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Solar Collector Test Facility

L. N. Ernst, R. S. Rusk

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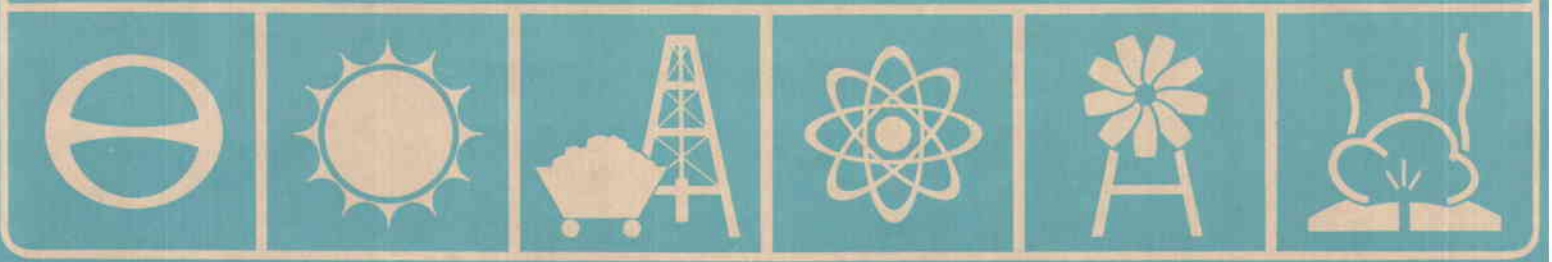
energy report



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SOLAR COLLECTOR TEST FACILITY

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ABSTRACT

This report describes the capabilities of Sandia Laboratories' Solar Collector Test Facility.

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SOLAR COLLECTOR TEST FACILITY

1. Purpose

The purpose of this report is to acquaint the reader with the capabilities of a Solar Collector Test Facility which is available at Sandia Laboratories, Albuquerque, New Mexico. This facility is available to interested parties for collector testing by contacting Sandia Laboratories Division 5712.

2. Design Goal

The Solar Collector Test Facility was built for the purpose of evaluating a variety of collectors under actual operating conditions. To achieve this, a heat transfer fluid is electrically heated to the desired test temperature and then pumped through the collector. The flow rate of the heated fluid is adjustable and along with the temperature comprise the two variable input conditions. The measured collector parameters are primarily collector efficiencies at different operating temperatures, flow rates, collector fluids, solar inputs, and varying wind speeds. To accomplish this goal, the fluid loop portion had to be capable of operating over a wide range of the following parameters: temperature, flow rate, working fluids, pressure, and the ability to be easily attached to differently configured collectors.

3. Fluid Loop Specifications*

Due to use of flexible high temperature hoses for interconnection of the test facility to the collector, the fluid loop can be attached to almost any type of solar collector.

a. Collector outputs from 1000 Btu/hr through 60,000 Btu/hr can be accommodated.

b. Heat transfer medium:**
   (1) water from ambient to 450°F (500 psi).
   (2) "Therminol 66" from ambient to 600°F at 180 psi, maximum.

*These specifications are for the system as it exists. However, requests for requirements outside our test range will be considered.

**Changing from water to oil and vice versa is possible but not a simple task. Therefore "Therminol 66" is the preferred fluid.

c. Flow rates: 0.1 → 10 GPM infinitely variable with accuracy exceeding 0.5 percent full scale.

d. Solar collector inlet-outlet temperature difference accuracy: ±0.1°F.

e. Fluid temperature: Selectable from ambient → 600°F at a temperature change rate of 3°F/minute, controllable within 1°F of selected test points.

f. Loop fluid capacity: ≅25 gallons.

4. Instrumentation

a. Temperature: System temperature is monitored by iron constantan thermocouples. Collector input and output temperatures are monitored by both iron constantan and copper constantan. The iron constantan is displayed by digital readout for operator convenience and the copper constantan is fed to the data acquisition system.

b. Flow rate: The flow meters are strain gauge type, used in a four-active-arm bridge circuit. The output is 2MV/V excitation. For operator convenience, the flow rate is displayed on an analog meter. In conjunction with this display, the electrical signal is fed to the data acquisition system.

5. Data Acquisition and Processing Capabilities

The system is designed to accommodate 30 channels of Type T thermocouple data, 10 channels of millivolt input data, and 16 channels of 5 volt input data. The computer directs the A/D converter to scan the input data as often as the experimenter wishes. This analog information is compensated, linearized, and digitized; it is then stored on magnetic tape. Also, this information may be printed on the teleprinter to give the experimenter "real time" data. After the tests are completed, the magnetic tapes may be played back on the large scientific computers, or on our data processing system. We have programs to plot temperature, efficiency, or solar insolation versus time on the x-y plotter. All programming is done in basic language; therefore, other programs are easily generated.

The system has 30 relay outputs and 12 analog outputs available, so some timing and control could be incorporated.

For further information regarding instrumentation or computer programming, contact R. S. Rusk, Division 5712, telephone (505) 264-5035 or 264-5036.

6. Sample Data Acquisition Program and Program Flow Diagram

Figure 1 is a sample data acquisition program, and Figure 2 is the program flow diagram.

```
LIST
1  REM "DATA ACQUISITION FOR FLAT PLATE  COLLECTORS - 9-23-74"
10  PRINT "FIRST RUN ON TAPE(1=YES)";
15  INPUT U
20  IF U#1 THEN 35
25  CALL (7,1,E1)
30  GOTO 85
35  PRINT "NUMBER OF FILES TO BE SKIPPED";
40  INPUT N
45  FOR X=1 TO N
50  CALL (6,F,1,E)
55  IF E=1 THEN 65
60  GOTO 50
65  CALL (6,F,1,E)
70  IF E=1 THEN 80
75  GOTO 50
80  NEXT X
85  PRINT "DAY,HOUR,MINUTE TO SET CLOCK";
90  INPUT D,H,M
95  CALL (4,D,H,M)
100  PRINT "NEW TEST?(1=YES)";
105  INPUT T5
110  IF T5#1 THEN 800
115  PRINT "ENTER NEW VARIABLES?(1=YES)";
120  INPUT T6
125  IF T6#1 THEN 200
130  GOSUB 1000
200  CALL (5,D1,H1,M1)
210  FOR X=1 TO 9
220  CALL (1,X,D[X],F[X],0)
230  IF F[X]=5 THEN 1500
240  NEXT X
245  LET R7=R9=C4=K7=03=04=0
250  FOR X=1 TO 10
260  LET C=X+9
265  GOSUB 1520
270  CALL (1,C,H[X],G[X],0)
280  IF G[X]=5 THEN 1500
290  NEXT X
292  FOR X=1 TO 7
294  LET C=X+19
295  GOSUB 1520
296  CALL (1,C,I[X],J[X],0)
297  IF J[X]=5 THEN 1500
298  NEXT X
```

