CENPD-201-A

SUPPLEMENT 1

SYSTEM 80
REACTOR COOLANT PUMP
LOSS OF COMPONENT COOLING
WATER TEST
REPORT

PLANT ENGINEERING

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LEGAL NOTICE

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1.0 PURPOSE

The purpose of this report is to verify the conclusion of CE Topical Report CENPD-201-A, Reference 4.1, i.e.,the System 80 Reactor Coolant Pumps are capable of operating without component cooling water (CCW) for 30 minutes without sustaining serious damage.

2.0 INTRODUCTION

CENPD-201-A analyzes the performance of the reactor coolant pump (RCP's) upon loss of CCW. The analysis shows that the most critically loaded component in the pump assembly is the oil lubricated pump thrust bearing. If this bearing is not adequately cooled and lubricated, the bearing could be damaged and thereby affect pump coastdown capabilities. The calculations performed in CENPD-201-A indicate that the bearing oil sump temperature would reach 240°F 30 minutes after a loss of CCW. The report concludes that at approximately 240°F oil sump temperature, the oil film between bearing surfaces will be maintained and the bearing will not sustain any damage.

The NRC review of CENPD-201-A accepted the conclusions of the report with the condition that CE demonstrate that with loss of CCW to the pump thrust bearing, the pump will continue to function without bearing damage which could affect pump coastdown.

As part of the loss of CCW test program, the NRC also requested that CE demonstrate that with loss of CCW to the pump seal assembly, the pump will continue to function without seal leakage in excess of design limits.

3.0 TEST PROGRAM

3.1 Loss of Component Cooling Water to Pump Thrust Bearing

3.1.1 Description

This test was run as part of a 50 hour performance test at CE-KSB on a production reactor coolant pump assembly. The test loop utilized is a closed loop designed to operate at normal plant operating pressure and temperature.

The upper thrust bearing which has been identified as the most severely load bearing has seven (7) pads. Six of the pads had thermocouples installed at the interface between the babbitt and the base metal. Thermocouples installed in this manner provide an accurate measure of pad babbitt temperature. However, this method can not be used as a permanent installation because of the possibility of local blowout when the babbitt is hot and under pressure. The seventh pad had a RTD installed in the base metal in the same manner as is done on every production pump. RTD's were also installed in one lower guide bearing pad, one upper guide bearing pad and in the oil reservoir. Table 1 lists this instrumentation along with other related instrumentation used for the test.

The reactor coolant pump was started and the test loop went through a normal heat up stabilizing at approximately 565^{o}F and 2175 psig. The component cooling water was set at a minimum temperature of 68^{o}F. The loop flow control valves were set to the design flow rate.

At approximately 18.5 hours after start up, the cooling water flow to the thrust bearing oil cooler was isolated. All bearing RTD's and thermocouples were recorded at 2 minute intervals. After an elapsed time of 30 minutes,cooling water flow was re-established to the oil cooler and bearing temperatures were allowed to stabilize.

3.1.2 Results

The results of the test are shown in Figure 1 for the thrust bearing thermocouples. Figure 2 is a plot of the bearing RTD sensors, reservoir oil temperature, cooling water flow rate and temperature. Figure 1 shows that the highest thrust bearing pad temperature measured after 30 minutes was 283^{o}F (TCPL 5); the lowest pad temperature was 267^{o}F (TCPL 6). The variation in pad temperature is due to the different loading on each pad caused by manufacturing tolerances on babbitt and pad thickness and bearing alignment (levelness). The bearing reservoir oil temperature reached 235^{o} after 30 minutes. As expected the upper and lower guide bearing temperatures (RTD's) reached lower temperature levels than the upper thrust bearing RTD, i.e. 240^{o}F (T007) and 229^{o}F (T006) versus 261^{o}F (T008).

