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Pump Heat Loss Test Report

Michael A. Quintana, Leroy E. Torkelson

Prepared by Sandia National Laboratories, Albuquerque, New Mexico 87185
and Livermore, California 94550 for the United States Department
of Energy under Contract DE-AC04-76DP00789

Printed January 1981

Sandia National Laboratories

SF 2900-Q(3-80)

Issued by Sandia Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America

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SAND80-2526
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Printed January 1981

Category
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PUMP HEAT LOSS TEST REPORT

M. A. Quintana
and
L. E. Torkelson
Experimental Systems Operations Division 4721
Sandia National Laboratories
Albuquerque, New Mexico 87185

ABSTRACT

This report describes a test which measures the heat loss from a centrifugal pump under both insulated and uninsulated conditions. Results showed a 27% reduction in heat loss by insulating the pump and an additional 50% reduction by changing to a pump seal not requiring liquid cooling.

CONTENTS

	Page
Introduction	7
Design Objectives	7
Test Configuration	9
Test Procedure	11
Test Results	13
Discussion	13

ILLUSTRATIONS

Figure		
1	Test Setup for Pump Heat Loss Test	8
2	Pump Heat Loss Test Setup without Insulation	10
3	Thermal Loss from Centrifugal Pump Uninsulated	14
4	Thermal Loss from Centrifugal Pump Insulated	15
5	Thermal Loss from Centrifugal Pump Insulated and Uninsulated	16

TABLES

Table		
1	Test Data: Uninsulated Pump	17
2	Test Data: Insulated Pump	18

PUMP HEAT LOSS TEST REPORT

Introduction

Thermal losses in plumbing components decrease the overall efficiency of solar collector fields. Pumps, typically not well insulated, are major contributors to these thermal losses. Pumps rated for the midtemperature range, up to 572°F (300°C), are often equipped with Teflon seals, nominally rated for 436°F (224°C). These seals must be cooled. Both the introduction of a seal coolant, usually water, and the large mass of the pump and its metal base make a pump a principal source of thermal energy loss.

This report examines thermal loss from a pump during operation. Test configuration, test procedures, and test results are detailed. These results will aid in computation of thermal losses in solar collector field designs.

Design Objectives

The main purpose of the test was to measure the heat lost from the fluid as it passed through the pump. The improvement due to insulating the pump was to be measured also. The test configuration is shown schematically in Figure 1. Heat losses from the fluid loop were minimized by thick insulation and by keeping the fluid loop as compact as possible. The heat lost through the pump was deduced by measuring the energy input to the pumped fluid. Critical test parameters were

