

# CLINCH RIVER BREEDER REACTOR PROTOTYPE SODIUM PUMP FINAL REPORT, PROTOTYPE PUMP SODIUM TEST PROGRAM

W. L. FRISBY

PREPARED FOR  
WESTINGHOUSE ELECTRIC CORPORATION  
CONTRACT NO. 54-7AO-192909

DO NOT MICROFILM  
COVER

CRBRP

GENERAL  ELECTRIC

RECEIVED BY OST APR 05 1985

## **DISCLAIMER**

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

## **DISCLAIMER**

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

~~For Distribution to  
CRBRP Participants Only~~

GE621-3-004  
CRBRP-GEFR-00688

DATE Nov. 15, 1983

~~APPLIED TECHNOLOGY~~

~~Any Further Distribution by any Holder of this Document or of the Data Thereon to Third Parties Representing Foreign Interests, Foreign Governments, Foreign Companies and Foreign Subsidiaries or Foreign Divisions of U. S. Companies Should Be Coordinated with the Deputy Assistant Secretary for Breeder Reactor Programs, Department of Energy.~~

TITLE: CLINCH RIVER BREEDER REACTOR PROTOTYPE SODIUM PUMP, FINAL REPORT,  
PROTOTYPE PUMP SODIUM TEST PROGRAM

AUTHOR: W. L. FRISBY

M85027869

CRBRP-GEFR--00688

TI85 027869

~~NOTICE  
This report contains information of a preliminary nature and was prepared primarily for internal use at the originating installation. It is subject to revision or correction and therefore does not represent a final report. It is passed to the recipient in confidence and should not be abstracted or further disclosed without the approval of the originating installation or USDOE Office of Scientific and Technical Information, Oak Ridge, TN 37830.~~

Prepared for

Westinghouse Electric Corporation

Contract No. 54-7A0-192909

9504622

Distribution of this report is Unlimited David Hamrin OSTI 8/6/2019

DISCLAIMER

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

MASTER

ADVANCED REACTOR SYSTEMS DEPARTMENT • GENERAL ELECTRIC COMPANY  
SUNNYVALE, CALIFORNIA 94086

GENERAL  ELECTRIC

~~Released for announcement  
in ATF. Distribution limited to  
participants in the LMFBR  
program. Others request from  
BRP DOE.~~

gsw

~~APPLIED TECHNOLOGY~~

~~Any further distribution by any holder of this document or of data therein to third parties representing foreign subsidiaries or foreign divisions of U.S. companies should be coordinated with the Director, Office of Reactor Research and Technology, U.S. Department of Energy.~~

DISCLAIMER

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

DISCLAIMER OF RESPONSIBILITY

This document was prepared by or for the General Electric Company. Neither the General Electric Company nor any of the contributors to this document:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information disclosed in this document may not infringe privately owned rights; or
- B. Assumes any responsibility for liability or damage of any kind which may result from the use of any information disclosed in this document.

## TABLE OF CONTENTS

		Page
	Table of Contents-----	iii
	List of Illustrations/Figures-----	vii
	List of Tables-----	xi
	Abstract-----	xiii
1.0	INTRODUCTION	1
1.01	Pump Description	2
1.02	Drive System Description	8
1.03	Flow Controller Description	11
1.04	Conclusions	11
1.05	Summary of Test Results	12
1.06	Test Report Arrangement	14
1.1	SODIUM TEST PLANNING	15
1.1.1	Development Requirements	16
	Specification #51.28	
	-- Test Articles	16
	-- Format Test Objectives	17
1.1.2	Test Request Document #22A3551	22
1.1.3	ETEC Procedures	23
1.1.4	ETEC Data Acquisition System	23
2.0	SODIUM TEST RESULTS	25
2.1	Pump Performance on Pony Motor	26
2.2	Pump Performance on Main Motor	33
2.3	Fluid Thermal Transient Testing	52
2.4	Cellular Convection Testing	59
2.5	NPSH & Cavitation Testing	79
2.6	Drive & Flow Servo Testing	85
2.6.1	Drive Test Results	85
2.6.2	Flow Controller Test Results	99

		Page
2.7	Miscellaneous Tests	
2.7.1	Rotor Hydraulic Impedance	106
2.7.2	Segment B14A, PPIF Temperatures Transient	111
2.7.3	Segment B11, Coastdown	112
2.7.4	Segment A5A & B14B Leak Test of drop Down Seal	118
2.7.5	Segment A10 Pony Motor Run	118
2.7.6	Segment A12AB Initial Main Motor Speed Run	120
2.7.7	Segments B5 & B13, Endurance Runs	123
2.7.8	Segment B10 One Loop Operation on Main Motor	124
2.7.9	Segment B3B, IHX Gas Injection	128
2.7.10	Segment C6, Pony Motor & Main Motor Startup	129
2.8	Installation, Assembly/Disassembly & Readiness Tasks	
2.8.1	Segment A1 Tank Installation	130
2.8.2	Segment A2 MG Set Installation	133
2.8.3	Segment A3, M-G Set Activation	137
2.8.4	Segments A4A & A4B, Pump Internals Receiving & Assembly	139
2.8.5	Segment A5, Innerstructure Installation Into Pump Tank	144
2.8.6	Segment A6, Vertical Drive Motor Installation	148
2.8.7	Segment A7, Final Cold Pump Checks	150
2.8.8	Segment A8, Preheat & Fill	151
2.8.9	Segments A9A & A9B, Purge Gas Supply & Level Control Checks	152
2.8.10	Segment B14C, Shaft Seal Replacement Demonstration	154
2.8.11	Segments C1 Through C6, Assembly & Preparation Tasks for Phase C	156
2.8.12	Segment B15, Pump Disassembly After Phase B	160
2.8.13	Segment C15, Pump Disassembly After Phase C	164

		Page
2.9	Miscellaneous	
2.9.1	Vibration	166
2.9.2	Pump Temperature Profile	178
3.0	SUMMARY OF REQUIREMENTS & OBJECTIVES	
3.1	DRS 51.28 Objectives	189
3.2	Test Request Performance Predictions & Criteria	194
3.2.1	Pump Performance	194
3.2.2	Drive System Performance	199

## APPENDIX

	Page
A. List of Test Segments & Reports	201
B. DRS 51.28 Flow Logic Phases A&B	205
DRS 51.28 Flow Logic Phase C	206
C. Drive System Problem Tabulation	207
D. Pump Problems Tabulation	220
E. Unusual Occurrence Reports	226
F. References	250
G. Data Tabulation (83ETEC-DRF-4811)	251
H. Power Efficiencies	271

LIST OF ILLUSTRATIONS/FIGURES

<u>Figure #</u>	<u>Description</u>	<u>Page</u>
1.0.1.1	Prototype Pump Isometric	3
1.0.1.1A	Prototype Pump Nomenclature	3A
1.0.1.2	Pump Hydraulic Operating Range	6
1.0.2.1	Drive System	9
1.0.2.2	Vertical Drive Motor	10
2.1.1	Pony Motor Impeller At 600°F	30
2.1.2	Pony Motor Impeller at 600°F & 1000°F	31
2.1.3	38.25 Inch Impeller at 1000°F	32
2.2.1	A13A Main Motor Map at 600°F	38
2.2.2	B3A Main Motor Map at 1000°F	39
2.2.3	Impeller Performance before & after Severe Transients	40
2.2.4	38.25 Inch Impeller at 600°F	41
2.2.5	38.25 Inch Impeller at 1000°F	42
2.2.6	Water to Sodium Performance Correlation	51
2.3.1	Mild up Transient IP9U	55
2.3.2	Shaft Position Trace IP9U	55
2.3.3	Mild up Transient PP4U	56
2.3.4	Severe Down Transient PP2U	56
2.3.5	Severe Down Transient PP11U	57
2.4.1	Thermocouple Ring Locations	61
2.4.2	Tank Temperatures & Bearing Gap	65
2.4.2.1	Oil Tank Gas Pressure, LOCG Accident	68
2.4.2.2	Upper Seal Vibration Sensor Response, LOCG Accident	68
2.4.2.3	Lower Seal Vibration Sensor Response, LOCG Accident	69
2.4.2.4	Supply Tank Oil Level, LOCG Accident	69
2.4.2.5	Lower Seal Oil Temperature, LOCG Accident	70
2.4.2.6	Drive Motor Current, LOCG Accident	70
2.4.3	Cellular Convection Tank Polar Plot	74
2.4.4	Tank Skin Temperatures	75
2.4.5	Cellular convection Filler Plates & Baffles	75A
2.5.1	Head Flow Operating Points	76
2.5.2	Head Droop at High Flow	80
2.5.3	Head Versus NPSH at R5	82
2.5.4	Head Versus NPSH at R5½	83
2.5.5	Head vs. NPSH for R6	84
2.5.6	NPSH vs. Normalized Q/N	84A
2.6.1.1	Speed Controller Block Diagram	93
2.6.1.2	Drive Step Response 100% to 90%	94
2.6.1.3	Drive Step Response 90% to 100%	94
2.6.1.4	40% Speed - 2% Senusoid	95
2.6.1.5	Speed Closed Loop Gain 40%/2%	96

LIST OF ILLUSTRATIONS/FIGURES  
CONTINUED

<u>Figure #</u>	<u>Description</u>	<u>Page</u>
2.6.1.6	Speed Closed Loop Phase 40%/2%	96
2.6.1.7	Nichols Chart Speed Response	97
2.6.1.8	Speed Open Loop Gain 40%/2%	98
2.6.1.9	Speed Open Loop Phase 40%/2%	98
2.6.2.1	Flow Controller Block Diagram	102
2.6.2.2	Flow Closed Loop Gain 40%/5%	103
2.6.2.3	Flow Closed Loop Phase 40%/5%	103
2.6.2.4	Nichols Chart Flow Response	104
2.6.2.5	Flow Open Loop Gain 40%/5%	105
2.6.2.6	Flow Open Loop Phase 40%/5%	105
2.7.1A	Hydraulic Impedance Flow vs. Time	106
2.7.1B	Pressure Versus Time 600°F Sodium	107
2.7.1C	Pressure Versus Flow 600°F Sodium	107
2.7.1D	Flow Versus Time 1005°F Sodium	109
2.7.1E	Pressure Versus Time 1005°F Sodium	109
2.7.1F	Pressure Versus Flow 1005°F Sodium	110
2.7.2	PPIF Temperature Transient	111
2.7.3.1	Coastdown Head Vs. Time Case 1C	115
2.7.3.2	Coastdown Flow Vs. Time Case 1C	116
2.7.3.3	Coastdown Speed Vs. Time Case 1C	117
2.7.4.1	Seal Cartridge & Drop Down Seal	119
2.7.8.1	One Loop R7 Speed Scan, 600°F	126
2.7.8.2	One Loop R7 Speed Scan 1005F	127
2.8.1.1	Typical Oven Panel	132
2.8.1.2	Modular Oven Panels	133
2.8.2	Shipping Plan, Drive	134
2.8.2.1	MG Set Heat Exchanger	136
2.8.4	Shipping Plan, Pump	140
2.8.4.1	Pump Innerstructure Assembly	145
2.8.5	UIS to Tank Attachment	146
2.8.10	Shaft Seal Removal Tool	155
2.8.11.1	Sodium Level Probe & In-Sodium Wiring	158
2.8.12.1	Bagging & Jacking Fixture at SPTF	162
2.8.12.2	Bagged Pump Transfer From SPTF to CHCF	163

LIST OF ILLUSTRATIONS/FIGURES  
CONTINUED

<u>Figure 1</u>	<u>Description</u>	<u>Page</u>
2.9.1.1	Cover & Nozzle Vibration, R3 Speed Scan	168
2.9.1.2	Shaft Seal Vibration, R3 Speed Scan	169
2.9.1.3	Pony Motor & Gear Box Vibration	171
2.9.1.4	Cover & Nozzle Vibration, R6 Speed Scan	172
2.9.1.5	Shaft Seal Vibration, R6 Speed Scan	173
2.9.1.6	Upper Bearing Gap During R3 Speed Scan	174
2.9.1.7	Lower Bearing Gap During R3 Speed Scan	175
2.9.1.8	Seal Vibration Versus NPSH	176
2.9.1.9	Nozzle Vibration Versus NPSH	177
2.9.2A-E	PHTS Pump Temperature Profile	179
2.9.2F-J	IHTS Pump Temperature Profile	184

APPENDIX B

DRS 51.28 Flow Logic Phases A&B	205
DRS 51.28 Flow Logic Phase C	206

## LIST OF TABLES

<u>Table #</u>	<u>Description</u>	<u>Page</u>
2.1.1	Pony Motor Shut off Head	28
2.1.2	Pony Motor Performance R3	28
2.2.1	Head/Flow Performance, Main Motor	36
2.2.1A	Head/Flow Performance Adjusted to 33,700 GPM	37
2.3.1	Transient Tests	54
2.6.1.1	Drive Speed Controller Frequency Response	87
2.6.1.2	Random Speed Variation	88
2.6.1.3	Drive Response to Step Commands	89
2.6.1.4	Drive Ramp Response Errors	90
2.6.1.5	Drive Steady State Speed Error	91
2.6.2.1	Steady State Flow Error	99
2.6.2.2	Flow Response to Step Commands	100
2.6.2.3	Flow Ramp Velocity Errors	101
2.6.2.4	Flow System Frequency Response	101
2.7.3.1	Coastdown Data	114
2.9.1.1	Spectrum Analyzer Vibration, Segment B13	166
2.9.1.2	Spectrum Analyzer Vibration, Segment B3A	167

## ABSTRACT

This document reports the results of qualification testing the Clinch River Breeder Reactor Plant Prototype Sodium Pump, Drive System and Flow Controller at the Energy Technology Engineering Center's Sodium Pump Test Facility. The document describes the test articles, describes the test planning documents, the test facilities, the data acquisition system, and presents the test results with observations/conclusions. Pump performance testing included hydraulic performance in sodium at pony motor and main motor speeds, cavitation testing, gaseous cellular convection testing, fluid thermal transient tests and endurance testing. Shaft seal heat exchanger performance with the sodium fluid as high as 1100 degrees Fahrenheit was validated. Pump assembly procedures were verified. Drive speed control servo testing was accomplished using the pump and hydraulic test loop as a load. Sinusoid, step, and ramp responses of the Drive System were tested; Drive gain margin and phase margin were determined for both closed loop and open loop conditions. The sodium flow servo loop, consisting of a flow controller, the drive and speed control system, the pump and hydraulic loop with a Permanent Magnet flowmeter were tested for sinusoidal, step and ramp responses. Test article performance against test program objectives and specification requirements is presented. This document forms the basis for the sodium test qualification of this pump design for plant use.

## ACKNOWLEDGEMENTS

The Test Program described herein was sponsored by the U.S. Department of Energy as part of the Clinch River Breeder Reactor Plant component development.

The pump qualification testing reported herein were accomplished in accordance with the General Electric Test Plan #22A3551 by the staff of the Energy Technology Engineering Center under the direction of Mr. D. J. Zweng and Mr. T. Boardman during the period of May 1981 through October 1983. The consistent cooperation and professionalism applied by the staff at ETEC has made it possible to provide this comprehensive report on sodium testing of the CRBRP Prototype Pump.

The Byron Jackson Pump Division of the Borg Warner Corporation has provided the information contained herein on water test performance and sodium performance predictions pertaining to the CRBRP Prototype Pump.

Mr. H. Busboom and J. T. Cochran of General Electric have provided inputs regarding the testing of archive material samples for expansion coefficient variation behavior with temperature.

Mr. L. Manners, J. T. Cochran, L. J. Petrucha of General Electric, and T. Boardman of ETEC and F. Costanza of Byron Jackson have provided review and editorial inputs to this test report. (Editorial review of the report contents does not necessarily imply concurrence with all contents)

Mr. J. Grimaldi served as the Test Requestors representative at the Energy Technology Engineering Center for the pump sodium tests described herein.

Mr. A. G. Pard of Rockwell provided information on the post test inspections of the journals and bearings.

INTRODUCTION

The Clinch River Breeder Reactor Plant "Overall Plant Design Description", OPDD 10, Paragraph 6.2, requires an acceptance test program for first-of-a-kind principle design features, and per Paragraph 6.2.1.2B, requires a sodium test of the prototype pump at the Sodium Pump Test Facility.

The required test objectives include demonstration of mechanical and hydraulic stability through the full speed range, determining hydraulic characteristics at all speeds, demonstration of ability to withstand temperature gradients and fluid borne temperature transients, sensitivity to gaseous cellular convection, fluid level control, coastdown characteristics, ability of auxiliaries (seal lube system) to support sustained operation, and verification of drive system response.

Pump specification 22A3444 Paragraph 6.3.3 calls for prototype pump performance tests in sodium:

"The sodium testing shall be done at SPTF. The type of testing and required instrumentation is outlined in GE specification 22A3551, CRBRP Pump Sodium Test Request."

Development Requirements Specifications #51.28 defined the required qualification test program, and identifies the Test Articles as:

- o Prototype Sodium Pump
- o Pump Sodium Level Probes
- o Drive System and Auxiliaries Which Are Common to CRBRP
- o Flow Controller

This document reports the qualification tests mandated by the above requirements.

## 1.0.1

### Pump Description

A prototype of the pumps to be applied for the heat transport loops of the Clinch River Breeder Reactor Plant (CRBRP) has been tested in sodium at the Energy Technology Engineering Center (ETEC) under the sponsorship of the Department of Energy.

The pump is rated at 458 feet total head at 33,700 GPM with 995°F sodium as the pumped fluid. The equipment specification requires that the pumps to be used in the primary and intermediate heat transport loops were to be as identical as possible. Tanks were to be identical (except for nozzles). The primary tanks were rated at 30 psig for the gaseous region and 200 psig for the hydraulics, at 1015°F; the intermediate pump tanks were rated at 325 psig at 775°F. The hydraulic design is characterized as a free surface type, double suction, single stage centrifugal pump, with a three volute static hydraulic assembly. The inner structure is removable from the pump tank vertically. The pump is a side suction (36 inch nozzle) and side discharge (24 inch nozzle).

Figure 1.0.1.1 illustrates the pump assembly. The pump tank lower end is spherical in shape and includes the thirty six inch suction nozzle and the twenty four inch discharge nozzle centered on the equatorial plane at right angles to each other. The suction nozzle opens directly into the sphere which serves as the plenum for the impeller suction passages. The pump discharge is confined by a seal cone joint and is piped to the discharge nozzle where it leaves the pump tank. The lower spherical end of the pump is separated from the central conical section by a horizontal annular impedance baffle which controls the rate of liquid interchange between the lower and center sections of the pump during transient conditions. The length of the central conical section of the pump tank is set by system considerations which require a specified impeller submergence (minimum fluid level) and which define the maximum level to which the sodium can rise (maximum fluid level). The upper end of the pump tank is cylindrical in crosssection and includes the radiation and thermal shield region as well as the flange on which the pump internal assembly and its direct connected drive motor are supported.

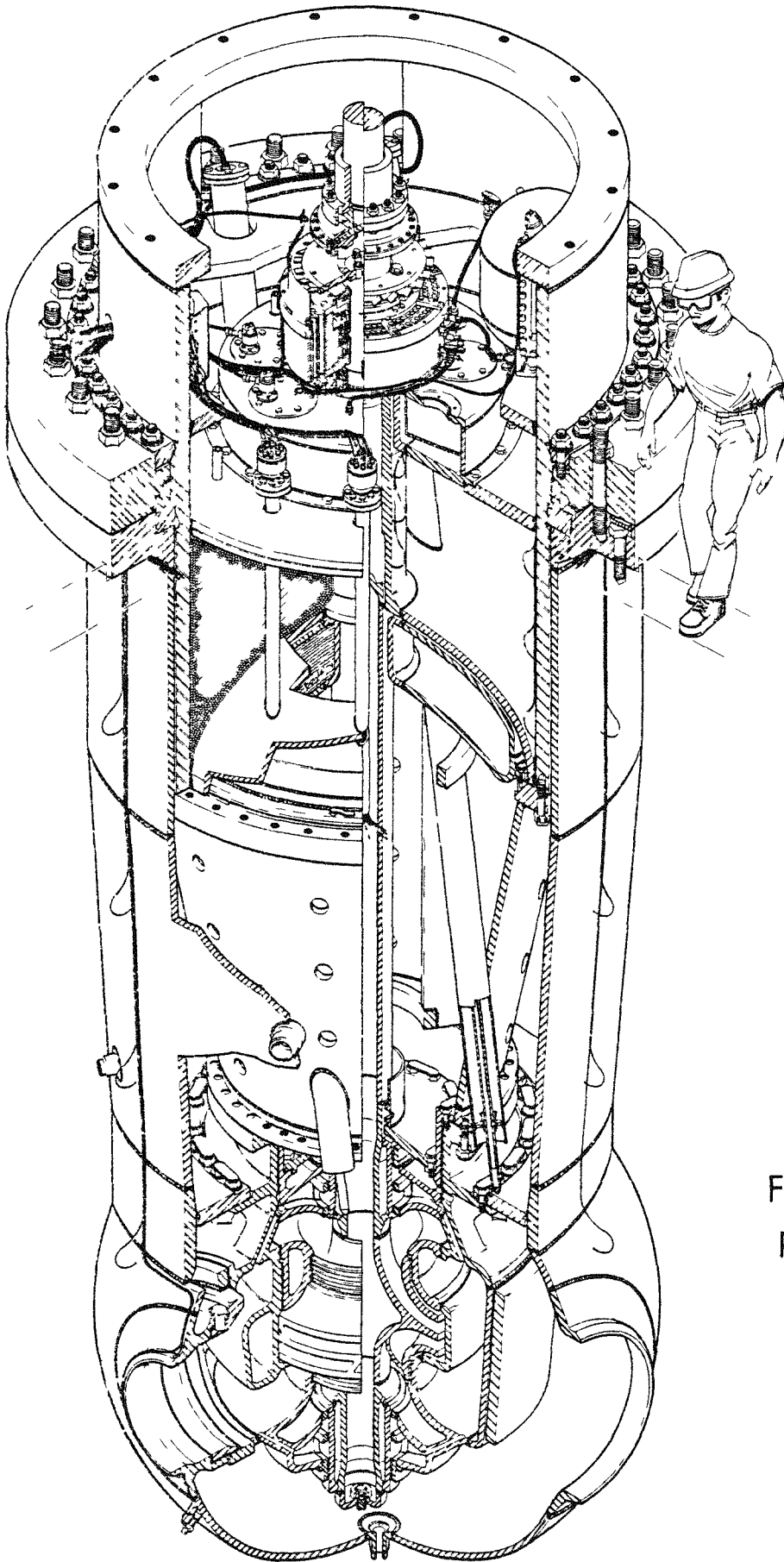
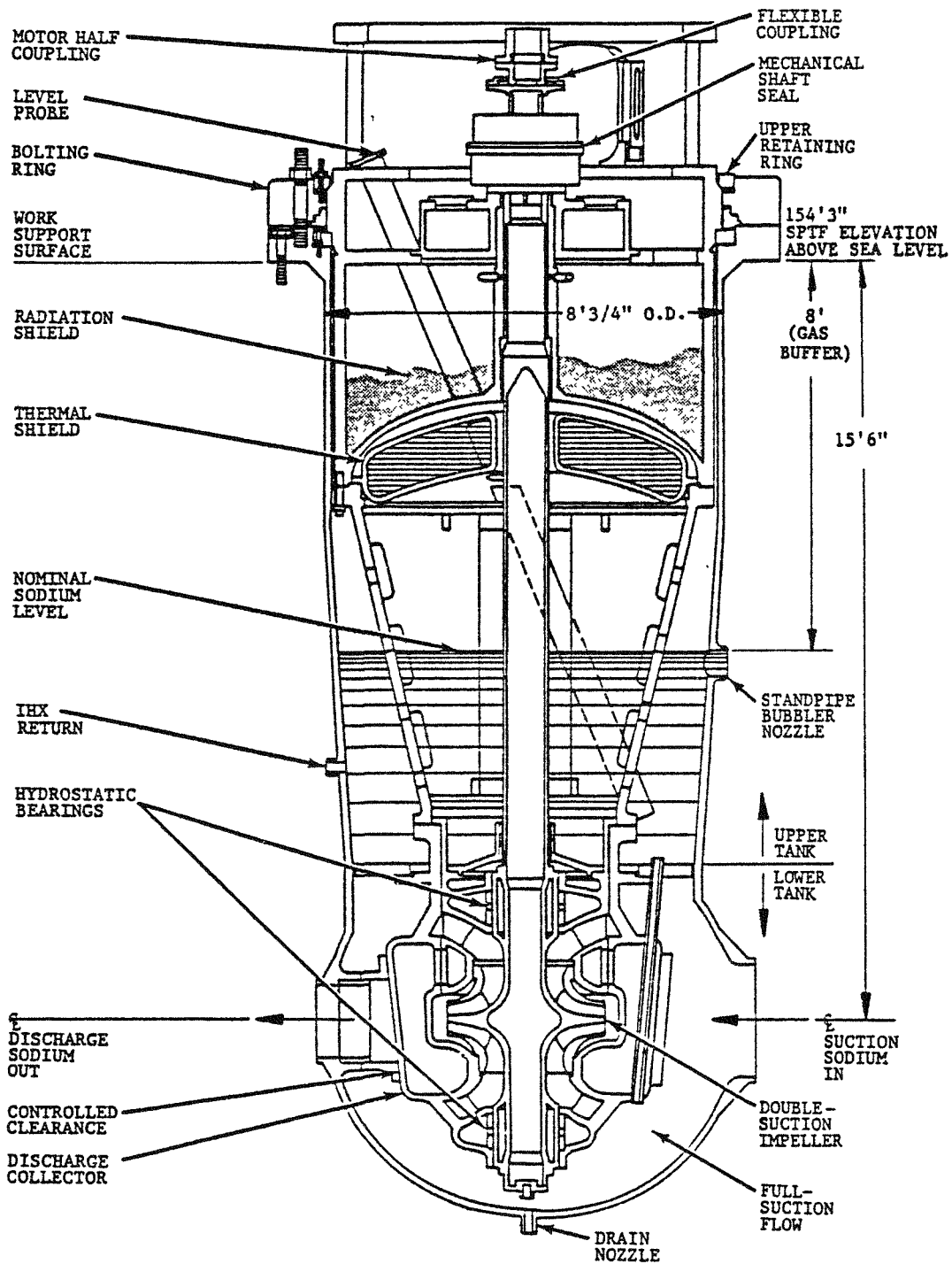


FIGURE 1.0.1.1  
PROTOTYPE PUMP



From:  
ER 1223

FIGURE 1.0.1.1A  
PROTOTYPE PUMP NOMENCLATURE

The pump rotating assembly consists of a seamless shaft welded to a double suction impeller straddle supported by two hydrostatic sodium bearings. Most of the shaft is hollow, evacuated and closed by seal welding. The entire pump operating range is below the first shaft critical speed. At its upper end, the shaft is coupled to the motor shaft by a diaphragm type coupling which acts as a pinned joint while transferring the weight of the pump shaft to the motor shaft and its thrust bearing. Removal of a spool piece containing the diaphragm coupling makes it possible to remove and replace the pump shaft seal cartridge without necessitating removal of the drive motor.

The Primary Pump Design is a modified version of a free surface pump which employs a standpipe bubbler as a means of limiting the rise of sodium in the pump tank to a lower level than would be reached if the pump tank cover gas were connected directly to the reactor cover gas space. In effect this constitutes an inverted manometer and when the sodium in the pump tank rises above the level of the stand pipe bubbler nozzle, the rising sodium cuts off the flow of purge gas from the tank, leading to a rise in pressure which will depress the sodium level in the pump and allow the gas to escape, thereby effectively pinning the sodium level at the standpipe bubbler nozzle elevation. An inert flow controlled purge gas is introduced into the upper part of the pump to provide the gas pressurization.

The pump tested at ETEC was the Primary Heat Transport System (PHTS) pump configuration, employing a standpipe bubbler, for Phases A & B of the test program. In the last part of the test program (Phase C), the pump internals were arranged in the IHTS pump configuration, with thermal shield removed and shot replaced with a thermal insulation. Insulation around the pump was similar to insulation of the Intermediate Heat Transport System (IHTS) pump, that is, no guard vessel was employed.

Since the plant PHTS pump is subjected to fluid borne transients which are different than the transients applied to the IHTS pumps, the pump designer, in order to provide the capability to withstand these differing transients, has provided the journals with fluid flow paths which contact/wash both sides of the cylinder which comprises the journal. The hole sizes of these flow paths are different for the PHTS and the IHTS pump configurations. In the prototype pump, the journal holes were drilled for the PHTS configuration.

The first of two rotating assemblies used in sodium test (SN171222) had an impeller trimmed to 37.5 inches, and the impeller material was SS316. The rotating assembly used for the last part of the tests was the unit originally used in water tests, (SN174848), with an impeller trimmed to 38.25 inches, and SS304 as the impeller material. The rotating assembly SN174848 with a 38.25 inch impeller provided a direct correlation between water tests and sodium test performance.

The configuration of the joint between the inner structure and the pump tank was different on the prototype as compared to the design planned for the plant pumps. In the prototype design a separate ring was provided in this joint which set the elevation of the inner structure, thereby establishing the radial gap at the hydraulics sealing cone. In the case of the plant pumps, this seal ring was made as an integral part of the upper-inner-structure.

The length of thread engagement for the studs at the joints between the hydraulic assembly and the lower inner structure, and between lower inner structure and the upper inner structure was different on the prototype pump as compared to the design planned for the plant pumps. In the prototype design it was determined after manufacture of parts that there was insufficient thread engagement to take the combined effects of the worst thermal transients and the safe shut down earthquake. The joints are adequately stiff to prevent loss of preload during thermal transient testing so there has been no loss of prototypicality unless an extremely severe earthquake were to occur at a time when a thermal transient is being performed.

The pump was designed and manufactured by the Byron Jackson Pump Division of the Borg Warner Corporation.

#### Pump Operation

The design and operating requirements of the pump are defined in the pump equipment specification GE Document #22A3444, which applied to the prototype, the PHTS, and the IHTS pumps. The equipment specification describes the code requirements, numerous analysis requirements and the fluid performance requirements, as well as the normal, upset, and faulted plant thermal transients.

At pony motor speed, which is changeable by gear replacement, the pump is required to provide approximately\* 7.5% of 33,700 gpm (2527 gpm) flow at 4.0 ft. of head and shut off head must be no more than 5.0 ft.

\*This requirement is stated in absolute terms in SDD51A and as approximate values in the pump equipment specification. The design is established by the full speed (main motor) R3 operating point, and performance at pony motor speed is not independently adjustable.

REQUIRED OPERATING RANGE - SHADED AREA

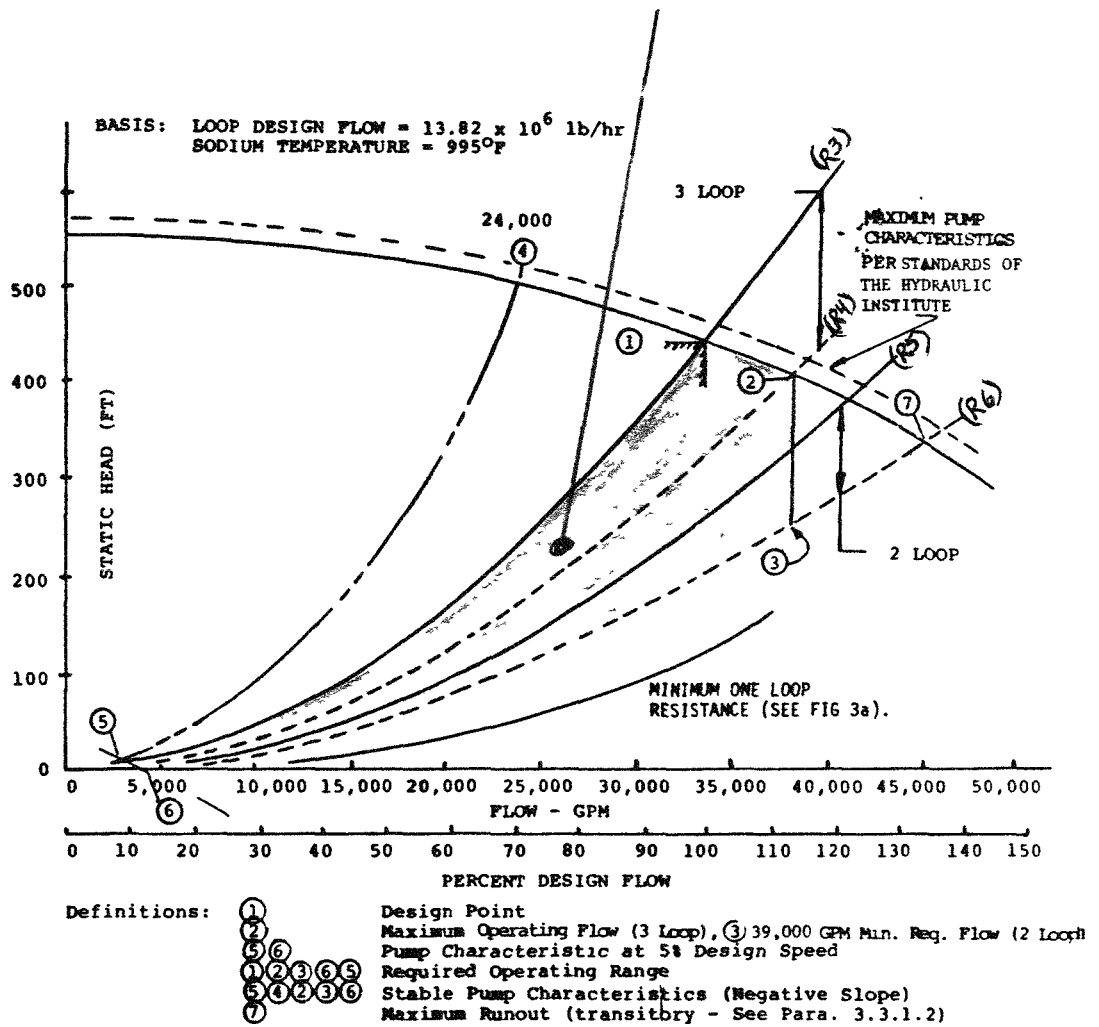


FIGURE 1.0.1.2  
PUMP HYDRAULIC OPERATING RANGE

Figure 1.0.1.2 (which is a reproduction of the equipment specification, Figure 3), shows the zone of operation required as the area bounded by circled numbers 1, 2, 3, 4, 5. Rated design point is circle 1 (458 ft. TDH at 33,700). The full speed region from circle 4 to circle 2 must have a negative slope.

#### ETEC Facility Differences

The Sodium Pump test Facility (SPTF) at ETEC had features which would differ from the plant installation, and are listed below for information:

- o The SPTF support structure was considerably more flexible than the support arrangement at CRBRP.
- o The tank external insulation approximated the IHTS pump insulation configuration) that is, no guard vessel such as used in the primary system building.
- o ETEC used an expansion tank to simulate reactor fluid elevation.

## 1.0.2

### Drive System Description

The Drive System consists of a Vertical Drive Motor rated at 5000 horsepower, 1116 RPM, 3941 volts, 3-phase, 56.3 Hertz squirrel-cage induction motor which is powered by a variable frequency Motor-Generator Set consisting of a 3970 KW Synchronous Generator, a hydraulic turbo coupling, and a 6000 horsepower, 1775 RPM, 3-phase, 60 Hertz, 13.2 KV squirrel-cage induction motor. A pony motor consisting of a vertical, geared, 60 cycle, squirrel-cage induction motor is mounted on top of the 5000 HP Vertical Drive Motor to provide low speed operation for starting and for plant decay heat removal.

Several panels are provided as a part of the Drive System. These are:

#### Instrument and Control Panel -

Provides instrumentation, protective and sequence relaying, annunciation, operating control and voltage regulation.

#### Speed Regulation Panel -

Speed regulator circuitry associated with the turbo coupler scoop tube position servo is in the SRP panel.

#### Motor Control Center -

This panel contains the starters.

#### Plant Protection System Breakers

These breakers are connected between the M-G Set generator and the Vertical Drive Motor.

Lubrication for the MG Set is provided by a redundant oil to water heat-exchanger, with pumps and associated valves. These heat exchangers were prototypical.

Drive equipment provided for the prototype pump test differed from that provided as plant equipment in the lube system heat exchanger for the Vertical Drive Motor. Plant VDM heat exchangers are oil to air whereas the arrangement for the prototype pump sodium test was an oil to water heat exchanger.

The Drive System, with the exception of the VDM lube system heat exchanger was a test article with performance being evaluated as a part of this test program.

The Motor Generator Set as positioned for factory test is shown in Figure 1.0.2.1, and the Vertical Drive Motor positioned above the pump at the Byron Jackson Water Test facility is shown in Figure 1.0.2.2.



Figure 1.0.2.1 Sodium Pump Drive System Equipment Being Checked Out At GE Factory

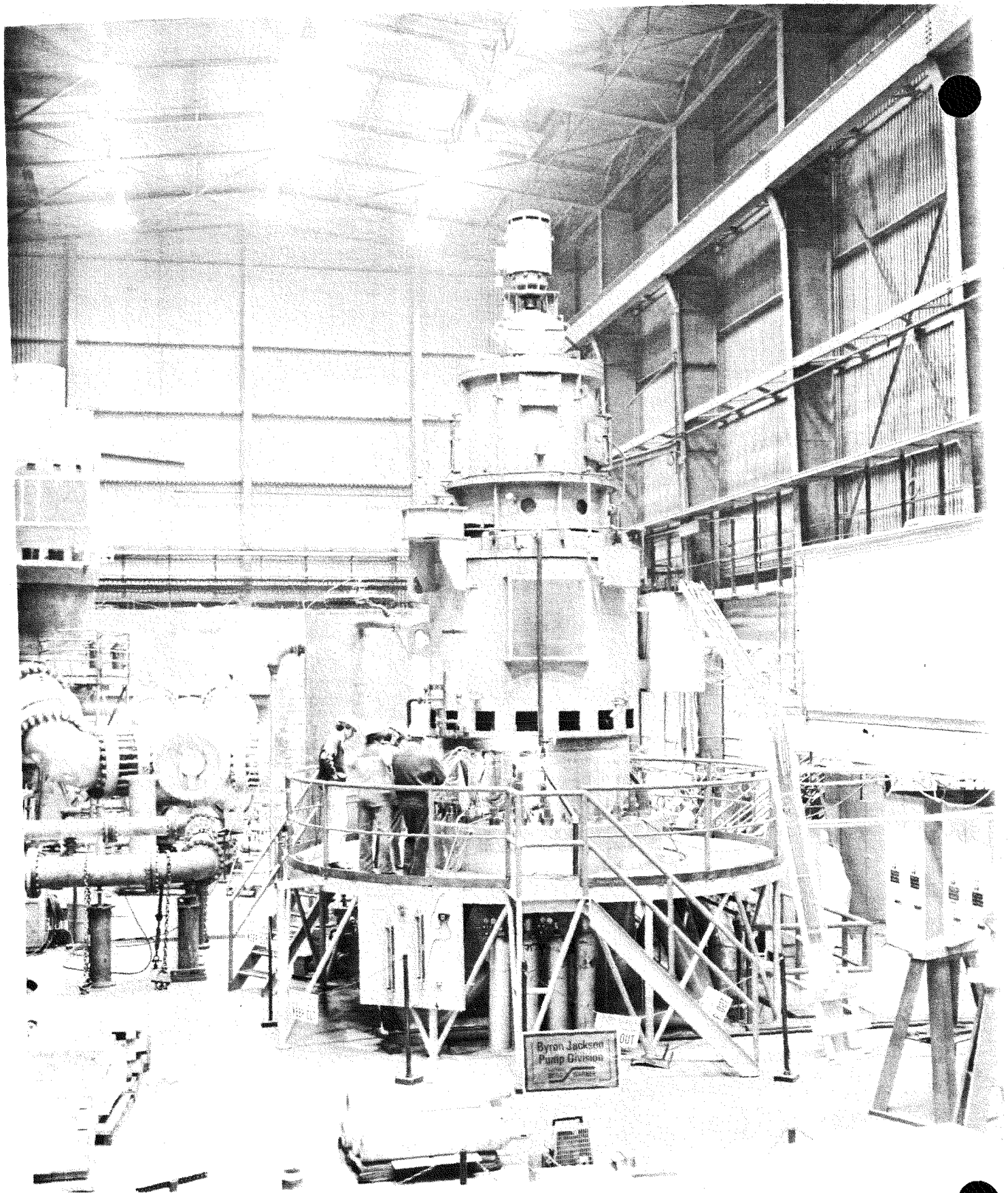


Figure 1.0.2.2 Prototype Sodium Pump Drive Motor At Byron Jackson

### 1.0.3

#### Flow Controller Description

The flow controller is a proportional and integral control system with sodium flow from a permanent magnet (PM) flowmeter as the feedback variable, and pump speed demand as the output variable. The equipment has an operator interface module which is cabled to the two bays (or panels) of the controller cabinet. The equipment is operable in automatic (with PM flowmeter feedback) or in a manual mode. The system has bumpless transfer features. The flow controller was provided by the Westinghouse Industry Electronics Division.

### 1.0.4

#### Conclusions

The test program reported herein supports the following conclusions:

1. The sodium and water test data with the same impeller provides a basis for establishing trim of the plant pump impellers.
2. The pump has been shown to operate free of cavitation over the specified operating range except at the two loop minimum impedance - maximum flow point where head loss was determined to be 4%, (requiring 52 feet NPSH to meet Hydraulic Standards for NPSH).
3. Thermal transients up to the maximum capability of the Sodium Pump Test Facility did not degrade pump performance.
4. A sustained endurance run at design speed, flow, and temperature has qualified the pump thermal design and the shaft seal thermal design for plant service.
5. The pump, as modified with baffling on the Upper Inner Structure, has been proven to be suitable for the pressurized environment of the IHTS system; i.e. cellular convection will not cause deleterious effect on pump operation.
6. Software and hardware adequacy for assembly and disassembly was demonstrated twice.
7. The servo response of the drive system when loaded with the pump and pump fluid test loop (simulating the plant hydraulic loop) has been proven to meet specified requirements excepting speed stability at 725 RPM, a variation which is correctable with turbo-coupler modification.

It is concluded that the pump and drive designs have been qualified for use in the Clinch River Breeder Reactor Plant.

1.0.5

Summary of Test Results

- o Data were taken which provides a direct comparison between water test results and performance in sodium using the same rotating assembly. When operating at 1116 RPM at the 3 loop maximum impedance (R3), (and with water test data adjusted for an 11 mil inner structure to tank gap), results are:

WATER		600°F SODIUM		1005°F SODIUM	
H(ft)	Q(gpm)	H	Q	H	Q
485	33,700	484	33,700	489	33,700

The above data were achieved with the 38.25 inch impeller.

- o The pump performance with the 37.5 inch impeller in sodium (1116 rpm, R3, & 11 mil gap and 600°F sodium) was 443.6 ft. head at 33,301 gpm as compared to the pump supplier prediction of 470 ft. of head at 34,200 gpm. (440 ft. realized versus 474.6 predicted if both heads are adjusted to a flow of 33,700 gpm).
- o A decision as to impeller diameters for plant pumps, to be rendered after this document is published, will determine whether or not there is need to change gears to meet the 5.0 ft. shut off head.
- o There is a hook in the H/Q curve at pony motor speed which is not in the normal operating range (between R2 and cut-off). See Figure 2.1.3. On main motor, there was no hook in the H/Q performance in the operating range.
- o For the 37.5 inch impeller, at the operating point of 39,100 gpm and the plant, 2 loop minimum impedance R6 ( $.171 \times 10^{-6}$  ft./gpm<sup>2</sup>) there was evidence of cavitation. The head loss with 45 ft. NPSH was 6%; the loss with 49 ft NPSH was 4%. (Forty-nine feet NPSH is available at the plant for 39,100 gpm operation).

- o For the 38.25 inch impeller, at the two loop minimum impedance ( $R_6 = .171 \times 10^{-6}$  ft/gpm<sup>2</sup>) operating point of 39,100 gpm, an NPSH of 57 feet is required\*, whereas only 49.2 ft. is available at the plant. Test segment C11 determined that if the plant 2 loop minimum impedance is  $0.200 \times 10^{-6}$  ft. gpm<sup>2</sup> or higher, there will be no cavitation at the 39,100 gpm sodium flow rate. (The resistance is between the maximum and minimum two loop impedance).
- o Cellular convection is not a problem at the planned PHTS loop cover gas pressure, however, for IHTS gas pressures (93 psig planned), it is necessary to install baffling and filler plates between the upper-inner-structure and the tank wall to reduce across-the-tank temperature differences and associated bending to an acceptable level.
- o The pump shaft seal experienced a damaged bumper stop and damaged screw pump, caused by a combination of tank bending and loss of cover gas pressure to the oil supply tank during cellular convection testing. When the incident occurred, about 40% of the loss of clearance (8 out of 20 mils available) at the seal was attributable to tank bending. Although the seal bumper stop was damaged, the shaft seal continued performing its sealing function for 3 months of additional testing.
- o The pump bubbler level control is satisfactory.
- o Pump thermal design (thermal shield) results in a temperature distribution which is satisfactory for the pump to plant interface.
- o Pump dynamics resulted in satisfactory vibration conditions.
- o Inertia of pump and motor shafts resulted in coastdown data which meets requirements of the CRBRP System (SDD51A).
- o The pump has successfully withstood all fluid borne thermal transients required by the test program.
- o The drive speed control servo, with the pump hydraulic load, meets performance requirements for frequency response, response to step commands, and ramp response tests. The random speed variation was not met at 725 RPM. This is correctable by modification of the Voith fluid coupler, but the modification was not installed and verified in this test.
- o The flow control servo system, with the drive and pump hydraulic load was tested and the overall system response to sinusoids, step functions and ramp functions was measured and recorded.

\*The two impellers operate at different speeds to achieve 39,100 gpm at R6. The larger impeller (38.25" diameter) requires 958 RPM to achieve 39,100 gpm at R6, the smaller impeller required 1002 RPM. Testing for NPSH required, then, was accomplished at two different speeds.

- o All anomalies occurring in this test program were identified and the corrective actions taken at ETEC, and those proposed for application at the plant are defined in the appendix.

See paragraph 3.0 for a summary of the detailed objectives and how the pump meets those objectives.

#### 1.0.6

##### Test Report Arrangement

This is a comprehensive report of the testing of the CRBRP Sodium Pump, Pump Drive, and Flow Controller at the Energy Technology Engineering Center. All segments of the program are reported, however, the segments covering one subject are combined in this report, and they are sequenced in an assumed order of interest to the plant system and component designers, rather than in the chronological order of performance.

If detail beyond that described in this report is required, the ETEC segment reports are listed in the appendix.

SODIUM TEST PLANNING

Planning for sodium testing of the Clinch River Breeder Reactor Plant (CRBRP) pump involved preparation of test definition documents, and coordinating planning definition with both Westinghouse Oak Ridge (W-OR) and the Energy Technology Engineering Center (ETEC). The controlling document for the test program was the Development Requirement Specification (DRS #51.28), which is a document defining the formal objectives of the evaluation program and a listing of the planned tests, with an abstract description of each test segment. The next level of planning documentation was a test plan identified as Test Request #22A3551 written in more detail than the DRS, and subordinate to the DRS. The Test Request was issued as a specification, and was used by ETEC as a basic working document, along with Installation, Operations and Maintenance (IOM) Manuals, Interface Control Drawings, and facility operating instructions in the preparation of the detailed procedures used by the test conductor and the test operators.

The Sodium Pump Test Facility (SPTF) at ETEC required modification to accommodate the increased flow rate (to 39,100 gpm) over the previous capability (20,000 gpm). ETEC accomplished this by adding a "high flow loop" (HFL) in parallel with the older "Main Flow Loop" (MFL). The arrangement required that all thermal transient tests be run using the MFL, since valving in the HFL was not designed to withstand the thermal stress of the planned fluid borne thermal transients. Use of only the MFL for transient testing posed no problem, since the flow capacity was higher than needed for all CRBRP transients. The use of parallel flow paths during nontransient testing required addition of the measured flow from each path to obtain the total pump flow. This was done routinely by the facility computer. The MFL could not be completely closed due to the design clearance in the butterfly valves of that loop. In this program the facility capability improvement was being developed in parallel with the evolution of the prototype pump design, with the pump changes impacting the SPTF design. To expedite information interchange ETEC prepared the test pump to SPTF Interface Control Drawings (ICD's), using General Electric Engineering Change Proposals (ECP's), rather than waiting for the finalized change notice information. While this approach risked impacting the SPTF material/construction due to redesign changes of the test article, it proved to be more efficient than waiting for change proposals to be processed through all of the CRBRP major contractors.

Planning for the implementation of the test program was accomplished with a document titled "Test Coordination Plan", which defined, in advance of the arrival of hardware, the intended approach to control of the test, dispositioning of anomalies, etc. The purpose of the document was to achieve agreement between the several parties as to how to handle "off normal" situations, as well as the routines of test release, data review, etc., before the program was underway.

1.1.1 Development Requirements Specification #51.28

DRS #51.28, subject to CRBRP Project Office approval and change control, defined the equipment to be tested, the formal test objectives, and provided an outline of the test program. The test philosophy selected was to subject the pump to tests of progressive severity, so that in the event of failure, the threshold of failure would be known.

Test Articles were:

- Sodium Pump
- MG Set and Auxiliaries
- Vertical Drive Motor
- Flow Controller\*
- Pump Handling Equipment
- Other\*\*

The DRS contained the following:

- Objective of the test program
- Assumptions, Limitations, & Special Factors
- Identification of Test Article and Supporting Equipment
- Abstract of Each Test Segment
- Reporting and Quality Requirements

\* Supplied by Westinghouse Industry Electronics Division

\*\* Permanent Magnet Flowmeters for the Clinch River Plant were a part of the test loop, however, test evaluation of the item was defined by a separate DRS.

The formal test objectives were defined as follows:

1. Demonstrate that the pump is mechanically and hydraulically stable when operated through its full design speed and flow range and verify hydrostatic bearing performance in the sodium environment.
2. Determine pump hydraulic characteristics (head-flow map and efficiency) in sodium.
3. Demonstrate that high-temperature, and the associated structural temperature gradients do not degrade mechanical operation or hydraulic performance.
4. Demonstrate that pump and pump auxiliaries are capable of sustained operation while pumping liquid sodium at variable flows and speeds.
5. Demonstrate pump pony motor operation; verify hydrostatic bearing performance in sodium at pony motor speed, demonstrate pony motor developed head at near shut-off, measure head/flow characteristics at different pony motor speeds and different hydraulic loop impedances.
6. Determine any deleterious structural distortion caused by convection in the gas space.
7. Demonstrate ability of the pump to withstand sodium fluid temperature transients which simulate predicted plant operating and upset transients (up to the limits of the test facility capability).

1.1.1 Continued

8. Demonstrate capability of the standpipe-bubbler to maintain adequate sodium level in the pump during steady-state and operating (speed and flow) transients.
9. Verify the pump drive response characteristics with the pump operating in sodium with loop impedance simulating the plant.
10. Demonstrate flow coastdown characteristics (head, flow, speed) from maximum facility flow and from pony motor speed and correlate to similar measurements made in water tests. Determine pump and motor compliance with rotating kinetic energy requirements per E-Specification 22A3444 Table 3.3.1.
11. Measure compliance with NPSH requirements.
12. Verify applicable IOM Manual procedures for checkout of assembly, operation, disassembly, maintenance, and inspection of pump and auxiliaries.
13. Demonstrate the CRBRP prototype flow controller operation with the drive system and the CRBR PM flowmeter. (Operating closed loop in the flow control mode).
14. Verify that established rate of dry pump preheat is satisfactory (as indicated by tank and internal temperature gradients).
15. Determine hydraulic impedance of the pump to low magnitude forward flow of sodium through the pump rotor.
16. Confirm performance of the shaft seal regarding leak rates.
17. Verify suitability of the pump for subsequent use in sodium after CHCF cleaning operations.
18. Evaluate whether sodium migration upward, or oil migration downward is a concern with the purge gas feed, labyrinth, and shaft seal arrangement.
19. Determine whether gas injection at the IHX return nozzle causes adverse effects on pump sodium level stability or if slug pumping occurs at the bubbler; and to measure sodium carryover from the bubbler to the gas system.

The most important part of the test program was the fluid thermal transient tests and the servo control testing related to speed response and flow control response (Segments B7, transients, and B6 servo control test).

### 1.1.1 Continued

The susceptibility to failure of instrumentation, where temperatures reach 1000°F, with sensors in sodium, dictated the "progressive severity" approach, because it was feared that the in-sodium bearing gap sensors would likely fail as temperatures exceeded 800°F. Thus, as much testing as possible was completed below 800°F before proceeding to the more severe environments.

The configuration of the journal "fluid wash" holes also restricted the transient test program to be primarily down transients. The most severe PHTS up transient is PP4U, with a delta T of +250°F which was applied to the pump. A more severe up transient, IP3U of +350°F was not applied because the journal holes were not optimized for the IHTS type transients. The test program called for applying as severe a down transient as the test facility was capable of applying, in this case, transient PPIIU, a -500°F transient. There were some restrictions on the test program dictated by test facility capabilities:

- ° The facility could not apply transients of two polarities back to back without a lengthy delay to change the sodium supply tank temperature, thus some transients in the equipment specification could not be applied in total.

(Because thermal transit time through all pump parts is longer than the reversal time of the plant transients, it is believed that a "back to back" capability at the test facility would not have been advantageous. A reversing transient is likely to be less severe than a large high rate unidirectional transient).

- ° The main flow loop alone exceeded the hydraulic impedance identified as the CRRP 3-loop maximum impedance. ( $R3 = 0.40 \times 10^{-6}$  ft/gpm<sup>2</sup>), therefore transient testing was run at an impedance slightly higher and a flow of 2680 gpm. (6% higher than plant nominal pony motor design flow rate). Initially ETEC indicated that they might not be able to control the transient at 2680 gpm, however, addition of a valve controller on the butterfly valve between the mixing and the draining "T's" provided adequate control.

### 1.1.1 Continued

(A transient was considered to be adequately controlled if the applied rate was within  $\pm 30\%$  of the rate specified in the test plan for a period of at least 60% of the total temperature change. Early in the program, it appeared that fluid thermal transients would have to be tested at a special head/flow condition requiring a special gear, but the addition of the valve controller between the mix and drain Tee's resulted in a recirculation ratio favorable to control the applied transient per the above definition. Successful programming of the feed valve and the recirculation valve and avoided costly transient thermal analyses.)

- ° The severity of thermal transient was judged primarily on the basis of total temperature change, and only secondarily on the basis of the rate of change because the former tends to cause distortion of the pump structure, while the effects of high rates of change is primarily to cause high surface stresses which do not cause distortion until a sufficient fraction of the total thickness is affected.
- ° Transients used in the test program were defined by defining an equivalent linear span and rate of change for each of the transients for which curves were published in the E-Specification 22A3444. A master list of these transients, arranged in progressive order of severity was used to arrive at the final transients tested in test segments A16, B2, and B7.
- ° The test facility could apply transients of  $+400^{\circ}\text{F}$  and  $-500^{\circ}\text{F}$ , but could not apply transients as severe as predicted per the pump equipment specification (IP6E is  $+700^{\circ}\text{F}$ ).

(For transients beyond the test facility design capability, qualification is by analysis)

Tests to be run were categorized as those below  $800^{\circ}\text{F}$ , (Phase A), those where temperature were taken to as high as  $1100^{\circ}\text{F}$  (Phase B), and tests to evaluate a cellular convection design fix and performance with the water test impeller (Phase C).

Phase A & B were run with rotating assembly Serial #171222 trimmed to 37.5 inches impeller diameter. Phase C was run with the rotating assembly Serial #174848, used in water tests, with the impeller trimmed to 38.25 inches. Coastdown tests were run when test conditions and operational plans permitted, although the coastdown test segment was formally identified as a Phase B segment.

#### Phase A Activities:

1. Receiving and installations
2. Pump Assembly and Mating to tank
3. Drive System Checkout
4. Preheat and fill
5. Initial runs & Mapping Practice
6. Low temperature gas convection checks
7. Baseline Mapping
8. Low temperature NPSH testing
9. Rotor Impedance Measurement
10. Low Temperature Thermal Transients
11. Baseline Recheck

#### Phase B Activities

1. High Temperature Gas Convection Check
2. Mild Thermal Transients
3. First run to rated temperature of 1000°F
4. IHX Gas Injection Test
5. High Temperature Rotor Impedance Measurement
6. Short Term Endurance Run
7. Drive & Flow Controller Servo Response
8. Severe Thermal Transients
9. Baseline Recheck
10. High Temperature NPSH Test
11. Coastdowns
12. Endurance Run
13. PPIF Transient (to 1100°F)
14. Shaft Seal Replacement Demonstration
15. Disassembly & Inspections

#### Phase C Activities

1. Pump reassembly with convection baffles, IHTS internal insulation, and with the rotating assembly which was used in water test.
2. Mating Innerstructure to Tank
3. Drive Installation & Checkout
4. Preheat & Fill
5. Initial Motor Runs (Drive Checkout)
6. Performance Mapping at 600°F
7. Cellular Convection Testing at 650°F
8. Performance Mapping at 1000°F
9. Cavitation check at 39,100 gpm (maximum plant flow rate)
10. Disassembly & Inspections

See Appendix A for listing of test Segment numbers, title, and the ETEC Segment Report number.

### 1.1.2 Test Request Document 22A3551

The purpose of the Test Request was to communicate to the testing agency (ETEC) the overall plan and requirements to evaluate the sodium pump, and to provide performance predictions and criteria. The Test Request is written at an expanded level of detail (as compared to the DRS), from which ETEC, using IOM Manuals, ICD's, and facility instructions, prepared the procedures used to assemble and to test the test articles. The Test Request was subordinate to the DRS.

The Test Request was laid out to define the chronology of the test program, in "segments". For each segment, the following was defined:

- An abstract of the scope of the segment
- The objective of the segment
- Prerequisites and assumptions
- IOM Manual references
- Instrumentation of most importance to this segment
- Required tasks
- Data requirements and objective evidence
- Completion criteria

The appendix of the Test Request was used to identify the following:

- Tabulations of sensors  
(Test article and loop sensors pertinent to test article performance)
- Guidelines for "Quick Look" Reports and final "Segment" Reports
- Reference information
  - Handling tools
  - Interface control drawings
- Requirements
  - Coastdown
  - Instrument accuracies
  - Operating alarms
  - Restrictive operating limits
  - Reporting requirements
  - Insulation, heaters
  - Nozzle loading
  - Expansion tank requirements
  - Heating
  - Unusual occurrence reporting
  - Hold points

- ° Performance Prediction/Criteria
  - Pump head & flow
  - Motor losses
  - Performance criteria
- ° Assembly and Test Flow Logic

### 1.1.3 ETEC Procedures

EETEC prepared the detailed procedures used during assembly and test. They were based on the Test Request, IOM Manuals, ICD's, and SPTF facility equipment instructions. These test segment procedures were prepared in two parts - part 1 being a specification; Part 2 being the step by step details. Part 1 was submitted to the Test Requestor for approval, part 2 was submitted for information only.

### 1.1.4 EETEC Data Acquisition System (DAS)

There were about 670 data sensors in the SPTF loop, including about 250 associated with Test Articles. Except for vibration data, all channels were digitized and recorded at a preselected sample rate. For the test article channels, the sample rate was specified by the test requestor. The alarm system was separated from the data acquisition system.

Recording was accomplished on both disk and on magnetic tape. On the disks, all 670 channels were recorded at two rates - 1 sample per second (with 4 hours storage capability) and at 1 sample every 10 minutes. The fast rate was used for immediate post test playback of events occurring over a short period of time; the low rate was used for locating data of interest (with respect to time), and for post test playback of events occurring over larger time periods.

A magnetic tape was constantly being used to record data at a sample rate which is established (and subject to change for the various test segments) by the test Cog. Engineer. A tape is capable of handling 10,000 full frames (each "frame" or "slice" is 670 channels). If recording rate is at 1 sample/second then a tape is good for about 3 hours. Many reels of tape were therefore generated on this test program. These are to be maintained in storage at EETEC for a period of seven years.

Selected vibration data goes onto FM tape recorders separate from the digitized system.

The ETEC cognizant engineer has available a keyboard link to the DAS computer which permits commanding one or several data channels be displayed on an X-Y plot and a CRT display. It is possible to select any time increment up to 3 weeks in the past (one disk storage capacity has 3 weeks of data - all 670 channels - recorded at 1 scan every 10 minutes. A second disk storage has 4 hours of stored data which was recorded at 1 scan per second) specify the scale of the horizontal axis (time), specify the vertical scale, and call for 1 to 6 specific data channels to be plotted on one Figure on "X-Y" plot. At the conclusion of any particular test, the DAS computer may be commanded to produce numerous X-Y plots, so that within twenty minutes of the end of a test, the channels of interest to that test are available for review. (This is "raw" data, not corrected for calibration or zero shift.)

The data digitizing/storage/playback equipment were adequate for this test program.

In the early part of the test program, there was concern regarding the accuracy of the head and flow measurements, resulting from a flow measurement at full speed which was about 10% low, or conversely, a head measurement which was about 7% below the pump suppliers prediction. (Prediction of 470 feet at 34,200 gpm versus 444 feet realized at 33,300 with 600°F sodium. This would be 440 ft. achieved versus 474.6 ft. predicted when adjusted to a flow of 33,700 gpm).

The speed measurement was checked by independent means and found to be dependable. Reviews of calibration methods were conducted regarding power, head, and flow. The power measurement was found to be in error; however, data recorded on the digital tapes could be corrected by mathematical methods, and the correction is included in the reported data.

An action plan was generated (XL-593-20557 dated October 1, 1982) to require comparison of the prototypicality of the SPTF Venturi set up with respect to the set up when that Venturi was calibrated in water. The concern was that ETEC had two 90° pipe bends upstream on the HFL loop, and only two pressure taps are brought out of the Venturi throat rather than the usual 4 to 6 taps to a common Piezometer ring.

ETEC checked the HFL flow meter against the MFL flowmeter by using the pump as a reference source. At a flow of 15,000 gpm in the MFL, the pump speed and developed differential pressure were recorded. The flow was then transferred almost entirely to the HFL and the flow sum (HFL + MFL leakage) compared to the previous flow sum (MFL + HFL leakage) at the same pump speed and differential pressure. The conclusion was that flow as measured in the HFL (low range) compared favorably with the MFL

flow readings. The MFL flow measurements had been reconciled with other water test measurements on a previous test program (FFTF).

Flow measurements were also checked with a neutron source, in which transit time of an activated wedge of sodium was measured and flow rate then calculated based on pipe size and measured transit time from the neutron source to the pick up sensor. This checked the Venturi of the HFL to be within 1½% of the neutron/transit time measurement method.

The head measurement was checked at ETEC using different instruments and different sensing points. The conclusion was that the head measurement and calibration technique was demonstrated to be adequate.

It was GE's technical judgement as a result of these investigations that the ETEC instrumentation is probably within the accuracies claimed by ETEC: Head to within 1%; and Flow to 2%; Speed to within 0.2 RPM. Details of instrumentation investigations are available in additional detail in references 1 through 5 of Appendix E.