Recognizing that the loss of cooling water test was run at 68^{o}F initial CCW temperature and that the range of CCW temperatures for a typical System 80 plant is 70^{o}F to 105^{o}F, a calculation was performed to project bearing and oil temperatures for a maximum CCW temperature of 105°F. The calculation, uses test data to establish initial oil and bearing temperatures for 105°F CCW temperature and projects these temperatures out to 30 minutes for a loss of cooling water event. The projection is based on the assumption that the oil and bearing temperatures for the higher cooling water condition run parallel to the test data for the lower cooling water condition. This assumption is conservative since the heat load will actually be lower due to the slightly lower oil viscosity at the higher oil temperatures.

The results of the calculation give a maximum oil temperature of 245°F after 30 minutes of operation without cooling water. The corresponding hottest thrust bearing pad temperature is 296°F which is below the 300°F maximum pad temperature limit established by CE. The 300°F is a conservative limit for the babbitt material since the threshold temperature at which babbitt will deform is approximately 325°F. Deformation is characterized by softening and creep of the babbitt material.

After the test, the bearings were inspected and found to be in good condition with no babbitt damage and with only normal wear marks on the bearing shoes.

3.1.3 CONCLUSIONS

The results of the test confirm the prediction of CENPD-201-A that the bearing reservoir oil temperature will reach approximately 240°F after 30 minutes of operation without component cooling water.

CENPD-201-A and the NRC evaluation therein concludes that at a 240°F oil temperature, bearing lubrication will be maintained and bearing damage will not result. The results of the test and subsequent bearing inspection support this since the pump ran for 30 minutes without sustaining bearing damage.

3.2 Loss of Component Cooling Water to Pump Seal Assembly

3.2.1 Description

This test was also run as part of a 50 hour performance test at CE-KSB on a production reactor coolant pump assembly.

The arrangement of the shaft seal system is schematically shown in Figure 3. The reactor coolant pump has redundant seal cooling systems; the first is the high pressure cooler and the seal (throttle) coolers and the second is seal injection which is introduced upstream of the high pressure cooler. Seal water temperatures are measured before and after the high pressure cooler and in each of the seal assemblies. Controlled leakage (staging flow) is also measured. Table 2 lists the above cited instrumentation along with other instrumentation used for the test.

The test was initiated at 40 hours and 10 minutes into the 50 hour test. The test loop was at approximately normal operating conditions of 563°F and 2170 psig. Component cooling water (CCW) temperature was initially 29.3°C (85°F) and seal injection water temperature was 30°C (86°F). Component cooling water (CCW) to the high pressure cooler and seal coolers was isolated. Seal water temperatures (T001 through T005) were measured, particularly T005 which is the most critical because it runs the hotest and it is the temperature in the last or top seal. Controlled leakage flow (F275) was monitored during the entire test.

3.2.2 Results

The results of the test are shown in Figure 4 which is a plot of the seal temperatures versus time. When CCW was isolated,T005 was initially at 40°C (104°F). After approximately one hour and twenty minutes T005 stabilized at 60°C (140°F). At that time seal injection water temperature was raised from 30°C (86°F) to 39.5°C (103°F) and maintained until seal temperatures stabilized. After seal temperatures stabilized and approximately two hours and twenty minutes further into the test, T005 stabilized at 70°C (158°F). After five hours and eighteen minutes component cooling was re-established.

Controlled leakage was measured througout the test and remained essentially constant between 0.685 and 0.705 m^3/hr (3.02 and 3.10 gpm) as shown in Figure 5. The nominal design value for controlled leakage flow is 3.0 gpm with a maximum allowable value of 5.0 gpm.

The normal operating limit on seal water temperature is 70°C (158°F) with a maximum limit of 80°C (176°F) at which time the pump should be shutdown to prevent overheating the seal. The test results (Figure 4) show that it takes an incremental change of 9.5°C (17°F) in seal injection water temperature to raise the seal temperatures 10°C (18°F). Based on this, the seal injection water temperature would have to be raised to approximately 49°C (120°F) before the maximum seal water temperature limit of 80°C (176°F) is reached.

Inspection of the seal assemblies after the test revealed that the seals were in good condition and passed the manufacturer's seal acceptance criteria.