1. Torque on the pump,
2. Energy input from a heater rod in the fluid loop,

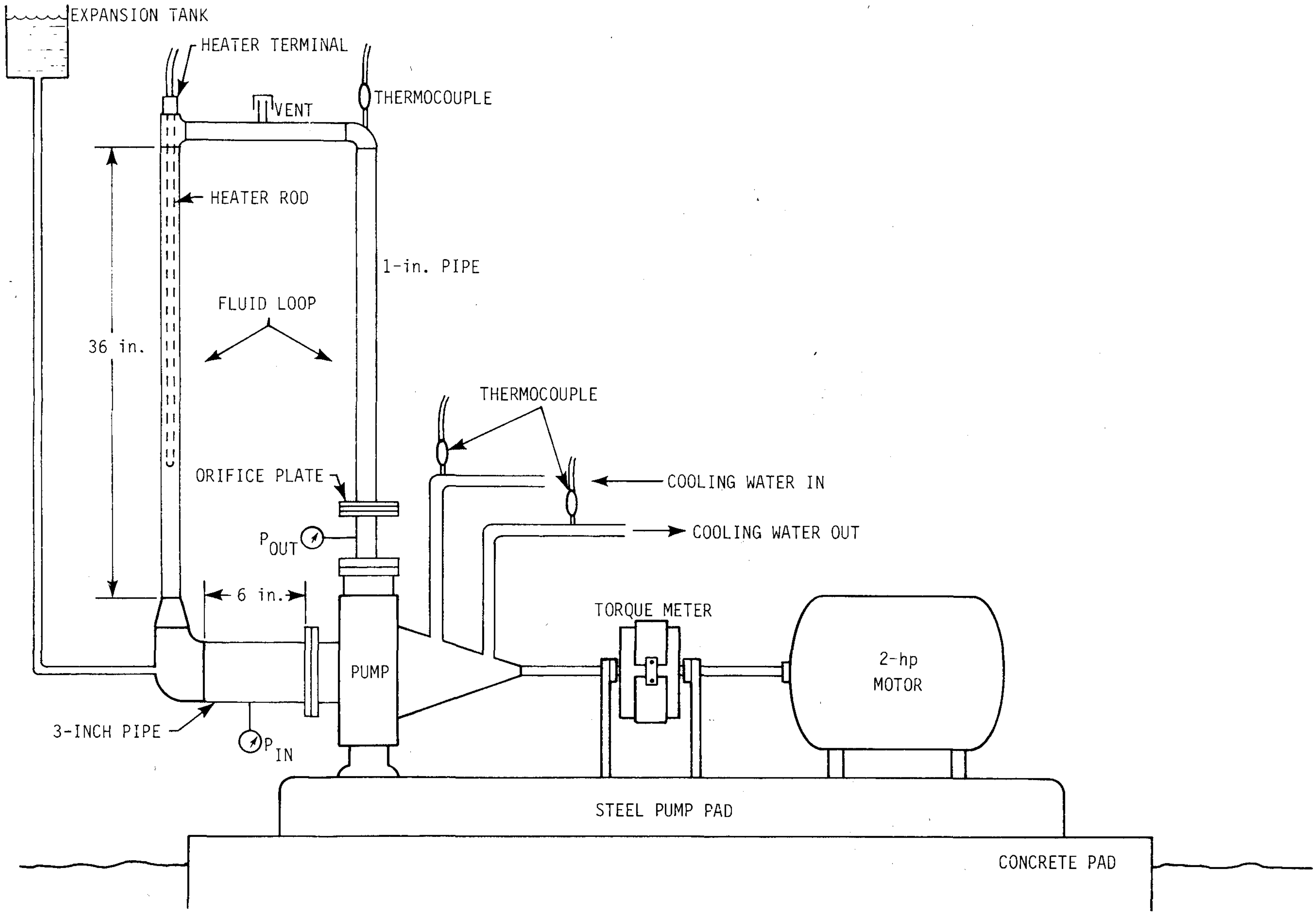

Figure 1. Test Setup for Pump Heat Loss Test

3. Fluid flow rate through the pump,
4. Fluid temperature in the loop,
5. Input and output temperature of the pump seal coolant,
6. Coolant flow rate through the seal,
7. Input and output pressure at the pump flanges, and
8. Ambient temperature and wind speed.

The flow rate and temperature of the pumped fluid, Therminol 66®, were varied. Seal coolant (water) temperature varied with loop temperature and flow rate.

Test Configuration

The following equipment was used in the test.

Components	Instrumentation and Control
Torque sensor: LeBow 1604-200	Readout: LeBow 7521
Flowmeter: Flow Technology, Inc. FTI 3176	Pulse Rate Converter: Flow Technology, Inc. PRC104AA3BZ
Heater: Watlow Firerod, 120 V, 3 kW	Variable Autotransformer: 120 V, 50 A
	Power Analyzer: Magtrol 4610
	Recorder: Hewlett-Packard 5050B
Thermocouples: Omega Type K	Recorder: Honeywell Type K1127-3
Pump: Dean Bros. Type R-434, Size: 1" x 3" x 7-1/2"	Recorder: Strip-chart, MFE Model 1600
Pressure Gauge: 2 @ Wika, 0 to 100 psi	
Vacuum Gauge: Marsh, 0 to 30 inches of Hg	

The loop was fabricated by Sandia National Laboratories (SNL) support personnel and set up at the Collector Module Test Facility (CMTF) in Albuquerque. Figure 2 is a photograph of the test setup prior to application of the insulation. Schedule 40 pipe was used to connect the pump output with the input. The 3-inch inlet pipe was reduced to 1 inch at the flange. A total of 2.8 linear meters of 1-inch schedule 40 pipe makes up the complete loop. Three inches of

