DRAPES ENGINEERING
CONSULTING ENGINEERS
Mechanical·Electrical
GREAT FALLS, MONTANA

LIFE OF MONTANA INSURANCE COMPANY SOLAR SYSTEM

EM-78-F-03-2147

MASTER

OPERATION AND MAINTENANCE MANUAL

MAY 1980

JOB NO. 7881

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1. INTRODUCTION AND SCOPE

This operation and maintenance manual is provided to assist the system operators in the operation and maintenance of the solar heating system at the Life of Montana Insurance Company building in Bozeman, Montana.

The solar heating system is a space heating system used to supplement the conventional heating system in the building. The system supplies heat only to the space heating system and none to the domestic water system. The solar system will supply only a portion of the total annual heating needs of the building, not all of its needs, although it may supply all of the heating needs of the building for one day if enough solar heat is available for that particular day.

The conventional heating system in the building is a hot water or hydronic heating system. Heat is supplied to the system by a natural gas-fired hot water boiler. This heat is then transferred to the building by pumping hot water through heating coils in the various heating units throughout the building.

The solar system is also a hydronic or liquid system. A liquid is pumped through the solar collectors to extract heat from the collectors when solar energy is available. This heat is then stored in two water storage tanks until the heat is needed in the building. When heat is needed in the building this heat is pumped through the coils in the heating units. If the storage tanks are drained of heat, the system automatically switches to supply heat from the boiler rather than the solar storage tanks.

Because water in the collectors will freeze in the winter in Bozeman's climate, the liquid circulating through the collectors is a solution of

ethylene glycol and water to prevent freezing. To avoid then having to fill the entire solar and conventional heating system with glycol, an intermediate heat exchanger has been introduced between the collector loop and storage loop to confine the glycol to as small a volume as possible to be used just in the collector loop.

2. SYSTEM OPERATION

A glycol holding tank has been provided to store the ethylene glycol solution. Initially the collector loop is drained and the glycol solution must be pumped into the system.

For system fill, all of the air vents in the collector loop should be valved open to allow purging the air from the system as it is filled. The system has been piped to permit filling the system by using the collector pump (Pump #1) to suck glycol from the glycol holding tank and pump it into the collector loop. This is accomplished by opening Valve S-4 in the line from the bottom of the glycol holding tank to the collector loop piping on the suction side of the pump. At the same time valve S-5 in the collector loop piping just upstream from this tee in the collector loop piping is closed thus permitting the collector pump to suck the glycol solution from the glycol holding tank and pump it into the collector loop system.

When the pump starts to cavitate or the glycol holding tank is empty Valve S-4 is closed and Valve S-5 opened. The system has now been charged with glycol. To pressurize the system a hose bibb, Valve S-6, has been provided in the collector loop piping and a hose bibb, Valve S-11, has been provided in the domestic water piping to inject city water under pressure to the collector loop to pressurize the system. The system should be pressurized to approximately 20 psi.

All of the air vents in the collector loop, with the exception of the air vent on the air purger, should be valved off after the system is filled and purged of air to prevent the air vents from becoming clogged due to the glycol. These air vents should be opened periodically to allow

for air puging and to check the operation of the air vents.

A drain valve, Valve S-7, has been provided in the collector loop on the discharge of the heat exchanger to allow testing of the glycol solution. The solution should be checked at the start of each heating season and periodically throughout the year. The solution should be checked for its specific gravity and ph.

The specific gravity check is used to ensure the solution still has a freezing point below the conditions it is expected to encounter. If not, additional glycol must be added. The ph should be checked for acidity. Glycol will tend to break down with repeated exposure to high temperatures and form an organic acid compound. Thus, the ph should be monitored and buffered periodically to maintain a slightly basic ph of 7.5 to 8.0.

After long use glycol may form a sludge compound which will block off or foul fluid passages in the solar collectors or heat exchanger. In addition, chemical treatments containing chromates will also form organic sludges fouling fluid passages. Therefore, compounds containing chromates must not be used with glycol solutions. The glycol solution should be checked periodically for formation of sludge compounds. If this condition occurs the glycol solution should be replaced.

Draining of the glycol solution from the collector loop can be accomplished by use of the collector pump. This is achieved by opening Valve S-8 in the line from the collector pump discharge to the glycol holding tank, closing valve S-9 in the collector loop piping just downstream from this tee in the collector loop piping, and opening Valve S-10 on the

vacuum breaker just downstream from Valve S-8. The collector pump can now be used to drain the system. Some of the glycol solution will remain in the system. If the system is to be totally drained, the remaining glycol solution can be removed by blowing out the lines with air.

Control of the collector pump and storage pump (Pump #2) is accomplished by means of a differential thermostat. The differential thermostat has two temperature sensors connected to it. One sensor is located in the discharge piping of the collectors and the other sensor is located in the top of storage tank #1 in the mechanical room. The differential thermostat compares the temperature from the two sensors to determine if solar heat is available in the collectors.

If the collector sensor is 20°F. higher (ΔT on) than the storage tank sensor, indiciating heat is available in the collectors, the differential thermostat turns on the collector and storage pumps. When the temperature difference falls to 3°F (ΔT off) the differential thermostats turns off the collector and storage pumps. These pumps also have hand-off-automatic (HOA) switches which enable them to be run manually for testing in the hand or manual position. In the automatic position the differential thermostat will control the collector and storage pumps.

The ΔT on and ΔT off of the differential thermostat are different to prevent cycling of the collector and storage pumps. When the system is first activiated the warm glycol in the collectors is replaced by colder glycol in the system piping. Therefore the temperature difference between the collectors and storage will drop. If the glycol entering the collectors is cold enough the temperature difference between the collectors and

storage tank will drop to less than three degrees and the differential thermostat will turn off the collector and storage pumps. Thus the ΔT on is set higher than the ΔT off to prevent cycling of the pumps.

When heat is needed in the building it is taken from either the solar storage tanks or the boiler. Control of the heating system taking heat from either of these two sources is accomplished by valves S-2 and S-3. A temperature sensor located in the top of storage tank #1 in conjunction with a pneumatic controller located in the solar system control panel determines if the solar heat stored in the storage tanks is at a temperature high enough to supply heat to the building. This controller has been set at 105°F. If the temperature in the storage tanks is above 105°F Valve S-3 is open and Valve S-2 is closed permitting the heating system to extract heat from the storage tanks. If the temperature falls below 105°F Valve S-3 is closed and Valve S-2 is open, thus taking heat from the boiler or backup system.

Although this controller for the changeover from solar heat to backup heat is initially set at 105°F it is field adjustable. The system should be operated at varying conditions to determine the minimum setting possible and still maintain the building at acceptable temperatures. The controller will switch back to solar heat when the temperature in the storage tank has risen 3°F above the set point.

The aquastat in the boiler should be set at approximately 120°F or the lowest practical setting to be compatible with the solar system changeover control.

The storage tanks have been piped to permit the independent operation of storage tank #1. Because the temperature of the energy collected by the solar system is a function of outdoor temperature and amount of solar insolation available, there may be periods when the amount of energy collected may not be enough to raise the temperature of the storage tanks above the threshold level of useful energy in the storage tanks. The system has thus been piped to permit shutting off storage tank #2 and putting all the available energy into storage tank #1 to permit raising its temperature above the useful threshold level. This is accomplished by closing Valves S-12, S-13, S-14, and S-15 on storage tank #2 and leaving open valves S-16, S-17, S-18 and S-19 on storage tank #1.

3. SAFETY CONTROLS

There are several safety controls incorporated into the system to protect the system from overheating, overpressure and freezing and safeguard the personnel operating and maintaining the system.

The collectors are a source of heat and are required to have pressure relief valves to protect the collectors from overpressure. There are 14 relief valves located on the collectors, one for each half row of the seven rows of collectors. The relief valves are installed so there is no shutoff valve between the collectors and the relief valves. These relief valves are all set to discharge at 75 psi and discharge to the ground at the collectors.

Because accidential discharge of the glycol-solution at the collectors can be a common occurrence due to pump malfunction, power outages, etc. another relief valve on the glycol system has been located at the heat exchanger and its discharge piped to the glycol holding tank. This relief valve is set at 50 psi in order to discharge before the collector relief valves and thus to save the glycol under most overpressure conditions.

The water side of the heat exchanger and the boiler are also sources of heat and are required to have relief valves. These relief valves discharge to the floor in the mechanical room.

Since the building does not require space heating in the summertime but the solar system continues to collect heat, this excess heat must be dumped or the system will overheat and eventually overpressure.

The traditional method to dump excess heat from liquid solar systems is to use a heat rejector in the system. As a means of avoiding the initial

cost and operation and maintenance costs and problems with this type of equipment this system has been constructed to use the collectors as heat rejectors at nighttime.

These controls consist of a controller and a temperature sensor located in the top of storage tank #1. When this sensor reaches 180°F the controller turns on the storage pump and the collector pump in order to take heat from the storage tanks and reject it to the outside at night. When the temperature in the storage tanks drops to 170°F the controller will turn the pumps off.

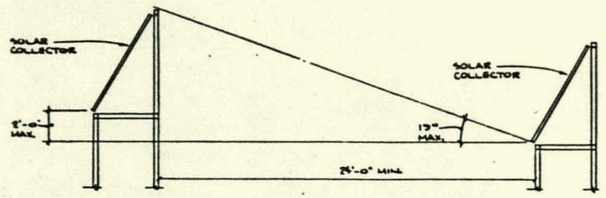
The system can also be drained to avoid overheating the system in the summertime. However the collectors will then stagnate at temperatures approaching 350°F. This condition should be avoided for long periods of time because damage to the collectors may result such as outgassing of the insulation, degradation of the seals, degradation of the selective surface of the absorber and other problems.

Freeze protection for the system is provided by the ethylene glycol solution in the collectors. However, a condition can occur with the heat exchanger during system shutdown where cold glycol below freezing can migrate or circulate by natural convection into the heat exchanger. Because one side of the heat exchanger contains water the cold glycol solution could freeze the water and damage the heat exchanger.

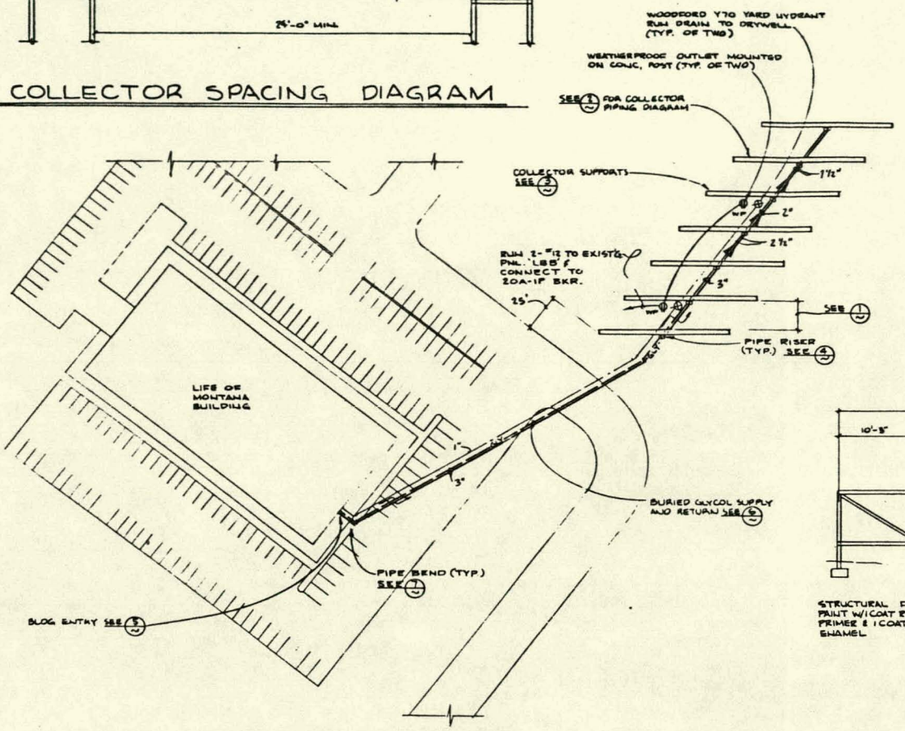
To prevent freezing of the heat exchanger, an automatic valve, Valve S-1, has been installed in the glycol piping adjacent to the heat exchanger to close when the system is shut down. This will prevent cold glycol from migrating into the heat exchanger and freezing the water.