## 2.0

### Sodium Test Results

Test results are summarized by the following categories:

1. Pump performance on pony motor at 600°F and 1000°F (37.5" diameter impeller SN 171222, and 38.25" diameter impeller SN 174848)
2. Pump performance on main motor at 600°F and 1000°F with both impellers
3. Fluid thermal transient applications
4. Cellular convection tests (prior to and after a design fix)
5. NPSH and cavitation testing
6. Drive and flow controller servo testing
7. Miscellaneous tests
8. Installation, assembly/disassembly and readiness tasks
9. Summary of performance against objectives, criteria and predictions

If detail beyond that presented in this report is required, then reference should be made to the ETEC issued Segment Reports listed in the Appendix or to correspondence covering Data Review Meetings.

## 2.1 Pump Performance on Pony Motor

Pump hydraulic performance on pony motor was checked by varying loop hydraulic resistance (via valving of the main flow loop) and recording head versus flow for that one speed. Speeds (via gear changes) used in sodium were 103.9 RPM and 81.6 RPM. Data was taken in the following test segments:

- o With the 37.5 inch impeller (rotating assembly #171222):
  - A13B - Initial baseline pony motor mapping at 103.9 and 81.6 RPM, R8 to shutoff @ 600°F
  - A17 - A one point H/Q measurement at 103.9 RPM and R3 impedance. (A17 followed Thermal Transient Test A16)
  - B3A - H/Q measurements at 103.9 and 81.6 RPM, R8 to shutoff, at 1005°F. (B3A followed Thermal Transient Test B2)
  - B8 - One point H/Q measurement 103.9 RPM and R3 at 600°F and 1005°F. (B8 followed Severe Thermal Transient Test B7)
  - B14 - H/Q measurement at at 103.9 RPM, R8 to shutoff, at 1005°F and 600°F. (B14 followed the endurance run Segment B13. The 600°F part was run after B14A, the PP1F transient)
- c With the 38.25 inch impeller (rotating assembly #174848):
  - C8 - H/Q measurements at 103.9 RPM, R8 to shutoff at 600°F (this is the initial baseline H/Q test with the water test rotating assembly)
  - C10 - H/Q measurements at 103.9 RPM, R8 to shutoff at 1005°F. (This is the baseline H/Q test with the water test rotating assembly at 1005°)

The purpose of this series of tests was to define shut off head, to measure developed head and flow relationship at several hydraulic impedances, for two (gear controlled) speeds at both 600°F and 1005°F sodium temperatures.

The criteria to be met (22A3444, Table 3.3.1 and Paragraph 3.3.1.3) is that shutoff head shall be less than 5.0 feet. If impeller trim does not yield less than 5 ft. of head at pony motor speed, the requirement may be met by a reduction in pony motor speed (gear change). Also, at pony motor speed the pump is required to provide approximately 7.5% flow (2527 gpm) at 4 feet of head.

Results are shown in the following Figures and Table. The pump meets performance requirements at pony motor speed with the understanding that shut off head can be kept below 5 feet via a gear change.

TABLE 2.1.1  
Pony Motor Shut Off Head (Feet)

Test Segment	600°F		1005°F	
	103.9RPM	81.6RPM	103.9RPM	81.6RPM
37.5 Inch Impeller:				
A13B	4.63	2.94	--	--
A17	--	--	--	--
B3A	--	--	4.87	2.92
B8	--	--	--	--
B14	4.92	--	5.00	--
38.25 Inch Impeller:*				
C8	5.04	--	--	--
C10	--	--	5.15	--

Table 2.1.2  
 Pump Pony Motor  
 Performance at R3\*\*  
 (Head in feet, Q in GPM)

Test Segment	600°F				1005°F			
	103.9RPM		81.6RPM		103.9RPM		81.6RPM	
37.5" Impeller: H	Q	H	Q	H	Q	H	Q	
SN 171222								
A13B	3.90	3136	2.37	2440	--	--	--	--
A17	3.95	3050	--	--	--	--	--	--
B3A	--	--	--	--	3.95	3150	2.4	2495
B8	4.09	3205	---	--	4.15	3284	--	--
B14	4.06	3194	--	--	4.15	3190	--	--
38.25" Impeller:								
SN 174848								
C8	4.15	3250	--	--	--	--	--	--
C10	--	--	--	--	4.30	3300	--	--

\* This impeller was oversized for the specified design point and a speed (gear) change may be employed to meet the shut off head requirements.

\*\* R3 is the 3 loop maximum hydraulic impedance =  $0.40 \times 10^{-6} \text{ft/gpm}^2$

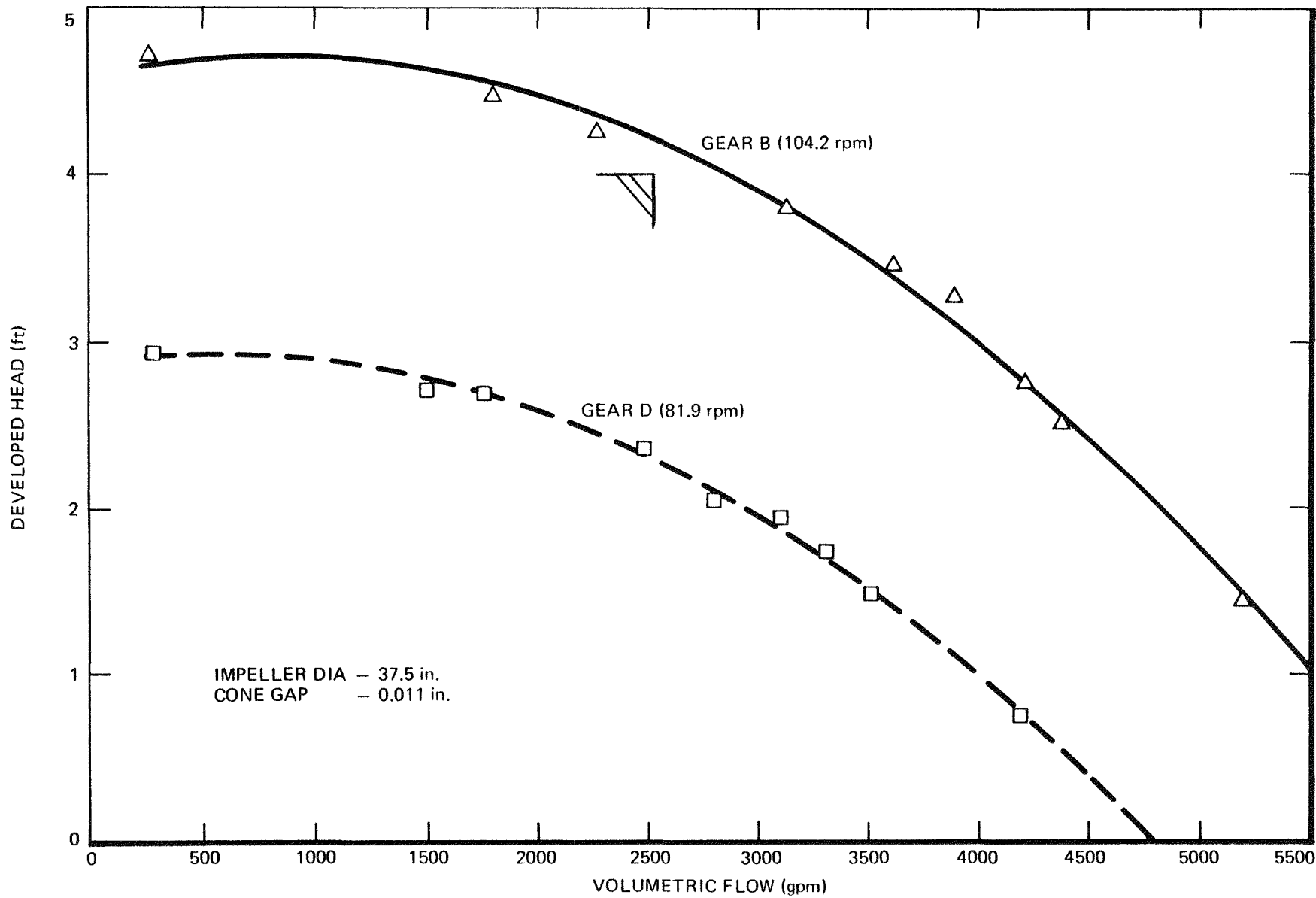
Pony motor performance plots are shown in the following figures:

- o Figure 2.1.1: The 37.5" impeller at 600°F, with gear B (104 RPM) and gear D (81.9 RPM)
- o Figure 2.1.2: The 37.5" impeller at both 600°F and 1000°F with both gears
- o Figure 2.1.3: The 38.5" impeller at 1005°F with gear B.

ETEC found that it took sixty four man hours applied during two working day periods to change a pony motor gear.

In Figure 2.1.3, sufficient data points were plotted in the flow region between 2000 gpm and cut-off to confirm that there is a "hook" in the curve. The same "hook" is probably present on the 37.5 inch impeller also, but insufficient data points were taken to prove its existence. This hook, or region of positive slope is outside the specified pump operating range and is not detrimental to the pump.

30



FROM: 83ETEC-DRF-1971 SEGMENT REPORT A13B

83-413-01



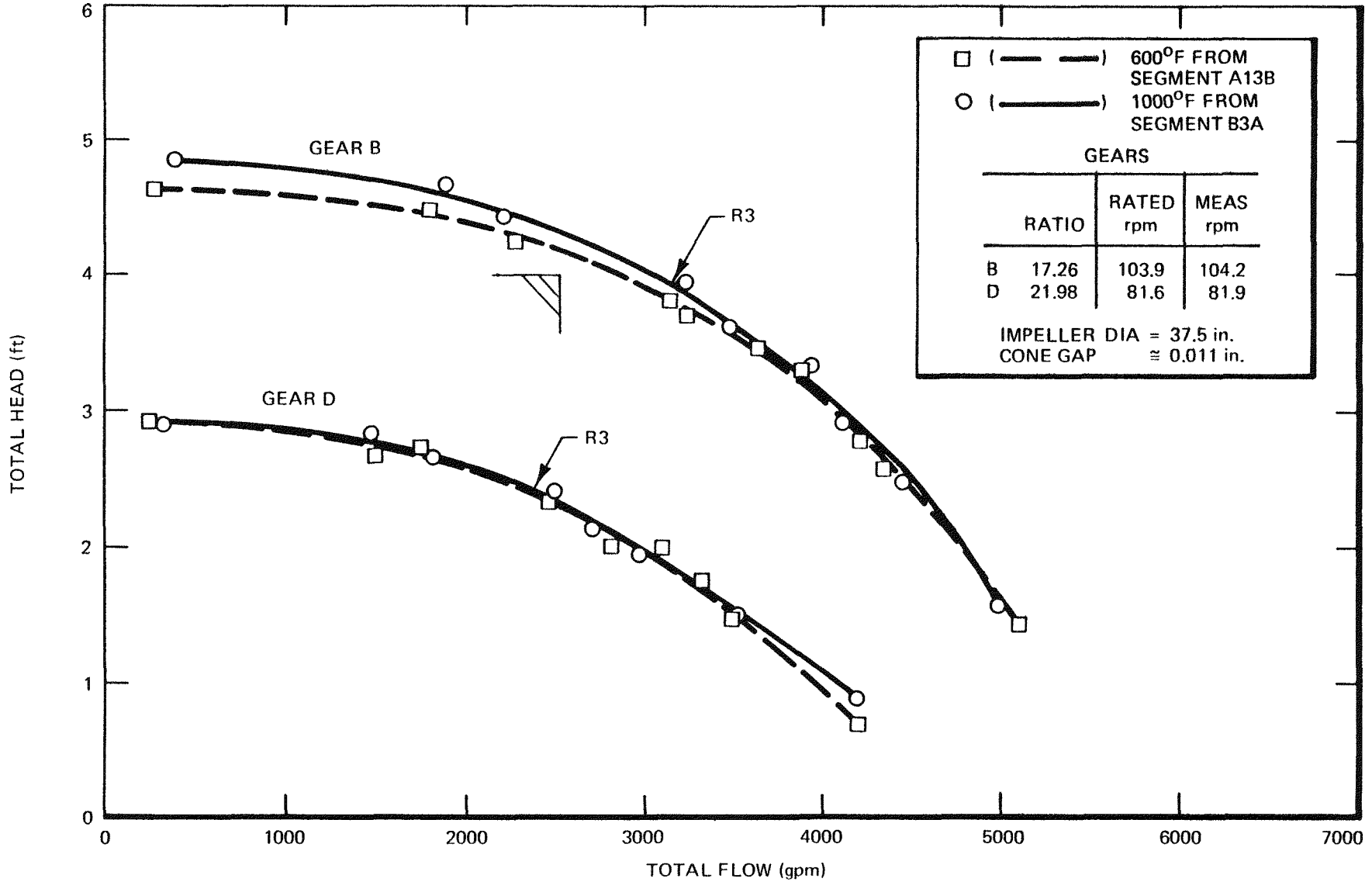
Figure 2.1.1

IMPELLER PERFORMANCE SODIUM TEMPERATURE - 600°F

IMPELLER DIA - 37.5 IN



13



FROM: 83ETEC-DRF-2086 SEGMENT REPORT B3A

83-413-02

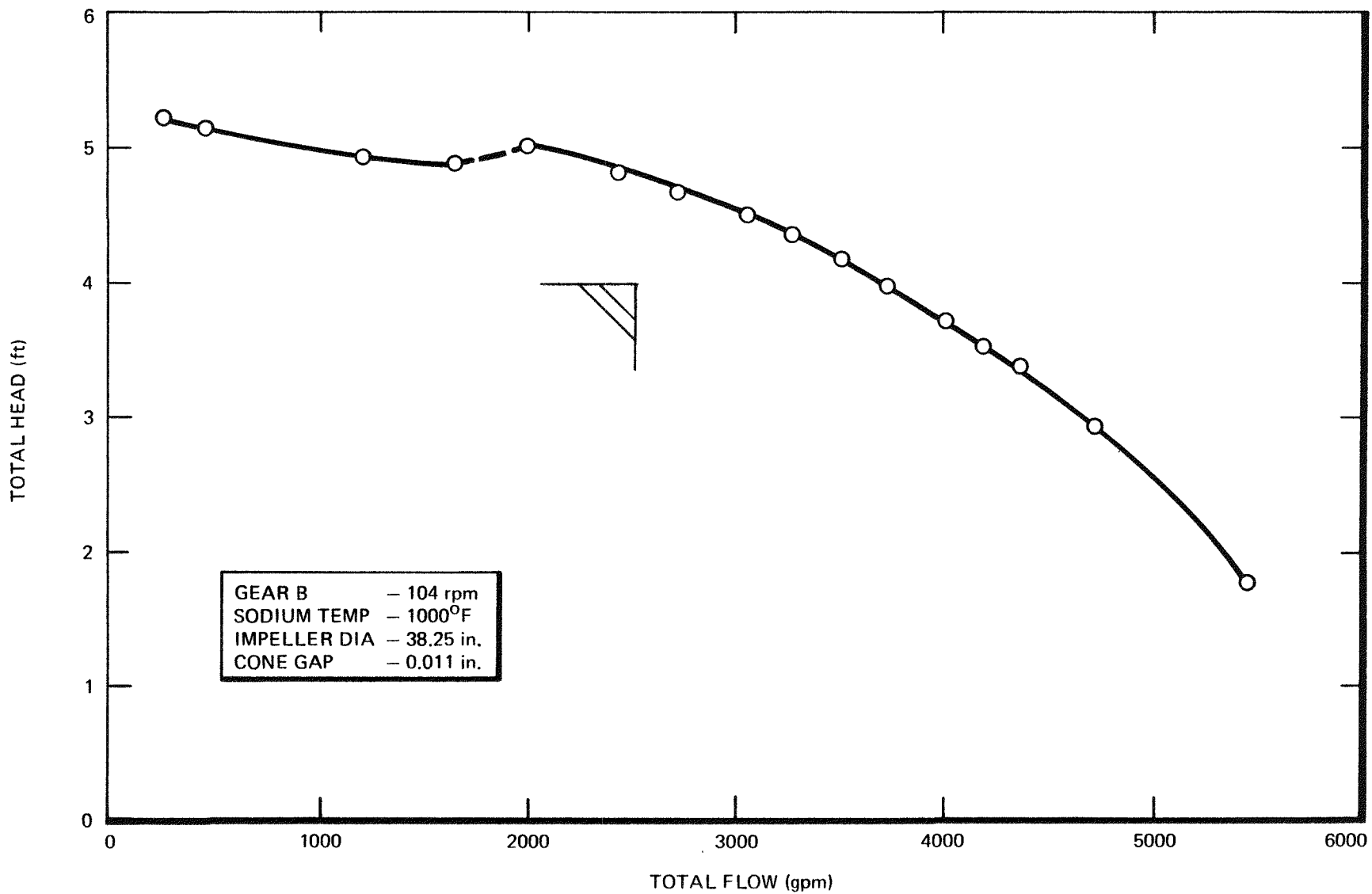


RATED DESIGN  
POINT

Figure 2.1.2

IMPELLER PERFORMANCE AT PONY MOTOR SPEEDS

IMPELLER DIA - 37.5 IN



FROM: 83ETEC-DRF-2111 SEGMENT REPORT C10

83-413-03



Figure 2.1.3 IMPELLER PERFORMANCE PONY MOTOR SPEED, 1000°F SODIUM

IMPELLER DIA - 33.25 IN



2.2

Pump Performance on Main Motor

Pump performance tests were conducted with two different impellers. The majority of testing including thermal transient tests were performed with a 37.50 inch diameter impeller which had not been subjected to water testing. The trim diameter of this impeller was based on water test data with a 38.25 inch diameter impeller. The final phase of sodium testing was conducted with the identical 38.25 inch diameter impeller which was used for water testing. Head developed at a 1116 RPM for the 37.5 inch diameter impeller fell about 9% lower than predicted. Similarly the head developed with the 38.25 inch diameter impeller in sodium at 1000°F was about 1.0% greater than the head developed in water test where as an increase of 3.5% would have been expected based an impeller growth. It is apparent that the full effect of impeller growth and developed head is partially offset by other factors which act to reduce the developed head.

Pump hydraulic performance at main motor speeds was checked periodically during the test program by plotting H/Q maps for different speeds and loop resistances. Resistances used were based on the plant loop resistance defined in CRBRP SDD51A Page 2-9 and covered the following:

- R3 -  $.40 \times 10^{-6}$  ft/gpm<sup>2</sup>, three loop maximum impedance
- R4 -  $.286 \times 10^{-6}$  ft/gpm<sup>2</sup>, three loop minimum impedance
- R5 -  $.229 \times 10^{-6}$  ft/gpm<sup>2</sup>, two loop maximum impedance
- R6 -  $.171 \times 10^{-6}$  ft/gpm<sup>2</sup>, two loop minimum impedance
- R7 -  $.126 \times 10^{-6}$  ft/gpm<sup>2</sup>, one loop minimum impedance

The equipment specification defines the design point as 458 ft. of total head with a flow of 33,700 gpm of sodium at 995°F at the R3 resistance. Since the facility computer could display the three parameters continuously (head in feet, flow in gpm, and loop resistance in ft. per gpm squared), two of these three variables may be specified as a set point and the third is then mathematically determined. The standard of the Hydraulic Institute, invoked by the equipment specification, allows the following variations:

<u>Set Conditions</u>	<u>Allowable Parameter Variation</u>
Speed and Head	Flow Tolerance: -0, +10%
Speed and Flow	Head Tolerance: -0, +5%
	(for heads under 500 ft.)

Conformity to both of the above is required.

In this pump, therefore, the following applies:

Given speed & Head:            Flow may vary from 33,700 gpm  
1116 RPM & 458 ft            to 37,070 gpm

Given speed & Flow:            Head may vary from 458 ft. to  
1116 RPM & 33,700 gpm        480.9 ft.

The only other requirement of the E-Spec concerning performance mapping is that the constant speed H/Q curve shall have a continuously negative slope in the region from 24,000 gpm to the intercept of the HQ curve with R4, the 3 loop minimum impedance curve at full speed, or at any speed in the H/Q zone bounded by circles 5-4-3-2-6 of Figures 1.0.1.2.

Early in the program ETEC chose to perform mapping by setting a hydraulic resistance, then recording Head and Flow data as speed was varied. Speeds selected were predetermined and defined in the test request so that maps or plots from test to test would produce data at consistent speed points: 1116, 1092, 1000, 893, 802, 678, 558, 446, 335, and 246 RPM. Later, data was taken as constant speed curves (changing loop impedance). With two flow loops, most of the mapping was accomplished with a flow split of 60% in the High Flow Loop (HFL) and 40% in the Main Flow Loop (MFL). Data was taken in the following segments:

- ° With the 37.5 inch impeller (rotating assembly #171222):
  - A13A - Initial baseline mapping with 600°F sodium data for R3, R4, R5 and R6.
  - A17 - Baseline performance with 600°F sodium for the R3 resistance only.
  - B3A - H/Q performance mapping with sodium at 1005°F for R3, R4, R5, R6 and one point at R7.
  - B8 - Baseline performance with both 600°F and 1005°F sodium for the R3 resistance only.
  - B14 - H/Q performance mapping with sodium at 1005°F, then at 600°F for R3, R4, R5, and R6.
- ° With the 38.25 inch impeller (rotating assembly #174848):
  - C8 - H/Q performance mapping with sodium at 600°F for R3, R4, R5, & R6.
  - C10 - H/Q performance mapping with sodium at 1005°F for R3, R4, R5, & R6.

See Paragraph 2.1 for description of events which have preceded each of the above baseline checks.

The following tabulation of data presents Head, Flow and Power data at/near the previously defined rated design point (The power is the input to the Vertical Drive Motor bus measured at the MG Generator output). The efficiency column is pump hydraulic efficiency calculated via

$$\text{Pump Eff} = \frac{H \times Q \times \text{SpG}}{3960 \times \text{KW(VDM Eff)}} = \frac{\quad}{.7457}$$

where VDM efficiency is .9478 (For the full rated design point)  
 Specific Gravity is .8763 for 600°F Sodium  
 and .82326 for 1000°F Sodium

Pump efficiency is a calculated value because the close coupled pump and drive motor design could not accommodate a torque meter to measure shaft torque. The electrical power out of the generator was measured by standard electrical measuring techniques and was assumed to be equal to the power into the vertical drive motor which is nearly correct since the line losses should be low. The efficiency of the electrical drive motor was calculated by a method similar to that of IEEE 112 on the basis of measured motor electrical parameters and was provided as a function of motor speed. The same derivation was used for both sodium and water test so that the results could be compared even though there may be some question about the absolute accuracy of the calculated motor efficiency.

Table 2.2.1

HEAD FLOW PERFORMANCE ON MAIN MOTOR AT DESIGN SPEED  
(H in feet, Q in GPM, P in KW, all data at 1116 RPM & R3

Test Segment	600°F				1000°F			
	H	Q	P	Eff.	H	Q	P	Eff.
* A13A	443.6	33,301	3665	70.2	--	--	--	--
* A17	444.5	33,335	3631	71.0	--	--	--	--
* B3A	--	--	--	--	445	33,294	3499	69.2
* B8	447.5	33,405	3534	73.6	453.5	33,510	3385	73.4
* B14	447.5	33,449	3643	70.6	453.2	33,660	3392	73.5
** C8	477.7	34,354	3798	75.2	--	--	--	--
** C10	--	--	--	--	480.3	34,631	3664	74.2

Performance mapping curves for both 600°F and 1005°F for both the 37.5" and the 38.25" impeller are shown in Figures 2.2.1 through 2.2.5.

- \* 37.5 inch diameter impeller
- \*\* 38.25 inch diameter impeller

The Test Data in Table 2.2.1, based on published Segment Reports from ETEC, does not list the head at a consistent flow point so that comparison may be made of developed head from one Test Segment to another. Therefore, a second table, derived by applying a correction factor of  $-.92$  ft. per 100 gpm (slope of the H/Q Curve for 1116 RPM at the R3 hydraulic impedance) is presented as Table 2.2.1A. Subsequent discussions of head will use the Table 2.2.1A data.

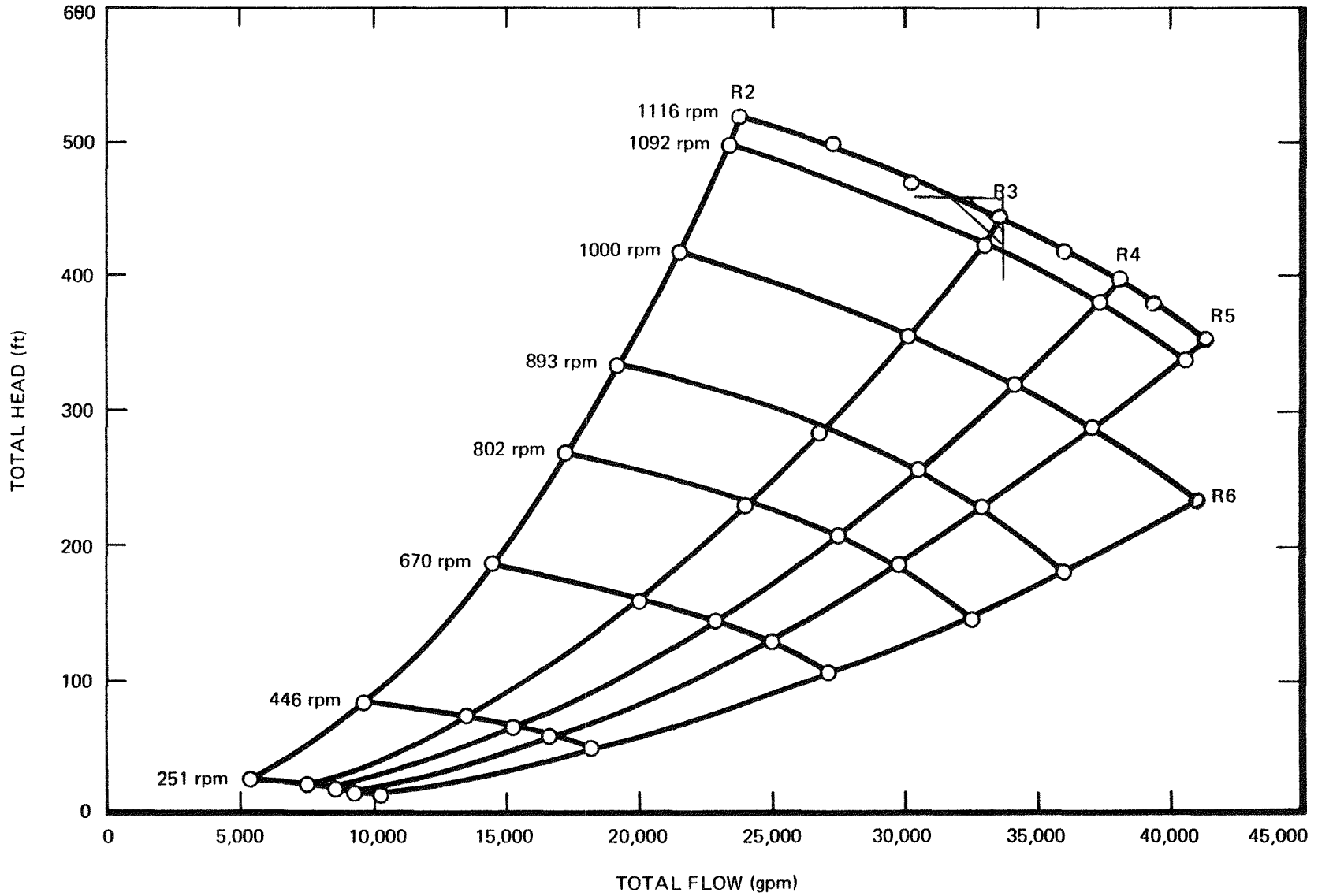
Test Segment	600°F		1000°F	
	(H(Ft))	Q(gpm)	H(ft)	Q(gpm)
* A13A	440.0	33,700	-	-
* A17	441.1	33,700	-	-
* B3A	-	-	441.3	33,700
* B8	444.8	33,700	451.8	33,700
* B14	445.2	33,700	452.8	33,700
**C8	483.7	33,700	-	-
**C10	-	-	488.8	33,700

TABLE 2.2.1A

HEAD FLOW PERFORMANCE ADJUSTED TO 33,700 GPM

\* 37.5 Inch Diameter Impeller

\*\* 38.25 Inch Diameter Impeller



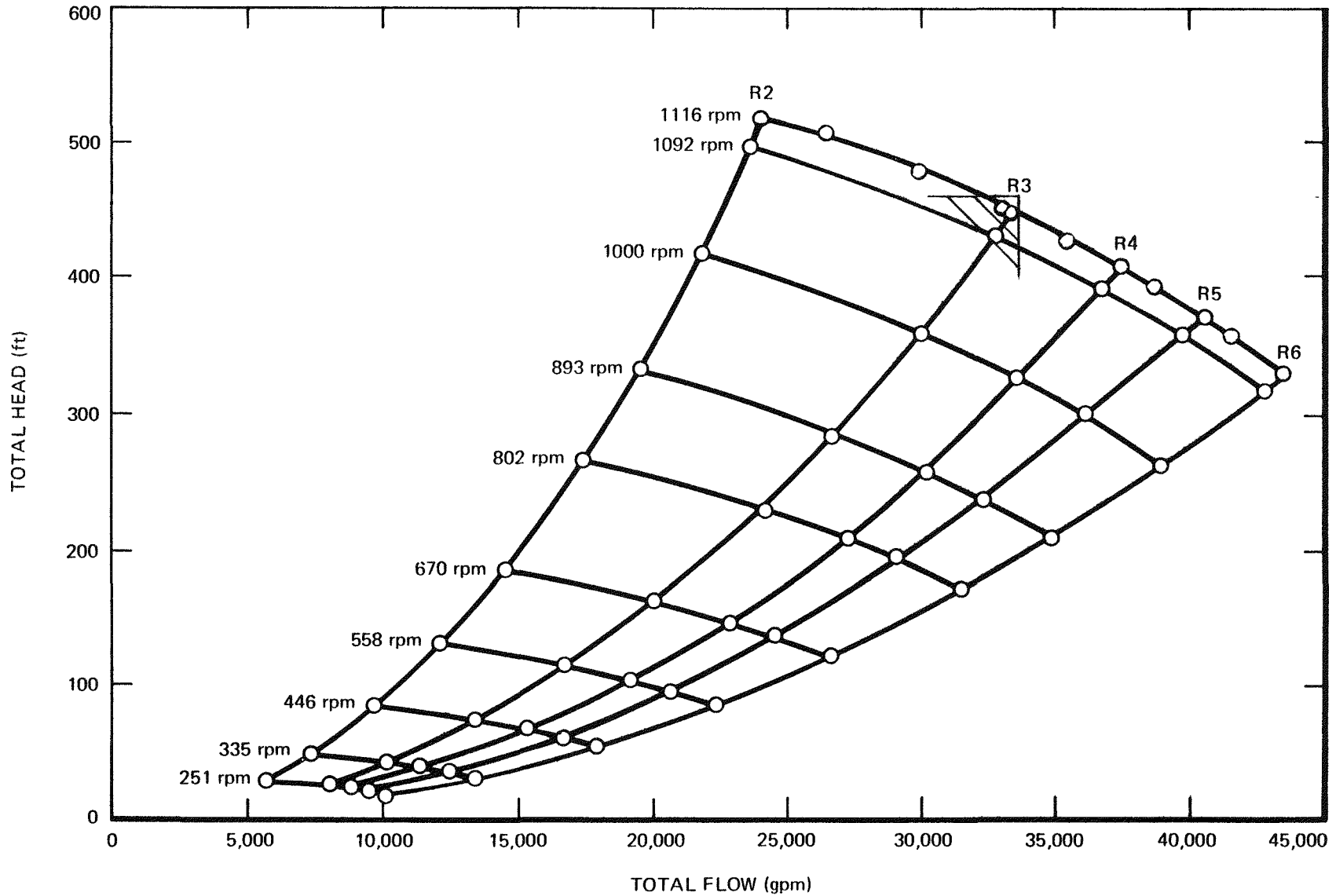
83-413-04

Figure .2.2.1

IMPELLER PERFORMANCE SODIUM TEMPERATURE – 600°F START OF TEST PROGRAM

IMPELLER DIA - 37.5 IN



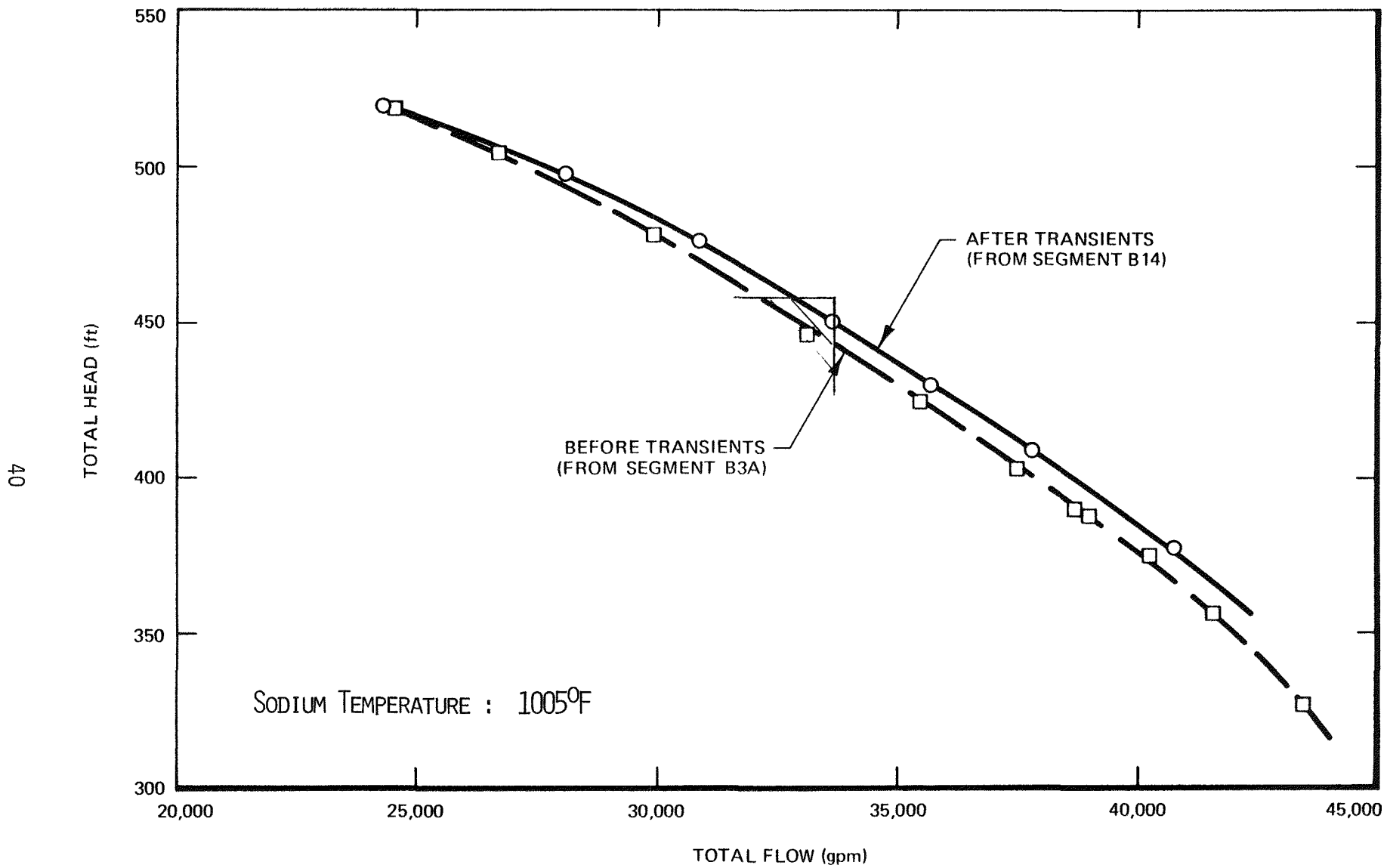


FROM: 83ETEC-DRF-2086 SEGMENT REPORT 83A

83-413-05

Figure 2.2.2 IMPELLER PERFORMANCE SODIUM TEMPERATURE – 1005°F SEGMENT B3A  
IMPELLER DIA - 37.5 IN

 RATED DESIGN POINT

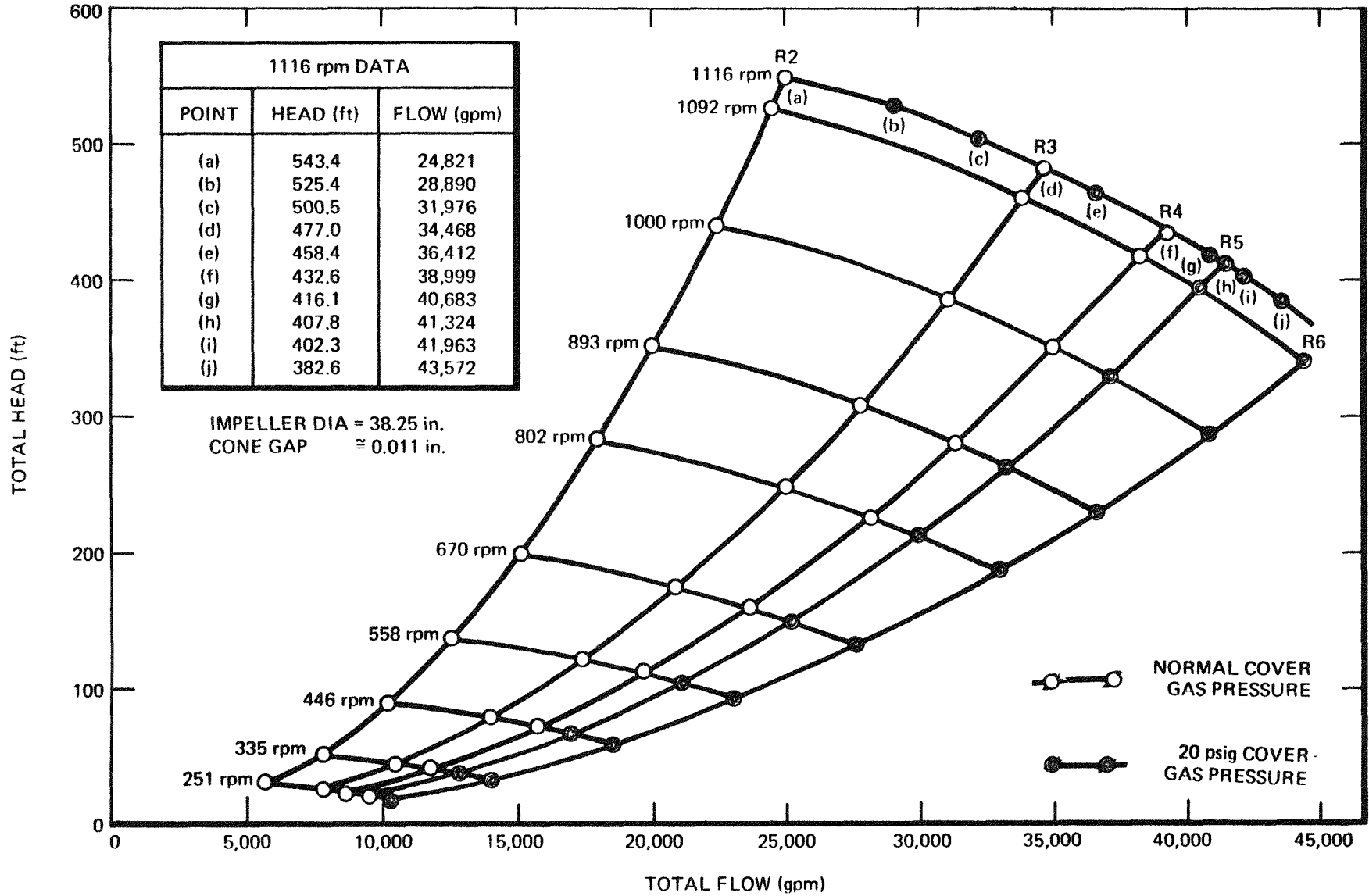


83-413-06

Figure 2.2.3

IMPELLER PERFORMANCE BEFORE AND AFTER SEVERE TRANSIENTS

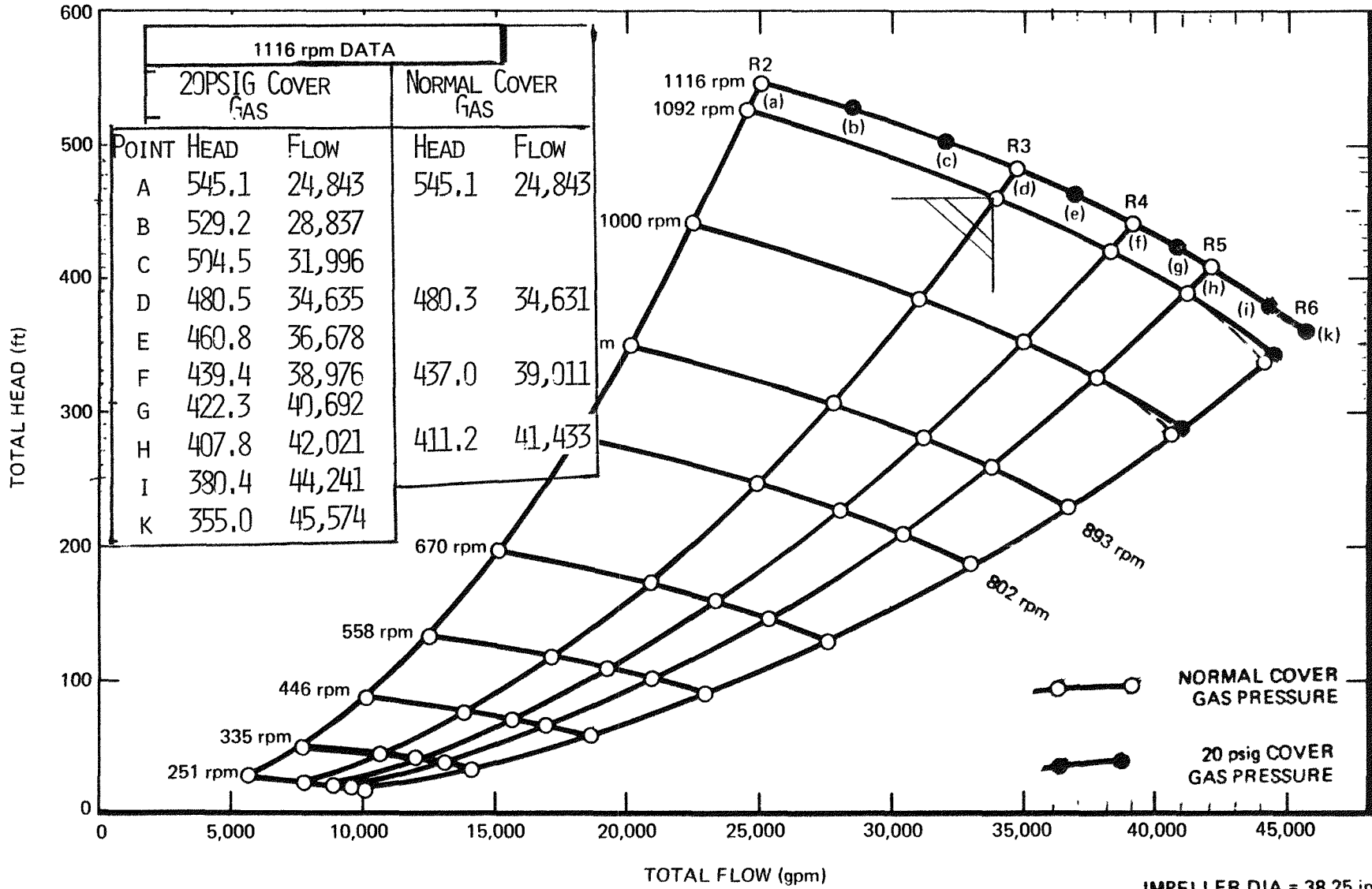
IMPELLER DIA 37.5 IN



FROM: 83 ETEC-DRF-2017 SEGMENT REPORT C8

83-413-07

Figure 2.2.4 IMPELLER PERFORMANCE SODIUM TEMPERATURE – 600°F



FROM: 83ETEC-DRF-2111 SEGMENT REPORT C10

IMPELLER DIA = 38.25 in.  
 CONE GAP ≈ 0.011 in.

Figure 2.2.5 SS304 IMPELLER PERFORMANCE SODIUM TEMPERATURE – 1005°F  
 IMPELLER DIA -- 38.25 IN



The pump supplier performance predictions, based on a 10 mil nominal controlled clearance gap are contained in Appendix C2 of 22A3551 Test Request. For the rated design point (1116 RPM at R3) with the 37.5 inch impeller, these predictions were:

<u>600°F</u>		<u>1005°F</u>	
H	Q	H	Q
462	34,100	468	33,700

In the Water Test Flow Report (Figure 5.2.2-1), the pump supplier predicts performance for both a 5 mil and a 17 mil controlled clearance gap. These predictions, for 1116 RPM, for an impeller trimmed (to 37.5") for the prototype test in sodium were:

<u>400°F</u>		<u>1000°F</u>			
17 mils		5 mils		17 mils	
H	Q	H	Q	H	Q
464	33,700	485	33,700	478	33,700

By interpolation, 600°F performance for a .017 mil cone gap would be about 469 ft. at 33,700 gpm, and an .011 mil gap at 1000°F would yield 481.5 ft. at 33,700 gpm.

The pump supplier trimmed the Phase A & B sodium test impeller to 37.5 inches (3/4" smaller than water test impeller) to compensate for thermal expansion from water to hot sodium and the above predictions reflect this trimming. The water test impeller was 38.25 inches diameter.

Pump supplier predictions of pump hydraulic efficiency were 75% for a 17 mil gap and 78% for a 5 mil gap.

Note: The 37.5" impeller had not been subjected to water test, but went directly from manufacture into sodium tests. The 38.25" water test impeller was tested in sodium in Phase C tests.

## Discussion of Performance Mapping Results

The following items will be discussed:

1. Low Head  
The Phase A & B impeller, trimmed to 37.5 inches diameter yielded a lower head in sodium than the pump supplier expected. (440 ft at 33, 700 gpm measured in Segment A13A vs. 474 feet at 33, 700 gpm predicted for 600°F sodium pump performance.)
2. Mid Test Change in Head  
There was an apparent change in pump performance (+ 10 feet or 2% change in head) after application of the severe thermal transients. (See Table 2.2.1A, H for B3A & B8).
3. Replacement Rotating Assembly  
38.25" diameter impeller performance in sodium

### Low Head

Referencing Table 2.2.1, the following observations are made:

- ° The first baseline performance data of A13A, and repeated in A17 indicates a head of 440 to 441 ft. compared with a pump supplier prediction of 474+ ft. (Flow Test Report ERI064), and an efficiency of 71% compared to 75% prediction. The low efficiency along with low head suggest the following possibilities:
  - ETEC instrumentation errors (speed, head, flow, power).
  - Pump supplier prediction methodology error.
  - Internal pump leakage phenomena which is dependent upon temperature change (possibly related to hydraulic assembly to tank clearance cone gap).
  - Pump water test instrumentation error (Wyle vs. BJ Venturi calibration).

The low head and low efficiency condition resulted in the several instrumentation calibration investigations referenced in Para. 1.1.4, and GE's technical judgement was that the ETEC instrumentation is probably within the accuracies claimed by ETEC: Speed  $\pm 0.2$  RPM, pressure  $\pm 1\%$  and flow  $\pm 2\%$ .

- ° Test Segment B8 indicated that the severe thermal transients (Segment B7) caused something to shift in the pump which results in a few feet of head increase (441 to 444.8 ft. at 600°F and 441.3 to 451.8 at 1000°F), or that ETEC instrumentation suffered a shift. This change in performance was confirmed in subsequent tests at Segment B14.

- ° The efficiencies measured in segments B8 and B14 display a 2% improvement over the 71% initially calculated for B13A and A17.
- ° The developed head at 33,700 gpm with the 38.25 inch impeller in Segments C8 and C10 yields 483.7 ft. at 600°F and 488.8 ft. at 1005°F as compared with 485 ft. delivered by the same impeller in water test (480.9 ft. with a 17 mil hydraulic assembly cone to tank gap, 490 ft. with a 5 mil gap, and by interpolation, 485 for a 11 mil gap.) Efficiency of the 38.25" impeller is very near to the 75% expectation.
- ° The efficiency value listed for test segment B3A (37.5 inch impeller at 1005°F) appears to be so far at variance with other data as to be an erroneous reading or calculation.

Data from both 600°F and 1000°F (A13A, A17, B8, B14) indicate that the head at design flow is lower than the pump supplier prediction for the 37.5 inch impeller (480 ft. (at 33,700 gpm) predicted vs. 441 ft. at 1000°F realized), per Table 2.2.1A, Segments B3A and B14).

In terms of conformance to the equipment specification, the 37.5 inch impeller is just slightly below specified head at design flow.

The cause of this marginal performance may be any one or a combination of the listed possibilities.

The 37.5 inch impeller rotating assembly used in sodium test was not water tested to avoid delay to the ETEC schedule. This impeller was manufactured to the same requirements, using the same pattern, as the impeller used in water tests but was trimmed to a smaller diameter to compensate for predicted growth with temperature. (Templates are used by Byron Jackson to control the hand ground dimensions at the vane inlet and also to control over and under filing of vanes at the impeller discharge.) Thus, a direct correlation of performance water to performance in sodium was not available during Phases A & B. The water test unit was subsequently subjected to sodium performance testing in test Segments C8 and C10 in order to provide that direct correlation.

Numerous investigations of the problem were initiated:

- Inspection records of the 37.5" impeller were reviewed.
- Pump assembly records were reviewed to ascertain if pump internals orientation was the same as for water test.
- Reviews were made of ETEC instrument accuracies, from design and calibration aspects.
- ETEC ran special flow loop checks to calibrate Venturi flowmeters against each other, using the pump speed and head as a constant reference.
- ETEC ran independent speed sensor checks.
- The pump was examined upon disassembly between Phases B and C to evaluate the "partial blockage" and the orientation possibilities.
- The disassembled 37.5" impeller was examined and remeasured by the manufacturers hydraulics expert.
- The 38.25" impeller was installed into the pump for the Phase C tests to obtain a direct correlation between water test data and sodium data.
- Thermal coefficients of expansion measurements were made on archive samples of castings and wrought materials to determine if differential thermal expansion at the controlled clearance gap was causing increased leakage with temperature.

Results of Investigations:

- (1) Pump disassembly inspections revealed no partial obstructions, no assembly orientation problems. All passages were clear.
- (2) ETEC's instrumentation review resulted in a correction of an error in power measurements, but speed, head, and flow measurements are believed to be within ETEC's claim of  $\pm 0.2$  RPM,  $\pm 1\%$  for pressure,  $\pm 2\%$  for flow.
  - A neutron activation of a wedge of flowing sodium and measurement of transit time correlated with the HFL Venturi.

- Switching fluid flow between the two loops, while monitoring to establish identical speed and head to assure equal flow in the two cases corroborated the HFL Venturi performance against the MFL Venturi to within  $1\frac{1}{2}\%$ .
  - Two different and independent pressure measuring systems provided the same head measurement where their range spans overlapped.
  - Speed measurement via different type of sensor confirmed that previously used sensor was correct.
- (3) Substitution of the 38.25" impeller resulted in the obtaining of sodium performance data for direct comparison to water test results.
- (4) Review of the water test Venturi calibration revealed that two calibrations were available to the pump supplier - one by Wyle Laboratories (obtained after the water tests had been completed) and one by the Byron Jackson test operations. The Wyle Laboratory calibration would result in observed flow performance of  $2\frac{1}{2}\%$  below the results with the Byron Jackson calibration. The pump supplier used the Byron Jackson calibration in water test, and to establish the trim of the impeller to be used for sodium test, since at the time, this was the only data available.
- (5) A review of the leakage analysis related to the controlled clearance cone indicated that there may be a phenomenon of distortion of the cone caused by pressure and the temperature coefficient of expansion which can increase leakage at the higher temperatures. It is probable that this increase in leakage may partially or totally offset the effect of 3 dimensional expansion of the impeller due to increase in temperature. However, such increase in leakage should be accompanied by a reduction in efficiency in hot sodium as compared to efficiency in water.

2.2

Continued  
Change in Head

In test segment B8, the 1000°F sodium performance data indicated an upward change in head of 10 ft. from that taken in segment B3A (451.8 ft. at B8, 441.3 ft. at B3A) adjusted to 33,700 gpm. (See Table 2.2.1A). The series of severe thermal transients of Segment B7 were applied to the pump between Segments B3A and B8. The developed head reading of segment B8 was confirmed after subsequent endurance run in the Baseline Test Segment B14. Efficiency improvement of B8 and B14 tests as compared to B3A tends to confirm less pump internal leakage. However, the calculated efficiency of Segment B3A is suspect.

Initially, it was a subject of speculation as to potential causes of this sudden head performance improvement. Upon disassembly at the end of the test program (Segment C15), it was discovered that the tank part of the leakage cone had gone oval, by about .350 inches with the short dimension being along the axis of the discharge and balance ports. (This cone was made of plate SS316, solution heat treated, followed by a 700°F heat treat after installation in the tank). It is believed that stresses were relieved in this component during the severe thermal transients of Segment B7.

Sodium Testing of 38.25" Impeller

The testing of the Rotating Assembly with the 38.25" impeller SN174848 provided a direct correlation of performance in water to performance in sodium.

In water at 1116 RPM, R3 impedance, tested performance of the 38.25 inch impeller was:

<u>Seal Cone Gap</u> (mils)	<u>Head</u> (ft)	<u>Flow</u> (GPM)
17 (Test)	480.9	33,700
5 (Test)	490	33,700
11 (Interpolation)	485.4	33,700

(Basis is ER1064, Figure 5.2.1-1) (The reader is reminded that the above data is based on the BJ flowmeter calibration, not the Wyle Lab calibration. There is a 2-1/2% difference.)

° In test at ETEC with the 38.25" Impeller, at 600°F, 1116 RPM, R3 Impedance and an 11 mil gap:

<u>H ft</u>	<u>Q (GPM)</u>	<u>Eff (%)</u>
477.7	34,354	75.1

- ° In test at ETEC with 38.25" Impeller at 1005°F Sodium, 1116 RPM R3 impedance and 11 mil gap:

H ft	Q (GPM)	Eff. (%)
480.3	34,631	74.2

If these head quantities are adjusted to a flow rate of 33,700 to permit comparison with water test results, the results would be:

- ° Water test head for 33,700 gpm (interpolated for 11 mil gap) - 485.4 ft.
- ° 600°F sodium head for 33,700 gpm - 483.7 ft.
- ° 1005°F sodium head for 33,700 gpm - 488.8 ft.

Thus, water test results land between results in sodium at 600°F and sodium at 1000°F.

#### Thermal Expansion Effects of Plate & Casting Materials

A review team meeting (January 11-13, 1983) was convened to investigate potential reasons for the lower than expected pump head in sodium testing at ETEC with the 37.5 inch diameter impeller. One hypothesis was that the different materials bounding the seal cone gap, one being plate SS316 (solution heat treated, followed by heat treatment to 700°F with the pump tank), the other being a cast CF8 material (given a proprietary heat treat by the pump supplier), caused a differential thermal expansion between the pump hydraulic casting (part of the removable innerstructure) and the wrought plate cone material (part of the pump tank), which may have resulted in an increase in internal leakage thereby degrading pump performance in hot sodium as compared to water test performance. (For the plant pumps, the tank part of the cone is to be cast instead of plate, and heat treat is being re-evaluated.)

The approach to proving/disproving this hypothesis was to obtain archive samples of the cast and the wrought materials in both heat treated and solution heat treated conditions, and to have a laboratory measurement (at Purdue University) of the coefficient of expansion.

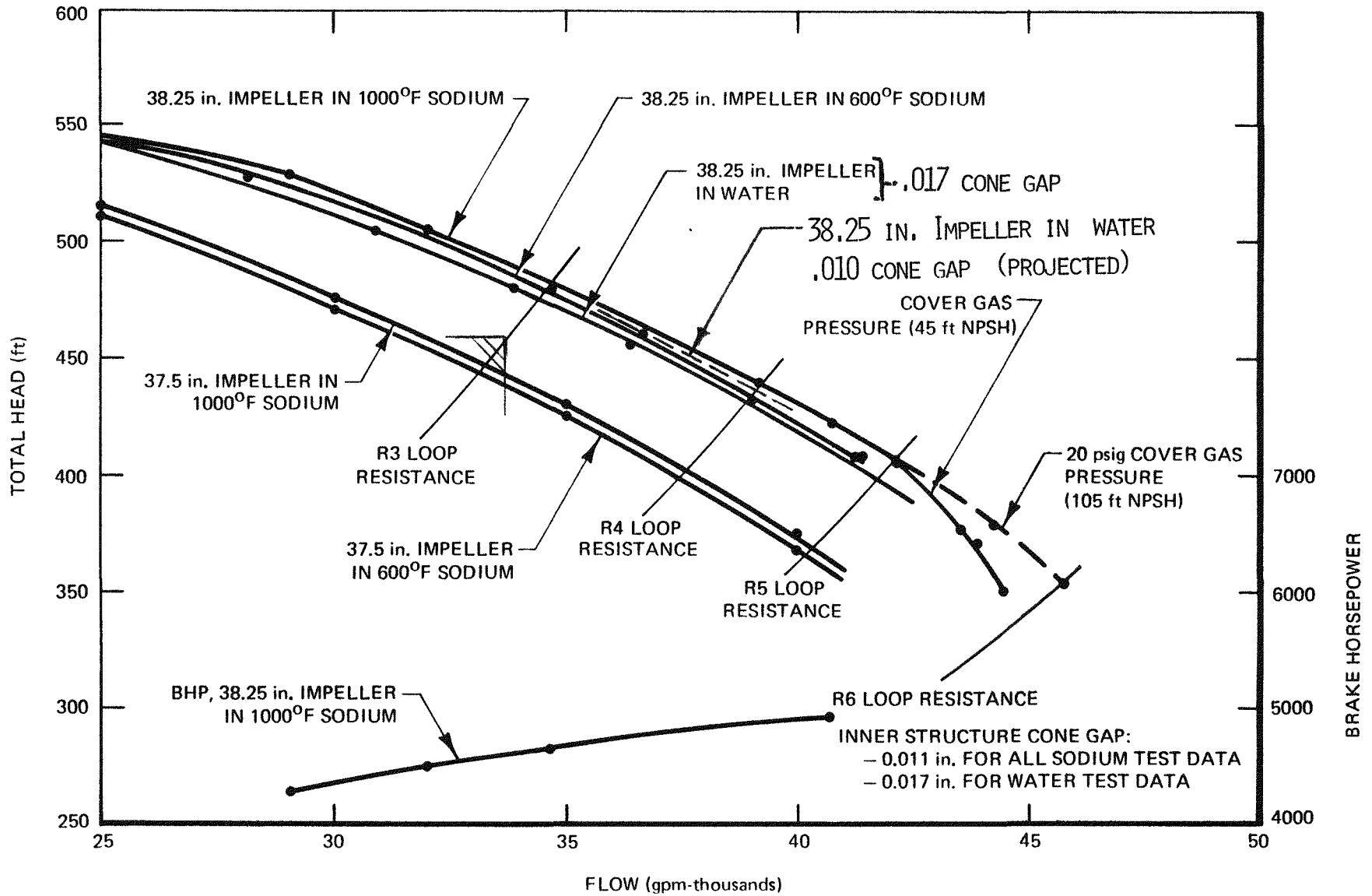
The conclusions of the expansion tests were:

1. Thermal expansion measurement data indicate that the sealing cone gap would increase from an initial value of 11 mils to a value of 19.6 mils at 1000°F.
2. The effect of heat treating the CF8M cast material at temperatures above 1300°F is to cause an increase in the coefficient of thermal expansion from that of the solution annealed material.

3. The effect of heat treatment on the CF8M plate material was to cause a relatively small change in the coefficient of thermal expansion.
4. The manufacturing procedures for the plant pumps should be reviewed and possibly modified to minimize the effect of differential thermal expansion on the seal cone clearance gap. (In the plant design, both the sealing cone and the hydraulic assembly are cast material; the heat treatment is being reconsidered.)

#### Conclusions Regarding Sodium Performance Mapping

1. The ETEC data should be accepted as accurate to the tolerances specified by ETEC (Speed  $\pm 0.2$  RPM, Pressure  $\pm 1\%$ , Flow  $\pm 2\%$ ).
2. Based on sodium test results, there is a change in this pump's sodium performance from the pump suppliers predictions which causes measured performance at 1000°F with sodium to be close to water performance, without exercising the trimming to compensate for thermal expansion.
3. The correlation of test results between water and sodium with Rotating Assembly #174848 (38.25" diameter) is:  
Water Test: 485.4 ft. at 33,700 gpm  
600°F Sodium: 483.7 ft. at 33,700 gpm  
1005F Sodium: 488.8 ft. at 33,700 gpm
4. For this design, the performance for impeller sizings of 37.5", and 38.25" is shown in Figure 2.2.6. Note that the water test curve for the 38.25 inch impeller is for a gap of 17 mils.
5. Impeller trim for plant pumps should take into account the sodium test experience in addition to accounting for three dimensional thermal expansion.
6. Prototype pump performance was shifted by bowing of the tank half of the leakage cone. Material and heat treat for both halves of the clearance cone should be re-examined in light of the experience on the prototype pump, where post test examination disclosed bowing of the tank cone. (Post test inspection of the tank sealing cone at Byron Jackson disclosed that the cone had distorted from round to oval by 0.35 inches in a direction which tended to reduce leakage).



BASIS: A13A, B3A, C8, C10 TESTS

83-413-09

Figure 2.2.6 WATER TO SODIUM PERFORMANCE CORRELATION

## 2.2 (Continued)

7. The pump efficiency reported is not known very accurately since the values are based on a calculated value of motor efficiency derived from measured motor winding parameters and these values were not verified by drive motor load tests or by an inline torque meter.
8. In the plant installation, which operates with a flow control servo system, each pump in the several loops will operate at slightly different speeds to supply the demand flow rate. The different speeds result from flow loop impedance differences and possibly minor variations of impellers and permanent magnet flowmeters.

## 2.3 Fluid Thermal Transient Testing

Transient testing was accomplished in three separate test segments, with low severity transients first, then mild transients which took the pump above 800°F followed with the severe thermal transients with pump temperature in the 1005°F range. There was one slowly applied transient (a plant faulted condition) which resulted in 1100°F at the pump. The purpose of transient testing was to determine if the hydrostatic bearing gap would survive thermally induced dimensional change.

The facility, after being adapted for the CRBRP Prototype pump testing, has a long run of piping between the mix-tee where the fluid used to induce the transient is mixed with the circulating fluid, and consequently at the 2870 gpm pony motor flowrate, there was a 150 second transport time lag between the mix tee and the pump inlet. This transport time lag and the changes in fluid temperature as a result of heat transfer to and from the loop as the sodium moves through the piping, required that, prior to each transient, the mix-tee temperature ramp which would induce a proper ramp at the pump inlet be predicted using a computer model of the pump loop. These computer predictions were fairly accurate in setting the ramp rate, but did not adequately predict the post-transient stabilization flow requirements, where it was desired to hold the end of transient temperature for 30 minutes. As each different transient was run, the procedure evolved and performance improved; the major change being the introduction of test conductor directed hold periods in the valve position programmer which stretched out the post-transient stabilization period to compensate for the MFL loop residual heat load and the extra heat loads introduced by the gradual mixing of the "dead leg" sodium and the main stream.