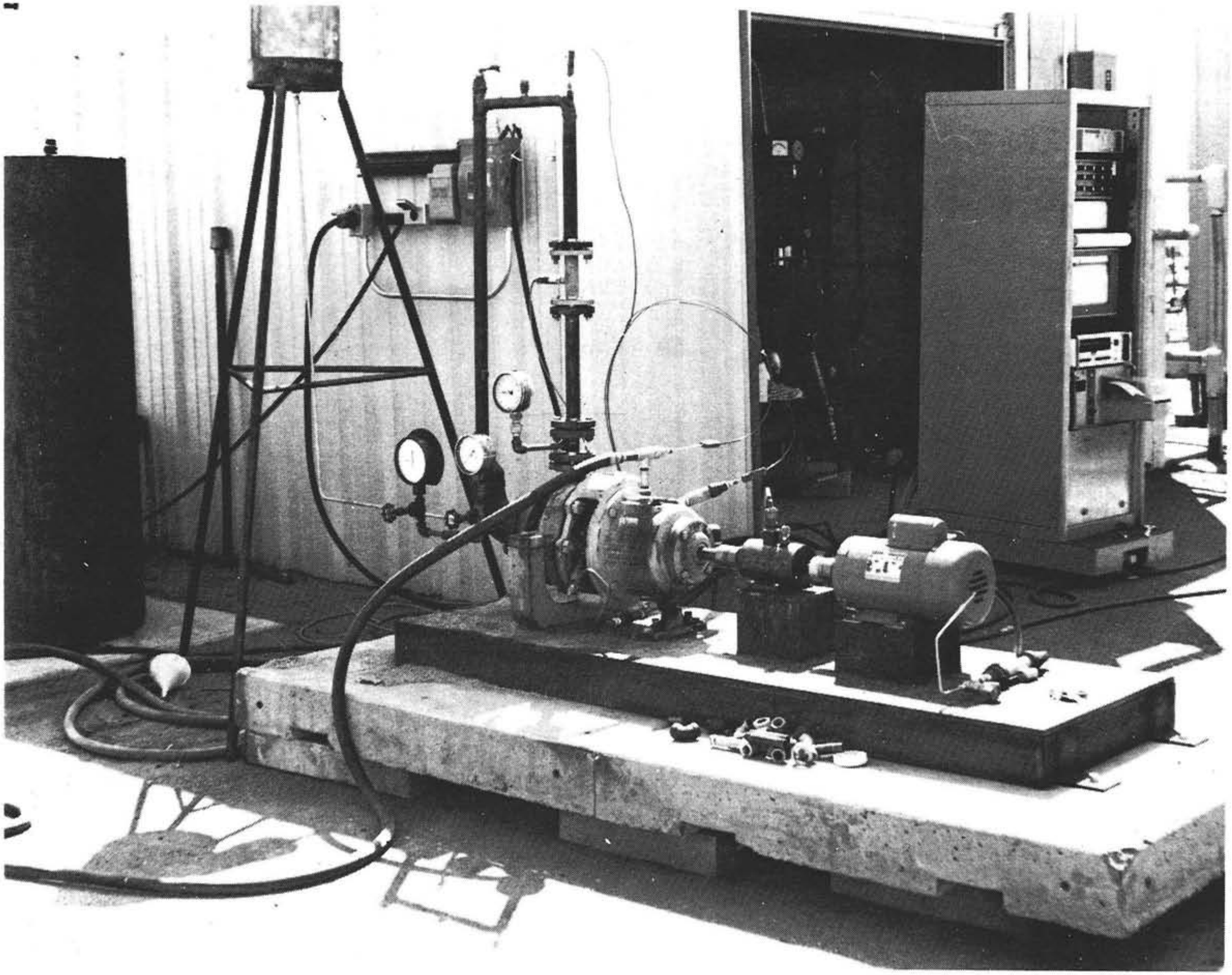

Figure 2. Pump Heat Loss Test Setup without Insulation

insulation and an aluminum jacket (0.016 inches thick) were applied to the pipe. The two innermost layers of insulation are each 1-inch-thick Johns-Manville Micro Lok-650 preformed fiberglass. The outermost layer is 1-inch-thick Upjohn U-thane 190 polyurethane. A pump pad (6 feet by 2 feet by 4 inches), fabricated with 0.25-inch steel, supported the motor, the torque sensor, and the pump assembly. The pump pad was mounted on a concrete pad. This is the typical mounting configuration of a pump in the Midtemperature Solar Systems Test Facility (MSSTF).