Figure 1. Sample data acquisition program

```
300  LET K8=K7/17
302  LET D[8]=C4/17
303  LET D[8]=D[8]-(C4/17)+(.58/10^6)
305  LET H[1]=R7/17
308  LET H[2]=R9/17
310  LET C5=((H[2]+H[1])/200)
312  LET C6=(C5-32)*5/9
314  LET G1=3.87408*10^1
315  LET G2=3.31902/10^2
316  LET G3=2.07142/10^4
317  LET G4=-2.19458/10^6
318  LET G5=1.10319/10^8
319  LET G6=-3.09276/10^11
320  LET G7=4.56533/10^14
321  LET G8=-2.76169/10^17
325  LET J1=G1+(2*G2*C6)+(3*G3*C6^2)+(4*G4*C6^3)+(5*G5*C6^4)+(6*G6*C6^5)
327  LET J2=(7*G7*C6^6)+(8*G8*C6^7)
329  LET J3=(J1+J2)*5/9
330  PRINT J3;"DV/DT"
332  LET J4=(D[8]*10^6)/J3
334  PRINT J4;"DELTA T"
336  PRINT (H[2]-H[1])*1.00000E-02;"TEMP OUT-TEMP IN"
340  GOSUB 600
350  PRINT INT((D[1]*2210/7.14)*100);"BTU TOTAL TRACKING"
360  PRINT INT((D[2]*2210/7.67)*100);"BTU TOT NOR"
370  PRINT INT((D[3]*2210/5.61)*100);"BTU NOR IN"
380  PRINT D[1]/D[3]*5.61/7.14;"TOTAL/NORMAL RATIO"
390  PRINT H[1]*1.00000E-02;"FLUID INPUT TEMP"
392  PRINT H[2]*1.00000E-02;"FLUID OUTPUT TEMP"
393  PRINT H[3]*1.00000E-02;"PLATE INPUT TC"
394  PRINT H[4]*1.00000E-02;"PLATE OUTPUT TC"
395  PRINT H[5]*1.00000E-02;"MID PLATE ON TUBE"
396  PRINT H[6]*1.00000E-02;"MID PLATE BETWEEN TUBES"
397  PRINT H[7]*1.00000E-02;"OUT TOP GLASS"
398  PRINT H[8]*1.00000E-02;"IN TOP GLASS"
399  PRINT H[9]*1.00000E-02;"OUT MID GLASS"
400  PRINT H[10]*1.00000E-02;"IN MID GLASS"
401  PRINT I[1]*1.00000E-02;"OUT MID INNER GLASS"
402  PRINT I[2]*1.00000E-02;"IN MID INNER GLASS"
403  PRINT I[3]*1.00000E-02;"OUT EDGE INNER GLASS"
404  PRINT I[4]*1.00000E-02;"IN EDGE INNER GLASS"
405  PRINT I[5]*1.00000E-02;"AMBIENT AIR"
410  LET K9=K8/3273
412  IF K9<1.2 THEN 418
414  IF K9<1.7 THEN 422
416  IF K9>1.7 THEN 426
418  LET W9=((K9-.396)/.278)^2.725
420  GOTO 430
422  LET W9=((K9-.54)/.157)^2
424  GOTO 430
426  LET W9=((K9-4.00000E-02)/.525)^3.472
430  PRINT W9"WIND SPEED NORMAL (FT/SEC)"
432  LET W3=100*(D[9]/2.533*1.689)
434  PRINT W3"WIND SPEED ACTUAL (FT/SEC)"
440  IF F2=1 THEN 446
442  LET E2=200*D[5]/S2
444  GOTO 454
446  LET E2=200*D[4]/S2
448  REM "GPM=.79568*(E2^.567) FOR 0.1 TO 0.2 GPM"
```

Figure 1. (Continued)

```
450  REM "GPM=.695*(E2^.5125) FOR 0.2 TO 1 GPM"
452  REM "GPM=6.81*(E2^.5025) FOR 1 TO 10 GPM"
454  IF F2=1 THEN 460
456  LET Y=6.81*(E2^.5025)
458  GOTO 462
460  LET Y=.695*(E2)^.5125
462  PRINT Y,"GPM"
464  LET Z=Y*21/60
466  PRINT Z,"MASS FLOW RATE, (LB/SEC"
470  LET J=Z*H3*3600*J4
480  LET D5=5.9*(INT((D[1]*2210/7.14)*100))
490  LET D6=J/D5
500  PRINT D6,"COLLECTOR EFFICIENCY"
510  CALL (5,D,H,M)
520  PRINT D;"DAY";H;"HOUR";M;"MINUTE"
530  GOTO 100
600  CALL (8,D1,2)
610  CALL (8,H1,0)
620  CALL (8,M1,0)
630  FOR X=1 TO 5
640  CALL (8,X,0)
650  CALL (8,D[X],0)
660  CALL (8,F[X],0)
670  NEXT X
675  CALL (8,99,1)
680  CALL (8,D1,2)
685  CALL (8,H1,0)
690  CALL (8,M1,0)
695  FOR X=6 TO 10
700  CALL (8,X,0)
705  CALL (8,D[X],0)
710  CALL (8,F[X],0)
715  NEXT X
720  CALL (8,99,1)
725  CALL (8,D1,2)
726  CALL (8,H1,0)
727  CALL (8,M1,0)
730  FOR X=1 TO 5
732  CALL (8,X+9,0)
734  CALL (8,H[X],0)
736  CALL (8,G[X],0)
738  NEXT X
740  CALL (8,99,1)
742  CALL (8,D1,2)
744  CALL (8,H1,0)
746  CALL (8,M1,0)
748  FOR X=6 TO 10
750  CALL (8,X+9,0)
752  CALL (8,H[X],0)
754  CALL (8,G[X],0)
760  NEXT X
763  CALL (8,99,1)
764  CALL (8,D1,2)
765  CALL (8,H1,0)
766  CALL (8,M1,0)
767  FOR X=1 TO 5
768  CALL (8,X+19,0)
769  CALL (8,I[X],0)
770  CALL (8,J[X],0)
```