A major element of pump instrumentation were sets of push-pull proximeter probes on both the upper and lower bearing. The probe sets on each bearing were interconnected to produce a Lissajou pattern which showed the orbit of the bearing journal and could be used to measure the gap between the respective bearings and journals during operation. Test buttons on the journals provided a 10 mil step which could be used for probe calibration, additionally the results of the shaft swing test were also used to confirm the bearing instrumentation calibration between each test segment or as swing tests were run for a new sodium temperature. With this instrumentation it is possible to deduce the bearing gap provided that the bearings and their respective journals expand and contract at the same rate.

Since the bearing proximeter probes were sensitive to temperature, the output signal did not serve as a useful real time indication of the journal orbit in the bearing during the actual transient. By use of an off line computer and probe calibration coefficients as a function of temperature, it was possible to calculate bearing orbit as a function of time during the transient, based on the assumption that the instrument measuring coil was at the same temperature as that indicated by the thermocouples on the bearing surfaces. Inspection of these results (See Figure 2.3.2) showed an apparent increase in journal orbit diameter during the transient and a shift in its position. Neither of these effects to produce a reduction in bearing gap was sufficient to indicate rubbing. Quantitative results were not believed to be sufficiently reliable to warrant additional analysis. All these probes failed when loop temperature was raised to 1000°F in preparation for the severe transient tests so no bearing gap data was available during severe transients.

In the first transient applied, the pump inlet temperature sensor used was TE1009, a resistance temperature device. After the first transient, element TE 1010, a thermocouple which has a faster reaction time response was used as the measure of the transient being applied at the pump suction nozzle. (The basis for the transients run in this test originate in the equipment E-Spec. E-Spec transients were listed in progressive order of severity (based on temperature span) and transients were then selected which would progressively increase the severity of test).

The following table defines the target transients and the resulting achieved transients.

Table 2.3.1  
Transient Tests

Segment A16 Low Temperature Transients

Transient	Start °F	Specified		Rate °F/sec	Note	Achieved	
		$\Delta T$ °F	Flow %			$\Delta T$ °F	Rate °F/sec
IP1U	700	-100	8.4	-3.8	(1)	-150	-1.4
IP6U	710	-110	40	-4.3		-126	-5.8
IP2U	600	+100	40	+1.0		+120	+0.80
IPI0U	600	+120	40	+3.5		+140	+3.6
IP9U	500	+200	8.5	+0.5		+200	+0.6
IP8E	700	-200	8.5	-3.2	(1)	-200	-1.5

Segment B2 Mild Thermal Transients

IP7U(B)	500	+200	8.5	+1.25		+170	+1.86
PP4U(A)	600	+250	40	+1.40	(2)	+278	+1.49

Segment B7 Severe Transients

Transient	Start °F	Specified		Rate °F/sec	Note	Achieved	
		$\Delta T$ °F	Flow %			$\Delta T$ °F	Rate °F/sec
PP4U(B)	840	-240	40	-2.6		-270	-2.6
"B"	1005	-300	8.5	-1.1		-316	-1.4
PP10U	950	-350	8.5	-1.0		-365	-1.1
PP2U	1005	-415	8.5	-2.0		-417	-2.7
PP1U	1005	-370	8.5	-2.3		-398	-2.9
PP11U	1005	-505	8.5	-0.8	(3)	-462	-0.9

Segment B14A PP1F Transient

PP1F	1005	+100	40 & 8.5	100°F in 12 hrs		+100	100° in 12 hrs
------	------	------	-------------	--------------------	--	------	-------------------

Notes:

- (1) The facility did not have the capability to apply a high temperature change rate with a low (8.5%) flow rate. In other tests, where flow rate was 40%, the facility could apply the higher temperature change rate. Data for IP1U and IP8E was accepted on the basis that higher temperature change rates were tested in other transients.

2.3

Continued

- (2) On PP4U(A), the +280°F achieved delta T tapered off to +200°F before end up the ½ hour holding period. Facility was unable to hold the specified end temperature due to supply tank limitations.
- (3) On PP11U, the temperature "bounced back" to 575°F at end of ½ hours holding period due to depletion of supply tank fluid.

The following are ETEC DAS traces of the applied transients:

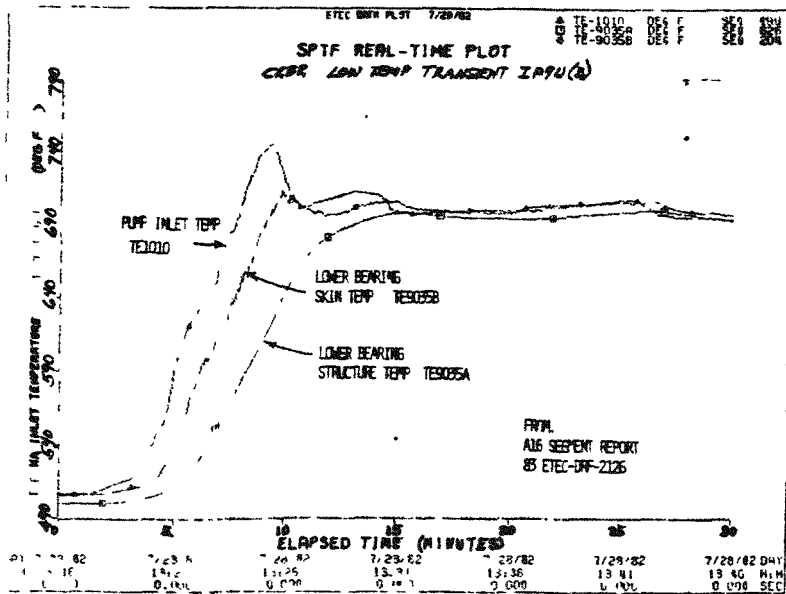


Figure 2.3.1  
Mild Up Transient IP9U

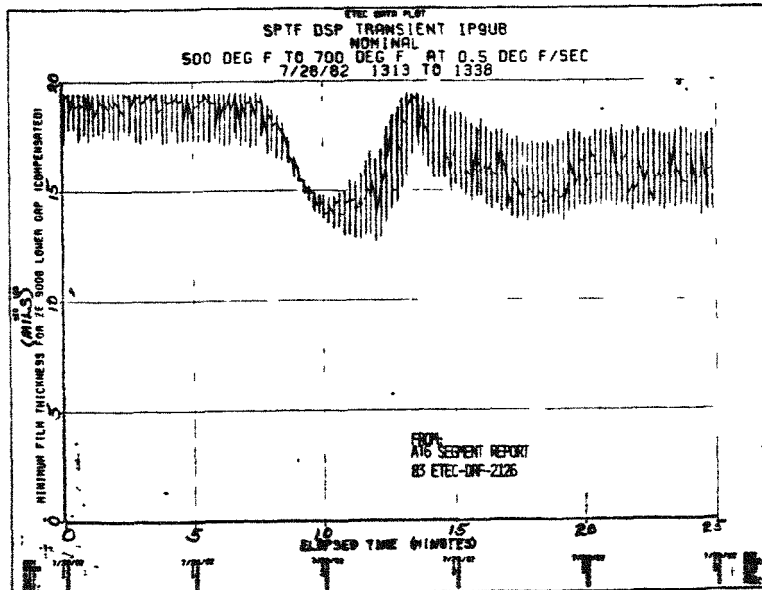


Figure 2.3.2  
Shaft Center Position Trace During IP9U

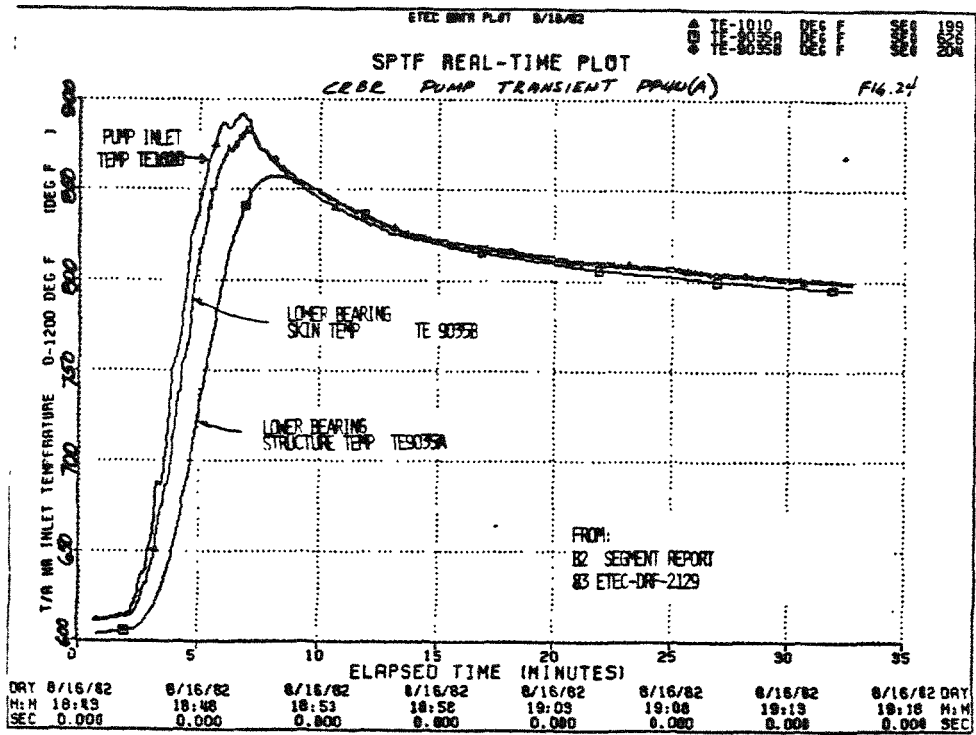


Figure 2.3.3  
Mild up Transient PP4U(A), +250°F

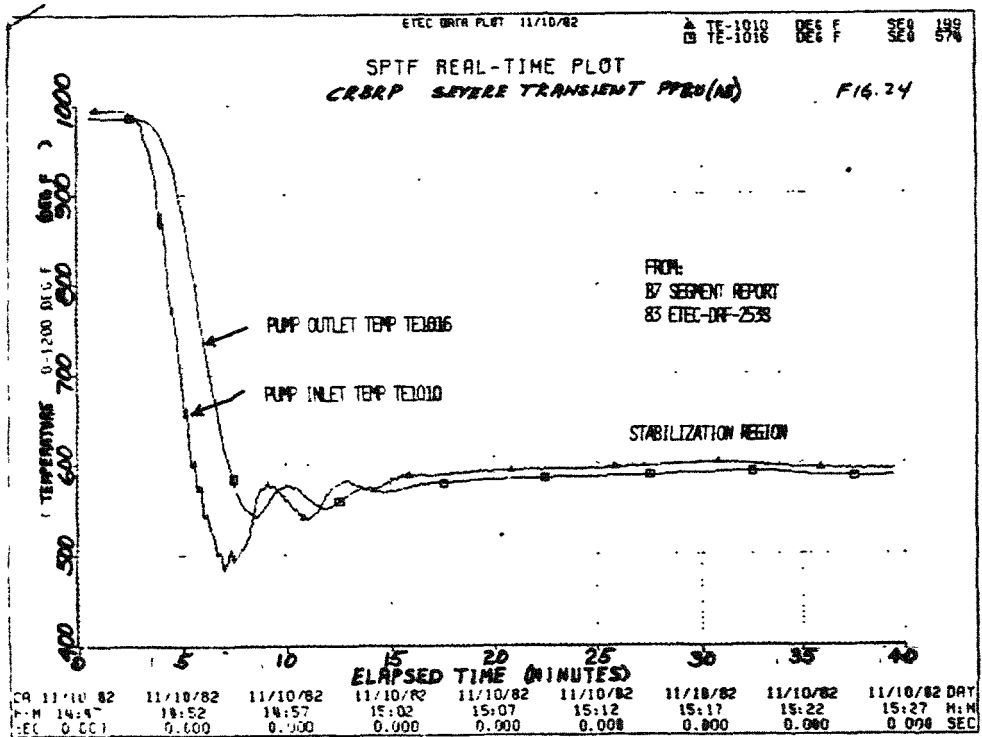


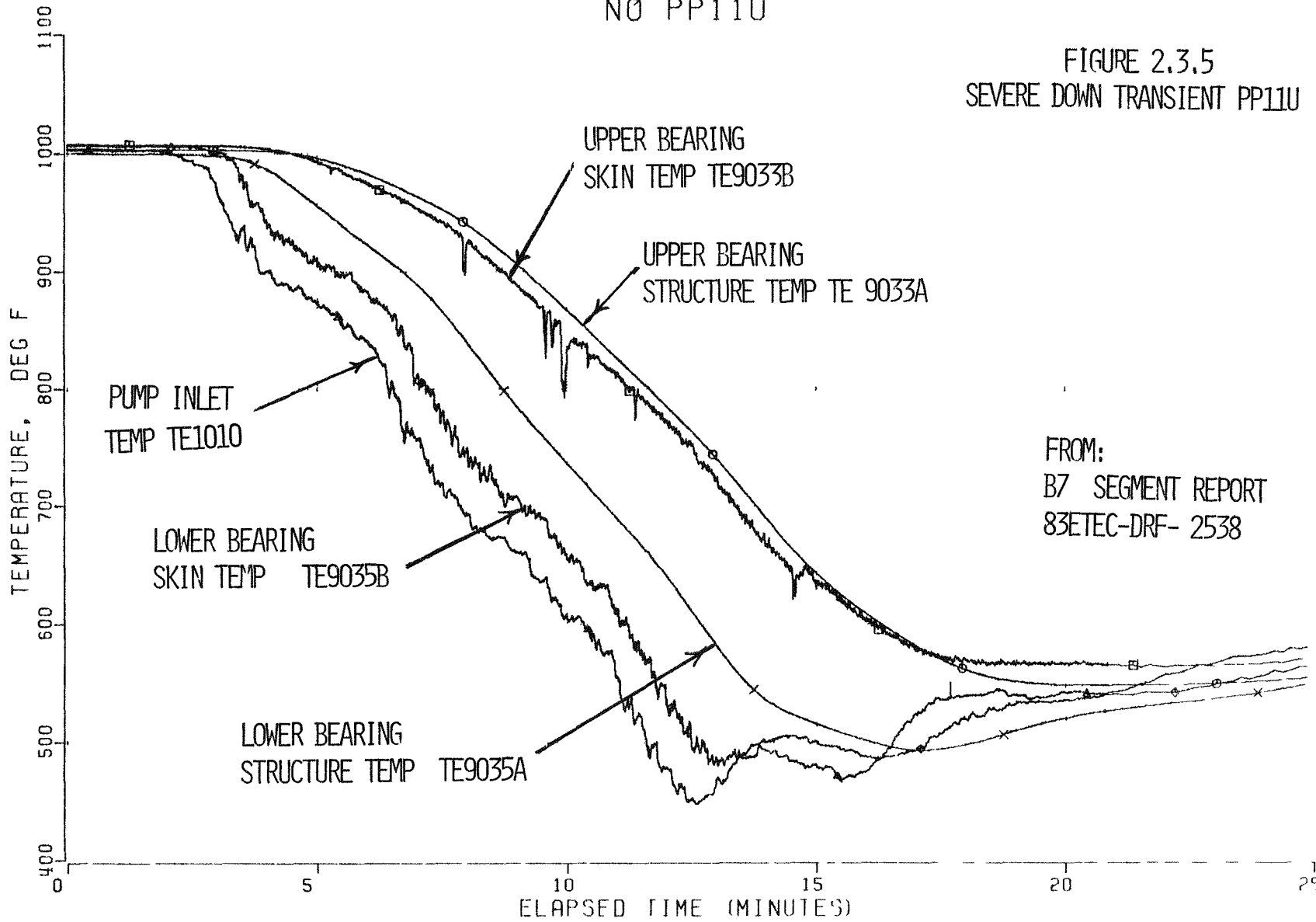
Figure 2.3.4  
Severe Down Transient PP2U, -415°F

ETEC DATA PLOT

CRBRP PROTOTYPE PUMP  
SEVERE THERMAL TRANSIENT  
NO PP11U

▲ TE-1010 DEG F	SEC	199
● TE-9033B DEG F	SEC	203
○ TE-9035B DEG F	SEC	204
□ TE-9034A DEG F	SEC	624
× TE-9035A DEG F	SEC	626

FIGURE 2.3.5  
SEVERE DOWN TRANSIENT PP11U



FROM:  
B7 SEGMENT REPORT  
83ETEC-DRF- 2538

PLOT # 2 FROM FILE P258 ON 10/4/83 AT 8:33

57

DRY 11/11/82  
HOUR 13  
MIN 40  
SEC 00  
MSFC 0

11/11/82  
13  
45  
00  
0

11/11/82  
13  
50  
00  
0

11/11/82  
13  
55  
00  
0

11/11/82  
14  
00  
00  
0

11/11/8  
14  
5  
00  
0

DRY  
HOUR  
MIN  
SEC  
MSFC

## 2.3 Continued

### Discussion/Observations Regarding Transient Testing

It was found that the facility was capable of applying the defined transients, with two problem areas:

- ° The facility could not apply a fast rate of change of temperature if the test loop flow rate and temperature was low. The upper capability was about 1.5°F/sec when flow rate was 2680 gpm (8.5% of nominal). Limitations resulted from low test loop-to-feed tank temperature difference (minimum feed tank temperature was 400°F) and maximum injection flow capability.
- ° On large Delta T's there was a tendency to run out of supply tank fluid at the end of the transient. When this happened, the pump inlet temperature would bounce back from the specified end test temperature.

The criteria for successful transient application was defined as follows:

The applied transient was considered to be controlled (acceptable) if the ramp rate was within  $\pm 30\%$  of the specified valve over at least 60% of the total delta T span.

Four thermocouples were installed on the pump hydraulic case assembly, two associated with the upper bearing and two with the lower bearing. In each case one of the thermocouples lies on the surface and provides a measure of the skin and local sodium temperature while the other is embedded two inches deep in the bearing support web metal and is labeled structure temperature (See Figure 2.3.5)

The Test Request required that the end thermal transient temperature be held for at least 30 minutes. The reason for this is that it takes considerable time for some parts of the pump to change temperature.

#### Conclusions:

The pump was able to accommodate the progressively more severe thermal transients, which included a range up to +250°F (600°F to 850°F) and -500°F (1005°F to 500°F), with no indication of impaired performance.

## 2.3 Continued

There is a time lag of approximately four minutes in the response of the upper bearing skin temperature with respect to the lower bearing skin temperature, while the time lag in the respective metal temperature is only three minutes. (See Figure 2.3.5)

These tests provided records of several internal pump temperatures with time after the transient event and such records are available in the several test segment reports.

Note: Large positive thermal transients were not applied because the pump journal shaft side flow holes were not configured for the IHTS pump configuration. IP3U, a +350°F transient (600°F to 950°F) was therefore not tested and qualification of this design for that transient is by analysis.

## 2.4 Cellular Convection Testing

Gas convection cells can be established in the pump region above the liquid sodium, which is normally occupied by pressurized argon. High temperature and high pressure tend to strengthen these convection cells, and their magnitudes and flow paths are affected by geometry. Convection cells may be detrimental to pump operation if the "cells" cause large across-the-tank temperature differentials resulting in tank bending. The cellular gas flow rates are not readily measurable; however, their effect in causing temperature differentials around the tank circumference are measurable via tank mounted thermocouples and the effect on hydrostatic bearing clearance is measurable via the in-sodium proximeters.

Variables which tend to influence the cellular convection phenomena:

	<u>PHTS</u>	<u>IHTS</u>
°Gas Pressure	°2.4 psig; sodium	°93 psig; sodium
°Sodium Temperature	to 1000°F; with	to 650°F; no
°Geometry	thermal shield	thermal shield -
	and shot in	thermal
	radiation shield	insulation in
	°1/4" gap between	radiation shield
	UIS and tank	°1/4" gap between
		UIS and tank

## 2.4 Continued

Instruments to detect the effect of convection cells consisted of rings of twelve thermocouples around the outside of the tank at different elevations, similar rings of thermocouples inside the radiation shield of the UIS, and proximeters on the sodium bearings. Locations of the thermocouples are shown in Figure 2.4.1. Those thermocouples on the outside of the pump tank were spaced every 30° around the tank (identified by ETEC as TE 9053-XX, 9054-XX, and 9055-XX). There was a thermocouple on the wall of the UIS directly adjacent to each tank thermocouple (identified by ETEC as TE 9090-XX and 9092-XX). Proximeters, located on both upper and lower bearings provided an indication of bearing gap closure due to tank bending. Gap closure does not occur until the tank cone assembly has been deflected enough to touch the inner structure at the controlled clearance cone, and the amount of bearing gap closure is, of course, influenced by whether the shaft is non-rotating, at pony motor speed, or is at some main motor speed. All tests were run with argon except that during off-normal (trouble shooting) activities to investigate cause of the convection cells, helium was used. The purpose of the helium test was to reduce convection inside the pump tank and thereby to determine whether the cause of the temperature assymetry was on the outside, in the space between the tank and the thermal insulation, or whether the assymetry was caused by pump internal gaseous convection cells in the upper half of the pump.

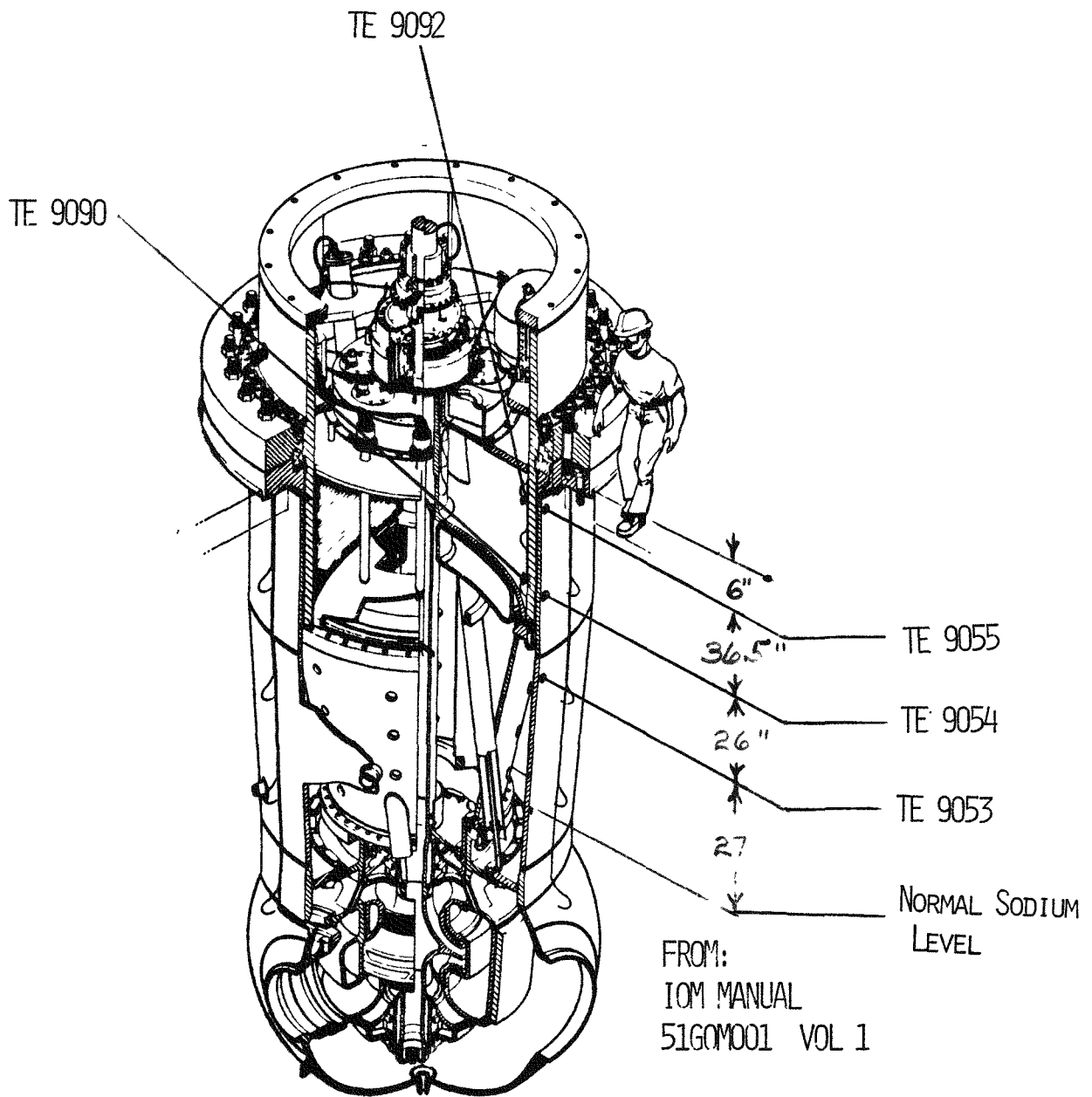


Figure 2.4.1  
Location of Thermocouple Rings for Convection Cell  
Differential Temperature Measurements

## 2.4 Continued

In this test program, there were three cellular convection tests:

- o Segment A11 - Low Temperature Gas Convection Test
- o Segment B1 - High Temperature Gas Convection Test
- o Segment C12 - Cellular Convection Fix Evaluation

In Segment A11, the sodium temperature was established at 470°F, in B1 at 775°F, in C12 at 650°F. The pump supplier had predicted in EM0288, "Cellular Convection Criteria", dated Dec. 14, 1978, that in the PHTS loops, where the pump cover gas pressure is 2.4 psig with sodium at 1000°F, the effect of cellular convection (on tank bending) would be negligible, but in the IHTS loop, where pump gas pressure is 93 psig, this analysis was indeterminant.

The significance of convection cell induced bending is the threat to operation on pony motor for decay heat removal -- since the restorative force of the hydrostatic bearing is low at low operating speeds, a severe tank delta T and its resultant tank bending may cause hydrostatic bearing touch down. Therefore, if cellular convection tank bending is large enough, it could result in journal bearing contact and possibly prevent operation on pony motor.

Initially, the pump supplier established a 60°F differential across the tank (180° apart) as the upper limit for operation. However, since the bearing proximeters provided visibility of the start of bearing gap closure, it was possible to conduct tests investigating the cellular convection effects up to a near journal to bearing touch down. Limits for the tests were subsequently revised to 90°F differential, or, if bearing gap proximeters were operating, a limit of 15 mils orbit (75% of nominal operating 20 mil radial gap) from center was the eventual applied limit, which would occur at about 150°F tank delta T.

## 2.4 Continued

The objective of all three of the cellular convection tests (A11, B1, & C12) were to verify that IHTS loop cover gas pressure, in combination with thermal energy from the sodium fluid in the tank and inner structure temperature gradients do not induce tank bending which would result in bearing to journal rubbing. Further, the objective is to determine the magnitude of temperature gradients for pressurized and unpressurized condition since the gap closure relationship to tank skin temperature distribution is measurable on the prototype pump, but not on the plant pumps, where there are no bearing gap proximeters and fewer tank skin thermocouples. Note that the cellular convection fix was installed for Segment C12.

### CELLULAR CONVECTION TEST RESULTS

#### Segment A11 Results

- o At the start of the test, with internal gas pressure at 0.5 psig, the temperature variation around the tank at the 42.5 inch (below flange) location was about 15°F from the average. (83ETEC-DRF-2490 Page 9).
- o During initial pressurization (in 31 psig steps to 93 psig) the convection cells caused a tank differential (measured at 42.5 inches below the flange) to reach the 60°F limit before thermal stability was achieved. The testing was discontinued pending resolution of insulation installation questions and possible limit relaxation.
- o The insulation was examined via optical pyrometer and rework of a hot spot completed. This reduced external heat loss assymetry as a possible cause of the observed tank surface temperature assymetry.
- o Limits were revised to permit 90°F Delta T or a 10 mil bearing gap loss.
- o To determine whether the convection cells were caused by pump internal conditions or by insulation, tests were run using helium at several pressures, including 93 psig. The results at 93 psig indicated a 33°F tank differential. (Because of its fluid physical properties, helium is much less likely to establish strong convection cells).

## 2.4 Continued

- o A retest with Argon to 93 psig with bearing gap monitoring disclosed that tank assymetry build up was at about 20°F per hour, with two pair of cells. At 4 hours into the test the circulation changed to one pair of cells, with a single hot spot at 240° azimuth and a single cold spot at 90° azimuth; there was a change in  $\Delta T$  buildup to about 7°F/hour. The test was terminated after 12 hours with a tank  $\Delta T$  of 161°F, and with the  $\Delta T$  still rising. Journal traverse in the bearing was in the order of 10 mils with upper and lower bearings moving in opposite directions.
- o A special test was subsequently run with sodium at 600°F and at the IHTS pressure of 93 psig. The pump was run on minimum main motor to provide ample bearing restorative forces. The results yielded a 216°F tank differential with a single pair of cells.

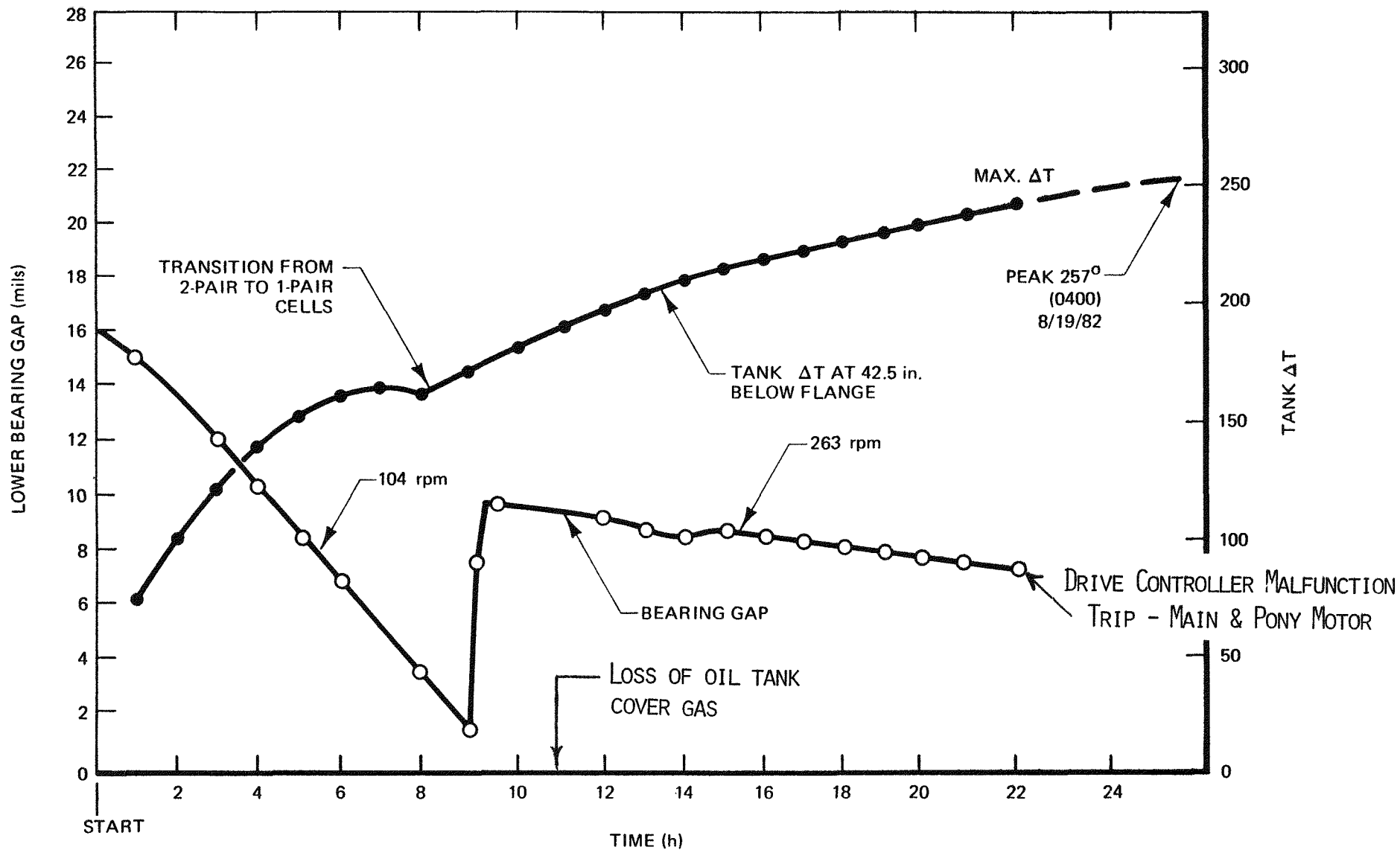
Average value of shaft turning torque ranged from 46 to 58 in lb; breakaway torque ranged from 80 to 90 in lb. No increases in these torque values were noted as cover gas pressure was increased.

The conclusions of the A11 tests were:

- o At PHTS pressures there is no detrimental cellular convection effects.
- o At IHTS argon gas pressures, in a pump without baffling between the UIS and the tank, gaseous convection cells will exist which can cause bearing deflections of sufficient magnitude to jeopardize the hydrostatic bearing during pony motor operation.

### Segment B1 Results

- o With sodium at 775°F, the pump was pressurized to 93 psig, and the tank differential increased at an initial rate of about 20°F/hour; there was evidence of bearing gap reduction at a rate of about 2 mils per hour. (775°F is the intermediate pump design temperature. The normal operating temperature is 650°F).
- o Figure 2.4.2 shows the increasing tank skin differential temperature versus time after pressurizing to 93 psi, and shows the closure of the gap of the in-sodium bearing resulting from the tank differential temperature (tank bending) while on pony motor and main motor at low speed.



83-413-10

Figure 2.4.2 TANK DIFFERENTIAL TEMPERATURES AND BEARING GAP (93 psig PRESSURIZATION, WITHOUT CONVECTION BAFFLES) SEGMENT B1

## 2.4 Continued

- o At about 8 hours into the test, the pattern of tank temperature differentials showed a change, postulated to be a transition from 2 pairs of cells to 1 pair.
- o At 9 hours into the test it was necessary to switch from pony motor to minimum main motor speed (to provide greater bearing stiffness) because the proximeters were indicating a very small bearing gap. A speed of 263 rpm caused the shaft to recenter by about 9 mils.
- o At 11 hours into the test a loss of pressure to the shaft seal lube oil supply tank was experienced; pressure was restored in 28 minutes with no immediate impact on this test (Reference Unusual Occurrence Report #ETEC-82-11-SCTL-82-01, Failure of Gate Valve HV-1004B, August 25, 1982 Initial, November 1, 1982 Final). Unknown at the time of occurrence, this incident caused damage to the shaft seal bumper bearing, (disclosed during subsequent disassembly).

This event occurred after the convection cells had established a tank skin delta T above the threshold for journal to bearing touchdown (threshold is 180°F based on Figure 2.4.2). The event caused overheating in the seal cartridge and forced an oil transfer from the shaft seal cartridge back to the supply tank. Instrumentation of the shaft seal oil temperature, seal housing vibration, oil supply tank oil level, oil tank cover gas pressure, and Vertical Drive Motor current provided information of the sequence of events following the loss of cover gas pressure at the oil tank. Date of occurrence was near midnight 8/18/82 and the first half hour of 8/19/82.

<u>Sequence Item</u>	<u>Time</u>
1. Loss of Oil Tank Cover Gas	23:50 ½
2. Start of Oil Level Rise in Supply Tank	23:51
3. Start First Power Surge	00:11 ¼
4. End First Power Surge	00:15
5. Oil Tank Cover Gas Restoration	00:18

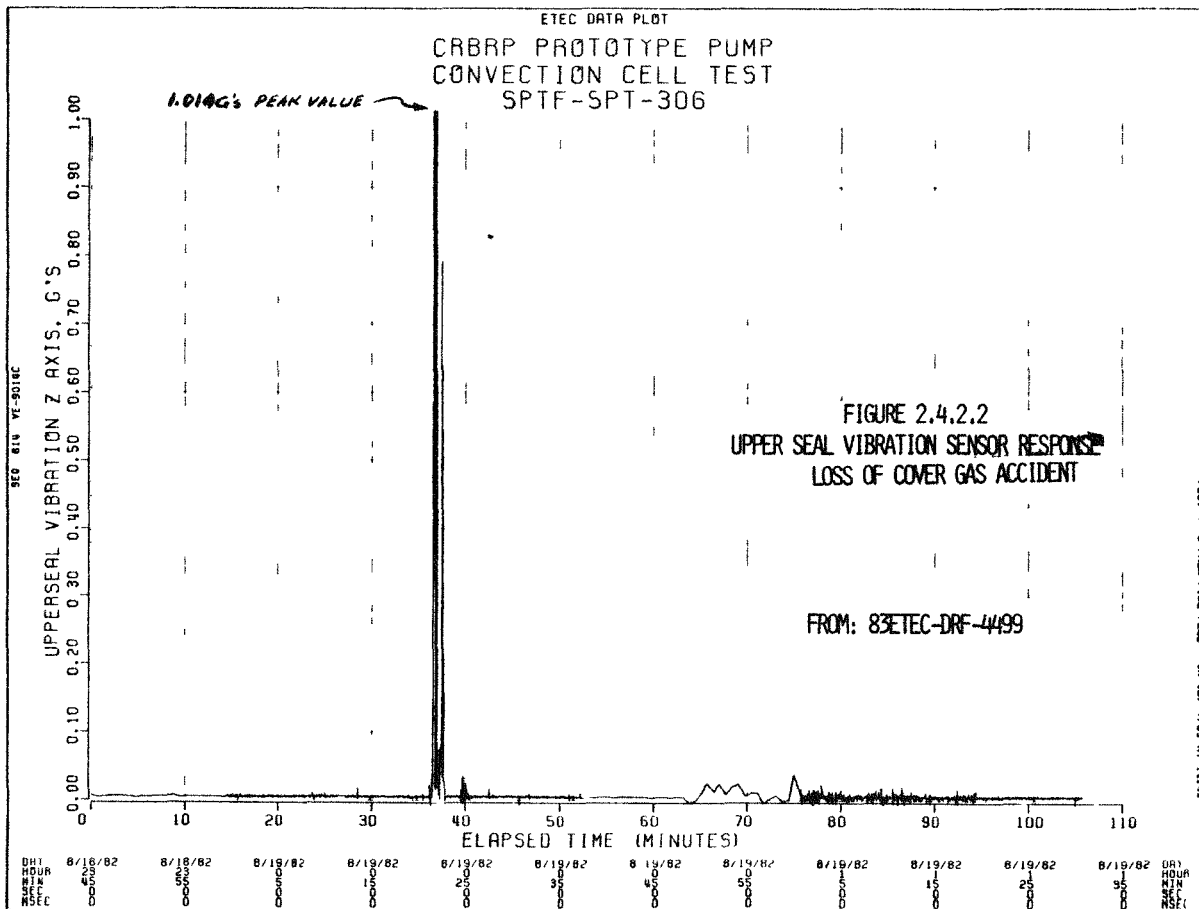
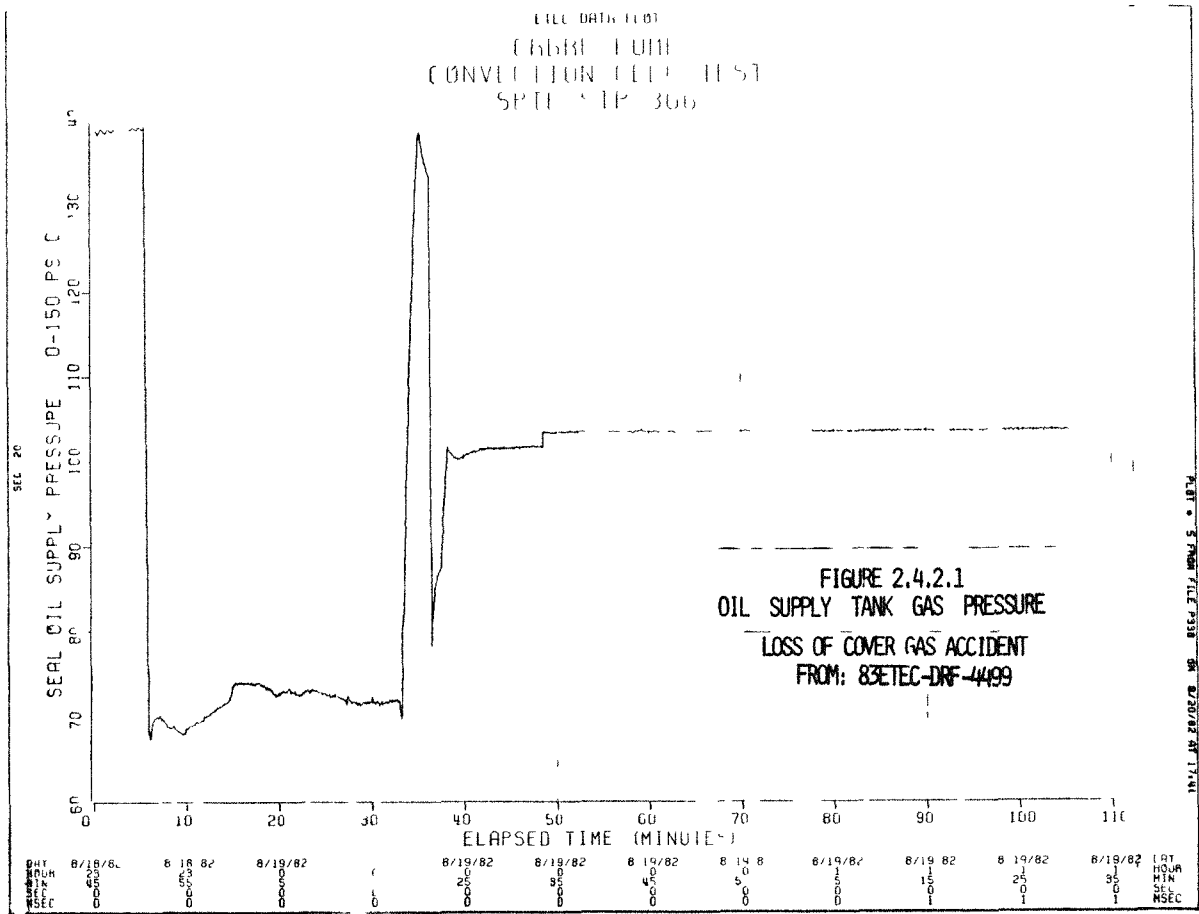
<u>Sequence Item</u>	<u>Time</u>
6. Start Oil Flow Back to Seal (Supply Tank Oil Level Drop)	00:18 +
7. Start Second Power Surge	00:19 ½
8. Peak Oil Temperature (Lower Seal)	00:20
9. End 2nd Power Surge	00:21 ½
10. Seal Z Axis High Vibration Pulse	00:21 ½
11. Complete Oil Flow Back to Seal (Supply Tank Oil Restored Within 10% of Preincident Level)	00:25 +

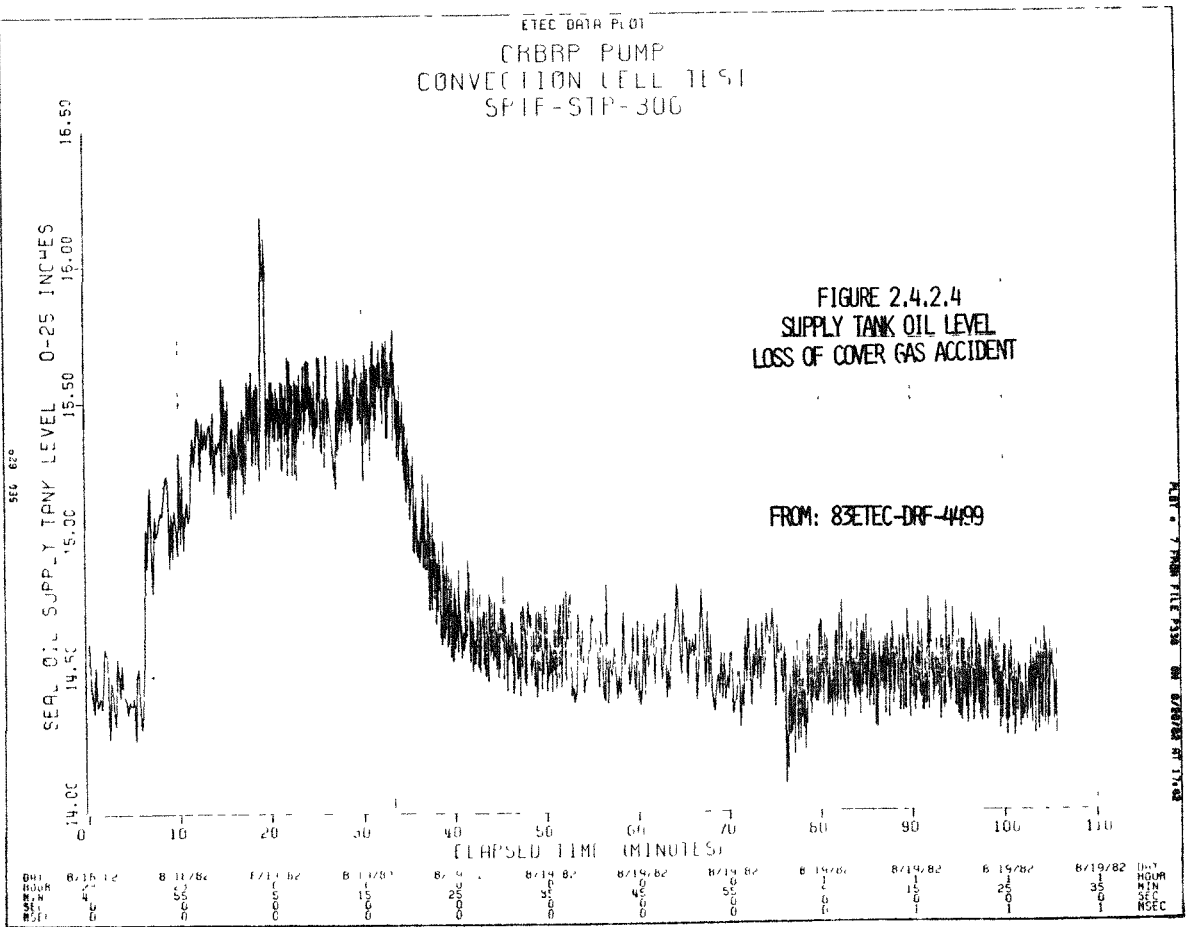
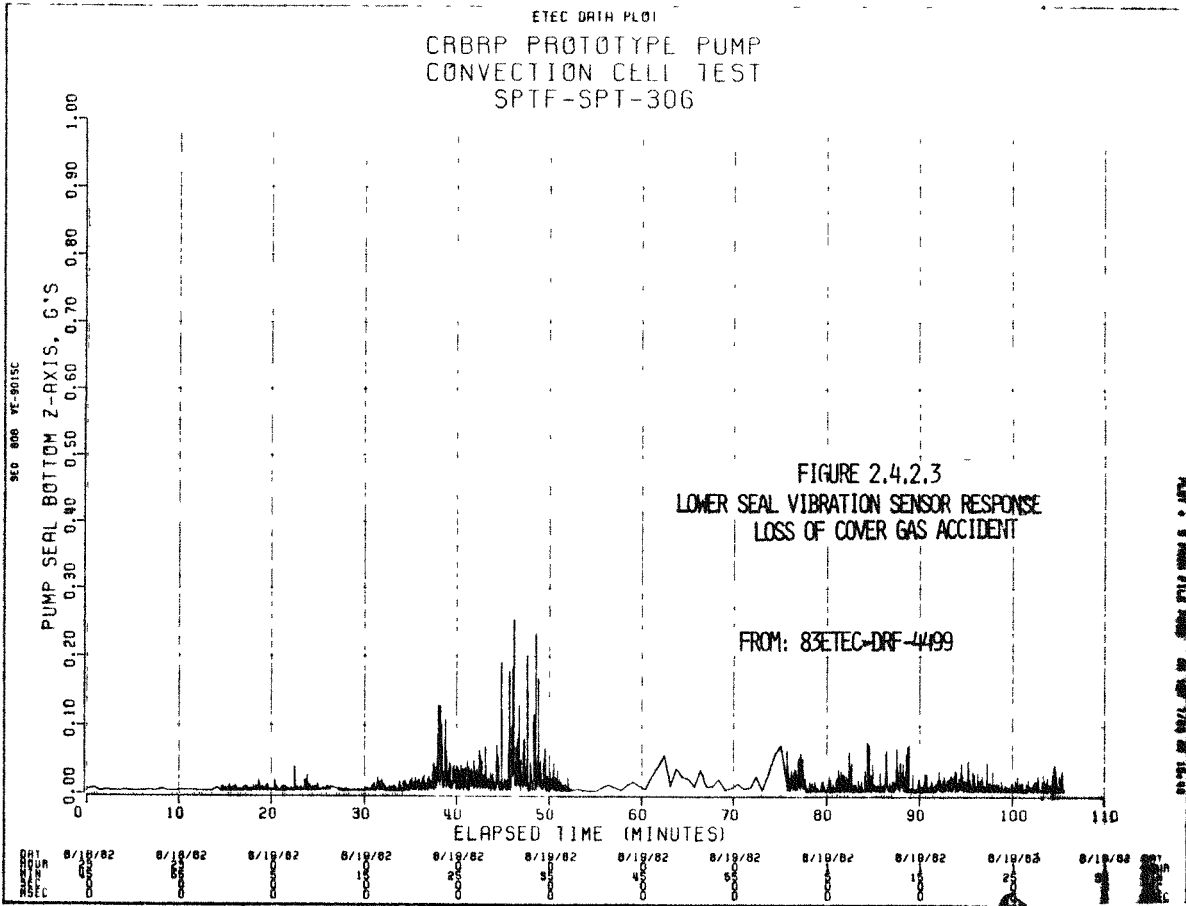
Note that this event occurred with high tank bending (caused by cellular convection) in a pump without the cellular convection baffling. Tank differential temperature at time of the event was 190° (Reference Figure 2.4.2).

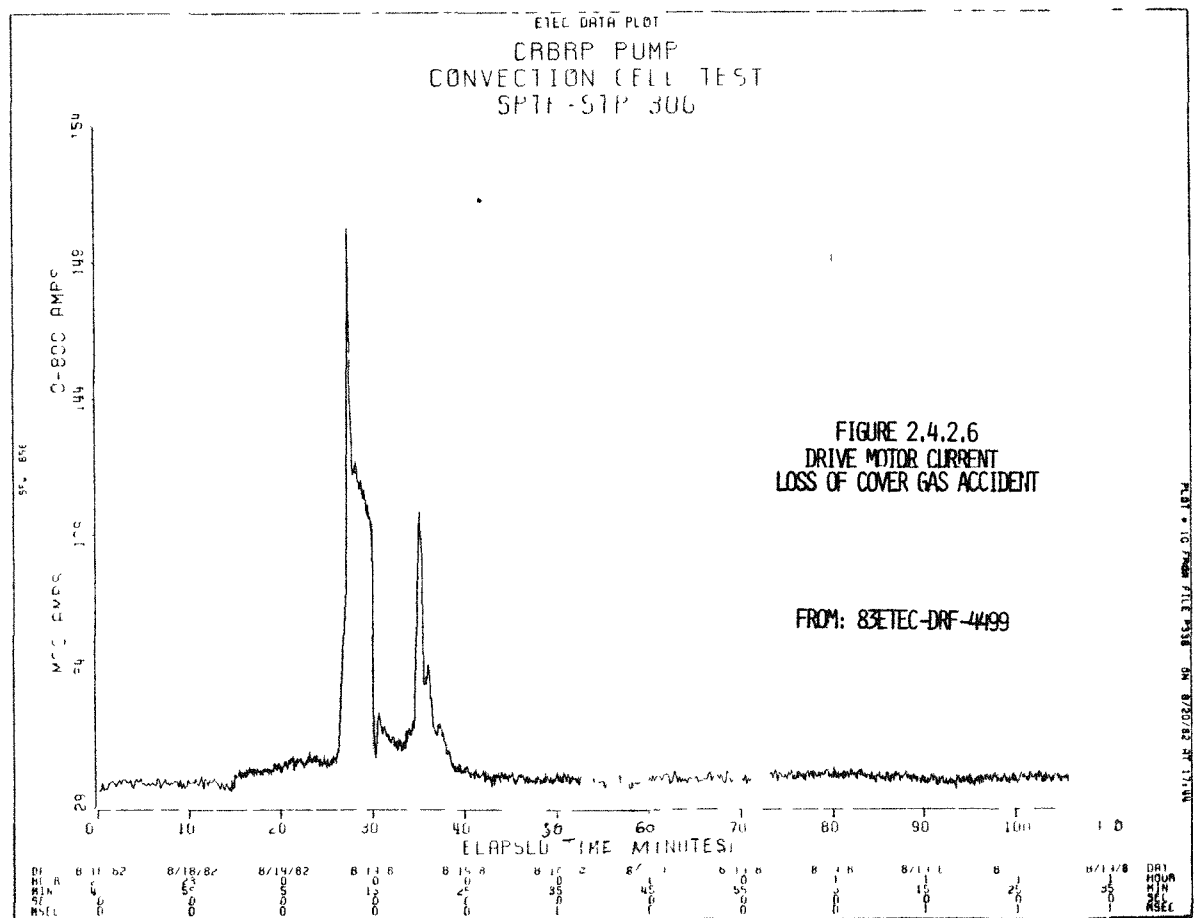
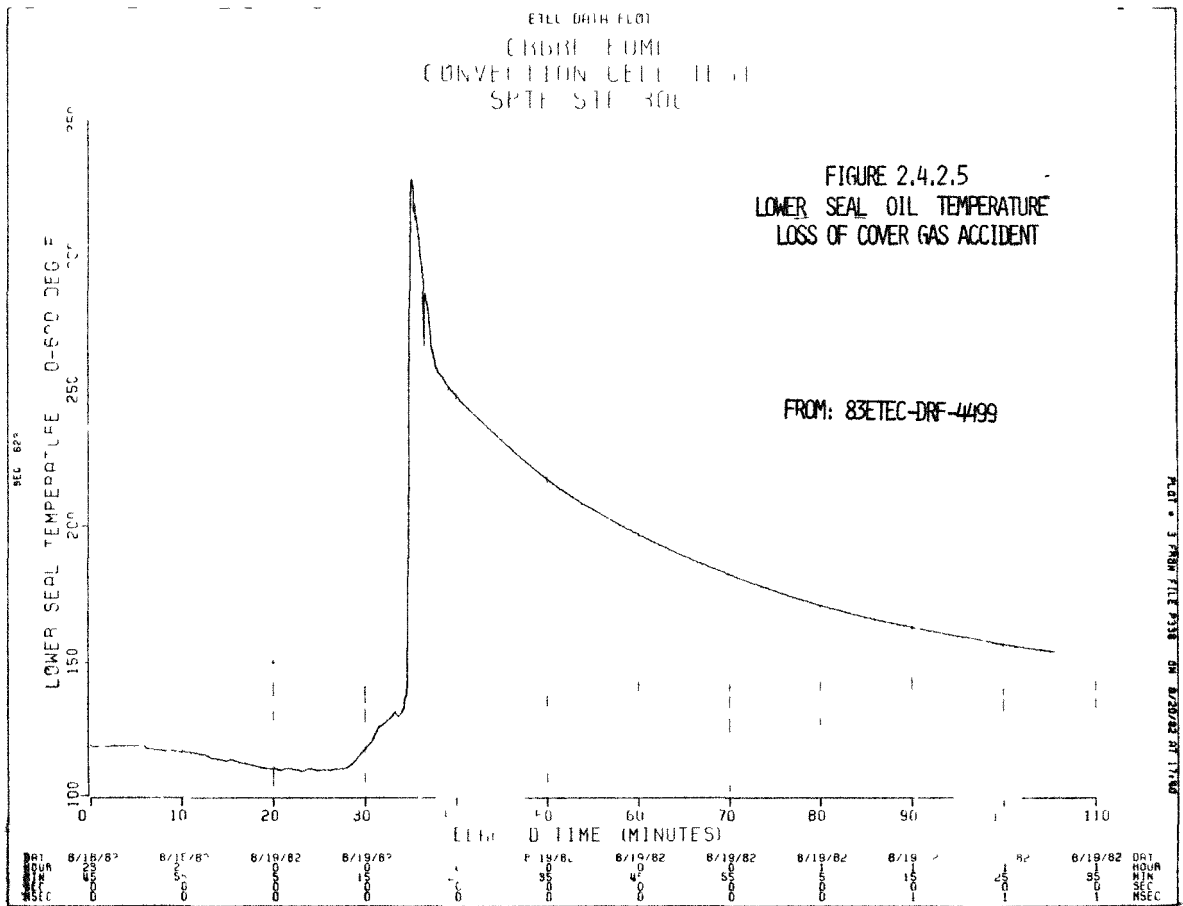
The following figures present the basis for the sequence of events in this loss of cover gas accident:

- Figure 2.4.2.1 - Oil Supply Tank Gas Pressure
- Figure 2.4.2.2 - Upper Seal Vibration Sensor Response
- Figure 2.4.2.3 - Lower Seal Vibration Sensor Response
- Figure 2.4.2.4 - Supply Tank Oil Level
- Figure 2.4.2.5 - Lower Seal Oil Temperature
- Figure 2.4.2.6 - Drive Motor Current

It should be noted that there were two parts revealed to be damaged upon disassembly at the end of Phase B: The bumper stop was grooved and the lower screw pump was damaged. It is believed that the reason for the large vibration pulse in the vertical axis (Figure 2.4.2.2) at the end of the 2nd power pulse was caused by a screw pump engagement which tended to lift the shaft. Note that the only effective alarm whose timing would potentially permit operator corrective action would be an alarm on oil tank cover gas pressure or on supply tank oil level increase. If an alarm were provided on seal oil temperature, seal vibration, on motor current, they are too late to permit operator corrective action.







- o At 23 hours into the test, a transistor in the drive system failed, thereby tripping the main motor off line. ETEC then tripped the pony motor also because of the very large delta T across the tank (which would have caused journal to bearing touchdown at pony motor speed).
- o At 27 hours into the test the tank differential temperature peaked out at 259°F.
- o The pump tank was left pressurized (at 93 psig) and not turning across the week-end (62 hours) to obtain data on the decay of the tank differential temperature.
- o After 105 hours, the tank differential temperature had fallen to 170°F

Test Segment B1 provided data inputs which enabled the pump supplier, along with the Segment A11 data, to verify an analytical model being used to design a fix for the effects of convection cells at the IHTS loop pressures.

At the conclusion of Segment B1, after the tank delta T was down to 62°F, a shaft torque check taken at the upper end of the pony motor revealed 300-400 inch lb. breakaway where 80 was normal, and the lower bearing proximeter was almost showing contact between journal and bearing. In trouble shooting this problem, an attempt to disconnect the motor shaft from the pump shaft (to determine if torque increase originated in motor or in the pump) revealed that the pump shaft would not lower onto the drop down seal in spite of its 5180 lb. weight (This made it impossible to run test segment B14B "Leak Test of Dropdown Seal" with shaft #171222). Recovery from this situation was realized by reconnecting the pump and motor shafts and with normal (2.4 psig) cover gas and low tank differential temperatures (62°F), the pump motor was turned on, resulting in recentering the journal in the sodium bearing. The seal operated satisfactorily for subsequent tests. It was subsequently revealed and reported, as a result of problems encountered during pump disassembly in Segment B15 that the shaft seal had been damaged as a result of the loss of gas pressurization on the oil supply tank. This was the subject of Unusual Occurrence Report #ETEC-83-01-SPTF-83-01, "Damage to CRBR Sodium Pump Shaft Seal Bumper", dated January 7, 1983 Initial, and March 28, 1983 Final. (See Appendix E). In spite of the damage inflicted to the seal bumper bearing and screw pump, it is significant that the seal continued to perform its sealing function from August 19, 1982, (loss of pressure incident) through all of the Phase B tests lasting through December 1982. (The damaged seal was replaced with the unit used during water tests for the follow-on Phase C testing.)

## 2.4 Continued

### Segment C12 Results

As a result of the data of Segments A11 and B1, a design change was engineered, fabricated, and installed for test verification in the Phase C tests. This design change consisted of baffles and filler plates (to reduce the annular gap) attached to the outside the Upper Inner Structure, intended to control the number and position of the convection cells. New proximeters were installed so that journal to bearing gap could be monitored during the test. The configuration was made as nearly identical to the IHTS pump as possible, i.e., no thermal shield, and fiber insulation replacing the shot in the radiation shield. This was different from the pump configuration during Segments A11 and B1 (where shot was used in the radiation shield, and, as per the PHTS configuration, a thermal shield was in place at the top of the lower innerstructure).

Test results indicated that the new baffling and filler plates installed on the O.D. of the upper inner structure was successful in forcing cellular convection to occur in two pair of cells, and effectively control the magnitude of across-the-tank temperatures. At 93 psig, with sodium at 650°F, there was no detectable displacement of the bearings (journal to bearing gap), indicating that the tank bending was not sufficient to deflect the tank cone to contact the inner structure at the controlled clearance cone gap. The maximum horizontal temperature difference was 160°F at points 90° in azimuth apart, and only 48°F at points 180° azimuth apart, compared to 259°F maximum difference at points 180° azimuth apart without the baffle and filler plates.

Pump Supplier drawings which defined the baffling were:

B400001 Rev. B Vertical Baffle Assembly  
B400003 Rev. 0 Field Modification, Cellular Convection Rework  
B300002 Rev. C Filler - Pump Tank - UIS Annulus

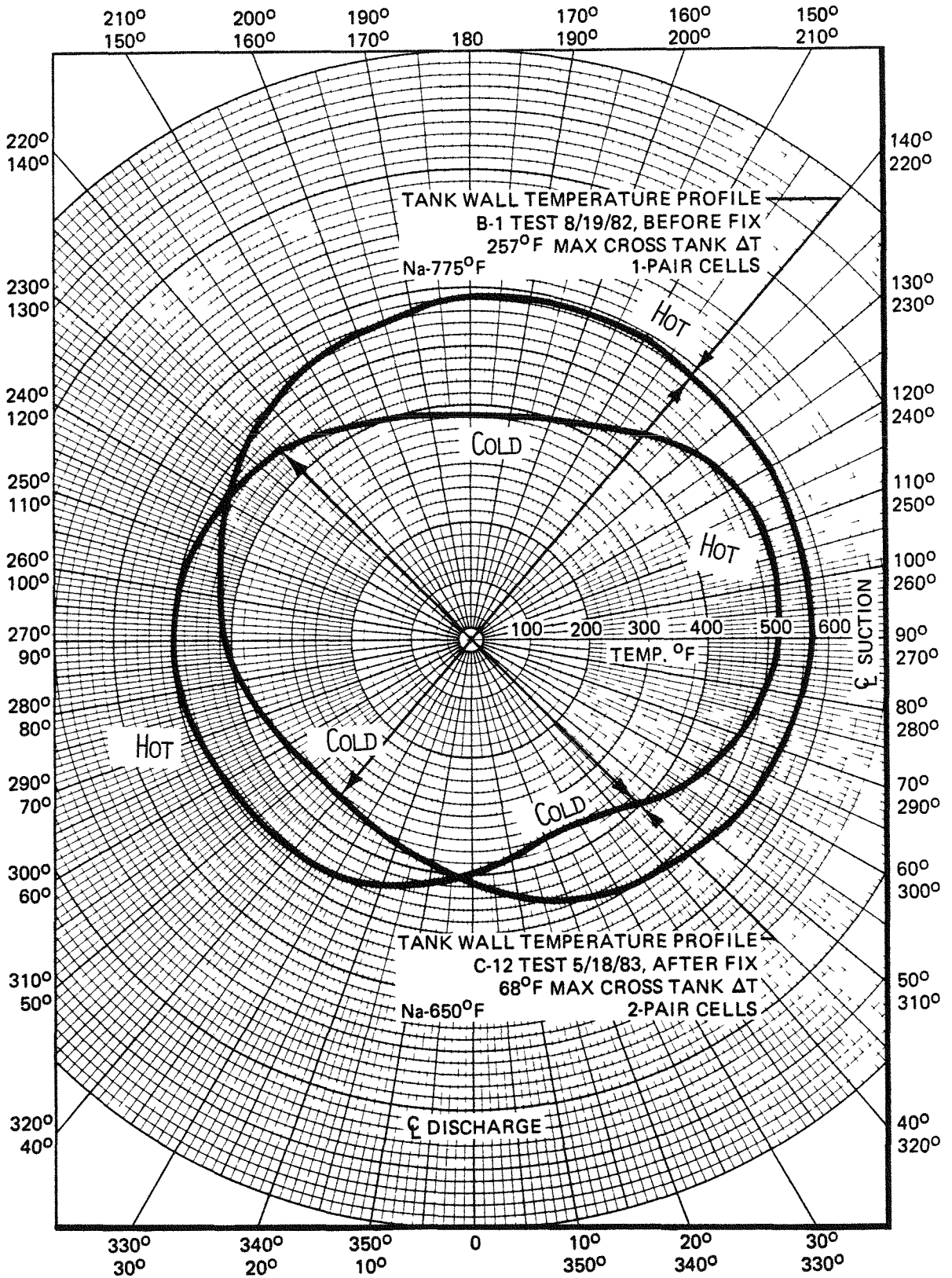
Figure 2.4.5 on Page 75A shows the filler plate and baffling.