Test Procedure

Heat loss during pump operation was measured at two different flow rates. Flow rate variation was accomplished by insertion of a 0.50-inch orifice plate at the flange interface of the output side of the pump. The first series of measurements was taken at the two flow rates with the pump uninsulated. Water was routed through the pump seal and then through a jacket around the pump bearing housing. Water flow was controlled to keep the heat loss to the water as low as possible while maintaining the bearing housing temperature in the 120° to 160°F (49° to 71°C) range, as per the manufacturer's specifications. Temperatures of the cooling water at the input and output of the seal and the output of the pump bearing housing were recorded. Water flow was determined by measuring the amount of time necessary to fill a quart container. The thermal loss due to cooling water was calculated as a function of temperature differential and flow rate. Additional heat loss occurs through conduction to the pad and by convection and radiation to the atmosphere. This quantity was not measured.

Thermal losses were measured at approximately 50-degree increments in loop temperature from 150° to 500°F (66° to 260°C). Power input from the heater, regulated by a variable autotransformer, was measured with a power analyzer in terms of kilowatts electric. The second power input is a function of the revolutions/minute and the torque transmitted to the pump by the motor. The revolutions/minute were measured with a strobe light. Total power input is the sum of the above inputs as calculated per the following equation.

$$\sum P_{in} = P_e + P_m$$

where

$\sum P_{in}$ = Total power input to the fluid loop
P_e = Electrical power consumed by the heater
P_m = Mechanical power input to the pump

P_m is calculated as follows:

$$P_m = \frac{2\pi NT}{33,000} \text{ (horsepower)} = \frac{2\pi NT}{44.25} \text{ (watts)}$$

where

N = Rotational speed of the pump shaft (revolutions/minute)
T = Torque applied to the pump shaft (foot-pounds)

Critical thermal loss measurements were taken after the system reached thermal equilibrium. A data point was then generated by integrating several measurements over a period of time. Over a period of 12 minutes, 12 temperature measurements were recorded. Power measurements began a minimum of 1 hour prior to thermal equilibrium then were integrated over time. Torque and flow indicators remained steady in most cases. When a deviation occurred, the measurement was integrated. Water flow was measured immediately prior to temperature recording.

The first set of data was taken with the pump uninsulated. Data were first taken at full flow, then with a flow restrictor in place. The pump was then insulated. A shell of 0.016-inch-thick aluminum sheet, slightly larger than the pump, was constructed. Within the shell was a lining of 2.5 inches of Owens Corning IQ 950 fiberglass. Small, odd-size pieces of insulation were used to fill the remaining space between the inner lining and the pump. All joints and penetrations in the shell were caulked with silicone. The second set of data was then recorded with the pump fully insulated.

Test Results

The test results are presented in Figures 3, 4, and 5 and in Tables 1 and 2. The figures are plots of thermal loss from the pump versus Therminol 66® temperature in the loop minus ambient air temperature. Figure 3 was plotted for the uninsulated pump; Figure 4, for the insulated pump; and Figure 5 is a comparison between the insulated and uninsulated pumps. The plots labeled "total loss" represent the sum of the losses from the pump and the fluid loop fastened to it. The maximum loss from the fluid loop was calculated to be 0.2 kW at peak loop temperatures. The loss from the loop, being small compared to the total, can be ignored. Since the test data were collected under equilibrium conditions, the values for total power input, as calculated above, were also used here as "total loss" values.

The plot of the thermal loss to the cooling water in Figures 3 and 4 illustrates the portion of the total thermal loss from the pump that is carried away by the cooling water which protects the seal.

The test data are presented in Tables 1 and 2. Table 1 contains the data for the uninsulated pump; Table 2, for the insulated pump.