Figure 1. (Continued)

```
771  NEXT X
772  CALL (8,99,1)
773  CALL (8,D1,2)
774  CALL (8,H1,0)
775  CALL (8,M1,0)
776  FOR X=6 TO 10
777  CALL (8,X+19,0)
778  CALL (8,I[X],0)
779  CALL (8,J[X],0)
780  NEXT X
781  CALL (8,99,1)
782  CALL (8,D1,2)
783  CALL (8,H1,0)
784  CALL (8,M1,0)
785  CALL (8,K8,0)
786  CALL (8,99,1)
798  CALL (7,3,E1)
799  RETURN
800  CALL (7,3,E1)
810  PRINT "REWIND";
815  INPUT V
820  IF V#1 THEN 830
825  CALL (7,1,E1)
830  STOP
1000  CALL (1,10,Z5,R3,0)
1005  IF R3=5 THEN 1500
1010  PRINT Z5*1.00000E-02
1015  PRINT "Z5*.01=DESIRED TEMP.?(1=YES)";
1020  INPUT I9
1025  IF I9#1 THEN 1000
1030  LET T1=Z5*1.00000E-02
1035  LET Z1=(-3.80178E-03*T1)+8.70701
1040  PRINT Z1,"DENSITY IN LB/GAL"
1045  LET Z2=(-2.84396E-02*T1)+65.1336
1050  PRINT Z2,"DENSITY IN LB/FT^3"
1055  LET S2=Z2/62.3164
1060  PRINT S2,"NEW SPGR"
1065  LET H3=5.00000E-04*T1+.33
1070  PRINT H3,"SP HEAT(BTU/LB-FT)"
1075  PRINT "ENTER FLOW METER USED(1=.1 TO 1),(2=1 TO 10)";
1080  INPUT F2
1085  CALL (1,10,Z5,R3,0)
1090  IF R3=5 THEN 1500
1095  PRINT Z5*1.00000E-02
1100  PRINT "Z5*.01=DESIRED TEMP.?(1=YES)";
1105  INPUT I8
1110  IF I8#1 THEN 1085
1120  CALL (1,5,R2,02,0)
1122  LET E2=200*R2/S2
1124  LET Y=6.81*(E2)^.50251
1125  PRINT Y;"CORRECT FLOW?(1=YES)";
1126  INPUT B6
1127  IF B6=1 THEN 1130
1128  GOTO 1120
1130  RETURN
1500  PRINT "DORIC MALFUNCTION"
1505  CALL (10)
1510  GOTO 200
1520  CALL (1,10,R6,0,0)
```

Figure 1. (Continued)

```
1522  LET R7=R6+R7
1530  CALL (1,11,R8,Q,0)
1533  LET R9=R9+R8
1535  CALL (11,0,K8)
1540  LET K7=K7+K8
1550  CALL (1,8,C3,Q,0)
1555  IF (C3*10^6)>500 THEN 1550
1560  LET C4=C3+C4
1570  CALL (1,0,D3,Q,0)
1572  LET D4=D3+D4
1800  RETURN
2000  END

READY
```

Figure 1. (Concluded)

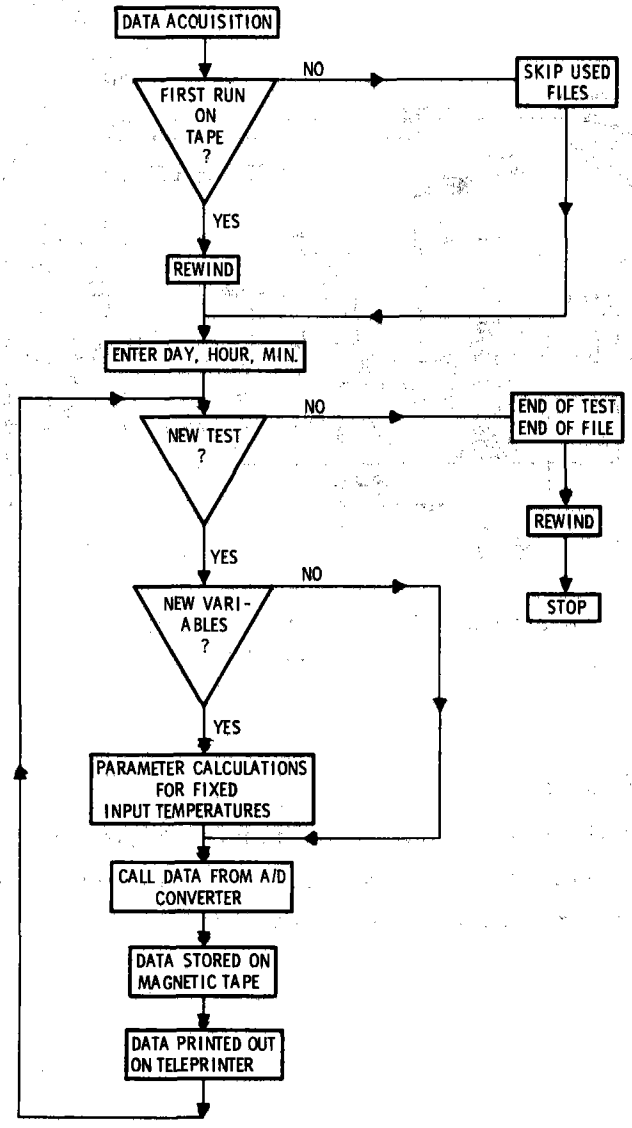


Figure 2. Program flow diagram

7. Fluid Loop Operating Procedure

This procedure is covered in great detail by Safe Operating Procedure Number S.O.P. 0600/7404/5712, dated 3/15/74, written by L. N. Ernst and J. H. Kesinger. A copy of this S.O.P. is included as Appendix A.

8. Functional Schematic

Figure 3 shows a functional system schematic.