Figure 2.4.3 is a polar plot of the tank temperatures before and after baffle installation. Figure 2.4.4 presents the same data in X-Y plot form and show that the magnitude of differential temperature is greatly reduced in Segment C12, where baffles & fillers are installed.

2.4 Continued

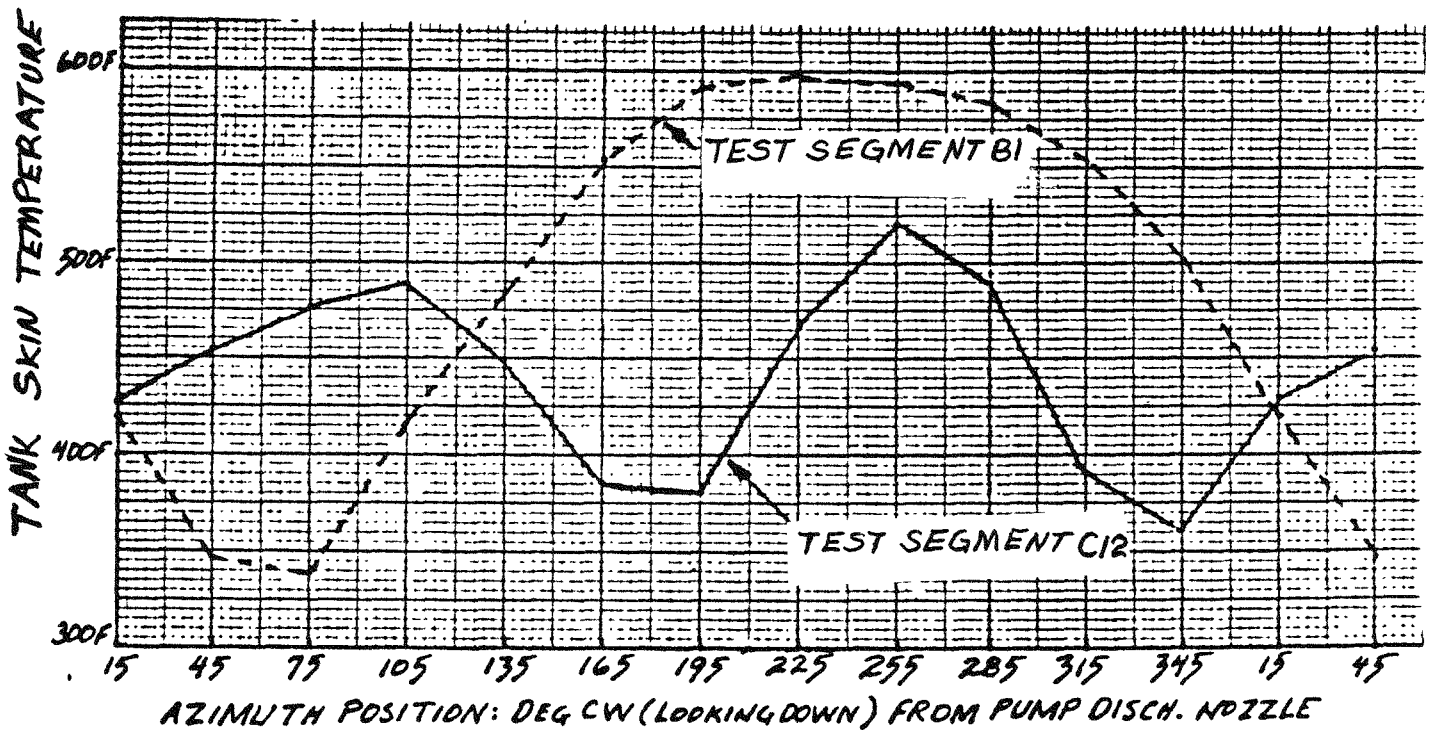
The following is a comparison of the results of Segments B1 and C12:

	<u>Test B1</u>	<u>Test C12</u>
Maximum horizontal delta T From TC's #TE9054	259°F	160°F
Azimuth Pair - Degrees	75-225	345-255
Maximum Diametral delta T From TC's #TE9054	256°F	48°F
Azimuth Pair - Degrees	75-255	195-15



83-413-11

Figure 2.4.3 GASEOUS CELLULAR CONVECTION TANK TEMPERATURE GRADIENTS



PUMP TANK SKIN TEMPERATURES  
 (42.5 " BELOW MOUNTING FLANGE)

FIGURE 2.4.4

FIELD INSTALLATION - ETEC  
THERMAL CONVECTION FIX, PROTOTYPE PUMP

75A

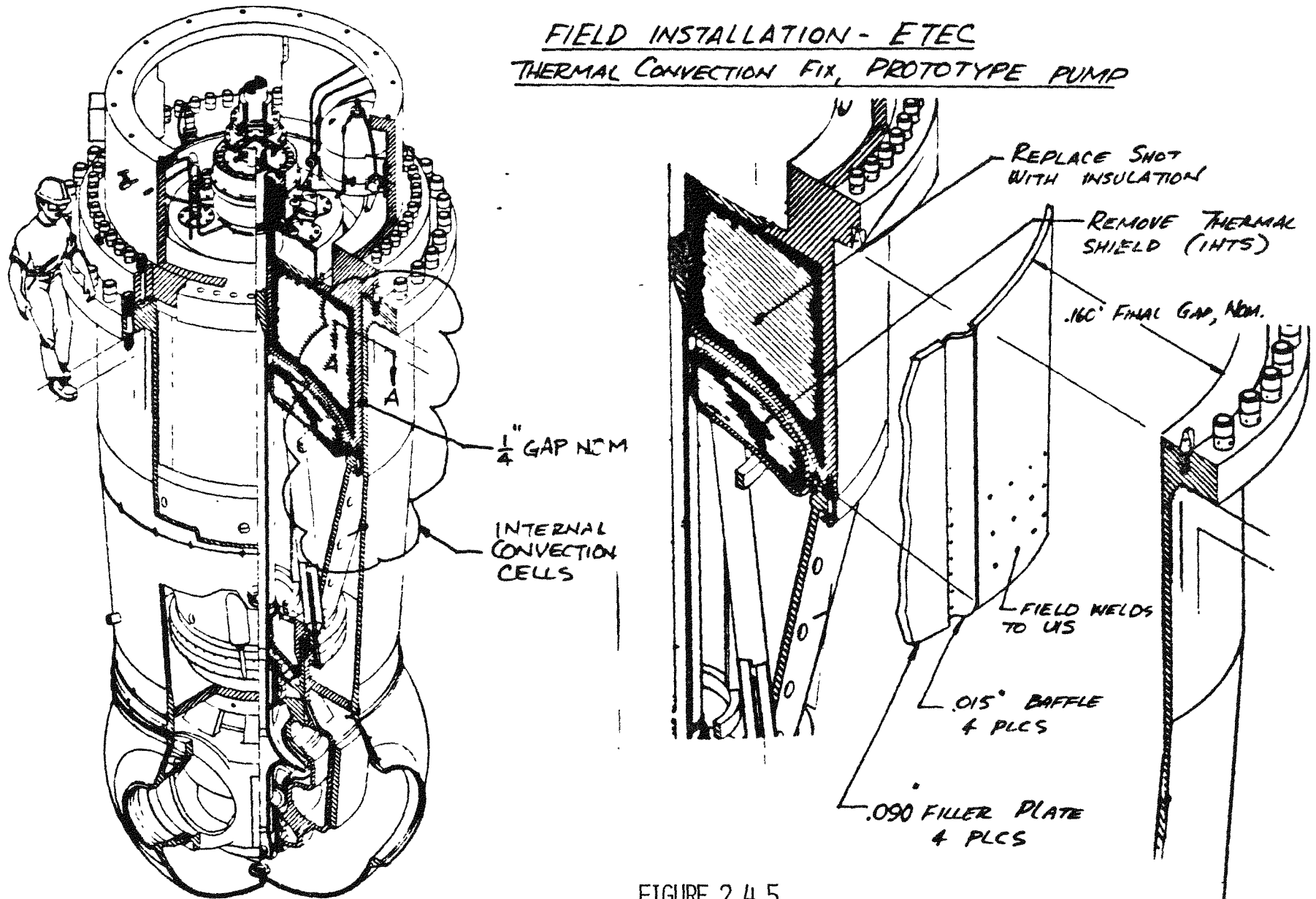


FIGURE 2.4.5  
CELLULAR CONVECTION FILLER & BAFFLING

## 2.5 NPSH & Cavitation Testing

At the plant, the following net positive suction head (NPSH) is available:

Flow (% Rated)	NPSH Available (Ft)
0	54.8
20	54.6
40	54.1
60	53.1
80	52.1
100 (33,700 gpm)	50.6
115 (39,100 gpm)	49.2

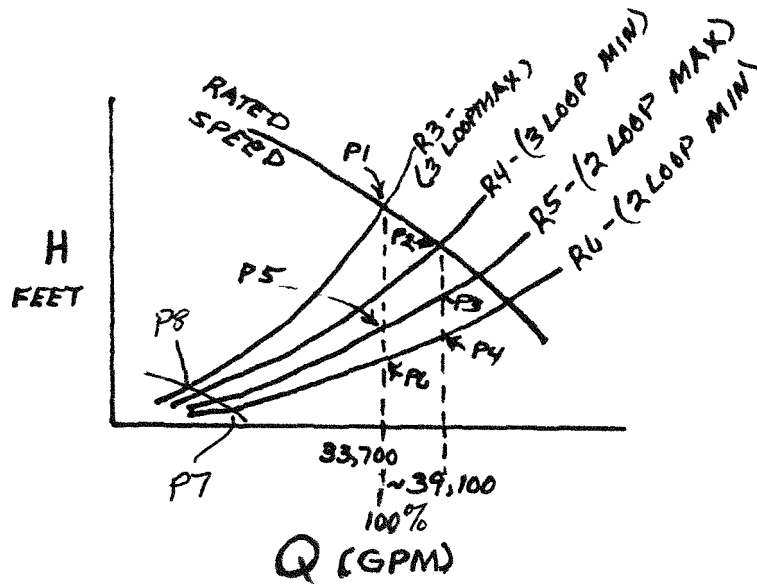


FIGURE 2.5.1  
HEAD/FLOW OPERATING POINTS

## 2.5 Continued

In the above illustration:

- P1 is rated design point, 458 Ft TDH at 33,700 gpm
- P2 is the operating point if plant 3 loop impedance is at minimum ( $.286 \times 10^{-6}$  ft/gpm<sup>2</sup>)
- P3 is a reduced RPM with plant 2 loop maximum hydraulic impedance ( $.2289 \times 10^{-6}$  ft/gpm<sup>2</sup>) and results in 115% of rated flow.
- P4 is a reduced RPM with plant 2 loop minimum hydraulic impedance ( $.1714 \times 10^{-6}$  ft/gpm<sup>2</sup>) and results in 115% of rated flow.
- P5 is a point at 33,700 gpm with reduced RPM with 2 loop maximum hydraulic impedance.
- P6 is a point at 33,700 gpm with reduced RPM with 2 loop minimum hydraulic impedance.
- P7 is minimum main motor speed (251 RPM) at 2 loop minimum hydraulic impedance (R6)
- P8 is minimum main motor speed (251 RPM) at 3 loop maximum hydraulic impedance (R3)

The pump supplier (ER1064 Fig. 5.2.2.1) indicated that an NPSH of at least 40 feet would be required for cavitation free operation up to 39,000 gpm flow, however, sustained operation at this point was not permitted in water test because the higher density of water caused an excessive motor power drain using the same Drive System as specified for CRBRP.

The requirement per System Design Description SDD51 A is that there shall be no cavitation at point 1 with 50.6 NPSHA, at point 2 with 49.2 NPSHA, at point 5 with 50.6 NPSHA, and at point 6 with 50.6 NPSHA. Note that operation of the plant on two loops is on hold in the System Design Description.

The requirement in the pump E-Spec is more stringent than the SDD: It requires cavitation free operation at P1 with 50.6 ft NPSHA, and at P2, P3, & P4 with 49.2 NPSHA. This includes operation at the intersection of the H-Q full speed curve and R4 (about 39,100 gpm) and at this flow on 2 loop minimum impedance at reduced speed. (See Figure 1.0.1.2).

The following tests were initially planned:

- ° Segment A14 - Low temperature NPSH tests
- ° Segment B9 - High Temperature NPSH tests

As a result of data collected in the above tests, an additional segment was added when the 38.25 inch diameter impeller was tested.

- ° Segment C11 - Cavitation Tests

2.5 Continued

In Segment A14, the sodium was at 600°F and the impeller was the 37.5 inch diameter. With a spread of 9 ft. between NPSH available (49.2 ft.) and the pump suppliers predicted NPSH required (40 ft), it was believed that no difficulty would be encountered if the check for cavitation (via the developed pressure drop method [3% head reduction]) was accomplished at 45 ft. The segment called for operating at points P1, P2, P3 and P4 with normal plant operation cover gas pressure, then reducing gas pressure until NPSH at the suction nozzle was 45 ft., and determine if there was evidence of pump developed pressure drop (the 3% loss method).

Test Results:

Segment A14, NPSH Test at 600°F with rotating assembly #171222 which had a 37.5 inch impeller: There is no cavitation at operating points P1, P2 and P3 with 45 ft. of NPSH.

At point P4, (R6 impedance at 39,100 gpm) the following results were measured:

Developed Head w/20 psig Cover Gas	Developed Head (ft) at Reduced NPSH	H	% Head Reduction (from 20 psig cover gas condition)
271.75	105	-	-
271.75	52.5	264.25	2.7
271.75	45	258.72	4.8

In performing this test, ETEC found it necessary to establish a non cavitating baseline against which to compare results. To do this, ETEC added to the test requirements the measuring (mapping) the H&Q data with 20 psig cover gas. The above data indicated that operation at 39, 100 gpm at the plant 2 loop minimum impedance was marginal: From the above, it would be expected that an NPSH of 49 feet at the R6 - 115% flow points would yield a developed head reduction in the order of 3.5 to 4% .

Segment B9, NPSH Test at 1005°F with rotating assembly #171222, which had a 37.5 inch impeller: Non cavitating results were first recorded with 20 psig cover gas pressure to provide a baseline of developed head for each point which could then be compared against the developed pressure with the reduced cover gas pressure.

## 2.5 Continued

In Segment B9, with sodium at 1005°F, non cavitating performance was established with a cover gas of 20 psig (105 ft. NPSH) at normal cover gas pressure (approximately 55 ft NPSH), then at reduced pressures of 49 ft. and at 45 ft.

### Test Points:

<u>Point</u>	<u>Condition</u>
1	100% Speed, R3 (3 loop max. R), 33,700 gpm
2	100% Speed, 39,100 gpm
4	990 RPM 39,100 gpm at R6 (2 loop min. R)
8	Min. Main Motor Speed (251 RPM) and R3
7	Min. Main Motor Speed (251 RPM) and R6

### Results:

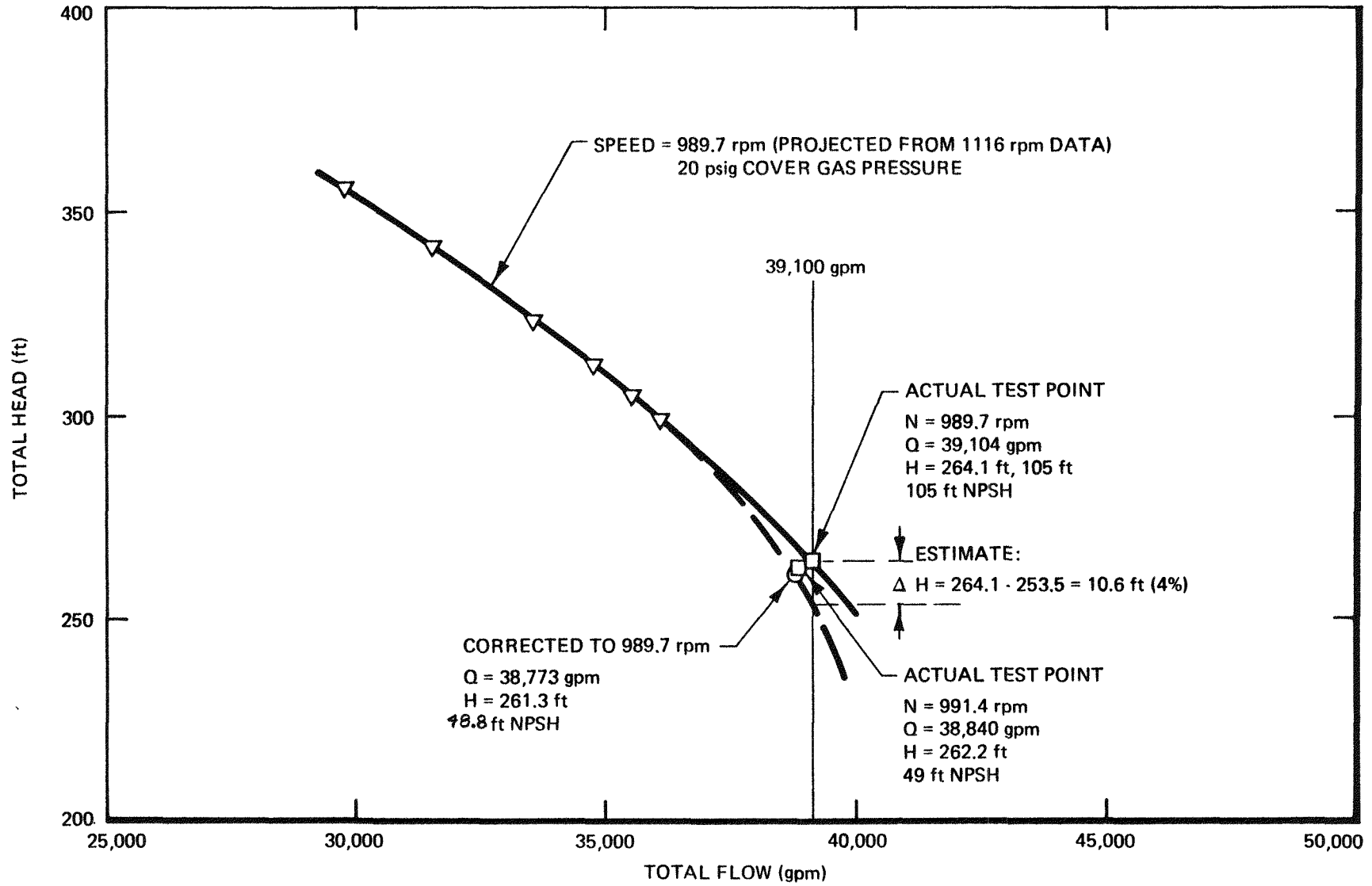
<u>Conditions</u>	<u>Test Points</u>				
	<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	<u>7</u>
o Head at 20 psig Gas Press.	452.6	396.5	264.13		
o Head at Normal Gas Press.	453.6	397.1		17.3	23.3
o Head at 49 Ft. NPSH	451.7	396.4	253.5		
Head Loss at 49 Ft. (%)	.41	.11	4.0		
o Head at 45 Ft. NPSH	451.3	395.4	248.0	17.3	23.6
Head Loss at 45 Ft. (%)	.4	.36	6.1		

NPSH available at CRBRP when operating at R6 (2 loop minimum impedance at 39,100 gpm) is 49.2 ft. and the pump has a 4% loss of head at this condition.

This situation as tested at ETEC is plotted in Figure 2.5.2 "Head Droop at High Flow", which plots the head/flow for an NPSH of 49 feet. Vibration sensors VE9012A & B, located in sodium on the bearing showed an increase in vibration level (.05 to .16 rectified RMS) when NPSH was changed from the 20 psig cover gas condition (105 Ft. NPSH) to the 45 Ft. NPSH condition (at R6 and 39,100 gpm).

### Segment C11 Cavitation Test Results

Test Segment C11 (rotating assembly #174848) was run with the 38.25 inch impeller (whereas Segments A14 and B9 were run with the 37.5 inch impeller) and with sodium at 1005°F. In sequence it was run after the cellular convection fix evaluation and after all mapping.



FROM: 83ETEC-DRF-3104 SEGMENT REPORT 7-13-83

83-413-12

ROTATING ASSEMBLY SN 171222  
37.5" DIAMETER IMPELLER

Figure 2.5.2 HEAD DROOP AT HIGH FLOW

## 2.5 Continued

The objective of this test was to determine the NPSH value at which the pump head is reduced by 3% due to cavitation, when operating at 39,100 gpm, sodium at 1005°F, and with loop resistances of R4 ( $286 \times 10^{-6}$  ft/gpm<sup>2</sup>), R5 ( $.229 \times 10^{-6}$  ft/gpm<sup>2</sup>) and R6 ( $.1714 \times 10^{-6}$  ft/gpm<sup>2</sup>).

Data from this test are not directly comparable to the data from Segments A14 and B9, because this test was run with a different impeller. With this larger impeller, the 39,100 gpm flow was reached at a lower RPM (956 RPM versus 1002 RPM for the 37.5 inch impeller). ETEC reported that the impeller shroud profile appeared to be smoother on the 38.25 inch impeller than was the case for the smaller (37.5") impeller used in the A14 and B9 segments.

ETEC points out that the 3% drop off in head does not represent a division between cavitation and non cavitating operation. (The 3% head drop off is simply a measurable drop off point, selected because it is referenced in the Hydraulic Institute Standards. The 3% drop-off method approach is most practical to implement when pump head is decreasing rapidly with small changes in NPSH.

ETEC measured head developed under both increasing and decreasing NPSH, and resulting head was within a 1% band over the range of NPSH values. Speed was controlled to within 2 to 3 RPM, and speed measurement accuracy of the data acquisition system was 0.2%. All head and NPSH data were corrected to the specified speed, using the square of the speed ratio as the correcting factor.

Two test runs were made for the R6 resistance condition because of the drooping shape of the curve as compared to the flat curve with a "knee" exhibited for the R4 and R5 conditions.

### Results of C11 Cavitation Tests:

- o At R6 (two loop minimum) impedance and 39,100 gpm, (corresponding to 955 RPM) an NPSH of approximately 57 feet is required, whereas, at CRBRP for R6 at 39,100 gpm, only 49.2 ft. is available.
- o At R5, (two loop maximum) impedance and 39,100 gpm, (corresponding to 1035 RPM) an NPSH of approximately 40.1 ft. is required, and at CRBRP 49.2 ft. is available (more than required) by the pump.
- o At R4, (three loop minimum) impedance and 39,100 gpm (corresponding to 1115.1 RPM), an NPSH of approximately 40.8 ft. is required and at CRBRP 49.2 ft. is available (more than required by the pump).

CRBRP PROTOTYPE PUMP

CAVITATION PERFORMANCE TEST

at R5 loop resistance  
 39,100 gpm with 1005°F of Na

FIGURE 2.5.3

HEAD VS NPSH AT R5, 39,059 GPM

LEGEND:

- INCREASING NPSH
- DECREASING NPSH

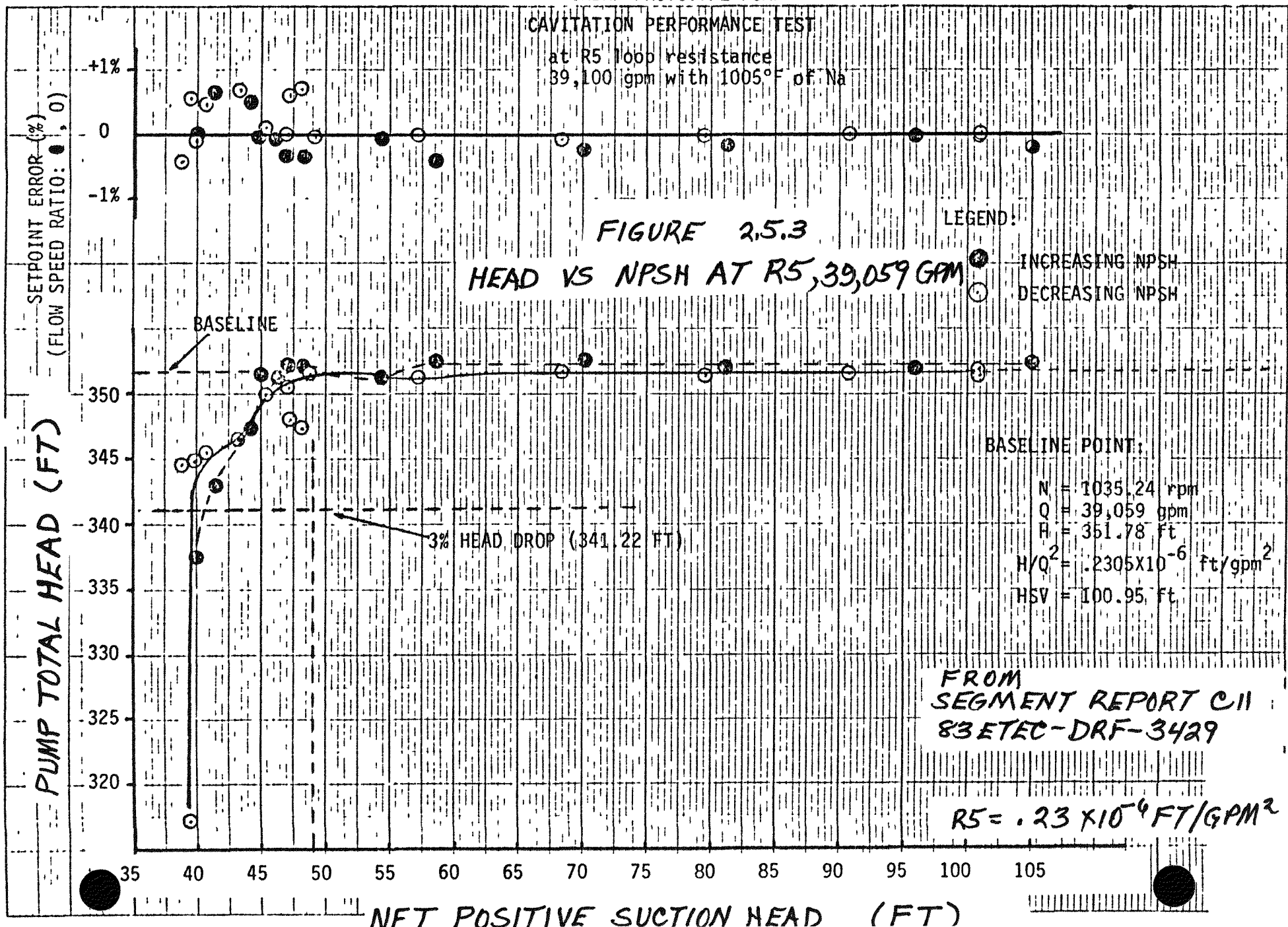
BASELINE POINT:

N = 1035.24 rpm  
 Q = 39,059 gpm  
 H = 351.78 ft  
 $H/Q^2 = .2305 \times 10^{-6} \text{ ft/gpm}^2$   
 HSV = 100.95 ft

FROM  
 SEGMENT REPORT C11  
 83ETEC-DRF-3429

$R5 = .23 \times 10^{-6} \text{ FT/GPM}^2$

82

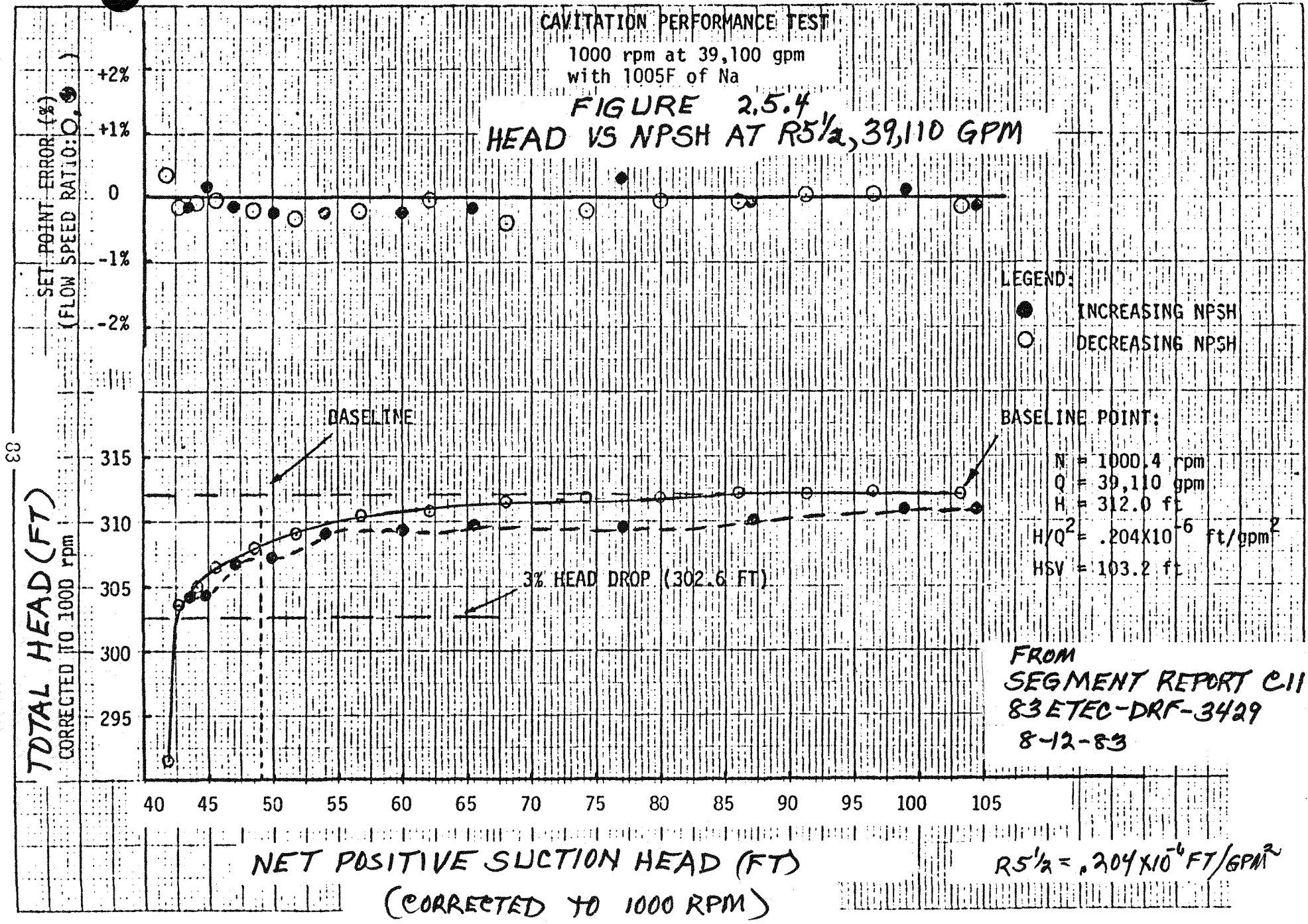


CRBRP PROTOTYPE PUMP

CAVITATION PERFORMANCE TEST

1000 rpm at 39,100 gpm  
with 1005F of Na

FIGURE 2.5.4  
HEAD VS NPSH AT R5 1/2, 39,110 GPM



LEGEND:  
● INCREASING NPSH  
○ DECREASING NPSH

BASELINE POINT:  
N = 1000.4 rpm  
Q = 39,110 gpm  
H = 312.0 ft  
 $H/Q^2 = .204 \times 10^{-6} \text{ ft/gpm}^2$   
HSV = 103.2 ft

FROM  
SEGMENT REPORT C11  
83ETEC-DRF-3429  
8-12-83

$R5 \frac{1}{2} = .204 \times 10^{-6} \text{ FT/GPM}^2$

CRBRP PROTOTYPE PUMP

CAVITATION PERFORMANCE TEST

At R6 loop resistance and  
 39,100 gpm with 1005°F Na  
 (1<sup>st</sup> Run)

FIGURE 25.5  
 HEAD VS NPSH AT R6, 39,262 GPM

SETPPOINT ERROR (%)  
 (FLOW SPEED RATIO: ●, ○)

+2%  
 +1%  
 0  
 -1%  
 -2%

LEGEND:  
 ● INCREASING NPSH  
 ○ DECREASING NPSH

PUMP TOTAL HEAD (FT)

260  
 255  
 250  
 245  
 240

BASELINE POINT:  
 N = 955.2 rpm  
 Q = 39,262 gpm  
 H = 261.8 ft  
 HSV = 102.43 ft

3% HEAD DROP (253.9 FT)

FROM  
 SEGMENT REPORT C11  
 83FTEC-DRF-3429  
 8-12-83

45 50 55 60 65 70 75 80 85 90 95 100 105

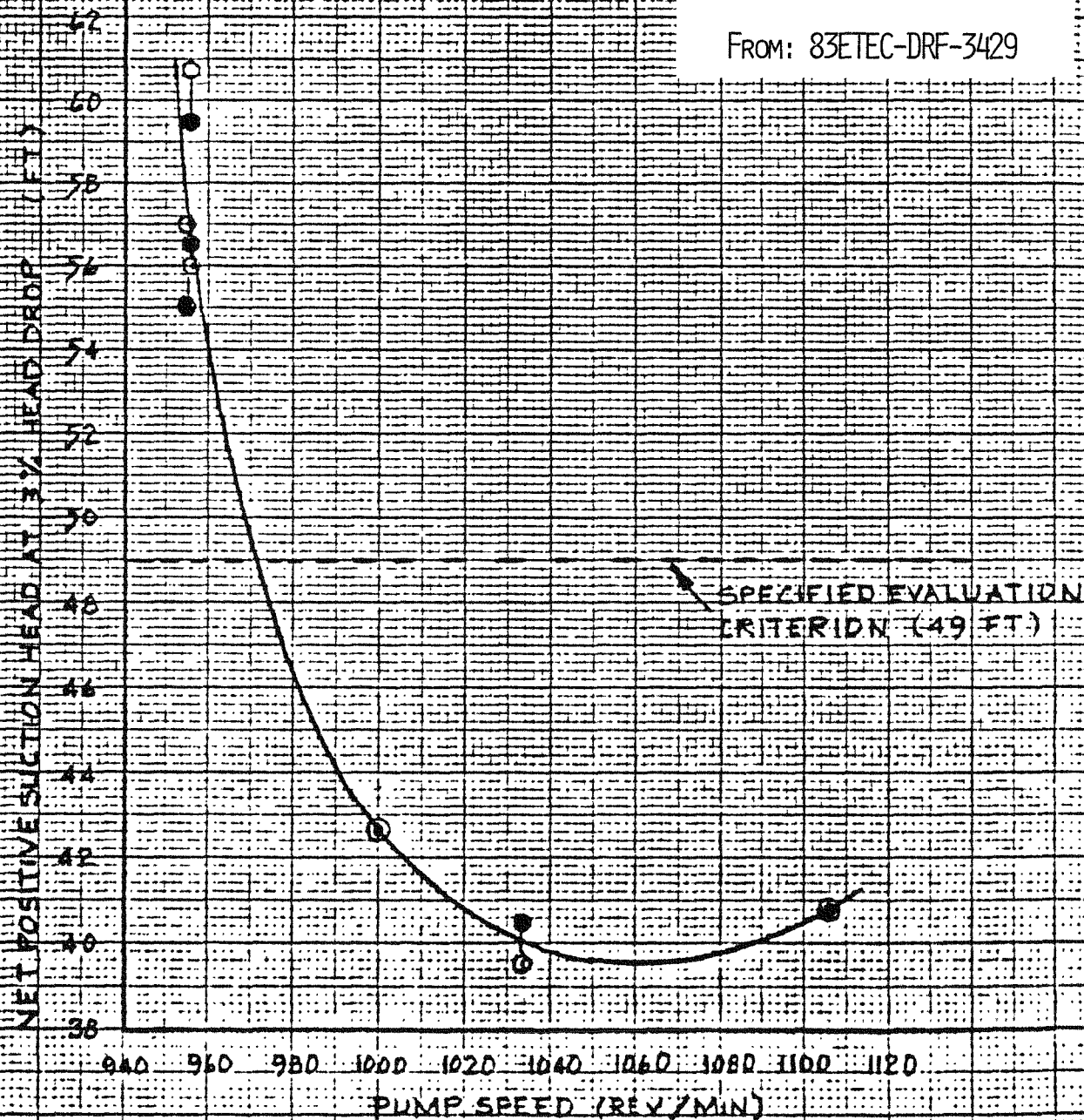
NET POSITIVE SUCTION HEAD (FT)

$R6 = .1714 \times 10^{-4} \text{ FT} / \text{m}^2$

84

CRBRP PROTOTYPE PUMP  
 NET POSITIVE SUCTION HEAD AT 3% HEAD DROP  
 FOR 39,100 GPM OPERATION WITH 1025°F SODIUM

FROM: 83ETEC-DRF-3429



$\frac{(Q/N)}{(Q/N)_{DES}}$	940	960	980	1000	1020	1040	1060	1080	1100	1120
		↑		↑		↑			↑	
		1.35		1.29		1.25			1.16	

FIGURE 2.5.6  
 NPSH VERSUS NORMALIZED Q/N

At a point between R5 and R6, at 1000 RPM and 39,100 GPM, an NPSH of approximately 42.6 ft. is required by the pump, and at CRBRP 49.2 ft. is available (more than required) this operating condition is synonymous with a loop resistance of  $.204 \text{ ft/gpm}^2$  ( $312/(39100^2)$ )

As shown in ETEC prepared Figure 2.5.6 a plot of NPSH vs. normalized Q/N, the optimum speed for NPSH is about 1060 RPM. Operation at speeds above or below this speed will require higher NPSH.

**Conclusion:**

The pump is operating in a slightly cavitating condition at 39,100 gpm and the R6 loop impedance. If CRBRP two loop minimum impedance is at least  $.20 \text{ ft/gpm}^2$  then the pump can operate without cavitation.

## 2.6 Drive & Flow Servo Testing

Drive system tests were run with full pump hydraulic load at R3, plant 3 loop maximum impedance and with sodium at 1005°F.

The objective of this test was to measure the dynamic response characteristics of the pump and drive when responding to commands of step, ramp and sinusoidal inputs to the speed controller with hydraulic loading equivalent to the CRBR Plant. It was also the objective to check on the threshold (sensitivity to a small signal), and to measure speed errors with a steady state control signal input. Following the tests and determination of compliance with the specified performance criteria of the Drive Speed Servo Control, step and ramp response data was to be recorded for the flow servo loop, where the CRBRP Permanent magnet flowmeter provided the flow achieved feedback signal to the servo loop.

### 2.6.1 Drive System Test Results & Conclusions

**Conclusions:** It is concluded that the speed control system meets the requirements specified in the Test Request 22A3551, except that at 725 RPM, the random speed variations was 1.05% as compared to the .4% allowable at 100% speed. (Tests were run at 25% speed rather than at 22% speed because the controls had been temporarily adjusted to prevent operation below 24% so that more function generator electrical segments could be committed at 720 RPM in an effort to minimize the random speed problem.)

(The above random speed error is correctable by rework of a part of the Voith fluid coupler of the M-G Set. The coupler used in this test was returned to the manufacturer for rework. Other units already delivered to CRBRP are to be disassembled and the rework handled by the manufacturers representative following demonstration of the fix during plant pump water tests.

### 2.6.1.1 Drive Frequency Response Test Results

Sinusoidal frequency response testing was conducted by applying a sinusoidal speed command signal to the closed loop system with an amplitude of 2% of design speed and at 10% of design speed. There were three speeds at which these command inputs were applied: 40% speed, 57.5% speed and 90% speed. A Fourier analysis was performed on both command and response signals. The approach was to accumulate a table of closed loop gain and phase angle versus frequency, prepare plots of gain versus frequency, prepare plots of phase angle versus frequency, then use a "Nichols" chart to convert from closed loop to open loop gain and phase versus frequency. The resulting curves for the 40% speed, 2% sinewave are reproduced at the end of this paragraph. The results of the frequency response testing is shown in Table 2.6.1.1, where the terms are defined as follows:

- o Bandwidth - The frequency at which the magnitude of the closed loop gain response has dropped to .707 times its low frequency value.
- o Phase Margin - The additional phase lag (negative phase shift) required at the open loop gain crossover frequency (frequency where gain is 1) to bring the system to the verge of instability (phase shift of  $-180^\circ$ ).
- o Gain Margin - The reciprocal of the magnitude of open loop gain at the frequency where the phase angle is  $-180^\circ$ .

The drive frequency response criteria were:

- o Bandwidth must exceed 0.1 radians/sec
- o Gain margin must be 20db or greater
- o Phase margin must be  $50^\circ$  or larger

As measured at ETEC, the drive speed control system, when operating with the CRBRP 3 loop maximum impedance ( $R3 = .4 \times 10$  ft/gpm<sup>2</sup>) and sodium at 1005°F met all of the specified criteria. Results are tabulated in Table 2.6.1.1

Speed %	Sinewave Amplitude %	Bandwidth Radians/ Sec.	Phase Margin Degrees	Gain Margin Db
40	2	.24	56	20+
40	10	.18	74	20+
57.5	2	.23	68	20+
57.5	10	.21	72	20+
90	2	.23	78	20.8
90	10	.22	97	20.2

TABLE 2.6.1.1

DRIVE SYSTEM SPEED CONTROLLER FREQUENCY RESPONSE

2.6.1.2 Drive Random Speed Variation

Random speed variation is a measurement of the speed control system's ability to overcome hydraulic load and or power variations to maintain speed at its commanded value. It is essentially an indication of drift. The criteria is  $\pm 0.4\%$  (or  $\pm 4.5$  RPM) at full speed of 1116 RPM and  $\pm 0.25\%$  (or  $\pm 2.8$  RPM) at the low main motor speed (22% or 246 RPM).

The test was run by adjusting the speed setpoint to a prescribed speed, allowing the system to run undisturbed for 1 hour after an initial stabilization period. Variation of speeds were recorded for the 1 hour period. Set points were: 25% (280 RPM), 40% (466 RPM), 50% (558 RPM), 65% (725 RPM), 90% (1004 RPM), and 100% (1116 RPM). Testing was run at 25% speed rather than 22% because the control system had been adjusted to prevent closed loop operation below 24% speed. The 65% point was added because a control system instability had been observed at this speed. All testing met the Test Request Criteria except for the 65% (725 RPM) speed point, where the Voith fluid coupler was displaying its identified instability. The results are shown in Table 2.6.1.2.

### 2.6.1.2 Continued

The control system passes the specified criteria for random speed variation except at the 65% (725 RPM) speed point

Setpoint Speed (RPM)	Measured High	Speed Low	Variation	
			RPM	%
282	281.65	281.4	±.25	0.02
445.2	448.5	447.75	±.45	0.04
559.4	558.98	558.23	±.38	0.03
726.7	736.8	713.7	±11.70	1.05
998.2	1009.3	1006.8	±1.30	0.12
1117.0	1119.8	1112.7	±3.55	0.32

TABLE 2.6.1.2  
RANDOM SPEED VARIATION

### 2.6.1.3 Response to Step Commands (Delay, Overshoot & Settling Time)

In this test, the system response to a series of step commands, both up and down from the set point was determined. The following are the terms of interest:

- o Response time: The time between initiation of the step change in the command signal and the time when the pump reaches 90% of its final steady state speed

Response time criteria:

Less than 20 seconds for 40% to 100% speed; less than 20.5 seconds for 30 to 40% speed; less than 33.2 seconds for 22% to 30% speeds

- o Settling time: The time between initiation of the step changes in command signal and the time when the pump first remains within ±3 RPM of final steady state speed

Settling time criteria:

50 seconds or less for a 10% speed step in the speed range of 40% to 100% speed

- o Overshoot: The maximum transient speed excursion in excess of the final steady state speed

Overshoot Criteria:

1% (11.16 RPM) of design speed for a 10% step in the 50% to 100% speed range, 2% in the 30% to 50% range (Note: ECP #G1412 baselined a change to 2% from 1% in the 30% to 50% speed range)

The speed controller met all requirements.

Step (RPM)	Response Time (Sec.)	Overshoot RPM	Settling Time (Sec.)
254 - 335	18	17.4	56.5
335 - 446	13	10.5	29.5
446 - 558	15.5	3.4	24
558 - 670	12.0	2.8	15
670 - 781	9.5	5.0	50
781 - 893	12.0	2.2	16
893 - 1004	12.5	3.9	27
1004 - 1116	12.5	2.8	17
1116 - 1004	12.5	0	17.5
1004 - 893	15.0	3.9	23.5
893 - 781	11.5	6.2	30.0
781 - 670	10.0	9.4	26.0
670 - 558	12.0	10.7	29.0
558 - 446	15.0	17.3	33.0
446 - 335	16.5	20.0	41.0
335 - 246	-- Control System Trips to MOR*		

TABLE 2.6.1.3  
DRIVE RESPONSE TO STEP COMMANDS DRIVE & PUMP SYSTEM  
(Test Run of Oct. 10, 1983)

\* MOR - Motor Operated Rheostat (Manual Control)

## 2.6.1.4

Drive Ramp Response & Velocity Error

Velocity error is the difference between the commanded value and actual value of output speed when the reference input is changing at a specified rate and all transients have expired.

The specified criteria is a maximum of 1% of design value (1% of 1116) on a 3%/minute ramp in the 40% to 100% range.

The drive system was tested to determine the velocity error for speed ramps of 1%/sec, 1%/minute, 3% per minute and 10%/min. Each ramp was conducted from 40% to 100% speed, and from 100% to 40%. X-Y plots of speed command and speed response vs. time for each ramp is included in appendix D of ETEC's Segment report for B6 (83ETEC-DRF-3834 dated August 26, 1984). Results indicated that the velocity error was in limits.

<u>% Of 1116 RPM PER MIN</u>	<u>RAMP RATE</u>	<u>MEASURED MAX. ERROR (RPM)</u>	<u>CRITERIA (MAX. RPM)</u>
60	11.16 RPM/Sec (Increasing)	60	N/A
60	11.16 RPM/Sec (Decreasing)	67	N/A
10	1.86 RPM/Sec (Increasing)	9	N/A
10	1.86 RPM/Sec (Decreasing)	15	N/A
3	.558 RPM/Sec (Increasing)	5	11.16
3	.558 RPM/Sec (Decreasing)	8	11.16
1	.186 RPM/Sec (Increasing)	3	N/A
1	.186 RPM/Sec (Decreasing)	5	N/A

TABLE 2.6.1.4  
DRIVE RAMP VELOCITY ERRORS

## 2.6.1.5

Drive Steady State Speed Error & Threshold

The steady state speed error is the difference between the requested speed and the final achieved speed after all transients have settled. The specified criteria require the final value to be within 1% of the requested value.

Results, shown in Table 2.6.1.5, indicate that the system was compliant. The test was not conducted at 22% speed because the speed controller was adjusted to automatically trip to open loop control at 24% speed.

CONTROL SIGNAL MILLIAMPS	CORRESPONDING SET POINT (RPM)	SEQ. 688 SPEED ACHIEVED (RPM)	ERROR RPM	ERROR AS % OF REQUEST (RPM) %
4.89	272.86	273.30	0.46	.168
8.03	448.07	448.85	0.78	.174
10.01	558.56	558.85	0.29	.052
12.02	670.72	671.83	1.11	.165
14.35	800.73	801.66	0.93	.116
16.01	893.36	895.27	1.91	.213
17.93	1000.49	1002.26	1.77	.177
20.01	1116.56	1111.83	4.73	.425

TABLE 2.6.1.5  
DRIVE STEADY STATE SPEED ERROR

#### 2.6.1.5

Continued

Threshold is the smallest change which can be made in the set point which will result in a change in pump speed. The test was run by changing the set point up and down by 0.1% of design speed. This corresponds to 1.1RPM speed change command. The test was run at both a low and at design speed. The specified criteria is that the threshold shall be less than 0.27% of design speed (3 RPM).

Test results showed that the controller responds to a 0.1% change in set point, therefore the criteria is met..

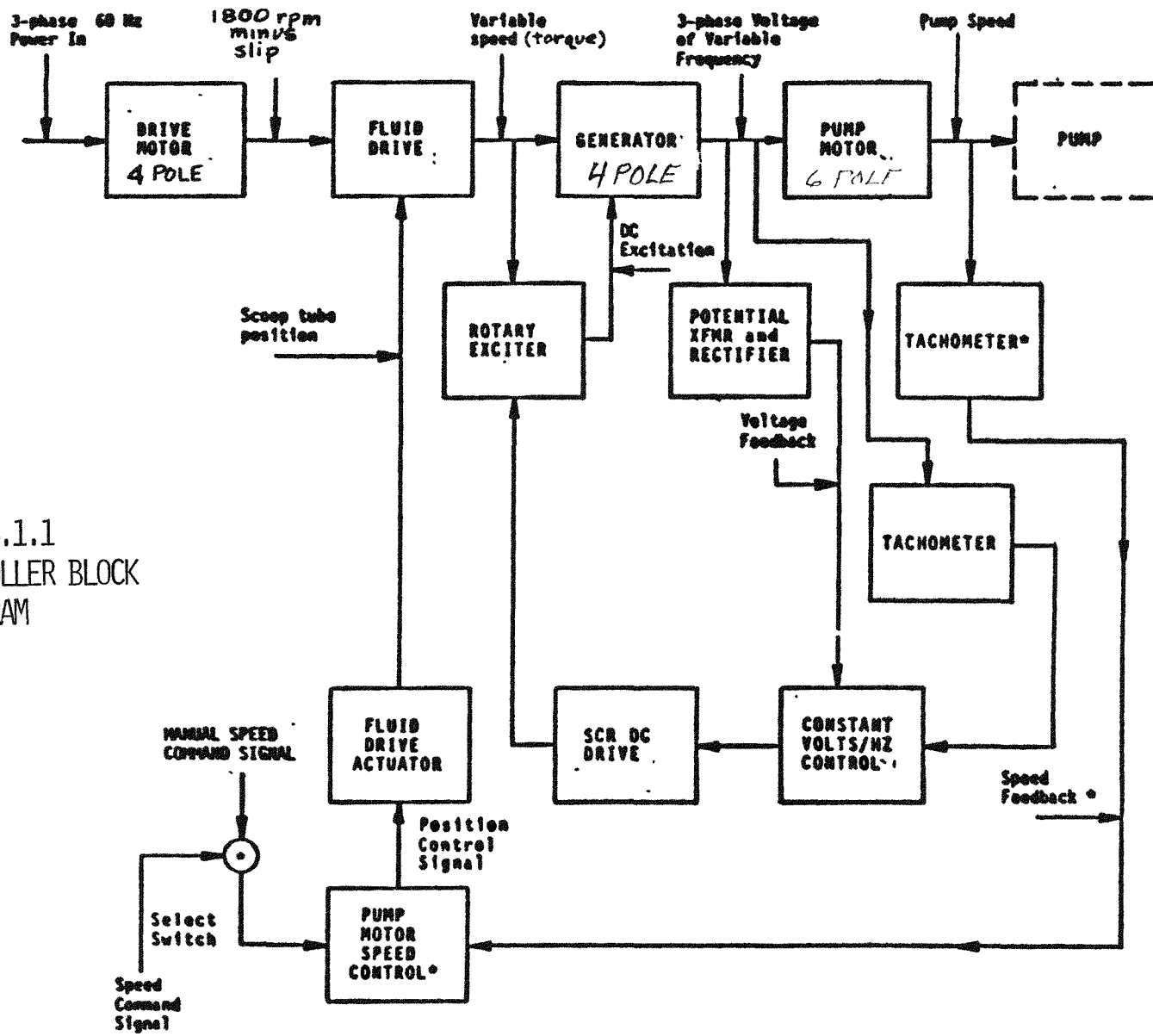
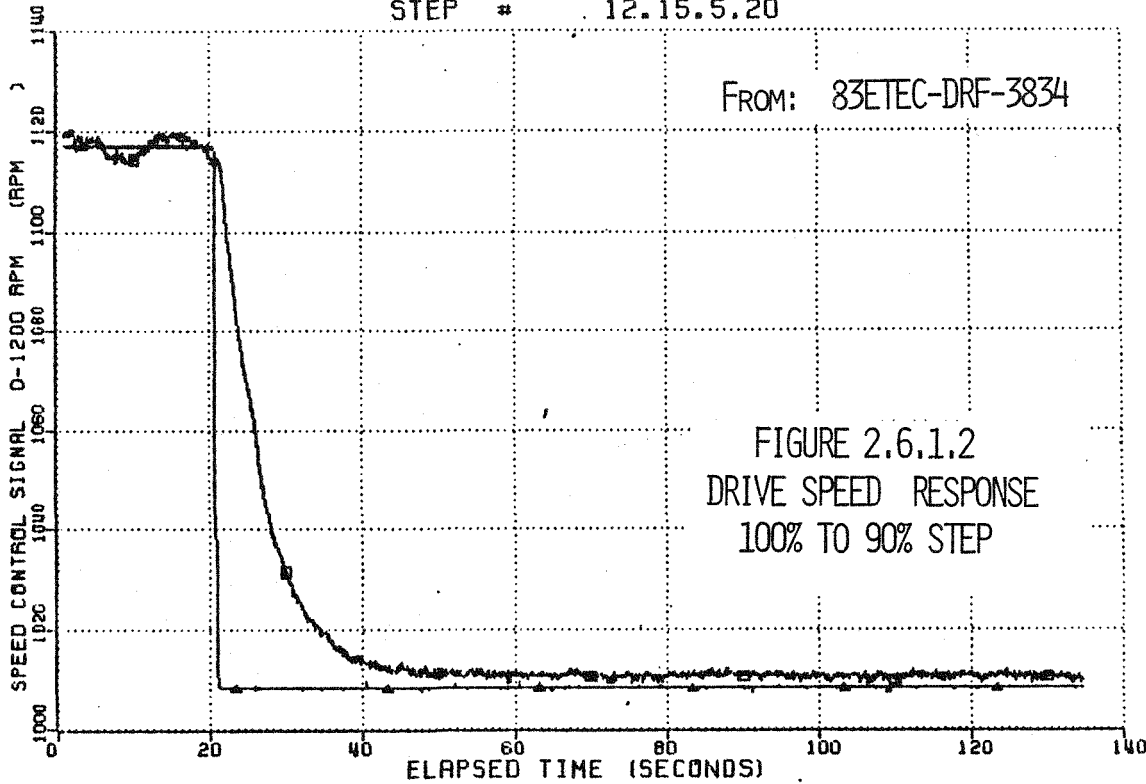


FIGURE 2.6.1.1  
SPEED CONTROLLER BLOCK  
DIAGRAM

MODIFIED  
FROM: 83ETEC-DRF-3834

SPTF CONTROL TEST  
PROCEDURE # 462 TP-0001  
STEP # 12.15.5.20

FROM: 83ETEC-DRF-3834

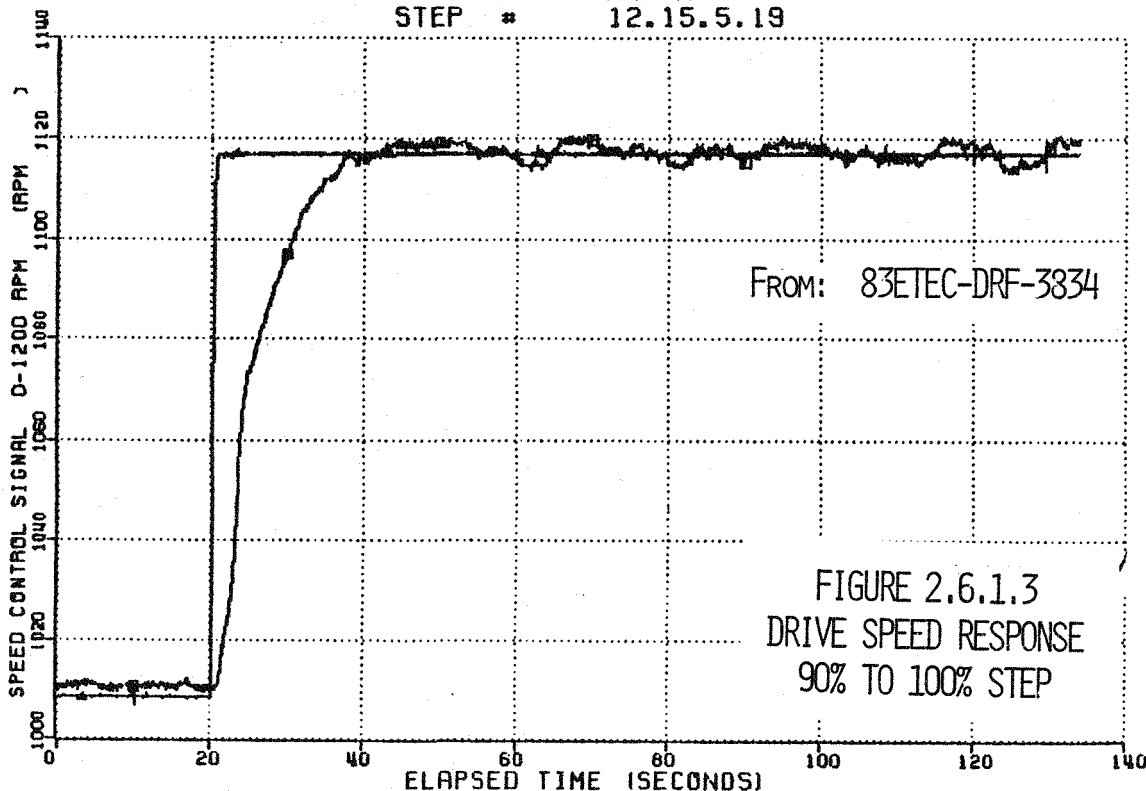


DAY 10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	DAY
H:M 20:49	20:49	20:50	20:50	20:50	20:51	20:51	20:51	20:51	H:M
SEC 22.000	42.000	2.000	22.000	42.000	2.000	22.000	42.000	SEC	

83DRF-3834  
08-26-83 PAGE 116

SPTF CONTROL TEST  
PROCEDURE # 462 TP-0001  
STEP # 12.15.5.19

FROM: 83ETEC-DRF-3834



DAY 10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	10/18/82	DAY
H:M 20:32	20:33	20:33	20:33	20:34	20:34	20:34	20:34	20:35	H:M
SEC 56.000	16.000	36.000	56.000	16.000	36.000	56.000	16.000	SEC	