Discussion

The results show that at an operating temperature of 500°F (260°C), the total thermal loss from an uninsulated pump, with a water-cooled seal, can be cut by 27% by insulating the pump body. A

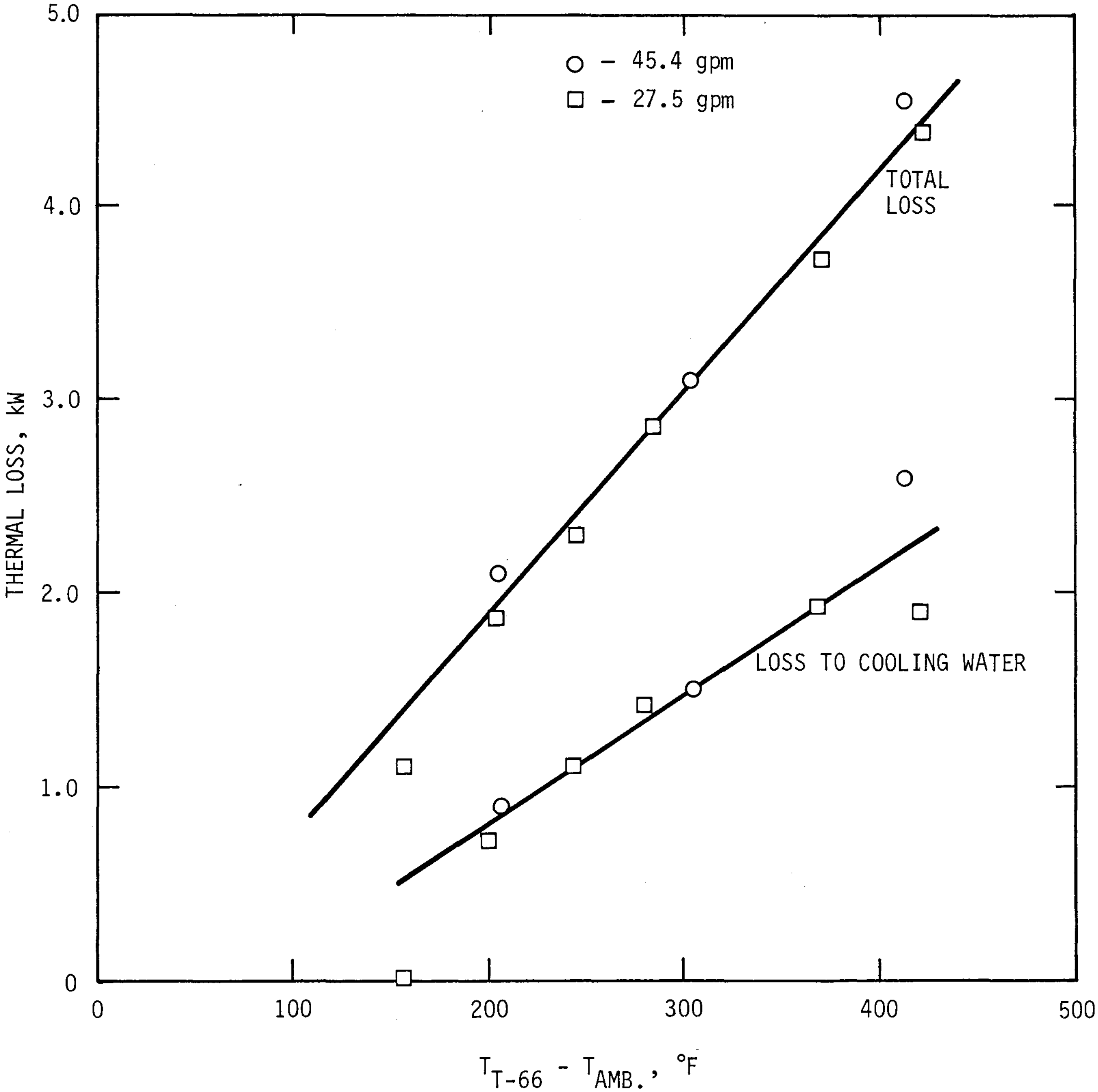

Figure 3. Thermal Loss from Centrifugal Pump Uninsulated

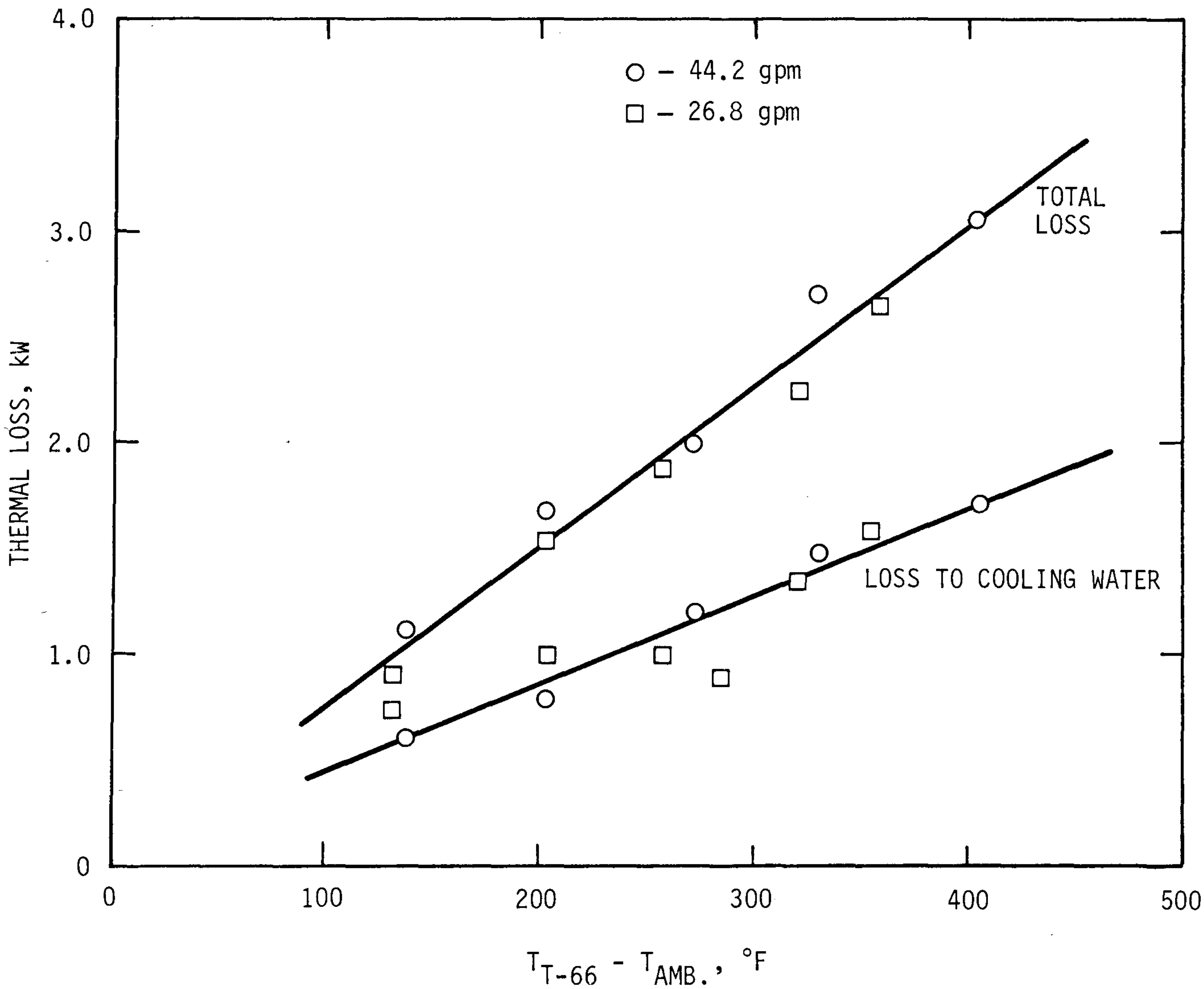

