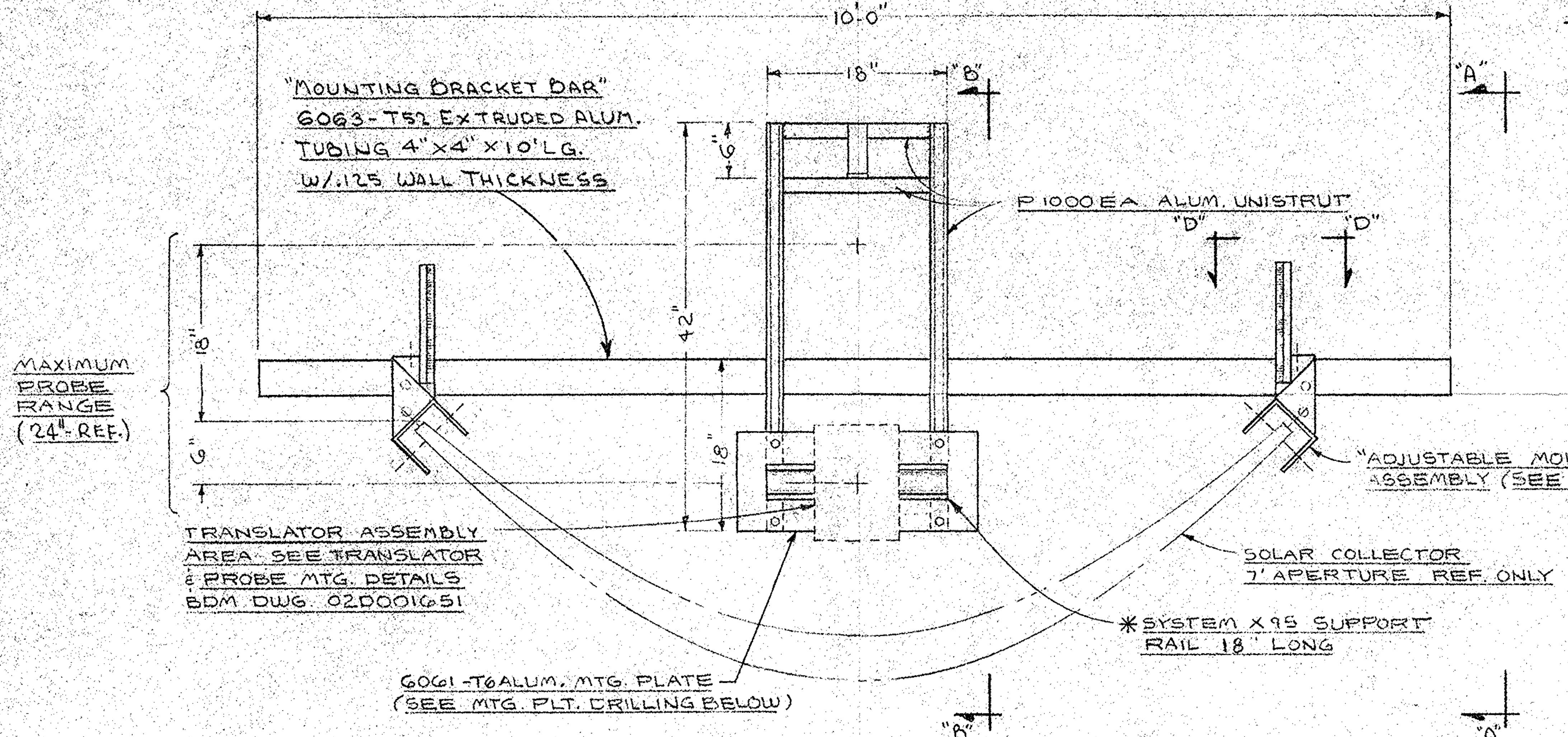
• SOLAR PROFILE INTENSITY GAUGE (S.P.I.G.) •
TRANSLATOR MOUNTING ASSEMBLY
NO SCALE



"ADJUSTABLE MOUNTING BRACKET" DETAIL
(DETAIL TYPICAL BOTH SIDES) MAKE FROM 3/8" STL. STOCK UNLESS OTHERWISE NOTED
SCALE: 1/4"=1'-0"