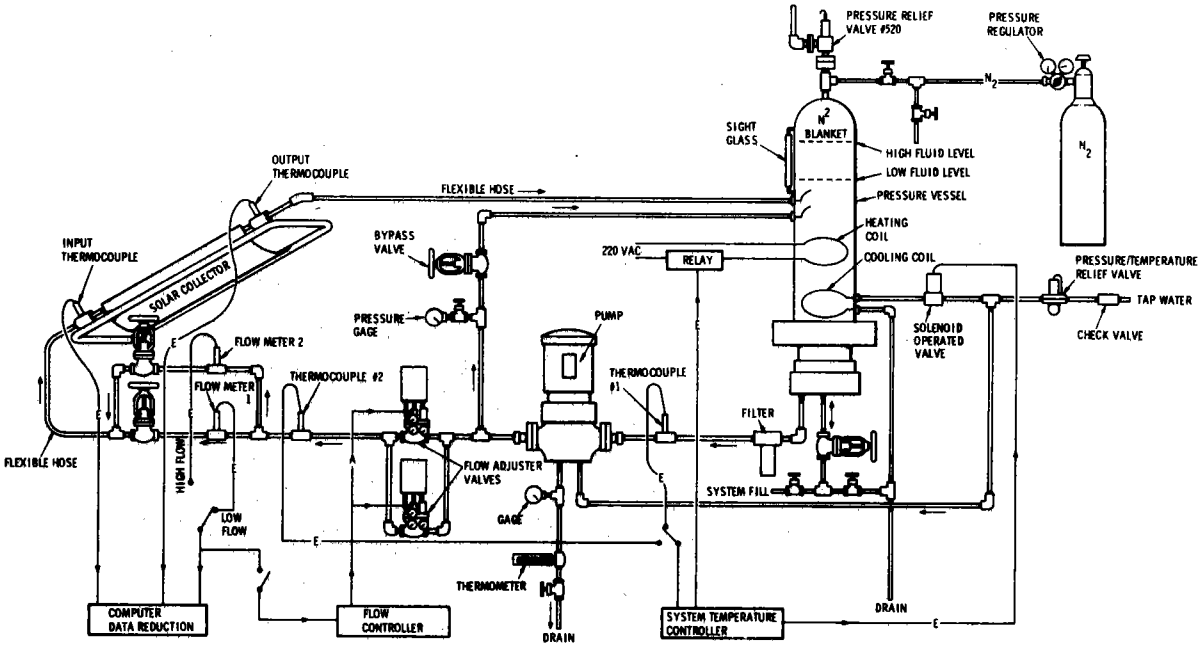


Figure 3. Instrumentation fluid loop, Solar Collector

9. Fluid Loop Photograph

Figure 4 shows the system in its operating configuration. The pressure tank and all piping are covered with calcium silicate insulation which in turn is covered with 0.016 aluminum for protection against moisture.

Fluid Loop Parts List

Cal Rod Heaters - Emerson Electric Co. MOD. TM1306
Filter - Filterite Corporation #1LH10 - 3/4
Filter Cartridge - Filterite Corporation # PWC 70X10S
Fittings - All 3000 # Forged A106 Steel
Flexible Hose - Anaconda BW21-1
Flow Meters - Ramapo Mark V
Hand Valves - Valtek "Mark One"
Modulation Valves - Valtek "Mark One"
Piping - A106 Black Iron
Pump - Sunstrand Fluid Handling Mod. LMV-802
Temperature Controller - Honeywell R7353A

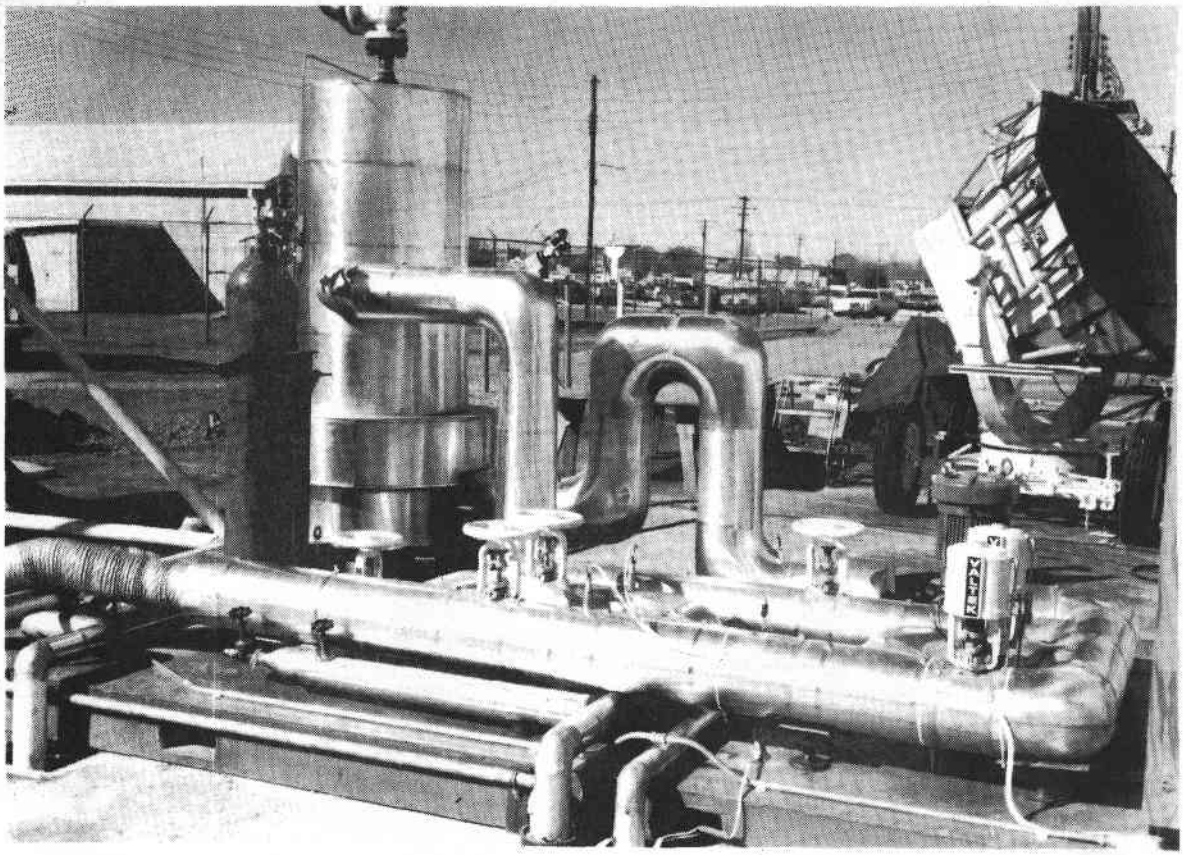


Figure 4. System in operating configuration

10. Overall View of Solar Collector Test Facility

Figure 5 is a drawing of the test facility.

