

348
7/30/79

DR. 2919

MASTER

DOE/NASA CONTRACTOR
REPORT

DOE/NASA CR-161238

**SOLAR ENERGY SYSTEM INSTALLED AT MOUNT RUSHMORE
NATIONAL VISITOR CENTER IN KEYSTONE, SOUTH DAKOTA**

Prepared from documents furnished by

South Dakota School of Mines and Technology
Rapid City, South Dakota 57701

Under DOE Contract EX-76-C-01-2399

Monitored by

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

For the U. S. Department of Energy



U.S. Department of Energy



Solar Energy


DISTRIBUTION THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

1. REPORT NO. DOE/NASA CR-161238	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE Solar Energy System Installed at Mount Rushmore National Visitor Center in Keystone, S. D.		5. REPORT DATE June 1979	
		6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT #	
9. PERFORMING ORGANIZATION NAME AND ADDRESS South Dakota School of Mines and Technology Rapid City, S. D. 57701		10. WORK UNIT NO.	
		11. CONTRACT OR GRANT NO. DOE EX-76-C-01-2399	
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546		13. TYPE OF REPORT & PERIOD COVERED Contractor Report	
		14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES This work was done under the technical management of Mr. Val Fogle, George C. Marshall Space Flight Center, Alabama.			
16. ABSTRACT This final report provides information on the system description, the design and installation of the solar energy system installed at the Mount Rushmore Visitor Center. The system is designed to furnish about 45 percent of the heating for the total facility and about 53 percent partial cooling for the 2000 square-foot observatory. The report contains such items as Acceptance Test Data, a complete set of as-built drawings, system performance data, problems, pictures, and other pertinent material.			
17. KEY WORDS		18. DISTRIBUTION STATEMENT UC-59a Unclassified-Unlimited  WILLIAM A. BROOKSBANK, JR. Mgr, Solar Energy Applications Projects	
19. SECURITY CLASSIF. (of this report) Unclassified	20. SECURITY CLASSIF. (of this page) Unclassified	21. NO. OF PAGES 41	22. PRICE NTIS

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

FINAL REPORT OUTLINE

Table of Contents

1 . Narrative Description of solar energy system and building	1
2 . Acceptance Test Data	5
3 . Complete set of as-built drawings	11
4 . Operation and Maintenance Manuals (references)	20
5 . Pictures of final installation	20
6 . Predicted System Performance Data	30
7 . Major problems encountered and resolutions thereto	37
8 . Lessons learned and recommendations	38
9 . Statements verifying the solar system	39

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

1 . Narrative Description of solar energy system and building

INTRODUCTION

This project is a solar retrofit project of Mount Rushmore National Memorial Visitor Center at Keystone, SD, where over two million tourists visit each year. The Visitor Center has a total space of approximately 6,000 sq. ft. The solar system is designed to furnish approximately 45% of heating for the total facility, and approximately 53% partial cooling of the 2,000 sq. ft. observatory room. There are a total of 112 panels of Lennox liquid circulated collectors, each 3 ft by 6 ft in dimension, with a gross surface of approximately 2,000 sq. ft. Collector panels are mounted in 5½ rows on the roof of the Visitor Center owned by National Park Service of the Department of Interior. The building was designed by the Spitznagel Partners, Inc. The project consists of four team members with South Dakota School of Mines and Technology as program manager; the Spitznagel Partners, Inc. as construction manager and designer; Honeywell as a collector supplier; and the Mount Rushmore National Memorial as the owner.

DESIGN PHILOSOPHY

The first design decision was to install collectors which used liquid rather than air as the heat transfer fluid. There were three factors which indicated that this was the best choice: (1) A liquid medium would integrate easily with the existing system by simply installing a heating coil in the furnace air duct. The liquid could be circulated directly from the collectors to the heating coil for optimum transfer without additional blowers. (2) There is a need for extra air-conditioning in the observatory room which could be met by solar activated lithium bromide absorption refrigeration units. Air collectors do not produce high enough temperatures to activate these units. (3) The limited space to mount the collector array required

collectors with high efficiency and air collectors are generally less efficient than liquid collectors.

Some of the more important design decisions were determined according to the following conditions: (1) The collector area (active area of 1720 sq. ft.) is the maximum which can be fit on the roof and allow enough spacing to avoid shading (5% of total in December). This is also based on the actual total fuel consumed in FY 1975 or 8,721 gallons of No. 2 oil, assuming a heating value of 140,000 BTU per gallon and a furnace efficiency of 50% due to the age of the furnace and an altitude of about one mile, the total annual heating load of about 6.1×10^8 BTU's is determined. (2) The three 3-ton Arkla units are the maximum number which can be operated with the given collectors. (3) The 3,000 gal. storage tank is a compromise between performance and available space. (4) The solar heat coil, effectiveness = 0.538, is the largest reasonable coil which can fit into the existing furnace duct. (5) The angle at which the collectors are placed is a combination of the orientation of the roof, a 45° angle relative to the roof for ease of construction, and a need for solar collection both in winter and summer. The optimum angle for this particular application was not determined, but other simple models show that the performance is probably only 2% less at this angle than at the optimum of about 55° in winter. The angles used here favor the air conditioning application. (6) The control system is designed to use solar heating or cooling first and then the current conventional system as backup. It will be possible to air condition and solar heat during the same day, even though this feature is not in the computer model for simplification.

Solar energy system calculations were based on climatological data for Rapid City supplied by the National Oceanic and Atmospheric Administration (NOAA). The climatological conditions at Mount Rushmore (25 miles southwest

and 2,000 feet higher than Rapid City) are expected to be more favorable due to the altitude and lack of pollution in the air, making these calculations conservative.

TRNSYS system developed by the University of Wisconsin modified by South Dakota School of Mines and Technology was used to simulate the solar system. The climatological data for 1971-74 was used for the simulation model. The TRNSYS program used here should enable the user to write a workable transient simulation program with a minimal knowledge of computers. TRNSYS has built-in checks to spot obvious errors such as calling for an input from a non-existent unit, failure to specify initial conditions, etc. Other errors such as improper conversion of units, crossing the temperature with the flow rate, etc. can be very difficult to spot. In this case the user must know enough about the system to realize that the answers are nonsense, even though the computer processes the numbers without printing an error message. If the program fails to produce answers which converge within the specified tolerances in the specified number of iterations, the user has recourse to decreasing the time step, raising the tolerances or number of iterations, or sticking the control units after fewer calls in one time step. When these fail to produce convergence, then it is essential to have familiarity with FORTRAN and general knowledge of iterative techniques to trace and correct the difficulty.

The flow rate is calculated on the basis of .3 gpm per collector panel specified by the supplier.

The 3,000 gallon storage tank to provide reasonable heat storage for heating and reasonable period of continuous cooling is housed above the ground with three 3-ton Arkla units, heat exchanger, pumps, and all controls in a building connected to the Visitor Center on the east side. This selec-

tion gives ease in installation of piping, storage tank and other equipment. The length of piping is minimized.

OPERATION OF THE SYSTEM

The whole system was completed in September of 1977. First the system was tested with pure water in the solar collector loop for about a week, and the system seemed to function properly and was then charged with ethelene glycol for continuous operation. The presence of air bubbles in the system was a constant problem. The pressure build-up due to the air bubbles was alleviated by frequent venting on the top of the roof. The system pressure could be in excess of 70 psig. The air venting could be as frequent as once a week.

The winter of 1977 in South Dakota was one of the severest ones experienced. The National Park Service was quite happy with the saving of many gallons of oil. The system apparently functioned well in solar heating. No major problems were detected except that the main system pump was always running for all modes of operation. Nobody knew exactly how well the system was functioning until the early part of May of 1978 when IBM contracted Site Data Acquisition System (SDAS) to begin to produce some computer print-outs. Quite a few anomalies were picked up by the SDAS such as the main system pump was running all the time; the sequence of operations was different from what was originally planned; solar and auxiliary heating have the same control setting; energy from storage is not always being taken to meet the heating load, etc.

The Arkla cooling units were started after mid-July of 1978. The cooling system was never utilized to its full capacity due to the fact that the control of the system was not completely under control. Adjustments and corrections are still being made by the Honeywell people. In general, most

major anomalies have been corrected. It is expected the system will operate properly both heating and cooling in seasons to come.

SUCCESSFUL COMPONENTS OR PROCESSES

Aesthetically the Park Service people were worried that the presence of solar energy heating project might distract from the main attraction. Since the installation of the collector panels, the visitors apparently are not aware of the presence of collector panels on the roof of the building. This seems to satisfy the Park Service. Comments from people who have seen the collector panels are good. Aesthetically, they blend in very naturally with the building.

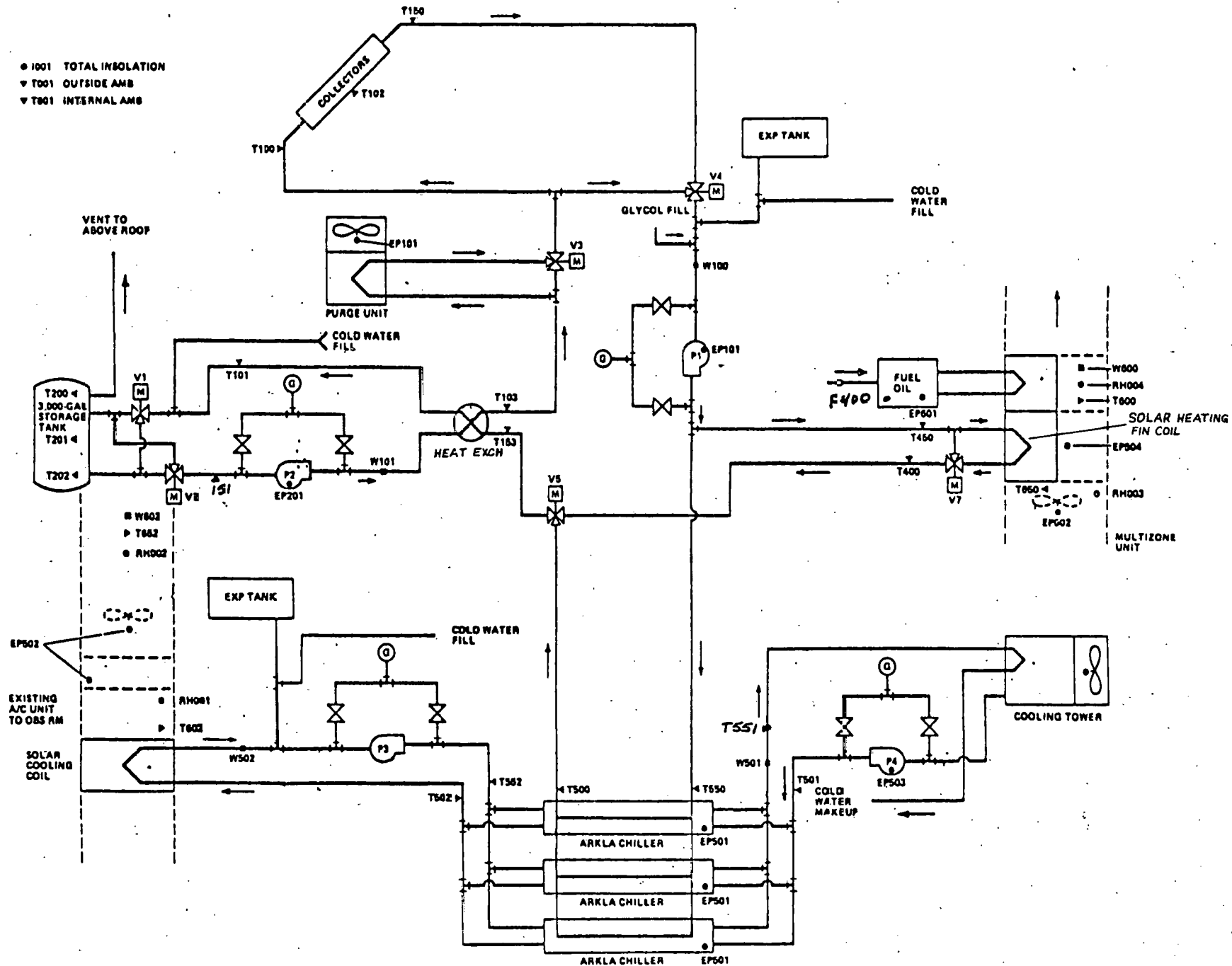
2. Acceptance Test Data

a. ACCEPTANCE TEST PLAN

The basic philosophy of the acceptance test plan will be simply to insure that the entire system functions as designed. The acceptance test will be primarily based on the results provided by the government's Site Data Acquisition System and its on-site monitor. Results of a minimum of one week of continuous operation are required for the acceptance test.

Referring to the attached diagram, a total of 44 sensors as shown are installed to the whole system. 8 sensors with a prefix of EP are for the measurements of electrical power consumed by pumps; 6 sensors with a prefix of W for the measurements of pump flowrate of liquid; 24 sensors with a prefix of T are for temperature measurements; and 6 remaining sensors are: 4 with a prefix of RH for the measurements of humidity, 1 with a prefix of F for the measurements of fuel oil flowrate, and 1 with a number of 1001 for the measurement of the total solar insolation. Results of the Site Data Acquisition System are obtained from the 44 sensors as shown in the attached diagram.

- 1001 TOTAL INSULATION
- ▼ T001 OUTSIDE AMS
- ▼ T001 INTERNAL AMS



MOUNT RUSHMORE SYSTEM SCHEMATIC (10/4/78)
FIGURE 1

IP7933714
Rev. C

On a component basis, the items to be tested will be all pumps, motors, heat exchanger, coils, fans, cooling tower, solar collectors, valves, controls and sensors, and ARKLA cooling units. A general visual and physical inspection of all items including leakage and insulation free from any defect will be conducted. Tolerances for various items are to meet within $\pm 10\%$ of the designed performance, for most of the items, as specified in the attached designed equipment schedule.

The controls will be tested according to the attached sequence of operations.

GENERAL

Space heating and cooling is controlled by the existing space thermostats. First stage heating is provided by solar heated water directly from the collectors or from the storage tank to the solar heating coil located in the existing multizone unit. Second and third stage heating are accomplished by firing the existing burner which is sequenced through two firing stages. First stage cooling is provided by the Arkla absorption units. Second stage cooling is accomplished by sequencing the existing multi-zone unit and direct expansion unit.

FIRST STAGE HEATING FROM COLLECTOR

On a call for heat from the space thermostats and by the discharge air temperature THD, valve V7 is modulated to control the hot deck temperature. Pump P1 is enabled to run and valve V4 is positioned A to AB if the collector plate temperature (TPH) is greater than 125°F (adjustable). A time delay will delay pump P1 shut down to prevent short cycling.

FIRST STAGE HEATING FROM STORAGE

Heating from storage is accomplished whenever energy is not available from the collectors, heating demand occurs and energy is available from storage. On a call for heat, valve V7 and V5 are in the heating positions.

Valve V4 is B to AB. Pump P2 and P1 are enabled to run if the storage tank temperature TSD is greater than 100°F (adjustable). Valves V1 and V2 are positioned B to AB respectively.

SECOND AND THIRD STAGE HEATING

If first stage heating cannot be satisfied from the collectors or storage as sensed by discharge air sensor THD and the space thermostat, then the existing burner will be sequenced through it's two firing stages.