Figure 4. Thermal Loss from Centrifugal Pump Insulated

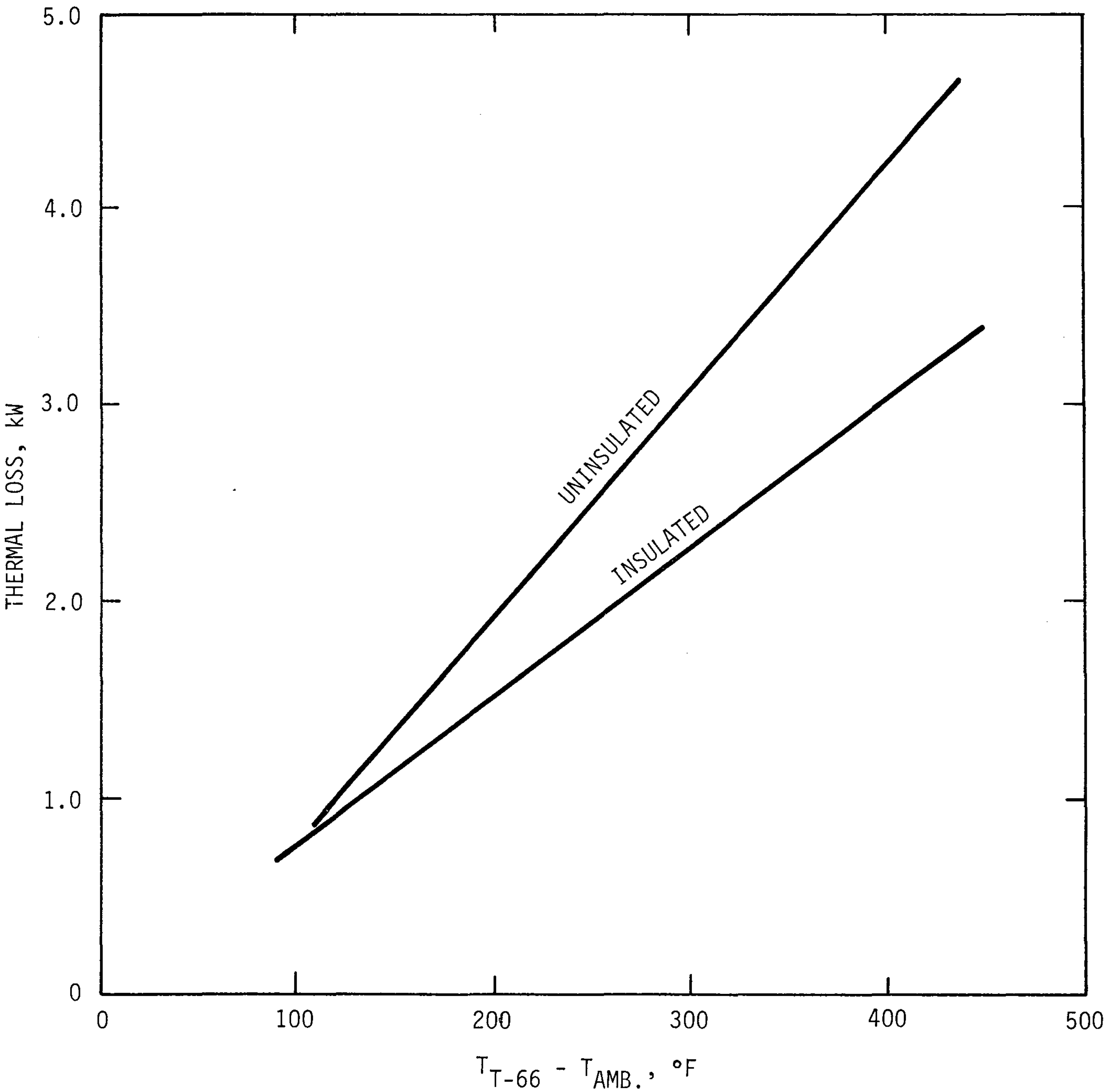

Figure 5. Total Thermal Loss from Centrifugal Pump Insulated and Uninsulated

Table 1

Test Data: Uninsulated Pump

Run No.	Therminol Flow (gpm)	Therminol Temp. (°F)	Water Flow (lb/h)	Water In Temp. (°F)	Water Out Temp. (°F)	Ambient Temp. (°F)
1	25.7	504.2	104.3	86.7	149.2	83.8
2	27.0	461.4	89.8	96.2	170.2	92.1
3	28.2	380.3	107.3	93.9	139.6	99.3
4	28.0	338.2	60.7	88.2	150.0	93.1
5	28.0	245.2	0.0	--	--	87.9
6	28.2	295.9	50.4	105.8	155.2	96.8
7	44.5	310.0	67.9	95.0	139.9	103.8
8	45.6	503.0	158.0	88.0	144.3	89.6
9	46.2	397.9	90.1	89.4	147.0	93.7