3.2.3 Conclusions

The results of the test demonstrate that with loss of component cooling water to the pump seal assembly, the pump will continue to function without exceeding design seal leakage limits and without exceeding seal temperature limits. This conclusion is based on providing seal injection water to the pump at or below 100°F. If the seal injection water temperature is initially at 120°F, the pump will have to be shutdown as T005 approaches 80°C (176°F), however based on the slow rate of temperature rises shown in Figure 4 the plant operator will have far in excess of 30 minutes to initiate suitable action after a loss of component cooling water.

The loss of CCW test for the pump thrust bearing, as described in Section 3.1 and the loss of CCW test for the pump seal assemblies were performed as separate tests in order to be able to fully control and evaluate the tests. If the test had to be terminated before

30 minutes duration because of failure of the pump thrust bearing then it would not be known whether the pump seals could have continued to run for 30 minutes and vice versa.

Separate tests for the pump thrust bearing and pump shaft seals produce results which are applicable to complete loss of CCW to all pump heat exchangers. Unless there is a gross failure of some component such as the pump shaft seals or pump thrust bearing, the increasing temperature in the pump oil reservoir does not affect pump operation, i.e. it would neither accelerate nor delay the pump shaft seal failure. Also, as long as there is no gross failure of the pump shaft seals, the increasing instability of the shaft seal controlled leakage has no affect on operation of the pump oil lubricated bearings.

4.0 REFERENCES

4.1 CE Topical Report, Performance of CE System 80 Reactor Coolant Pump with Loss of Component Cooling water, CENPD-201-A, dated March, 1976.

TABLE 1

INSTRUMENT LIST

INSTRUMENT TAG NUMBER	DEVICE	DESCRIPTION	UNITS
F403	Rotameter	Cooling Water Flowrate to the Oil Cooler	Cubic Meters per hour
T006	RTD	Lower Guide Bearing Pad Temperature	C
T007	RTD	Upper Guide Bearing Pad Temperature	C
T008	RTD	Thrust Bearing Pad Temperature	C
T009	RTD	Reservoir Oil Temperature	C
T400	RTD	Cooling Water Temperature Inlet to Oil Cooler	C
TCPL1	Thermocouple	Thrust Bearing Pad Temperature	F
TCPL2	Thermocouple	Thrust Bearing Pad Temperature	F
TCPL3	Thermocouple	Thrust Bearing Pad Temperature	F
TCPL4	Thermocouple	Thrust Bearing Pad Temperature	F
TCPL5	Thermocouple	Thrust Bearing Pad Temperature	F
TCPL6	Thermocouple	Thrust Bearing Pad Temperature	F

TABLE 2

INSTRUMENT LIST

INSTRUMENT TAG NUMBER	DEVICE	DESCRIPTION	UNITS
T001	RTD	HP Cooler Inlet Temperature	C
T002	RTD	HP Cooler Outlet Temperature	C
T003	RTD	Seal No. 1 Outlet Temperature	C
T004	RTD	Seal No. 2 Outlet Temperature	C
T005	RTD	Seal No. 3 Outlet Temperature	C
T225	RTD	Seal Injection Water Inlet Temperature	C
F275	Rotameter	Controlled Leakage Flow	Cubic Meters per hour
F225	Rotameter	Seal Injection Water Flow	Cubic Meters per hour