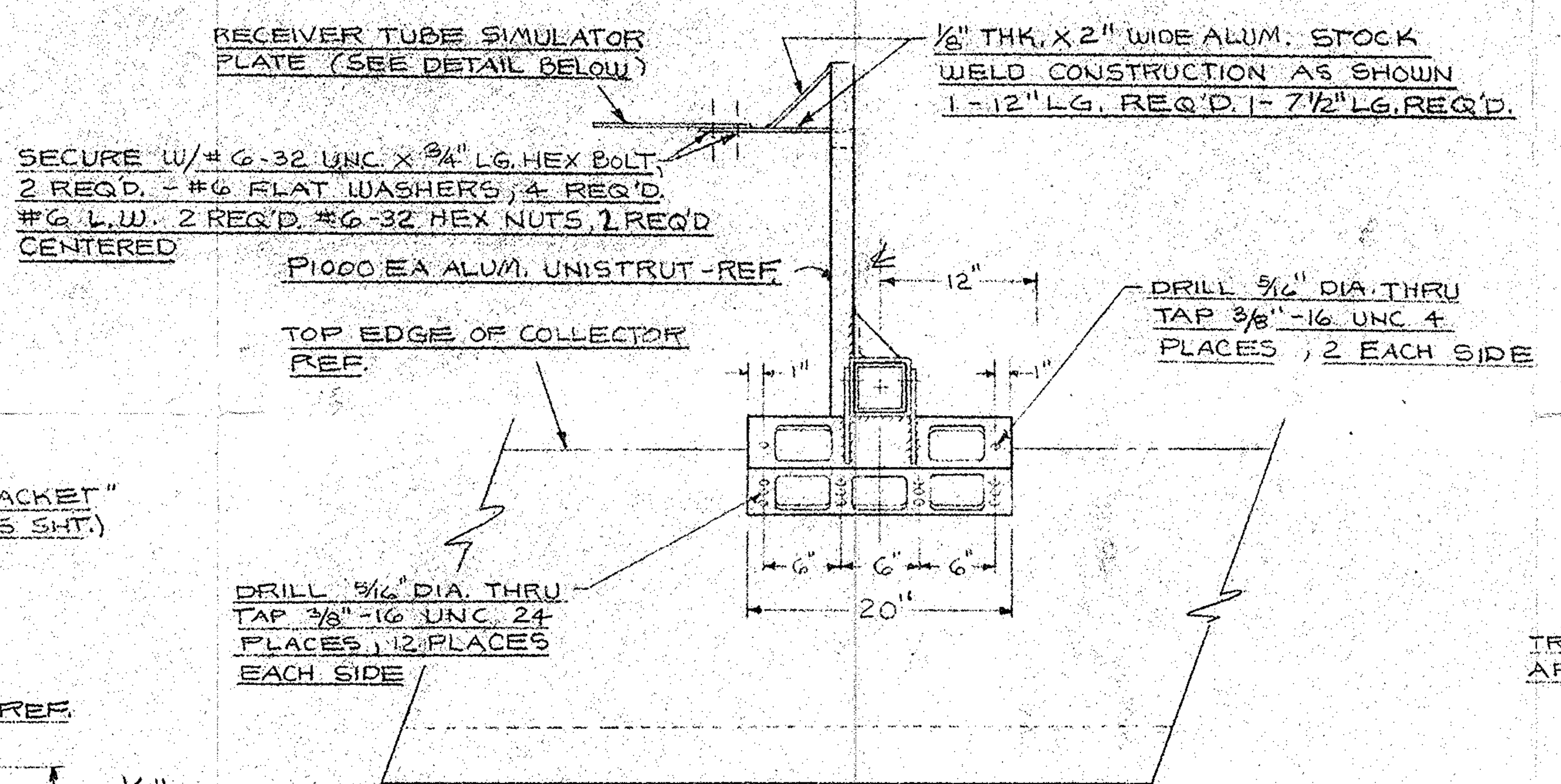


VIEW "C-C"
ADJUSTABLE MOUNTING BRACKET W/ LIGHTENING HOLES AS SHOWN
SCALE: 1/4=1'-0"