83DRF-3834  
08-26-83 PAGE 114

SPTF CONTROL TEST  
 PROCEDURE \* P048E-B88-TS021  
 STEP \* 12.15.3.11A

96

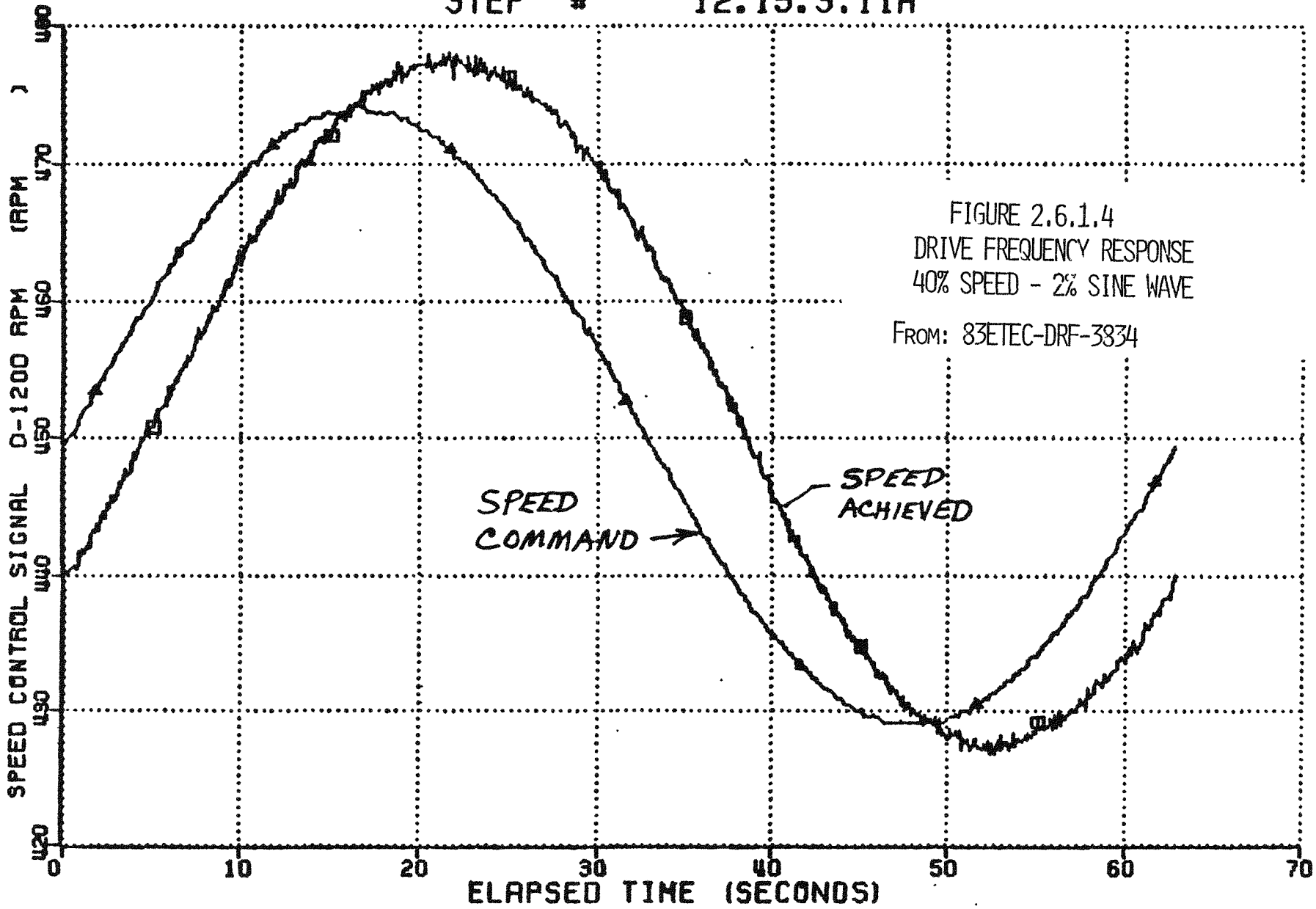
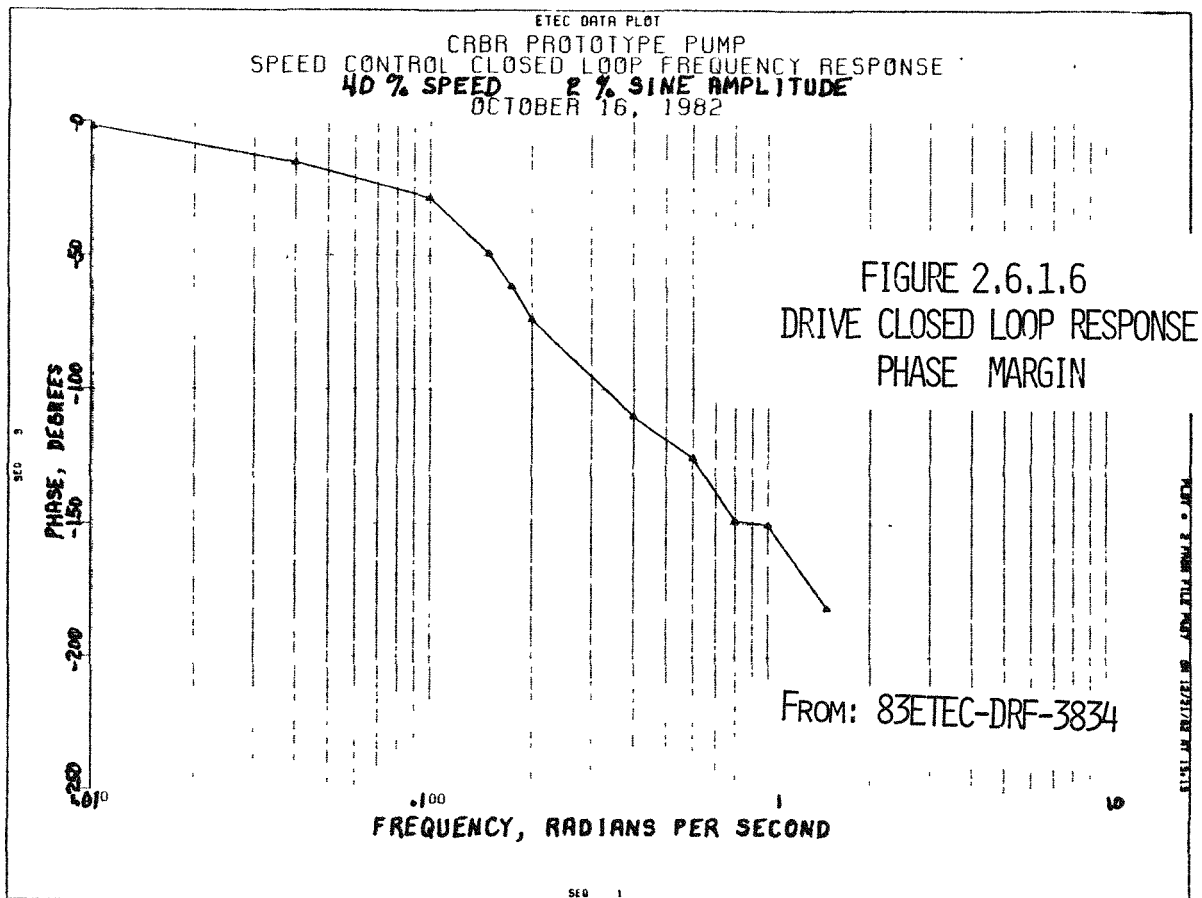
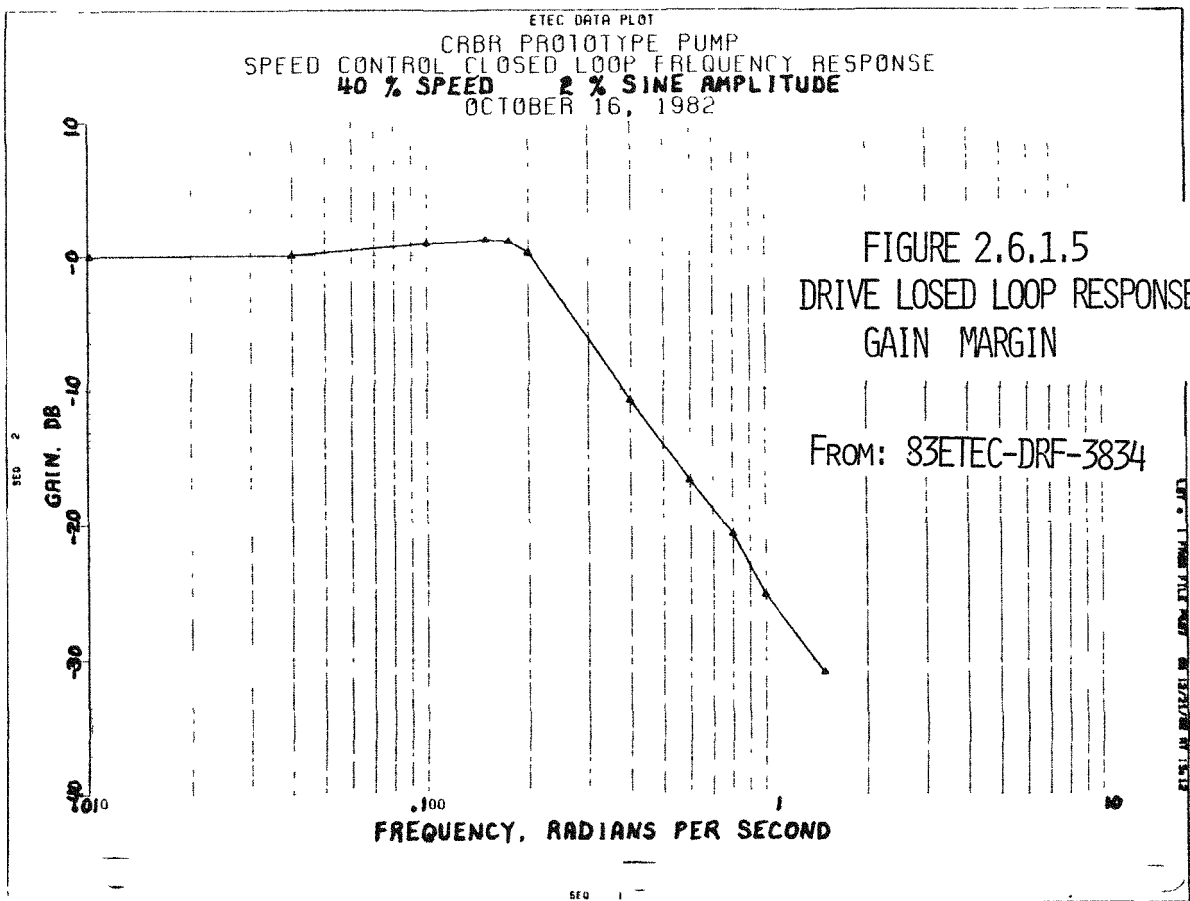


FIGURE 2.6.1.4  
 DRIVE FREQUENCY RESPONSE  
 40% SPEED - 2% SINE WAVE  
 FROM: 83ETEC-DRF-3834

DAY	10/16/82	10/16/82	10/16/82	10/16/82	10/16/82	10/16/82	10/16/82	10/16/82	DA
H:M	19:30	19:30	19:30	19:30	19:30	19:31	19:31	19:31	H:M
SEC	18.707	28.707	38.707	48.707	58.707	6.707	16.707	28.707	SEC



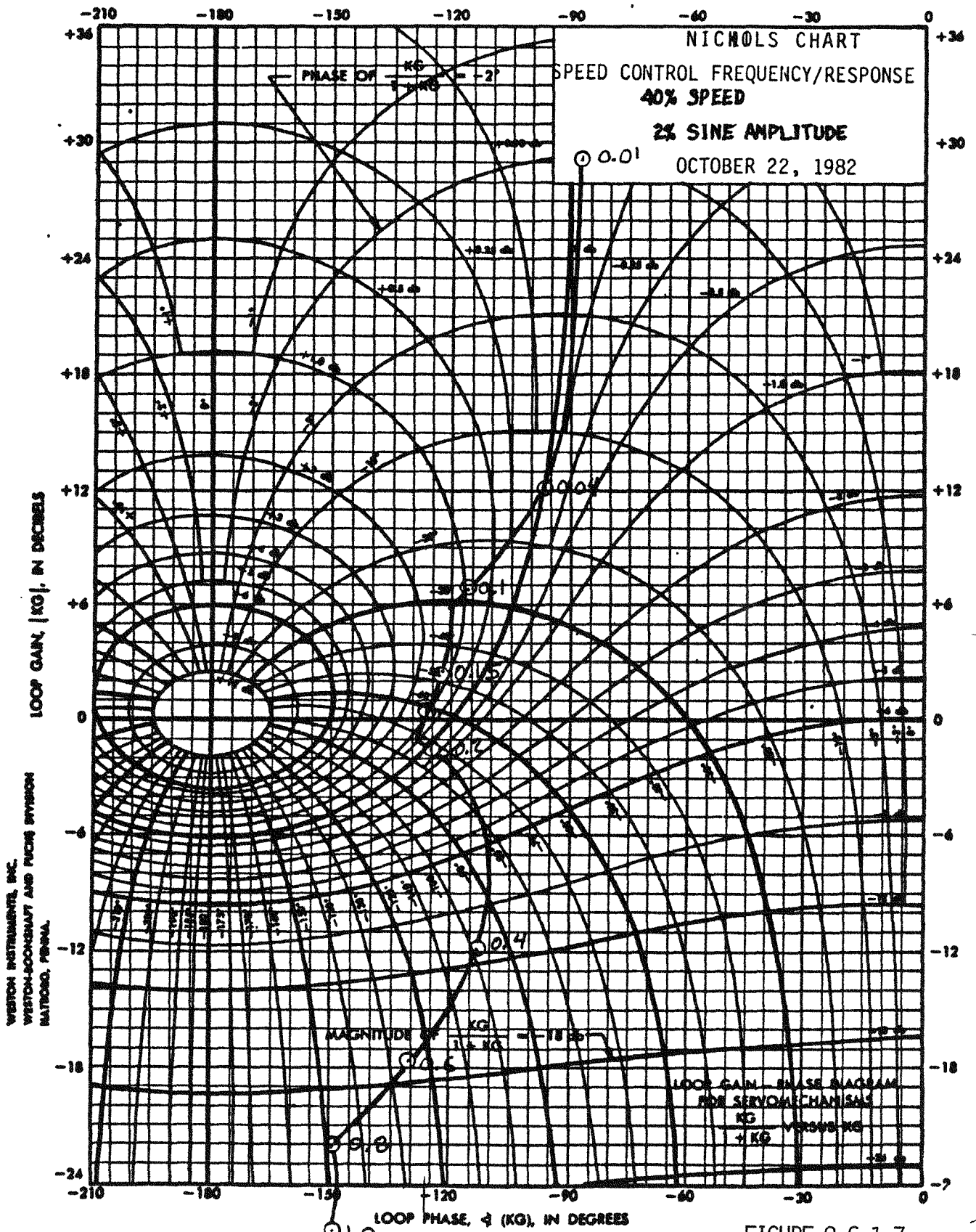
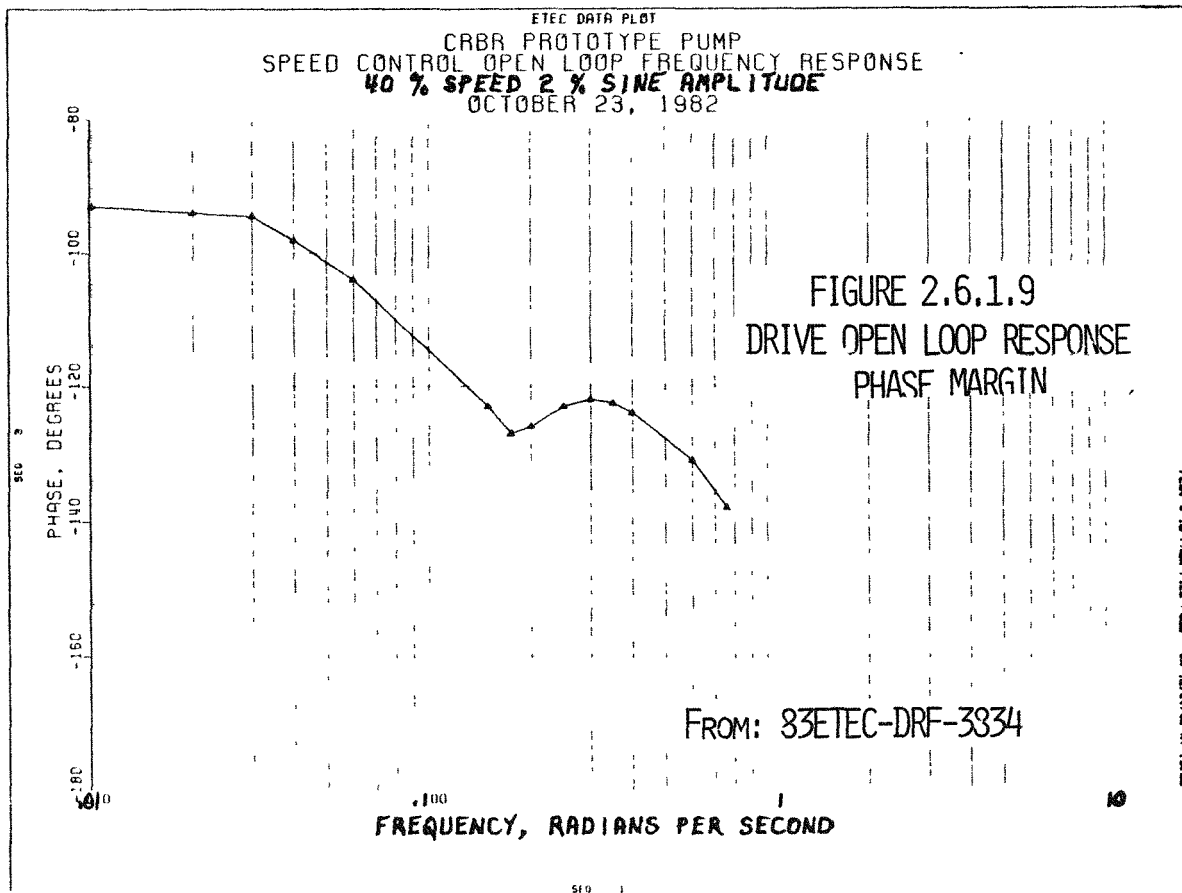
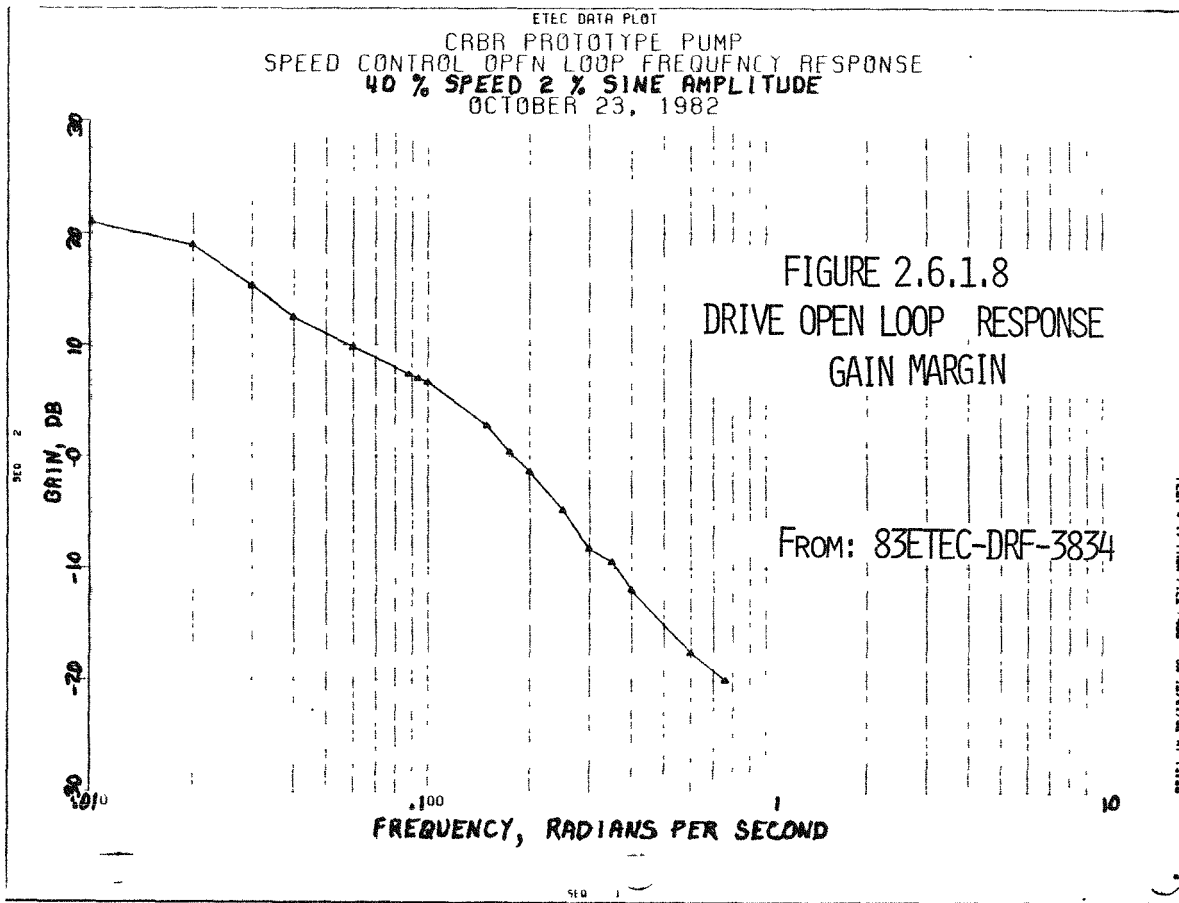


FIGURE 2.6.1.7  
 NICHOLS CHART - SPEED  
 FROM: 83ETEC-DRF-3834



2.6.2

Flow Controller Tests

Flow controller tests were conducted with sodium temperature at 1005°F and loop resistance adjusted to R3A resistance (a point midway between CRBRP 3 loop maximum and 3 loop minimum, or  $.34 \times 10^{-6} / \text{gpm}^2$ , which is achieved by adjusting loop valves for 36,059 gpm at a speed of 1116 rpm.

A 24-inch Permanent Magnet flowmeter was used to measure flow rate and to provide feedback to close the flow servo loop. The flowmeter was previously calibrated against the Venturi flowmeter. The nonlinear flowmeter output was digitized at 30 samples/sec and reconverted to a driving analog signal for the flow controller. The flow controller output becomes the speed command input to the Drive speed controller. For the final segment B6 flow controller tests, the controller manufacturer's representative made final controller adjustments to .48 volts/volt, reset of 3 seconds per reset, and  $\pm 0.5\%$  deadband.

Flow data presented in this report is from the test segment B6 Report #83ETEC-DRF-3834. General Electric makes no interpretations or conclusions regarding the data since the equipment and systems are the responsibility of others.

Steady State Flow Error

Steady State Flow Error is the difference between the flow set point (command) and the actual achieved flow. The test was made in 10% increments between 30% and 100% flow. There was no criteria for acceptance imposed in the test specification. Table 2.6.2.1 presents the test results:

FLOW SET POINT (GPM)	FLOW HIGH (GPM)	ACHIEVED LOW (GPM)	MEAN (GPM)	ERROR (GPM)
10840	11020	10410	10700	140
14450	14670	14050	14435	115
18045	18230	17550	17900	145
21675	22100	21080	21550	125
25280	25570	24480	25100	180
28870	28480	28140	28700	170
32490	33100	31400	32310	180
36020	37200	34550	35850	170

TABLE 2.6.2.1  
STEADY STATE FLOW ERROR

## 2.6.2

Continued  
Response to Step Inputs, Flow System

The The flow system was subjected to 10% (of design flow) step changes in flow commands, from 30% to 100% of design flow and back to 30%. The system response to each step was evaluated for response time, overshoot and settling time. ETEC applied flowmeter signal conditioning in which the feedback signal was the running average of the last 30 samples of flowmeter output. This put a delay of 0.5 seconds in the flowmeter feedback signal and improved the quality of the signal. The terms used in presenting the data are defined as follows:

**Response Time:** Time between initiation of the step change in the command signal and the time when the flow reaches 90% of its final steady state speed.

**Settling Time:** Time between initiation of the step change in the command signal and the time when the flow remained within 100 GPM of the final value.

**Overshoot:** The maximum transient flow excursion in excess of the final steady state flow value.

There was no criteria for acceptance imposed in the test specification. Table 2.6.2.2 presents the results.

Flow Command Step (GPM)	Step (%)	Response Time (Seconds)	Overshoot	Settling Time (Seconds)
10,800-14,420	30-40	12.5	16	41
14,420-18,030	40-50	14.0	12	37
18,030-21,630	50-60	14.2	3	26
21,630-25,240	60-70	13.5	0	50
25,240-28,845	70-80	14.0	1.5	91
28,845-32,455	80-90	15.0	0	21
32,455-36,059	90-100	18.0	0	24
36,059-32,455	100-90	23.0	2.5	33.5
32,455-28,845	90-80	19.5	7	46
28,845-25,240	80-70	15.0	0	91
25,240-21,630	70-60	20.2	0	30.5
21,630-18,030	60-50	14.0	2	40
18,030-14,420	50-40	14.5	27	49
14,420-10,800	40-30	16.5	33	110

TABLE 2.6.2.2  
RESPONSE TO STEP COMMANDS  
FLOW, DRIVE & PUMP SYSTEMS

## 2.6.2

Continued  
Flow Ramp Response Test

The flow control system consisting of the flow controller, the drive, and the pump were tested to determine velocity errors with flow ramps of 1%/minute, 3%/minute, and 10%/minute, applied from 30% to 100% flow and 100 to 30% flow. The results are tabulated in Table 2.6.2.3.

Ramp (GPM/Sec)		Maximum Error (GPM)
360.6	Increasing	2900
360.6	Decreasing	3500
60.1	Increasing	800
60.1	Decreasing	800
18.03	Increasing	400
18.03	Decreasing	350
6.0	Increasing	300
6.0	Decreasing	0 (Approx.)

TABLE 2.6.2.3  
FLOW RAMP VELOCITY ERRORS

Flow Frequency Response

Sinusoidal frequency response testing was conducted by applying a sinusoidal flow command to the closed loop flow system with a sinusoidal amplitude equivalent to 5% of rated design flow (5% of 36,059 or 1802.9 GPM). Plots of closed loop gain vs. frequency were prepared and a table of closed loop gain, phase vs. frequency were prepared. A "Nichols" chart was prepared from the closed loop table, and from the Nichols chart, a table of open loop gain and phase vs. frequency was prepared. This data was then tabulated and plotted as requested in the test Request 22A3551. Results are tabulated in Table 2.6.2.4.

Flow Rate (% of Design Flow)	Command Sinusoidal Amplitude (% of Design)	Bandwidth (Radians/sec)	Gain Margin (db)	Phase Margin (Degree)
40	5	0.25	20	72
57.5	5	0.19	20	74
90	5	0.12	20	87

TABLE 2.6.2.4  
FLOW SYSTEM FREQUENCY RESPONSE

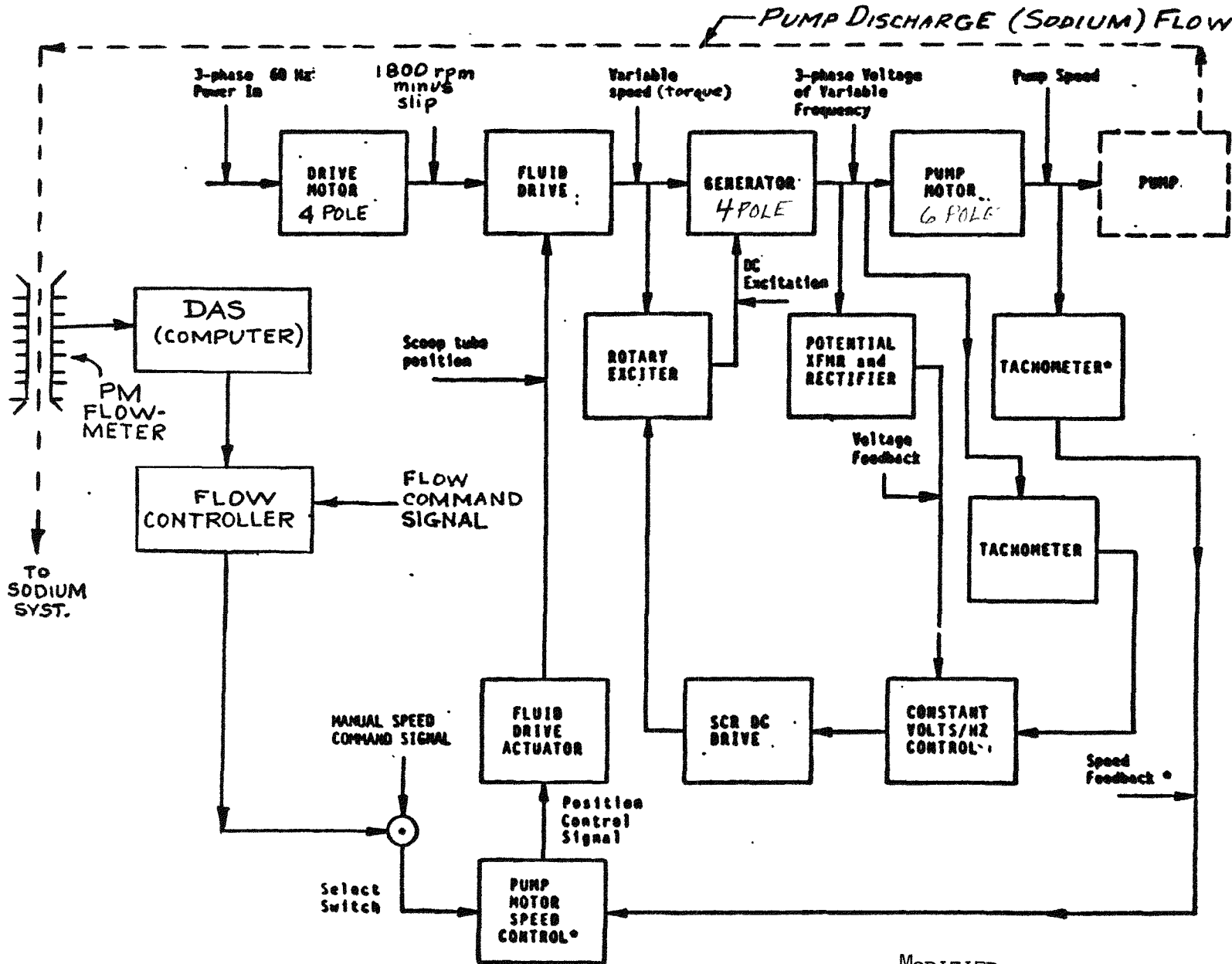
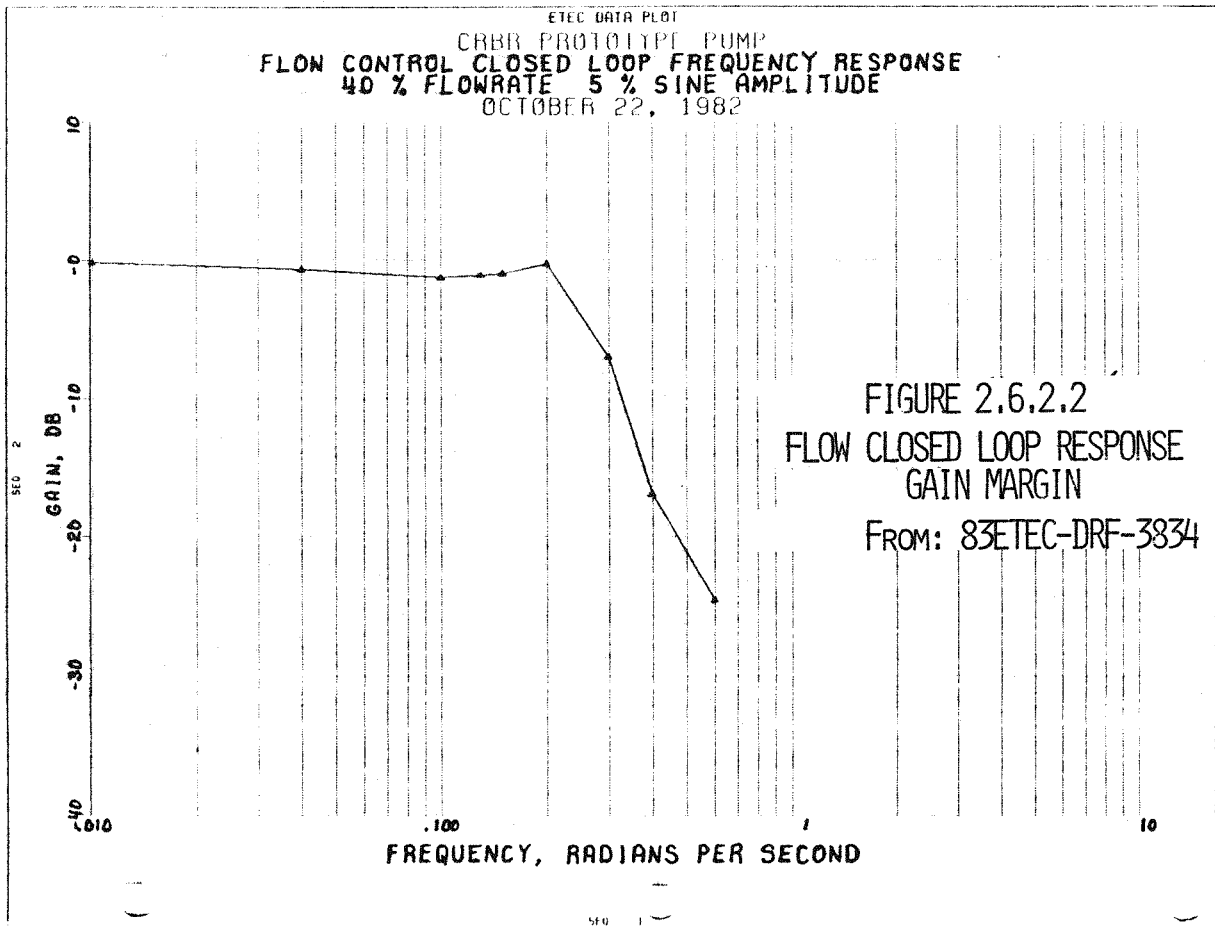
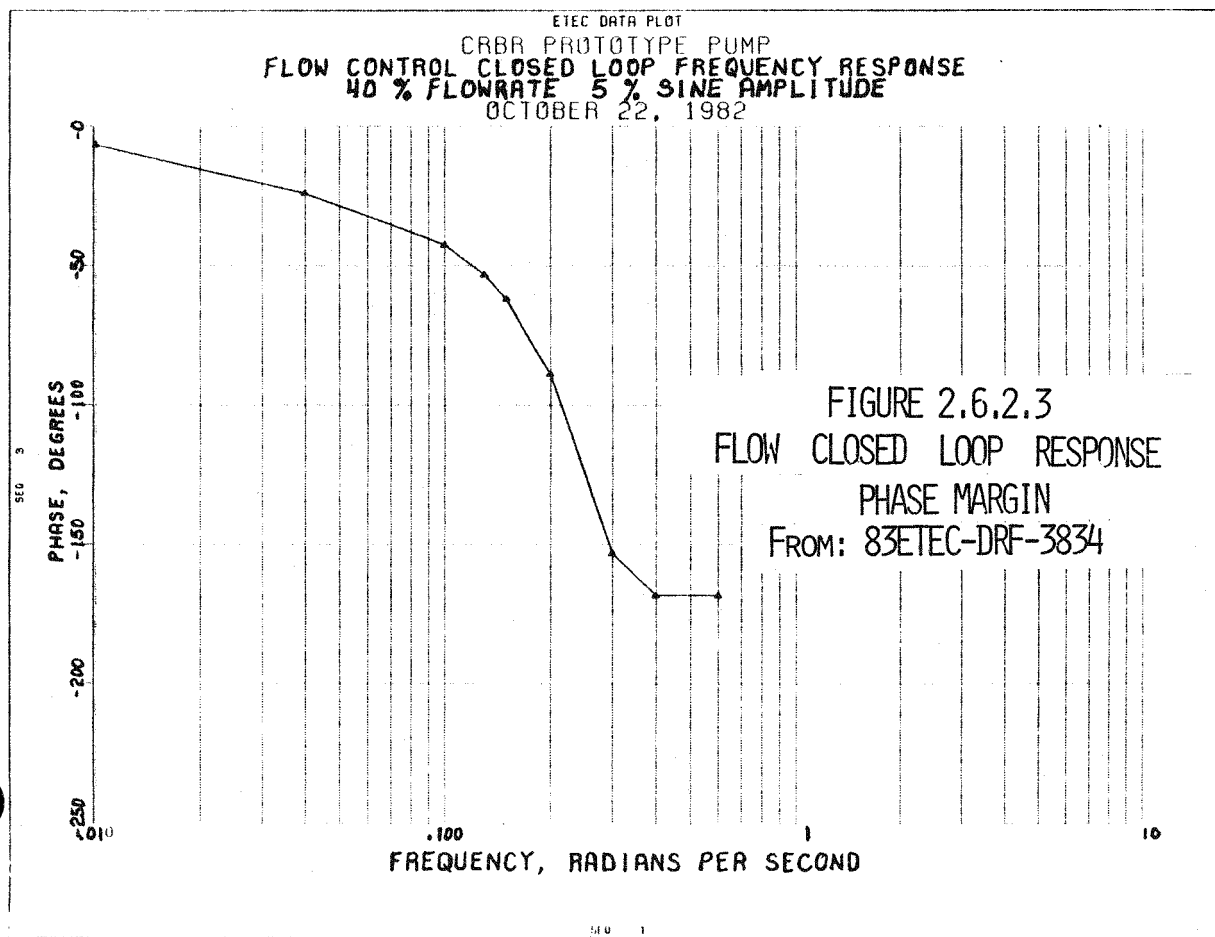


FIGURE 2.6.2.1  
FLOW CONTROLLER BLOCK DIAGRAM

MODIFIED  
FROM: 83ETEC-DRF-3834



83-DRF-3834  
 08-26-83 PAGE 1058



83-DRF-3834  
 08-26-83 PAGE 1059

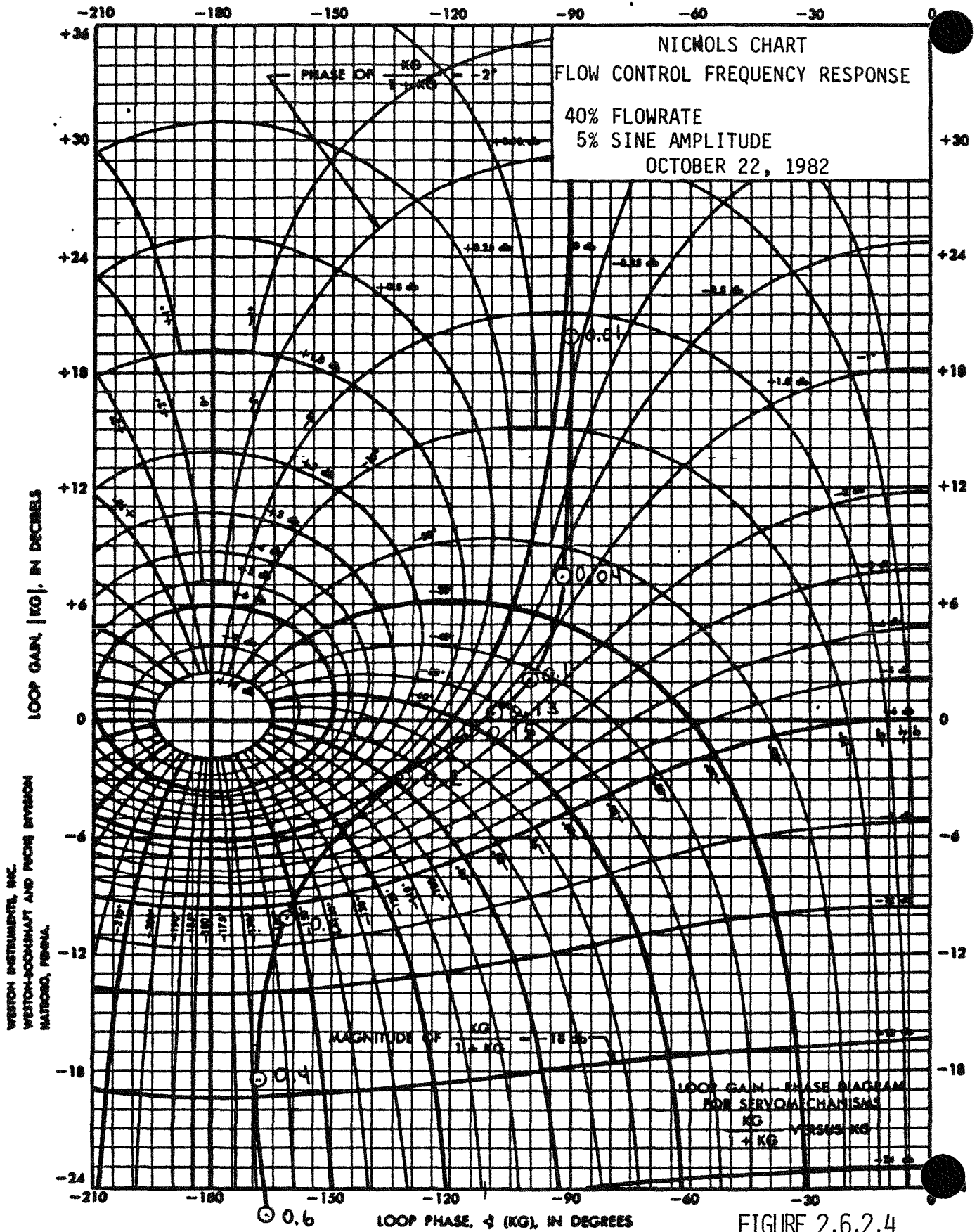
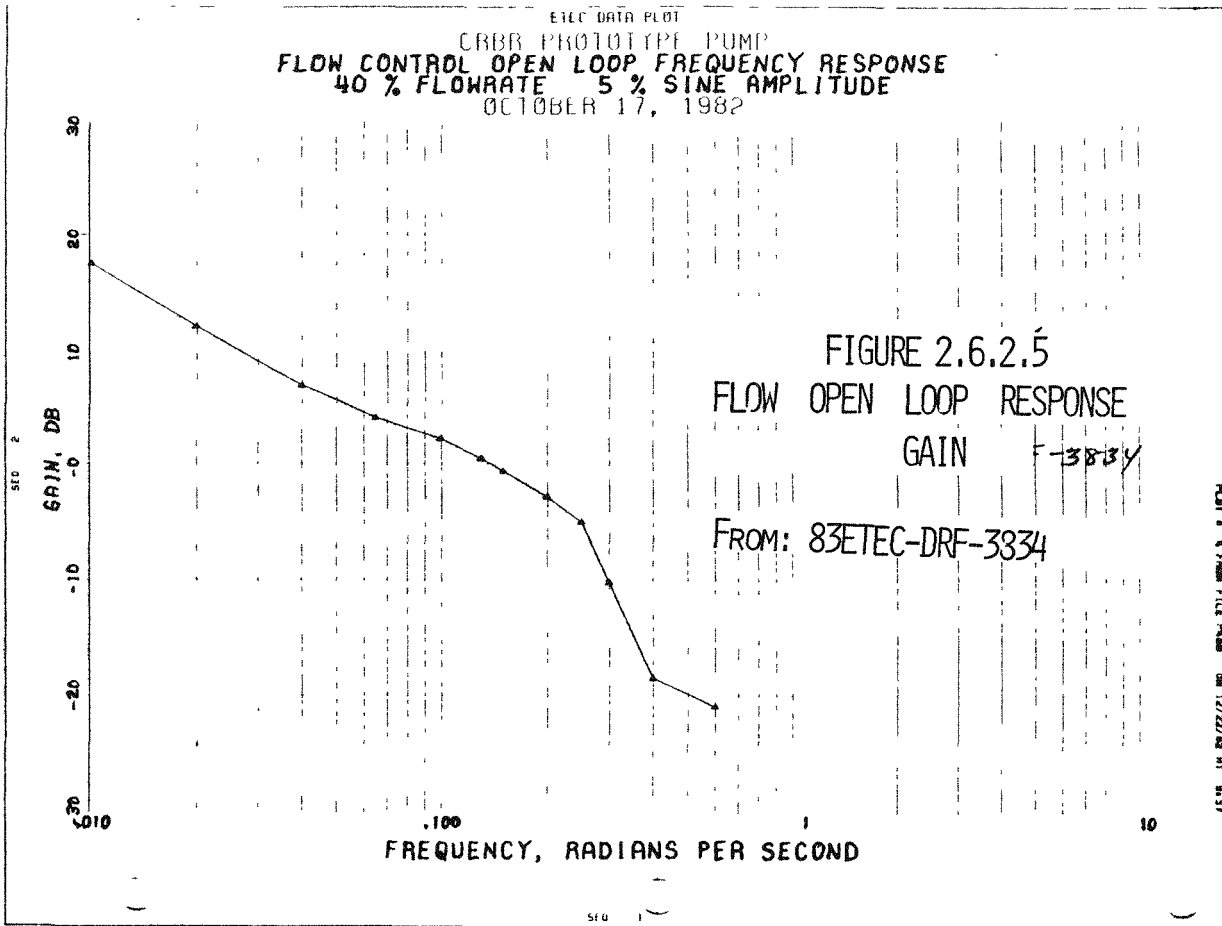
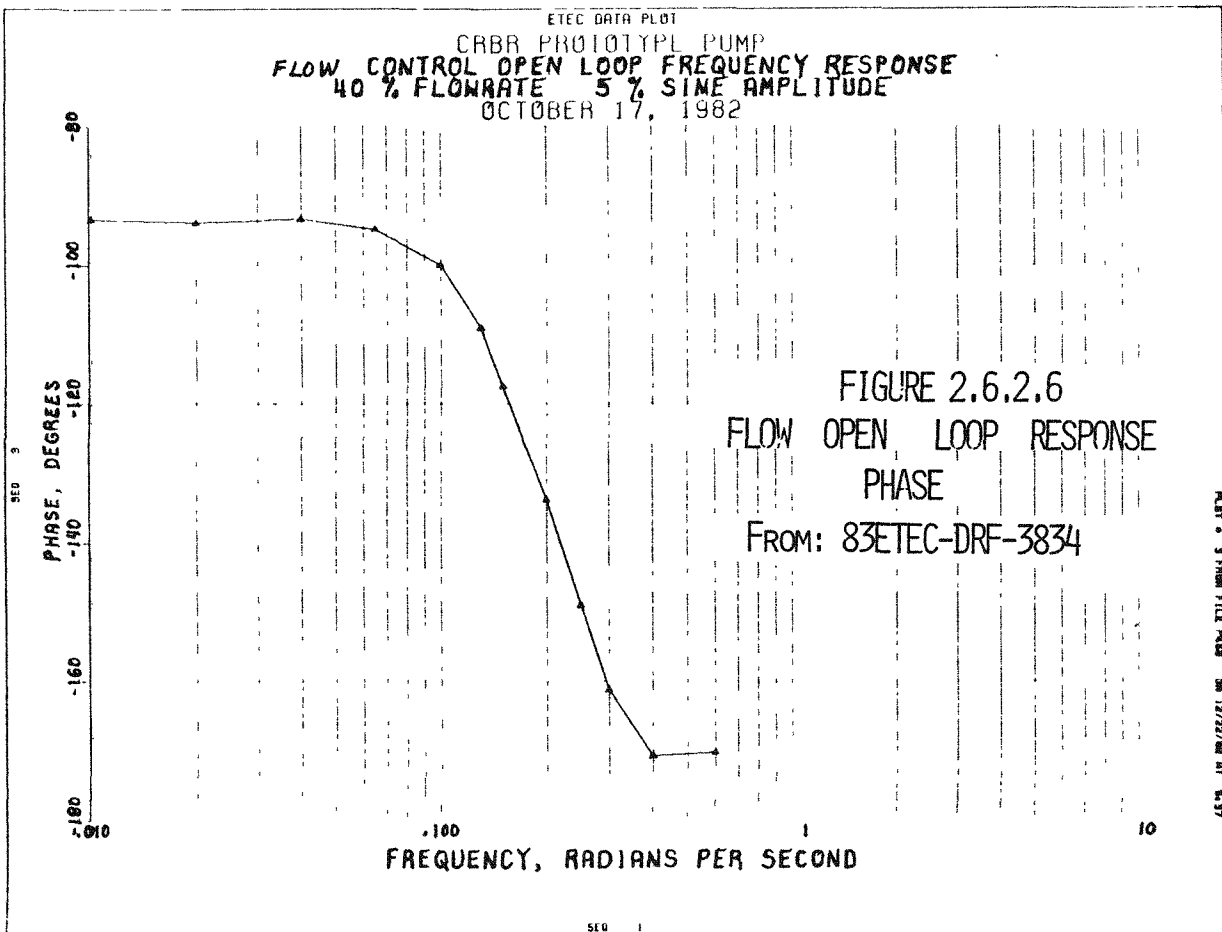


FIGURE 2.6.2.4  
NICHOLS CHART - FLOW



REF. 3 FROM FILE NAME ON 12/22/82 AT 11:37

83-DRF-3834  
 08-26-83 PAGE 1062



REF. 3 FROM FILE NAME ON 12/22/82 AT 11:37

83-DRF-3834  
 08-26-83 PAGE 1063

## 2.7 Miscellaneous Tests

### 2.7.1 Rotor Hydraulic Impedance Tests

The purpose of this test is to determine the resistance to natural circulation flow of a stopped pump.

There were two checks made of the hydraulic impedance of the pump to fluid flow through the suction to the discharge nozzle:

- Segment A15 - Hydraulic Impedance with 600°F Sodium
- Segment B4 - Hydraulic Impedance with 1005°F Sodium

Each of the above tests were run with the impeller free to rotate from two orientations, with vanes shifted in position by 18°. The technique used was to pressurize the SPTF sodium supply tank to 134 psia with Argon cover gas, open the dump tank drain valve and the supply tank feed valve and pneumatically "blow" the fluid in the forward direction through the pump until the supply of sodium was exhausted. The pump internal impedance through the suction to discharge flow path was then calculated by using the measured values of pump differential pressure and the corresponding sodium flow rate values. The flows achieved were in the order of 4700 to 4900 gpm at a differential pressure of 55 to 60 inches (W.G.), and the time required to transfer the fluid from supply to drain tank was in the order of 5 to 6 minutes. The free to rotate shaft did not rotate. The lift pump was not in operation during this test. The curves developed with 600°F sodium are shown in Figures 9.2.7.1A through 9.2.7.1C:

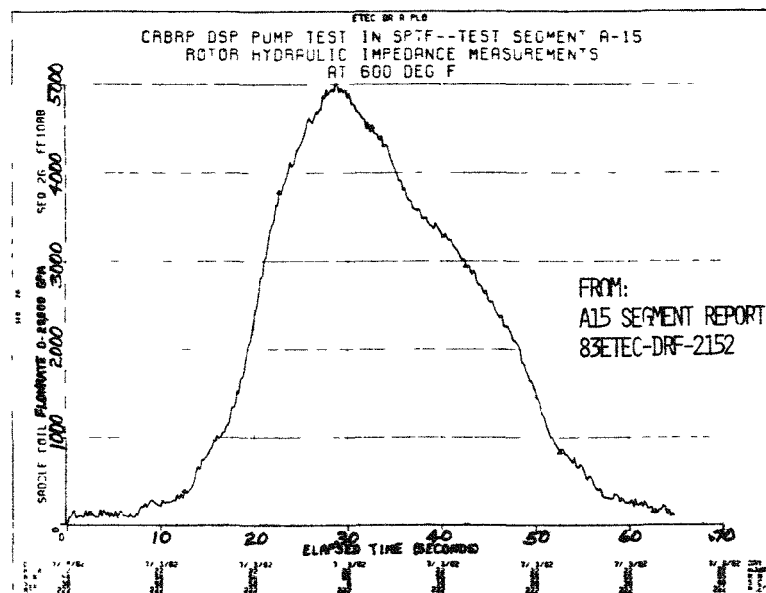


FIGURE 2.7.1A  
FLUID FLOW VS. TIME, 600°F SODIUM

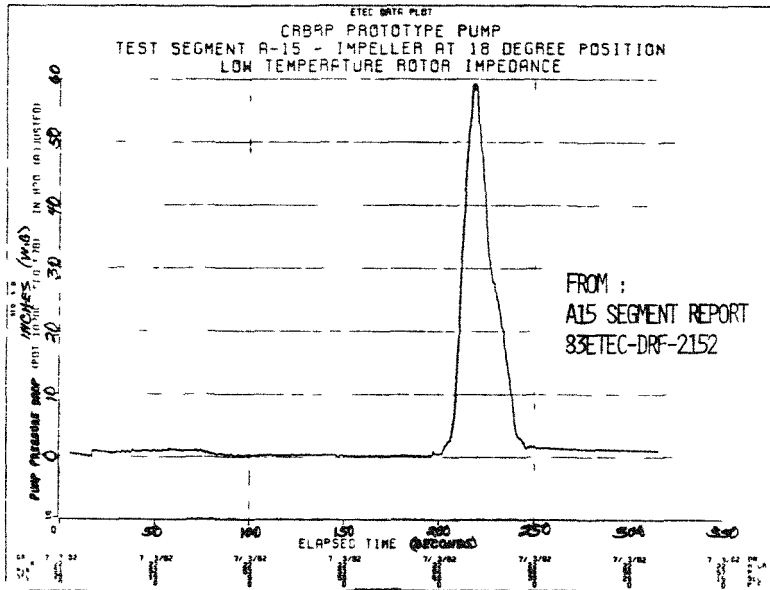


FIGURE 2.7.1B  
PRESSURE DROP VS. TIME, 600°F SODIUM

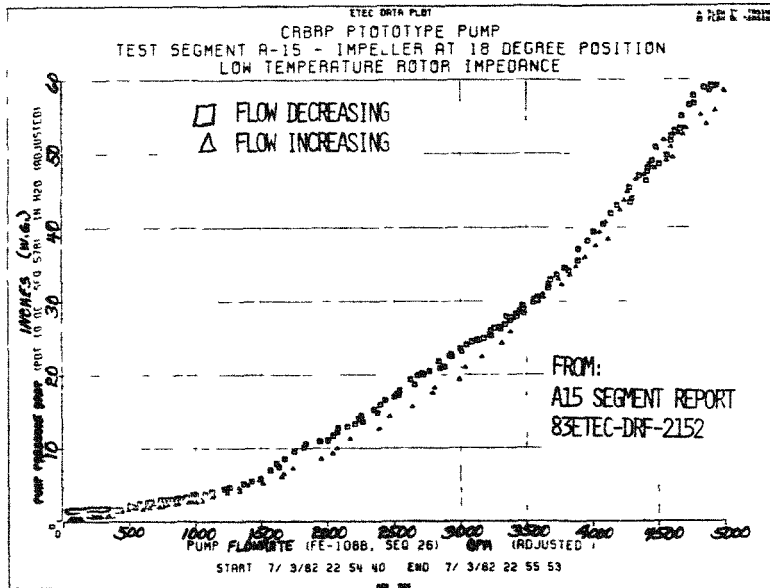


FIGURE 2.7.1C  
PRESSURE VS. FLOW, 600°F SODIUM  
(IMPEDANCE, SUCTION TO DISCHARGE)

Interface control drawing CG52004, Table 1-1 defines forward impedance in terms of pressure drop (ft) divided by the normalized flow. Using  $H/W^2$ , the above plot yields\* the following:

Pump	H	Flow	$(Q/33,700)^2$	Impedance $H/W^2$
Inches	Ft.			
10	.8333	1800	.002981	279
20	1.666	2700	.006419	259
30	2.500	3550	.011097	225
40	3.333	4050	.014442	230
50	4.166	4500	.017831	233

\*Using the plot of flow decreasing

In test Segment B4, an identical test was run, except that sodium was at 1005°F and the forcing pressure resulted in a pump tank delta pressure of 4 to 5 psid (140 inches) as compared to 60 inches in segment A15. The results are shown in Figures 9.2.7.1D through 9.2.7.1F:

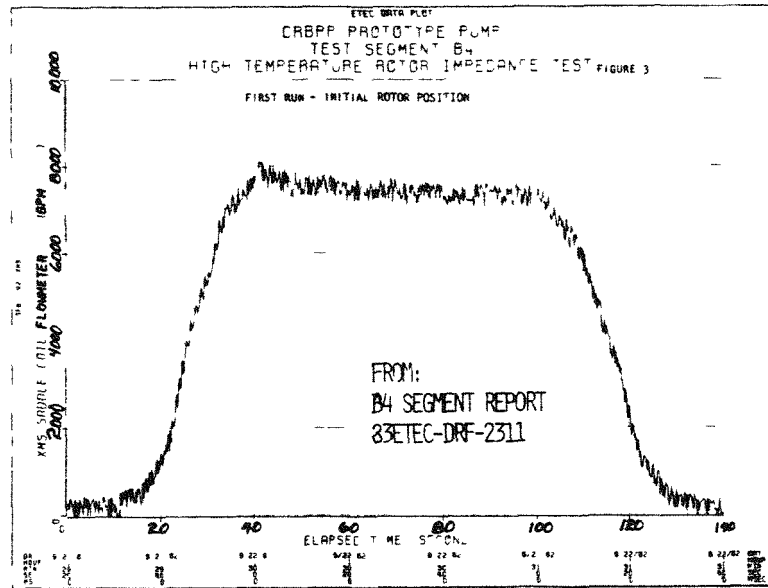


FIGURE 2.7.1D  
FLUID FLOW VS TIME, 1005°F SODIUM

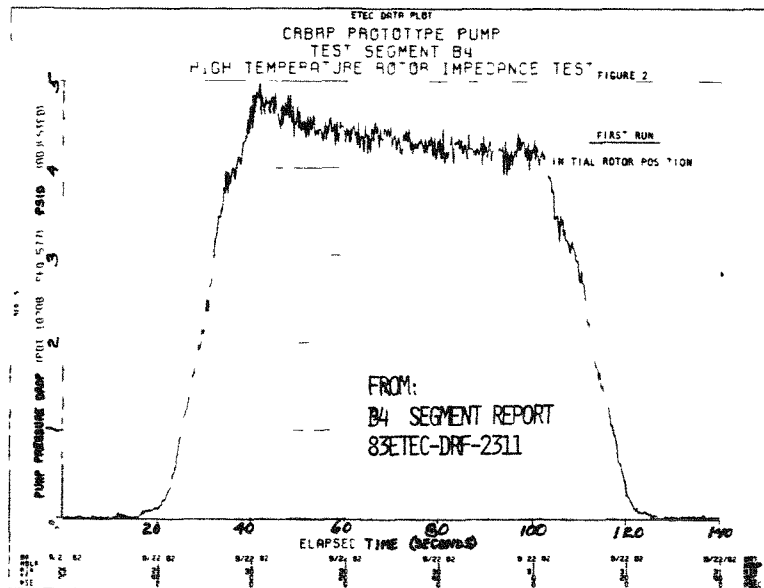


FIGURE 2.7.1E  
PRESSURE DROP VS. TIME, 1005°F SODIUM

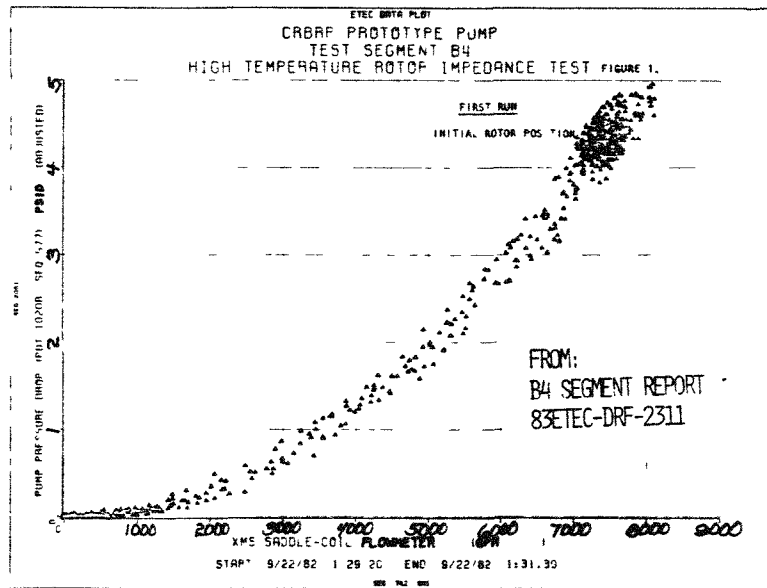


FIGURE 2.7.1F  
 PRESSURE VS. FLOW, 1005°F SODIUM  
 (IMPEDANCE, SUCTION TO DISCHARGE)

The above data yields the following impedance numbers (one inch sodium at 1000°F = .0297 PSI)

PSID	INCHES	FT	FLOW	$(Q/33,700)^2$	Impedance $H/W^2$
.297	10	.8333	2000	.00352	236
.594	20	1.666	2640	.00614	271
.891	30	2,500	3300	.00959	260
1.188	40	3,333	3900	.01340	248
1.485	50	4,166	4400	.01705	244
3.00	101	8.417	6150	.03330	252
4.25	143	11.91	7380	.04795	248

Although there is considerable data scatter, it is concluded that  $H/W^2$  is about 250, thus meeting the specification requirement.

## 2.7.2 Segment B14A, the PPIF Temperature Transient.

This faulted event transient is defined as a slowly rising temperature, from 1000°F to 1100°F, occurring in a 12 hour period, holding at 1100°F for four hours, followed by a slowly falling temperature -4°F/hr, at a pony motor flow rate of about 2900 gpm.

The temperature excursion applied at ETEC used the main motor during the up ramp to aid in the addition of heat energy. After achieving and holding 1100°F (actually 1094°F) for four hours, the drive was tripped to pony motor speed, then gradually returned to 1005°F across a 12-hour period. The objective of the test was to demonstrate that the excursion to 1100°F did not degrade mechanical operation or hydraulic performance. The record of the transient applied is shown in Figure 2.7.2.

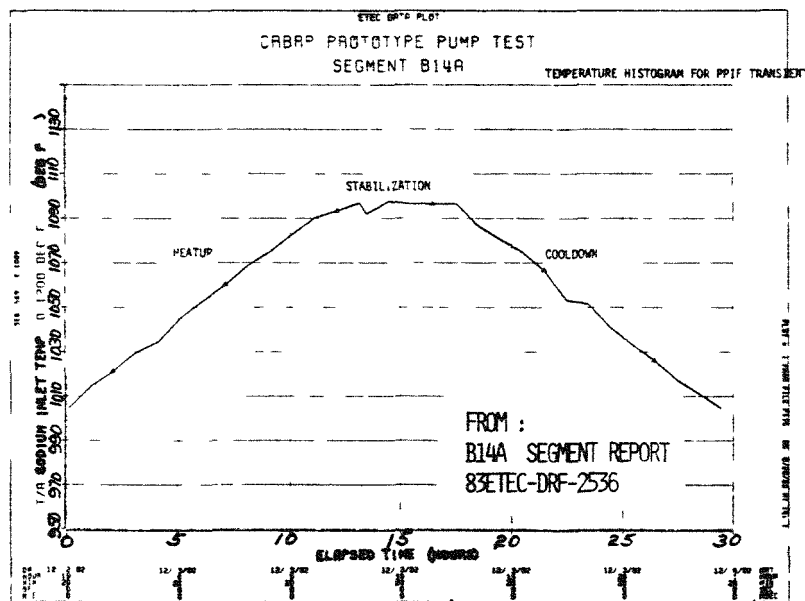


Figure 2.7.2  
PPIF Temperature Transient

The test results of Segment B14A indicated that neither mechanical performance nor hydraulic performance were degraded. The baseline rechecks were compared with performance before (Segment B14) and after (Segment B14A) this test and tables listing head and flow for each speed of interest for R3 loop impedance ( $.4 \times 10^{-6}$  ft/gpm<sup>2</sup>) are contained in the segment report. This test shows that the CRBRP pump can experience this faulted transient event without detrimental dimensional changes at critical assemblies (hydrostatic bearing and rotating assembly).

### 2.7.3 Segment B11 Coastdown

This series of tests consisted of numerous coastdowns, a total of 40, in which head, speed and flow vs. time were recorded where different plant conditions (sodium temperatures and loop resistance) were simulated. Some coastdown runs were made with the pony motor tripped in advance of the main motor PPS breaker, and others were made with the pony motor and main motor tripped simultaneously with the PPS breaker trip. Neither of these are normal plant trips but rather are extreme cases. The normal plant trip involves the main motor only and the pump coasts down until it reaches pony motor speed at which point the overrunning clutch engages and maintains the pump at pony motor speed.

Since establishing facility conditions of fluid temperature and loop impedance is time consuming, all coastdown runs were accomplished during any test segment where the proper conditions existed.

The coastdown cases are shown in the following table.

COASTDOWN CASES FOR SEGMENT B11

Case	No Runs	Initial Speed Run	Loop Resistance	Sodium Temp	Pony Motor Trip Advance*	Trip Simult.
Ca1 1	1	1116	R2 (Note 2)	600		X
Ca1 2	1	1116	R2 (Note 3)	600		X
Ca1 3	1	1116	R2 (Note 4)	600		X
Ca1 4	1	1116	R2 (Note 2)	1005		X
Ca1 5	1	1116	R2 (Note 3)	1005		X
Ca1 6	1	1116	R2 (Note 4)	1005		X
1A	6	1116	R3	600		X
1B	3	1116	R3	600	X	
1C	6	1116	R3	1005		X
1D	3	1116	R3	1005	X	
2A	1	1116	R4	1005		X
2B	1	1116	R4	1005	X	
3A	1	Note 1	R6	1005		X
3B	1	Note 1	R6	1005	X	
4C	3	1116	R3	1005		X
4D	3	1116	R3	1005	X	
5A	1	103.9	R3	600		
5B	1	103.9	R8	600		
5C	1	81.6	R3	600		
5D	1	81.6	R8	600		
6A	1	103.9	R3	1005		
6B	1	81.6	R8	1005		

Note 1: Whatever speed yields 39,000 gpm with R6 this will be close to 970 rpm.

Note 2: Main Flow Loop only (loop flow limit: approximately 19,000 gpm)

Note 3: High Flow Loop Only

Note 4: Split Flow MFL and HFL

\*5 second in advance with respect to main motor PPS breaker trip

## 2.7.3

The test results presenting all cases in normalized tables is contained in ETEC's Segment Report #83ETEC-DRF-3438 dated August 4, 1982. The results of both water testing and one of the numerous cases run at ETEC (Case 1C, Coastdown from 1116 RPM with sodium at 1005°F, loop resistance at R3) are presented in Table 2.7.3.1.

Seconds After Removing Drive Motor Voltage	Normalized			
	Requirements		Results	
	Required Flow Min.	Max	Water Test BJ	Sodium Test ETEC (Case 1C)
0	1.0	1.0	1.0	1.0
1	.82	.84	.86	.837
2	.70	.73	.75	.731
3	.61	.65	.65	.629
4	.53	.58	-	.562
5	.48	.52	-	.506
6	.43	.47	.45	.460
8	.36	.40	-	.389
10	.29	.34	.33	.340
15	.22	.26	-	.252
20	.16	.21	-	.200
25	.12	.17	-	.165
35	.07	.13	.13	.120
45	.04	.11	-	.094
55	.01	.09	-	.065

TABLE 2.7.3.1  
COASTDOWN DATA

## Results:

ETEC provided 116 plots of speed/head/flow vs. time to cover the numerous cases and they also provided normalized data for each case, including those cases where it was required that they be repeated.