	Inlet Pressure (psi)	Outlet Pressure (psi)	Heater Power (kWe)	Pump Shaft Torque (in./lb)	Pump Shaft Rotation (rpm)	Wind Velocity (m/s)
1	2.0	14.0	3.52	40.4	1818	3.4
2	2.0	17.0	2.84	41.4	1818	2.4
3	2.0	17.0	1.92	44.0	1818	3.2
4	2.0	17.0	1.34	46.0	1818	3.5
5	1.5	18.0	0.0	51.0	1818	2.2
6	1.5	17.0	0.84	48.0	1818	3.1
7	2.0	15.0	0.96	54.0	1818	6.9
8	1.5	14.0	3.54	48.0	1818	2.7
9	2.0	15.0	2.02	50.7	1818	4.5

Table 2

Test Data: Insulated Pump

Run No.	Therminol Flow (gpm)	Therminol Temp. (°F)	Water Flow (lb/h)	Water In Temp. (°F)	Water Out Temp. (°F)	Ambient Temp. (°F)
1	44.0	240.3	73.3	91.9	119.9	102.1
2	44.3	304.7	92.6	92.0	120.9	102.7
3	44.3	361.7	76.3	92.0	145.4	89.6
4	44.3	421.6	139.7	92.8	127.2	93.6
5	28.1	373.2	0.0	--	--	89.0
6	28.1	219.7	87.1	90.0	119.6	84.8
7	28.1	290.9	74.0	91.7	137.9	90.9
8	24.8	502.2	104.3	93.4	148.9	99.3
9	25.8	452.0	85.1	98.6	161.4	95.2
10	25.8	404.7	65.5	91.7	162.3	84.4
11	27.0	358.9	65.5	97.0	149.2	101.7

Run No.	Inlet Pressure (psi)	Outlet Pressure (psi)	Heater Power (kWe)	Pump Shaft Torque (in./lb)	Pump Shaft Rotation (rpm)	Wind Velocity (m/s)
1	2.5	16.0	0.0	52.8	1818	2.30
2	2.5	15.0	0.56	51.3	1818	2.21
3	1.5	15.0	0.93	50.0	1818	2.42
4	2.0	14.0	1.57	52.0	1818	2.20
5	1.0	19.0	0.0	42.0	1818	--
6	1.0	19.0	0.0	47.3	1818	2.09
7	2.0	18.0	0.56	46.0	1818	3.77
8	2.5	12.0	2.24	37.0	1818	3.18
9	2.0	16.0	1.80	39.5	1818	1.63
10	1.5	17.0	1.37	41.0	1818	1.28
11	2.0	18.0	0.85	48.0	1818	1.15

little over half the total loss from the insulated pump was shown to be carried off by the seal cooling water. It is possible to specify seals for pumps that do not require cooling water for operating temperatures up to 600°F (316°C). One high-temperature pump with such a seal has been operating successfully at the MSSTF in Albuquerque for the past 3 years. The seal is a metal bellows type with a carbon ring rotating on a tungsten-carbide ring. The external surfaces of the rings are flushed with nitrogen gas at a flow rate of 0.15 ft^3/h (1 cm^3/s).

The results also show that the heat loss from a well-insulated pump that does not require cooling water for its seal will still be significant. This suggests that work needs to be done in the area of pump mounting in order to block the heat leakage path from the base of the pump to its mounting pad.

In conclusion, when a pump is being specified for a solar heating system, some type of seal not requiring liquid cooling should be selected. Also, the pump should be well insulated, and care should be taken to minimize the heat loss from the base of the pump.

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Lawrence, KS 66045
Attn: R. F. Riordan

University of New Mexico (2)
Department of Mechanical Eng.
Albuquerque, NM 87113
Attn: M. W. Wilden
W. A. Cross

Winsmith
Div. of UMC Industries, Inc.
Springville, NY 14141
Attn: R. Bhise

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