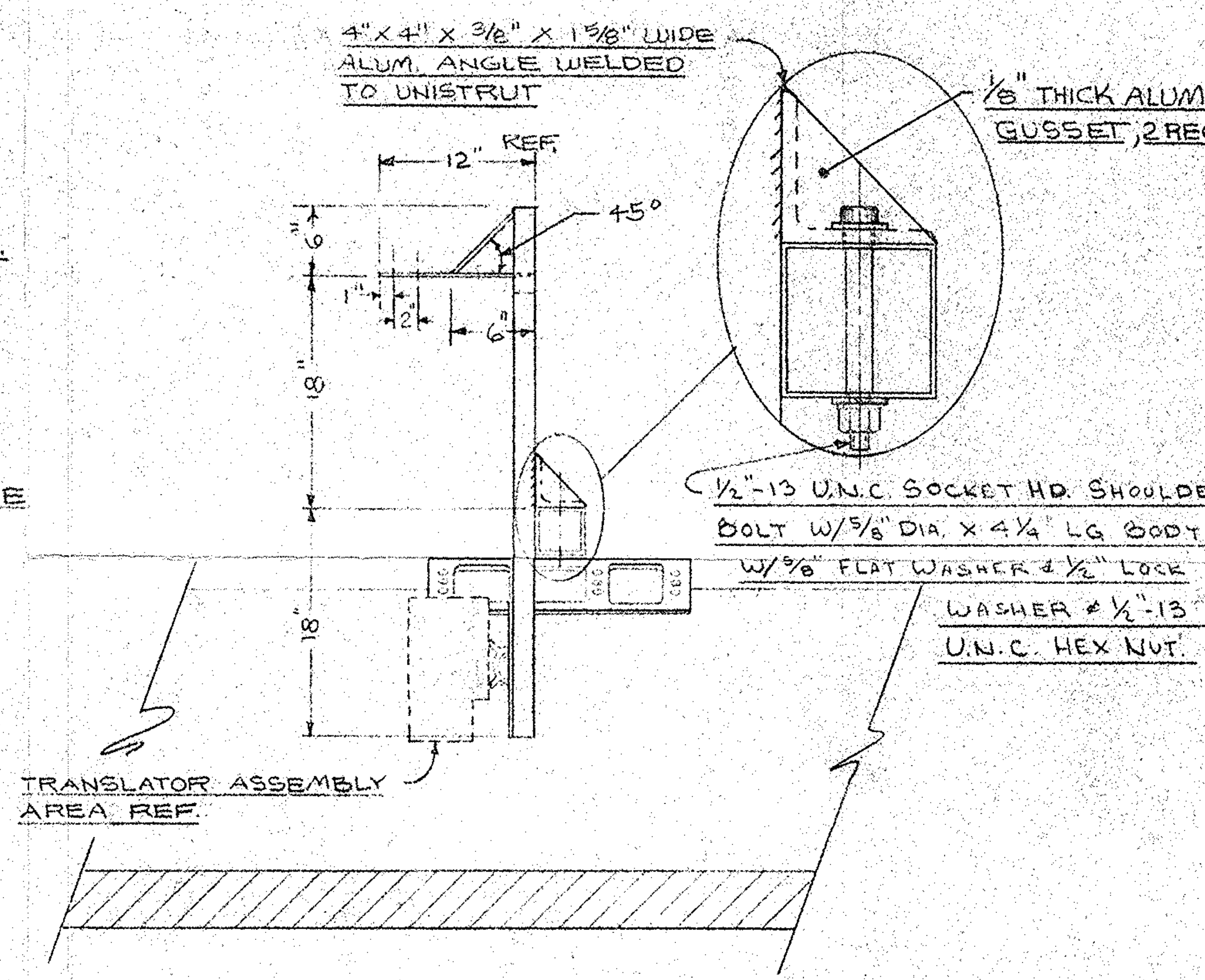


END VIEW

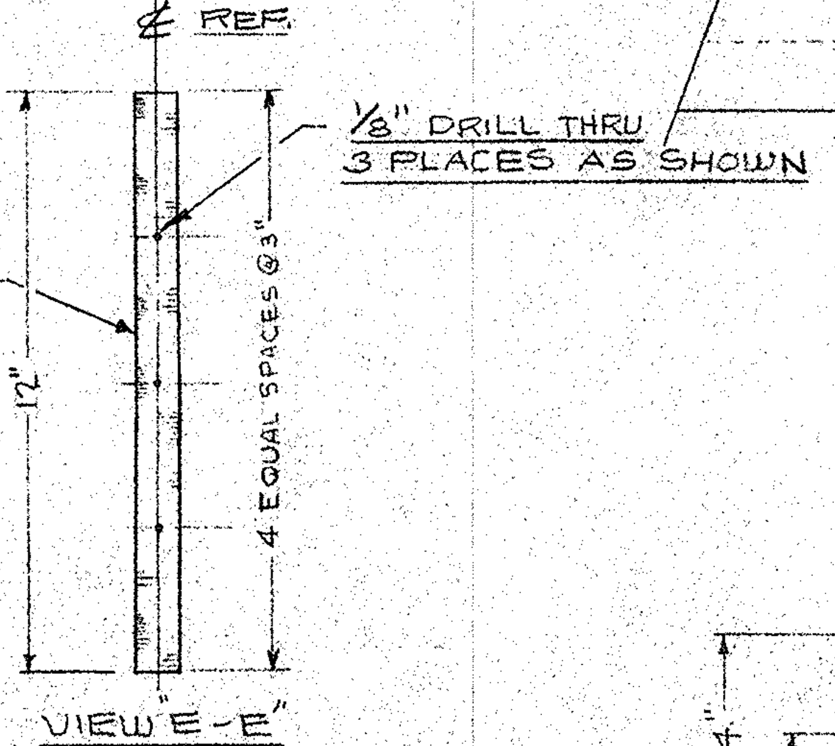
NOTE: ALUM. SUN SHIELD OMITTED FOR CLARITY (SEE DETAIL BDM DWG. 02D001653)
SCALE: 1"=1'-0"



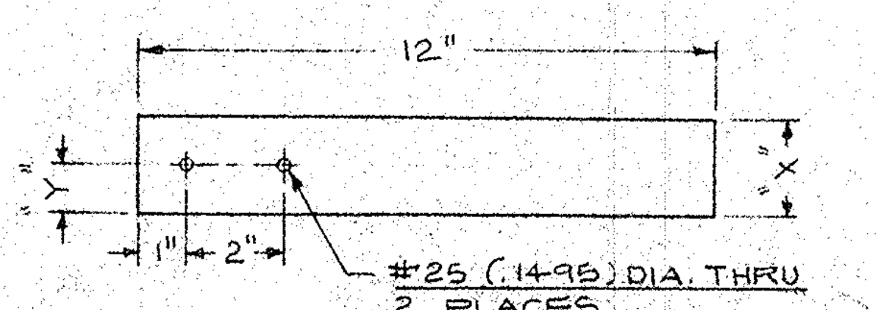
VIEW "A-A"
SCALE: 1"=1'-0"



VIEW "B-B"
(RECEIVER TUBE SIMULATOR PLATE OMITTED THIS VIEW FOR CLARITY)
SCALE: 1"=1'-0"



VIEW "E-E"