FIRST STAGE COOLING FROM COLLECTORS

First stage cooling is provided by the Arkla Absorption units A1 through A3. On a call for cooling, valve V5 is positioned A to AB and valve V7 is positioned B to AB. If solar heat is available from the collectors, which is sensed by collector plate sensor TPH, then pump P1, P3 and P4 are enabled to run. Plate temperature TPH must be greater than 180°F (adjustable) for cooling by the absorption units. A time delay will delay Pump P1 shut down to prevent short cycling. A fan aquastat in the cooling tower will cycle the cooling tower fan to hold sump temperature to 85°F (adjustable).

SECOND STAGE COOLING

Second stage cooling is accomplished sequencing the existing multi-zone unit and direct expansion units. When second stage cooling is called, the multi-zone unit will be activated. If the discharge air temperature TCD is greater than 60°F (adjustable) and second stage cooling is on, the direct expansion unit will then operate.

STORAGE TANK CHARGING

Storage tank charging is accomplished only when there is energy available from the collectors (TPH or TPC - set), and TF in is greater than TSC by 20°F (adjustable). Valve V1 and V2 are positioned A to AB respectively and pumps P1 and P2 are enabled to run.

PURGE UNIT

The purge or heat rejection unit is activated by positioning valve V3 B to AB whenever TF out is greater than 200°F (adjustable). The fan is under the control of the fan aquastat which cycles the fan on if the discharge temperature is greater than 205°F.

EQUIPMENT SCHEDULE

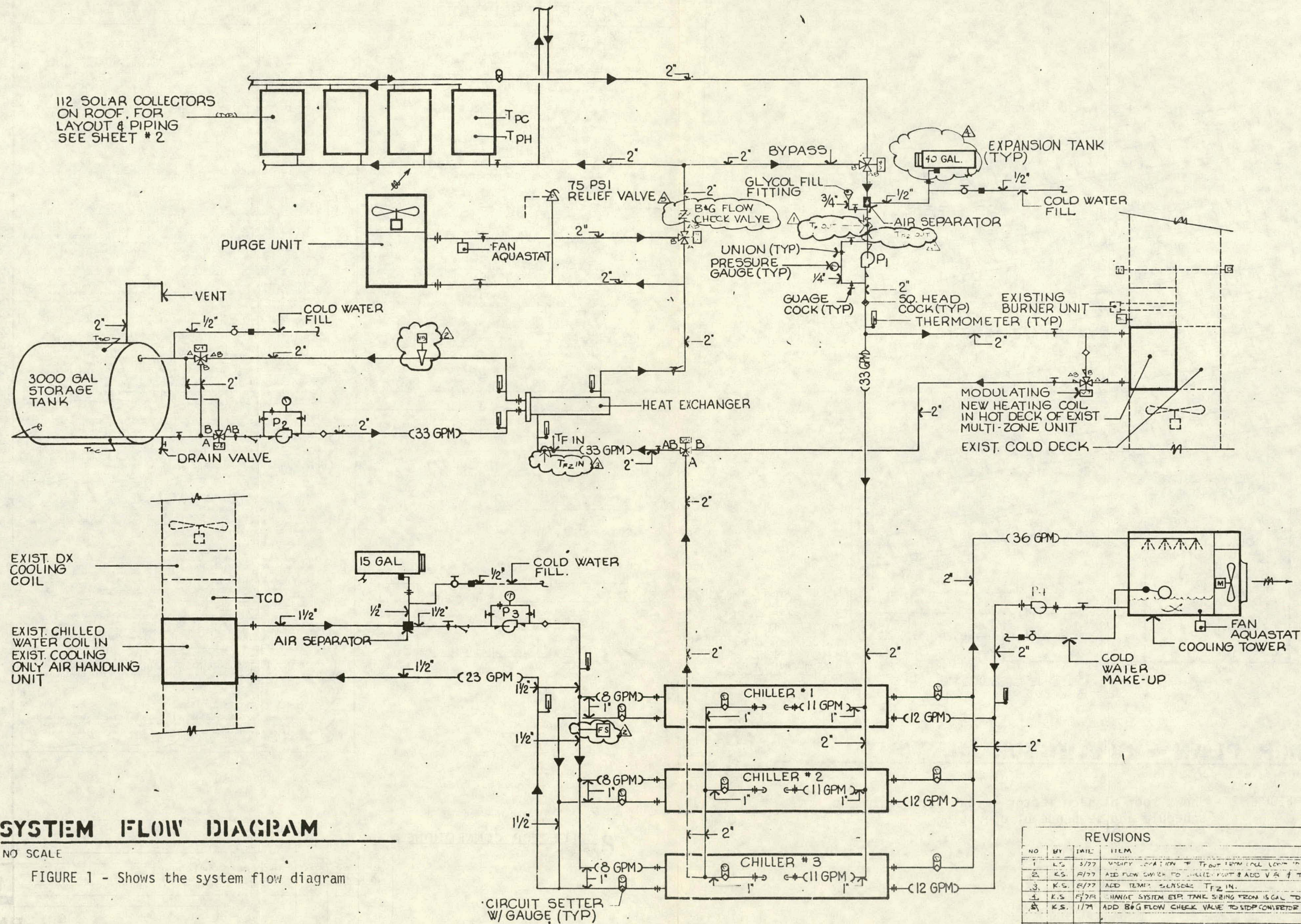
System Pump	-	B & G Model PD-35, 33 GPM at 21' H ₂ O, $\frac{1}{2}$ HP. 208V-60-3 Spare set of seals.
Storage pump	-	B & G Series 1 $\frac{1}{2}$, 33 GPM at 5.5' H ₂ O, 1/6 HP. 115V-60-1 Spare set of seals.
Chilled water pump	-	B & G Series HD3, 23 GPM at 17.5' H ₂ O, 1/3 HP, 115V-60-1 Spare set of seals.
Condenser Water pump	-	B & G Series 1522 AB-5", 36 GPM at 23' H ₂ O, 1/2 HP, 120V-60-1. Spare set of seals.
Heat Exchanger	-	B & G Shell & Tube Heat Exchanger #QWU-88-44 Shell side, 33 GPM, 50% Glycol, 122°EWT, 107°LWT, 6' H ₂ O P.D. - Tube side, 33 GPM, 90°EWT, 103°LWT, 1.5' H ₂ O P.D., Heat trans- mitted at rate of 200 MBH.
Cooling Tower	-	Marley Model 46-17, 1/3 HP, 115V-60-1.
Cooling Coil	-	MacQuay Model LHD-108, 1 HP, 208V-60-3, 3800 CFM. 33 GPM, 200°EWT, 180°LWT, 4.7' H ₂ O Water P.D., 0.7" H ₂ O A.P.D., 100% EAT, 175°LAT, 326 MBH, Coil #5WH 1204C.
Solar Collector	-	(112 thus) Honeywell/Lennox #LSC18, .3 GPM/collector. 1.9' H ₂ O Water P.D., Total Sq. ft. of collectors = 2016 sq. ft.
Chiller	-	(3 thus), Arkla/Solaire 36 (WF-36), Data for each-cooling capacity 36,000 BHUH, Hot water input requirement 50,000 BTUH at 210°F, Heat rejection requirement 86,000 BTUH. 115 volt 250 Watts electrical.
Storage Tank	-	3000 gal. capacity, 7" x 10.5' loop, 7 Gauge steel tank.
Expansion Tank	-	B & G 15 gal, 13" x 34 1/2" long, slight glass. AFT-9 Tank fitting, Drain cock.
Pressure Relief	-	located near purge unit, set at approximately 100 PSI.

- b. Acceptance test results including corrective action taken for non-conformance. Acceptance test was based on the Instrumented Solar Site Status report dated 9-25-78 put out by IBM. (A copy of the report is attached.) The anomalies and actions involving the grantee are summarized in the following table.

<u>System</u>	<u>Anomaly</u>	<u>Action</u>	<u>Activity</u>	<u>Remarks</u>
S/I	Main system pump runs continuously (1/78)	Control adjustment is needed and has been requested from Honeywell. The problem is due to the way hot deck temperature was set. Damper needs to be readjusted as well as the hot deck temperature so that Valve V7 will cycle to open and close.	Grantee	
S/I	Solar energy simultaneously goes to load and storage. Does not agree with control definition (2/78)	Control definition has been changed and drawing has been corrected. Storage is not used for cooling.	Grantee	
S	Solar & auxiliary heating (fuel oil) have same control setting. Disagrees with control definition (2/78)	Damper cam should be readjusted to start solar heating prior to auxiliary heating. We have requested Honeywell controls to make due adjustment.	Grantee	
S	Solar energy not being taken from storage to meet heating load (2/78)	See above	IBM/Grantee	
S	Single plate temperature control sensor may cause over heating.		Grantee	It was okayed to delete this.

S/I	Pump P-2 is running even when pump P-1 is off. Does not agree with control definition (6/78)		Grantee/ IBM	It was okayed to delete this.
S	Purge unit should come on when TF out is 220°F. T103 indicates purge unit is coming on at 175° to 180°F (6/78)	Has been corrected to 200°F (V3)	Grantee	Purge unit rarely ran.
S	Collector loop becomes active at 8:30 AM - runs until 8:30 PM. System losing energy from 4:00 PM - 8:30 PM.		Grantee	It was okayed to delete this.

3. Complete set of as-built drawings with wire and piping schematics.



MT RUSHMORE VISITOR CENTER SOLAR ENERGY SYSTEM

PROJECT NO. 6114.1

DATE 10/14/76

DESIGNED BY SCHMIDT

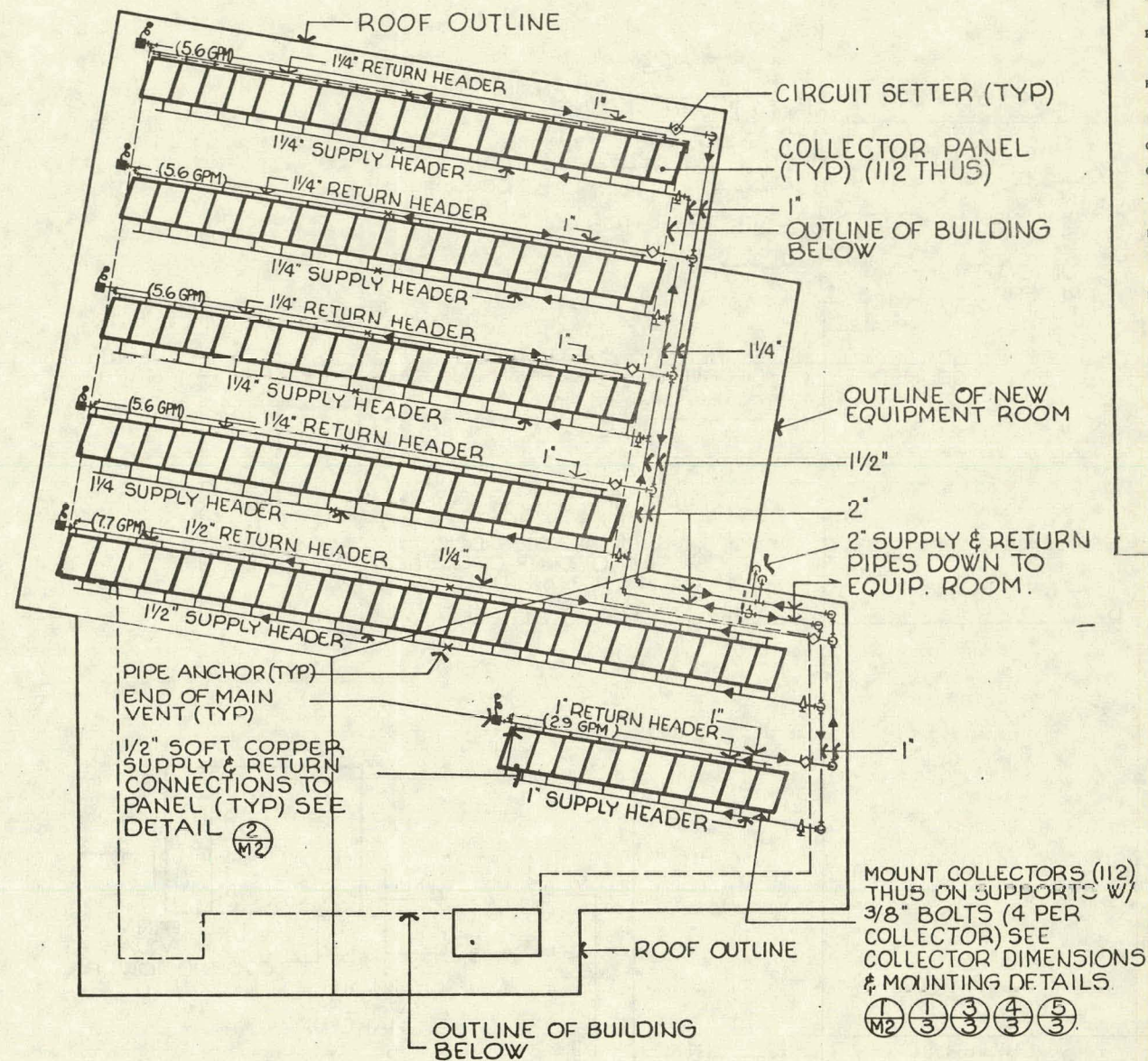
CHECKED BY DLR

SYSTEM FLOW DIAGRAM

The Spitznagel Partners Inc.

RM-1

OF 4



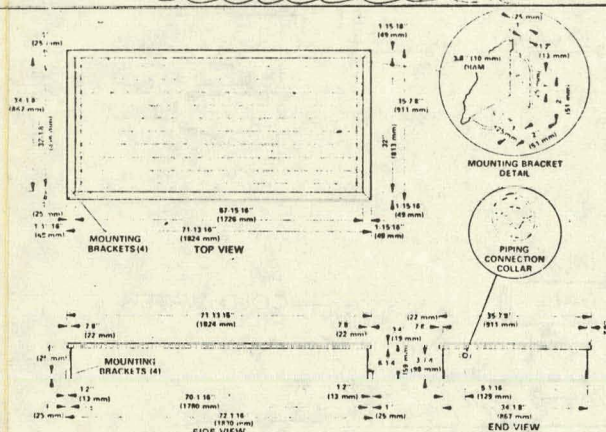
ROOF PLAN - COLLECTOR LAYOUT

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

FIGURE 2 - Shows roof plan-collector layout with equipment schedule and sequence of operation

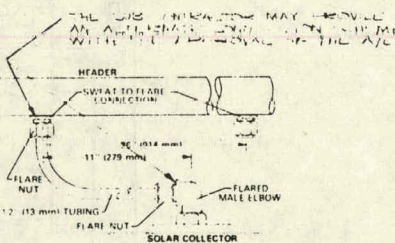
EQUIPMENT SCHEDULE

P-1	System Pump - B & G Model 40-2A-7 33 GPM at 54' H ₂ O, 2 HP, 208V-60-3. Spare set of seals.
P-2	Storage Pump - B & G Series 1 1/2, 33 GPM at 5.5' H ₂ O, 1/6 HP, 115V-60-1. Spare set of seals.
P-3	Chilled Water Pump - B & G Series HD3, 23 GPM at 17.5' H ₂ O, 1/3 HP, 115V-60-1. Spare set of seals.
P-4	Condenser Water Pump - B & G Series 1522-B 36 GPM at 23' H ₂ O, 1/2 HP, 120V-60-1. Spare set of seals.
HEAT EXCHANGER	B & G Shell & Tube Heat Exchanger QMU-8P-44 Shell side, 33 GPM, 50% Glycol, 122° EWT, 107° LMT, 6' H ₂ O P.D. - Tube side, 33 GPM, 90° EWT, 103° LMT, 1.5' H ₂ O P.D., Heat transmitted at rate of 200 MBH.
COOLING TOWER	Marley Model 46-17, 1/3 HP, 115V-60-1.
COOLING COIL	McQuay #5WH 1005, 10 Fins/inch, 5 Rows, 36" wide by 20" high, 23 GPM, 45° EWT, 55° LMT, 80° DB/57° WB EAT, 55° DB LAT, 33 FPM F.V., 5.3' H ₂ O Water P.D., & 1.2" H ₂ O A.P.D., 4000 CFM.
HEATING COIL	McQuay #5WH 1403, 14 Fins/inch, 3 Rows, 51" wide by 24" high, 130° EWT, 115° LMT, 33 GPM, 225 MBH, 73° EAT, 108° LAT, 706 FPM F.V., 5.3' H ₂ O Water P.D., & .8" H ₂ O A.P.D., 6000 CFM.
PURGE UNIT	McQuay Model LS-108, 1 HP, 208V-60-3, 3800 CFM, 33 GPM, 200° EWT, 180° LMT, 4.7' H ₂ O Water P.D., 0.7' H ₂ O A.P.D., 160° EAT, 175° LAT, 326 MBH, Coil #5WH 1204C.
SOLAR COLLECTOR	(112 third) Honeywell/Lennox #LSC18, 0.3 GPM/Collector, 1.0' H ₂ O Water P.D., Total SQ. FT. of Collectors = 2046 SQ. FT.
CHILLERS A1, A2, & A3 (3 thus)	Arkla/Solaire 16 (WF-36), Data for each - Cooling Capacity 36,000 BTUH, Hot water input requirement 50,000 BTUH at 210° F. Heat rejection requirement 86,000 BTUH. 115 Volt 250 watts electrical.
STORAGE TANK	3000 Gal. capacity, 7' x 10.5' Long, 7 Gauge steel tank.
EXPANSION TANKS	B & G 15GAL, & B & G 40 GAL W/ Sight glass, B&G Tank fitting, Drain cock.