SECTION 4

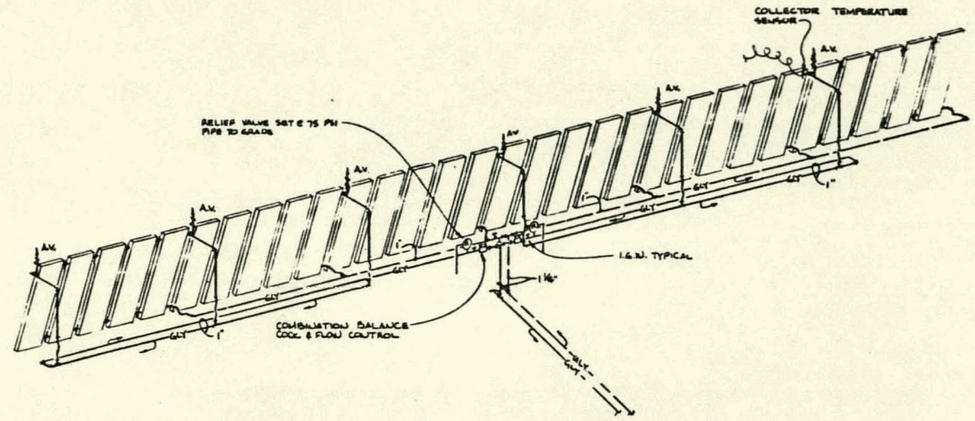
AS-BUILT DRAWINGS



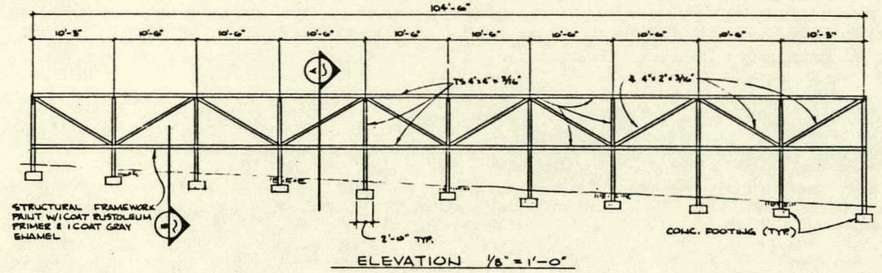
① COLLECTOR SPACING DIAGRAM



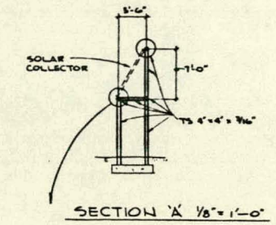
SITE PLAN 1"=50'-0"



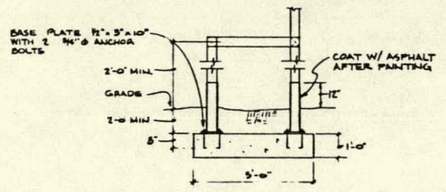
② COLLECTOR PIPING DIAGRAM (TYPICAL OF 7)



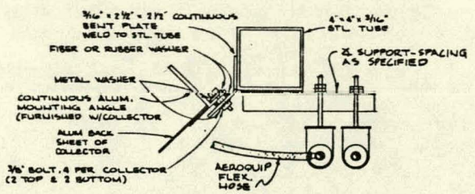
ELEVATION 1/8"=1'-0"



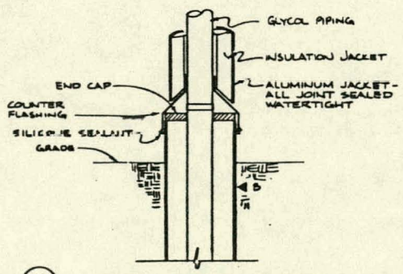
SECTION 'A' 1/8"=1'-0"



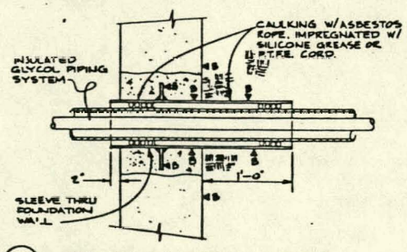
SECTION 'B' 3/8"=1'-0"



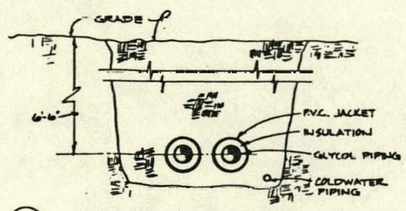
③ COLLECTOR SUPPORT DETAILS



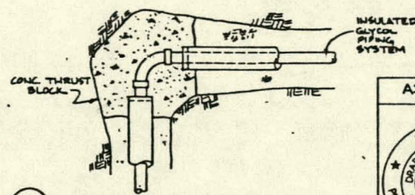
④ PIPE RISER DETAIL



⑤ BLDG. ENTRY DETAIL



⑥ BURIED PIPE DETAIL



⑦ PIPE BEND DETAIL

AS-BUILT 4-21-80

MONTANA DRAPER ENGINEERING P.O. DRAWER 10280 BOZEMAN, MONTANA 59715 REGISTERED PROFESSIONAL ENGINEERS

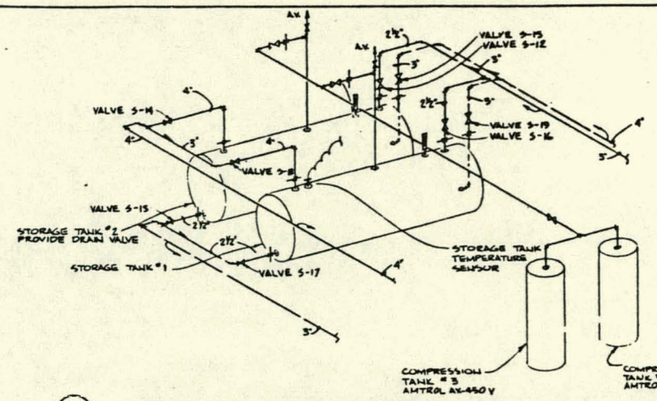
LIFE OF MONTANA OFFICE BUILDING SOLAR SYSTEM

BOZEMAN MONTANA

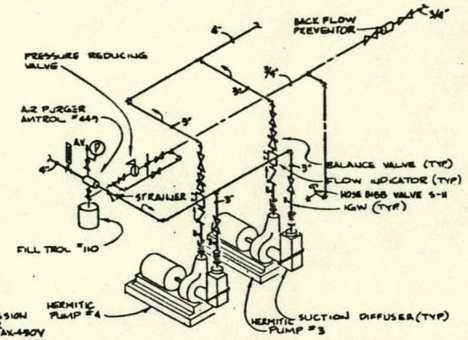
Drawn C.D.
Date 8&9/81
Rev. JAN 11 1979

Mechanical & Electrical Engineers Great Falls, Montana DE DAVID ENGINEERS

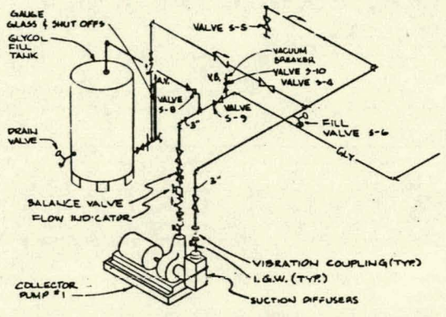
Sheet number 1 of 4



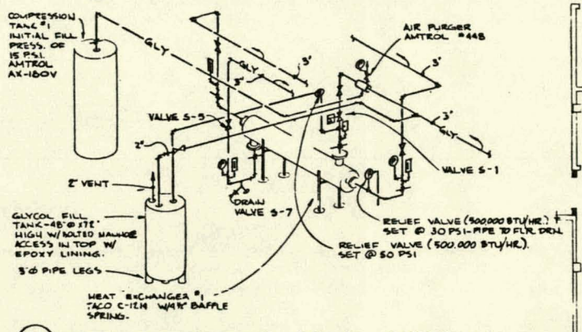
1 STORAGE TANKS - PIPING DIAGRAM



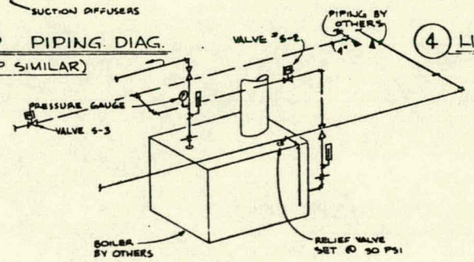
2 HEATING PUMPS PIPING DIAG.



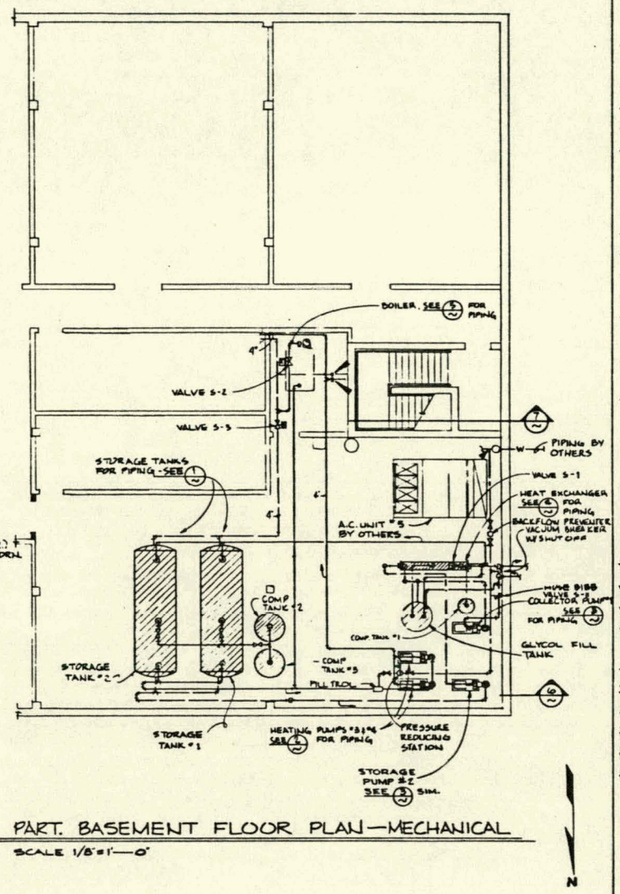
3 COLLECTOR PUMP PIPING DIAG.
(STORAGE PUMP SIMILAR)



4 HEAT EXCHANGER PIPING DIAGRAM

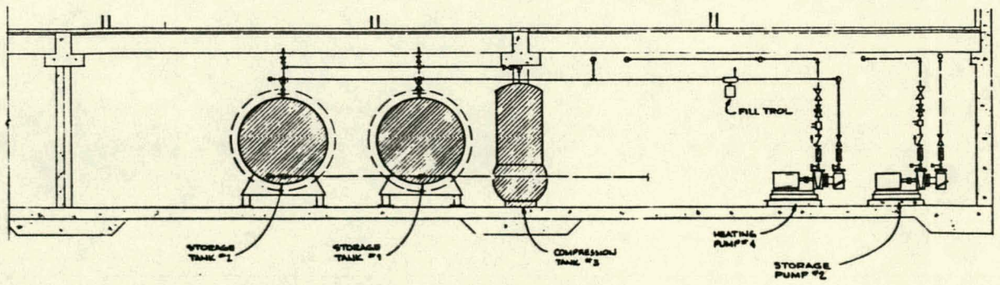


5 BOILER PIPING DIAG

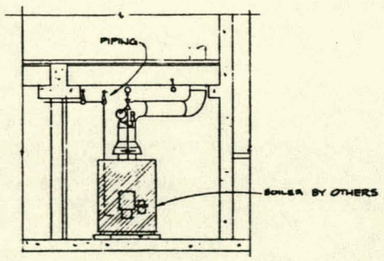


PART. BASEMENT FLOOR PLAN—MECHANICAL

SCALE 1/8"=1'—0"