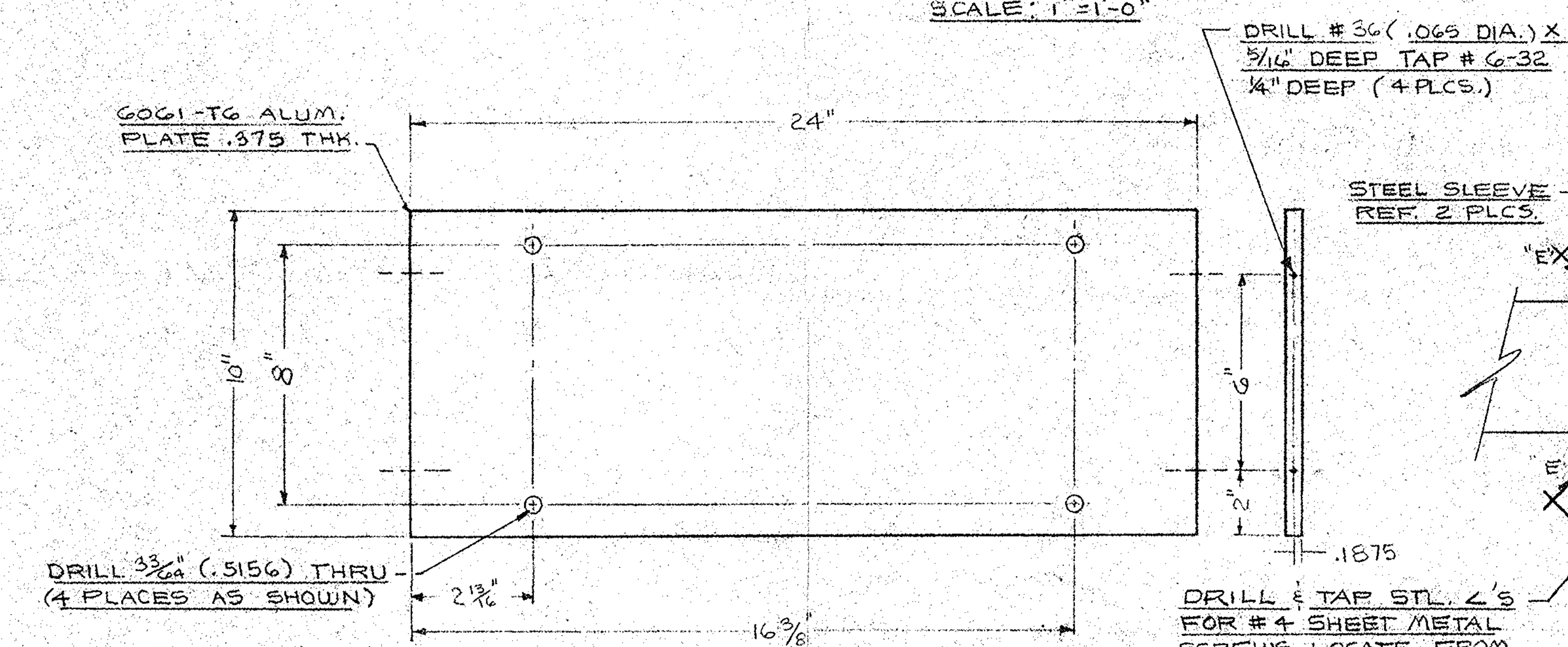


"X"	"Y"
1/2"	1/4"
1"	1/2"
1 1/2"	3/4"
2"	1"

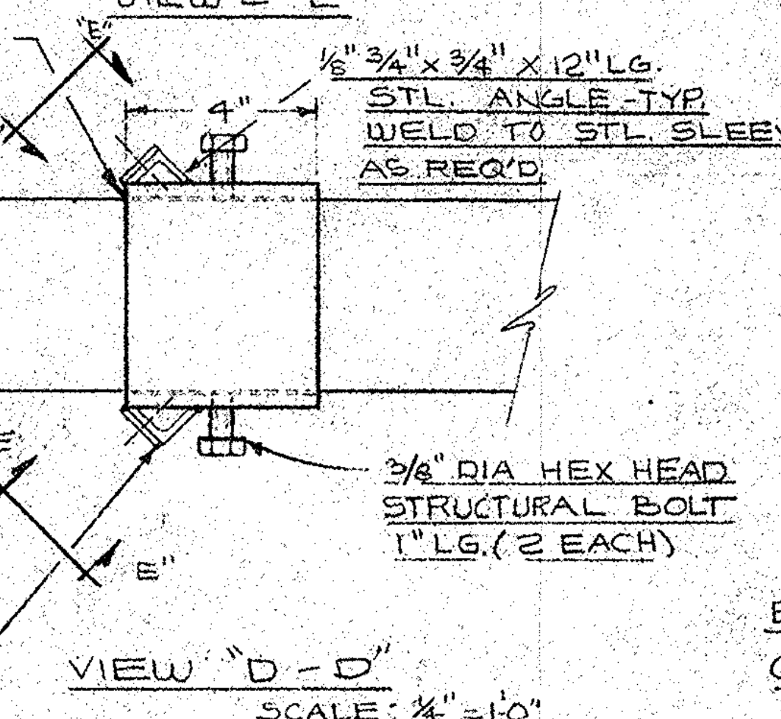
1 EACH REQ'D.

SIMULATOR PLATE DETAIL
MAKE FROM 1/8" THK. STK. ALUM.
SCALE: 1/4 SIZE

NOTE:
1. ALL STEEL ATTACHING HARDWAR
TO BE CADMIUM PLATED
2. * DENOTES FURNISHED
BY BDM.