COLLECTOR DIMENSIONS

NO SCALE



COLLECTOR CONNECTIONS

NO SCALE

SEQUENCE OF OPERATIONS

General

Space heating and cooling is controlled by the existing space thermostats. First stage heating is provided by solar heated water directly from the collectors or from the storage tank to the solar heating coil located in the existing multi-zone unit. Second and third stage heating are accomplished by the existing fuel fired burner. First stage cooling is provided by three solar water fired absorption water chillers. Second stage cooling is provided by activating the cooling on the multi-zone unit. A third stage of cooling is provided by the existing vapor compression unit.

First Stage Heating from Collector

On a call for heat from the space thermostats and by the discharge air temperature THD, valve V7 is modulated to control the hot deck temperature. Pump P1 is enabled to run and valve V4 is positioned A to AB if the collector plate temperature (TPH) is greater than 100° F (adjustable). A time delay will delay pump P1 shut down to prevent short cycling.

First Stage Heating from Storage

Heating from storage is accomplished whenever energy is not available from the collectors, heating demand occurs and energy is available from storage. On a call for heat, valve V7 and V5 are in the heating positions. Valve V4 is B to AB. Pump P2 and P1 are enabled to run if the storage tank temperature TSD is greater than 100° F (adjustable). Valves V1 and V2 are positioned B to AB respectively.

Second and Third Stage Heating

If first stage heating cannot be satisfied from the collectors or storage as sensed by discharge air sensor THD and the space thermostat, then the existing burner will be sequenced through it's two firing stages.

First Stage Cooling from Collectors

First stage cooling is provided by the Arkla Absorption units A1 through A3. On a call for cooling, valve V5 is positioned A to AB and valve V7 is positioned B to AB. If solar heat is available from the collectors, which is sensed by collector plate temperature TPH, then pump P1, P3 and P4 are enabled to run. Flow temperature TFC must be greater than 180° (adjustable) for cooling by the absorption units. A time delay will delay Pump P1 shut down to prevent short cycling. A fan aquastat in the cooling tower will cycle the cooling tower fan to hold sump temperature to 85° F (adjustable).

First Stage Cooling from Storage

Cooling from storage is accomplished whenever energy from the collectors is not available, a cooling demand occurs and the storage tank temperature TSD is greater than 180° F (adjustable). On a call for cooling, valves V7 and V5 are in the cooling positions. Valve V4 has been positioned to bypass the collectors (TPH - act). Pumps P1 and P2 are then enabled to run and the absorption units function as previously described.

Second Stage Cooling

Second stage cooling is accomplished sequencing the existing multi-zone unit and direct expansion units. When second stage cooling is called, the multi-zone unit will be activated. If the discharge air temperature TCD is greater than 60° F (adjustable) and second stage cooling is on, the direct expansion unit will then operate.

Storage Tank Charging - No Cooling

Storage tank charging is accomplished only when there is energy available from the collectors (TPH or TPC - set), there is no demand for cooling and TFin is greater than TSC by 20° F (adjustable). Valve V1 and V2 are positioned A to AB respectively and pumps P1 and P2 are enabled to run. Valve V4 shall be energized and open when P2 is energized.

The purge or heat rejection unit is activated by positioning valve V3 B to AB whenever TP out is greater than 220° F (adjustable). The fan is under the control of the fan aquastat which cycles the fan on if the discharge temperature is greater than 210° F.

*Add to First Stage Cooling: flow switch FS in the chilled water circuit shall prevent V5 from positioning A to AB, and allowing hot water to flow through the chillers unless P3 is running and flow is sensed.

Storage Tank Charging When Cooling:

Storage Pump P2 shall be enabled to run when the system is in the cooling mode only when TFC out is greater than 190° F (adjustable) and all of the criteria under Storage Tank Charging (no cooling) are met.

REVISIONS

NO	BY	DATE	ITEM
1	CS	5/77	CLV-4 CONTROL SYSTEM
2	CS	8/78	CHANGE P1 TO LARGE PUMP
3	CS	8/78	CHANGE EXP. TANK SIZES

MT. RUSHMORE VISITOR CENTER SOLAR ENERGY SYSTEM
MOUNT RUSHMORE NATIONAL MONUMENT, SOUTH DAKOTA

PROJECT NO. 6114.1
DRAWN BY SCHMIDT
CHECKED BY D.L.R.
DATE 10/14/76

The Spitznagel Partners Inc.

RM-2
OF 4

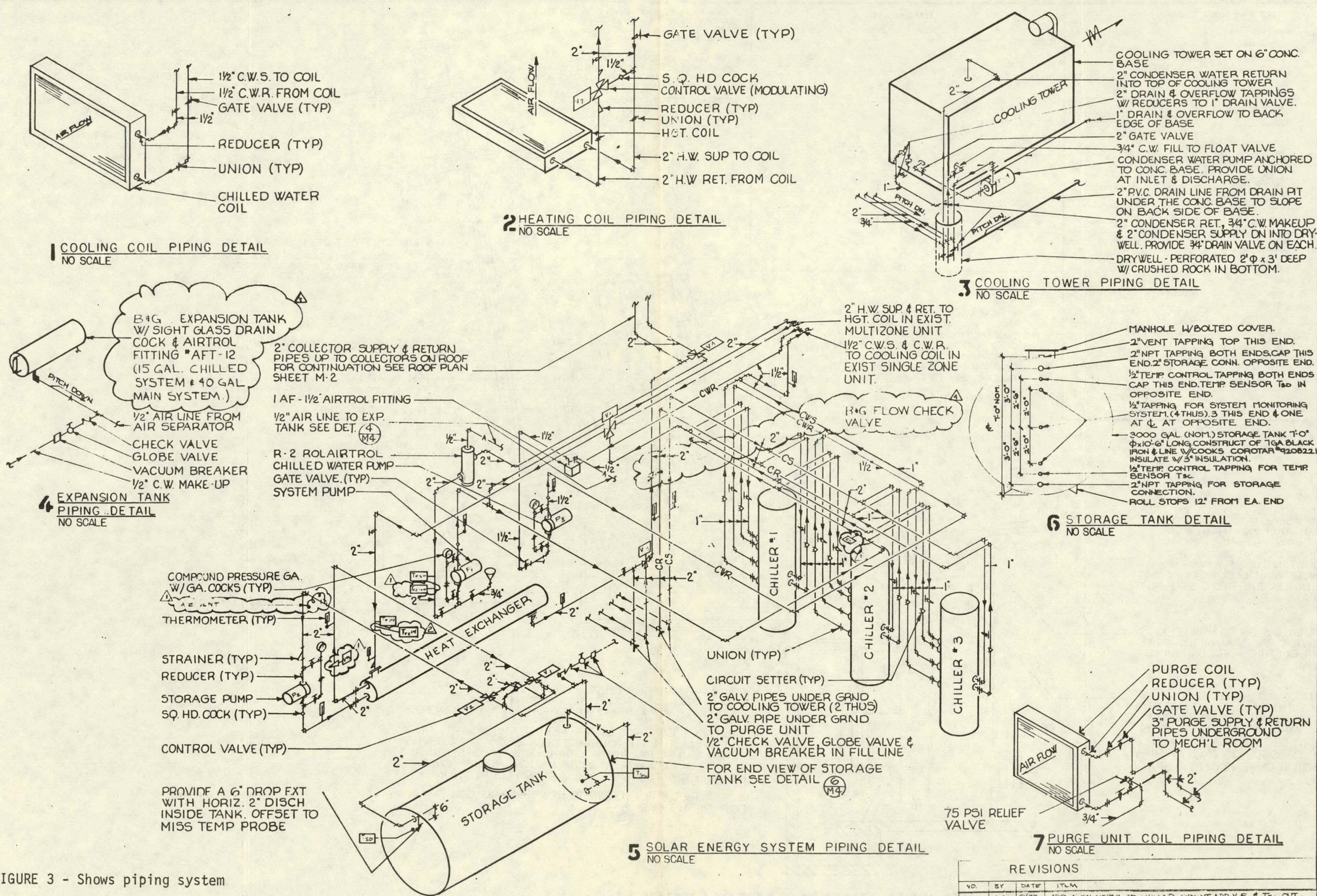


FIGURE 3 - Shows piping system

REVISIONS			
NO.	BY	DATE	ITLM
1	ES	6/77	ADD FLOW SWITCH TO CHILLED CIRCUIT, ADD VENT & TIE OUT.
2	ES	6/77	ADD AIR VENT & 5 GAL. AIR COIL TO CHILLED WATER CIRCUIT.
3	ES	6/77	ADD TEMP. SENSOR T ₂ IN.
4	ES	8/78	REVISE SYSTEM EXP. TANK SIZE TO 40 GAL.
5	ES	1/79	ADD B & G FLOW CHECK V. TO ELIMINATE FREEZE-UP

1. Verify piping details, specifications, or report was prepared by me or under my direct supervision and that I am a "Professional Engineer" under the laws of the State of South Dakota.

Due 10/15/1776 Reg. No. 25562

PROJECT NO. 6114.1
DATE 10/14/76

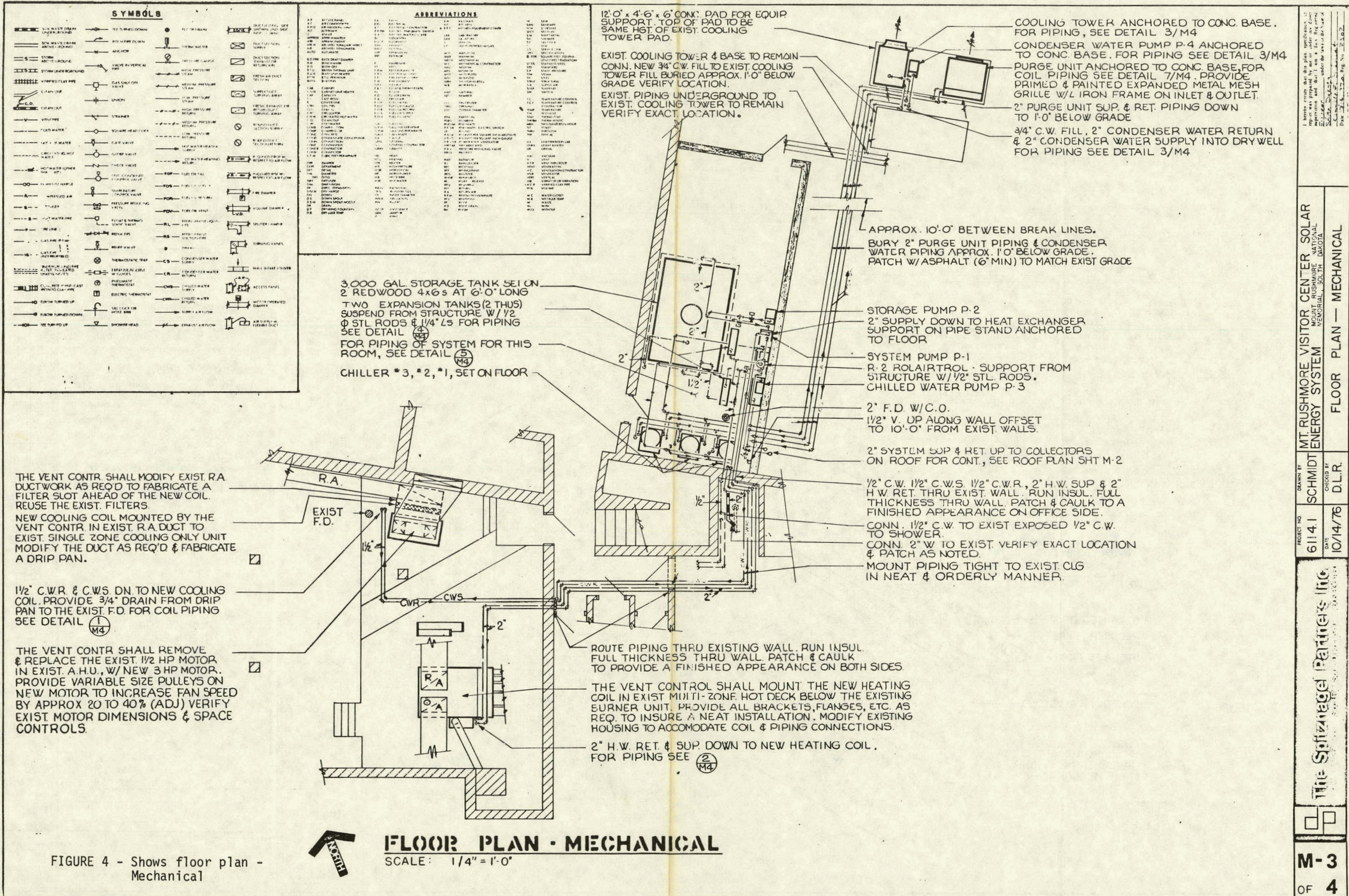
DRAWN BY SCHMIDT
CHECKED BY D.L.R.

MT. RUSHMORE VISITOR CENTER SOLAR ENERGY SYSTEM

DETAILS

The Spitznagel Partners Inc.

RM-4 OF 4



1. Verify existing conditions. If not shown, assume as shown. If not shown, assume as shown. If not shown, assume as shown.

PROJECT NO. 61141
DATE 10/14/76
DRAWN BY SCHMIDT
CHECKED BY D.L.R.

MT RUSHMORE VISITOR CENTER SOLAR ENERGY SYSTEM
MOUNT RUSHMORE NATIONAL MONUMENT, SOUTH DAKOTA

The Spitznagel Partners, Inc.