6 SECTION 1/8"=1'-0"



7 SECTION 1/8"=1'-0"

MECHANICAL LEGEND

- DOMESTIC COLD WATER
- DOMESTIC HOT WATER
- DOMESTIC RECIRCULATING HOT WATER
- S — SANITARY SEWER SOIL AND WASTE
- SANITARY SEWER VENT
- G — NATURAL GAS
- HEATING WATER SUPPLY
- HEATING WATER RETURN
- GLY — GLYCOL SUPPLY
- GLY — GLYCOL RETURN
- PIPE UP
- PIPE DOWN
- ECCENTRIC REDUCER
- UNION
- STRAINER
- FLEXIBLE PIPE
- BALANCE STATION FLOW INDICATOR
- A.V. AIR VENT
- V.B. VACCUM BREAKER
- THERMOSTAT
- P TEMPERATURE GAUGE OR THERMOMETER
- PRESSURE GAUGE
- GATE VALVE
- GLOBE VALVE
- CHECK VALVE
- BALANCE COCK
- GAS COCK
- 3-WAY VALVE
- MOTORIZED VALVE
- R RELIEF VALVE
- SHEET METAL DUCT (SIZE, WIDTH X DEPTH)
- SHEET METAL DUCT (ACOUSTICALLY-LINED)
- SHEET METAL DUCT (EXTERIOR INSULATION)
- FIBROUS DUCT
- FLEXIBLE DUCT
- SD SPLITTER DAMPER
- V.D. VOLUME DAMPER
- TURNING VANES
- AIR EXTRACTOR VANES
- FLEXIBLE DUCT CONNECTION
- F.D. FIRE DAMPER
- SD SUPPLY AIR DIFFUSER, GRILLE OR REGISTER
- RG RETURN OR RELIEF AIR GRILLE OR REGISTER
- EG EXHAUST AIR GRILLE OR REGISTER

ABBREVIATIONS

- F.A. FRESH AIR (OUTSIDE AIR)
- R.A. RETURN AIR
- E.A. EXHAUST AIR
- C.O. CLEANOUT (PLUMBING SYSTEM)
- I.G.W. PRESSURE-TEMPERATURE GAUGE WELL

SYMBOLS

- HEATING OR COOLING UNIT IDENTIFICATION
- PLUMBING FIXTURE MARK
- BITUMASTIC COATING.
- CONNECT TO EXISTING PIPING

AS-BUILT 4-21-80

MONTANA DRAPES ENGINEERING 410 DRAPES BLDG SPC MONTANA REGISTERED PROFESSIONAL ENGINEERS

LIFE OF MONTANA OFFICE BUILDING SOLAR SYSTEM

BOZEMAN MONTANA

DE 7881

DE DRAPES ENGINEERING Mechanical & Electrical Engineers Great Falls, Montana

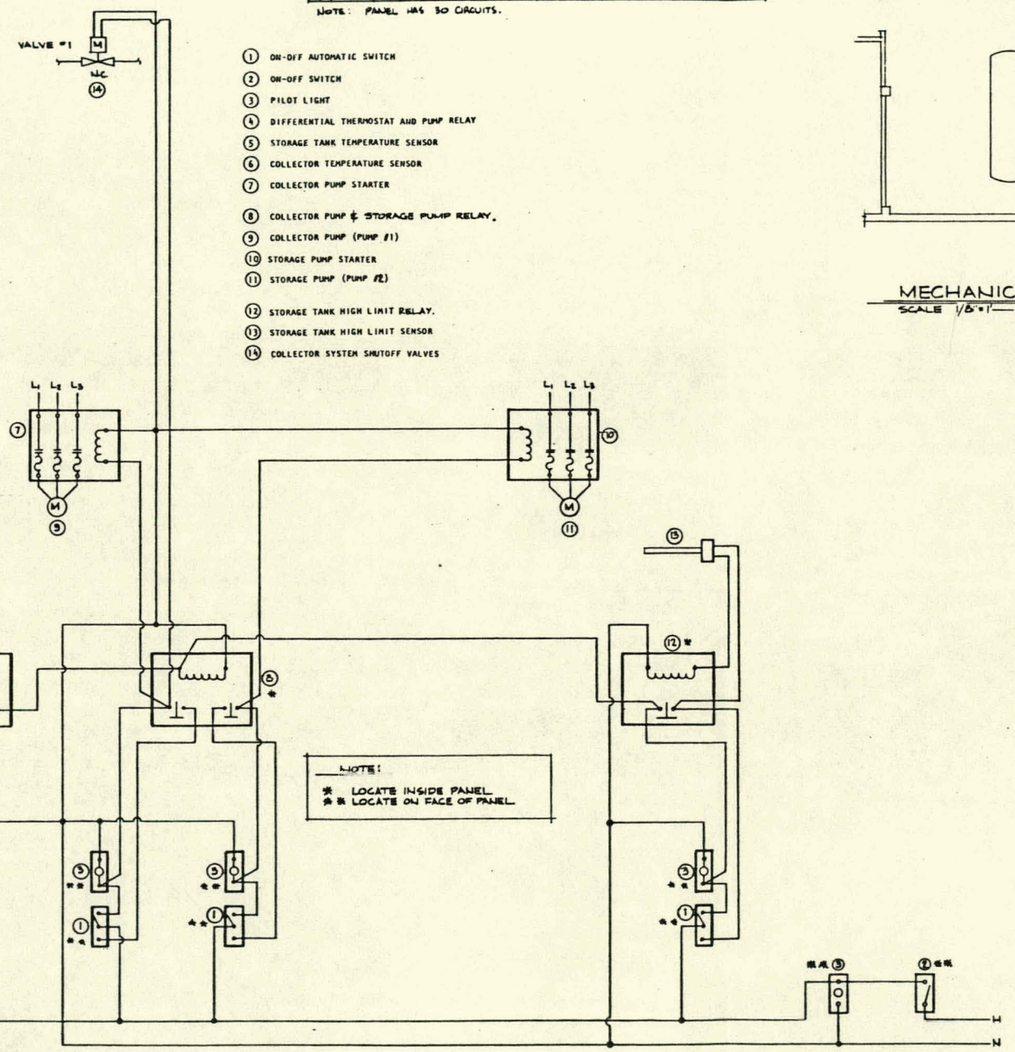
2 2 - 4

PANEL SCHEDULE

PANEL SO CHAR. 277/480V 3Ø 4W MAINS 225A MOUNTING SURFACE
PANEL FEED TOP FEEDERS CU. 4 #3/0
MISC.

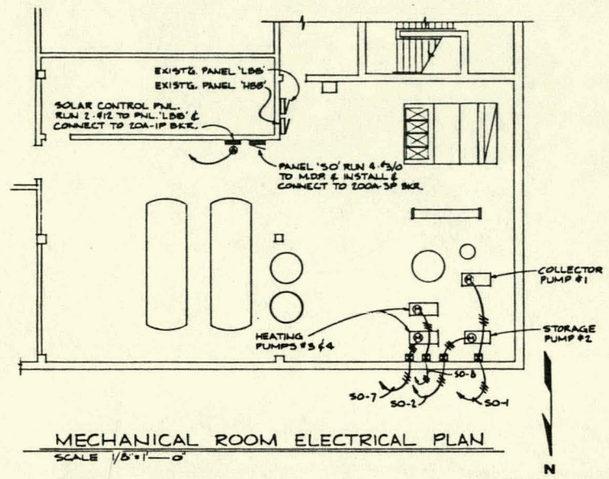
CKT	FRAME	WIRE	LOAD	CKT	FRAME	WIRE	LOAD
1	100A-3P	#12	PUMPS #1	2	30A-3P	#12	PUMPS #2
3				4			
5				6			
7	100A-3P	#10	PUMPS #3 &	8	100A-3P		PUMP #4
9				10			
11				12			
13	3P		SPACE	14	3P		SPACE
15				16			
17				18			

NOTE: PANEL HAS 30 CIRCUITS.



CONTROL WIRING DIAGRAM

1. ON-OFF AUTOMATIC SWITCH
2. ON-OFF SWITCH
3. PILOT LIGHT
4. DIFFERENTIAL THERMOSTAT AND PUMP RELAY
5. STORAGE TANK TEMPERATURE SENSOR
6. COLLECTOR TEMPERATURE SENSOR
7. COLLECTOR PUMP STARTER
8. COLLECTOR PUMP & STORAGE PUMP RELAY.
9. COLLECTOR PUMP (PUMP #1)
10. STORAGE PUMP STARTER
11. STORAGE PUMP (PUMP #2)
12. STORAGE TANK HIGH LIMIT RELAY.
13. STORAGE TANK HIGH LIMIT SENSOR
14. COLLECTOR SYSTEM SHUTOFF VALVES



MECHANICAL ROOM ELECTRICAL PLAN
SCALE 1/8"=1'-0"

ELECTRICAL LEGEND

- PANEL
- STARTER - COMBINATION MAGNETIC
- FRACTIONAL HP. MOTOR SENTINEL
- DISCONNECT SWITCH
- BRANCH CIRCUIT CONCEALED IN WALL OR CEILING
- BRANCH CIRCUIT CONCEALED IN OR UNDER FLOOR
- BRANCH CIRCUIT - RUN EXPOSED
- EMPTY CONDUIT - 3/4" UNLESS OTHERWISE NOTED
- HOME RUN TO PANEL. NUMBER OF ARROWS INDICATES NUMBER OF CIRCUITS.
- NUMBER OF HASHMARKS INDICATES NUMBER OF CONDUCTORS. NO HASHMARKS INDICATES TWO CONDUCTORS.
- INCANDESCENT LIGHT FIXTURE (CEILING OR WALL MOUNT)
- FLUORESCENT LIGHT (SUSPENDED)
- DUPLEX CONVENIENCE RECEPTACLE
- WP WEATHERPROOF RECEPTACLE
- MOTOR
- SPECIAL EQUIPMENT OUTLET
- JUNCTION BOX OR J-BOX
- S SWITCH
- S^P SWITCH - W/PILOT

PUMP SCHEDULE

PUMP	MANUFACTURER	CATALOG NO	CAPACITY GPM	CAPACITY HEAD	MOTOR HP	MOTOR RPM	MOTOR ELECTRICAL	NOTES
1	TACO	SB-2508	75	65	5	1750	460V/3Ø	(1)
2	TACO	SB-3006	110	72	7½	1750	460V/3Ø	(1)
3	TACO	SB-3008	153	55	5	1750	460V/3Ø	(1)
4	TACO	SB-3008	153	55	5	1750	460V/3Ø	(1)

(1) PROVIDE PUROCELL FILTER

AS-BUILT 4-21-80

MONTANA DRAKE ENGINEERING REGISTERED PROFESSIONAL ENGINEERS

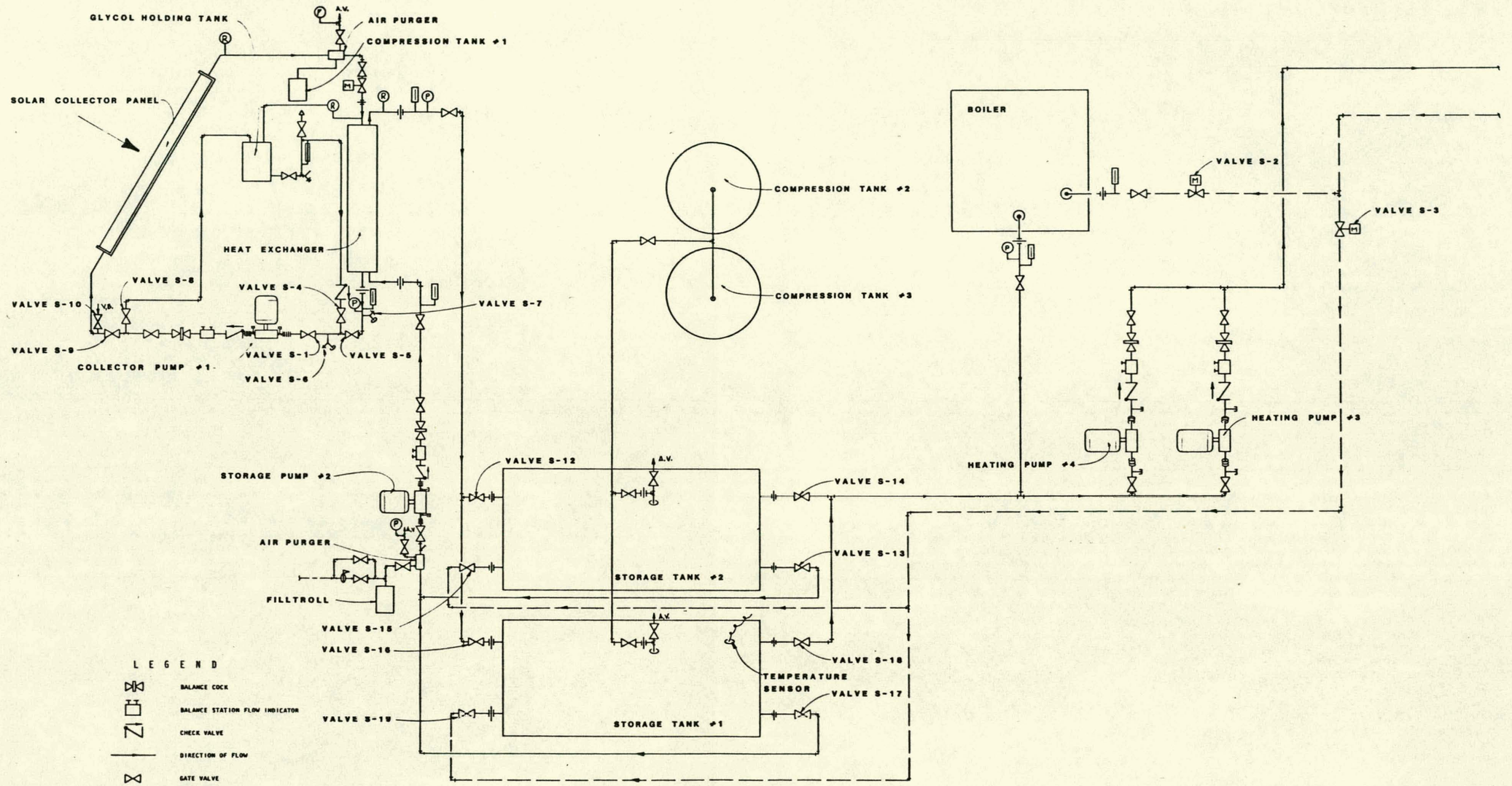
LIFE OF MONTANA OFFICE BUILDING SOLAR SYSTEM