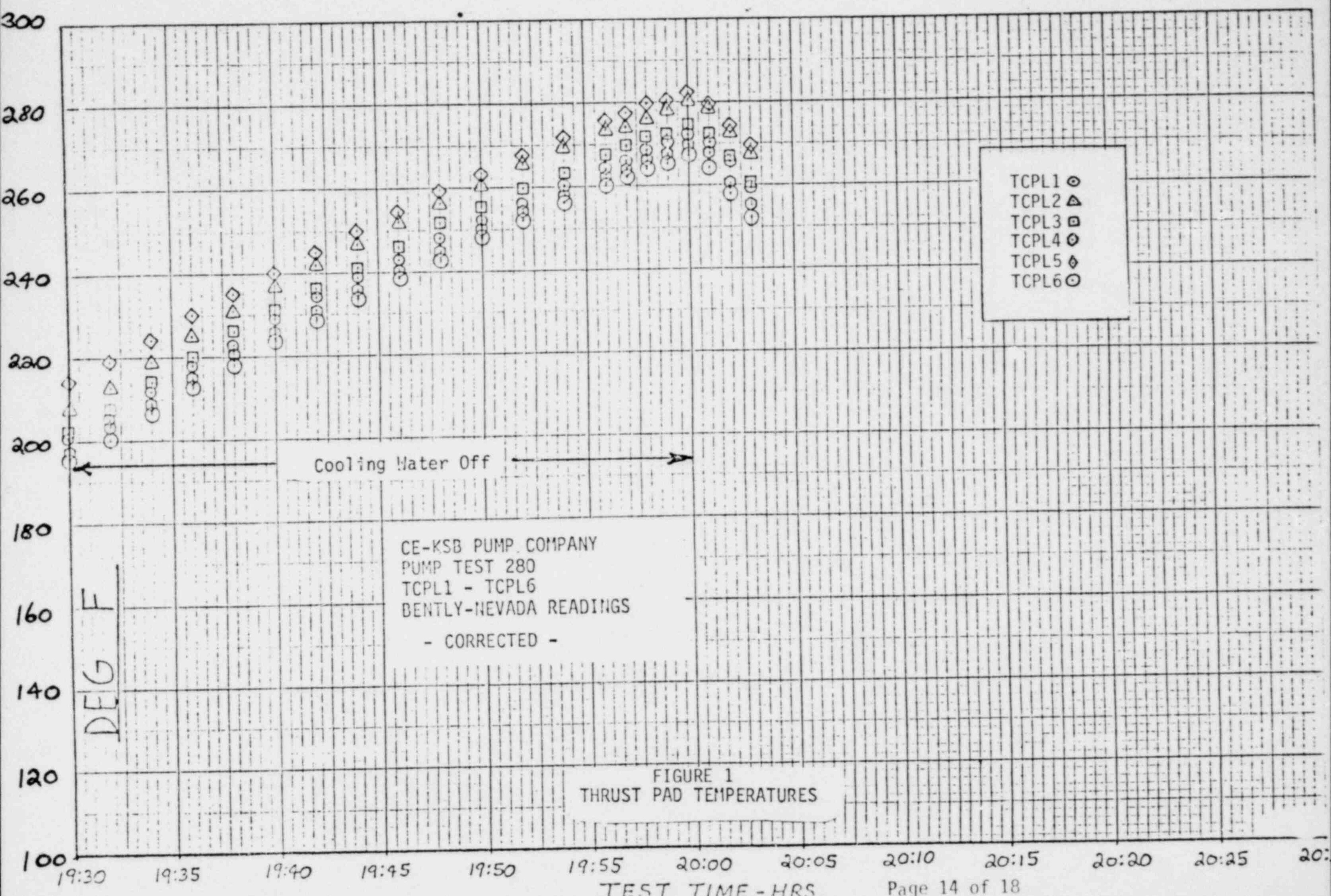