FLOOR PLAN - MECHANICAL

M-3
OF 4

ELECTRICAL SYMBOL LEGEND									
○	Outlet	Capital letter indicates fixture type. Small letter indicates switching. Shaded line indicates recessed.	14"						
○	Wall outlet		14"						
○	Outlet section box		14"						
○	Wall section box		14"						
○	Outlet exit sign		14"						
○	Wall exit sign		14"						
○	Surface fluorescent to ceiling. Shaded line indicates recessed. Fixtures on emergency circuit.		14"						
○	Switch: single pole		14"						
○	Double pole		14"						
○	3-way		14"						
○	4-way		14"						
○	Key operated		14"						
○	With pilot lamp		14"						
○	Interlocking contact		14"						
○	Dimmer. Number indicates wattage		14"						
○	Duplex receptacle		14"						
○	Duplex receptacle, half switched		14"						
○	Fluorescent outlet, additional symbol indicates type		14"						
○	Special purpose outlet. Letter indicates type. See spec.		14"						
○	Multi-outlet assembly - M.O.A.		14"						
○	Underfloor duct		14"						
○	Telephone outlet		14"						
○	Clock outlet		14"						
○	Time switch		14"						
○	Phone call		14"						
○	Lighting and appliance panelboard		14"						
○	Power panelboard		14"						
○	Motor. Number indicates hp. See motor schedule.		14"						
○	Interference		14"						
○	Receptacle in service		14"						
○	Thermal switch		14"						
○	Thermistor		14"						
○	Push button		14"						
○	Control relay		14"						
○	Telephone outlet		14"						
○	Special equipment cabinet as noted.		14"						

ELECTRICAL SYMBOL LEGEND									
○	Transformer	Small circle indicates quantity of 812 wires. 1/2" circle indicates two 812, 1/2" C. Arrows indicate quantity of conductors. Numbers indicate panel and circuits.	14"						
○	Conduit connected in wall or ceiling		14"						
○	Conduit up		14"						
○	Conduit down		14"						
○	Conduit concealed in floor		14"						
○	Conduit exposed		14"						
○	Emergency circuit		14"						
○	Feeder conduit		14"						
○	Devotes empty conduit		14"						

ELECTRICAL SYMBOL LEGEND									
○	Transformer	Small circle indicates quantity of 812 wires. 1/2" circle indicates two 812, 1/2" C. Arrows indicate quantity of conductors. Numbers indicate panel and circuits.	14"						
○	Conduit connected in wall or ceiling		14"						
○	Conduit up		14"						
○	Conduit down		14"						
○	Conduit concealed in floor		14"						
○	Conduit exposed		14"						
○	Emergency circuit		14"						
○	Feeder conduit		14"						
○	Devotes empty conduit		14"						



FLOOR PLAN - ELECTRICAL

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

REVISIONS				
NO	BY	DATE	DESCRIPTION	
1	ES	4/28	CHG P-1 HP FROM 1/2 HP TO 2 HP	

E-1
OF 1

The Spitznagel Painting Co.
10101 1st Ave. S.
Minneapolis, MN 55426

PROJECT NO.
6114.1
DATE
10/14/76

DRAWN BY
R.W.G.
CHECKED BY
D.L.R.

MT. RUSHMORE VISITOR CENTER SOLAR ENERGY SYSTEM
NATIONAL DAKOTA
MOUNT RUSHMORE NATIONAL MONUMENT, SOUTH DAKOTA
DESIGNED BY
DATE
10/14/76
Rev. No. 2207

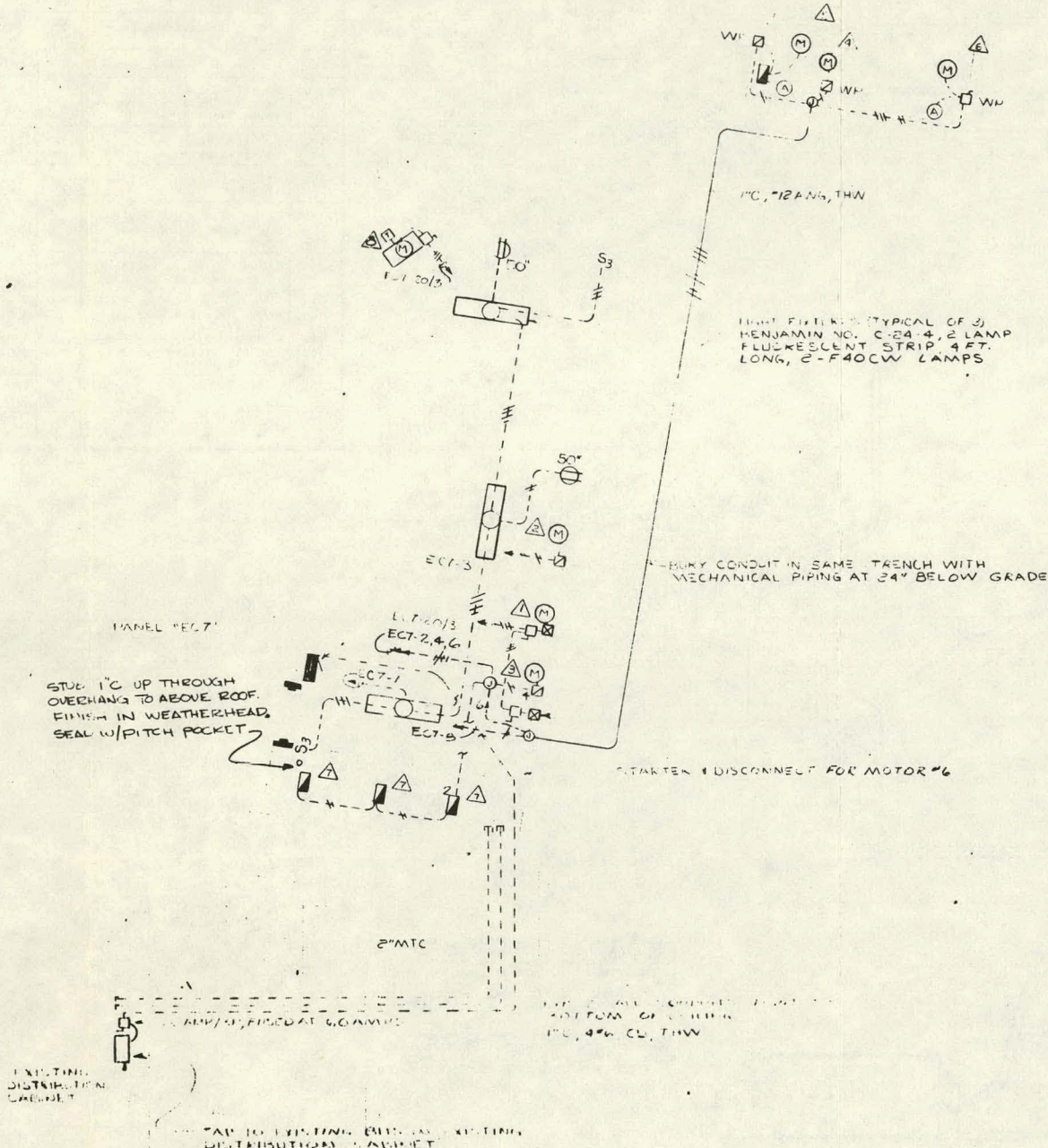


FIGURE 5 - Shows floor plan-Electrical

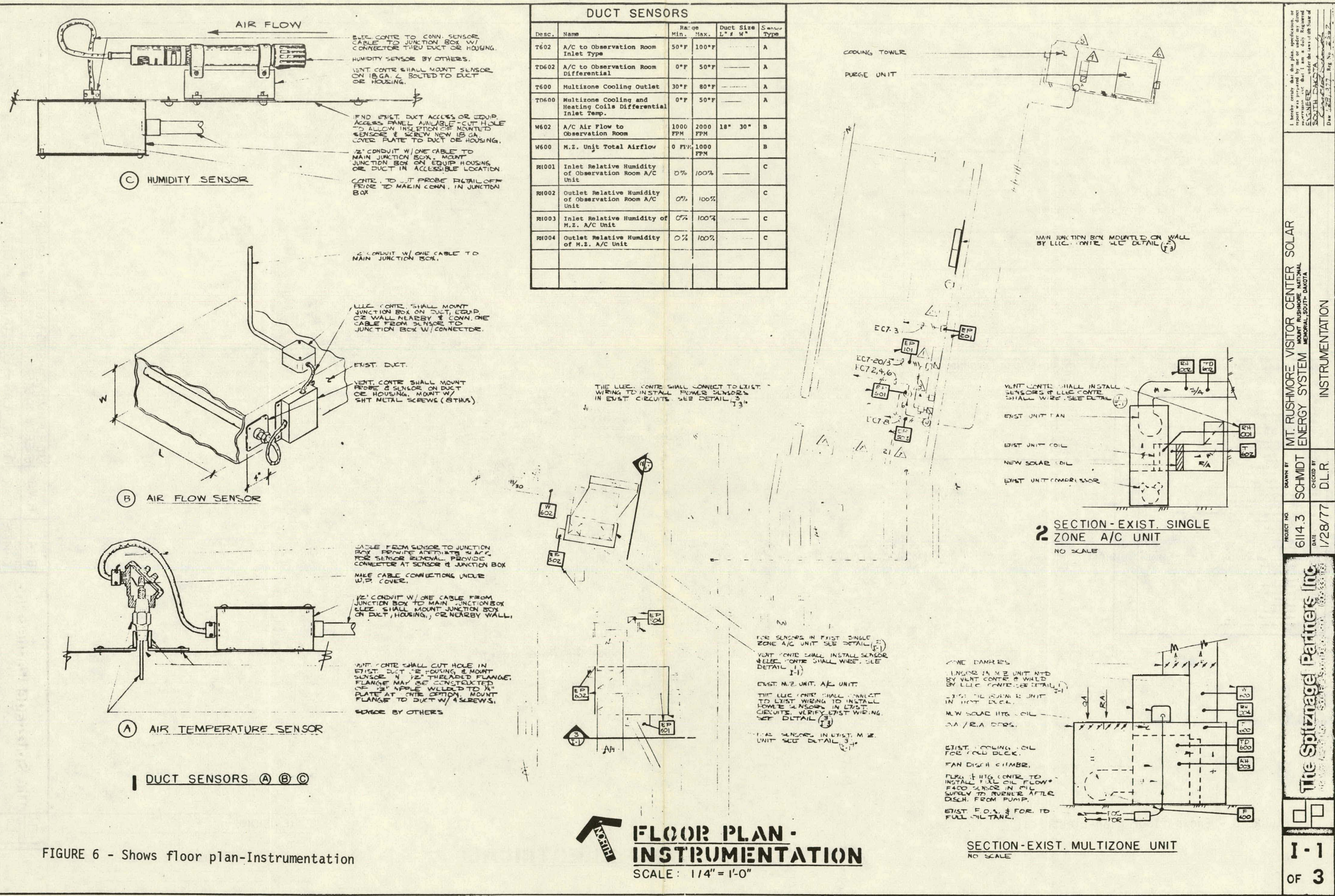
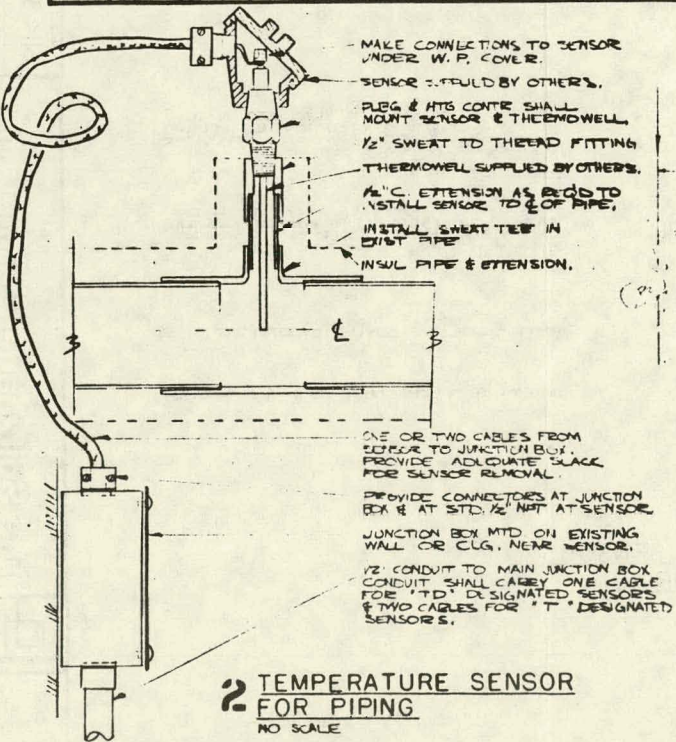


FIGURE 6 - Shows floor plan-Instrumentation

TEMPERATURE SENSORS FOR PIPING

Desc.	Name	Range (°F) Min. Max.	Pipe Size (Inches)	Sensor Size
T100	Collector Array Inlet Temp.	30 220	Copper 2"	1/2"
TD100	Collector Array Differential Temp.	0 50	Copper 2"	1/2"
T101	Storage Tank Inlet Temp.	50 200	Copper 2"	1/2"
TD101	Storage Tank Differential Temp. (+)	0 100	Copper 2"	1/2"
T200	Storage Tank Upper Temp.	50 200	1/2" Tank Fitting	1/2"
T201	Storage Tank Center Temp.	50 200	1/2" Tank Fitting	1/2"
T202	Storage Tank Lower Temp.	50 200	1/2" Tank Fitting	1/2"
T400	Heating Coil Outlet Temp.	50 250	Copper 2"	1/2"
TD400	Heating Coil Differential Temp.	0 50	Copper 2"	1/2"
T500	Arkla Generator Outlet Temp.	150 250	Copper 2"	1/2"
TD500	Arkla Generator Differential Temp.	0 50	Copper 2"	1/2"
T501	Arkla Condenser Inlet Temp.	30 100	Copper 2"	1/2"
TD501	Arkla Condenser Water Differential Temp.	0 50	Copper 2"	1/2"
T502	Arkla Chilled Water Outlet	30 80	Copper 1-1/2"	1/2"
TD502	Arkla Chilled Water Differential Temp.	0 30	Copper 1-1/2"	1/2"
T103	Collector/Heat Exchanger Outlet Temperature	30 250	Copper 2"	1/2"
TD103	Collector/Heat Exchanger Differential Temperature	0 150	Copper 2"	1/2"



1/2" CONDUIT TO MAIN JUNCTION BOX, MOUNT JUNCTION BOX ON CLG. OR WALL NEAR SENSOR.
CABLE FROM SENSOR TO JUNCTION BOX, PROVIDE ADEQUATE SLACK FOR SENSOR REMOVAL. PROVIDE CONNECTOR AT SENSOR & JUNCTION VALVE.
INSTALL BYPASS & VALVE AROUND SENSOR IN EXIST. PIPE.

EXIST. PIPE

INSTALL ISOLATION VALVES (2 THIS) IN EXIST. PIPE.
UNION (TYP) WHEN SCHEDULED.
2" BRASS SWEAT TO 4 BOLT FLANGE, PROVIDE GASKETS. SEE SCHEDULE.
PLEG & HTG. CONTR. TO INSTALL SENSOR, ELEC. TO WIRE.