There appears to be no significant effect of advanced tripping of the pony motor. There were no unusual vibration events during the coastdown runs.

In the interest of brevity, only the plots of case 1C (Coastdown from 1116 RPM with R3, the 3 loop maximum resistance, and sodium at 1005°F) are included in this report. Recipients of this report who have need for normalized tabulated data are referenced to the segment report #83ETEC-DRF-3438, dated August 4, 1983.

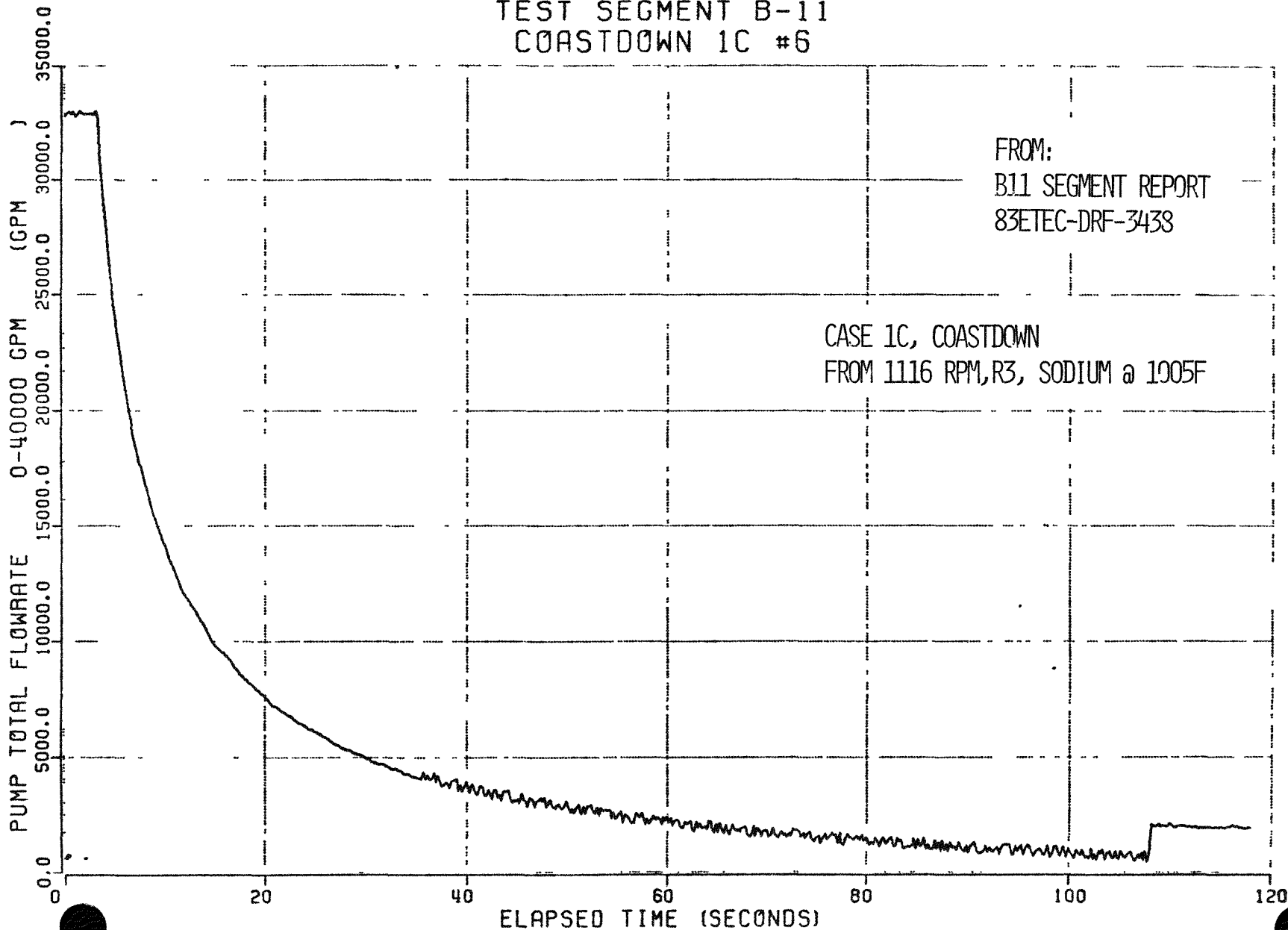


ETEC DATA PLOT

CRBRP PROTOTYPE PUMP  
TEST SEGMENT B-11  
COASTDOWN 1C #6

FROM:  
B11 SEGMENT REPORT  
83ETEC-DRF-3438

CASE 1C, COASTDOWN  
FROM 1116 RPM, R3, SODIUM @ 1005F



116  
SEQ 89M QP

PLOT # 17 FROM FILE #208 ON 7/28/83 AT 18:30

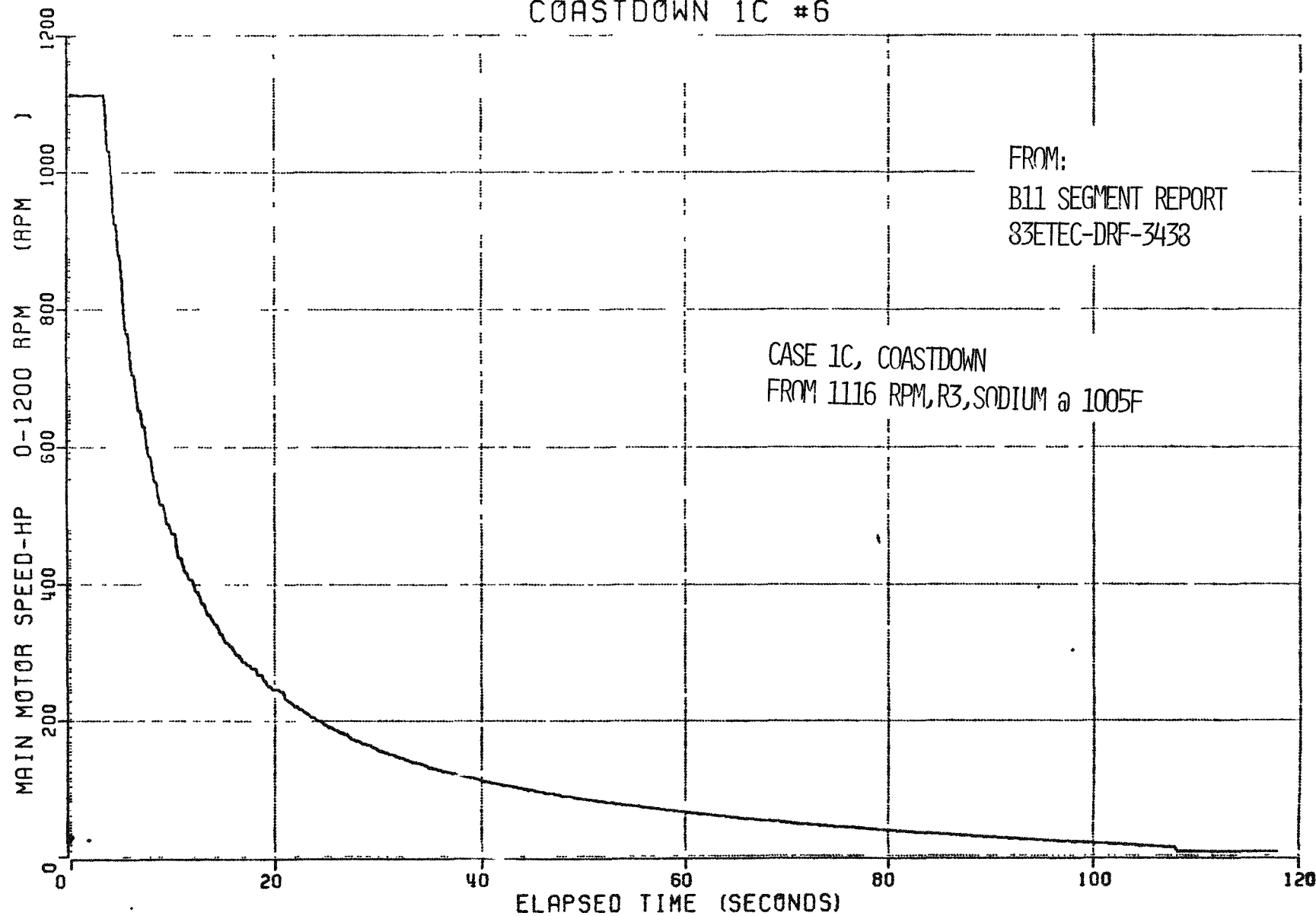
AUGUST 4, 1983  
PAGE 70

9/11/82 22:13 DAY 09R 13  
9/11/82 22:13  
9/11/82 22:13  
9/11/82 22:14  
9/11/82 22:14  
9/11/82 22:14  
9/11/82 22:15 DAY HOUR MIN

ETEC DATA PLOT  
 CRBRP PROTOTYPE PUMP  
 TEST SEGMENT B-11  
 COASTDOWN 1C #6

FROM:  
 B11 SEGMENT REPORT  
 83ETEC-DRF-3438

CASE 1C, COASTDOWN  
 FROM 1116 RPM, R3, SODIUM @ 1005F



6426-36 889 035

117

27.3.3

PLOT - IS FROM FILE P206 ON 7/28/83 AT 16:28

AUGUST 4, 1983  
 PAGE 69

DAY	9/11/82	9/11/82	9/11/82	9/11/82	9/11/82	9/11/82	DAY
HOUR	22	22	22	22	22	22	HOUR
MIN	19	13	19	14	18	14	MIN
SEC	0	30	50	10	50	50	SEC
MSEC		0	0	0	0	0	MSEC

#### 2.7.4 Segments A5A and B14B Leak Test of Drop Down Maintenance Seal

The objective of these tests was to quantify the leakage rate of argon gas past the "drop down" seal. The "drop down" seal is the contact circle between the shaft slinger and the UIS shaft annulus tube which is in contact when the shaft is lowered for seal cartridge removal. (Figure 2.7.4.1 shows the drop down seal. Part circle 46 is the slinger). Test Segment A5A was run with the pump at room temperature using rotating assembly #171222. Segment B14B was taken at the end of the test program, with sodium in the pump at 600°F, and with rotating assembly #174848 (used in water test). The same slinger was used for all tests.

Leak testing of the drop down maintenance seal revealed the following leak rates:

<u>Applied Gas Pressure</u>	<u>Measured Leak Rate A5A</u> ft <sup>3</sup> /hr	<u>Measured Leak Rate B14B</u> ft <sup>3</sup> /hr	<u>Measured @ Water<sub>2</sub> Test</u> ft <sup>3</sup> /hr
10" WG	1.1	0.8	-
1 PSIG	4	1.3	1.8
2 PSIG	9	3	4.8
3 PSIG	13	4.4	5.4
4 PSIG	18	5.7	6.0
5 PSIG	20	7.4	7.8

#### 2.7.5 Segment A10 Initial Pony Motor Run

The purpose of this test was to verify hydrostatic bearing performance on pony motor, to measure sodium level variations during pony motor starts and stops; to measure shut off head at pony motor speed; to purify sodium to less than 5PPM oxygen, and to record head and flow relationships.

##### Results:

Oxygen purity was taken to 3 PPM at 750°F as verified by both plugging temperature and chemical analyses of a sodium sample. Oscilloscope display of shaft orbit from the in-sodium proximeters was well within the ETEC established 25% clearance limit. Proximeter probes displayed considerable temperature sensitivity, resulting in a conclusion that recalibration every 50°F would be required. The proximeters should be viewed as a gap indicating tool for isothermal conditions, and as a less than perfect indicating tool during fluid borne thermal transients.

ETEC's sensor for measuring developed head initially indicated 5.1 ft, which is above the specified 5.0 ft. maximum. ETEC subsequently concluded that they had a zero drift error. (Measurement in A13B yielded 4.63 ft. for this impeller at 104 RPM).

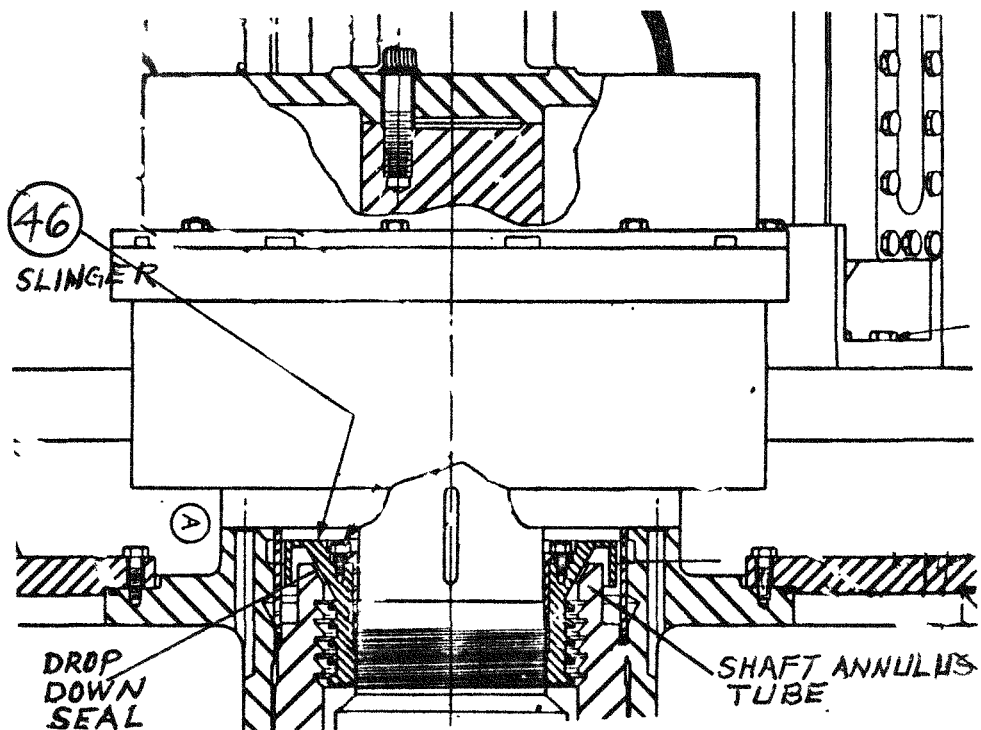


Figure 2.7.4.1  
Seal Cartridge & Drop Down Seal

## 2.7.5 Continued

There were no discernible sodium level changes in the pump tank as the pony motor was started and stopped, and vibration was satisfactory.

There was a noticeable increase in tank circumferential differential temperatures as fluid temperature was increased, which indicated the presence of internal gaseous convection cells.

The drive motor lube system lower bearing would initiate a high level alarm when the bypass valve was adjusted to set oil pump discharge pressure as required for proper flow. This situation was resolved by orificing the oil line near the motor.

Non conformances generated:

<u>NPR#</u>	<u>Subject</u>
2669	Pony Motor overspeed trip
2675	VDM lube oil pressure switches for lower bearing

See the Appendix for details of corrective actions taken at ETEC.

## 2.7.6 Segment A12AB, Initial Main Motor Speed Run

The purpose of this segment is to make adjustments to the drive speed servo loop and verify that the MG set lube auxiliaries and the VDM lube auxiliaries are functioning properly; also to determine how to run pump head flow mapping using two parallel flow loops. Specific objectives were:

- o To make adjustments to the speed servo loop to achieve proper speed response.
- o To verify lube auxiliary performance.
- o To verify satisfactory MG and VDM vibration levels.
- o To verify satisfactory MG & VDM winding temperatures.
- o To verify I&C Panel Instrumentation Display.
- o To verify pump stability through the speed range.
- o To obtain PM flowmeter vs. Venturi flowmeter data.
- o To run coastdown cases 1A and 1B.

Results:

The pump drive speed control system was adjusted with the aid of factory representatives. Operation was verified from local control in MG facility and from the control room. Step and ramp commands were applied and the speed control found to be responsive and stable except at 725 RPM. Vibration alarms were encountered during the test, but were subsequently determined to be caused by high frequency pickup, resolved by adding low pass filters. Nonconformances generated in the process

2.7.6

Continued

of startup were documented and are contained in Appendix C of this document.

Segment A12AB was intended to achieve activation of the Drive System, to conduct such pump hydraulic operation as was necessary to define/instruct how to hydraulically "map" using two parallel flow loops, and to run the first coastdown case. Another expected side benefit was to identify any interface problem with the flow controller. Except for the coastdown runs, this segment was not intended to yield final test data. The test was successful in activating the drive system and establishing that it was ready for use in supporting the subsequently planned pump test segments. Flow controller adjustments were made per factory representative instructions.

ETEC made several recommendations as a result of this segment which deserve highlighting and a response thereto:

- a) ETEC believed that the quantity of permissive interlocks on pump start (with resulting automatic trip) is large, and that it is not always easy to identify which interlocks initiated the trip. ETEC recommends more visibility of interlock circuitry status via additional panel lights or a computerized printout, and that each trip be evaluated to see if it could be satisfied by an alarm.

Response: The February 1983 Drive Design Review called for transferring some of the automatic trip interlocks to become alarms. There is capability in the drive system to add additional indicators if the plant operators should at some future time so direct. Changes of this type would have considerable effect on the quantity of plant wiring.

- b) ETEC recommends that the MG Set heat exchangers be modified to employ a mechanically ganged oil and water valve arrangement for transfer of both oil and water sides of the dual heat exchanger simultaneously. This is based on an incident (UOR #ETEC-82-06-SPTF-86-02) where the water side failed to switch when called for.

Response: The failure to achieve simultaneous oil and water switching at ETEC was determined to be caused by a combination of improper water valve pressure assist piston size and low water pressure. It is believed that these two aspects are corrected for CRBRP. See Appendix C, NCR's 2599 and 2615 for further information.

2.7.6 Continued

- c) ETEC recommends better visual monitoring of MG set oil reservoir level.

Response: The design is accepted and baselined. Expenditure to improve accessibility not considered justifiable at this time.

- d) ETEC recommended that the outer reservoir of the VDM oil system be provided with a level switch.

Response: At ETEC, the oil level arrangement consisted of an oil to water heat exchanger and an orifice and bypass to increase pressure so that the pressure switch functioned correctly, which is different from the CRBRP set up, where the heat exchanger pressure switches and piping were matched to the application. At CRBRP due to the considerably better match between heat exchanger and the piping, i.e., smaller pumps and design pipe length, the bypass valve does not have to operate wide open and most of the oil flow will go directly from the heat exchanger to VDM bearing oil reservoir and back again to the heat exchanger instead of being bypassed as it was at ETEC. Therefore, the problem of matching two flow rates between three reservoirs does not exist at CRBRP.

- e) ETEC recommended that an independent restart circuit be provided for the VDM without stopping and restarting the MG Set.

Response: There are deliberate limits on the VDM restarts for the protection of the VDM due to extremely high inrush currents experienced in startup. Most startup difficulties are encountered immediately after installation or during speed controller adjustments. It is a judgement factor that the permissive circuitry should be left as for CRBRP.

- f) ETEC recommended that valve position sensor wiring for position indicator lights should be changed as per NCR #2705.

Response: Incorporated

ETEC concluded that operation of major components was satisfactory.

Non conformance encountered during this segment are listed below:

<u>NCR#</u>	<u>SUBJECT</u>
2688/2690	Abnormal noise at Voith coupler
2687	Valve actuator broken
2693	VDM Bearing Noise
2697	MG trip-timer problem
2699	Speed drift to 1132 RPM
2704	Hx transfer-water failed to switch
2705	ICP status light wiring error

See Appendix for the details of corrective actions taken at ETEC and actions planned for CRBRP.

#### 2.7.7 Segments B5 & B13, Endurance Runs

The purpose of these segments was to demonstrate operation at rated temperature (995°F) and hydraulic conditions (Full speed at CRBRP 3 loop maximum impedance).

The first of these segments was for 48 hours, (9/23/82-9/25/82) and was run shortly after the first run up to full temperature, but before application of the severe thermal transients. The second segment was run after the series of significant tests where sodium was at 1005°F (B6 through B10). The second, or long term endurance run was constrained by schedule plans and was limited to seven days in order to facilitate the schedule for testing the cellular convection fix.

Specifically, each of these segments was to demonstrate sustained operation at rated temperature, speed and flow, demonstrate mechanical stability.

##### Results Segment B5:

- o The short-term endurance run consisted of 57 hours at 1116 RPM, R3 impedance and 1005°F sodium. There were no unusual events. The tank fluid level was constant at 146.3 ft. ± .2 ft. Hydrostatic bearing orbit was stable.

The breakaway and running torques at the end of the test were unchanged from start of test data. End of test breakaway :110 in lb, turning torque :87 in lb.

The segment report for B5 contained attachments with the following:

- A - Temperature Profile for tank T/C's
- B - Summary of tank, Shield & Cover T/C's
- C - Oil Temperature & Seal Hx temperature
- D - VDM & MG Bearing Temperature
- E - Frequency Domain Information
- F - Structural Vibration & Seal Oil Level Sensor Readings

The data referenced is available in Segment report #83ETEC-DRF-2380.

Results Segment B13.

Test Segment B13 was run from November 20, 1982 through November 28, 1982, for a total 170 hours during the test, with 452 hours total accumulated time at 1005°F and rated flow.

One unusual event caused an interruption of the test: The SPTF facility air blast cooler fan motor failed and caused an increase in sodium temperature to 1058°F for a short period. It was concluded that no pump damage resulted.

Attachments, similar to those tabulated above, are contained in the segment report #83ETEC-DRF-3910, including H/Q speed scan taken at the start and at the completion of the test. See Paragraphs 2.9.1 and 2.9.2 for summaries of vibration and temperatures.

#### 2.7.8 Segment B10, One Loop Operation on Main Motor

The purpose of this test was to provide data for system 51A to define head and flow relationship at the one loop impedance R7 ( $0.126 \times 10^{-6}$  ft/gpm<sup>2</sup>), to define head flow characteristics at a high flow to speed ratio, and to demonstrate pump ability to withstand a speed overshoot upon startup.

Results:

An R7 speed scan recording Head vs. flow at 400 RPM, 300 RPM, 251 RPM and 104 RPM was completed with sodium at 600°F and at 1005°F, using the 37.5 inch impeller. There was no cavitation at R7 and 251 RPM. ETEC experienced some data fluctuations at the 251 RPM test point; this was caused by readjustments of the drive speed control, to improve gain at the 725 RPM speed, where instability was previously experienced. This situation was not deemed to have significance. Diagnostic sensors of pump and drive were reviewed and indicated no anomalies. The Head/Flow data taken during this test is plotted as Figures 2.7.8.1 and 2.7.8.2. Results are listed as follows:

FLOW AND HEAD

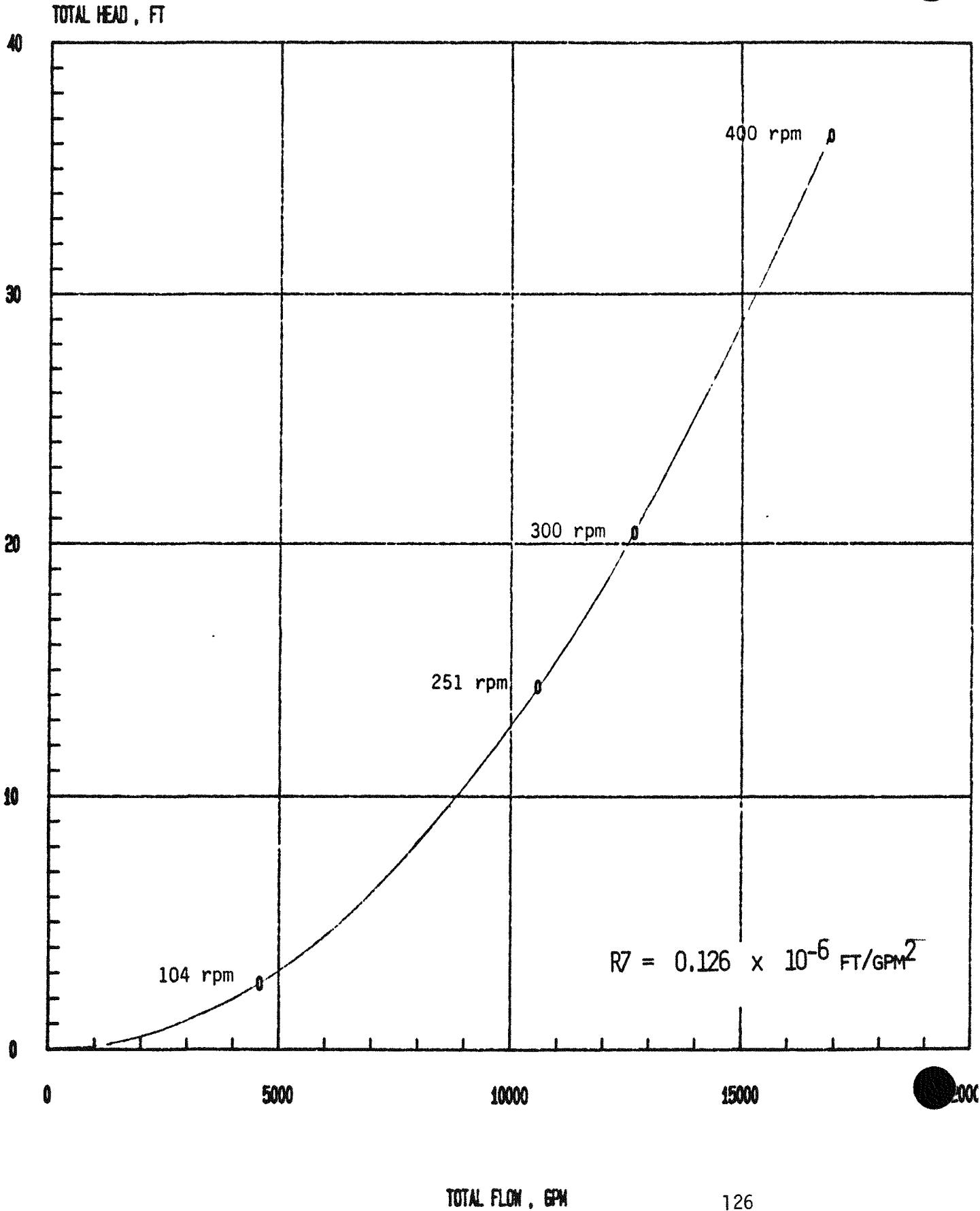
SPEED RPM	600°F		1000°F	
	<u>GPM</u>	<u>FT</u>	<u>GPM</u>	<u>Ft</u>
104.3	4599	2.68	4605	2.68
251	10,589	14.43	10,781	14.72
300	12,686	20.53	12,837	20.71
400	16,938	36.39	17,099	36.95

TABLE 2.7.8  
R7 SPEED SCAN

# CRBRP PROTOTYPE PUMP - TEST SEGMENT B10

FIGURE 2.7.8.1  
R7 SPEED SCAN AT 600 OF

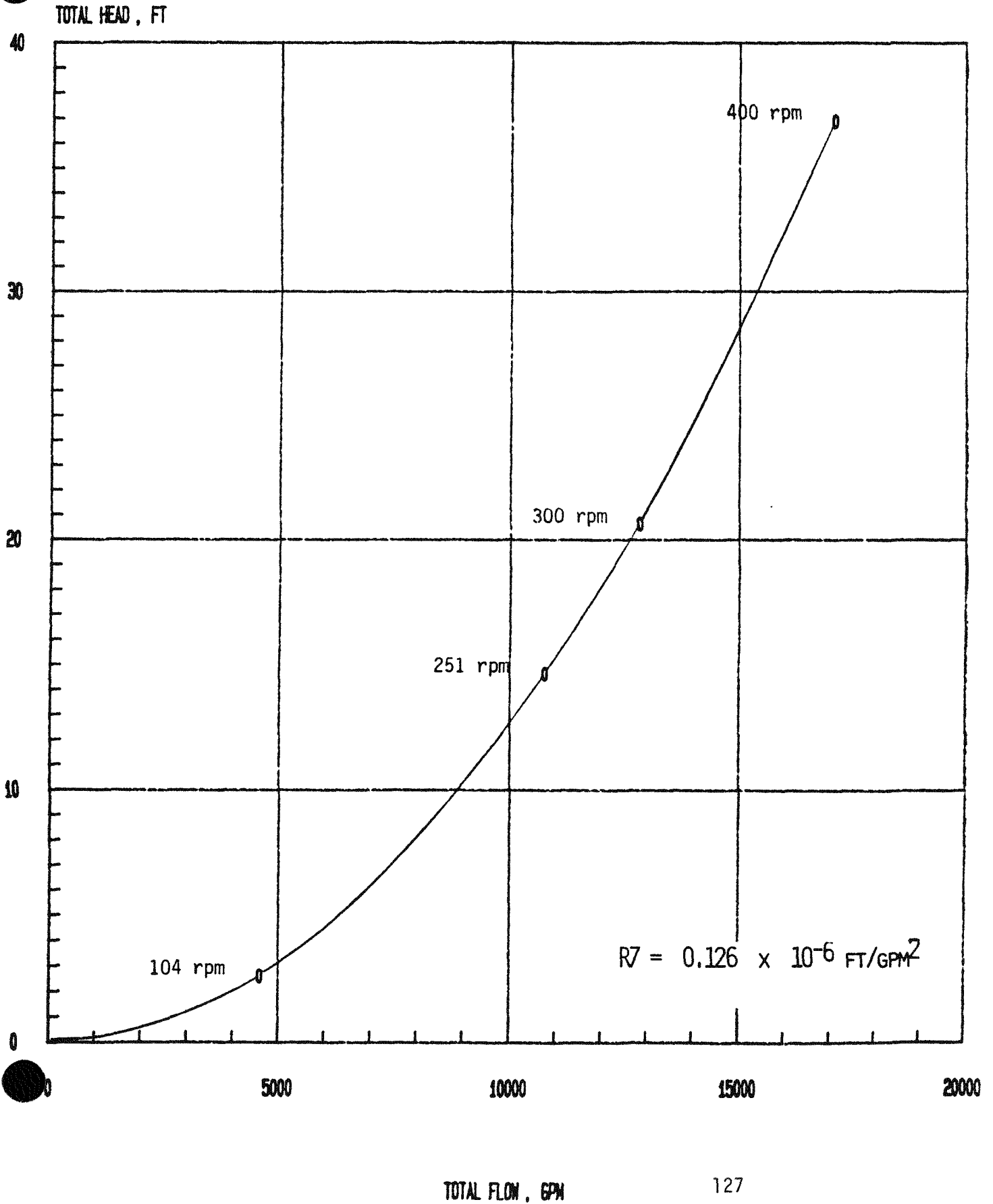
FROM: 83ETEC-DRF-3909  
8-30-83 Page 10



# CABRP PROTOTYPE PUMP - TEST SEGMENT B10

FIGURE 2.7.8.2  
R7 SPEED SCAN AT 1005°F

FROM: 83ETEC-DRF-3909  
8-30-83 Page 11



### 2.7.9 Segment B3B, IHX Gas Injection

The purpose of this test was to confirm tank fluid level stability with several rates of gas injection into the IHX nozzle, and to determine if slug pumping occurs in the bubbler pipe as evidence by sodium carryover measurements.

The SPTF loop was arranged with a pipe to carry sodium from the pump discharge, through a valve to the pumps IHX return nozzle, so that at 1116 RPM and R3 impedance, 200 gpm of sodium would be returned to the pump sump via the IHX nozzle. This sodium line was arranged for a manually controlled rate of gas injection.

Three sodium flow rates were used: pony motor flow, 33,700 gpm (100%), and 39,100 gpm (116%). Three IHX gas rates were used: 0, .22, and .55 scfm. Gas injection at the IHX nozzle was in addition to the nominal gas flows into the pump at interface #10. Gas flows were measured at the purge inlet (interface #10), oil collection tank gas bleed outlet (interface #12), the IHX gas inlet, and the bubbler outlet. Sodium level in the pump tank was measured.

The test consisted of taking a series of sodium carryover measurements by draining off a measured volume of the bubbler gas flow, into a special sampling tube. The tube was then removed and sent to a laboratory for measurement of sodium content in terms of milligrams of sodium per standard cubic foot of gas. The test involved diversion of normal bubbler flow into the measurement apparatus. The system for diversion and sampling of bubbler gas was a "first-of-its-kind" at ETEC. No previous experience or literature record was available for design of a system to handle the sodium aerosol/sodium vapor/argon mixture and provide a representative test sample suitable for laboratory analysis.

The test results were considered questionable regarding carryover measurements.

Without IHX gas injection, but with the normal purge gas flow, the carryover measurement method yielded about 4 milligrams per standard cubic foot, which is far below the saturation density of 300+ milligrams/scf expected at 1000°F. Since the gas bubbles through liquid sodium in the bubbler, it might be expected to be saturated with sodium vapor, assuming that subsequent piping is heated sufficiently to prevent cold trapping. (If saturation is a reasonable expectation for this bubbling gas, then the system designers should use the saturated density to predict carryover magnitude. The question is whether saturation is to be expected in this situation.)

#### 2.7.9 Continued

As soon as ETEC diverted bubbler gas from the normal bubbler gas return line into the measuring apparatus, the impedance of the gas flow path was increased, and its effect was that the increased backpressure caused bubbler gas flow reduction, and an increase in pump internal pressure. This would result in a level reduction in the pump, starting shortly after gas diversion to the measuring apparatus. It is postulated that the carryover measurements represent gas flow in a non bubbling state.

The IHX gas injection without the bubbler carryover apparatus in the bubbler line caused no level disturbance.

The measured quantity of sodium carryover for each of the IHX gas and purge gas flow rates is not presented in this report for the reasons stated above.

#### 2.7.10 Segment C6, Pony Motor & Main Motor Startup Run

This test segment was the first pump operation following the disassembly and reassembly of the pump with a change in the rotating assembly (from 37.5 inch diameter impeller to 38.25 inch diameter impeller), and with the addition of baffling between the upper innerstructure and the tank (the "fix" for the gaseous cellular connection problem).

The purpose of this test segment was

- o To circulate sodium so that the sodium purification process was started.
- o To determine that pony motor and main motor instrumentation was performing satisfactorily (after being disconnected and reconnected in the pump rotating assembly change).
- o To determine if the lubrication systems of the MG Set and Vertical Drive Motor were performing as intended.

To make adjustments (if needed) to the function generator (of the speed regulator).

The results indicated that the sodium loop purity was satisfactory at less than 3 ppm oxygen.

#### 2.7.10 Continued

Pony motor and gear box vibration (displacement) during steady state speeds were satisfactory at .58 mils and .22 mils respectively.

Vertical Drive Motor and MG-Set winding and lube oil temperatures were normal, as were vibration (displacement) sensor indications; these were documented in the Segment Report (83ETEC-DRF-4222).

The first attempt at starting the vertical drive motor with loop impedance set for R3 ended with a protective circuit trip, assumed to have been caused by the slower acceleration supposedly resulting from the larger diameter impeller. The system was successfully started on the second attempt, when loop resistance was set to R2. Thus, no speed regulator function generator adjustments were necessary.

ETEC provided plots of vibration sensor output of Pony Motor and gear box for both startup and coastdown, indicating displacements of less than 1.5 mils.

ETEC presented traces of pony motor speeds showing the differences in sensor outputs between the test article analog output (SE9252) and the speed registered by the digital pickup which is magnetically coupled to rotating gear teeth (SE9249). At the conclusion of this segment, the drive system was proven ready to support the Phase C pump tests.

### 2.8 Installation, Assembly/Disassembly and Readiness Tasks

#### 2.8.1 Segment A1 Tank Installation

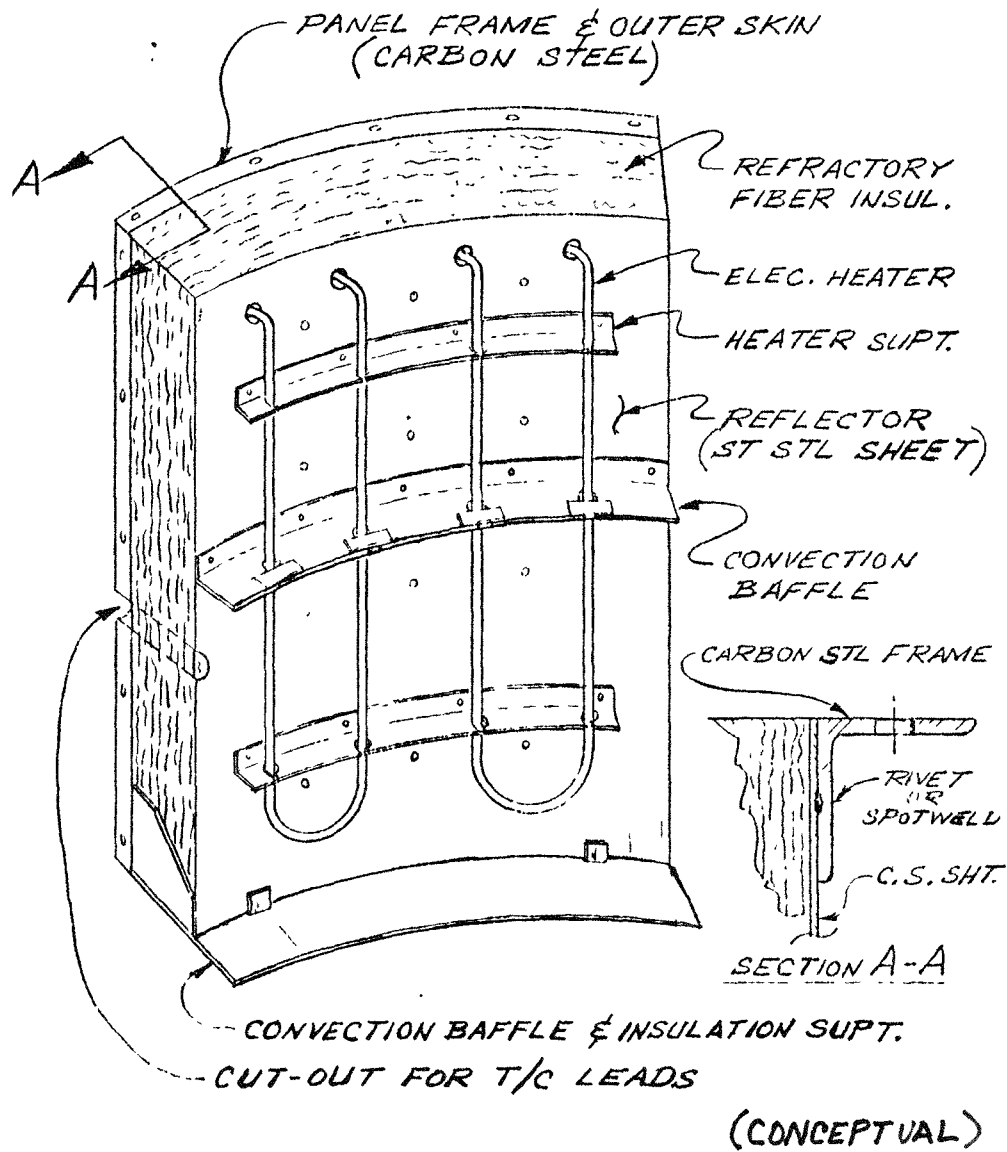
The purpose of Segment A1 was to install the tank in the SPTF loop; make five pipe connections; install tank mounted sensors, and complete the heater and insulation installation.

All objectives were met. The tank was installed and pipe connections were welded and radiographed. The suction nozzle weld required repair. The insulation was installed with no weight being applied to the pump. The following non-conformances were identified and dispositioned.

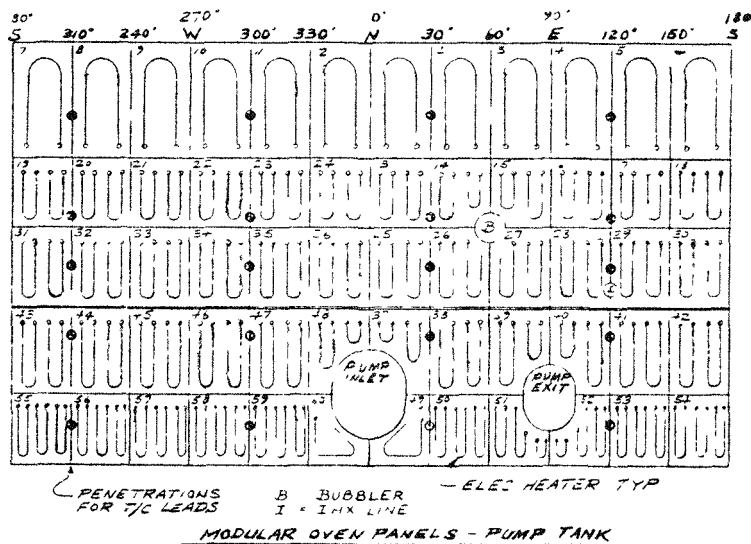
2.8.1 Continued

<u>NCR#</u>	<u>SUBJECT</u>
8680	Stained appearance
8679	Damaged bolts

The insulation and heater arrangement was not prototypical of the CRBRP design because the SPTF design was leading the CRBRP design by several years. ETEC document 78ETEC-DRF-3347 dated December 4, 1978, defines the heater/insulation approach. A typical oven panel is shown in Figure 2.8.1.1, and the total tank heater layout is shown in Figure 2.8.1.2. Thermocouples to be used for tank preheat monitoring were secured to the tank by means of a Marimet 45 insulation block with a 5/8 inch wide X .010 thick strap spot welded to the tank, and similar straps were used for anchoring leadout hardwires.



TYPICAL OVEN PANEL  
FIGURE 2.8.1.1



MODULAR OVEN PANELS  
FIGURE 2.8.1.2

2.8.2 Segment A2 MG Set Installation

In this task, the Motor Generator Set and its auxiliaries, and the Vertical Drive Motor and its auxiliaries are received, and all except the Drive Motor are installed. Electrical power and instrumentation connections are made, and oil and water lines are interconnected. Wiring between the drive and the flow controller is installed.

Results:

- o Shipping of Drive equipment was made per the shipping plan (reproduced on a subsequent page).
- o The MG Set and the lube oil system was installed with electrical & hydraulic connections.
- o The MG Set oil system was serviced.
- o The VDM lube oil system was installed.

Non Conformances:

<u>NCR#</u>	<u>SUBJECT</u>
2497	Contaminated Lube Oil
2499	MG Set Motor bearing wear
2505	Foreign material in Fluid Coupler Reservoir
2508	Missing hardware & rats nests in power enclosure

SHIPPING PLAN FOR PROTOTYPE PUMP DRIVE SYSTEM

Sh. 1 of 2

134

	MOTOR GENERATOR SET										CONTROL PANELS		
	Generator Conduit Box	Generator	D/Motor Conduit Box	Drive Motor	Heat Exchanger Assy	With Fluid Drive Coupler	With Pump & Instrument Panel	Coupling Housings & Spacers	With Fluid Drive Piping & Valves	Misc. Items & Assembly Parts	PPS Breaker Cubicles	PPS Breaker	Speed Regulator Panel
1. Equipment Shipper	Byron Jackson Pump Division, Borg-Warner Corporation, Los Angeles, California												
2. Supplier (GFE)	Department of Energy												
3. Purchase Order No.	(3) M124-195 BMP						(4) 1D0-K2Y00						
4. Point of Origin	Vernon-Los Angeles, California												
5. Schedule Shipment Date	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81	5/29/81
6. Estimate Date of Arrival at ETEC	As above	As above	As above	As above	As above	As above	As above	As above	As above	As above	As above	As above	As above
7. Equipment Ident. No. (See Note 1)	34D842757	34D108801	34D842758	34D109787	3.60-9653	3.60-9652	3.60-9654	228K7718 See Note 2	441K445 See Note 2	441K450 See Note 2	0147D3054	269A6146	D-3236
8. Component Quantity	1	1	1	1	1	1	1	2	Many	Many	2	3	1
9. Number of Pieces (Shipping)	1	1	1	1	1	1	1	1	2	1	2	3	1
10. Dimensions-Approx (Inches)	65Hx63W x75L	110Hx96W x255L	57Hx63W x77L	112Hx96W x134L	65Hx125W x144L	118Hx102W x120L	86Hx58W x102L	32Hx35W x89L	61Hx42Wx149L 29Hx47Wx178L	25Hx40W x75L	106Hx76W x95L	54Hx28W x71L	45Hx47W x102L
11. Shipping Weight Approx. (lbs.)	3050	34,700	2800	36,700	8700	18,500	5300	825	3700	825	4710	1300	2100
12. Proposed Method of Shipment	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck
13. Enclosure	Crated	Covered	Crated	Covered	Crated	Skid Covered	Crated	Crated	Crated	Crated	Crated	Crated	Crated
14. Documents to Accompany Shipment	<ul style="list-style-type: none"> <li>• Packing List</li> <li>• Shipping Release (Byron Jackson)</li> <li>• Shipping Release (GE-ARSD)</li> </ul>												
15. Special Shipment Instruction	Byron Jackson is contracted to prepare, package and ship this equipment consistent with the requirements of IOM Manuals: Variable Frequency Motor-Generator Set GEK-42757, Main Pump Motor GEK-42758 and System for Sodium Pump Drive GEK-42759.												
NOTES:	(1) LM&G Drawing Part Nos. are used in place of CRBRP EIM's.									SP No. XL-593-00884 Rev. 0 12/18/80			
	(2) LM&G Sub-Vendor Shop Order Nos. are used in place of CRBRP EIM's.									Rev. 1 02/06/81			
										Rev. 2 04/16/81			

FIGURE 2.8.2  
DRIVE SHIPPING PLAN

SHIPPING PLAN FOR PROTOTYPE PUMP DRIVE SYSTEM

Sh. 2 of 2

	CONTROL PANELS		VERTICAL DRIVE MOTOR (See Note 5)									
	Motor Control Center	Instr'n & Control Panel	D/Motor Heat Exchanger	Clutch Coupling	Spare Gear Sets	Pony Motor & Gear Assembly	Misc. Items & Assembly Parts	Upper Support Cover	Drive Motor			
1. Equipment Shipper	Byron Jackson Pump Division, Borg-Warner Corporation, Los Angeles, California								(5)	GE/Large Motor & Generator Department Schenectady, New York		
2. Supplier (GFE)	Department of Energy											
3. Purchase Order No.	(3) M124-195 BMP				(4) 100-K2Y00							
4. Point of Origin	Vernon-Los Angeles, California											
5. Schedule Shipment Date	5/29/81	5/29/81	8/28/81	8/28/81	8/28/81	8/28/81	8/28/81	8/28/81	8/28/81			
6. Estimate Date of Arrival at ETEC	As above	As above	9/25/81	9/25/81	9/25/81	9/25/81	9/25/81	9/25/81	9/25/81			
7. Equipment Ident. No. (See Note 1)	21285376	014108348	C-76-E-60	34E773092	441K441 See Note 2	934C773115	441K441 See Note 2	136D5672G-1	554E220			
8. Component Quantity	1	1	1	1	5	1	Many	1	1			
9. Number of Pieces (Shipping)	1	1	1	1	1	1	1	1	1			
10. Dimensions - Approx (Inches)	110Hx51W x72L	108Hx56W x104L	100Hx120W x65L	27Hx22W x24L	20Hx30W x25L	60Hx100W x60L	12Hx50W x99L	21Hx77W x88L	197Hx161W x120L			
11. Shipping Weight Approx (lbs)	2100	4800	5830	400	1000	4500	340	5300	90,000			
12. Proposed Method of Shipment	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck			
13. Enclosure	Crated	Crated	Crated	Crated	Crated	Crated	Crated	Crated	Crated	Skid Covered		
14. Documents to Accompany Shipment	See Sheet 1											
15. Special Shipment Instruction	See Sheet 1											
NOTES:	(3) Dummy P.O. No. Identifier required by ETEC.					(5) Vertical Drive Motor will be shipped from GE/LM&G to ETEC			SP No. XL-593-00884 Rev. 0 12/18/80 Rev. 1 02/06/81 Rev. 2 04/16/81			
	(4) GE Inter Divisional Order No.											

135

FIGURE 2.8.2  
DRIVE SHIPPING PLAN

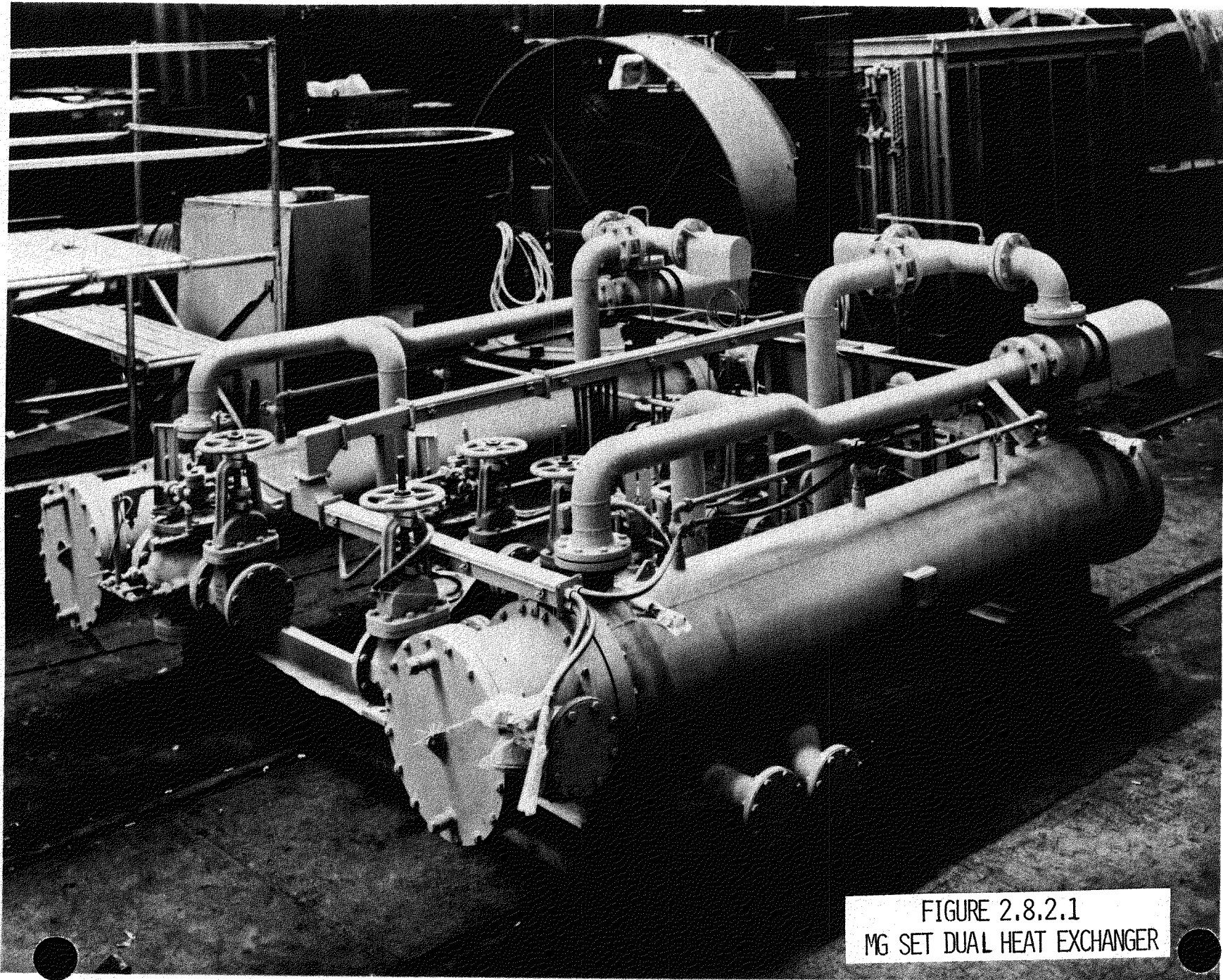


FIGURE 2.8.2.1  
MG SET DUAL HEAT EXCHANGER

NCR#SUBJECT

2542	As built jumper location discrepant with drawing
2572/77	Broken fan and drip pan missing
2551	Temperature & pressure gages missing

Additional details of these non conformance and the corrective actions taken for ETEC and CRBRP are contained in the appendix. Procedures used for MG Set Handling and Installation (which include alignment) were transmitted as objective evidence of completion via 81ETEC-DRF-4052 dated October 9, 1981.

### 2.8.3 Segment A3 M-G Set Activation

The purpose of this task was to accomplish pre operational and initial operating tasks on the lube system and the M-G Set, and perform a no load run up of the MG Set to verify power and instrumentation connections and lube oil system switching.

#### Results:

The M-G Set was activated and run under no load conditions for a period of 4 hours and 45 minutes. New oil pressure switches were installed. Tachometer magnetic pickups were adjusted. Static alignment of the speed regulator was completed. The lube oil system was flushed. Voith fluid coupler pressure regulators were adjusted. In the absence of a training program for operators, it was found that the IOM Manual instructions for start-up and checkout required supplemental detailed instructions which were prepared by ETEC Engineering in consultation with the Test Requestor. ETEC activation procedures which were based on the IOM Manual required extensive field (red line) changes; and, a number of special test procedures had to be prepared to supplement or to replace portions of activation procedures after its official release. The drive system as received at ETEC was used equipment, having been operated for over one year in support of water tests. This resulted in encountering numerous discrepancies in this test segment:

1. Pressure switches in the MG set cooling system required repair or recalibration.
2. A valve actuator was inoperative.
3. Water flow switches had cracked paddles.
4. MG Set speed control was non-functional due to a missing wire.

5. The speed control drifted.
6. Excessive travel of the Voith scoop tube was experienced.
7. There was a wiring error on the annunciator panel.
8. A Ross water valve was badly encrusted with hard water deposits, and as a result was inoperative.
9. Internal wiring of the MG motor terminal box was incorrectly installed as received at ETEC.

There was an abnormal amount of difficulty encountered in the activation of this equipment at ETEC. Contributing to the condition were the following:

- o The equipment was the first of a series of six, and had non-conformances which may have been unique to the first unit.
- o The system had been used as GFE supporting equipment for water test, but had not been checked for conformance with specified configuration and functional performance prior to shipment.
- o Personnel operating the equipment in water test and at ETEC were not formally trained in its use. Training occurred while troubleshooting.
- o The procedures of the IOM Manual had never been validated and were not suitable in detail or in accuracy for use by untrained personnel unfamiliar with the equipment.

Non conformances identified include the following:

<u>NCR#</u>	<u>SUBJECT</u>
2544	Cover missing
2580	Resistors missing
2581	Heater fuse wiring
2584	Broken cover plate & tags missing
2587	Thermocouples inoperative
2588	Gear speed indicator missing
2593	Lube oil skid as built wiring & drawing discrepancy
2594	Temperature sensor location in error
2599	MG Hx water valve not functioning
2600	Circuit Breaker inoperative
2601	MG Set motor wiring error

Additional details of these non conformance and corrective actions taken for ETEC & CRBRP are contained in the appendix. Details of the difficulties encountered by ETEC are contained in the A3 Segment Report #ETEC-TDR-82-10.

#### 2.8.4 Segments A4A and A4B Pump Internals Receiving and Assembly

The purpose of the A4A Segment was to receive and inspect incoming pump parts. The A4B Segment involved assembly of pump internals.

Pump parts were received at ETEC on the following schedule:

<u>Item</u>	<u>Date(1981)</u>
Tank	May 5
Rotating Assembly	July 17
LIS	July 31
Thermal Shield	July 31
Hydraulics	August 7&14
Thermal Liner	August 14
Lube Tank	August 21
UIS	August 28
Instrumentation	August 28 thru October 9
Tools	With each shipment
Shaft Seal	October 1

Internals Assembly was completed November 30, 1981.

#### Results, Segment A4A

All of the pump parts and special tools were off loaded from the suppliers carrier, inspected and stored pending use for assembly. The shipping and packaging plan (DT #AC-0003-1689C) adequately defined the packaging, but was obsolete and therefore not effective for inventory accountability during receiving. For communication of active shipping plans, General Electric issued a prototype pump shipping plan, #XL593-00775 which identified to ETEC and other interested parties, with pertinent facts concerning the shipments - what, when, number of pieces, size, weight, enclosure type, etc. This shipping plan is contained in the following pages. In practice, this plan was updated and reissued as shipments took place.

The physical packaging of parts by the pump supplier was good, providing adequate protection during transport and off loading.

SHIPPING PLAN FOR PROTOTYPE PUMP

Sht 1 of 3 Shts.

	Pump Tank	Lower Inner Structure		Hydraulic Assembly						Upper inner Structure (10)			Lube Sys.
	Tank & Cone Assembly	LIS Assembly	Thermal Shield	Top Bearing Assembly	Pump Case Brg. Cage Assembly	Baffle Plate	Bearing Shroud to Standpipe	Innerma Liner	Spacer(s)	UIS Assembly	Tank Assembly	Cover Shot Access	Oil Supply Tank Assembly
1. Procurement Participant	Byron Jackson Pump Division, Borg-Warner Corporation, Los Angeles, California												
2. Supplier	Advanced Reactor Systems Department, General Electric Company, Sunnyvale, California												
3. Purchase Order No.	(4) H124-180 BRP (5) AC-0003												
4. Point of Origin	Vernon - Los Angeles, California												
5. Schedule Shipment Date	5/5/81A	7/31/81A	7/31/81A	8/7/81A	8/14/81A	8/14/81A	8/14/81A	8/14/81A	8/14/81A	8/28/81A	8/21/81A	9/11/81A	8/21/81A
6. Estimate Date of Arrival at ETFC	As above	As above	As above	As above	As above	As above	As above	As above	As above	As above	As above	As above	As above
7. Equipment Ident. No. (See Note 1)	509608	409073	409088	436503	436504	333522	333285	437012	136228	509610	409091	294522	436508
8. Component Quantity	1	1	1	1	1	1	1	1	48	1	1	3	1
9. Number of Pieces (Shipping)	1	1	1	1	1	1	1	1	1	1	1	1	1
10. Dimensions - Approx. (Inches)	Bottle Shape 124 <sup>Ø</sup> /Dx249	100 Cube	90x90x36	63x53x53	96 Cube	93x89x7	51x46x25	54x54x23	19x19x13	Vert. Cyl. 90 <sup>Ø</sup> /Dx116	71 Cube	24x16x16	37x33x32
11. Shipping Weight Approx. (Lbs.)	54,400	15,000	5,500	4,900	16,654	3,129	955	1,850	150	40,000	3,224	309	690
12. Proposed Method of Shipment	Low Bed Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Low Bed Truck	Truck	Truck	Truck
13. Enclosure	Open Cradle	Crated	Crated	Crated	Crated	Crated	Crated	Crated	Crated	Open Cradle	Crated	Crated	Crated
14. Documents to Accompany Shipment	<ul style="list-style-type: none"> <li>• Packing List</li> <li>• Shipping Release (Byron Jackson)</li> <li>• Shipping Release (ARSD-GE)</li> <li>• Applicable Handling &amp; Receiving Inspection Instructions</li> <li>• Each approved Waiver or VCR that applies to the equipment being shipped</li> <li>• Applicable Material Certifications (Not Delivered, Shown by Testimony in Certificate of Compliance)</li> </ul>												
Notes:	(1) Prototype Test Unit Drawing Part No. is Used in Place of CRBRP EIN'S.									(2) See T-1499-001, 002, 003 Appendix 1 of BJ's H, P & Shipping Plan No. PA-9001			
										SP No. XL-593-00775 Rev. 0 10/31/80 Rev. 1 2/6/81 Rev. 2 4/16/81 Rev. 3 6/16/81 Rev. 4 12/10/81			

140

SHIPPING PLAN FOR PROTOTYPE PUMP

Sh: 2 of 3 sheets.

	Shaft Seal Assembly			Rotating Assembly		Final Assembly Parts								
	Cartridge Assembly	Inst'n. Accessories	Fan and Fan Shroud		Rotating Assembly	"O" Ring & Retainer	Mainten Seal	Bolting Ring	Upper Retaining Ring	Motor Half Coupl Spac. Split Ring	Locking Straps	Studs B/S to LIS Joint	Locking Straps	
1. Procurement Participant	Byron Jackson Pump Division, Borg-Warner Corporation, Los Angeles, California													
2. Supplier	Advanced Reactor Systems Department, General Electric Company, Sunnyvale, California													
3. Purchase Order No.	(4) M124-180 BMP (5) AC-0003													
4. Point of Origin	Vernon - Los Angeles, California													
5. Schedule Shipment Date	10/1/81A	10/1/81A	10/1/81A		7/17/81A	9/11/81A	9/4/81A	8/28/81A	8/28/81A	9/18/81A	9/4/81A	8/28/81A	8/28/81A	
6. Estimate Date of Arrival at ETEC	As above	As above	As above		As above	As above	As above	As above	As above	As above	As above	As above	As above	
7. Equipment Ident No. (See Note 1)	2F1819	2F1816	333503 333509		509612	2-433674 -70 333526	340569	312804	333507	333500a 222997 222998a	284963	284968	294545 to 294549	
8. Component Quantity	1	Many-See Note (6)	1 ea.		1	1 ea.	1	1	1	1	24	48	80 Pieces Total	
9. Number of Pieces (Shipping)	1	1	1		1	1	1	1	1	1	1	1	1	
10. Dimensions - Approx. (Inches)	31 Cube	32x29x 12-1/2	32x32x16		282x48x48	14x14x 6-1/2	120x120x12	144 x 144 x 15-1/2	144x112x10	19x19x13	16x16x5	32x24x16	22-1/2 x 8 x 8	
11. Shipping Weight Approx. (Lbs.)	1200	80	TBD (3)		8050	14	2,550	17150	2050	172	27	370	110	
12. Proposed Method of Shipment	Truck	Truck	Truck		Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck	
13. Enclosure	Crated	Crated	Crated		Crated	Crated	Crated	Crated	Crated	Crated	Crated	Crated	Crated	
14. Documents to Accompany Shipment	See Sheet 1													
Notes:	(3) Note deleted. (5) BJ Contract No. with GE.					(4) Dummy P.O. No. Identifier Required By ETEC (6) See T-1479 Appendix 1 of BJ's H.P & Shipping Plan No. PA-9001				SP No XL-593-00775 Rev. 0 10/31/80 Rev. 1 2/6/81 Rev. 2 4/16/81 Rev. 4 12/10/81 Rev. 3 6/16/81				

141

FIGURE 2.8.4  
PUMP SHIPPING PLAN

SHIPPING PLAN FOR PROTOTYPE PUMP

Sht 3 of 3 Shts

	Final Assembly Parts - Continued				Instrumentation (9)				Deliverable Spares SEE NOTE (11)			
	Pump Tank to Foundation Bolts	Curvic Teeth Flex Coupling	Rotating Vapor Barrier	Fasteners and Misc.	Penetration Assembly	Junction Box Assembly	Thimble Assy-Level Probe	Instr'n and Hardware				
1. Procurement Participant	Byron Jackson Pump Division, Borg-Warner Corporation, Los Angeles, California											
2. Supplier	Advanced Reactor Systems Department, General Electric Company, Sunnyvale, California											
3. Purchase Order No.	(4) N124-180 BHP (5) AC-0003											
4. Point of Origin	Vernon - Los Angeles, California											
5. Schedule Shipment Date	5/8/81A	9/4/81A	9/4/81A	10/9/81A	8/28/81 A	5/29/81A	10/9/81A	Completed 10/9/81A				
6. Estimate Date of Arrival at ETEC	As above	As above	As above	As above	As Above	As above	As above	As above				
7. Equipment Ident. No. (See Note 1)	648965	436525	333525	1F8275	284973	536520	333536	2E2520				
8. Component Quantity	40	1	1	Many-See Note (7)	1	1	2	Many-See Note (2)				
9. Number of Pieces (Shipping)	2	1	1	29	3	1	2	3				
10. Dimensions - Approx. (Inches)	40x16x6	21x21x17	18x18x10	40x40x48	66x11x12	78x31x30	200x12x12	48x40x40				
11. Shipping Weight Approx. (Lbs.)	480 ea.	440	45	2,000	100	670	638	600				
12. Proposed Method of Shipment	Truck	Truck	Truck	Truck	Truck	Truck	Truck	Truck				
13. Enclosure	Crated	Crated	Crated	Boxes Strapped on Pallet	Crated	Crated	Crated	Crated				
14. Documents to Accompany Shipment	<p>See Sheet 1</p> <p>NOTES: (9) Partial Instrumentation Release: Pump Tank Instrumentation Delivered 6/29/81A. 16 - Proximity Probes Delivered 7/17/81A. Remainder 10/9/81.</p> <p>(10) UIS Delivery Includes Cover Gas Line Orifice(s).</p> <p>(11) Pump Spares will be stored by Byron Jackson and delivered incrementally to ETEC on a need basis.</p>											
Notes:	(7) See T-1474-002, to 065 Appendix 1 of BJ's H,P & Shipping Plan No. PA-9001							(8) See Appendix 1 & 9 of BJ's H,P & Shipping Plan No. PA-9001 for Applicable Handling/ Installation Tools, delivered with each shipment.				
								SP No. XL-593-00775 Rev. 0 10/31/80 Rev. 1 2/6/81 Rev. 2 4/16/81 Rev. 4 12/10/81 Rev. 3 6/16/81				

142

FIGURE 2.8.4  
PUMP SHIPPING PLAN

Lifting gear was, at ETEC's choice, proof tested at ETEC, although the supplier provided "blanket" certification (not individual tool certification).