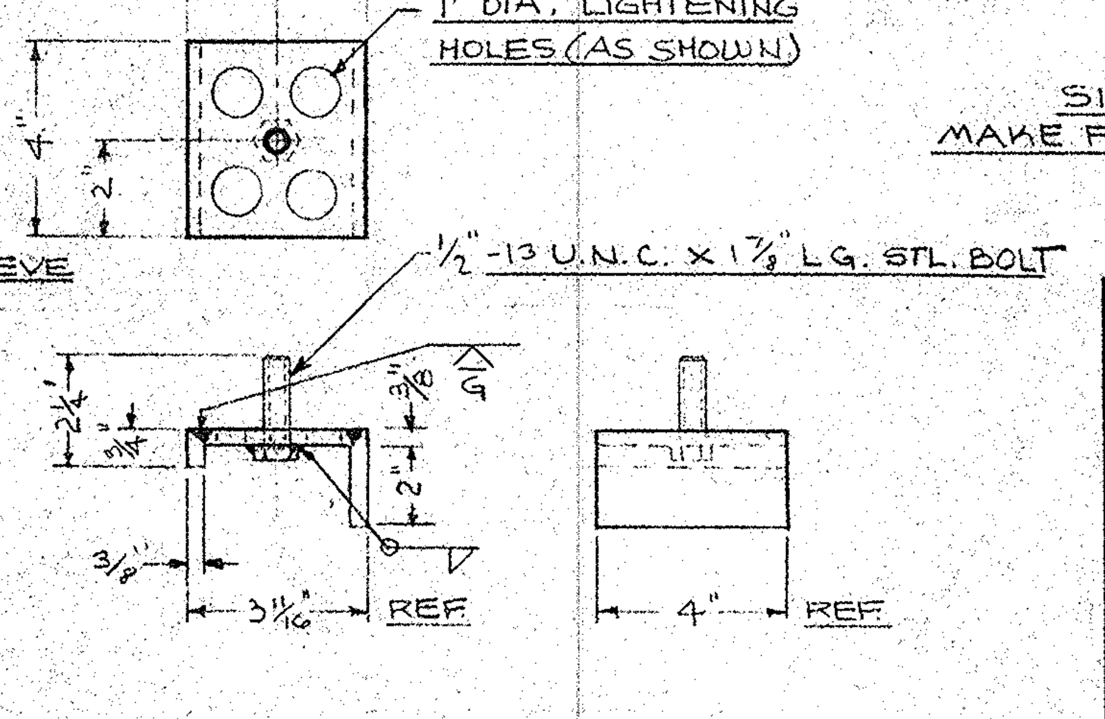


MOUNTING PLATE DRILLING
(MAKE FROM 3/8" STOCK.) SCALE: 3"=1'-0"



VIEW "D-D"
SCALE: 1/4"=1'-0"

NOTE: COLLECTOR GRIP NOT SHOWN THIS VIEW



BRACKET TO MOUNTING BAR
CONNECTOR-(WELD CONSTRUCTION)-2 REQ'D.
MAT'L.-STEEL VIEW "C-C" BDM DWG. 02D001654
SCALE: 1/4"=1'-0"

NO. REQ'D	PART NO.	MATERIAL	DESCRIPTION	ITEM
LIST OF MATERIAL				

DRAWN: K COX DATE: 1/2/81
CHECKED: 2-12-81
ENGINEER W 2/12/81
PROJ. ENGR.
PROGRAM MANAGER Wayne 2/20/81
MATERIAL:
FINISH:
TOLERANCES:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
CONTRACT OR COST CENTER