FLOW SENSOR FOR PIPING
NO SCALE

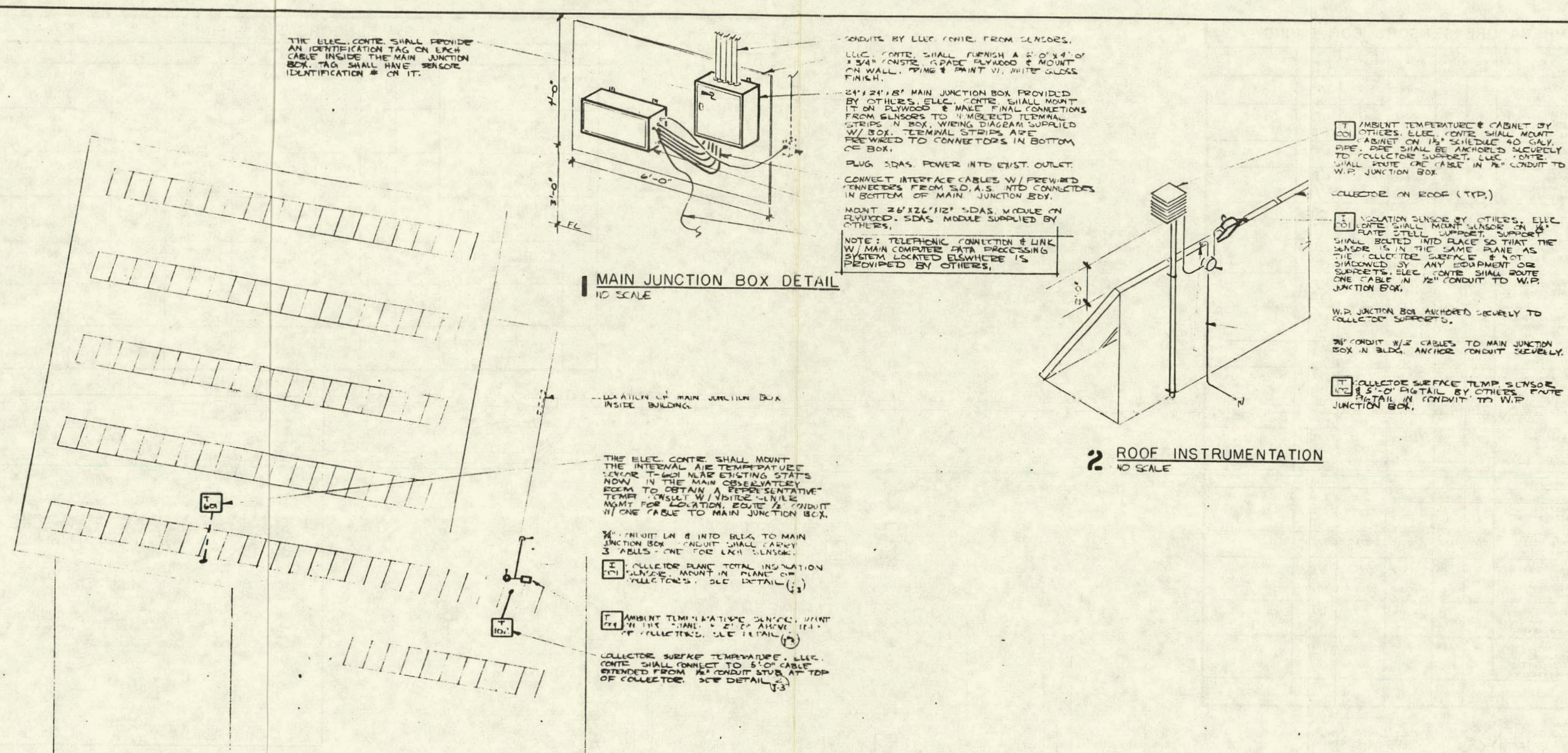
TYP. FLOW SENSOR. PLEG & HTG. CONTR. TO INSTALL SENSOR & BYPASS, ELEC. CONTR. TO WIRE. SEE DETAIL (1-2)

FLOW SENSORS FOR PIPING

Desc.	Name	Range (GPM)			Pipe Type	Flow Meter Type	Size A	B	C	D	E (Min.)	F (Min.)
		Min.	Design.	Max.								
W100	Collector Array Flow Rate	20	33	50	Copper	2" Flanged	2-2" Sweat Flanges W/4-4"x5/8" Bolts	Not Required	2"	20"	10"	
W101	Storage Tank Supply Flow Rate	20	33	50	Copper	2" Flanged	2-2" Sweat Flanges W/4-4"x5/8" Bolts	Not Required	2"	20"	10"	
W501	Arkla Condensing Water Flow Rate	20	36	50	Copper	2" Flanged	2-2" Sweat Flanges W/4-4"x5/8" Bolts	Not Required	2"	20"	10"	
W502	Chilled Water Flow Rate	15	23	35	Copper	1-1/2" Threaded	2-1-1/2" Sweat to Threaded Nipples	1-1/2" Union	1-1/2"	15"	8"	
F400	Fuel Flow to Multizone Heating Unit	0 - 5 G.P.H.			Copper	1/2" Threaded	2-1/2" Sweat to Threaded Nipples	1/2" Union	1/2"	6"	4"	