There were some shortages of documents which were to accompany the shipments (91 missing out of 1308 documents).

Inventory records of parts were prepared by ETEC as parts were received.

Non conformance generated during segment A4A were:

<u>NCR#</u>	<u>SUBJECT</u>
2535	Handling fixture cradle hinge
2536	Rotating assembly nicks
2538	Thermocouples are grounded type, non grounded specified

See listing of non conformance in the Appendix if additional details are needed.

#### Results, Segment A4B

The purpose of A4B was to assemble the pump internals and to verify procedures.

The IOM Manual was found to be adequate for pump assembly if supplemented by addition of details and by providing drawings of individual parts.

It was found that match marks on certain individual parts were non existent (had been machined off). In particular alignment match marks for azimuth alignment of internals to the tank were missing.

Assembly clearances were within tolerances specified in the IOM Manual.

Axial travel measured 1.96 inches.

- ° Assembly of the internals, using a different crew than for water test, proved that with existing part tolerances, existing procedures, and new crew, the pump could be assembled and that the same rotor swing test results were achieved even with a different rotating assembly than that used for water test. (Bearing swing test clearances were 35 to 41 mils at ETEC as compared to 38 to 41 mils at the pump supplier's facility.)
- ° As run assembly procedures were preserved as a data output of this test segment.

Non conformance were as follows:

Two interferences were revealed during assembly:

- ° The level probe radiation shielding plug flange interfered with the motor support flange of the UIS, and required factory rework. (This item was not used during water test.)
- ° The oil level probe preamplifier conduit box was discovered to have a potential for interference with the vertical drive motor (relocated). (Both of the above interferences have been corrected on plant drawings).

<u>NCR#</u>	<u>SUBJECT</u>
2545	Cable support cap-sharp edges
2558	Galled nut
2563/65	Oil probe flange fillet interference
2571	Lead lengths too short
2575	Level probe flange interferes with motor mount
2583	Bracket hole alignment

For additional details on non conformance, see the appendix listing.

The pump innerstructure assembly is shown in Figure 2.8.4.1

#### 2.8.5 Segment A5 Innerstructure Installation Into Pump Tank

The purpose of this task was to transfer the previously assembled innerstructure from the component handling facility (CHCF) to the pump tank in SPTF, install the assembly into the tank, and perform the post assembly tasks of connections for purge gas, loading shot into the radiation shield, completion of connections for the shaft seal and checking for leak integrity.

Results:

The transfer of the innerstructure and installation into the tank was accomplished without problems. Seventeen tons of shot were loaded into the radiation shield. It was found to be difficult to disperse the shot to the far circumference of the cavity because of feed location. ETEC found a deficiency in hardware and the IOM Manual regarding azimuthal orientation of the innerstructure with respect to the tank (no scribe marks for alignment), and special steps were improvised to establish orientation. The match marks had been removed in the process of changing the inner structure support from the adjustable wedge design (used in water test) to the maintenance seal ring design (used at ETEC for sodium test).

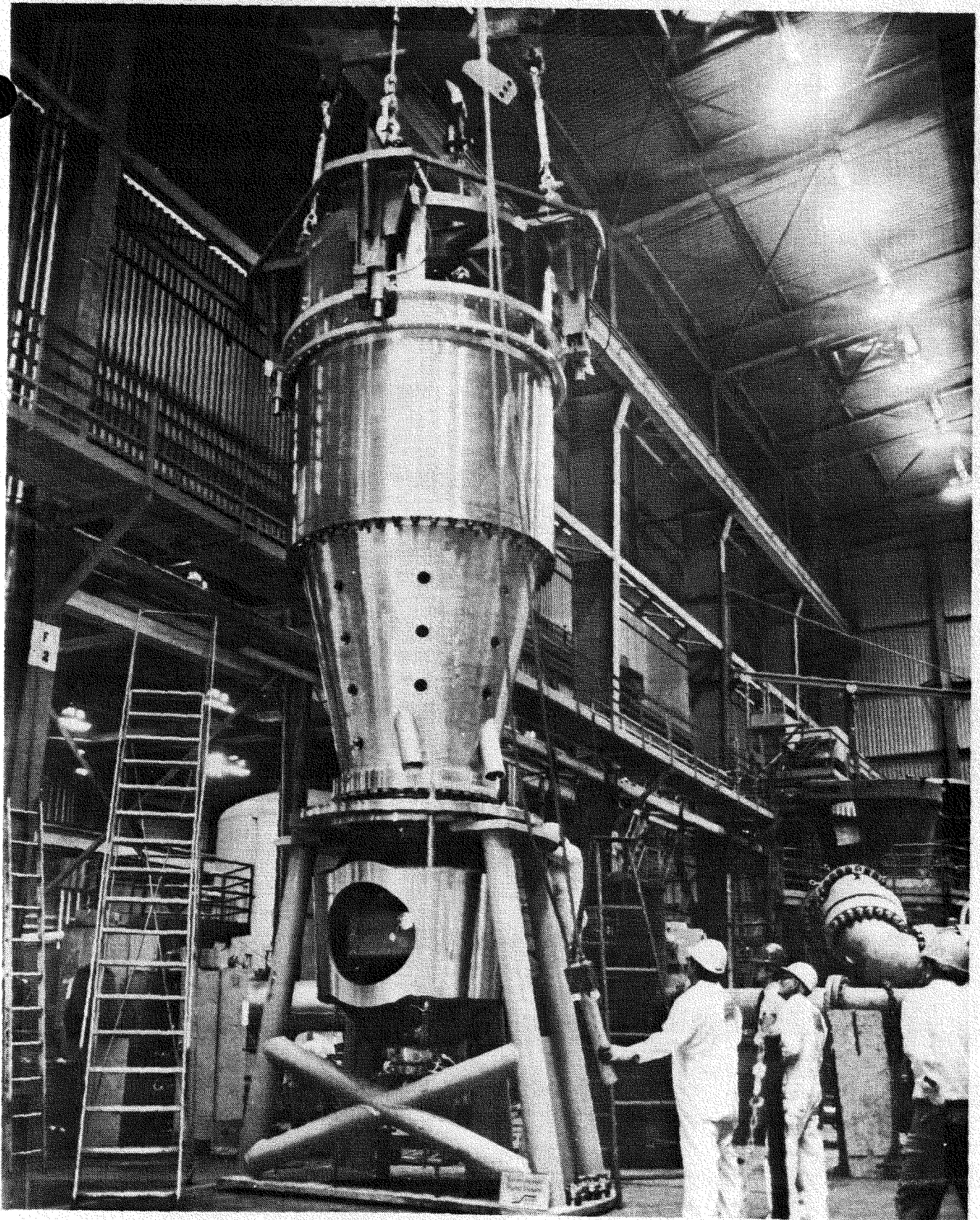


FIGURE 2.8.4.1  
PUMP INNERSTRUCTURE ASSEMBLY

Upon completion of installation, a leak test of the Upper Inner Structure (UIS) to tank seal was accomplished by pressurizing the buffer zone between two O-rings (one was a metal ring prototypical of the plant) and measuring the decay across a 1-hour period. (Note: the prototype pump employed a different design than plant pumps for the UIS to tank attachment. The prototype pump at ETEC employed a large ring forging to establish elevation of the internals in the tank and to seal the pressure boundary. See Figure 2.8.5. the prototypical O-Ring is on the upper surface of the maintenance ring forging and identified as part #23).

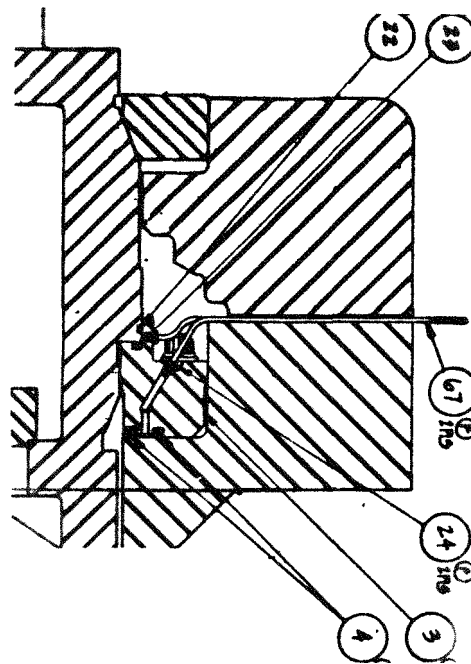


Figure 2.8.5  
 Prototype Pump UIS to Tank Attachment

The leak test of the backup maintenance seal by the pressure decay method after installation of the upper retaining ring passed\* the decay criteria of  $1 \times 10^{-5}$ , scc/sec per cm length per atmosphere (this was an unfinished item of this test segment which was run just prior to preheat).

Helium leak test of the shaft seal O-rings were not run during this segment, but was run after shaft seal centering, just prior to preheat.

\* Initial verbal report indicated that test passed. Subsequently, ETEC documentation left some uncertainty regarding identification of two buffer zones.

In 83ETEC-DRF-4500 (A5 Segment Report), Page 8, ETEC indicated that the leak test of the back up maintenance seal had been completed and that it had met the criteria of 1 psi/half hour at 5 psi leak rate. Subsequent notification however, indicated a possible lack of configuration control, that there was uncertainty regarding which of two pipes which bring the buffer zone pressure connection out of the maintenance ring was the one which contained the metal O-Ring. As of the publication of this document, ETEC concluded that there was uncertainty as to whether the metal O-Ring sealed, since one of the two chambers leaked and one did not, and pipe identification was questionable.

The sealing cone gap measurements at ETEC are checked indirectly by using a measurements from the top of the bolting ring to the motor mounting surface, then comparing this measurement to the similar measurement made at the water test set up, where cone gap has been correlated to the bolt ring to mount measurement. At BJ, a bolt ring to mount measurement of 38.414 inches corresponded to a sealing cone gap of 14 to 17 mils (as measured by entering the tank and inserting feeler gages into the gap where it was accessible). At ETEC, the measurement was 38.350, indicating that the inner structure was seated lower in the tank. This yields a theoretical clearance gap at the cone of 0.011 inches for the ETEC assembly (38.414 - 38.350) divided by 12.8\* yields .005 inches less than the water test gap, or .011 inches. This compares with a requirement of .010 ± .005 inches.

The time required for each task of the Inner Structure installation were somewhat obscured due to separate crews working in two facilities intermittently. ETEC's records indicate the following:

	<u>Time (Hrs.)</u>	<u>Man-Hours</u>
o Install Internals Into Tank	16	115
o Load Shot	24	96
o Maintenance Installation	12	36
o Bolting & Retaining Ring Installation	24	72
o Inert Gas Connections	8	20
o Service Seal With Oil	4	8

\* Radial taper

Non conformances generated as a result of this effort:

<u>NCR#</u>	<u>SUBJECT</u>
2653/2655	Shot loading not complete
2654	IOM Manual error regarding tool used for loading

ETEC made several recommendations regarding innerstructure mating to the tank:

- o Fresh oil servicing connection should be located away from vicinity of shot access cover so that oil spill will not enter shot cavity.
- o The oil supply tank should be equipped with a vent valve.
- o Shot access covers should be gasketed.  
(These items have been resolved for the plant pump design)

#### 2.8.6 Segment A6 Vertical Drive Motor Installation

The purpose of this segment was to mate the motor to the pump support ring, to service the lube reservoirs, to perform preoperational electrical checks, to connect the motor shaft to the pump shaft and measure the torque required to turn motor and pump, and to check diagnostic instrumentation.

##### Results:

Installation and operation of the vertical drive motor was accomplished with only minor anomalies. Additional tests were performed as requested by the test Requestor to operate the VDM under closed loop speed control from the SPTF control room. The VDM and MG Set were ready to support subsequent planned adjustments and tests at the conclusion of this segment.

ETEC found that they could apply only 500 ft lb of torque to the motor mounting bolts due to insufficient access space in the motor frame for the torque wrench. The VDM lube oil system required partial disassembly for removal of foreign materials. The IOM Manual was found lacking in instructions for oil servicing, and in definition of proper oil supply pressure drops in the loop. An orifice was added by ETEC to achieve proper operation of oil pressure switches.

2.8.6 Continued

ETEC's measurement of torques at the top of the pony motor yielded 70 in lb breakaway and 50 in lb running torque (with 17.26 to 1 gear ratio installed in pony motor gear box). This was the start of test torque baseline.

Non conformances identified during this test segment include the following:

<u>NCR#</u>	<u>SUBJECT</u>
2602	Terminal identification
2603	Voith level switches
2604	Limit switch wiring
2605	Ratio of instrument transformer
2606/2608	Thermocouple inoperative
2607	Speed transducer linearity
2609	Scoop tube position unstable
2610	Technician error
2611	Low pressure switch orifice
2614	Acceleration problem
2615	Ross valves & pressure
2617	De-energized oil pump
2623	Water in air duct
2624	Relief valve leak
2625	Oil level exceeds limit
2628	Ammeter pegged
2636	Wiring of instrument transformers
2678	Alarm on scoop tube
2680	Actuator valve for heat exchanger B

See the Appendix of this report for details of the above, with corrective actions taken at ETEC and corrections planned for CRBRP.

### 2.8.7 Segment A7 Final Cold Pump Checks

The purpose of this task was to verify that tasks which can only be done with the pump cold have been accomplished. These tasks are in the nature of verifications. Included are checks of the following:

- o Purge/bleed gas connections
- o Sensor connections complete
- o Heater and insulation complete
- o Heater controls and TC's checked out
- o Seal lubrication ready
- o Drive lubrication ready
- o Drive pump coupling ready
- o Start of test program turning torque baseline

A readiness review meeting was held at ETEC on February 19, 1982. ETEC presented Data Acquisition system tabulations of sensor readings which permitted a review for anomalous channels. Numerous channels on both drive and pump were identified as being anomalous. In addition to these instrument channels, a formal letter to ETEC listed the items requiring completion prior to releasing hold #A8 (start of Preheat). This letter (593-FR-82021, dated February 24, 1982) required ETEC to accomplish certain unfinished tasks:

1. The drop down seal leakage test (Part of Segment A5A).
2. Maintenance seal leakage test (Part of Segment A4B).
3. Shaft to seal coupling & alignment.
4. Shaft seal leakage test (Part of Segment A5).
5. Resolve numerous data acquisition system channel discrepancies.

Additional concerns were communicated to ETEC in Letter #593-FR-82023, dated March 2, 1982.

The readiness review team expressed concern that segments were proceeding without previous tasks being completed, all anomalies identified, and a Quick Look report issued as a condition of proceeding to subsequent segments. The review team requested a list of items known by ETEC to require resolution and GE provided the previously referenced letter listing unfinished tasks required to remove the hold.

In the segment Report (82ETEC-DRF-4023), ETEC identified the documents which provided the objective evidence of completion of the eleven tasks listed in the Test Request for Segment A7. ETEC Letter 82ETEC-DRF-0465 dated March 2, 1982, provided closure status of items identified by 593-FR-82023 requiring resolution for release of the hold A8.

#### 2.8.8 Segment A8 Preheat and Fill

The purpose of this task was to preheat the pump and the loop to the sodium fill temperature, to fill with sodium, and to raise sodium temperature for the purpose of wetting the level sensors.

##### Results:

The start of test breakaway and running torque readings were followed by readings approximately every four hours. Temperature "maps" were recorded very four hours during preheat. Heat up rate target was set by ETEC at 2°F/hour, although the test request permitted 3°F/hour for the dry condition. There was concern that heater elements might induce severe gradients in the tank envelope. Initially, a limit on diametral temperature difference was set at 30°. This was changed 3/12/82 to 60°F. Preheat was completed March 22, whereupon sodium was introduced at a temperature within 25°F of tank temperature (400F).

Early in the preheat period it was necessary to lift grounding of the metallic shields of the tank skin thermocouples in order to get correct readings (they indicated 40-50°F lower than heater control thermocouples). This was caused by the fact that the pump tank thermocouples were grounded units when they had been specified to be ungrounded units. (Ref. NCR 2523).

While sodium fill operations were in process, two solid state relays associated with the heaters failed, and resulted in unwanted energization of four heaters. As a result of this malfunction, a maximum tank differential of 146°F was experienced with temperature beyond limits for a period of 5 hours. Pump shaft breakaway and running torques remained normal, so it was concluded that journal to bearing touch down did not occur. Reference Unusual Occurrence Report #ETEC-82-03-SPTF-82-01.

ETEC filled the pump to an intermediate level, drained, refilled to a higher level, then the cycle repeated until the bubbler level was reached. After bubbler level control was confirmed, filling of piping to higher sodium levels of the loop (to the air blast heat exchanger at elevation 174) (pump flange elevation was 154'3") was accomplished. Sodium temperature was cycled to 700°F for the purpose of wetting the level probes.

Considerable temperature "mapping" data was taken as the pump was brought to fill temperature, intended for potential use by thermal analysts if needed.

Non conformances identified with this segment:

<u>NCR#</u>	<u>SUBJECT</u>
2658	Torque reading of motor to pump bolting
2660	Tank insulation not to drawing
2662	Tank delta T = 146°, limit is 60°F
2665	Gaps in insulation
2666	Oil level probe inoperative
2667	Temp gradient limit definition in test request

For additional details of the above non conformances, refer to the Appendix.

#### 2.8.9 Segments A9A and A9B Purge Gas Supply & Level Control Checks

The purpose of these segments was to checkout the SPTF purge and bleed gas systems, i.e. verify that gas flow control was operative at both normal and elevated pressures; to verify that the gas flow valves and the bubbler can maintain level control, and to confirm that the SPTF electrical discrete signals to switch gas feed occurs with either high sodium level or with operator command.

The A9A tasks include the verifying of alarms as sodium level are purposely swung high and low.

A9A also involved pressurizing to 93 psig to verify that the purge and bleed gas flow control valves worked.

Segment A9B called for reduced cover gas pressure operation - to verify gas flow control valve operation assumed to be necessary for subsequent NPSH tests at 45 ft. NPSH.

Results:

- o High tank level alarm at 148 ft was activated
- o High tank level trip at 149 was activated
- o Low level alarm was activated at 144.5 ft.
- o Low level trip was activated at 143 ft.
- o Level probe span was 143.09 ft. to 149 ft.
- o At both normal ( 4 psig) and elevated pressure (93 psig) gas flow at the purge input interface 10 was .47 to .51 scfm, and at interface 12, the gas bleed flow rate was .24 to .26 scfm.
- o Manually controlled transfer of purge gas feed from interface #10 to interface #18 was demonstrated.
- o Internal thermocouple TC6 was shown to be effective in detecting level via the covering and uncovering of the junction by fluid sodium.
- o Level control at normal pressure was demonstrated.
- o Correlation between sodium level and the suction nozzle pressure was inconclusive. ETEC indicated that there was an apparent defect in PT1018 sensor (used for head calculation) however, no non conformance report was issued.

#### 2.8.10 Segment B14C, Shaft Seal Replacement Demonstration

The purpose of this segment was to verify the procedures used to install the shaft seal cartridge with the Vertical Drive Motor in place.

The shaft seal cartridge installed in the pump at segment A4B was a non code unit; and was replaced between segments A10 and A11. This replacement resulted in the required demonstration, Segment B14C being performed out of sequence. This demonstration was accomplished using the removal tool #436577 and procedure MP9018, a part of the Installation, operation and Maintenance Manual.

The seal cartridge removal and reinstallation was accomplished with two technicians, a Quality Control inspector and a supervisor in five shifts of eight hours each. ETEC documented some changes to the MP9018 procedure. The tooling provided was adequate for the tasks; the crew provided suggestions for improvement. The verified (as run) procedure is available at ETEC.

The removal tool is shown in Figure 2.8.10

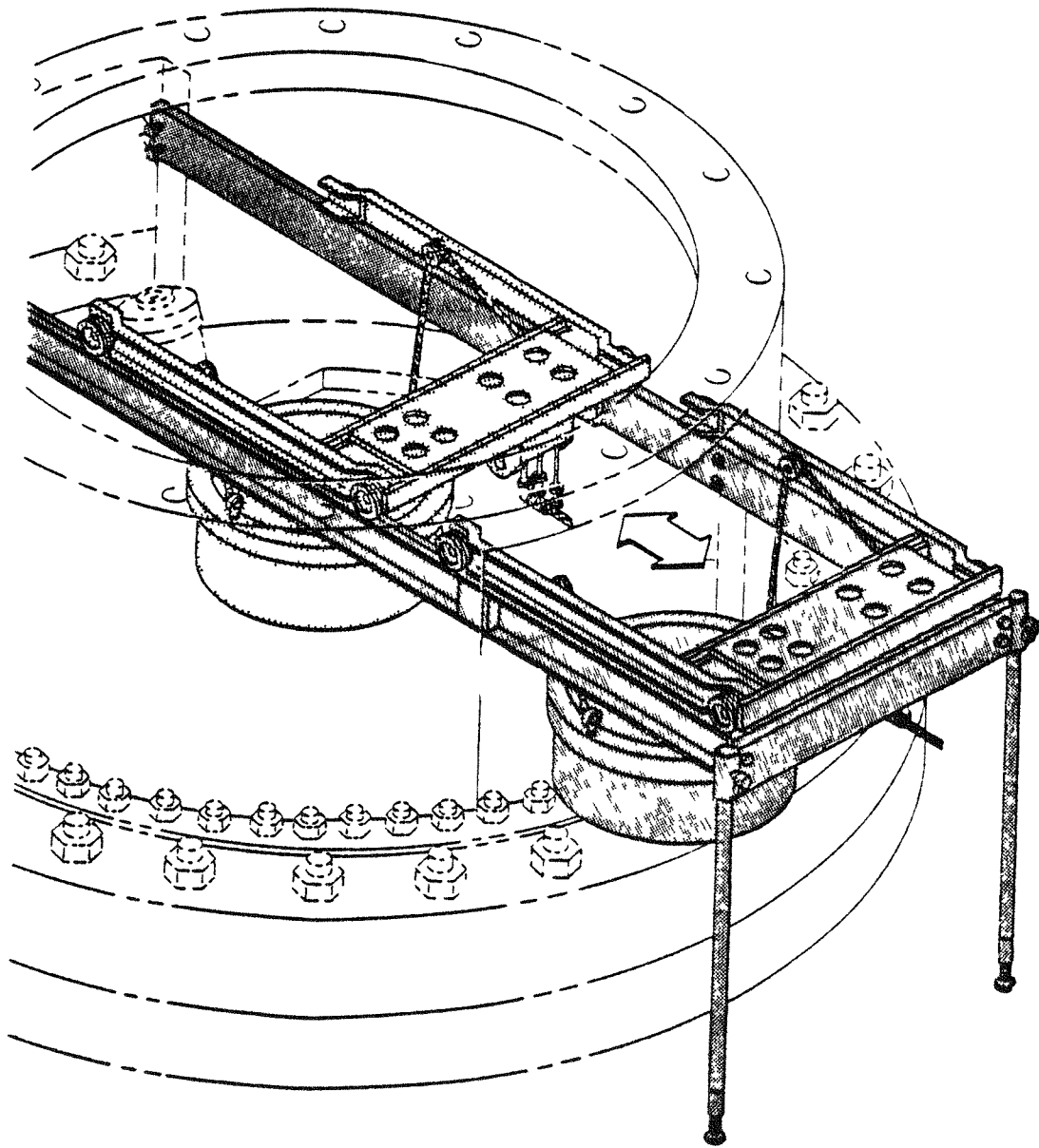


FIGURE 2.8.10

SHAFT SEAL REMOVAL TOOL

FROM:  
IOM MANUAL  
51GOM 001

2.8.11 Segments C1 Through C6, Pump Assembly, Mate PISA to Tank, Install Motor, Preheat and Sodium Fill

The purpose of these test segments was to rebuild the pump innerstructure assembly (PISA), mate the PISA to the tank; install and connect the vertical drive motor to power, data acquisition system and (mechanically) to the pump; preheat the pump and fill with sodium, and ascertain readiness to start the Phase C test series.

The following changes to configuration were made during this reassembly;

- ° Rotating assembly #174848, previously used in water test (with impeller diameter of 38.25 inches) was installed for Phase C sodium testing, replacing Rotating Assembly #171222 (with impeller diameter of 37.5 inches) previously used for Phases A&B tests.
- ° Anti convection baffle and filler plates were installed on the outside diameter of the upper inner structure.
- ° The thermal shield, previously used in Phases A&B were omitted.
- ° The shot used for Phases A&B testing was replaced with a "Fiber Frax" insulation material.
- ° Shaft center position proximeters were replaced. The bearing gap proximeters and upper bearing accelerometers were not replaced (therefore not functional in Phase C tests).

Results: Innerstructure assembly resulted in the following measurements:

- ° Axial travel: 1.938 inches
- ° Swing Test Motion: 

	Swing (Inches)	
<u>Keway Azimuth</u>	<u>0</u>	<u>90</u>
0°-±80° Plane	.036	.038
45°-114° Plane	.040	.039
90°-270° Plane	.041	.042
135°-315° Plane	.038	.037

Requirements: 28 to 50 mils

- Pump assembly was accomplished with no problems using the procedures previously used in Segments A4B the buildup includes installing the thermal insulation in the Upper Innerstructure, and installation of oil collection tank, shaft seal cartridge, oil supply tank, and the pump shaft to motor shaft flexible coupling, all accomplished at the Component Handling and Cleaning Facility (CHCF). The CHCF stiff leg derrick was able to handle the transfer of the completed assembly, because its weight (without shot) was within the derrick capacity of 70 tons. (Insulation weight was 325 lbs, as compared to 32,000 lb of shot previously used in phases A&B).
- After mating the innerstructure assembly to the pump tank, a leak test of the innerstructure to tank seal (See Figure 2.8.5) was run. The requirement (Appendix C3 of test request 22A3551) called for a leak rate of less than .05 SCC/sec (Helium) at a 5 psig pressure. The test did not meet the requirement, however, a special test was run to see if the leak was inward or outward from the buffer zone. Test results showed no leakage outward, therefore, the situation was acceptable and Phase C testing was released.
- When the pump shaft to motor shaft coupling was attempted, it was found that the replacement shaft being of slightly different overall length than the previous shaft, required remachining of the split collar (reference Appendix D, listing of Pump Problems, NCR2854). This machining is a normal assembly requirement identified in IOM Manual.
- A 1-hour uncoupled run with pony motor and main motor was run and diagnostic instrumentation was verified. Bearing & winding temperatures and vibration sensors on all drive components was satisfactory.
- Torque readings taken from the top of the pony motor with gear "B" (17.6 to 1 ratio) provided the following results:

	Uncoupled (in-lb)	Coupled (in-lb)
Breakaway	50	90
Running (Avg)	24.6	54
Low	10	50
High	40	60
- A final cold pump check review meeting was held April 15, 1983 and evidence of completion of tasks was presented, and a list of DAS and test article instrument channels in need of resolutions and procedure checks were identified.

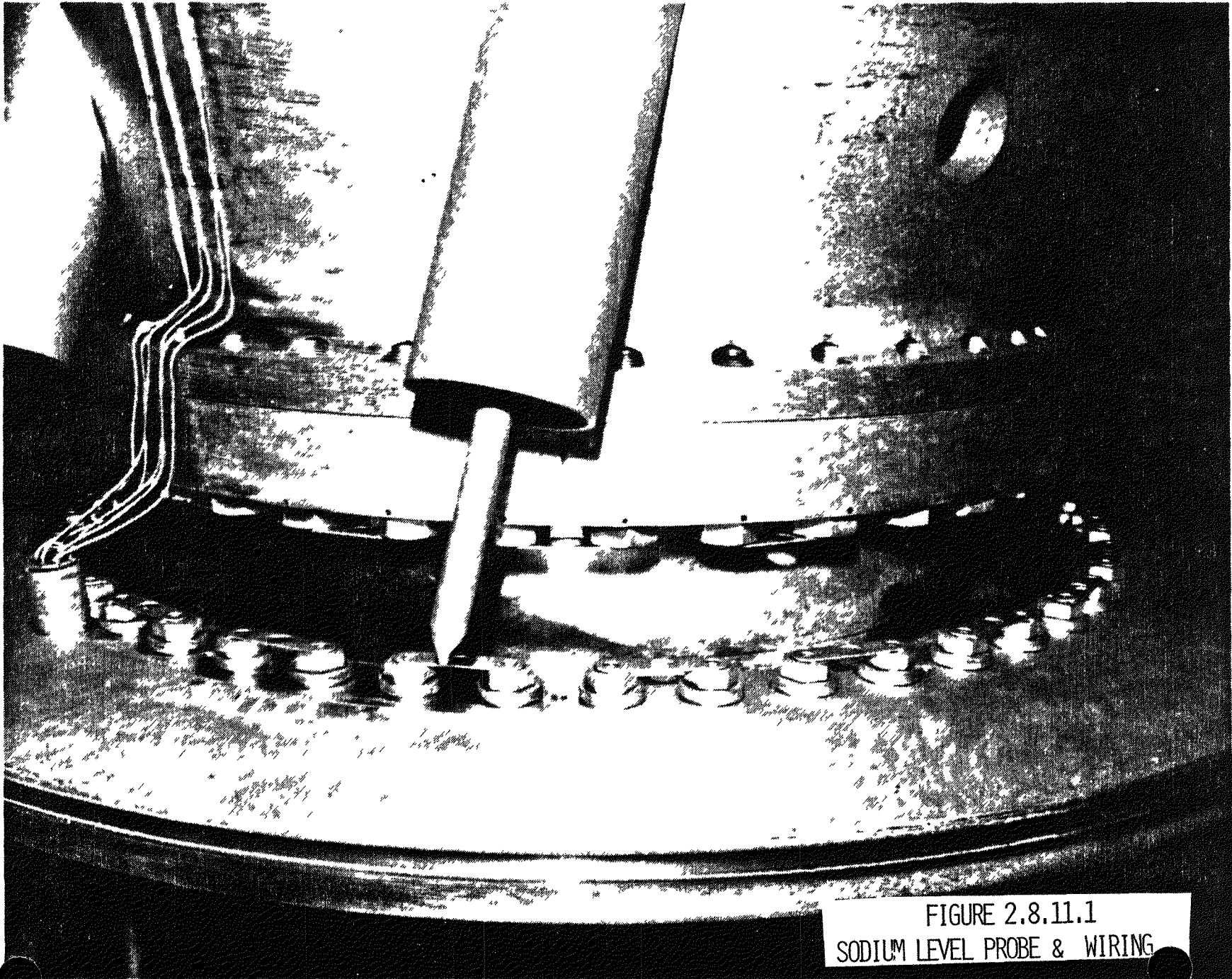


FIGURE 2.8.11.1  
SODIUM LEVEL PROBE & WIRING

- ° Figure 2.8.11.1 shows the sodium level probe and sheathed wiring leads from the lower bearing as they exit a penetration and traverse the side of the lower innerstructure. This photograph, which was taken during pump disassembly at the end of Phase C tests, also shows effective sodium draining.
- ° Preheat was started April 22 and completed on April 28, 1983.
  - Breakaway torque after sodium fill was 130 inch lb.
  - Running torque was 95 to 105 after sodium fill.

After sodium fill, sodium temperature was cycled to 680°F, and all pump thermocouples were recorded (Listed in Table 4 of the Segment Report 83-ETEC-DRF-4302). The test program was interrupted by a smoke alarm in the SPTF High Flow Loop area, which was subsequently revealed to be oil soaked insulation. The insulation was replaced after a sodium drain. Refill was accomplished on May 2, 1983.

## 2.8.12 Segment B15, Pump Disassembly (End of Phase B)

The purpose of this task was to remove the innerstructure from the pump tank, transfer the assembly to the cleaning tank, clean, transfer to the Component Handling and Cleaning Facility (CHCF), disassemble the parts, and perform post test inspections. ETEC was to record any unusual disassembly step, and report observations of component inspections.

### Results:

- o Removal of the Vertical Drive Motor, disconnections of gas, power and instrumentation connections were routine, with no problems.
- o Considerable difficulty was encountered with shaft seal removal. It was necessary to partially disassembly the cartridge in place, destroy the upper rubbing seal faces to apply heat to the sleeve to achieve release from the shaft. This incident resulted in Unusual Occurrence Report #ETEC83-01-SPTF-83-01 (See Appendix D).
- o PISA was bagged out of the pump tank, transferred to the cleaning tank and cleaned with alcohol without problems.
- o Some of the nuts and studs which had seen sodium immersion had sodium deposits remaining, while some came out clean.
- o Some of the pump innerstructure parts had a region of black stain, (assumed to result from the loss of cover gas incident in Segment B1):
  - The UIS had a black stain on the bottom side
  - The LIS had black, rust and white deposits which varied along the circumference. The black discoloration was mostly between the upper two rows of holes. The patterns showed a gas contaminant circulation of between inside and outside the LIS, and a convection cell between the adjacent pairs of holes in the LIS (The pump supplier used these observations to orient the cellular convection baffles on the outside of the upper innerstructure).
  - The sodium level probes showed a black deposit above sodium level.
  - The shaft had a region (visible through the hole pattern of the LIS during bagged removal) of black discoloration. The shaft also had some sodium frost deposits in the upper region near the labyrinth.

[A chemical analysis of the black deposits indicated that it was a hydrocarbon with 20% carbon composition. The presence of this material is believed to have originated in conjunction with the loss of oil supplier tank cover gas pressure, at 00:21 on 8/19/82 when the screw pump of the shaft seal rotating assembly imparted a high vertical lift to the pump shaft, causing a short term lifting of the lower seal rubbing faces. With 70 psi still remaining on the sea oil, a lifting of the rubbing face of the lower seal would result in a large oil flow surge above the slinger, part of which went into the shaft annulus.]

- o Inspection of the curvic coupling showed that it looked good, showing even loading.
- o The shaft journal looked good -no cracks. Hardface showed no evidence of scoring or heat checking. There was evidence of a white deposit in the press fit between journal and shaft.
- o At impeller inlet, about 3 inches from the outer shroud there is a bulge where the cast surface intersects the machined surface, all around, abrupt 1/8 inch high, blended, with no step. (This reflects as received condition).
- o The hydraulic assembly to UIS studs showed sodium carbonate deposits which required hand cleaning. The lower bearing showed no evidence of rubbing. There were no deformations of original machining marks which would be indicative of contact between the hydraulic assembly and the tank seal cone.
- o Thermal baffle was clean and bright.
- o Thermal shield color was typical of a part which had not been subject to sodium immersion.
- o The upper and lower bearing showed no evidence of a bearing rub. Almost indistinguishable was a pattern on the surface of the bearing land similar to a group of comet-tails. Photographs of the pattern were taken by ETEC of these patterns. The significance of these patterns is under investigation.

NCR #2840, reporting inability to follow the IOM Manual for shaft seal cartridge removal, and UCR#ETEC83-01-SPTF-83-01 was issued to define the details of the incident.

Figures 2.8.12.1 shows the bagging and jacking fixture at SPTF.

Figure 2.8.12.2 shows the bagged pump above the SPTF.

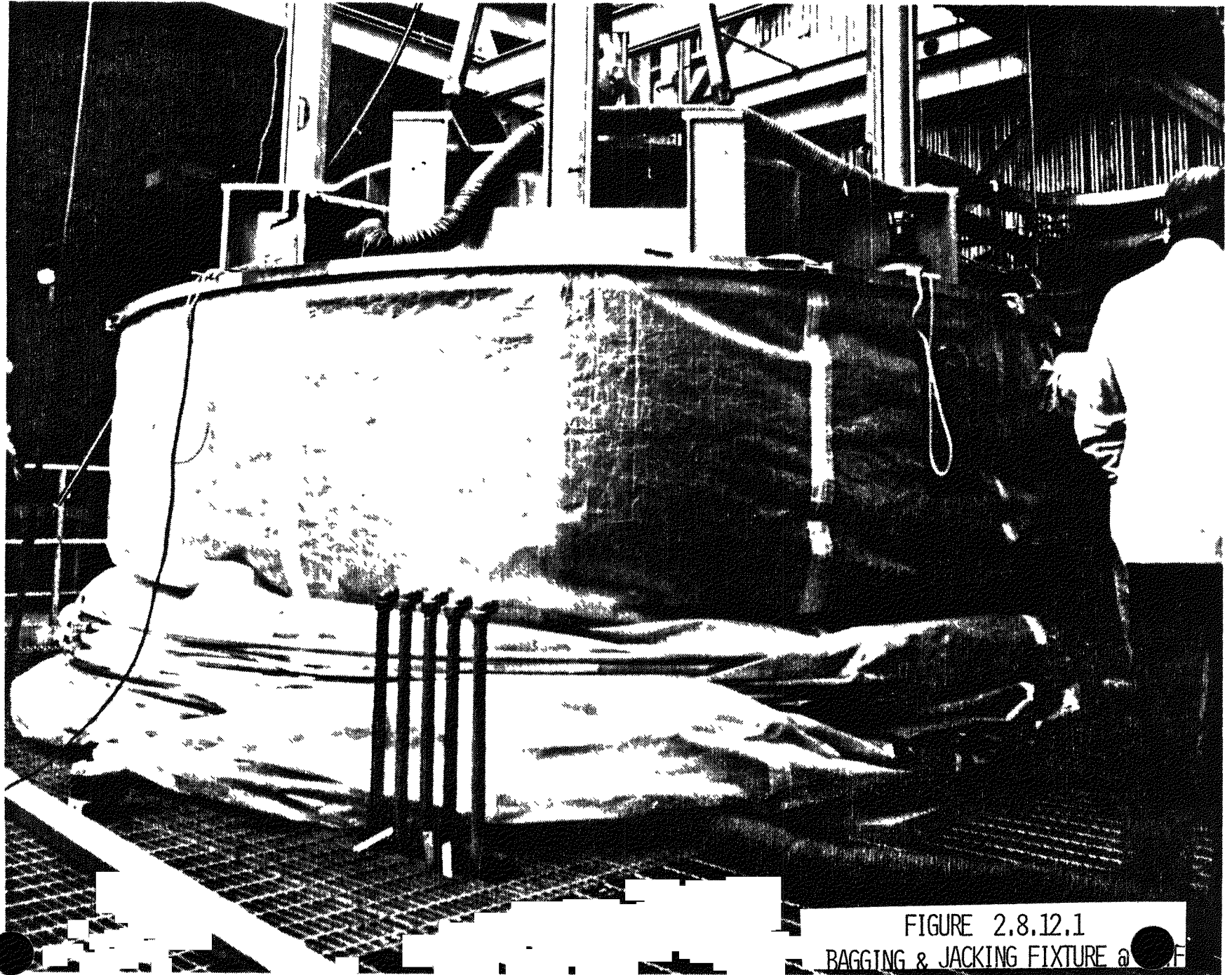
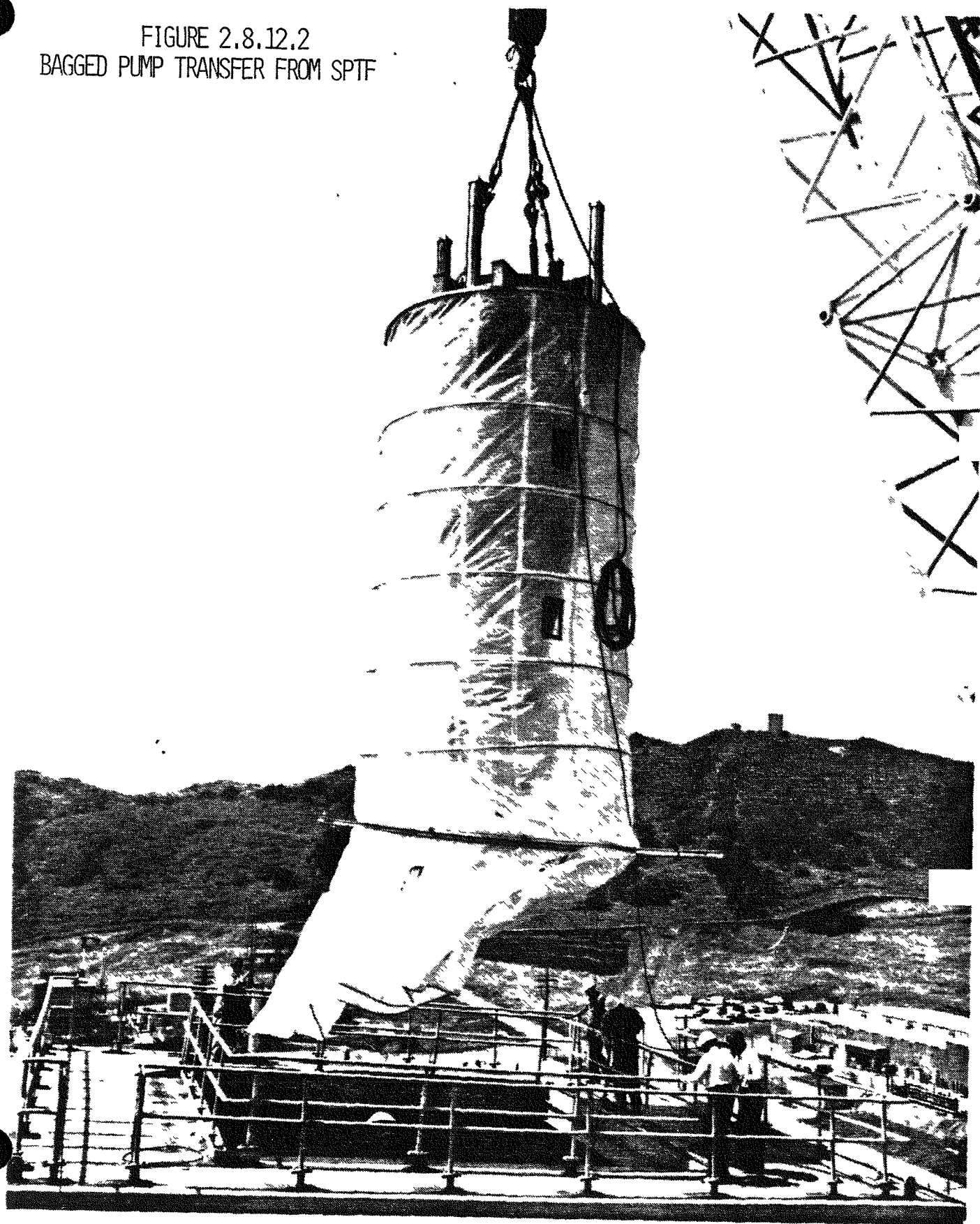


FIGURE 2.8.12.1  
BAGGING & JACKING FIXTURE @

FIGURE 2.8.12.2  
BAGGED PUMP TRANSFER FROM SPTF



### 2.8.13 Segment C15, Pump Disassembly (At End of Phase C)

The purpose of this task was to drain sodium, cool down the pump, remove the motor, demate the innerstructure from the tank, transfer the PISA to the cleaning tank, clean, transfer to CHCF, and disassembly.

#### Results

The significant items of this disassembly were:

- o Two cracks were observed in the upper bearing journal. The two cracks were separated by an arc segment subtended by an angle of about 55°. One crack was 25 centimeters long, the other 15 centimeters. The general direction of each crack was axially (vertically) along the journal. Inspections indicated that there was no evidence of delamination between the hardface and the substrate.
- o There appeared to be incipient cavitation surface "comet tails" on the bearing housings, located on the trailing edges of the bearing pockets. (These were previously seen and reported at Segment B15).
- o There was no difficulty encountered in removing the bolts which attach the hydraulic assembly to the LIS. However, the studs which attach the upper bearing and suction piece to the hydraulic assembly required application of external heat to make removal easier.
- o There was no evidence of any oil contamination of the pump internals from the Phase C testing.
- o Draining was good. No evidence of residual pockets of sodium.
- o Post test inspection of the tank part of the sealing cone assembly indicated that the cone had gone oval with the short dimension being in the axis of the discharge and balance parts. Extent of ovality: About .35 inches difference between the long and short dimensions (90° with respect to each other).

It should be noted that the journals which displayed cracking of hardface material were not prototypical of the CRBRP design. These journals, used in water test, (Shaft #174848) had a hardface application all the way to the end of the journal. The journals of Shaft #171222, used for Phases A and B, (employs a 1/4 inch journal land to contain the hardfacing) were prototypical of the CRBRP pump shaft design, did not experience cracking.

2.8.13 Continued

The "comet tails" on the bearing housings are a subject deserving continued investigation. The ovality change may explain the jump in head after the severe thermal transients as first detected in Segment B8. If details beyond that reported herein are desired, the reader is referenced to the ETEC Segment Report on Segment C15 (See Appendix A).

## 2.9 Miscellaneous

### 2.9.1 Vibration

Accelerometers were used on the shaft seal, the tank nozzle, the pump cover, and the in-sodium hydrostatic bearing to detect pump vibration. ETEC processed the accelerometer output by direct recording and by signal conditioning consisting of rectification and recording on the data acquisition system (sampling and digitizing). After segments A13A and A13B, ETEC added low pass filters (100 Hertz) to sensors 9015ABC (shaft seal) 9020ABC (tank nozzle), 9010AB (tank cover), 9012AB (Bearing), and 9014AB (shaft seal). Channels 9012A and 9014C were inoperative during part of the test program.

Drive System sensors were displacement units with the Drive System test article performing the signal conditioning (conversion to a 0-10 VDC output), then ETEC's data acquisition system performing sampling, digitizing and recording.

During certain test segments, ETEC used a Hewlett-Packard spectrum analyzer to measure the frequency and magnitude of the dominant energy level of the several sensors.

Table 2.9.1.1 list the spectrum analyzer results recorded during the endurance run, Segment B13. During this endurance run, the pump is operated at rated design conditions, that is, 1116 RPM, R3 loop resistance ( $.40 \times 10^{-6}$  ft/gpm<sup>2</sup>) with sodium at 1005°F, and flow at approximately 33,700 gpm.

<u>Sensor</u>	<u>Location</u>	<u>Level(G's)</u>	<u>Frequency(Hz)</u>
VE9012A	Sodium Bearing (Suction)	.007	55.6
VE9012B	Sodium Bearing (Suction)	.012	55.6
VE9014A	Shaft Seal X Axis	.001	92.0
VE9014B	Shaft Seal Y Axis	.004	92.0
VE9014C	Shaft Seal Z Axis	.011	92.0
VE9015A	Shaft Seal X Axis	.003	92.0
VE9015B	Shaft Seal Y Axis	.004	92.0
VE9015C	Shaft Seal Z Axis	.008	92.0
VE9020A	Tank Nozzle X Axis	.012	92.0
VE9020B	Tank Nozzle Y Axis	.005	92.0

TABLE 2.9.1.1  
SPECTRUM ANALYZER VIBRATION  
SEGMENT B13  
ENDURANCE RUN

After the first run up to rated temperature (during Segment B3A), the spectrum analyzer was used to scan vibration energy vs. frequency for different loop valves settings. The results presented in Table 2.9.1.2 shows the 3d and 5th harmonics of the 18.6 Hz operating speed.

	G	R2		R3		R4		R5		R6	
		F	G	F	G	F	G	F	G	F	
VE9012A Bearing(Suc.*)	.047	56	.051	56	.055	56	.055	56	.060	56	
VE9012B Bearing(90°S)	.012	56	.012	56	.012	56	.012	56	.012	56	
VE9014A Seal X	.001	92.8	.001	92.8	.001	92.4	.001	92.4	.001	92.4	
VE9014B Seal Y	.009	93.2	.007	92.4	.006	92.4	.004	92.4	.006	92.4	
VE9014C Seal Z	.026	92.8	.023	92.4	.021	92.4	.016	92.4	.016	92.4	
VE9020A Nozzle X	.008	92.8	.010	92.4	.007	92.4	.001	92.4	.005	92.4	
VE9020B Nozzle Y	.009	92.8	.006	92.4	.003	92.4	.002	92.4	.005	92.4	

TABLE 2.9.1.2  
SPECTRUM ANALYZER VIBRATION  
SEGMENT B3A

$$R2 = .88 \times 10^{-6} \text{ ft/gpm}^2$$

$$R3 = .40 \times 10^{-6} \text{ ft/gpm}^2$$

$$R4 = .286 \times 10^{-6} \text{ ft/gpm}^2$$

$$R5 = .229 \times 10^{-6} \text{ ft/gpm}^2$$

$$R6 = .199 \times 10^{-6} \text{ ft/gpm}^2$$

The vertical drive motor is arranged with a gear box and the pony motor protruding above the main drive motor, and the pony motor and gear box vibration sensors are therefore sensitive indicators of VDM vibration health. The highest reading during all sodium testing (Phases A, B, & C) of pony motor sensor VE9281H was 3.8 mils, recorded during segment C10. The gear box sensor VE9284 indicated levels from 0.2 to 5 mils. Throughout the sodium test program, the in-sodium bearing sensors nominally read less than 0.1 g's. Seal sensor VE9014A was usually 0.03 gs or less. Tank nozzle sensors (actually on the sphere) usually read less than .5 g's, but in Segments B14 and C8, the sensor VE9020A approached 0.9 g at 1000 RPM and at 1116 RPM \*(See R3 speed scan page 27 of 83ETEC-DRF-3711). Typical vibration levels were recorded during Segment C10 where plots were made of vibration level vs. speed during a speed sweep from min main motor speed to full speed.

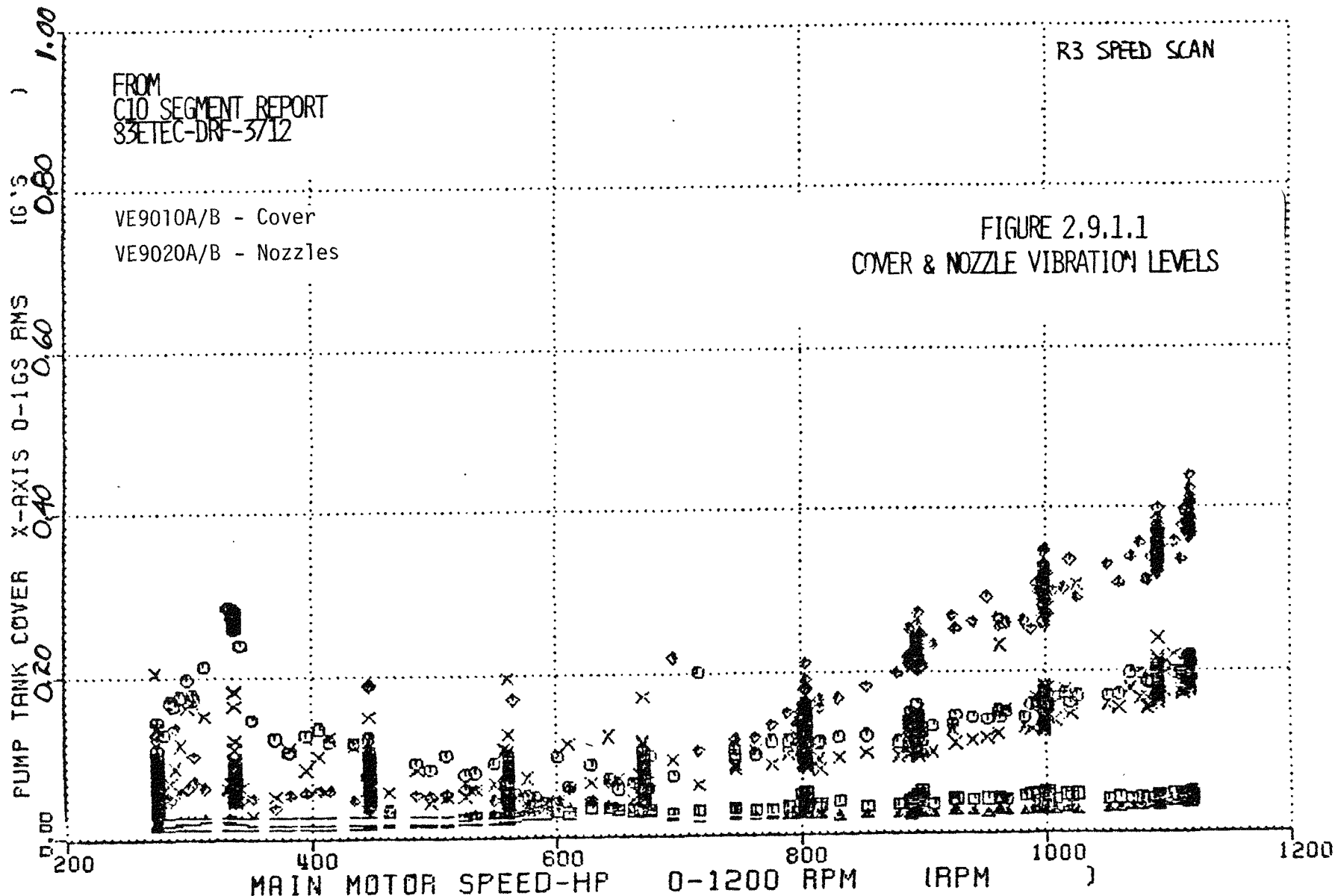
Figure 2.9.1.1 shows the cover vibration (VE9010A & VE9010B) and tank nozzle vibration (VE9020A, & VE9020B) during a speed scan at R3.

Figure 2.9.1.2 shows the shaft seal sensors (VE9014A, B, C) during a speed sweep at R3.

\*Sensitive along axis of suction nozzle

△	VE-9010A	G'S	SEQ	606
□	VE-9010B	G'S	SEQ	609
◇	VE-9020A	G'S	SEQ	609
○	VE-9020B	G'S	SEQ	610
X	VE-9020C	G'S	SEQ	611

### SPTF REAL-TIME PLOT



TIME FROM 5/21/83 AT 15:50: 0.740 TO 5/21/83 AT 17:49:16.751

SEQ 688 SE-9249

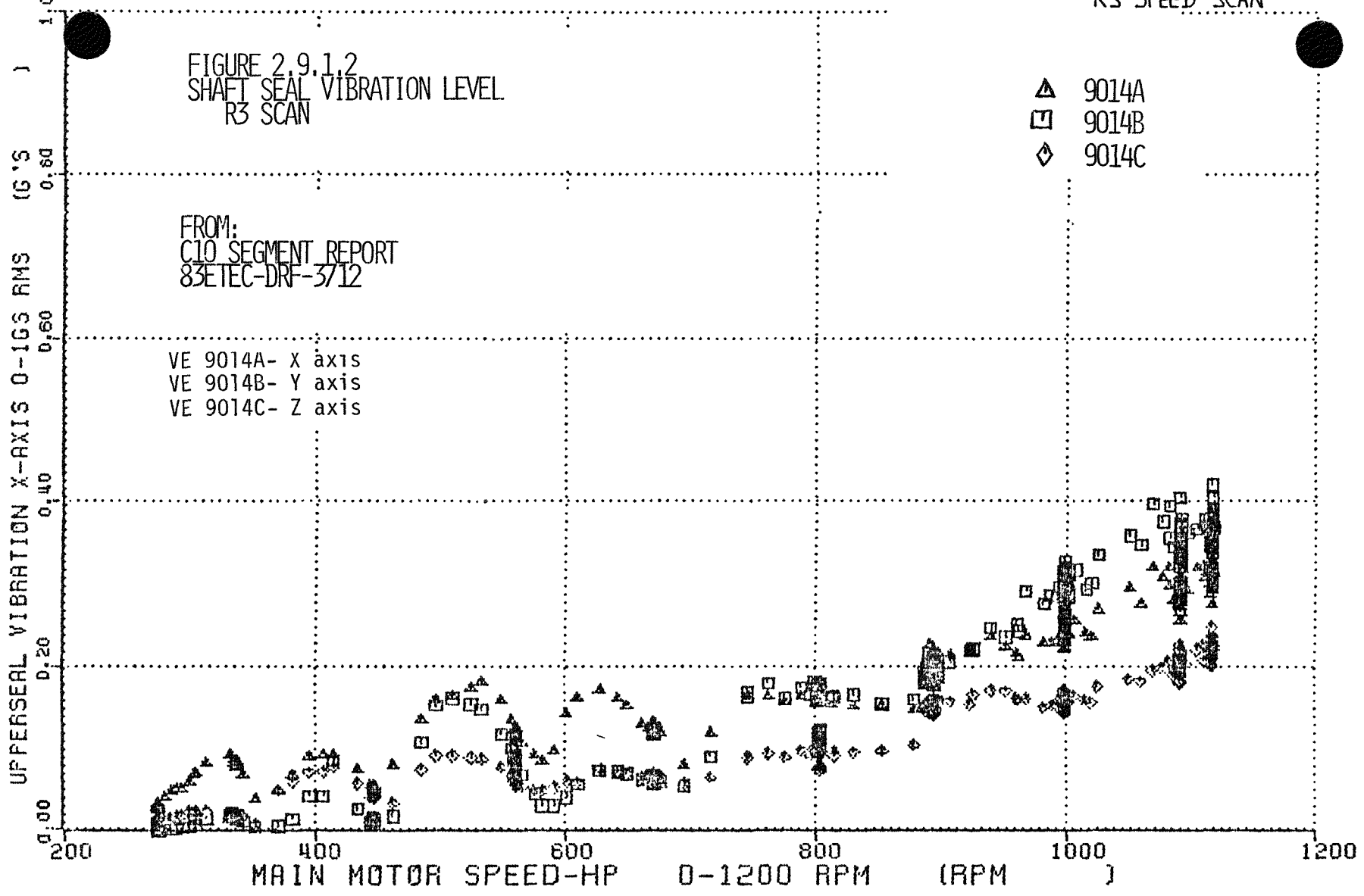
FIGURE 2.9.1.2  
SHAFT SEAL VIBRATION LEVEL  
R3 SCAN

- ▲ 9014A
- 9014B
- ◇ 9014C

FROM:  
C10 SEGMENT REPORT  
83ETEC-DRF-3712

VE 9014A- X axis  
VE 9014B- Y axis  
VE 9014C- Z axis

161



TIME FROM 5/21/83 AT 15:50: 0.740 TO 5/21/83 AT 17:49:16.751  
SEQ 688 SE-9249

Figure 2.9.1.3 shows the pony motor (VE9283) and the gear box (VE9284) levels vs. frequency for a speed sweep at R3.

Figure 2.9.1.4 shows a plot of cover vibration (VE9010A & B) and tank nozzle vibration (VE9020 A&B) levels vs. frequency for a speed sweep at R6.

Figure 2.9.1.5 shows a plot of seal vibration (VE9014A, B, C) level vs. frequency for a speed scan at R6.

Shaft traverse in the hydrostatic bearing during a speed scan was recorded on an X-Y plot during Segment C8. Figure 2.9.1.6 shows the upper bearing movement in mils as an R3 speed scan is accomplished. Figure 2.9.1.7 shows the lower bearing movement in the same speed scan from min main motor speed to full speed.

The accelerometer sensors were sensitive to the onset of cavitation. In Segment C11, where cover gas pressure was being reduced to check on possible cavitation at 39,100 gpm and R6, plots of the seal (VE9014 series) and the tank nozzle (VE9020 series) vibration levels vs. NPSH were made. These are shown in Figure 2.9.1.8 and 2.9.1.9 the seal sensors show an increasing noise/vibration level at about 45 ft NPSH. (increasing as NPSH is lowered), and the tank sensors show a sharp rise in detected noise/vibration at about 42 ft. NPSH.

The overall conclusion is that there are no speeds in which the pump operation should be restricted, and the levels observed at ETEC indicate that there should be no vibration problems with this pump and vertical drive motor assembly in the plant application.

## 2.9.2 Pump Temperature Distribution

The temperature distribution throughout the pump when pumping sodium at 1005°F is shown in Figure 2.9.2A through 2.9.2E. (PHTS configuration).

The maximum drive system temperatures experienced during the Endurance Run (Segment B13) are presented in Table 2.9.2.

The temperature distribution throughout the pump for the IHTS configuration (no thermal shield and shot replaced with "fiber frax" insulation is shown in Figures 2.9.2F through 2.9.2J. The reader is reminded that the nominal IHTS pump sodium temperature is 650°F (the IHTS pump is in the cold leg of the IHTS loop).