NEXT ASS'Y.
APPLICATION

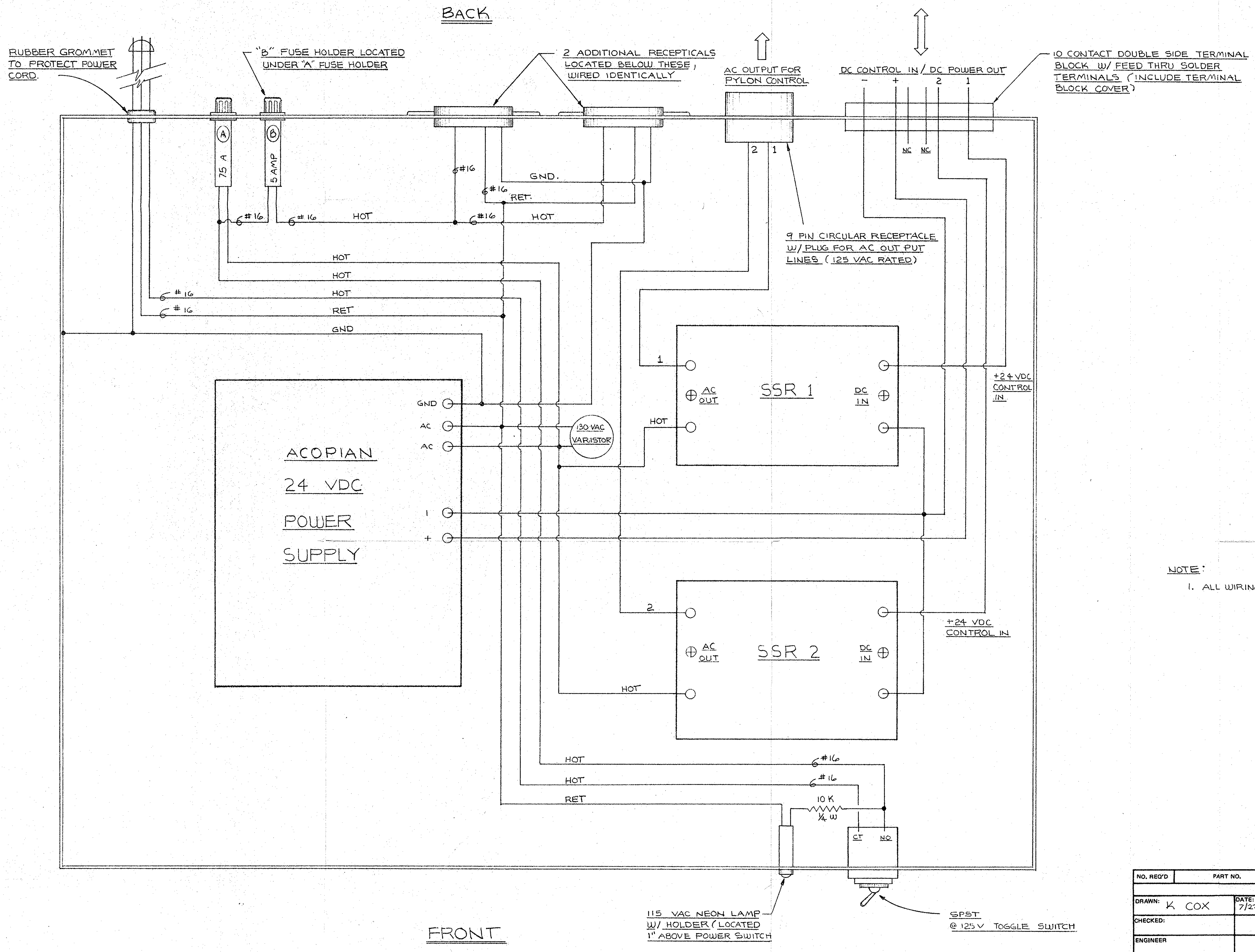
THE BDM CORPORATION
2600 YALE BLVD., S.E., ALBUQUERQUE, NM 87106

JUL 27 1981

TITLE:
TRANSLATOR MOUNTING ASSEMBLY
(S.P.I.G.)

CODE IDENT. 52308
SIZE D
DWG. NO. 02D001650
SCALE: AS NOTED
SHEET 1 OF 1

BRUNING 40-105



NOTE:

1. ALL WIRING #18 STRANDED UNLESS OTHERWISE NOTED.

NO. REQ'D	PART NO.	MATERIAL	DESCRIPTION	ITEM

LIST OF MATERIAL

DRAWN: K COX
DATE: 7/22/81
CHECKED:
ENGINEER
PROJ. ENGR.
PROGRAM MANAGER
MATERIAL:
FINISH:
TOLERANCES:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
CONTRACT OR COST CENTER
NEXT ASS'Y.
APPLICATION

THE BDM CORPORATION
2600 YALE BLVD., S.E., ALBUQUERQUE, NM 87106
JUL 27 1981

TITLE:
SPIG POWER SUPPLY
RELAY BOX
(S.P.I.G.)

CODE IDENT. 52308
SIZE D
DWG. NO. 02D001656
SCALE: NONE
SHEET 1 OF

BRUNING 40-105