GENERAL NOTES

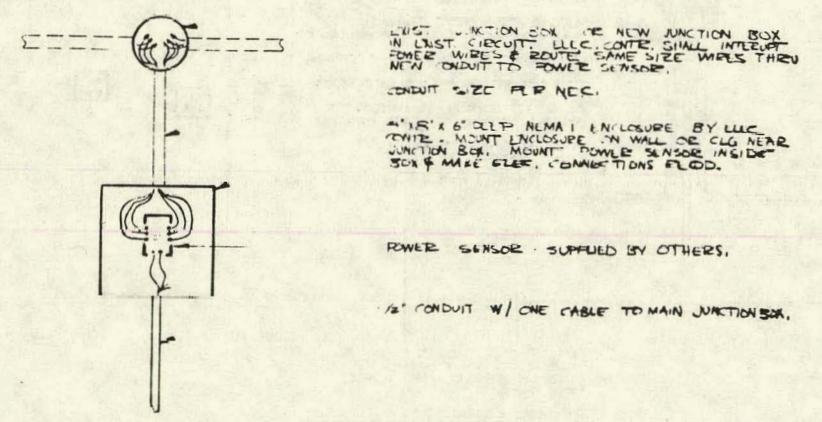
- 1) BLUE PLANS PROVIDED FOR THE INSTALLATION OF A DATA ACQUISITION SYSTEM FOR THE MOUNT RUSHMORE VISITOR CENTER SOLAR ENERGY SYSTEM. THE ADDITION OF THESE ITEMS DOES NOT & SHALL NOT AFFECT THE ORIGINAL SYSTEM & CREATION.
- 2) PRODUCTS & MATERIALS USED FOR THE INSTALLATION OF THIS INSTRUMENTATION SHALL BE THE SAME AS & BE COMPATIBLE W/ THOSE USED ON THE ORIGINAL SYSTEM & IN THAT SPECIFICATION MANUAL.
- 3) ALL WORK WHEN SHALL BE DONE IN A NEAT & THOROUGH WAY TO OBTAIN A QUALITY PRODUCT.
- 4) PORTIONS OF THE WORK HEREIN APPLY TO THE PIPING & HEATING CONTRACTOR, THE VENTILATION CONTRACTOR, & THE ELECTRICAL CONTRACTOR. EACH SHALL DO THE WORK SO NOTED OR RECORDED TO HIM.
- 5) WRITE IN THE ELECTRICAL CONTRACTOR'S NOTES: "ABLE TO BE REPLACED TO IT SHALL MEAN 4" DIA. FOR 4" & 6" DIA. FOR 6" & 8" DIA. FOR 8" & 10" DIA. FOR 10" & 12" DIA. FOR 12" & 14" DIA. FOR 14" & 16" DIA. FOR 16" & 18" DIA. FOR 18" & 20" DIA. FOR 20" & 22" DIA. FOR 22" & 24" DIA. FOR 24" & 26" DIA. FOR 26" & 28" DIA. FOR 28" & 30" DIA. FOR 30" & 32" DIA. FOR 32" & 34" DIA. FOR 34" & 36" DIA. FOR 36" & 38" DIA. FOR 38" & 40" DIA. FOR 40" & 42" DIA. FOR 42" & 44" DIA. FOR 44" & 46" DIA. FOR 46" & 48" DIA. FOR 48" & 50" DIA. FOR 50" & 52" DIA. FOR 52" & 54" DIA. FOR 54" & 56" DIA. FOR 56" & 58" DIA. FOR 58" & 60" DIA. FOR 60" & 62" DIA. FOR 62" & 64" DIA. FOR 64" & 66" DIA. FOR 66" & 68" DIA. FOR 68" & 70" DIA. FOR 70" & 72" DIA. FOR 72" & 74" DIA. FOR 74" & 76" DIA. FOR 76" & 78" DIA. FOR 78" & 80" DIA. FOR 80" & 82" DIA. FOR 82" & 84" DIA. FOR 84" & 86" DIA. FOR 86" & 88" DIA. FOR 88" & 90" DIA. FOR 90" & 92" DIA. FOR 92" & 94" DIA. FOR 94" & 96" DIA. FOR 96" & 98" DIA. FOR 98" & 100" DIA. FOR 100" & 102" DIA. FOR 102" & 104" DIA. FOR 104" & 106" DIA. FOR 106" & 108" DIA. FOR 108" & 110" DIA. FOR 110" & 112" DIA. FOR 112" & 114" DIA. FOR 114" & 116" DIA. FOR 116" & 118" DIA. FOR 118" & 120" DIA. FOR 120" & 122" DIA. FOR 122" & 124" DIA. FOR 124" & 126" DIA. FOR 126" & 128" DIA. FOR 128" & 130" DIA. FOR 130" & 132" DIA. FOR 132" & 134" DIA. FOR 134" & 136" DIA. FOR 136" & 138" DIA. FOR 138" & 140" DIA. FOR 140" & 142" DIA. FOR 142" & 144" DIA. FOR 144" & 146" DIA. FOR 146" & 148" DIA. FOR 148" & 150" DIA. FOR 150" & 152" DIA. FOR 152" & 154" DIA. FOR 154" & 156" DIA. FOR 156" & 158" DIA. FOR 158" & 160" DIA. FOR 160" & 162" DIA. FOR 162" & 164" DIA. FOR 164" & 166" DIA. FOR 166" & 168" DIA. FOR 168" & 170" DIA. FOR 170" & 172" DIA. FOR 172" & 174" DIA. FOR 174" & 176" DIA. FOR 176" & 178" DIA. FOR 178" & 180" DIA. FOR 180" & 182" DIA. FOR 182" & 184" DIA. FOR 184" & 186" DIA. FOR 186" & 188" DIA. FOR 188" & 190" DIA. FOR 190" & 192" DIA. FOR 192" & 194" DIA. FOR 194" & 196" DIA. FOR 196" & 198" DIA. FOR 198" & 200" DIA. FOR 200" & 202" DIA. FOR 202" & 204" DIA. FOR 204" & 206" DIA. FOR 206" & 208" DIA. FOR 208" & 210" DIA. FOR 210" & 212" DIA. FOR 212" & 214" DIA. FOR 214" & 216" DIA. FOR 216" & 218" DIA. FOR 218" & 220" DIA. FOR 220" & 222" DIA. FOR 222" & 224" DIA. FOR 224" & 226" DIA. FOR 226" & 228" DIA. FOR 228" & 230" DIA. FOR 230" & 232" DIA. FOR 232" & 234" DIA. FOR 234" & 236" DIA. FOR 236" & 238" DIA. FOR 238" & 240" DIA. FOR 240" & 242" DIA. FOR 242" & 244" DIA. FOR 244" & 246" DIA. FOR 246" & 248" DIA. FOR 248" & 250" DIA. FOR 250" & 252" DIA. FOR 252" & 254" DIA. FOR 254" & 256" DIA. FOR 256" & 258" DIA. FOR 258" & 260" DIA. FOR 260" & 262" DIA. FOR 262" & 264" DIA. FOR 264" & 266" DIA. FOR 266" & 268" DIA. FOR 268" & 270" DIA. FOR 270" & 272" DIA. FOR 272" & 274" DIA. FOR 274" & 276" DIA. FOR 276" & 278" DIA. FOR 278" & 280" DIA. FOR 280" & 282" DIA. FOR 282" & 284" DIA. FOR 284" & 286" DIA. FOR 286" & 288" DIA. FOR 288" & 290" DIA. FOR 290" & 292" DIA. FOR 292" & 294" DIA. FOR 294" & 296" DIA. FOR 296" & 298" DIA. FOR 298" & 300" DIA. FOR 300" & 302" DIA. FOR 302" & 304" DIA. FOR 304" & 306" DIA. FOR 306" & 308" DIA. FOR 308" & 310" DIA. FOR 310" & 312" DIA. FOR 312" & 314" DIA. FOR 314" & 316" DIA. FOR 316" & 318" DIA. FOR 318" & 320" DIA. FOR 320" & 322" DIA. FOR 322" & 324" DIA. FOR 324" & 326" DIA. FOR 326" & 328" DIA. FOR 328" & 330" DIA. FOR 330" & 332" DIA. FOR 332" & 334" DIA. FOR 334" & 336" DIA. FOR 336" & 338" DIA. FOR 338" & 340" DIA. FOR 340" & 342" DIA. FOR 342" & 344" DIA. FOR 344" & 346" DIA. FOR 346" & 348" DIA. FOR 348" & 350" DIA. FOR 350" & 352" DIA. FOR 352" & 354" DIA. FOR 354" & 356" DIA. FOR 356" & 358" DIA. FOR 358" & 360" DIA. FOR 360" & 362" DIA. FOR 362" & 364" DIA. FOR 364" & 366" DIA. FOR 366" & 368" DIA. FOR 368" & 370" DIA. FOR 370" & 372" DIA. FOR 372" & 374" DIA. FOR 374" & 376" DIA. FOR 376" & 378" DIA. FOR 378" & 380" DIA. FOR 380" & 382" DIA. FOR 382" & 384" DIA. FOR 384" & 386" DIA. FOR 386" & 388" DIA. FOR 388" & 390" DIA. FOR 390" & 392" DIA. FOR 392" & 394" DIA. FOR 394" & 396" DIA. FOR 396" & 398" DIA. FOR 398" & 400" DIA. FOR 400" & 402" DIA. FOR 402" & 404" DIA. FOR 404" & 406" DIA. FOR 406" & 408" DIA. FOR 408" & 410" DIA. FOR 410" & 412" DIA. FOR 412" & 414" DIA. FOR 414" & 416" DIA. FOR 416" & 418" DIA. FOR 418" & 420" DIA. FOR 420" & 422" DIA. FOR 422" & 424" DIA. FOR 424" & 426" DIA. FOR 426" & 428" DIA. FOR 428" & 430" DIA. FOR 430" & 432" DIA. FOR 432" & 434" DIA. FOR 434" & 436" DIA. FOR 436" & 438" DIA. FOR 438" & 440" DIA. FOR 440" & 442" DIA. FOR 442" & 444" DIA. FOR 444" & 446" DIA. FOR 446" & 448" DIA. FOR 448" & 450" DIA. FOR 450" & 452" DIA. FOR 452" & 454" DIA. FOR 454" & 456" DIA. FOR 456" & 458" DIA. FOR 458" & 460" DIA. FOR 460" & 462" DIA. FOR 462" & 464" DIA. FOR 464" & 466" DIA. FOR 466" & 468" DIA. FOR 468" & 470" DIA. FOR 470" & 472" DIA. FOR 472" & 474" DIA. FOR 474" & 476" DIA. FOR 476" & 478" DIA. FOR 478" & 480" DIA. FOR 480" & 482" DIA. FOR 482" & 484" DIA. FOR 484" & 486" DIA. FOR 486" & 488" DIA. FOR 488" & 490" DIA. FOR 490" & 492" DIA. FOR 492" & 494" DIA. FOR 494" & 496" DIA. FOR 496" & 498" DIA. FOR 498" & 500" DIA. FOR 500" & 502" DIA. FOR 502" & 504" DIA. FOR 504" & 506" DIA. FOR 506" & 508" DIA. FOR 508" & 510" DIA. FOR 510" & 512" DIA. FOR 512" & 514" DIA. FOR 514" & 516" DIA. FOR 516" & 518" DIA. FOR 518" & 520" DIA. FOR 520" & 522" DIA. FOR 522" & 524" DIA. FOR 524" & 526" DIA. FOR 526" & 528" DIA. FOR 528" & 530" DIA. FOR 530" & 532" DIA. FOR 532" & 534" DIA. FOR 534" & 536" DIA. FOR 536" & 538" DIA. FOR 538" & 540" DIA. FOR 540" & 542" DIA. FOR 542" & 544" DIA. FOR 544" & 546" DIA. FOR 546" & 548" DIA. FOR 548" & 550" DIA. FOR 550" & 552" DIA. FOR 552" & 554" DIA. FOR 554" & 556" DIA. FOR 556" & 558" DIA. FOR 558" & 560" DIA. FOR 560" & 562" DIA. FOR 562" & 564" DIA. FOR 564" & 566" DIA. FOR 566" & 568" DIA. FOR 568" & 570" DIA. FOR 570" & 572" DIA. FOR 572" & 574" DIA. FOR 574" & 576" DIA. FOR 576" & 578" DIA. FOR 578" & 580" DIA. FOR 580" & 582" DIA. FOR 582" & 584" DIA. FOR 584" & 586" DIA. FOR 586" & 588" DIA. FOR 588" & 590" DIA. FOR 590" & 592" DIA. FOR 592" & 594" DIA. FOR 594" & 596" DIA. FOR 596" & 598" DIA. FOR 598" & 600" DIA. FOR 600" & 602" DIA. FOR 602" & 604" DIA. FOR 604" & 606" DIA. FOR 606" & 608" DIA. FOR 608" & 610" DIA. FOR 610" & 612" DIA. FOR 612" & 614" DIA. FOR 614" & 616" DIA. FOR 616" & 618" DIA. FOR 618" & 620" DIA. FOR 620" & 622" DIA. FOR 622" & 624" DIA. FOR 624" & 626" DIA. FOR 626" & 628" DIA. FOR 628" & 630" DIA. FOR 630" & 632" DIA. FOR 632" & 634" DIA. FOR 634" & 636" DIA. FOR 636" & 638" DIA. FOR 638" & 640" DIA. FOR 640" & 642" DIA. FOR 642" & 644" DIA. FOR 644" & 646" DIA. FOR 646" & 648" DIA. FOR 648" & 650" DIA. FOR 650" & 652" DIA. FOR 652" & 654" DIA. FOR 654" & 656" DIA. FOR 656" & 658" DIA. FOR 658" & 660" DIA. FOR 660" & 662" DIA. FOR 662" & 664" DIA. FOR 664" & 666" DIA. FOR 666" & 668" DIA. FOR 668" & 670" DIA. FOR 670" & 672" DIA. FOR 672" & 674" DIA. FOR 674" & 676" DIA. FOR 676" & 678" DIA. FOR 678" & 680" DIA. FOR 680" & 682" DIA. FOR 682" & 684" DIA. FOR 684" & 686" DIA. FOR 686" & 688" DIA. FOR 688" & 690" DIA. FOR 690" & 692" DIA. FOR 692" & 694" DIA. FOR 694" & 696" DIA. FOR 696" & 698" DIA. FOR 698" & 700" DIA. FOR 700" & 702" DIA. FOR 702" & 704" DIA. FOR 704" & 706" DIA. FOR 706" & 708" DIA. FOR 708" & 710" DIA. FOR 710" & 712" DIA. FOR 712" & 714" DIA. FOR 714" & 716" DIA. FOR 716" & 718" DIA. FOR 718" & 720" DIA. FOR 720" & 722" DIA. FOR 722" & 724" DIA. FOR 724" & 726" DIA. FOR 726" & 728" DIA. FOR 728" & 730" DIA. FOR 730" & 732" DIA. FOR 732" & 734" DIA. FOR 734" & 736" DIA. FOR 736" & 738" DIA. FOR 738" & 740" DIA. FOR 740" & 742" DIA. FOR 742" & 744" DIA. FOR 744" & 746" DIA. FOR 746" & 748" DIA. FOR 748" & 750" DIA. FOR 750" & 752" DIA. FOR 752" & 754" DIA. FOR 754" & 756" DIA. FOR 756" & 758" DIA. FOR 758" & 760" DIA. FOR 760" & 762" DIA. FOR 762" & 764" DIA. FOR 764" & 766" DIA. FOR 766" & 768" DIA. FOR 768" & 770" DIA. FOR 770" & 772" DIA. FOR 772" & 774" DIA. FOR 774" & 776" DIA. FOR 776" & 778" DIA. FOR 778" & 780" DIA. FOR 780" & 782" DIA. FOR 782" & 784" DIA. FOR 784" & 786" DIA. FOR 786" & 788" DIA. FOR 788" & 790" DIA. FOR 790" & 792" DIA. FOR 792" & 794" DIA. FOR 794" & 796" DIA. FOR 796" & 798" DIA. FOR 798" & 800" DIA. FOR 800" & 802" DIA. FOR 802" & 804" DIA. FOR 804" & 806" DIA. FOR 806" & 808" DIA. FOR 808" & 810" DIA. FOR 810" & 812" DIA. FOR 812" & 814" DIA. FOR 814" & 816" DIA. FOR 816" & 818" DIA. FOR 818" & 820" DIA. FOR 820" & 822" DIA. FOR 822" & 824" DIA. FOR 824" & 826" DIA. FOR 826" & 828" DIA. FOR 828" & 830" DIA. FOR 830" & 832" DIA. FOR 832" & 834" DIA. FOR 834" & 836" DIA. FOR 836" & 838" DIA. FOR 838" & 840" DIA. FOR 840" & 842" DIA. FOR 842" & 844" DIA. FOR 844" & 846" DIA. FOR 846" & 848" DIA. FOR 848" & 850" DIA. FOR 850" & 852" DIA. FOR 852" & 854" DIA. FOR 854" & 856" DIA. FOR 856" & 858" DIA. FOR 858" & 860" DIA. FOR 860" & 862" DIA. FOR 862" & 864" DIA. FOR 864" & 866" DIA. FOR 866" & 868" DIA. FOR 868" & 870" DIA. FOR 870" & 872" DIA. FOR 872" & 874" DIA. FOR 874" & 876" DIA. FOR 876" & 878" DIA. FOR 878" & 880" DIA. FOR 880" & 882" DIA. FOR 882" & 884" DIA. FOR 884" & 886" DIA. FOR 886" & 888" DIA. FOR 888" & 890" DIA. FOR 890" & 892" DIA. FOR 892" & 894" DIA. FOR 894" & 896" DIA. FOR 896" & 898" DIA. FOR 898" & 900" DIA. FOR 900" & 902" DIA. FOR 902" & 904" DIA. FOR 904" & 906" DIA. FOR 906" & 908" DIA. FOR 908" & 910" DIA. FOR 910" & 912" DIA. FOR 912" & 914" DIA. FOR 914" & 916" DIA. FOR 916" & 918" DIA. FOR 918" & 920" DIA. FOR 920" & 922" DIA. FOR 922" & 924" DIA. FOR 924" & 926" DIA. FOR 926" & 928" DIA. FOR 928" & 930" DIA. FOR 930" & 932" DIA. FOR 932" & 934" DIA. FOR 934" & 936" DIA. FOR 936" & 938" DIA. FOR 938" & 940" DIA. FOR 940" & 942" DIA. FOR 942" & 944" DIA. FOR 944" & 946" DIA. FOR 946" & 948" DIA. FOR 948" & 950" DIA. FOR 950" & 952" DIA. FOR 952" & 954" DIA. FOR 954" & 956" DIA. FOR 956" & 958" DIA. FOR 958" & 960" DIA. FOR 960" & 962" DIA. FOR 962" & 964" DIA. FOR 964" & 966" DIA. FOR 966" & 968" DIA. FOR 968" & 970" DIA. FOR 970" & 972" DIA. FOR 972" & 974" DIA. FOR 974" & 976" DIA. FOR 976" & 978" DIA. FOR 978" & 980" DIA. FOR 980" & 982" DIA. FOR 982" & 984" DIA. FOR 984" & 986" DIA. FOR 986" & 988" DIA. FOR 988" & 990" DIA. FOR 990" & 992" DIA. FOR 992" & 994" DIA. FOR 994" & 996" DIA. FOR 996" & 998" DIA. FOR 998" & 1000" DIA. FOR 1000" & 1002" DIA. FOR 1002" & 1004" DIA. FOR 1004" & 1006" DIA. FOR 1006" & 1008" DIA. FOR 1008" & 1010" DIA. FOR 1010" & 1012" DIA. FOR 1012" & 1014" DIA. FOR 1014" & 1016" DIA. FOR 1016" & 1018" DIA. FOR 1018" & 1020" DIA. FOR 1020" & 1022" DIA. FOR 1022" & 1024" DIA. FOR 1024" & 1026" DIA. FOR 1026" & 1028" DIA. FOR 1028" & 1030" DIA. FOR 1030" & 1032" DIA. FOR 1032" & 1034" DIA. FOR 1034" & 1036" DIA. FOR 1036" & 1038" DIA. FOR 1038" & 1040" DIA. FOR 1040" & 1042" DIA. FOR 1042" & 1044" DIA. FOR 1044" & 1046" DIA. FOR 1046" & 1048" DIA. FOR 1048" & 1050" DIA. FOR 1050" & 1052" DIA. FOR 1052" & 1054" DIA. FOR 1054" & 1056" DIA. FOR 1056" & 1058" DIA. FOR 1058" & 1060" DIA. FOR 1060" & 1062" DIA. FOR 1062" & 1064" DIA. FOR 1064" & 1066" DIA. FOR 1066" & 1068" DIA. FOR 1068" & 1070" DIA. FOR 1070" & 1072" DIA. FOR 1072" & 1074" DIA. FOR 1074" & 1076" DIA. FOR 1076" & 1078" DIA. FOR 1078" & 1080" DIA. FOR 1080" & 1082" DIA. FOR 1082" & 1084" DIA. FOR 1084" & 1086" DIA. FOR 1086" & 1088" DIA. FOR 1088" & 1090" DIA. FOR 1090" & 1092" DIA. FOR 1092" & 1094" DIA. FOR 1094" & 1096" DIA. FOR 1096" & 1098" DIA. FOR 1098" & 1100" DIA. FOR 1100" & 1102" DIA. FOR 1102" & 1104" DIA. FOR 1104" & 1106" DIA. FOR 1106" & 1108" DIA. FOR 1108" & 1110" DIA. FOR 1110" & 1112" DIA. FOR 1112" & 1114" DIA. FOR 1114" & 1116" DIA. FOR 1116" & 1118" DIA. FOR 1118" & 1120" DIA. FOR 1120" & 1122" DIA. FOR 1122" & 1124" DIA. FOR 1124" & 1126" DIA. FOR 1126" & 1128" DIA. FOR 1128" & 1130" DIA. FOR 1130" & 1132" DIA. FOR 1132" & 1134" DIA. FOR 1134" & 1136" DIA. FOR 1136" & 1138" DIA. FOR 1138" & 1140" DIA. FOR 1140" & 1142" DIA. FOR 1142" & 1144" DIA. FOR 1144" & 1146" DIA. FOR 1146" & 1148" DIA. FOR 1148" & 1150" DIA. FOR 1150" & 1152" DIA. FOR 1152" & 1154" DIA. FOR 1154" & 1156" DIA. FOR 1156" & 1158" DIA. FOR 1158" & 1160" DIA. FOR 1160" & 1162" DIA. FOR 1162" & 1164" DIA. FOR 1164" & 1166" DIA. FOR 1166" & 1168" DIA. FOR 1168" & 1170" DIA. FOR 1170" & 1172" DIA. FOR 1172" & 1174" DIA. FOR 1174" & 1176" DIA. FOR 1176" & 1178" DIA. FOR 1178" & 1180" DIA. FOR 1180" & 1182" DIA. FOR 1182" & 1184" DIA. FOR 1184" & 1186" DIA. FOR 1186" & 1188" DIA. FOR 1188" & 1190" DIA. FOR 1190" & 1192" DIA. FOR 1192" & 1194" DIA. FOR 1194" & 1196" DIA. FOR 1196" & 1198" DIA. FOR 1198" & 1200" DIA. FOR 1200" & 1202" DIA. FOR 1202" & 1204" DIA. FOR 1204" & 1206" DIA. FOR 1206" & 1208" DIA. FOR 1208" & 1210" DIA. FOR 1210" & 1212" DIA. FOR



ROOF PLAN - INSTRUMENTATION SCALE: 1/8" = 1'-0"

FIGURE 8 - Shows roof plan-instrumentation

POWER SENSORS						
Desc.	Name	Phase	Volts	Amps	Power	Sensor Model No.
EP101	Collector Pump & Purge Unit Fan Power P-1	3	208		1/2 HP	PCS-5
EP201	Storage Pump Power P-2	1	115		1/6 HP	PCS-1
EP503	Cooling Tower Pump Power P-3	1	115		1/2 HP	PCS-10
EP501	Solar Space Cooling Unit Operating Energy which includes:					PCS-19
	Cooling Tower Fan Power	1	115		1/3 HP	
	Three Arkla Units Operating Power	1	115		250 Watts/unit	
	Chilled Water Pump Power P-3	1	115		1/3 HP	
EP502	Observation A/C Room Blower A/C Unit & Air Blower Power	3	208	45	9360 Watts 3 HP	PCS-51
EP504	Multizone A/C Unit Power	3	208	70	15 HP	PCS-53
EP601	Multizone Heating Unit Power (Fuel Oil Pump & Burner)	1	120		1/4 HP	PCS-1
EP602	Multizone Cooling & Heating Air Blower Power	3	208		3 HP	PCS-14