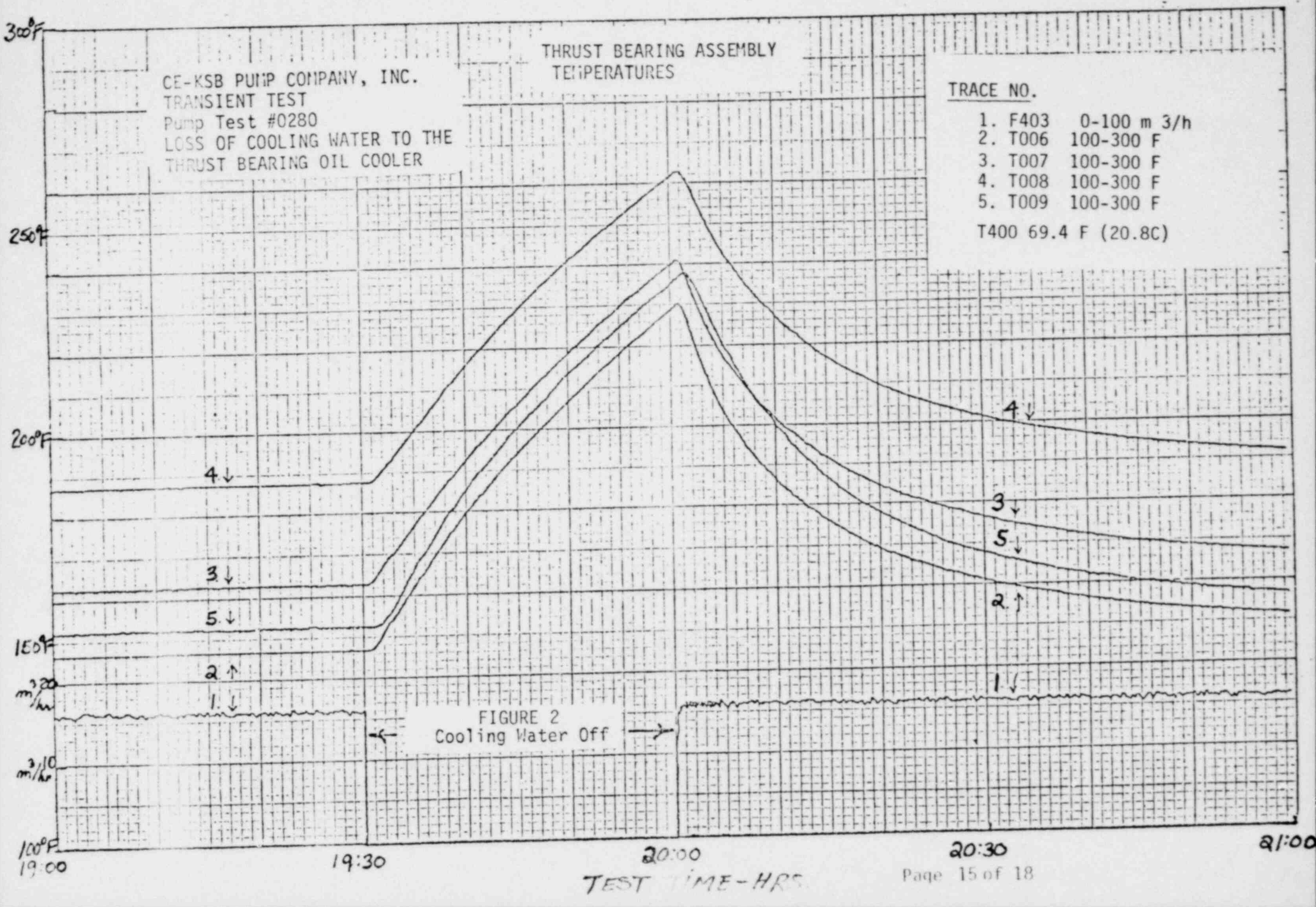