BOZEMAN MONTANA

Drawn G.D.
Checked DE 7681
Date June 11, 1979

DE DRAKE ENGINEERING Mechanical & Electrical Engineers Great Falls, Montana SOLAR ENGINEERS

Sheet Number 3
3 - 4



SYSTEM FLOW DIAGRAM

"AS-BUILT" 4-21-80

MONTANA DRAKE ENGINEERING REGISTERED PROFESSIONAL ENGINEERS

LIFE OF MONTANA
OFFICE BUILDING
SOLAR SYSTEM

BOZEMAN MONTANA

Drawn by EVB
Job Number D.E. 7934
Date APRIL 8, 80

DE DRAKE ENGINEERING Mechanical & Electrical Engineers Great Falls, Montana

Sheet Number 4
4 - 4

DRAPES ENGINEERING
CONSULTING ENGINEERS
Mechanical·Electrical
GREAT FALLS, MONTANA

LIFE OF MONTANA INSURANCE COMPANY SOLAR SYSTEM

FINAL REPORT

FOR

DEPARTMENT OF ENERGY

EM-78-F-03-2147

MAY 1980

JOB NO. 7881

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1. INTRODUCTION AND SCOPE

The new home office of the Life of Montana Insurance Company is located in Bozeman, Montana approximately one mile east of the city on Haggarty Lane.

The building is a three-story office building approximately 208 feet long, and 90 feet wide comprising a total area of over 56,000 square feet. The lower level is below grade and contains a parking garage, computer facilities, lunchroom, storage areas and a mechanical room housing the boiler, an air handling unit and the solar equipment. The upper two levels are office space for Life of Montana and leased space for other tenants.

The HVAC system consists of five multizone units for heating, cooling and ventilating. The cooling system uses a DX refrigerant coil in each unit and a companion air-cooled condenser-compressor unit mounted on the roof. The heating system is hydronic with heat supplied from either a gas-fired boiler or the solar system. Heat is transferred from the hot water system to the building through a heating coil in each multizone unit.

The heating coils in the multizone units were designed to supply heat to the building at a supply water temperature of 110°F because of the low temperature heat supplied by the solar system. This resulted in a four-row heating coil instead of a standard one row heating coil in each multizone unit. The switchover control from solar to backup heat is a fixed temperature of 105°F, but is field adjustable for flexibility and testing.

The solar system is a liquid system employing a 50% solution of ethylene glycol and water in the collector loop with an intermediate heat exchanger between the collector loop and storage loop to limit the glycol solution to just the collector loop.

The hydronic solar collectors are manufactured by Sunworks. They are double-glazed panels, 3 feet X 7 feet, with tempered low iron 1/8" non-glare glass. The absorber is a copper sheet coated with a selective surface of copper oxide. The collectors have been tested in accordance with ASHRAE 93-77 and meet all interim performance criteria and stagnation tests and are warranted for five years.

The total collector area is 4,410 gross square feet and 3,885 net square feet. The collectors are located on the ground approximately 250 feet southwest of the building. The ground location was chosen because of spacing problems and interference with the air-conditioning condenser units if the collectors were placed on the roof. In addition, this location permits easy access to the collector array for observation and maintenance.

The collectors transfer heat to a water storage system via a glycol to water heat exchanger. The heat exchanger is a single pass counterflow heat exchanger to obtain maximum heat transfer and minimum temperature penalty.

The storage system consists of two 3,000 gallon pressure storage tanks. The storage tanks are insulated with 6" of expanded polystyrene insulation and thermally isolated from the tank supports with neoprene pads. Two tanks were used to permit shutdown of one tank in cold and cloudy weather to maintain usable storage temperature.

A pressure system for storage and collector system was chosen over a drain down or open system to avoid the long term problems with corrosion in an open system from continually introducing new oxygen into the system and the problems experienced in drain down solar systems from inadequate drainage and subsequent freezing.

Control of the solar system is achieved by a differential controller with one sensor located in the collector discharge manifold and one in the storage system. The controller is set to turn on the system at 20°F ΔT and turn off the system at a 3°F ΔT. Switchover from solar to backup is achieved by two pneumatic motorized valves that divert heating system water from the storage tanks to the boiler at a temperature of 105°. The system switches back to storage at a temperature of 108°F. This controller is field adjustable to permit testing and adjustment to achieve optimum performance.

Overpressure protection in the glycol system is achieved by relief valves located in the collector discharge to protect the collectors and a relief valve in the mechanical room that discharges into a glycol holding tank. The relief valve in the mechanical room discharges at 50 psi and the relief valves on the collectors discharge at 75 psi. This permits recovery of the glycol under most overpressure conditions such as pump shutdown. Overpressure protection in the heating system water is by means of a relief valve located on the heat exchanger discharging at 30 psi and a relief valve on the boiler also discharging at 30 psi.

Overheat protection is provided by rejecting heat at night using the collectors as heat rejectors. A high limit controller activates the collector and storage pumps when the storage temperature reaches 180°F.

2. ACCEPTANCE TEST

a. Acceptance Test Plan

The system has been provided with balancing valves, flow meters and instrument gauge wells throughout the system to permit balancing of flows and monitoring of flow, pressures and temperatures.

The collector loop system is piped in seven rows of thirty collectors each. Each row is piped in reverse return with six banks of five collectors internally manifolded. The seven rows are then piped in direct return to the mechanical room. Each row contains two balancing valves, two flow meters and four instrument gauge wells to balance the flow on one-half of each row and between rows. In addition, there is another balance valve, flow meter and instrument gauge well on the collector loop pump discharge to set the loop flow at the pump.

The storage loop is piped in reverse return to the storage tanks. This loop also has a balance valve, flow meter and instrument gauge well on the pump discharge to set the loop flow at the pump.

The heating system has a balance valve, flow meter and instrument gauge well on the system pumps as well as similar instruments on each multizone and heating unit to facilitate balancing of the entire system.

The acceptance test plan consisted of monitoring collector, heat exchanger and storage temperatures under varying collector loop and storage loop flow conditions to determine the effect of these parameters on system performance.

2. ACCEPTANCE TEST (CONT'D)

The differential thermostat was tested to assure that the system turned on and off at the specified temperature differences and high limit setting.

The safety features of the system were tested by popping the relief valves in the glycol loop under collector stagnation conditions.

b. Acceptance Test Results

The acceptance test was performed on November 14, 1979. Present at the test were Mike Bonkoski, Department of Energy, San Francisco; Fen Salter, Lawrence Berkeley Laboratory; Greg Cunniff, Drapes Engineering; and Dick Grover, R.H. Grover Company.

The system was balanced and the flow and temperatures recorded to determine the effects of varying flow rates on system performance and efficiency. Low flow rates were initially used to achieve higher temperatures. The system was finally balanced to the higher flow rates recommended by the manufacturer and used in the design of the system as follows:

1. Collector loop flow rate = 105 gpm
2. Storage loop flow rate = 200 gpm
3. Heating system loop flow rate = 300 gpm

The results of the balancing and flow tests are shown on the worksheet at the end of this section.

The safety controls of the system were tested by stagnating the collectors. The relief valve on the glycol system discharged first into the glycol holding tank. Two relief valves on the collectors discharged but have since shown no signs of weeping.

2. ACCEPTANCE TEST (CONT'D)

The differential thermostat and high limit controls were tested and found to operate satisfactorily. The changeover control from solar to backup heat was tested and also found to operate satisfactorily. This control was set at 105°F.

The storage tank sensors were incorrectly located but have subsequently been relocated and the system operated satisfactorily.

LAWRENCE BERKELEY LABORATORY · UNIVERSITY OF CALIFORNIA

ENGINEERING NOTE

PAGE ___ OF ___

SERIAL

DATE

CODE

LOCATION Bldg 90

DEPARTMENT Plant Engineering LBL

AUTHOR Fen Salter

11-1-79 LIFE OF MONTANA BOZEMAN, MONTANA SOLAR SYSTEM

ATTACHMENT A

TIME	FLOW METER READING IN. H_2O	EQUIV. GPM	TEMP AT HEAT EXCHANGER GLYCOL LOOP IN	GLYCOL LOOP OUT	GLYCOL LOOP ΔT	STORAGE LOOP IN	STORAGE LOOP OUT	STORAGE LOOP ΔT	HEAT TRANSFER GLYCOL 500 AT GPM SOUT GM[3] 1.15 BTU/HR	HEAT TRANSFER STORAGE 500 AT GPM	
	19.2	78									Glycol Exist. Setting[2.]
	37.8	110									Glycol Full Open[1.,2.]
1:55 PM		110	150F	134F	16F				765000		1.,2. 670,000 BTU/HR AVG.
	18	115				116F	126F	10F		575000	
2:00 PM		110	151F	134F	17F				813000		1.,2. 662,000 BTU/HR AVG
		115				117F	126F	9F		518000	
	23	85	152F	132F	20F				739000		2. 600,000 BTU/HR AVG
		115				118F	126F	8F		460000	
2:20PM		85	152F	130F	22F				813000		
	58"	200 ± 5.				118F	125F	7F		700000 ±	766,000 BTU/HR AVG.
2:30 PM	34"	105 GPM 6.	148F	130F	18F				822000		
		200 ± 5.				120F	125F	5F		500000 ±	661,000 BTU/HR AVG.
2:50 PM.		105	142	127	15F				685000		
		200±				120F	124F	4F		400000 ±	543,000 BTU/HR AVG.

Data by Greg Cunniff
Mike Bonkoski
Fen Salter
11-14-79

1. BALANCE VALVE AT PUMP FULL OPEN
2. BALANCE VALVES AT ARRAY ARE 75% OPEN
3. CORRECTION FOR 50% GLYCOL AT 190F = 1.15
4. FLOW METER: GERAND ENG CO MODEL M-50 SERIAL 10-2577
5. EXTRAPOLATTED
6. SUNWORKS DESIGN FLOW. 210 CORRECTED FOR 190F

3. PREDICTED SYSTEM PERFORMANCE

The performance of the solar system was estimated on the basis of an f-chart analysis. For the 3,885 net square feet installed the f-chart estimate shows that approximately 30% of the building space heating load can be supplied by the solar system.

The solar data used for the f-chart analysis was based upon total insolation measurements for Bozeman published by the Montana Department of Natural Resources from a solar insolation monitoring contract. These insolation measurements were taken at a 60° angle from the horizontal which is the tilt of the collector array on the project. Therefore, any errors from modeling techniques used to calculate insolation data for a tilted surface based on measured data for a horizontal surface have been eliminated.