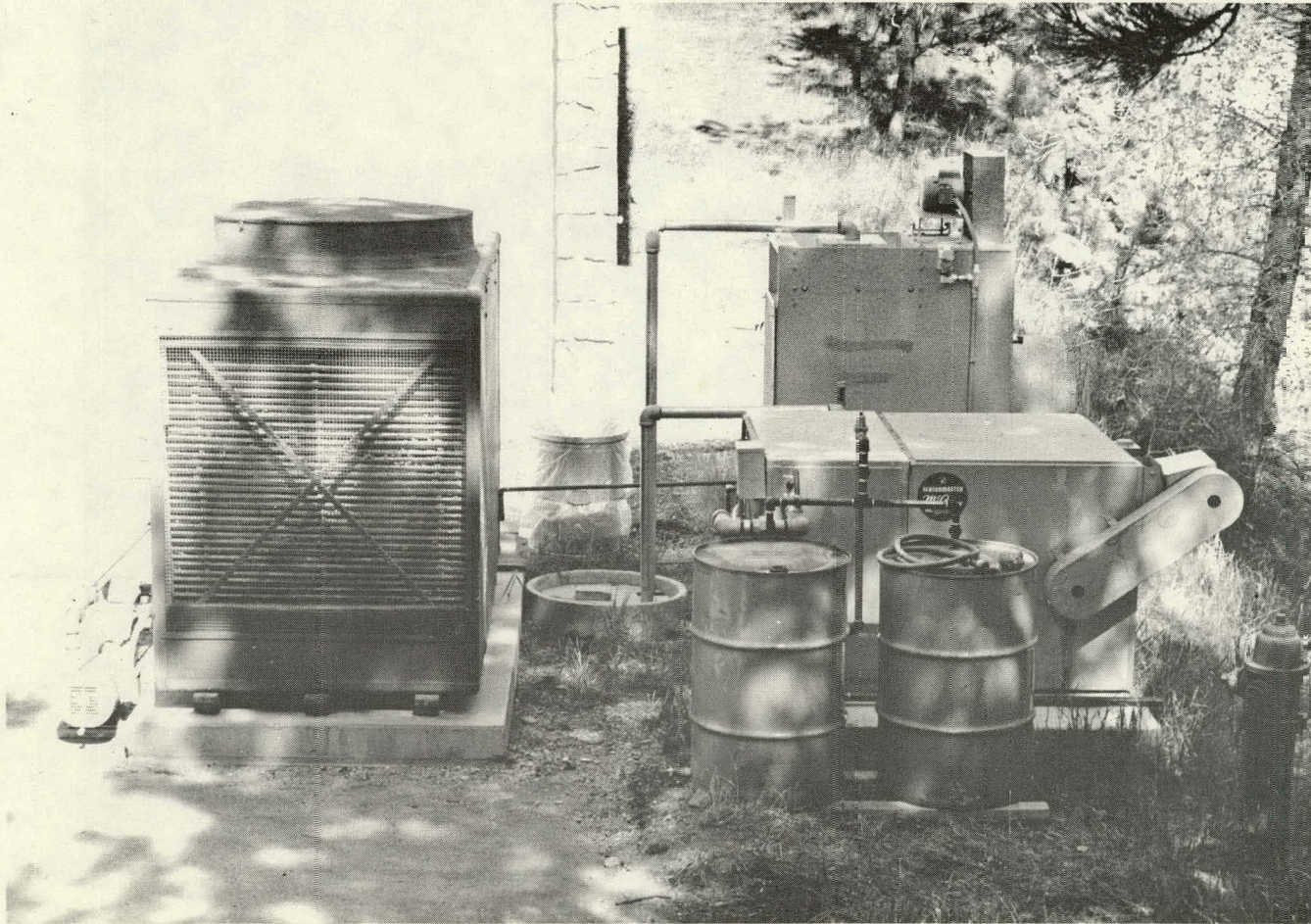


3 POWER SENSORS FOR WIRING NO SCALE

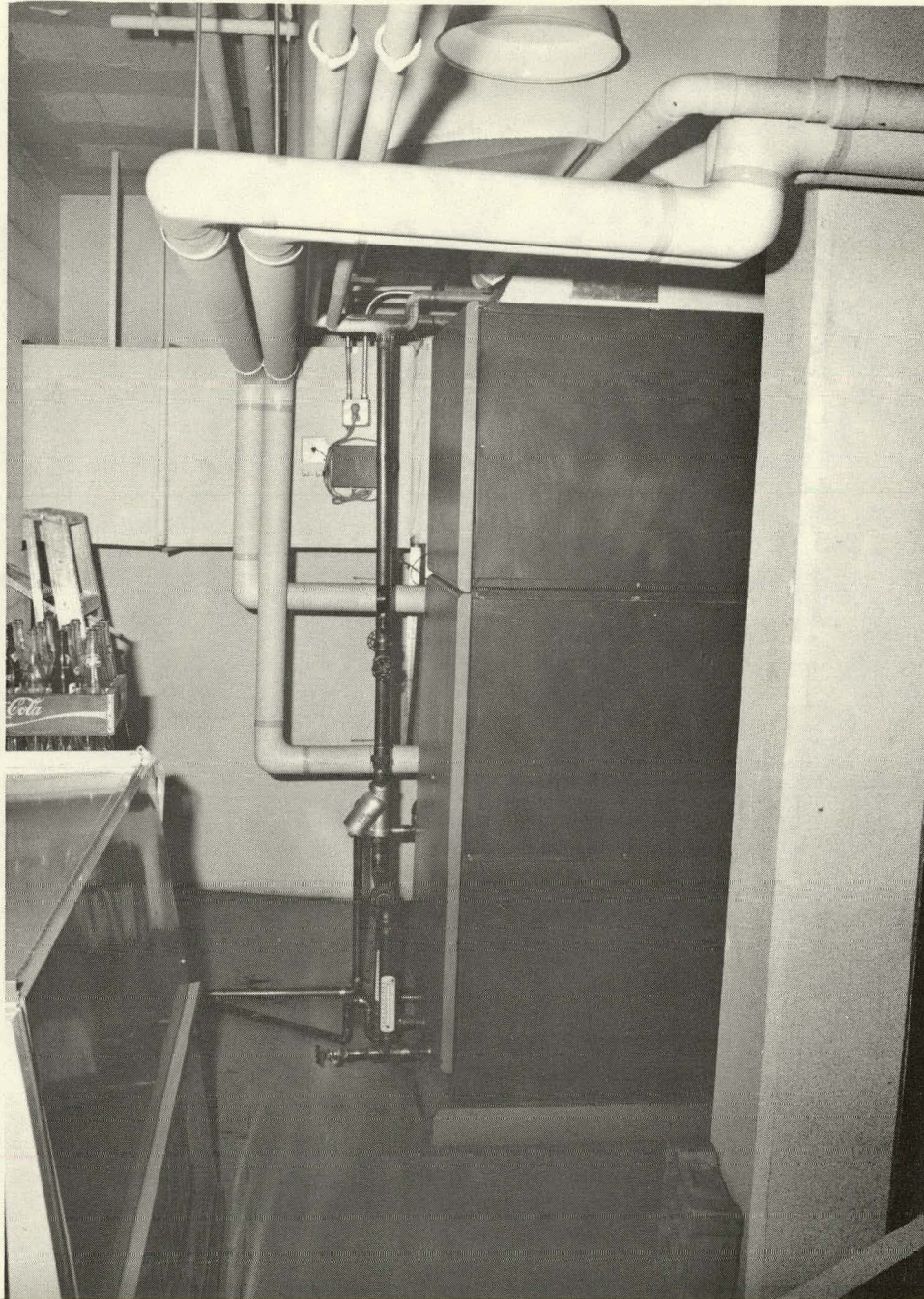
4. Operation and Maintenance Manual

Due to the fact that the O & MM is too bulky to make a part of this report for many reproductions, three complete copies of this manual are available at the following locations. One is located at the site of Mount Rushmore Visitor's Center; one as contractor's file at MSFC; and one in the office of Dr. C. W. Chiang, Mechanical Engineering Department, South Dakota School of Mines and Technology, Rapid City, SD 57701.

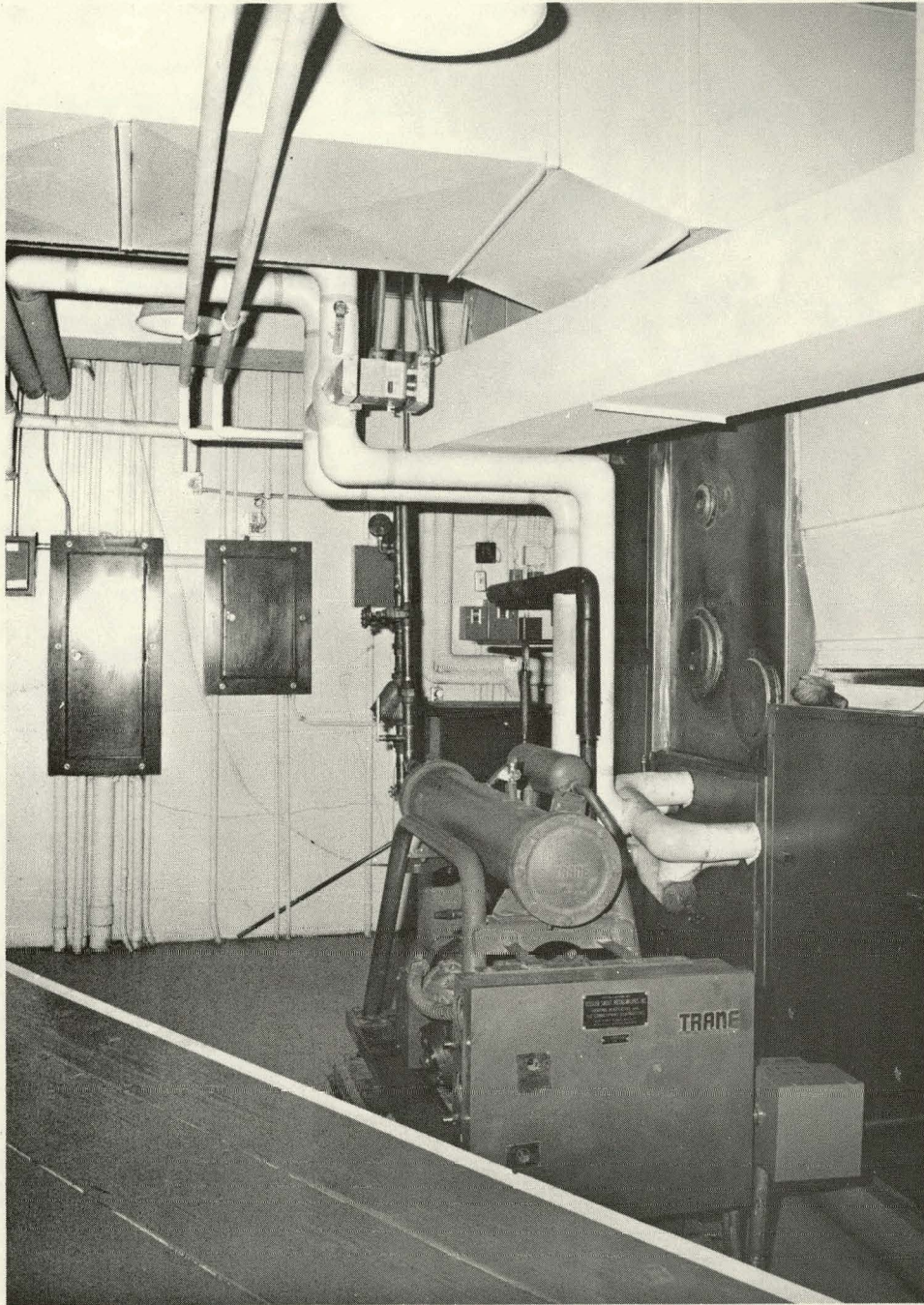
5. Pictures of final installation.