FIGURE 1
THRUST PAD TEMPERATURES



CE-KSB PUMP COMPANY, INC.
TRANSIENT TEST
Pump Test #0280
LOSS OF COOLING WATER TO THE
THRUST BEARING OIL COOLER
THRUST BEARING ASSEMBLY
TEMPERATURES
TRACE NO.
1. F403 0-100 m 3/h
2. T006 100-300 F
3. T007 100-300 F
4. T008 100-300 F
5. T009 100-300 F
T400 69.4 F (20.8C)
300°F
250°F
200°F
150°F
100°F
m³/hr 20
m³/hr 10
4↓
3↓
5↓
2↑
1↓
Cooling Water Off
19:00
19:30
20:00
20:30
21:00
TEST TIME-HRS

FIGURE 2

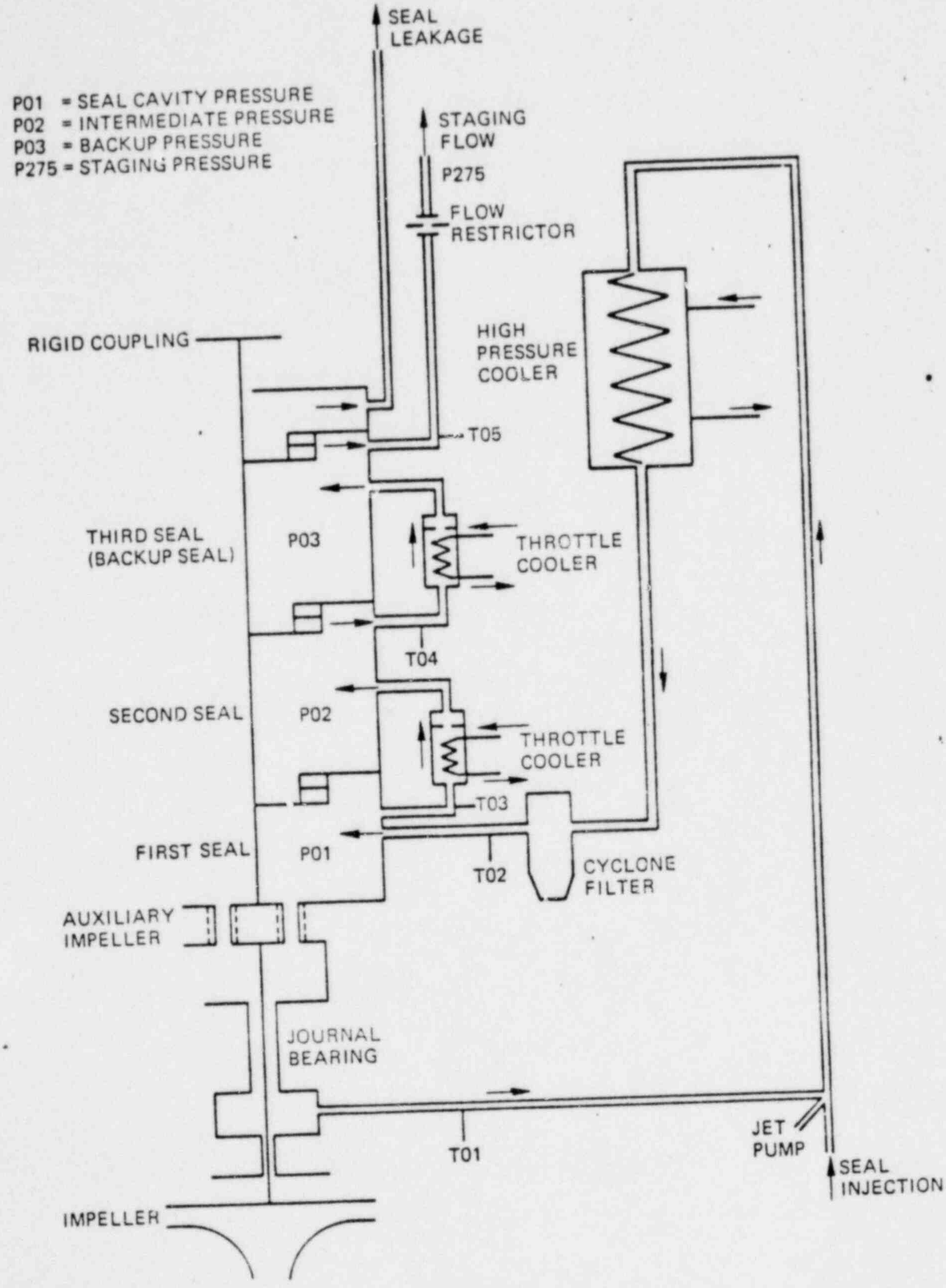


Figure 3 Flow Diagram for Hydrodynamic Shaft Seal System.

HOUSTON INSTRUMENT
DIVISION OF BAUSCH & LOMB
TEXAS
CHART NO. 81012-H
PRINTED IN U.S.A.