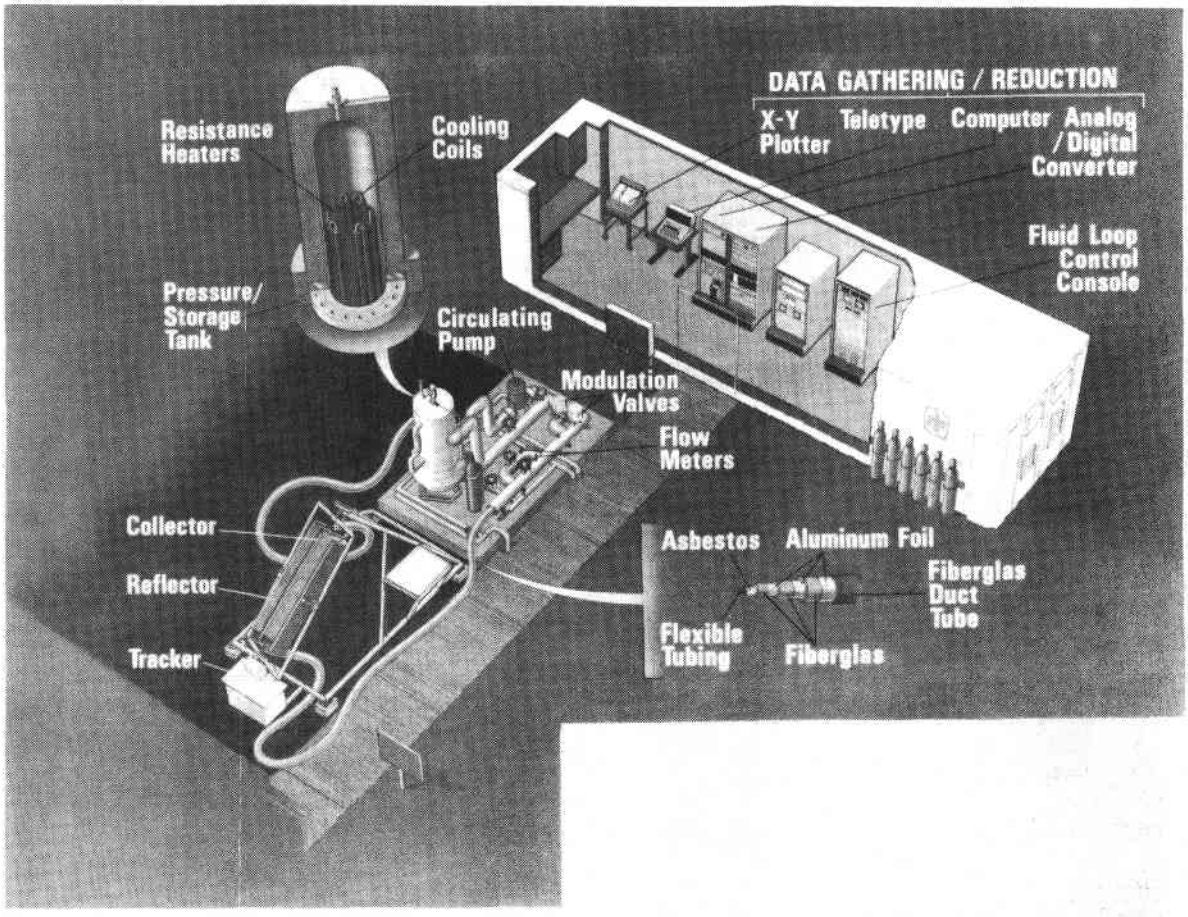


Figure 5. Solar Collector Test Facility

11. Test Collector Specifications

There are many requirements to be met by any collector that is to be connected to the system and tested. They are as follows.

Materials

a. No rubber in any form - hoses included.

b. No hose clamps or makeshift fittings.

Pressure

a. If using water, the receiver assembly must be able to withstand 500 psi if the 450°F maximum temperature is to be the test temperature.

b. If using Therminol 66, the receiver assembly must be able to withstand 180 psi independent of the test temperature.

c. The complete receiver assembly must be hydrostatically tested to 1.5 times the maximum expected operating pressure. This test must be performed by the company or organization wishing to have their collector evaluated prior to its being coupled to the Solar Test Facility.

Flow Rates

a. The complete assembly as it is to be attached to our facility must be able to achieve the maximum desired test flow in gpm with a 20 psi input pressure.

b. Maintain pressure drops at a minimum.

   (1) Use small thermocouple wells on custom instrumentation.
   (2) Keep the number of 90-degree fittings to a minimum.
   (3) Use 1/2 inch or larger tubing in the collector assembly wherever feasible.

Mechanical Interface

a. The collector must have either 1/2 or 1 inch 37-degree male hydraulic fittings such as Aeroquip dash size 6-8S or 16-16S.

b. The stub hydraulic connector must be capable of mechanically holding 25 pounds dead weight (the weight of our connecting hoses).

Therminol 66 Data

The data published by Monsanto on this heat transfer fluid is reproduced in Appendix B. It is included so that a potential experimentor can determine compatibility with his equipment and the tests he intends to have performed.

Technical compatibility of a collector system for testing at this facility must be made through L. N. Ernst, phone 505-264-4478 or 264-5036. To reduce interface problems, contact him as early in your proposed testing program as possible.

APPENDIX A

S. O. P. FOR "SOLAR COLLECTOR
TEST BED" USING THERMINOL 66 HEAT TRANSFER FLUID

Ref: PSAR Dated November 30, 1973

Subject: Instrumentation Fluid Loop, Solar Collector

1.0 GENERAL

1.1 For the objective of ensuring personnel protection, this S. O. P. was developed to control testing activities during the operation of the "Solar System Collector Instrumentation Loop." The subject system will be used for the evaluation of heat energy collector sub-systems using "Therminol 66" as the transfer fluid. No changes will be made to this procedure w/o the prior approval of safety. The procedure was evaluated by representatives of the line organization involved, safety, and by fire prevention.

1.2 Potential hazards include heat from the piping, heat from the heat transfer fluid, and focused light from the solar mirrors.

1.3 This Safe Operating Procedure shall be used by members of the Solar Energy Projects Division, 5712, only.

1.4 All authorized operating personnel will review this procedure quarterly and will sign an amendment sheet to indicate their capability.

1.5 This S. O. P. will be reviewed by a representative of the Safety Standards Division and operational personnel in the Solar Energy Projects Division at least every 12 months.

1.6 It is the responsibility of the Solar Energy Projects Division, 5712, to control access to the Solar Collector test bed area.

1.7 The test fluid used in the solar system, per this S. O. P., will be approximately 22 gallons of Therminol 66.

2.0 GENERAL SAFETY PRECAUTIONS

2.1 Personnel shall not look at solar mirrors without using proper eye protection.

2.2 Personnel shall not touch system components without previously donning asbestos gloves.

2.3 The pressure from the nitrogen cylinder shall be controlled by a relief valve which will ensure that the tank will never see a pressure in excess of the system MAWP.

2.4 Fail safe temperature controls will be used in the heater circuit to eliminate the possibility of exceeding the intended test temperature. (Controlled by a temperature limiting heat exchanger.)

2.5 In the event that a system component other than the collector tube is to be changed, the pressure shall be bled off the system and the temperature shall be reduced to ambient.

3.0 FIRE CONTROL

3.1 Fire extinguishers will be located, conspicuously, in the immediate area for first aid fire protection as specified by the fire prevention engineers. Two of those extinguishers shall be of 5 pound size to facilitate their use in cramped quarters. The others will be of a size recommended by the Planning Division (Fire Prevention).