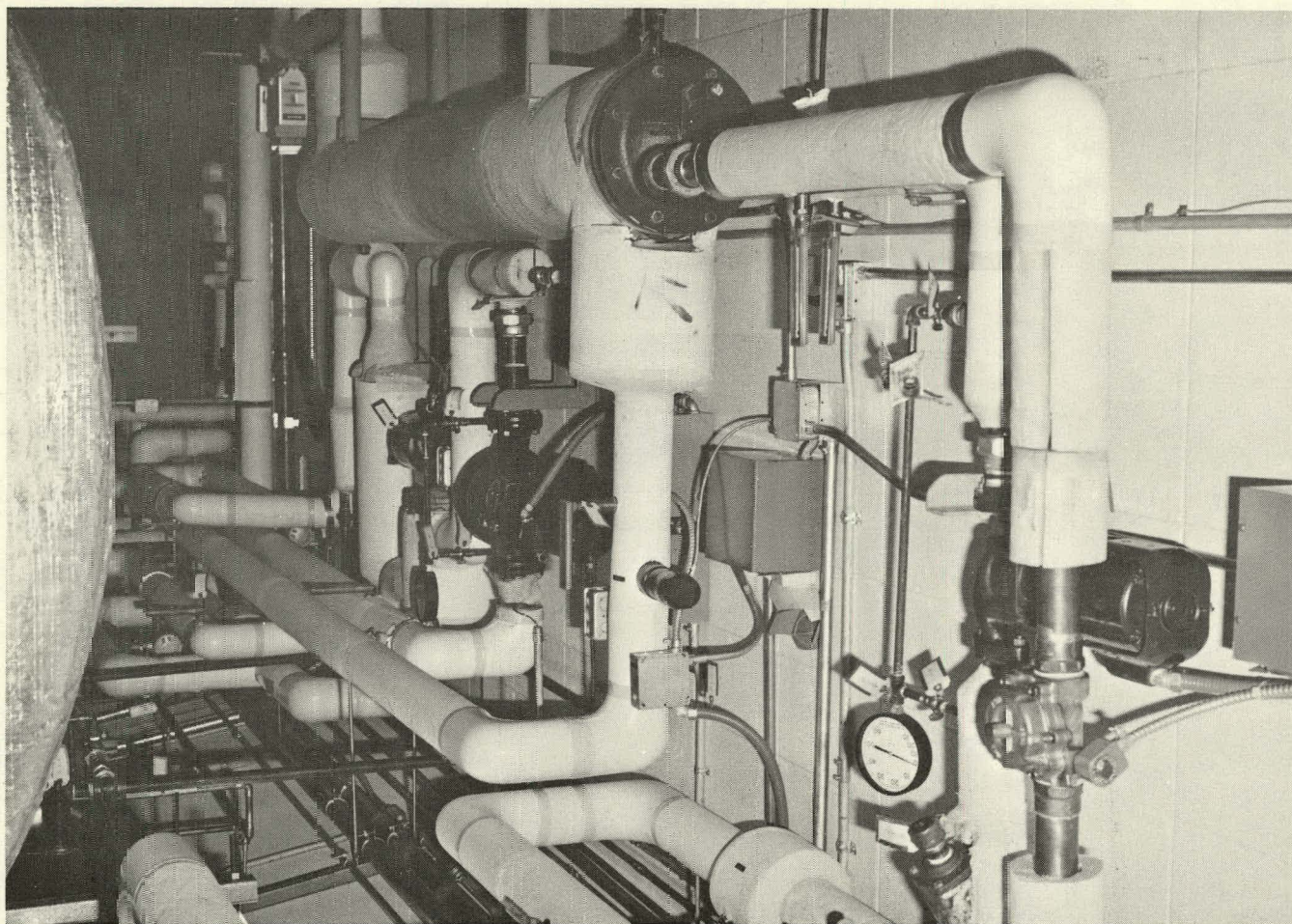
PURGE UNIT AND EXISTING COOLING TOWER



COOLING COIL AND PIPING TO EXISTING AIR HANDLING UNIT



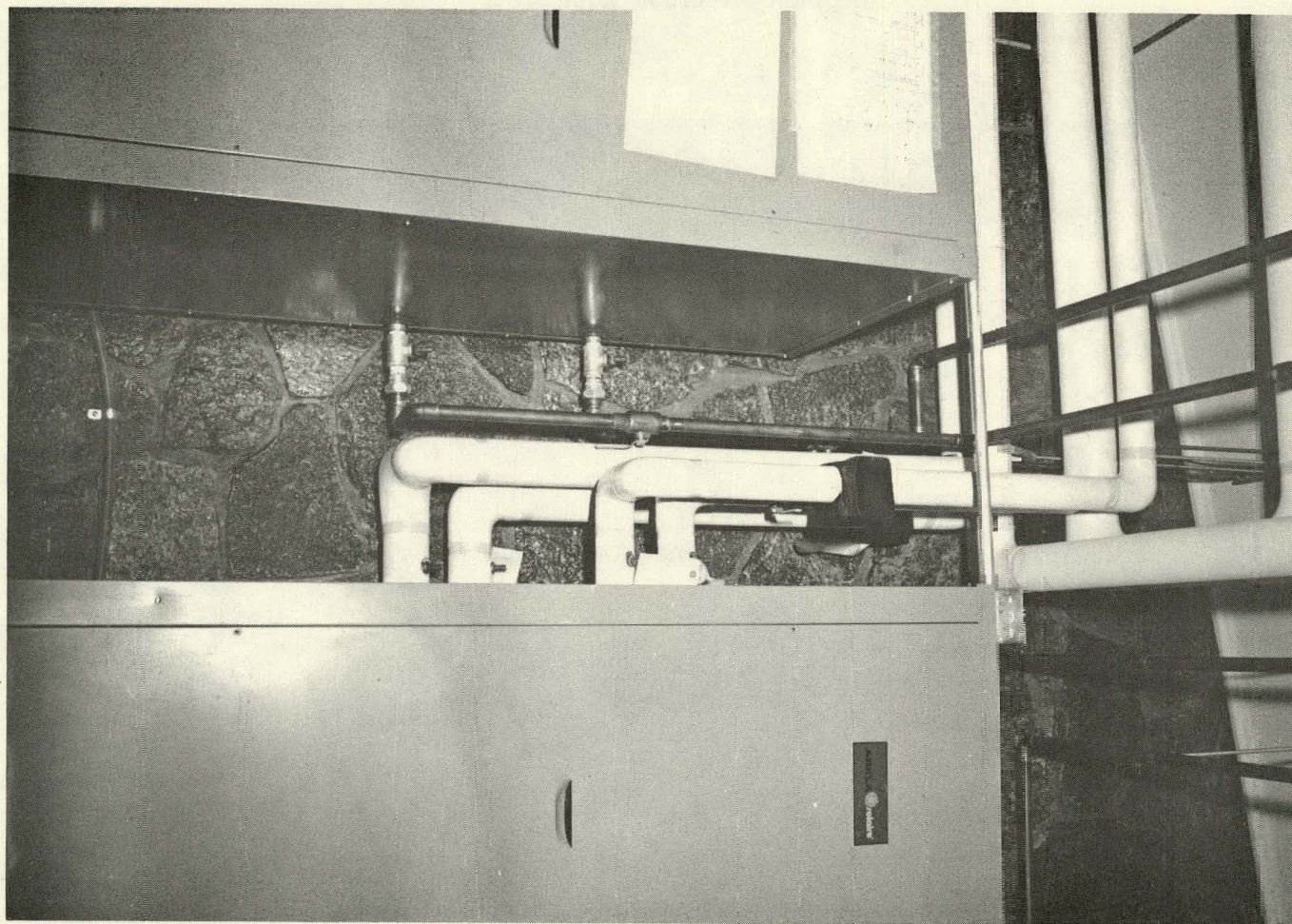
HEATING COIL WITH PIPING IN VALVE LEADING
TO EXISTING FURNACE



HEAT EXCHANGERS, PUMPS AND PIPING AT THE RIGHT
PART OF STORAGE TANK AT THE LEFT



ROOM ADDITION HOUSING
STORAGE TANK AND MECHANICAL SYSTEMS



TWO OF THE THREE ARKLA UNITS WITH PIPING



COLLECTORS WITH PIPING ON THE ROOF



COLLECTORS ON THE ROOF
SIDE VIEW



View of Complete Collector Arrays on the roof of Mount Rushmore Memorial
Visitor Center

6. Predicted System Performance Data

Heating load calculations indicate a maximum heating load of 400,000 Btu/hr for severe winter, as shown by Table B. 3-1. The total fuel consumed in FY 1975 was 8721 gallons of No. 2 oil. Assuming a heating value of 140,000 Btu/gal and a furnace efficiency of 50 percent due to the age of the furnace and an altitude of about one mile, the total conventional heat supplied was about 6.1×10^8 Btu.

Load calculations of the observatory room indicate a cooling load of 15-ton refrigeration needed as shown by Table B. 3-2. Solar energy system calculations were based on climatological data of Rapid City supplied by the National Oceanic and Atmospheric Administration (NOAA). The climatological conditions at Mount Rushmore (25 miles southwest and 2000 feet higher than Rapid City) are more favorable due to the altitude and lack of pollution in the air, making these calculations conservative.

The calculations are based on 2000 ft² of Honeywell LSC-18-1 double-glazed collectors tilting at a slope of 45.7 deg and facing 18.8 deg west of south. These angles are the result of mounting the collectors at 45 deg with respect to the roof, which has a slope of 9.3 deg facing 28 deg south of east. The collectors have a transmissivity absorptivity product of 0.84 and a heat loss coefficient of 0.68 Btu/hr-ft²-°F. The fluid flow rate is taken to be 40 gpm. The heat demand of the building, based on the actual heating data, was taken to be $2900 (70 - T_{amb})$ Btu/hr. The heat available from the solar system was taken to be $500 (T_{st} - 90)_x + 500 (T_{st} - T_{amb})$. (T_{st} = storage temperature, T_{amb} = outside temperature.) This assumes a heating coil design which allows 200,000 Btu/hr heating with 130°F water and no heating at 90°F and pre-heat coil for 10 percent ventilation. The heat capacity of storage was taken to be 32,000 Btu/°F. The solar insolation was calculat-

Table B.3-1. Heating Load Calculation

Room Name	Dimension ft x ft	Infiltra- tion ft	Glass ft ²	Wall ft ²	Roof ft ²	Floor ft ²	Btu/hr	Factor	Subtotal Btu/hr
102 Elect. vault	8x12			64		96	1990 192		2182
103 Storage	12x12	20	30	96		144	1260 1560 2980 290		6090
104 Work Room	20x38	60	110	460		760	3780 5720 14260 1520	10%	27,800
107 Work Room	25x14	52	64	413		350	3280 3330 12800 700		20,110
108 Women toilet room	13x5			54		65	1675 130		1805
110 Men toilet room	13x5			54		65	1675 130		1805
201 Men toilet room	28x12	44		468	366	366	2770 14500 4020 740	10%	24,230
202 Observatory	57x35	70	1360	550		2000	4400 70700 17000 22000	15%	135,800
203 Office	20x20	40	70	430	400		2520 3640 13300 4400	10%	26,440
204 office	13x14	40	53	90	182		2520 2760 2790 2000		10,070

Table B.3-1. Heating Load Calculation (Concluded)

Room Name	Dimension ft x ft	Infiltra- tion ft	Glass ft ²	Wall ft ²	Roof ft ²	Floor ft ²	Btu/hr	Factor	Subtotal Btu/hr
205 office	17x15	20	53	135	255		1260 2760 4190 2805		11,015
208 office	13x11	40	56	136	143		2520 2910 4230 1570		11,230
210 office	12x12	20	32	112	144		1260 1660 2470 1585		7975
211 office	12x16	40	48	204	192		2520 3400 6330 2100		14,360
212 audio control	4x7			48	28		1485 3080		4565
213 lobby	36x44	154	470	550	1660	1660	9700 24400 17050 18300 3350		72,800
214 women toilet room	28x12	44		468	366	366	2770 14500 4020 740		22,030
215 janitor closet	5x5			45	25	25	1345 275 50		1670
							Total		401,977

Table B.3-2. Cooling Load Calculation

Room 202 observatory:

Design conditions

Outside temp - 95°F, inside temp - 80°F, difference - 15°F

Outside walls: (sq ft)

<u>Side</u>	<u>Glass</u>	<u>Net wall</u>
North	150	450
West	1200	

Cooling load: BTU/HR

<u>Items</u>	<u>Sensible</u>	<u>Latent</u>	<u>Remarks</u>
Sensible heat gain thru glass 150 sq. ft. x 23 Btu/ft ² /hr	3,450		
(22-3.5) x 54 x 140	140,000		3.5 ft approx. shading solar heat gain approx 140 Btu/ft ² /hr 4:00 pm July 21

Transmission gain

Walls 450 sq ft x .20 (factor) x 15 (ΔT)	1,350
Roof 2000 x .80 x 15	24,000

Internal heat gain:

People & lights

People:

<u>No.</u>	<u>Sensible factor</u>	<u>Latent factor</u>
40 x 200	8,000	
40 x 250		10,000

Lights: 5000 watts x 3.4

17,000

Total

149,800

10,000

Ventilation or infiltration

450 CFM x 1.08 x 35 = 17,000 Sensible

450 CFM x 1.08 x $\frac{35}{3}$ = 5,700 Latent

Total load = 149800 + 10,000 + 17,000 + 5,700 = 182,500 Btu/hr.

or $\frac{182,500}{12,000} \approx 15$ tons

ed by multiplying a typical direct sunlight reading in Rapid City of 290 Btu/hr-ft² by a geometrical factor and also multiplied by the percentage sunlight for the particular day. The geometrical factor was the scalar product of the normal to the collector surface with the sun's rays expressed as a function of tilt of the earth's axis, local latitude, slope of the roof, orientation of the building, slope of the collector with respect to the roof, day of the year and time of day. The geometric factor also includes the shading effect of adjacent collectors.

The model was run using the climatological data for 1971-1974. The results shown in Table B.3-3 are for a typical day using the average high and low temperatures for that month and assuming 100 percent sunshine. This total is multiplied by the average percentage sunshine for the month. This method of approximation was checked by detailed hour-by-hour calculation using February 1973, when the storage temperature dropped to nearly 80°F every night, and October 1973, when the storage temperature rose to around 160°F. In both cases the results were very close to the approximation; for February it was 3 percent low; for October the difference was less than 1 percent.

The percentage heating carried by the solar system is expected to be at least 53 percent since the atmospheric conditions at Mount Rushmore are more favorable than in Rapid City. Based on the current market price of \$0.39 per gallon for No. 2 fuel oil, the savings amounts to about \$1,710 of the \$3,226 worth of fuel consumed in FY 1975.

Solar cooling calculations are based on 165,000 Btu/hr of heat delivered to the cooling units at 210°F from the collectors. The limiting conditions of ambient temperature, percentage sunshine and time of day under which the above criteria could be met were determined. The climatological

Table B. 3-3. Heating/Cooling Solar Contribution

Heating Based on 1971-74 climatological data for Rapid City								Cooling based on 1971 data			
Month	Percent Sunshine	T _{ave} °F	T _{max} °F	T _{min} °F	Q _{need} 10 ⁶ Btu	Q _{solar} 10 ⁶ Btu	Monthly total 10 ⁶ Btu	Cooling Hrs	Cooling °days	Solar Cooling Hrs	Solar Cooling °days
Jan	54.8	20.9	32.7	9.0	3.44	0.99	29.7				
Feb	63.0	27.0	38.9	15.1	3.01	1.33	39.8				
March	63.5	33.5	48.4	23.6	2.56	1.51	45.1				
April	52.0	44.9	57.2	32.5	1.77	1.18	35.3				
May	58.0	54.1	67.2	41.0	1.12	>1.12	33.6				
June	61.3	65.6	78.8	52.4	0.30	>0.30	9.0	294	81	56	25
July	68.5	70.4	85.2	55.6				441	142	104	62
Aug	75.3	71.3	86.4	56.1				567	284	112	98
Sept	66.2	57.9	72.4	43.4	0.85	>0.85	25.5	186	43	62	40
Oct	66.3	48.2	61.7	34.8	1.53	1.46	43.8				
Nov	56.3	33.6	44.6	22.5	2.54	1.07	32.1				
Dec	60.3	24.1	35.6	12.5	3.21	0.99	29.7				
Total	62.2						323.6	1488	550	334	225
Heating contribution = $\frac{3.24 \times 10^8}{6.1 \times 10^8} = 53 \text{ percent}$ Cooling contribution = $\frac{225}{550} = 41 \text{ percent}$											

data of 1971 were then examined to determine the number of hours that the limiting conditions were exceeded when there was also a demand for cooling in the observatory. This is recorded in Table B. 3-3 as the number of solar hours of cooling. The total number of hours of cooling demand and the number of cooling degree days are also in that table.

The number of degree days when the solar absorption units were operating was found. The percentage of solar cooling was then figured by the ratio of solar degree days to cooling degree days.

$$\text{Percent solar} = \frac{\text{Solar degree days}}{\text{Cooling degree days}} \times 100$$

The savings from solar cooling can be approximated by assuming 334 hours of operation replacing a nine-ton conventional-type chiller with a coefficient of performance of 2.5. The savings is about 4230 kW-hr. At an estimated 3¢ per kW-hr, the saving amounts to about \$127.00 per year.

7. Major problems encountered and resolutions thereto

One of the major problems is the air bubbles in the system. As explained in the operation of the system, constant venting with frequencies as much as once a week to prevent a buildup of temperatures and pressures was necessary. The main pump was originally designed at the flow rate of 30 gpm. It was felt that the higher flow rate could solve the problem of pressure buildup or air bubbles problem. A larger pump was installed with the flow rate of approximately 48 gpm. This seemed to solve the air bubble problem. The frequency of air venting has drastically reduced.

Another problem encountered was one transformer was struck by lightning on August 14, 1978. Because of this, the main pump had lost the electric power supply so that the stagnant ethylene glycol solution in the collector loop was overheated and turned into steam. It took more than two weeks to repair the transformer, recharge the system and get it back into operation. This situation rarely happens.

The third major problem encountered was the thermosiphoning. On the last day of 1978, the ambient temperature was extremely low and the cold antifreeze back-flowed into the main heat exchanger through a three way valve V4. Apparently there was a slight leakage through the three way valve V4 even though the three way valve was in a completely shut off position. The cold antifreeze back-flowed into the jacket of the main heat exchanger and froze the water inside the tube bundle. As a result, the cover plate of the main heat exchanger cracked about 5 to 6 inches; there were two cracked lines of about 3/4" in two tubes; and antifreeze began to leak out. The system was drained, the cracks on the tube bundle were brazed, and the cover plate was replaced. The whole system was down for about one month. A check valve was installed in the pipeline to prevent any future back-flow of antifreeze into the main heat exchanger.

The last major problem is the control adjustment. In particular, the cam of all three way valves needs fine readjustment such that the sequence of operations will follow closely.

8. Lessons learned and recommendations

From the major problem of frequent air venting encountered in the operation of the system, the biggest cause may be the wrong locations of the inlet and outlet tubings to each solar panel. The roof on which the collector banks are mounted is sloping towards the east, such that each collector bank axis is tilting toward the east. The outlet tubings are on the lower end of each panel, thus any vapor lock or air bubbles may stay in the upper header tube of each panel and can never escape. This was a negligence on the part of collector supplier in shipping panels which were not according to shop drawings. A lesson learned here was that a close check of the panels before installation could have avoided the frequent air venting problems.

The second lesson learned from this project is that positive stop valves should be used instead of leaky three way valves. With positive stop valves the problem of thermosiphoning of cold antifreeze into the main heat exchanger could have been avoided.

The third lesson learned is that some of the sensor locations should have been at different places to ensure more meaningful results. For example, the inlet and outlet water temperature sensors to collectors were placed too close to the three way valve, V4. When the water is not circulating in the collectors, the two sensors do not represent the true readings due to heat conduction from piping.

The fourth lesson learned is that the current control system is too complex. A slight mal-adjustment of the three way valve cam can easily

cause malfunction of the operation sequence. A simpler control system is needed for the whole system such that any trouble-shooting will be much easier.

The last lesson learned from this project is a definite need of an on-site-monitor (OSM). During the last few months of operation, Mr. Val Fogle of Marshall Space Flight Center, NASA, Huntsville, Al (project monitor) helped install (on short loan basis) an on-site-monitoring system to the system. Through the OSM system, instant monitoring of various temperatures, flow rates, power requirement for various pumps and fans help understand and adjust the control sequence. Thus it enables us to know whether the system is in the right mode of operation.

9. The project manager, Dr. C. W. Chiang, of the South Dakota School of Mines has verified the following:
 - a. The solar system was installed per the enclosed as-built drawing.
 - b. The solar system met the acceptance test plan provisions.
 - c. The solar system met the interim performance criteria (NBSIR-1187) requirements.