The insolation measurements used in the f-chart are an average of the two years for which data is available which is 1977 and 1978. This may vary from long term averages, but it was felt that this provided a higher degree of confidence than correlating with long term averages from another site.

S O L A R S Y S T E M D E S I G N

THERMAL AND ECONOMIC PERFORMANCE EVALUATION

FOR

LIFE OF MONTANA INSURANCE CO. BLDG

BOZEMAN, MT

MARCH 31, 1980

BY

DRAPES ENGINEERING
202 EKLUND BUILDING
GREAT FALLS, MONTANA

JOB NO.7881

CLIMATIC INFORMATION FOR BOZEMAN, MT

WEATHER DATA AND LOAD DATA

MONTH	HEATING DEGREE DAYS	MEAN AMBIENT TEMP (°F)	SUPPLY WATER TEMP (°F)	DOMESTIC HOT WATER LOAD (MMBTU)	COOLING LOAD (MMBTU)
JAN	1370	20.8	0.0	0.00	0.00
FEB	1086	26.2	0.0	0.00	0.00
MAR	1088	29.9	0.0	0.00	0.00
APR	693	41.9	0.0	0.00	0.00
MAY	440	50.8	0.0	0.00	0.00
JUN	239	57.6	0.0	0.00	0.00
JUL	53	66.4	0.0	0.00	0.00
AUG	80	65.0	0.0	0.00	0.00
SEP	312	55.3	0.0	0.00	0.00
OCT	592	45.9	0.0	0.00	0.00
NOV	975	32.5	0.0	0.00	0.00
DEC	1237	25.1	0.0	0.00	0.00

INSOLATION DATA

MONTH	MEASURED HORIZONTAL INSOLATION (BTU/SF-DAY)	OUTER ATMOSPHERE INSOLATION (BTU/SF-DAY)	K_T	OVERALL TILT FACTOR	COLLECTOR SURFACE INSOLATION (BTU/SF-DAY)
JAN	429.0	1021.4	.4200	2.23	957.0
FEB	690.0	1500.9	.4597	1.67	1152.7
MAR	1124.0	2153.1	.5220	1.29	1452.5
APR	1505.0	2871.1	.5242	.97	1460.2
MAY	1626.0	3408.7	.4770	.80	1299.0
JUN	1900.0	3639.6	.5220	.74	1396.7
JUL	1850.0	3523.6	.5250	.76	1409.3
AUG	1720.0	3081.5	.5582	.89	1534.5
SEP	1200.0	2415.6	.4968	1.13	1359.7
OCT	915.0	1695.4	.5397	1.59	1455.4
NOV	415.0	1135.5	.3655	1.83	757.4
DEC	335.0	896.7	.3736	2.28	763.5

SOLAR SYSTEM AND ECONOMIC PARAMETERS

SYSTEM PARAMETERS

SYSTEM TYPE : HYDRONIC		
MANUFACTURER : SUNWORKS		
COLLECTOR ORIENTATION:		
STATIONARY FLAT SURFACE		
SURFACE TILT FROM HORIZONTAL	60.00	DEG
SURFACE AZIMUTH ANGLE	0.00	DEG
LATITUDE OF SITE	45.67	DEG N
HEAT EXCHANGER UA PRODUCT	NA	BTU/HR-DEGF
HEAT EXCHANGER EFFECTIVENESS	.73	BTU/HR-DEGF
COLLECTOR LOSS COEFFICIENT x FR	.80	BTU/HR-SF-DEGF
AVG. TRANS.-ABS. PRODUCT x FR	.70	
COLLECTOR HEAT REMOVAL FACTOR,FR	.94	
COLLECTOR LOOP FLOW RATE	11.00	LB/HR-SF
COLLECTOR FLUID SPECIFIC HEAT	.83	BTU/DEGF-LB
STORAGE LOOP FLOW RATE	22.00	LB/HR-SF
STORAGE LOOP FLUID SPECIFIC HEAT	1.00	BTU/DEGF-LB
STORAGE SIZE	50070	LB
STORAGE MATERIAL SPECIFIC HEAT	1.00	BTU/DEGF-LB
CORRELATION REFERENCE TEMP	212	DEGF
DOMESTIC H.W. OUTLET TEMP	140	DEGF
AIR SYSTEM NOMINAL VALUES:		
STORAGE SIZE	50	LB R.ROCK/SF
FLOW RATE	13.8	LB AIR/HR-SF
HYDRONIC SYSTEM NOMINAL VALUES:		
STORAGE SIZE	15.36	LB H2O/SF
COLLECTOR LOOP FLOW CAPACITANCE	11.4	BTU/HR-DEGF-SF
STORAGE LOOP FLOW RATE		LB H2O/HR-SF
HEAT EXCHANGER CAPACITANCE x εL	2.0	BTU/HR-DEGF-SF
HEAT LOSS	1032000	BTU/HR

ECONOMIC PARAMETERS

FIRST COST	$300,000.00
PERCENT FINANCED (% OF FC)	0.0
MORTGAGE INTEREST RATE (%)	0.0
MORTGAGE LIFE (YEARS)	0
ECONOMIC LIFE (YEARS)	30
ELECTRIC ENERGY COST TO OPERATE SYSTEM ($/YR)	450
ELECTRIC INFLATION RATE (%)	8.0
SALVAGE VALUE ($)	20000
MAINTAINCE COST (% OF FC)	.3
MAINTAINCE INFLATION RATE (%)	6.0
REPLACEMENT COST 1 ($)	0
REPLACEMENT YEAR 1 (YR)	0
REPLACEMENT COST 2 ($)	0
REPLACEMENT YEAR 2 (YR)	0
DEPRECIATION METHOD	NONE
INCOME TAX RATE (%)	0.0
PROPERTY TAX RATE (%)	0.0
PROPERTY TAX INFLATION RATE(%)	6.0
INSURANCE COST (% OF FC)	.3
INSURANCE INFLATION RATE (%)	6.0
RATE OF RETURN (INTEREST RATE)	8.0
BACKUP FUEL INFLATION RATE (%)	13.0
BACKUP FUEL : NATURAL GAS	
BACKUP FUEL UNITS: MCF	
UTILITY COMPANY : MONTANA PWR CO	

BACKUP FUEL RATE SCHEDULE :

SERVICE CHARGE = 0.00

RATE ($)	CUTOFF (MCF)
3.4500	0
0.0000	0
0.0000	0
0.0000	0
0.0000	0

SOLAR SYSTEM THERMAL PERFORMANCE

FOR 3885 SQUARE FEET OF COLLECTOR SURFACE AREA

MONTH	TOTAL INCIDENT SOLAR RADIATION (MMBTU)	TOTAL SOLAR HEAT DEMAND (MMBTU)	ENERGY DELIVERED BY SOLAR (MMBTU)	AVERAGE EFFICIENCY (%)	ENERGY CONTENT OF BACKUP FUEL (MMBTU)	PERCENT OF LOAD BY SOLAR (%)
JAN	115.26	350.09	49.03	42.5	389.06	14.0
FEB	125.39	277.52	57.40	45.8	284.46	20.7
MAR	174.93	278.03	84.12	48.1	250.59	30.3
APR	170.18	177.09	78.22	46.0	127.78	44.2
MAY	156.44	112.44	64.76	41.4	61.62	57.6
JUN	162.79	61.07	53.43	32.8	9.88	87.5
JUL	169.73	13.54	13.54	8.0	0.00	100.0
AUG	184.81	20.44	20.44	11.1	0.00	100.0
SEP	158.47	79.73	59.26	37.4	26.46	74.3
OCT	175.28	151.28	77.87	44.4	94.88	51.5
NOV	88.28	249.15	33.74	38.2	278.38	13.5
DEC	91.95	316.11	34.77	37.8	363.57	11.0
TOTAL	1773.51	2086.51	626.58	35.3	1886.68	30.0

SOLAR SYSTEM ECONOMIC PERFORMANCE

SOLAR SYSTEM ANNUAL COST ($)	SOLAR FUEL COST ($/MMBTU)	COMBINED SYSTEM ANNUAL COST ($)	COMBINED SYSTEM FUEL COST ($/MMBTU)	ANNUAL COST W/O SOLAR ($)	FUEL COST W/O SOLAR ($/MMBTU)	PAYBACK PERIOD (YEARS)
30441.56	48.58	67538.06	32.37	50709.58	24.30	45.4

4. MAJOR PROBLEMS AND SOLUTIONS

The major problems associated with the project and their solutions are briefly summarized as follows.

The site for the collector array was to be graded during construction of the building, but was not accomplished due to delays in construction. A change order to the contract was negotiated with the solar system contractor to grade the site and construction of the system continued on schedule.

Shipment of the heat exchanger was delayed for several weeks, but the project was completed on schedule since the contractor was able to work on other parts of the project during shipment of the heat exchanger.

The temperature sensors in the storage tanks were installed incorrectly and in the wrong location. After clarification with the contractor the sensors were relocated to the correct location.

The temperature gauges in the storage tanks were out of calibration. These gauges have been replaced with a temperature sensor and a remote readout temperature gauge in the temperature control panel to facilitate easier reading of the gauges.

Two of the relief valves on the collector array showed initial signs of weeping. Further monitoring of the relief valves show no continued weeping problems.

The ethylene glycol solution originally installed in the system did not have corrosion inhibitors. The corrosion inhibitors have been added after startup of the system.

5. LESSONS LEARNED AND RECOMMENDATIONS

The solar system was installed by a reputable firm with much experience in plumbing and metal fabrication. As a result, installation problems, questions and delays were minimal as opposed to the problems and additional cost in dealing with an inexperienced contractor. As a result it is highly recommended that a competent, experienced contractor be used on similar projects.

Because the building was under construction when the grant award and decision to install the system was announced, there was a delay and difficulty in integrating the solar system into the building. This resulted in some increased costs and a change in the type of system installed. Since good planning is essential to the success of this type of project similar projects should make every effort to incorporate a system of this nature at the earliest stage in project planning.

6. STATEMENT OF COMPLIANCE

To the best of the designer and installers knowledge the system has been:

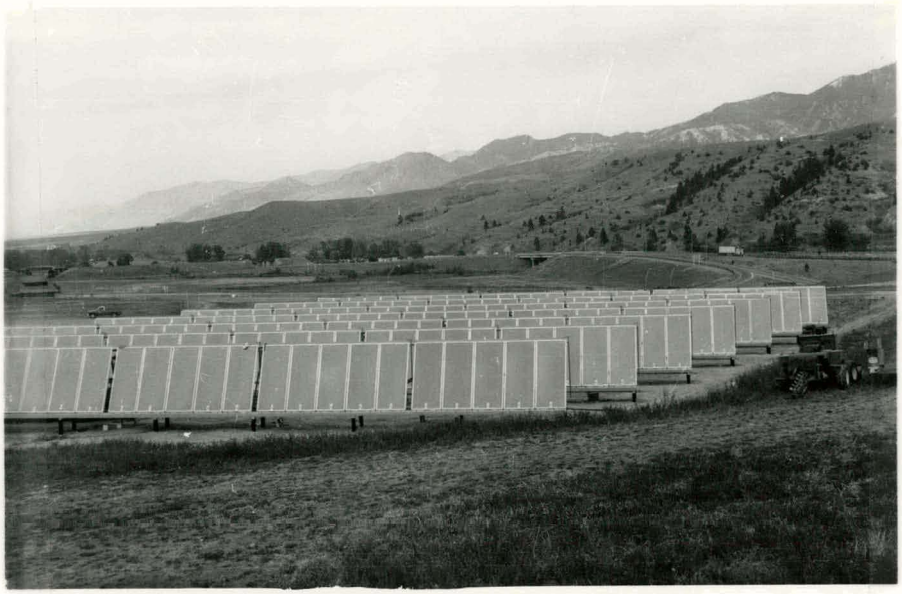
a. Installed as per as-built drawings.