3.2 Due to the proximity of the Sandia Medical Clinic to the test site, no first aid kit for burns will be procured.

4.0 PROTECTIVE GEAR

4.1 All personnel working around the solar mirrors shall wear shaded spectacles with side shields of a color density of four.

4.2 Personnel replacing system components while that system is charged with heated transfer fluid shall wear tinted chemical splash goggles.

4.3 Asbestos gloves shall be available at the work site for use when changing out components in the system.

5.0 OPERATING PROCEDURE

The following procedure will bring the system "on line." It will establish all conditions required for the controller to bring the system up to and to maintain the selected test temperature. The appropriate flow level for the selected test point is controlled by the pneumatic control station and is adjusted by the red thumb wheel at the bottom of the controller. To increase the flow rate, the thumb wheel is turned counterclockwise. For any given test point, the temperature will be fixed and the flow rate will be adjusted. Throughout the series of tests, these two parameters will be changed/adjusted many times.

5.1 Turn on main water valve in manhole.

5.2 Open water valve in pump seal cooling line 1/2 turn.

5.3 Open pump bypass valve 1-1/2 turns.

5.4 Check fluid level in sight glass to make sure it is visible.

5.5 Pressurize tank with 10 psig nitrogen.

5.6 Turn on temperature controller.

5.7 Adjust main air pressure regulator to 100 psig.

5.8 Adjust "control signal" air pressure regulator to 20 psig.

5.9 On the pneumatic controller, turn the left lever to "valve," the right lever to "manual."

5.10 Turn on main power (on outside panel) to the pump and to the heaters.

5.11 Start up pump.

5.12 Dial first test temperature into temperature controller.

5.13 Make sure heaters No. 2 and 3 are off.

5.14 Turn on "relay control" power supply.

5.15 Turn on heaters No. 2 and 3.

5.16 Determine the appropriate flow meter to be used for the first temperature test.

5.17 Make sure that the appropriate flow meter to be used has its valve fully open. Simultaneously, make sure that the flow meter not to be used has its valve fully closed.

5.18 Select the appropriate electrical output from the flow meter with the switch on the control panel.

6.0 PROCEDURE FOR COLLECTOR TUBE CHANGE-OUT

If at the end of a series of tests, the collector tube is to be changed and a new series of tests run, the following cool-down procedure should be used.

6.1 Turn off heaters No. 2 and 3.

6.2 Select a temperature of 150°F on the temperature controller.

6.3 Turn off the "relay control" power supply.

6.4 Open "main power breaker" to heaters.

6.5 Let the system run until the temperature throughout is down to the selected 150°F.

6.6 Turn off pump.

6.7 Open "main power breaker" to pump.

6.8 Bleed off tank pressure to atmosphere.

6.9 Close both flow meter valves.

6.10 Wearing asbestos gloves, loosen the fittings at the end of the tubes being careful not to burn yourself. Remove the tube, replace it with the new one, and tighten the fittings.

6.11 Open flow meters.

6.12 Close main power breaker to pump.

6.13 Pressurize tank with 10 psig of nitrogen.

6.14 Start up pump. Check for leaks at the tube fittings.

6.15 Check fluid level in sight glass to make sure it is visible.

6.16 Dial in the new test temperature.

6.17 Close "main power breaker" to heaters.

6.18 Turn on the "relay control" power supply.

6.19 Turn on heaters 2 and 3.

6.20 Determine the appropriate flow meter to be used for the first temperature test.

6.21 Make sure that the appropriate flow meter to be used has its valve fully open. Simultaneously, make sure that the flow meter not to be used has its valve fully closed.

6.22 Select the appropriate electrical output from the flow meter with the switch on the control panel.

7.0 NORMAL SHUTDOWN

To shut the system down when no components are to be changed, reverse the operating procedure starting with 5.15.

8.0 ABORT OR EMERGENCY SHUTDOWN

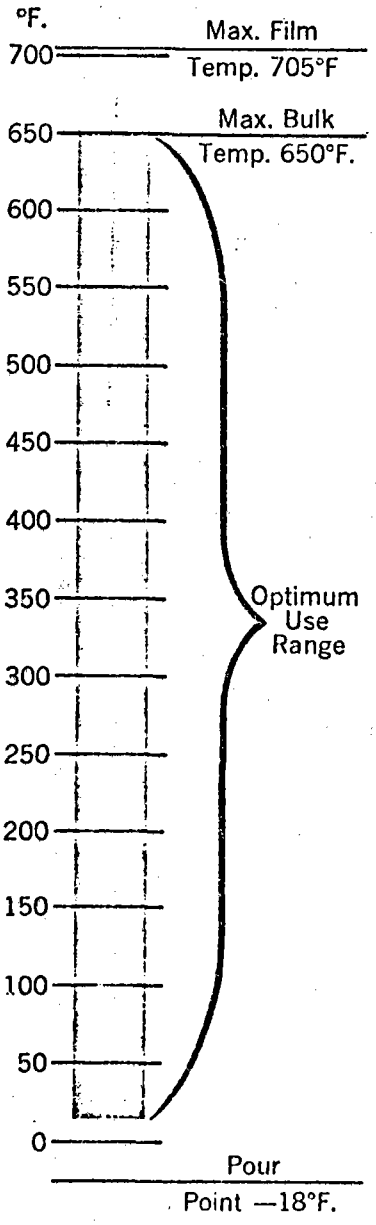
1. Dial 100°F into temperature controller.
2. Stop pump.
3. Close pneumatic valves.
4. Bleed system pressure to atmosphere.
5. Open heater breaker on main power board.
6. Avoid contact with exposed fluid.

APPENDIX B

THERMINOL 66

Therminol® 66

IC/FF-35



. . . wide-range liquid phase heat transfer fluid for non-pressurized indirect heating to 650°F.

Heat transfer fluids are intended only for *indirect* heating purposes. Under no circumstances should this product contact or in any way contaminate food, animal feed, food products, food packaging materials, pharmaceuticals or *any items which may directly or indirectly be ultimately ingested by humans.* Any contact may contaminate these items to the extent that their destruction may be required. Precautions against ignitions and fires should be taken with this product.

Monsanto

FUNCTIONAL PRODUCTS / Monsanto Industrial Chemicals Co.
800 North Lindbergh Blvd., St. Louis, Missouri 63166

Therminol® 66 . . .

is a high-performance synthetic heat transfer fluid offering low-temperature pumpability along with outstanding high-temperature performance — up to 650°F. Therminol 66 is ideally suited to replace organic fluids which have lower boiling points and must operate under pressure at 650°F.