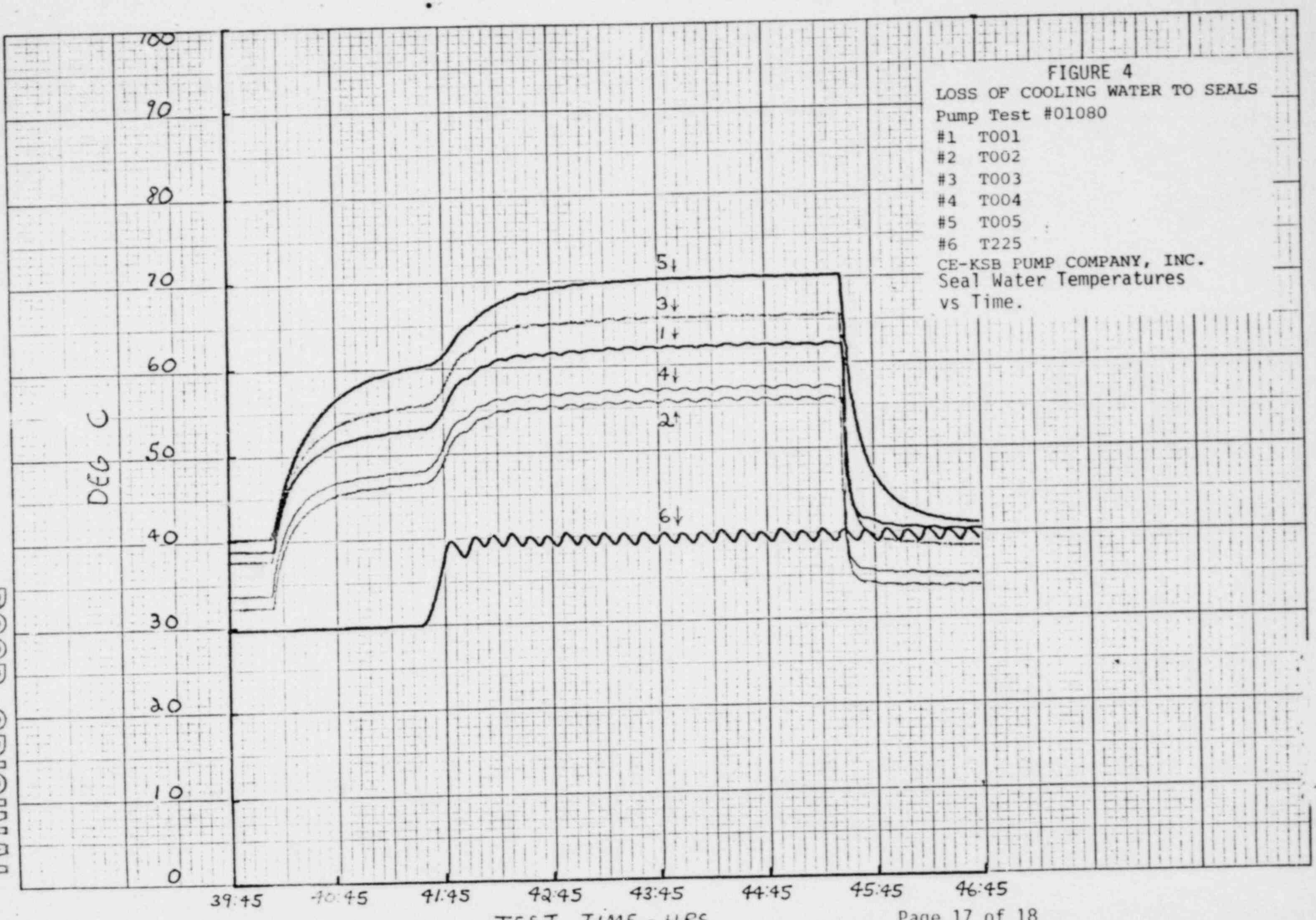


FIGURE 4
LOSS OF COOLING WATER TO SEALS
Pump Test #01080
#1 T001
#2 T002
#3 T003
#4 T004
#5 T005
#6 T225
CE-KSB PUMP COMPANY, INC.
Seal Water Temperatures vs Time.

FIGURE 5
Loss of Cooling Water to Seals
Pump Test #01080
Controlled Leakage Flow (F225)
vs
Time