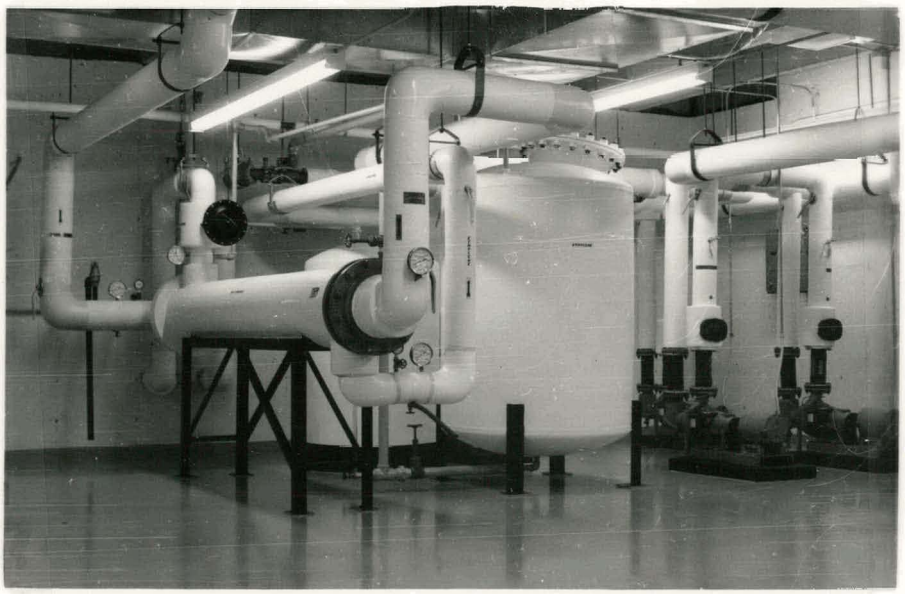
b. Met the acceptance test plan provisions.

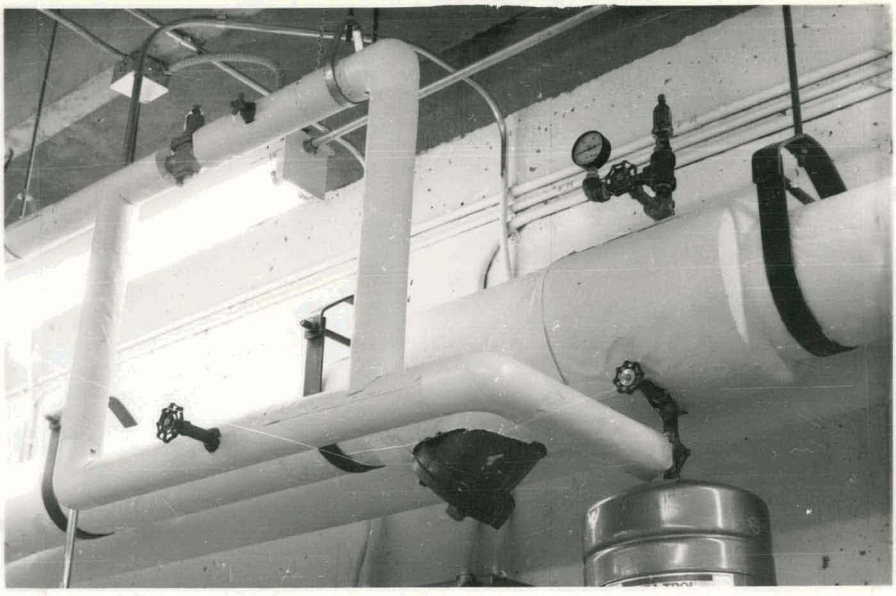
c. Met the interim performance criteria requirements.

SECTION 7

PHOTOGRAPHS OF INSTALLATION



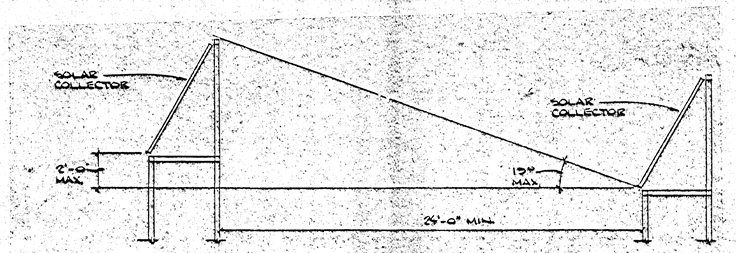




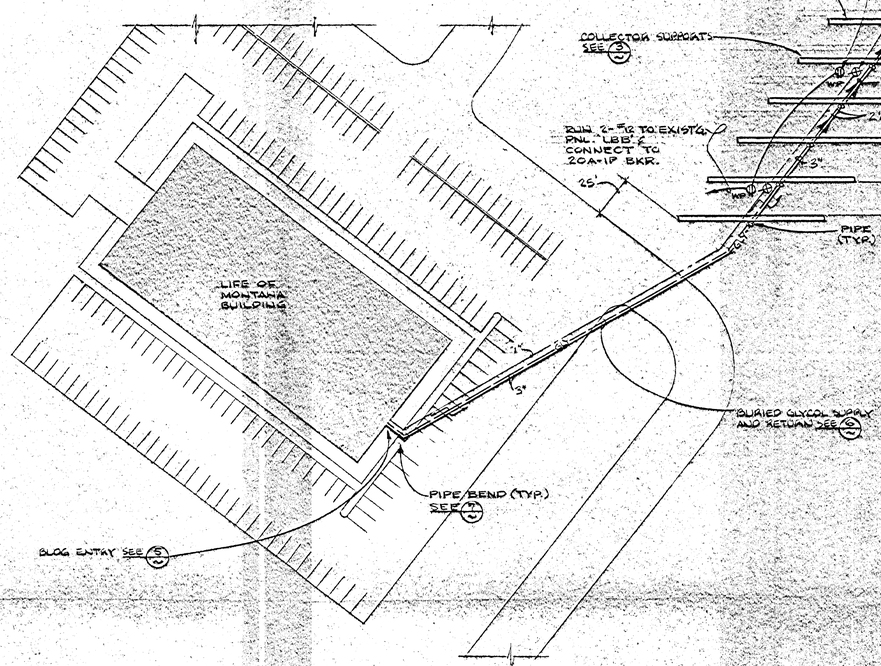


SECTION 8

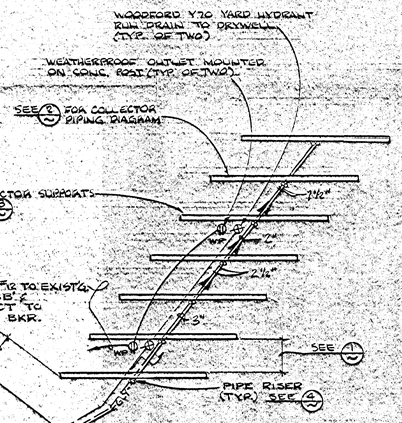
AS-BUILT DRAWINGS

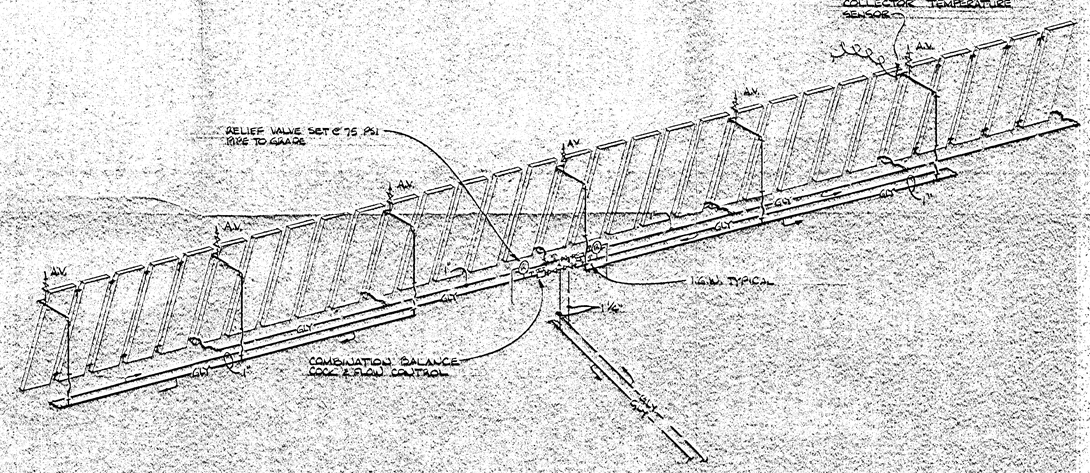


1 COLLECTOR SPACING DIAGRAM

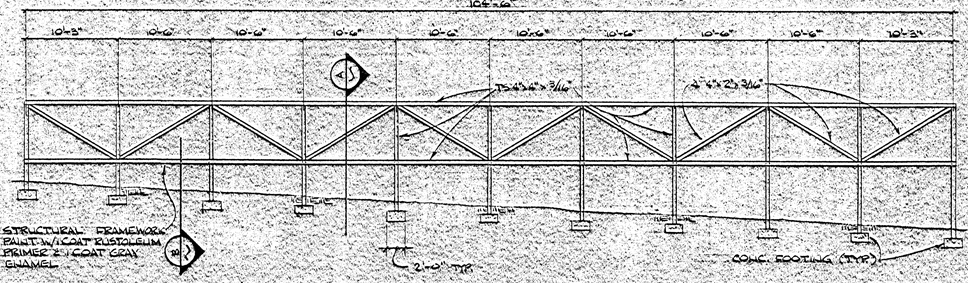


SITE PLAN 1"=50'-0"

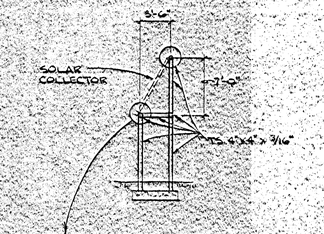




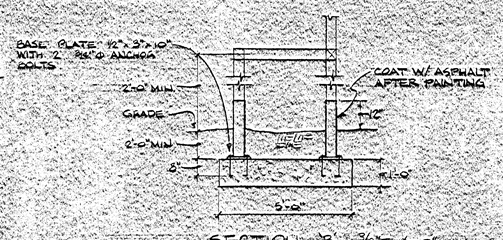
2 COLLECTOR PIPING DIAGRAM (TYPICAL OF 7)



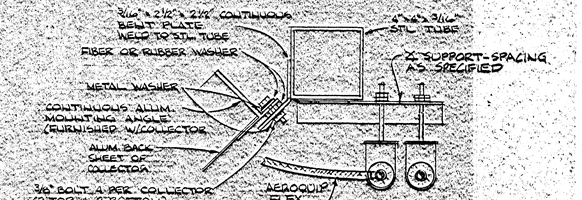
ELEVATION 1/8"=1'-0"



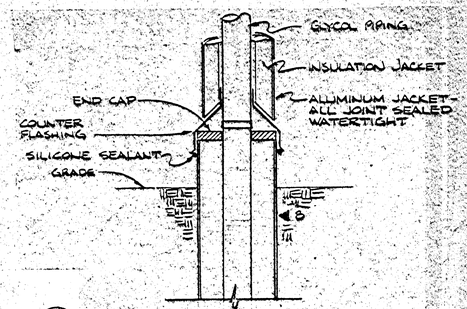
SECTION 'A' 1/8"=1'-0"



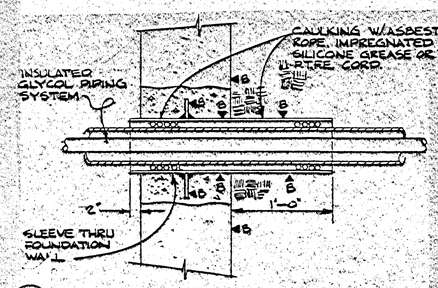
SECTION 'B' 3/8"=1'-0"