This fluid is designed for use in non-pressurized indirect heating systems. It delivers efficient, dependable process heat with no need for high pressures, costly "extra" equipment, or continuous supervision.

Therminol 66 is not classified as a fire-resistant heat transfer fluid. Consequently, the use of protective devices may be required to minimize fire risk. The insurer of your property should be consulted relative to this matter.

To minimize fluid oxidation, Therminol 66 systems should be blanketed with an inert atmosphere. A system relief valve should also be provided.

Therminol 66 offers long service life within its recommended operating temperature range, and is non-corrosive to metals commonly used in the design of heat transfer systems.

Typical Properties

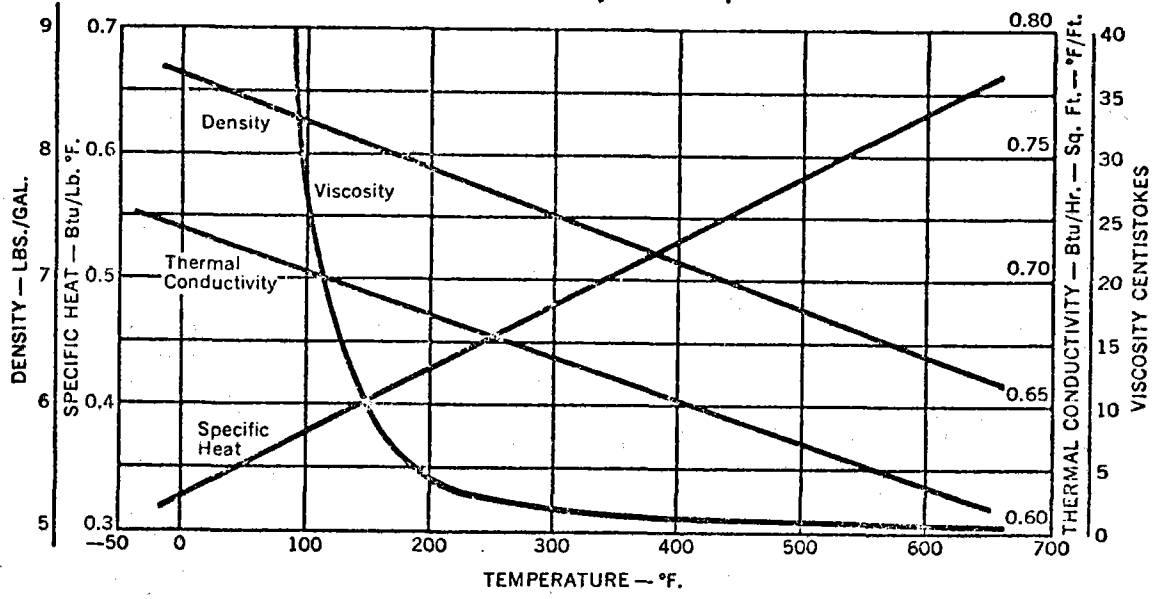
Composition	Modified Terphenyl
Appearance	Oily liquid, practically colorless
Odor	Faint, characteristic
Pour Point	−18°F. (−27.8°C.)
Density @ 75°F.	8.35 lbs./gal.
Flash Point	355°F. (180°C.)
Fire Point	382°F. (194°C.)
AIT	705°F. (374°C.)
Coefficient of Expansion	0.00070 cc/cc/°C.
Boiling Range:	
10%	644°F. (340°C.)
90%	745°F. (396°C.)
Average Molecular Weight	240

Variations of Properties With Temperature

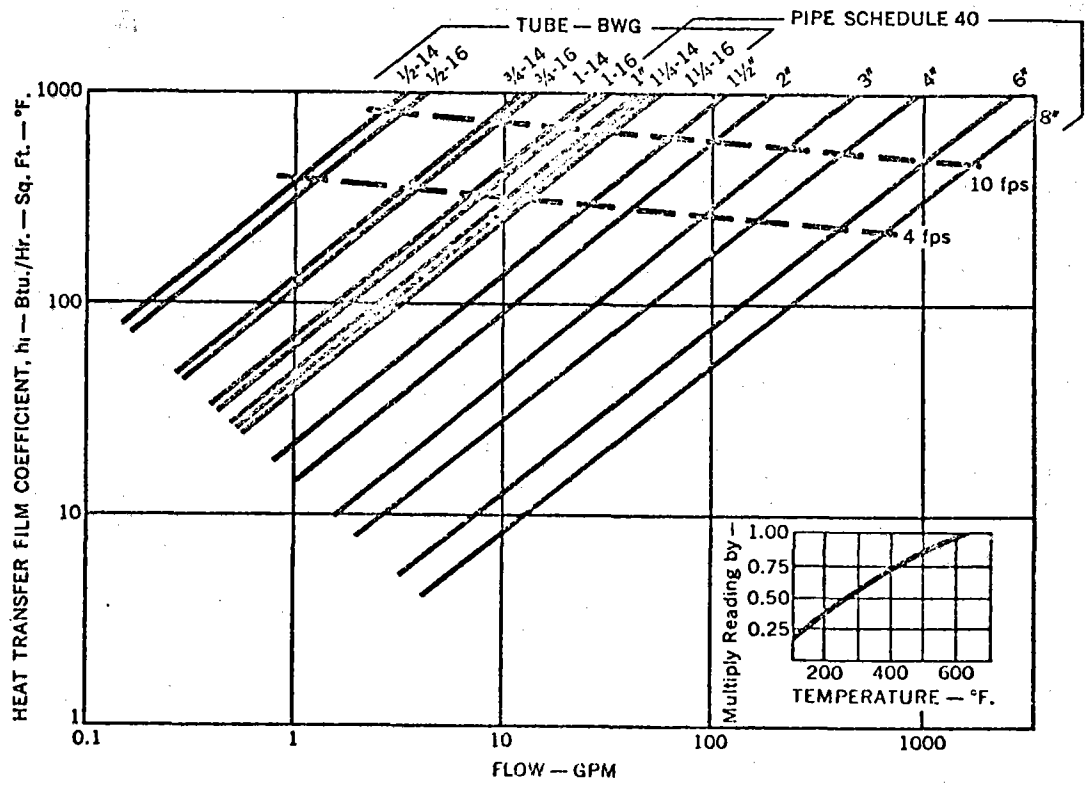
Temperature		Density			Specific Heat		Thermal Conductivity		Viscosity		Vapor Pressure	
°F	°C	lbs./gal.	lb./ft.³	Kg./m.³	BTU/lb. °F	Kcal./Kg. °C	BTU/ft. hr. °F	Kcal./m. hr. °C	lb./hr. ft.	cs	mmHg. absolute	Kg. cm.²
0	−18	8.67	64.9	1040	0.320	0.320	0.0720	0.1072	150000	50000		
50	10	8.51	63.6	1020	0.350	0.350	0.0711	0.1058	617	250		
100	38	8.34	62.4	1000	0.380	0.380	0.0703	0.1046	67.8	28.0		
150	66	8.14	60.9	975	0.405	0.405	0.0695	0.1034	23.6	10.0		
200	93	7.91	59.3	950	0.430	0.430	0.0687	0.1022	10.1	4.40	0.1	—
250	121	7.77	58.0	930	0.455	0.455	0.0678	0.1008	5.86	2.60	—	—
300	149	7.59	56.8	910	0.480	0.480	0.0670	0.0997	3.75	1.70	2.0	0.003
350	177	7.39	55.2	885	0.505	0.505	0.0662	0.0985	2.57	1.20	—	—
400	204	7.17	53.6	860	0.530	0.530	0.0653	0.0972	1.88	0.90	20.0	0.027
450	232	7.04	52.5	840	0.555	0.555	0.0645	0.0959	1.40	0.69	50.0	0.068
500	260	6.75	50.5	810	0.580	0.580	0.0637	0.0948	1.08	0.55	100.0	0.136
550	288	6.62	49.5	793	0.605	0.605	0.0628	0.0935	0.87	0.46	200.0	0.272
600	316	6.42	48.1	770	0.630	0.630	0.0620	0.0923	0.82	0.44	350.0	0.476
650*	343	6.24	46.8	750	0.655	0.655	0.0613	0.0912	0.65	0.36	760.0	1.034
700	371	6.09	45.6	730	0.680	0.680	0.0605	0.0900	0.49	0.28	1000	1.360

*Maximum Recommended Bulk Temperature: 650°F.

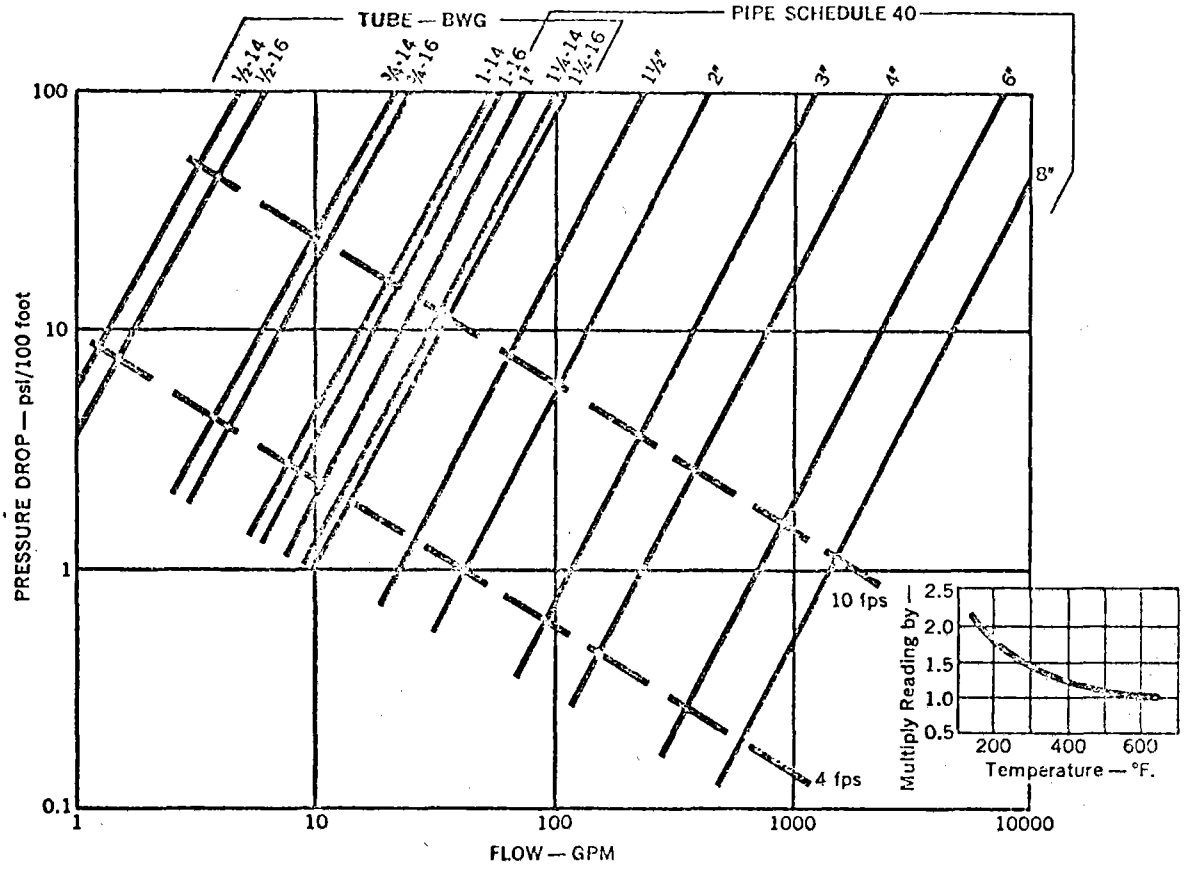
Therminol® 66 – Physical Properties



Therminol® 66 – Heat Transfer Coefficients



Therminol® 66—Pressure Drop



Therminol 66—Safety of Handling

Therminol 66 is virtually non-toxic and non-irritating, posing no special handling problems. It is not absorbed through the unbroken skin in significant quantities, is non-irritating to the skin and only mildly irritating if eye contact occurs. Immediate flushing of the eye with copious amounts of water will avoid irritation or after-effects. It is suggested that Therminol 66 be washed off the skin with soap and water as soon as possible after contact, but no serious irritation should be observed. Handled like any other industrial chemical, Therminol 66 is quite safe to store and use.

Therminol 66 vapors are not toxic, but may cause discomfort if coming off of heated fluid. There is no vapor exposure problem when transferring the fluid from its shipping container to the heat transfer system. On the other hand, vapors emitted by Therminol 66 heated to elevated temperatures may be mildly irritating upon prolonged exposure. In heat transfer installations, the fluid is used in a closed, non-pressurized system free from leaks and with the expansion tank vent trapped so as to condense any vapors. Consequently, there should be little or no opportunity for workers to come in contact with vapors.

While Therminol 66 poses no serious problems with respect to the environment, as a concerned supplier to industry, Monsanto urges the user to maintain a tight system, to correct leakage promptly, and to exercise care in the handling and disposal of this and all other such products. A tight maintenance program not only protects the environment, but keeps employes comfortable, the working area clean, and the system running smoothly.

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