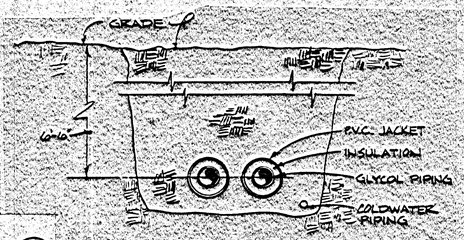
3 COLLECTOR SUPPORT DETAILS



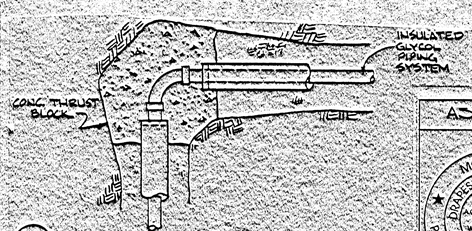
4 PIPE RISER DETAIL



5 BLDG. ENTRY DETAIL



6 BURIED PIPE DETAIL



7 PIPE BEND DETAIL

AS-BUILT 4-21-80

MONTANA BOARD OF ENGINEERING & ARCHITECTURE AS GRADUATE ENGINEER WCC KLEYKAMP REGISTERED PROFESSIONAL ENGINEERS

LIFE OF MONTANA OFFICE BUILDING SOLAR SYSTEM

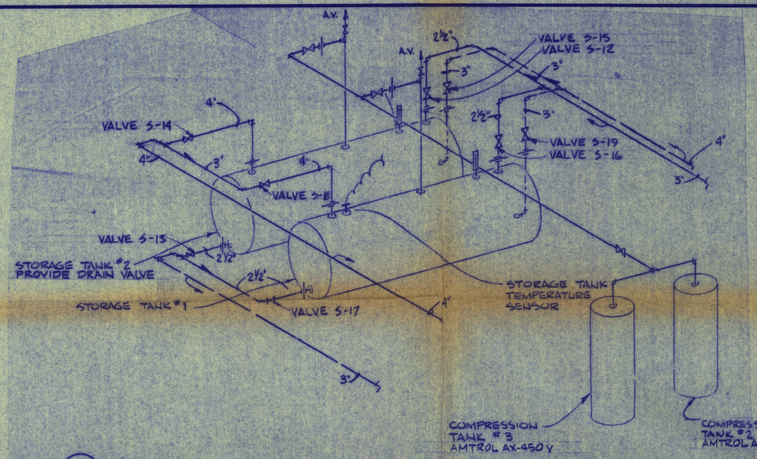
BOZEMAN MONTANA

Drawn by A.C.
Job Number 78-31
Date JAN. 11, 1979

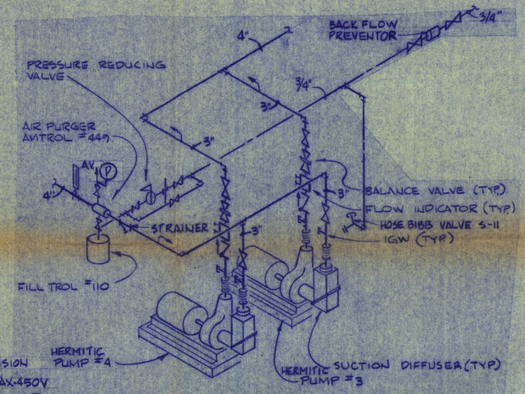
Mechanical & Electrical Engineers
Great Falls, Montana

DRAKE ENGINEERING

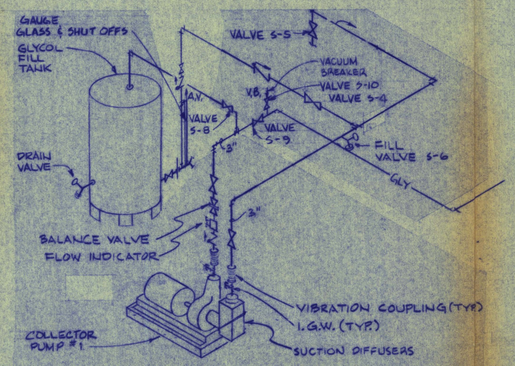
Sheet Number 1 of 4



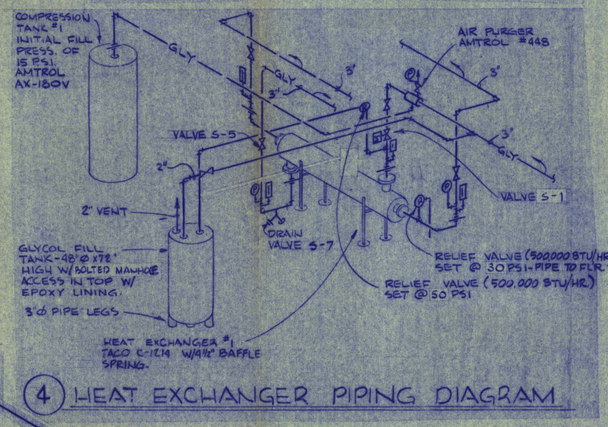
1 STORAGE TANKS - PIPING DIAGRAM



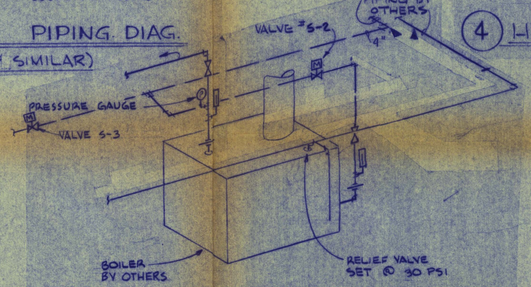
2 HEATING PUMPS PIPING DIAG.



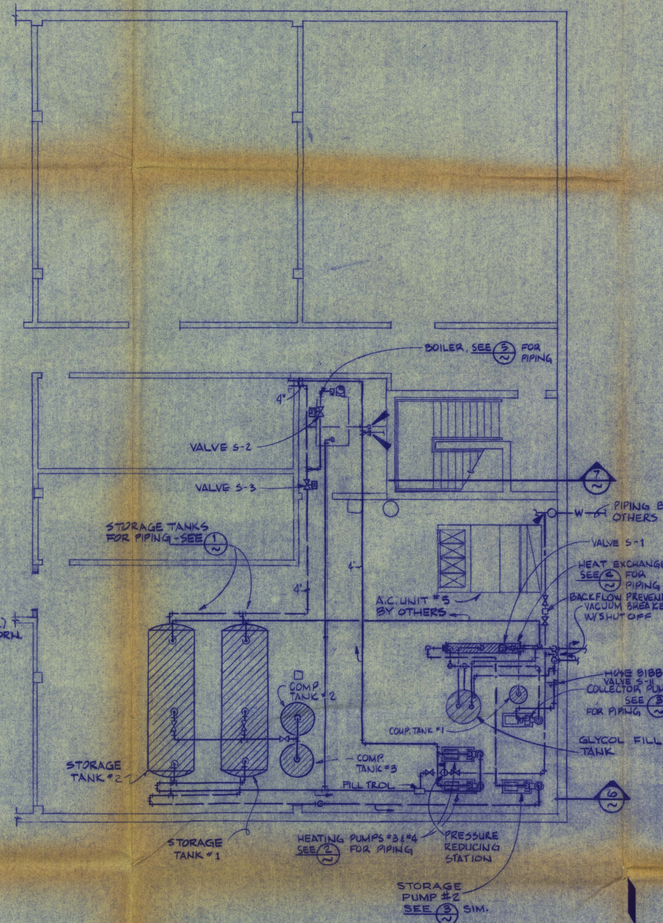
3 COLLECTOR PUMP PIPING DIAG.
(STORAGE PUMP SIMILAR)



4 HEAT EXCHANGER PIPING DIAGRAM

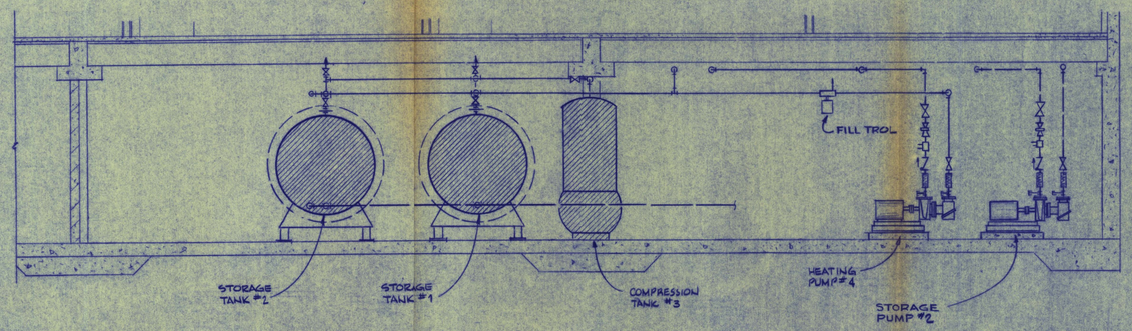


5 BOILER PIPING DIAG

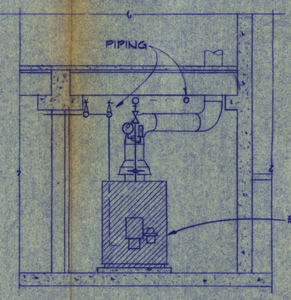


PART. BASEMENT FLOOR PLAN—MECHANICAL

SCALE 1/8"=1'—0"



6 SECTION 1/4"=1'—0"



7 SECTION 1/4"=1'—0"

MECHANICAL LEGEND

- DOMESTIC COLD WATER
- DOMESTIC HOT WATER
- DOMESTIC RECIRCULATING HOT WATER
- S — SANITARY SEWER SOIL AND WASTE
- SANITARY SEWER VENT
- G — NATURAL GAS
- HEATING WATER SUPPLY
- HEATING WATER RETURN
- GLY — GLYCOL SUPPLY
- GLY — GLYCOL RETURN
- PIPE UP
- PIPE DOWN
- ECCENTRIC REDUCER
- UNION
- STRAINER
- FLEXIBLE PIPE
- BALANCE STATION FLOW INDICATOR
- A.V. — AIR VENT
- V.B. — VACUUM BREAKER
- THERMOSTAT
- TEMPERATURE GAUGE OR THERMOMETER
- P — PRESSURE GAUGE
- GATE VALVE
- GLOBE VALVE
- CHECK VALVE
- BALANCE COCK
- GAS COCK
- 3-WAY VALVE
- MOTORIZED VALVE
- R — RELIEF VALVE
- SHEET METAL DUCT (SIZE, WIDTH X DEPTH)
- SHEET METAL DUCT (ACOUSTICALLY-LINED)
- SHEET METAL DUCT (EXTERIOR INSULATION)
- FIBROUS DUCT
- FLEXIBLE DUCT
- SD — SPLITTER DAMPER
- V.D. — VOLUME DAMPER
- TURNING VANES
- AIR EXTRACTOR VANES
- FLEXIBLE DUCT CONNECTION
- F.D. — FIRE DAMPER
- SD — SUPPLY AIR DIFFUSER, GRILLE OR REGISTER
- RG — RETURN OR RELIEF AIR GRILLE OR REGISTER
- EG — EXHAUST AIR GRILLE OR REGISTER

ABBREVIATIONS

F.A.	FRESH AIR (OUTSIDE AIR)
R.A.	RETURN AIR
E.A.	EXHAUST AIR
CO.	CLEANOUT (PLUMBING SYSTEM)
I.G.W.	PRESSURE-TEMPERATURE GAUGE WELL

SYMBOLS

- HEATING OR COOLING UNIT IDENTIFICATION
- PLUMBING FIXTURE MARK
- B — BITUMASTIC COATING.
- CONNECT TO EXISTING PIPING

AS-BUILT 4-21-80

MONTANA DRAPER ENGINEERING A.G. DRAPER 15388 W.C. KILBY 10618 REGISTERED PROFESSIONAL ENGINEERS

LIFE OF MONTANA OFFICE BUILDING SOLAR SYSTEM

BOZEMAN MONTANA

Drawn by:

Job number DE 7881

Date

Mechanical & Electrical Engineers Great Falls, Montana DE DRAPER ENGINEERING

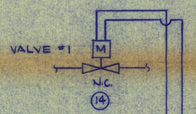
Sheet number 2 2 of 4

PANEL SCHEDULE

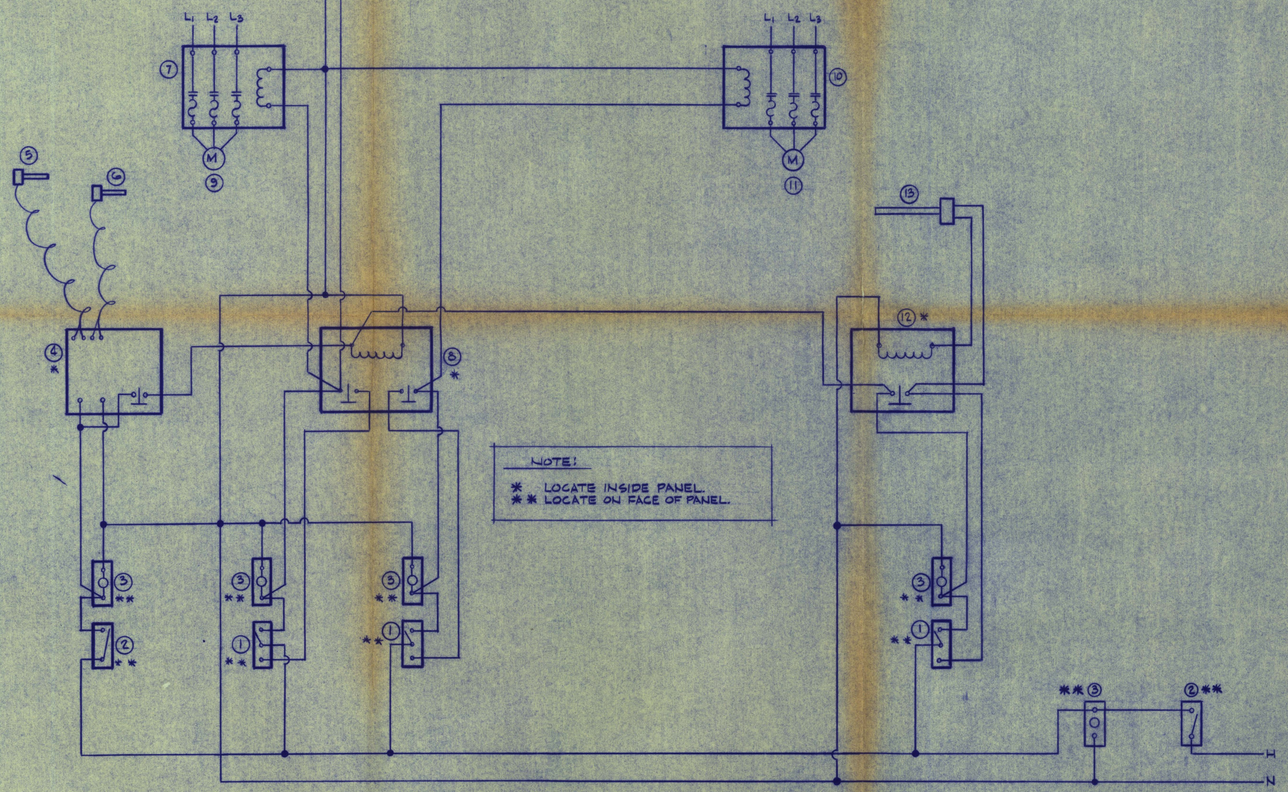
PANEL SO CHAR. 277/480V 3Ø 4W MAINS 225A MOUNTING SURFACE
PANEL FEED TOP FEEDERS CU. 4 #3/0
MISC.

CKT	FRAME	WIRE	LOAD	CKT	FRAME	WIRE	LOAD
1	20A-3P.	#12	PUMPS #1	2	20A-3P.	#12	PUMPS #2
3				4			
5				6			
7	20A-3P.	#10	PUMPS #3 &	8	20A-3P.		PUMP #4
9				10			
11				12			
13	3P.		SPACE	14	3P.		SPACE
15				16			
17				18			

NOTE: PANEL HAS 30 CIRCUITS.

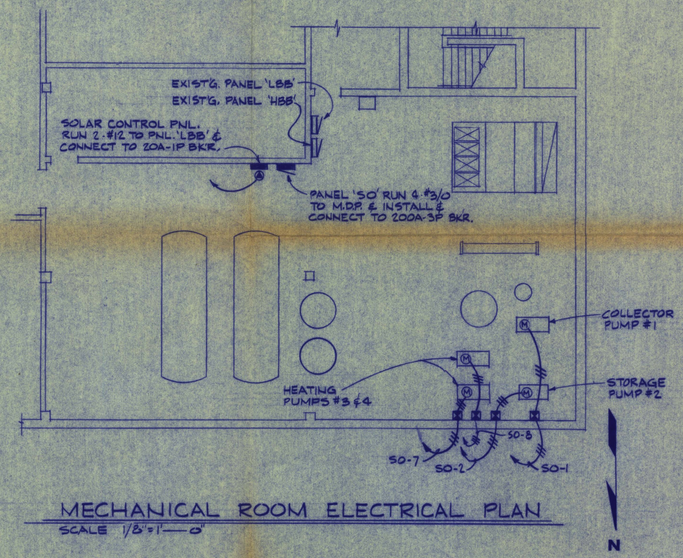


1. ON-OFF AUTOMATIC SWITCH
2. ON-OFF SWITCH
3. PILOT LIGHT
4. DIFFERENTIAL THERMOSTAT AND PUMP RELAY
5. STORAGE TANK TEMPERATURE SENSOR
6. COLLECTOR TEMPERATURE SENSOR
7. COLLECTOR PUMP STARTER
8. COLLECTOR PUMP & STORAGE PUMP RELAY.
9. COLLECTOR PUMP (PUMP #1)
10. STORAGE PUMP STARTER
11. STORAGE PUMP (PUMP #2)
12. STORAGE TANK HIGH LIMIT RELAY.
13. STORAGE TANK HIGH LIMIT SENSOR
14. COLLECTOR SYSTEM SHUTOFF VALVES



NOTE:
* LOCATE INSIDE PANEL.
** LOCATE ON FACE OF PANEL.

CONTROL WIRING DIAGRAM



MECHANICAL ROOM ELECTRICAL PLAN

SCALE 1/8"=1'—0"

ELECTRICAL LEGEND

- PANEL
- STARTER - COMBINATION MAGNETIC
- FRACTIONAL HP. MOTOR SENTINEL
- DISCONNECT SWITCH
- BRANCH CIRCUIT CONCEALED IN WALL OR CEILING
- BRANCH CIRCUIT CONCEALED IN OR UNDER FLOOR
- BRANCH CIRCUIT - RUN EXPOSED
- EMPTY CONDUIT - 3/4" UNLESS OTHERWISE NOTED
- HOME RUN TO PANEL. NUMBER OF ARROWS INDICATES NUMBER OF CIRCUITS.
- NUMBER OF HASHMARKS INDICATES NUMBER OF CONDUCTORS. NO HASHMARKS INDICATES TWO CONDUCTORS.
- INCANDESCENT LIGHT FIXTURE (CEILING OR WALL MOUNT)
- FLUORESCENT LIGHT (SUSPENDED)
- DUPLEX CONVENIENCE RECEPTACLE
- WP WEATHERPROOF RECEPTACLE
- MOTOR
- SPECIAL EQUIPMENT OUTLET
- J JUNCTION BOX OR J-BOX
- S SWITCH
- SP SWITCH - W/PILOT

PUMP SCHEDULE

PUMP	MANUFACTURER	CATALOG NO.	CAPACITY GPM	CAPACITY HEAD	MOTOR HP	MOTOR RPM	MOTOR ELECTRICAL	NOTES
1	TACO	SB-2508	75	65	5	1750	460V/3Ø	(1)
2	TACO	SB-3006	110	22	1½	1750	460V/3Ø	(1)
3	TACO	SB-3008	153	55	5	1750	460V/3Ø	(1)
4	TACO	SB-3008	153	55	5	1750	460V/3Ø	(1)

(1) PROVIDE PUROCELL FILTER

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MONTANA DRAPER ENGINEERING A.G. DRAPER 15386 W.C. KELBY 10618 REGISTERED PROFESSIONAL ENGINEERS

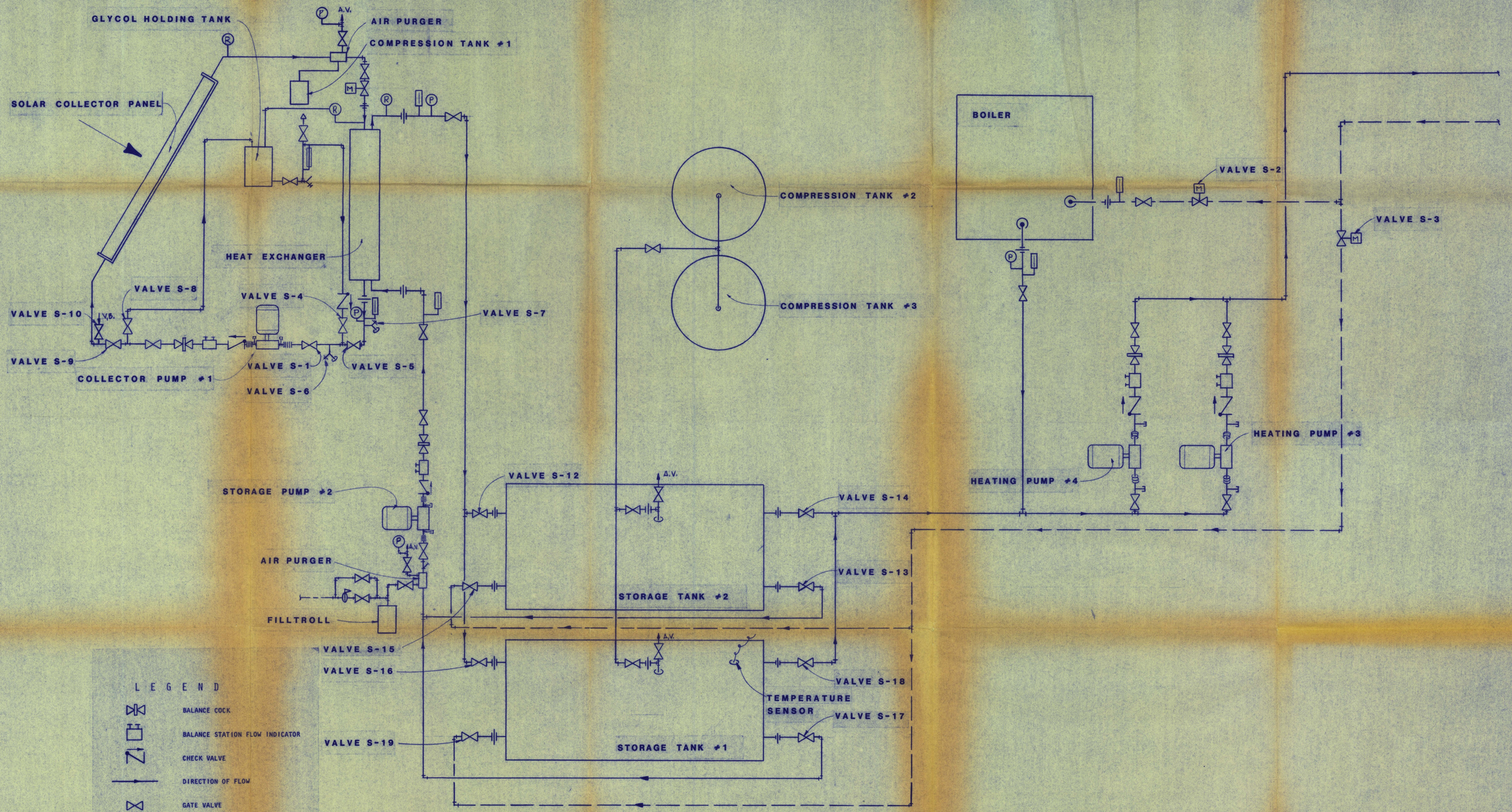
LIFE OF MONTANA OFFICE BUILDING SOLAR SYSTEM

BOZEMAN MONTANA

Drawn by: G.O.
Job number: DE 7881
Date: JAN. 11, 1979

Mechanical & Electrical Engineers Great Falls, Montana DRAPER ENGINEERING

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LEGEND

- BALANCE COCK
- BALANCE STATION FLOW INDICATOR
- CHECK VALVE
- DIRECTION OF FLOW
- GATE VALVE
- HOSE BIBB
- MOTORIZED VALVE
- PRESSURE GAUGE
- RELIEF VALVE
- TEMPERATURE GAUGE
- UNION
- SUPPLY
- RETURN

SYSTEM FLOW DIAGRAM

"AS-BUILT" 4-21-80

MONTANA DRAPES ENGINEERING A.G. DRAPES 15381 W.C. KELBY 10618 REGISTERED PROFESSIONAL ENGINEERS

LIFE OF MONTANA
OFFICE BUILDING
SOLAR SYSTEM

BOZEMAN MONTANA

Drawn by: RVB
Job number: D.E. 7821
Date: APRIL 2, 80

Mechanical & Electrical Engineers
Great Falls, Montana
DRAPES ENGINEERING

Sheet number: 4
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