# SPTF REAL-TIME PLOT

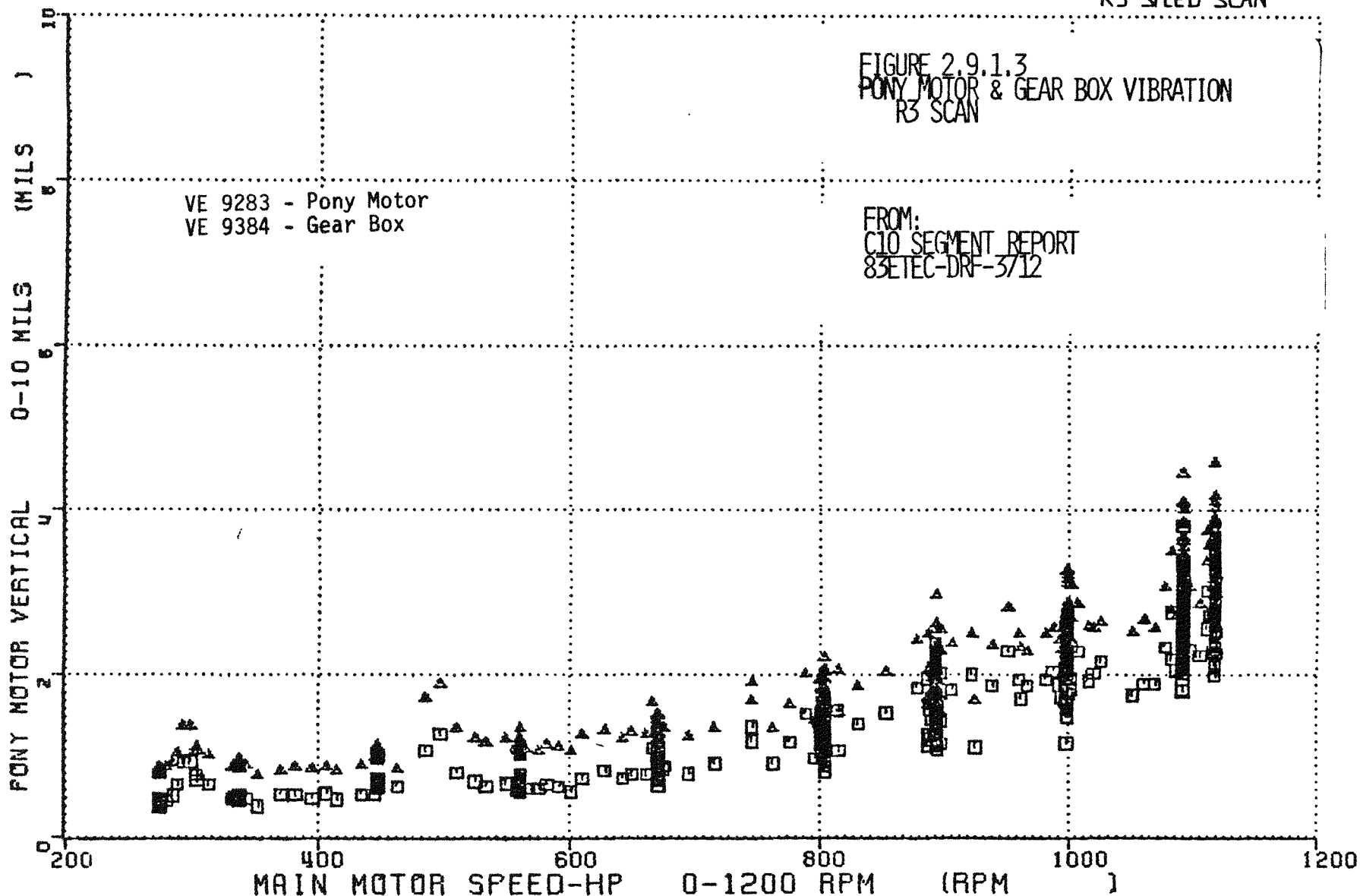
R3 SPEED SCAN

FIGURE 2.9.1.3  
PONY MOTOR & GEAR BOX VIBRATION  
R3 SCAN

VE 9283 - Pony Motor  
VE 9384 - Gear Box

FROM:  
C10 SEGMENT REPORT  
83ETEC-DRF-5712

171



TIME FROM 5/21/83 AT 15:50: 0.740 TO 5/21/83 AT 17:49:16.751

SEQ 688 SE-9249

# SPTF REAL-TIME PLOT

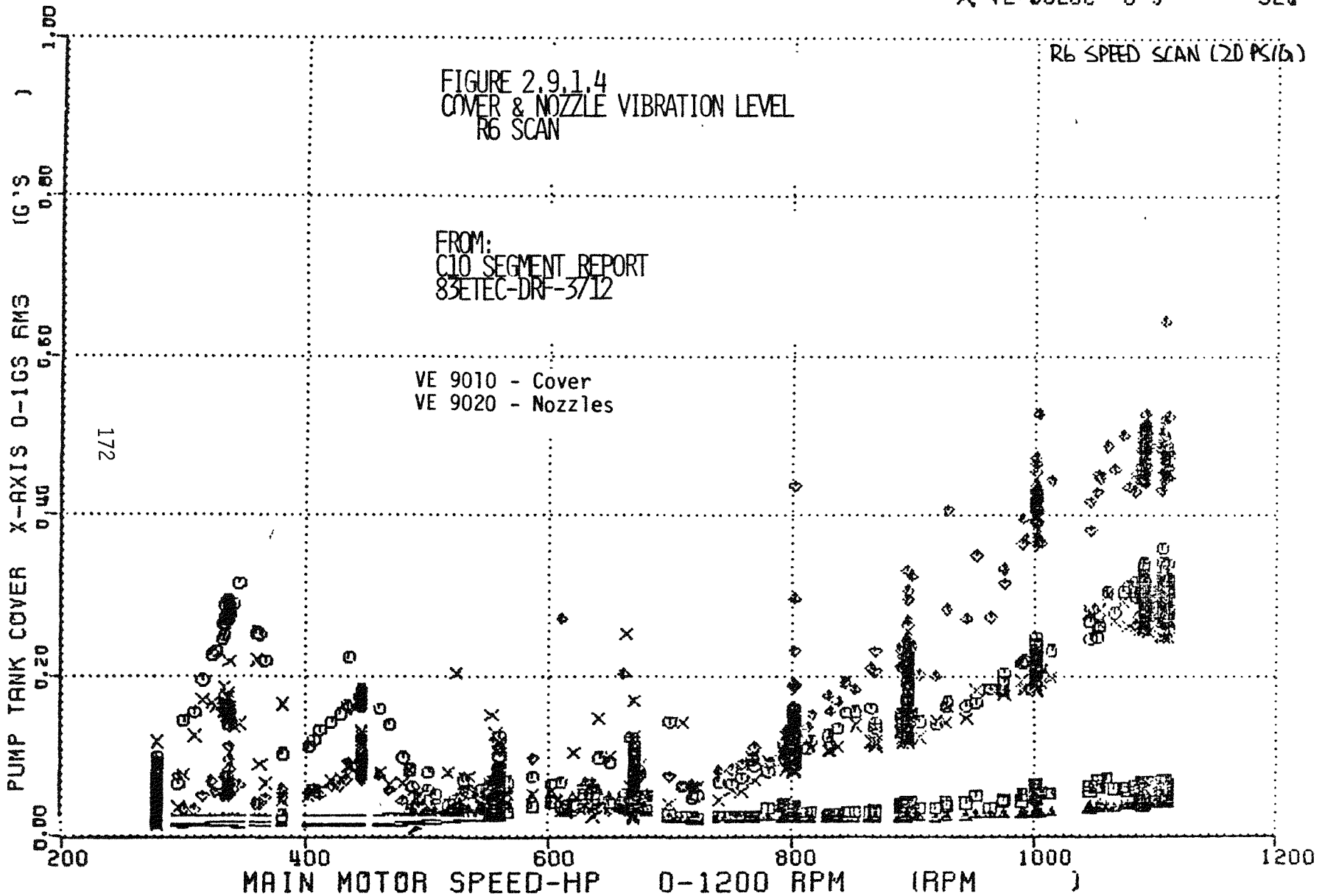
△	VE-9010A	G'S	SEFQ	602
□	VE-9010B	G'S	SEFQ	603
◇	VE-9020A	G'S	SEFQ	609
○	VE-9020B	G'S	SEFQ	610
X	VE-9020C	G'S	SEFQ	611

## FIGURE 2.9.1.4 COVER & NOZZLE VIBRATION LEVEL R6 SCAN

R6 SPEED SCAN (20 PS/G)

FROM:  
C10 SEGMENT REPORT  
83ETEC-DR-3712

VE 9010 - Cover  
VE 9020 - Nozzles



TIME FROM 5/22/83 AT 16:44: 0.481 TO 5/22/83 AT 19: 0:50.904

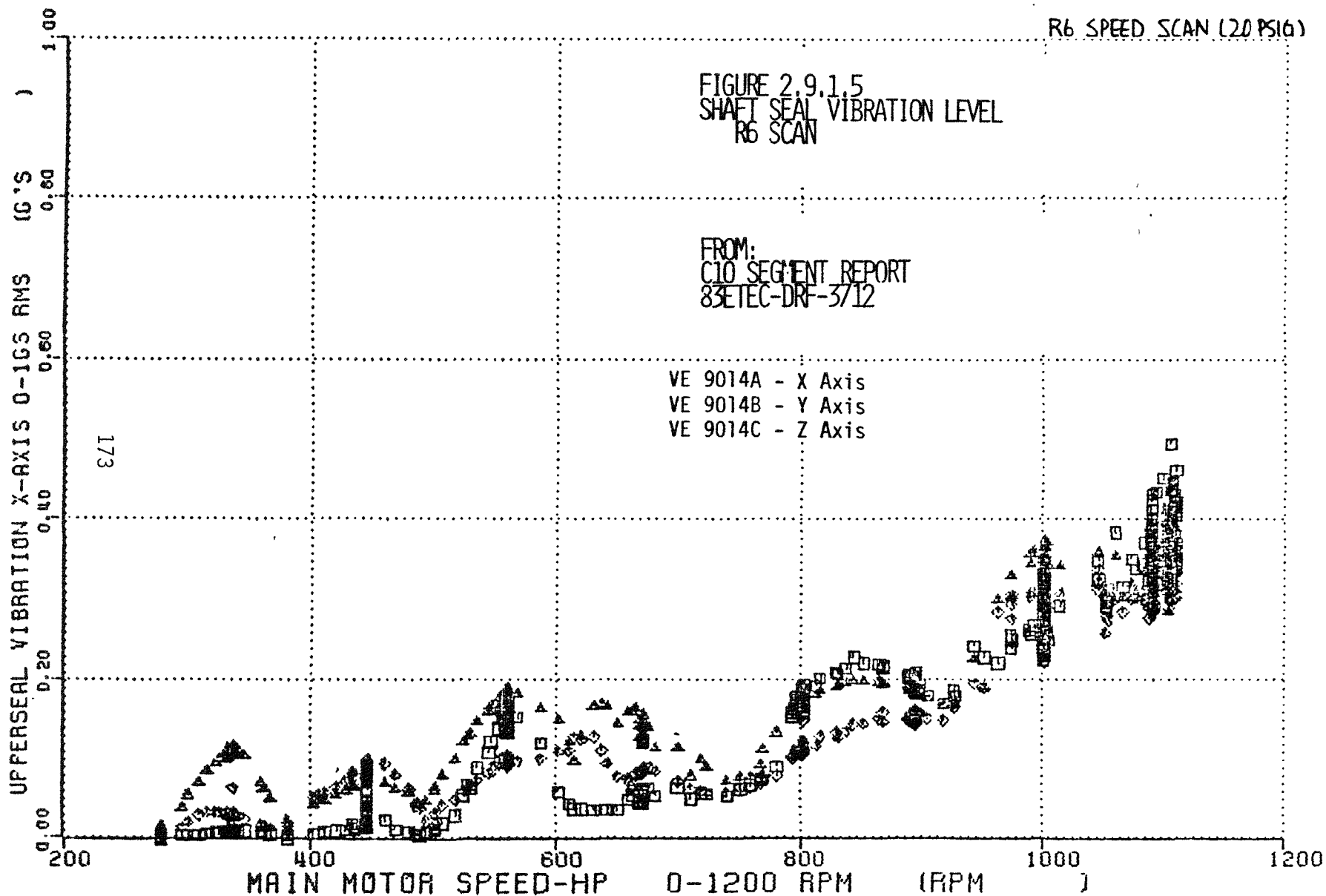
# SPTF REAL-TIME PLOT

R6 SPEED SCAN (20 PSI6)

FIGURE 2.9.1.5  
SHAFT SEAL VIBRATION LEVEL  
R6 SCAN

FROM:  
C10 SEGMENT REPORT  
83ETEC-DR-3712

VE 9014A - X Axis  
VE 9014B - Y Axis  
VE 9014C - Z Axis

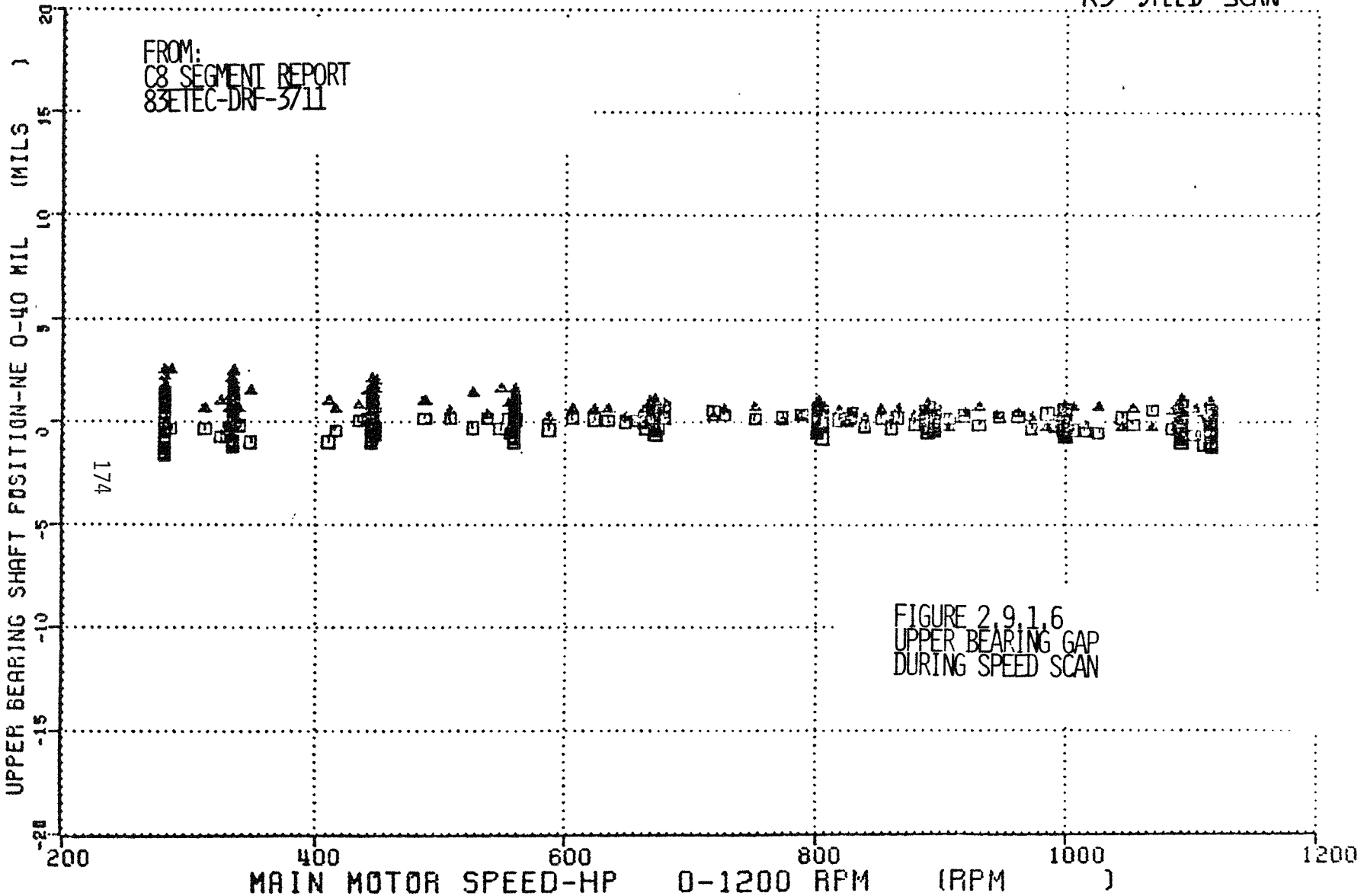


TIME FROM 5/22/83 AT 16:44: 0.461 TO 5/22/83 AT 19: 0:50.904

SEQ 688 SE-9249

### SPTF REAL-TIME PLOT

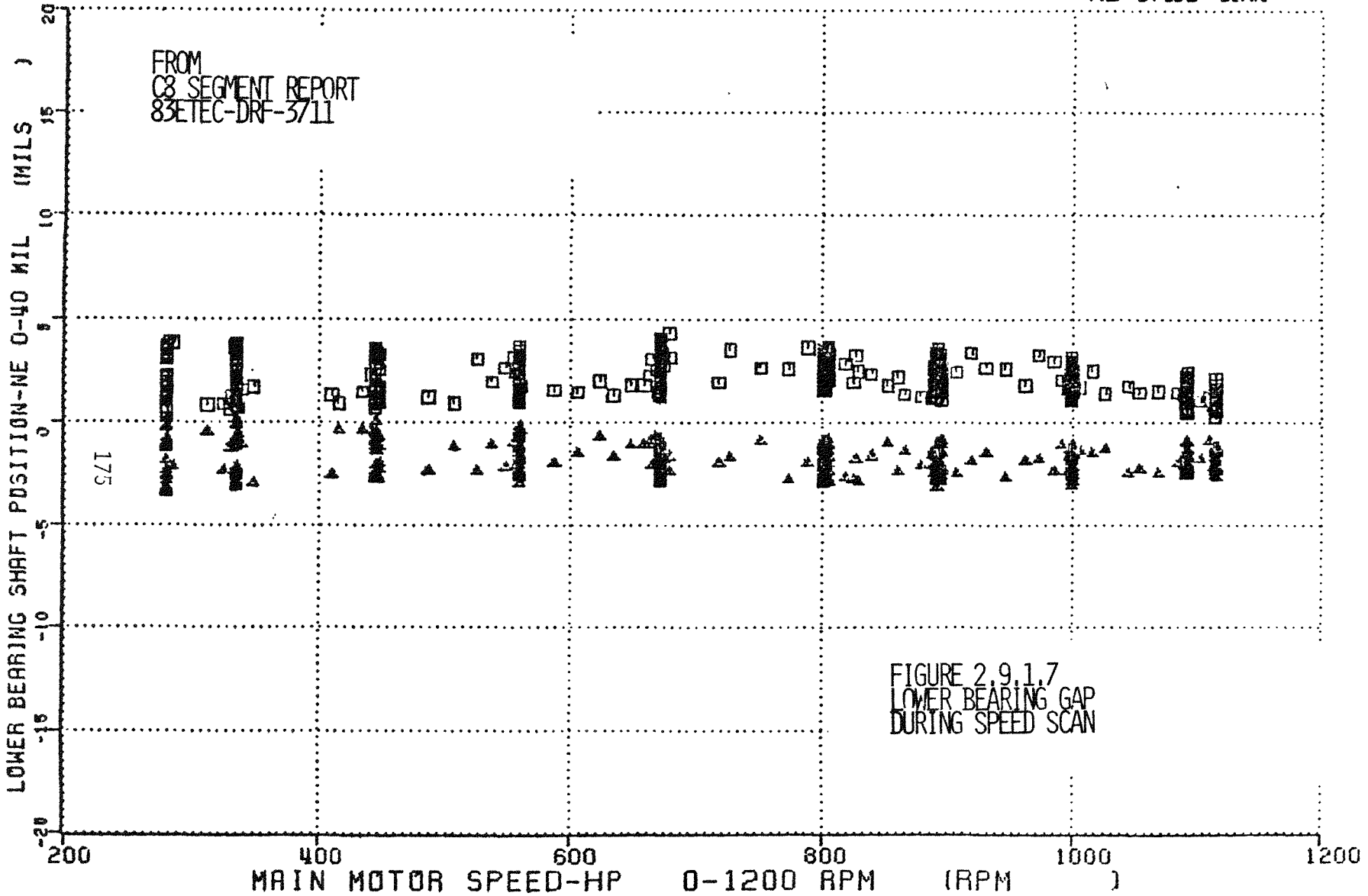
R3 SPEED SCAN



TIME FROM 5/10/83 AT 22:36:59.880 TO 5/11/83 AT 1: 9:50.769

### SPTF REAL-TIME PLOT

R3 SPEED SCAN



TIME FROM 5/10/83 AT 22:36:59.880 TO 5/11/83 AT 1:9:50.769

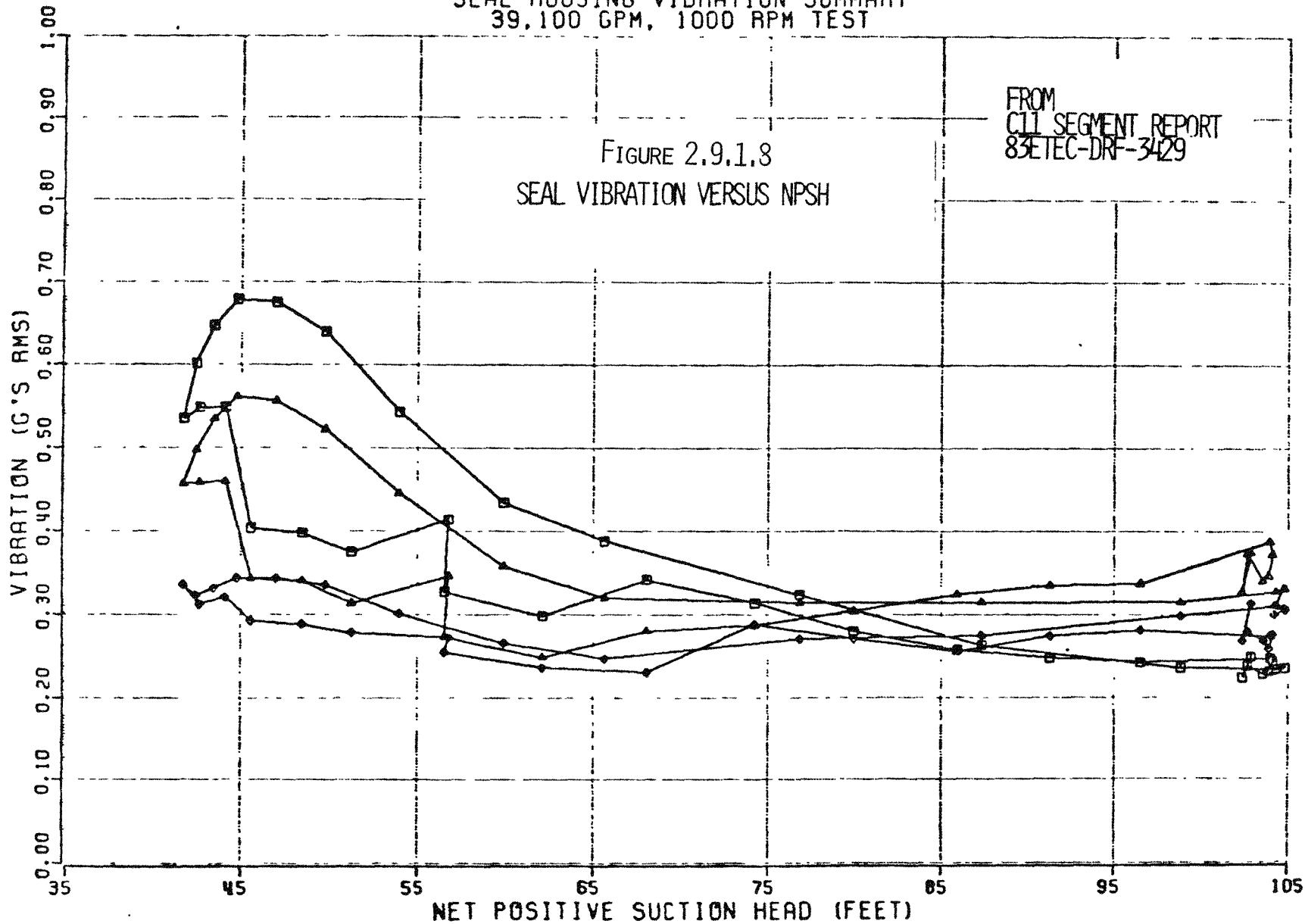
ETEC DATA PLOT  
 CBRP PROTOTYPE PUMP  
 TEST SEGMENT C11  
 CAVITATION TEST  
 SEAL HOUSING VIBRATION SUMMARY  
 39,100 GPM, 1000 RPM TEST

VE-901446'S  
 VE-901486'S  
 VE-9014CC'S

012  
 013  
 014

FROM  
 C11 SEGMENT REPORT  
 83ETEC-DR-3429

FIGURE 2.9.1.8  
 SEAL VIBRATION VERSUS NPSH



176

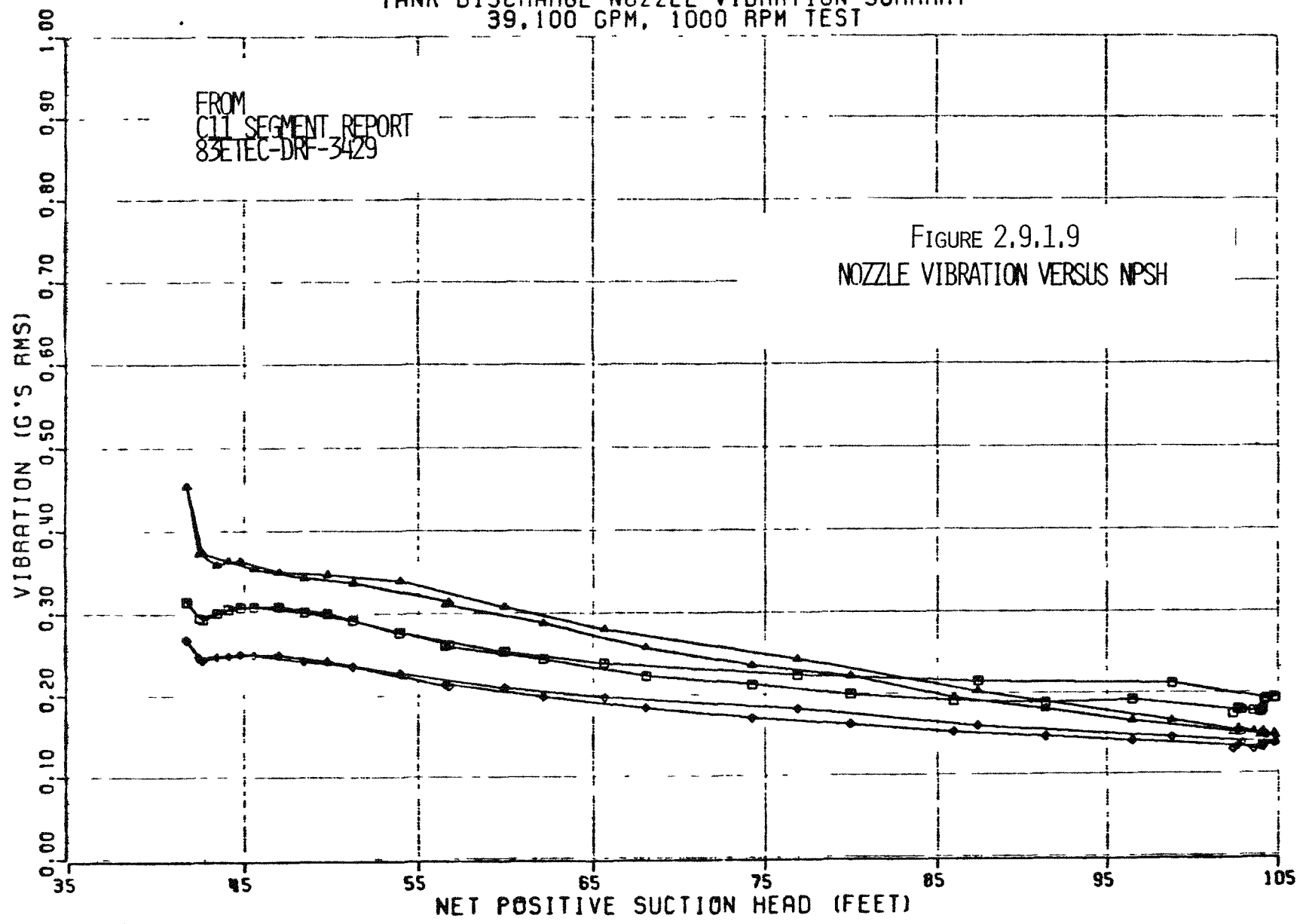
PLT 0 8 FROM FILE 2208 ON 6/6/83 AT 17:55

Figure 18

START 6/ 6/83 9:52:35 END 6/ 6/83 16:29: 2

ETEC DATA PLOT  
 CABRP PROTOTYPE PUMP  
 TEST SEGMENT C11  
 CAVITATION TEST  
 TANK DISCHARGE NOZZLE VIBRATION SUMMARY  
 39,100 GPM, 1000 RPM TEST

▲ VE-9020AC 18  
 □ VE-9020BC 19  
 ◆ VE-9020CC 5



177

PLANT - 10 FASH WILEY P208 ON 6/7/83 AT 17:38

Figure 19

START 6/ 6/83 9:52:35 END 6/ 6/83 16:29: 2

		<u>Recorded High (°F)</u>
TE9210A	MGM Winding #1 Temp	161
TE9213	MGM Winding #2 Temp	166
TE9217C	MGM Winding #3 Temp	159
TE9218A	MGM C. End Bearing Temp	143
TE9219A	MGM F. End Bearing Temp	134
TE9220C	MGG Winding 1 Temp	184
TE9221B	MGG Winding 2 Temp	185
TE9222B	MGG Winding 3 Temp	183
TE9223A	MGG EXC Bearing Temp	125
TE9224A	MGG Input Bearing Temp	133
TE9240C	VDM Winding 1 Temp	131
TE9241D	VDM Winding 2 Temp	189
TE9242A	VDM Winding 3 Temp	129
TE9243C	VDM Lower G Brg Temp	146
TE9244B	VDM Upper G Brg. Temp	139
TE9245B	VDM Thrust Brg. Temp	151
TE9246C	VDM Anti Rev. Brg. Temp	186
TE9257B	Pony Motor Gear	85
TE9261A	Voith Brg. TS08-C Temp	148
TE9262A	Voith Brg. TS08-I Temp	161
TE9263A	Voith Brg. TS08-B Temp	147
TE9264A	Voith Brg. TS08-A Temp	148
TE9265A	Voith Brg. TS08-E Temp	153
TE9266A	Voith Brg. TS08-F Temp	147
TE9267A	Voith Brg. TS08-J Temp	149
TE9268A	Voith Brg. TS08-G Temp	148
TE9269A	Voith Brg. TS08-H Temp	147

Based on B13 Segment Report

TABLE 2.9.2  
DRIVE SYSTEM TEMPERATURES  
WITH RATED PUMP LOAD  
(1116 RPM, R3, 1005°F SODIUM)

SOURCE: SEG B13

462-TP-0004

STEP 12.17.6

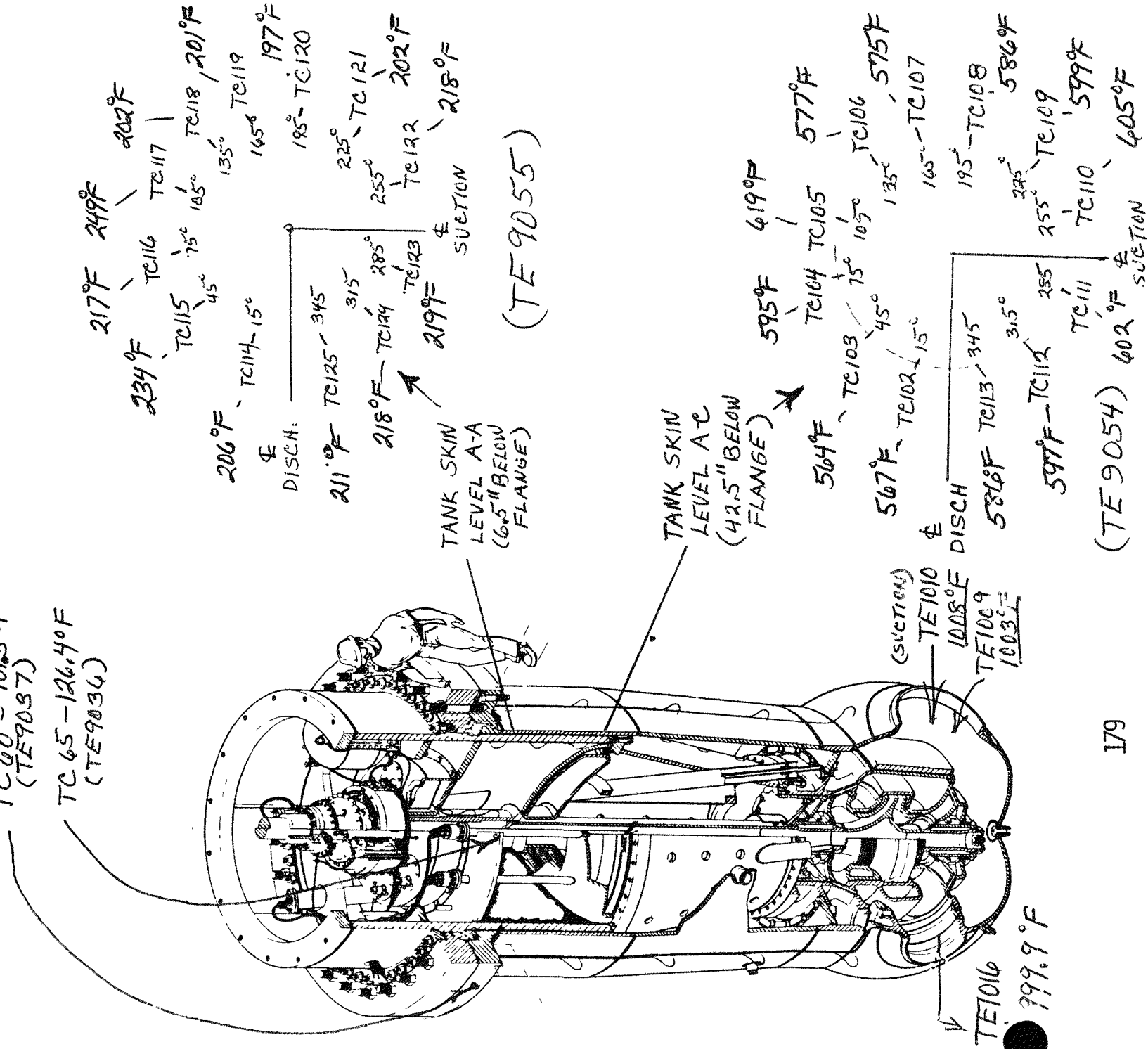
1:30AM 11/20/52

(THIS CONFIGURATION)

TC 60 - 101.5°F  
(TE9037)

TC 65 - 126.4°F  
(TE9036)

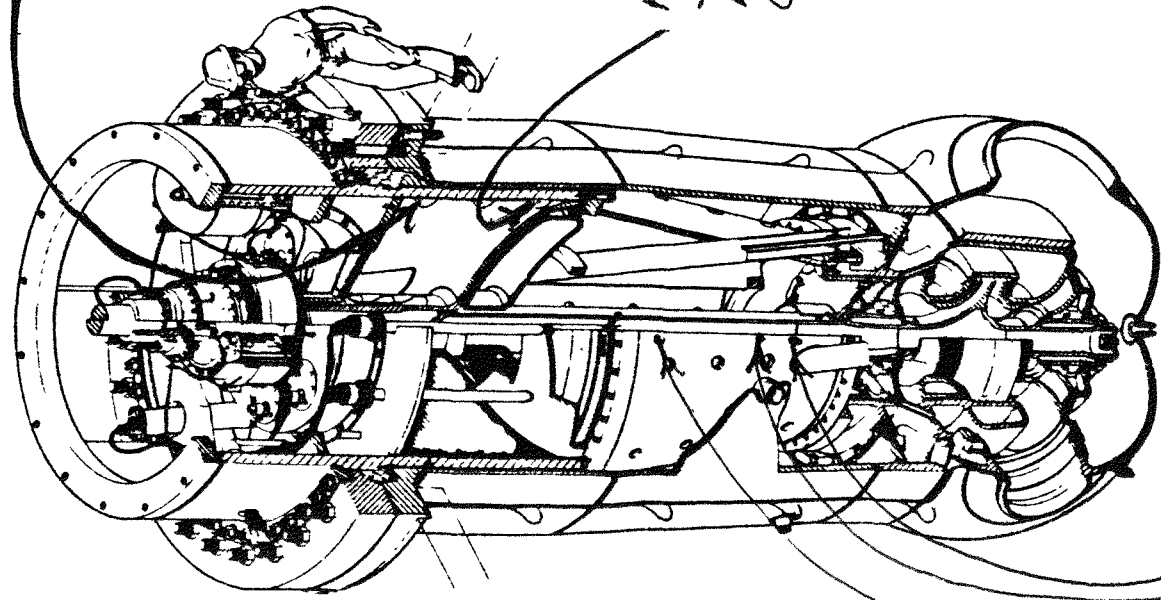
FIGURE 2.9.2A  
PUMP TEMPERATURES  
WITH 100SF SODIUM





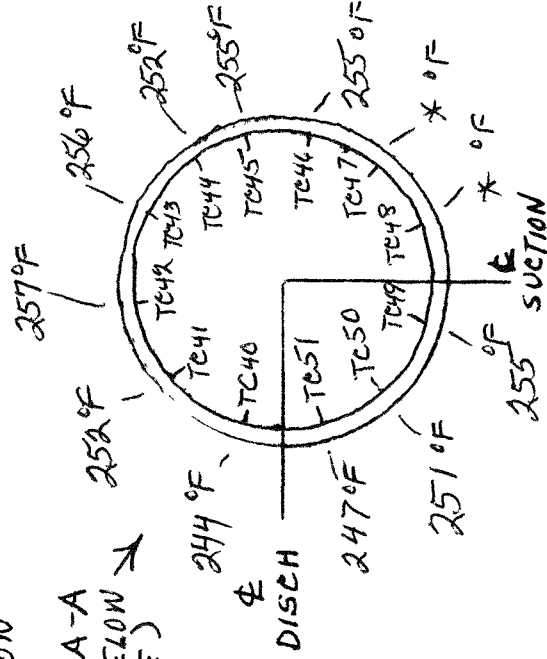
SEGMENT B13  
PHTS CONFIGURATION

FIGURE 2.9.2C  
PUMP TEMPERATURES  
WITH 1005F SODIUM



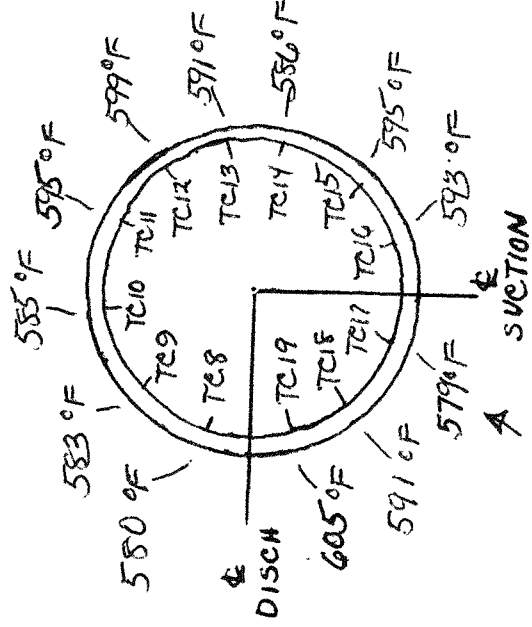
RADIATION SHIELD LEVEL A-A (6.5" BELOW FLANGE) →

RADIATION SHIELD LEVEL A-C (42.5" BELOW FLANGE) →



(TE 9092)

\* INOPERATIVE SENSOR



TE 9090

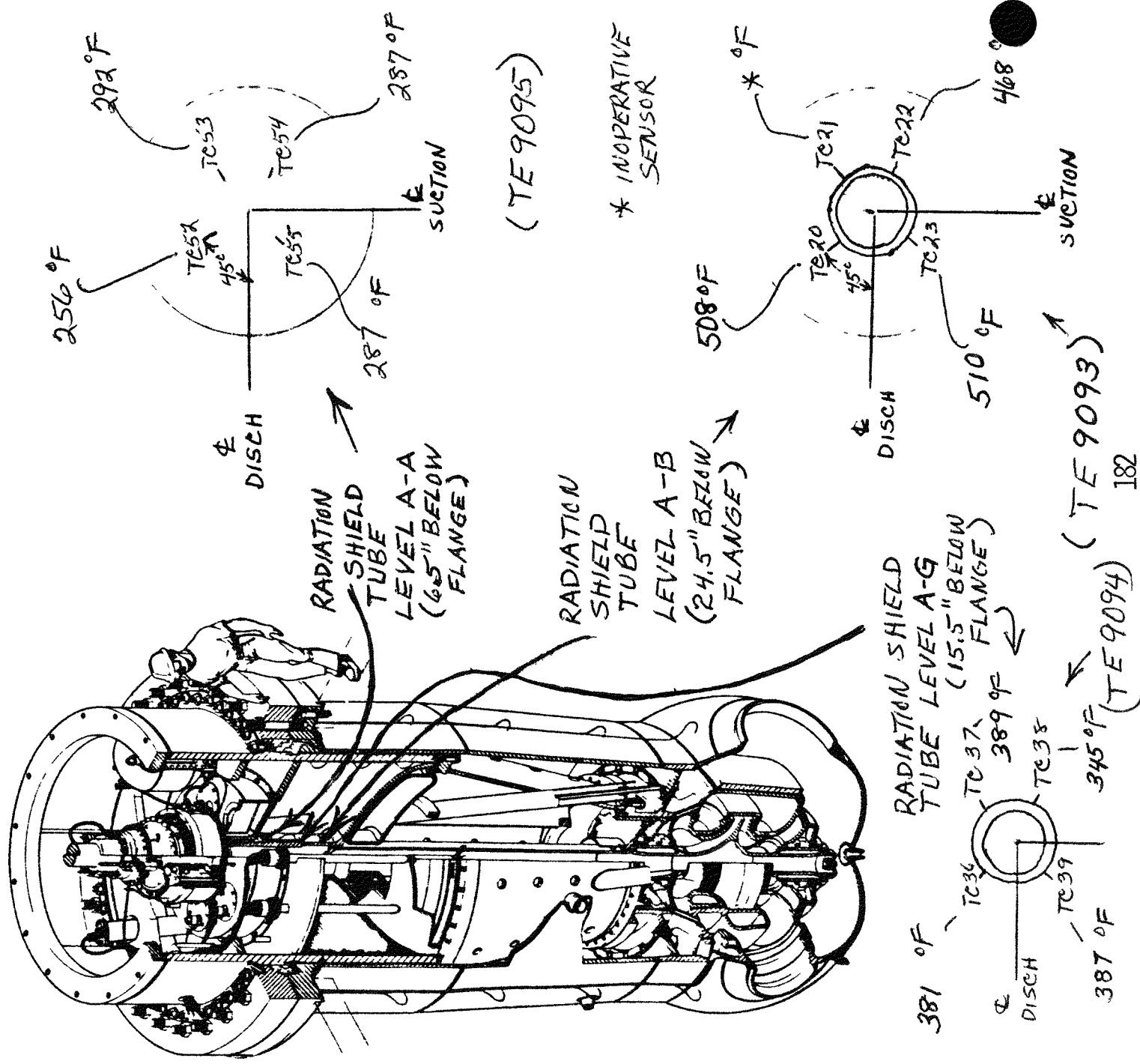
TC5 (TE 9009) - 1004°F

TC4 (TE 9008) - 934°F

TC7 (TE 9007) - 850°F

SEGMENT B13  
PIPS CONFIGURATION

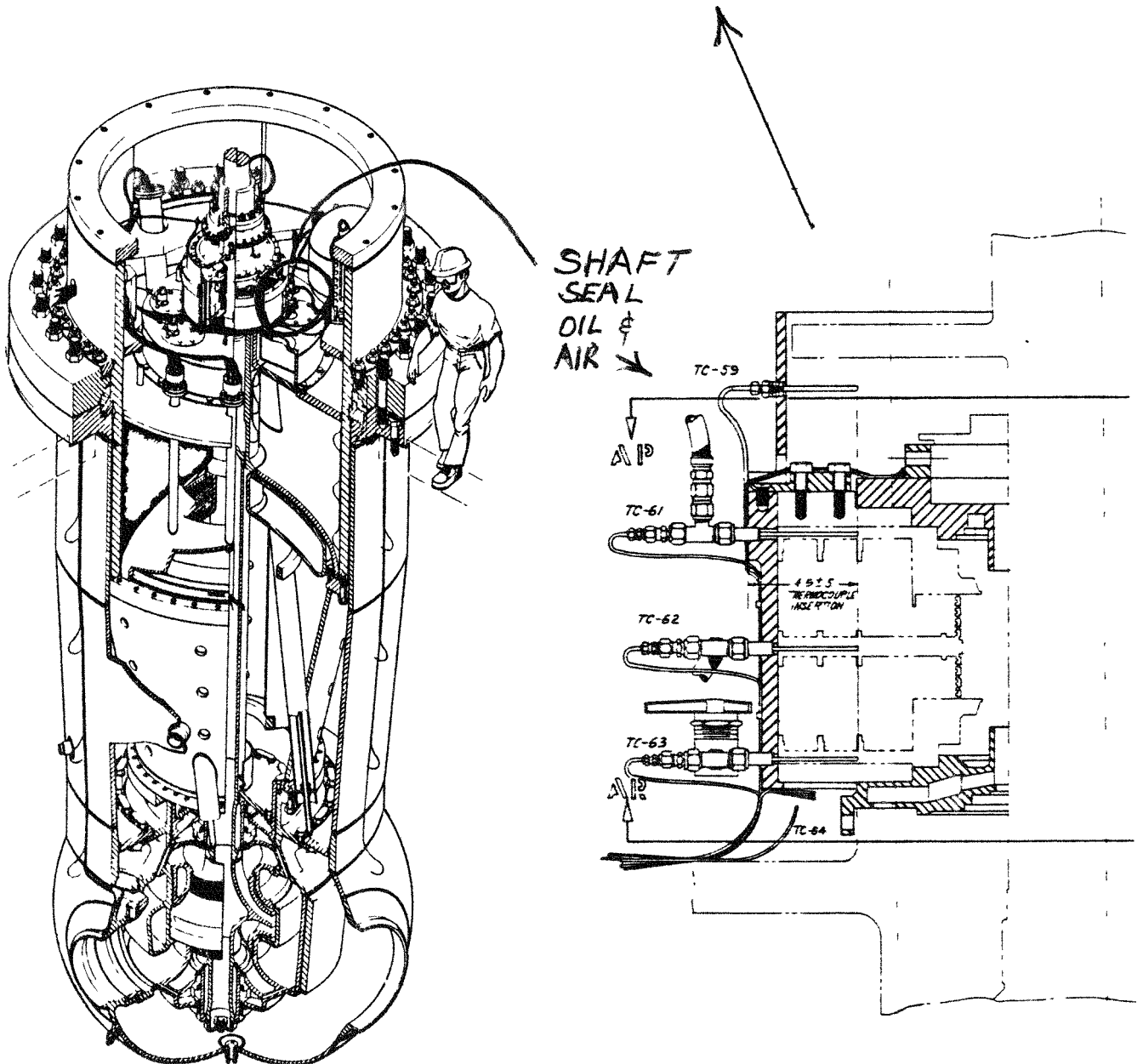
FIGURE 2.9.2D  
PUMP TEMPERATURES  
WITH 1005F SODIUM



SEGMENT B13  
PHTS CONFIGURATION

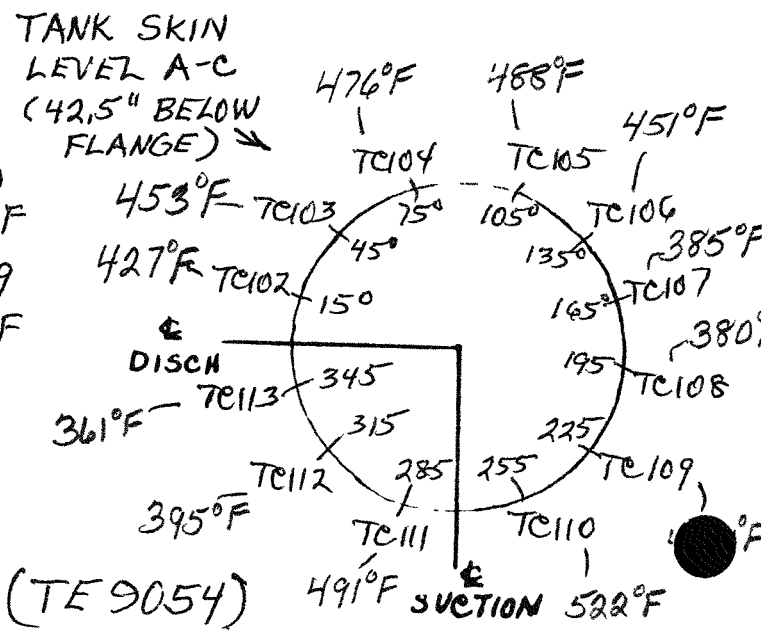
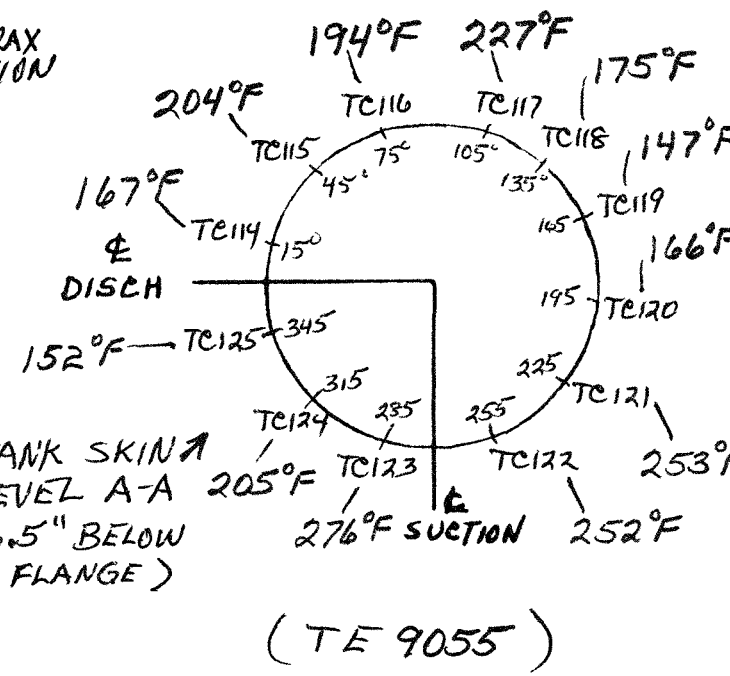
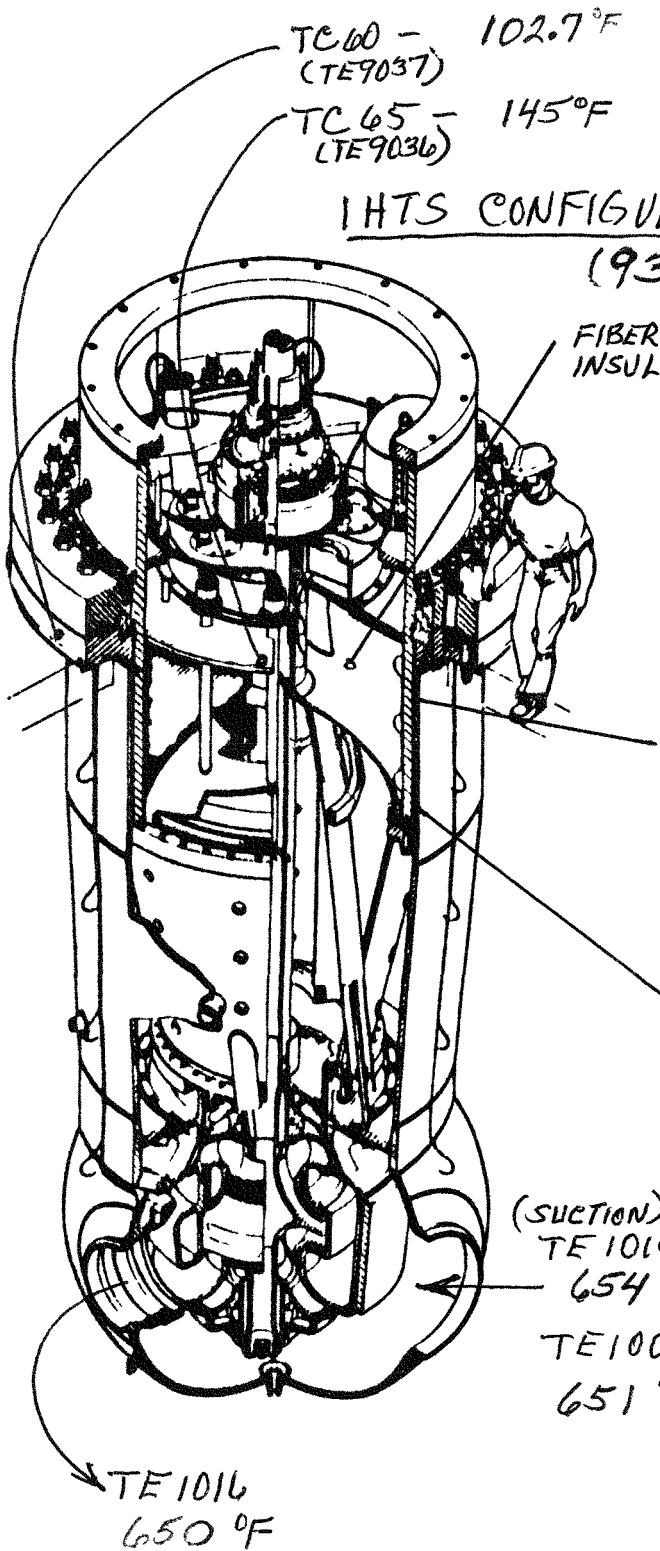
FIGURE 2.9.2E  
 PUMP TEMPERATURES  
 WITH 1005F SODIUM

(TE9038)	TC 59	AIR INTO HX -	81.1 °F
(TE9034)	TC 64	AIR OUT HX -	85.9 °F
(TE9031)	TC 61	UP HX OIL IN -	138.9 °F
(TE9031A)	TC 62	OIL FEED & HX OUT -	126.6 °F
(TE9031B)	TC 63	LO HX OIL IN	- 126.8 °F



SPEED - (SE9249) - 104.2 RPM  
FLOW - 35% 694 - 3283 GPM  
POWER - SER JI9255 - 8.4 kW

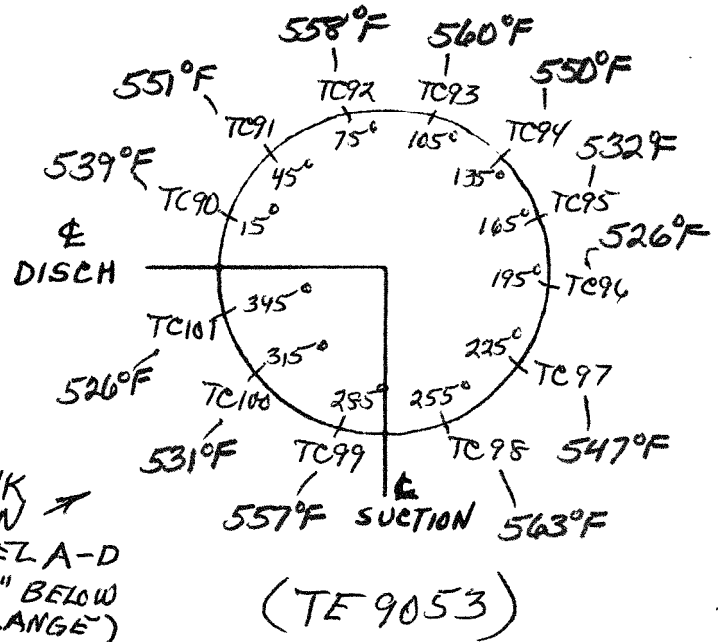
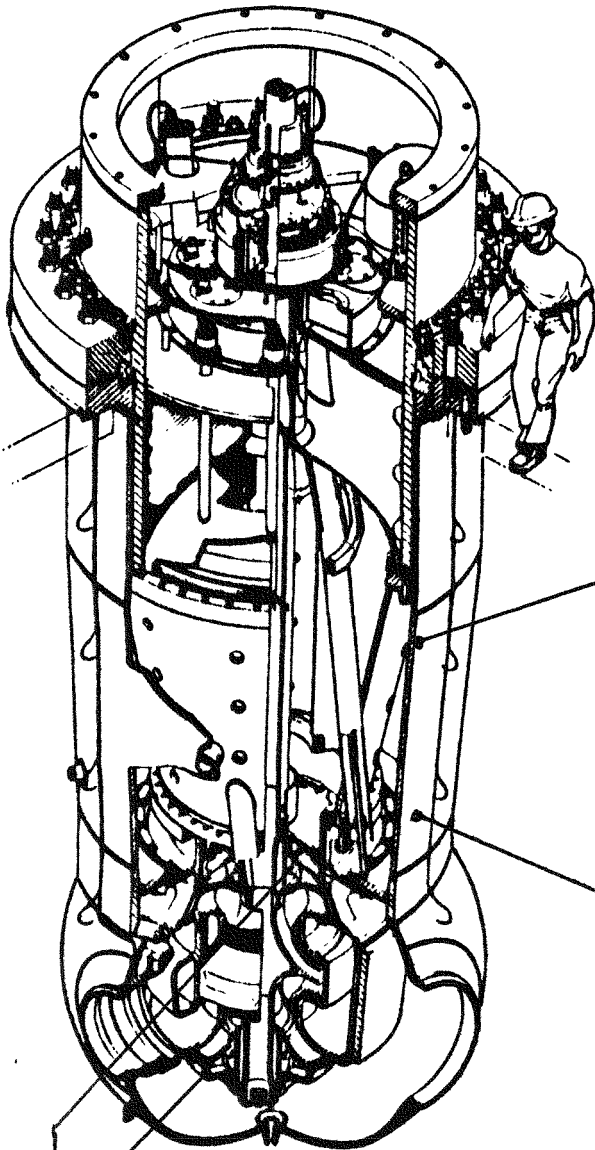
IHTS CONFIGURATION  
(93 PSI COVER GAS)



NOTE: FIG. 2.9.2 F THROUGH FIG 2.9.2 J SHOWS IHTS PUMP (TE 9054) (NO THERM. SHIELD ASSY, BUT WITH FIBRE FRAX INSULATION IN UIS) SODIUM @ 650°F. MAX IHTS TEMP AT (RBRP) IS 775°F.

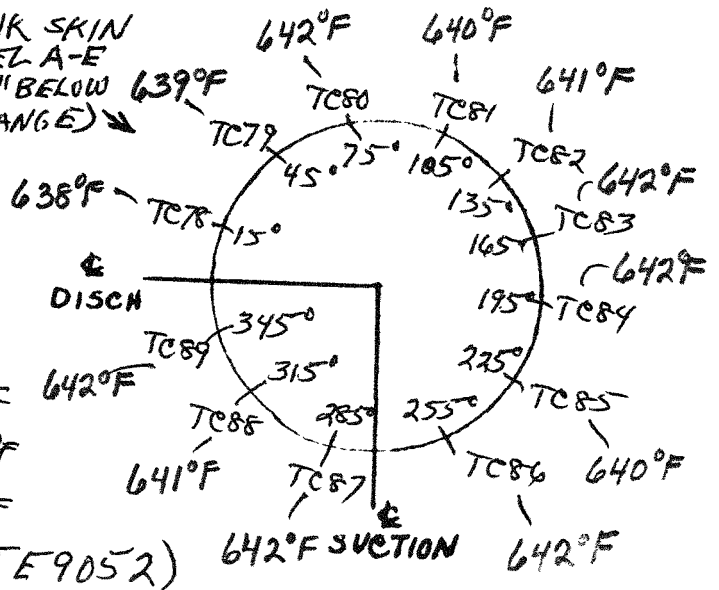
SEGMENT C12  
IHTS CONFIGURATION

FIGURE 2.9.2 G  
 IHTS PUMP TEMPERATURES



TANK SKIN  
 LEVEL A-D  
 (68.5" BELOW  
 FLANGE)

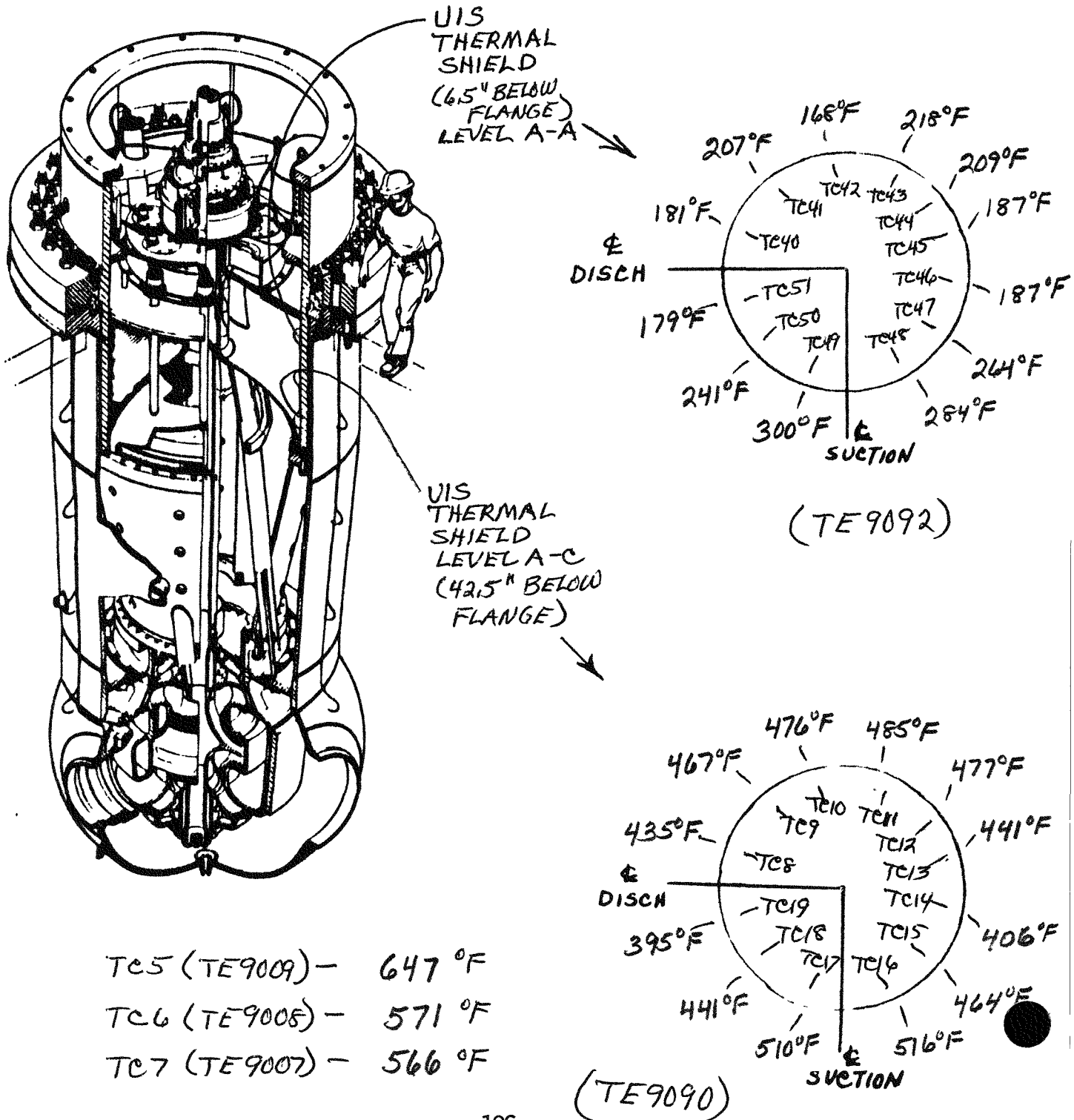
TANK SKIN  
 LEVEL A-E  
 (123" BELOW  
 FLANGE)



- TE9035A - TC1 - LO BRG STR. - 647.9°F
- TE9035B - TC2 - LO BRG SKIN - 655.9°F
- TE9033A - TC3 - UP BRG STR. - 649.8°F
- TE9033B - TC4 - UP BRG SKIN - 655.6°F

SEGMENT C12  
IHTS CONFIGURATION

FIGURE 2.9.2 H  
 IHTS PUMP TEMPERATURES



SEGMENT C12

FIGURE 2.9.2 I  
IHTS PUMP TEMPERATURES

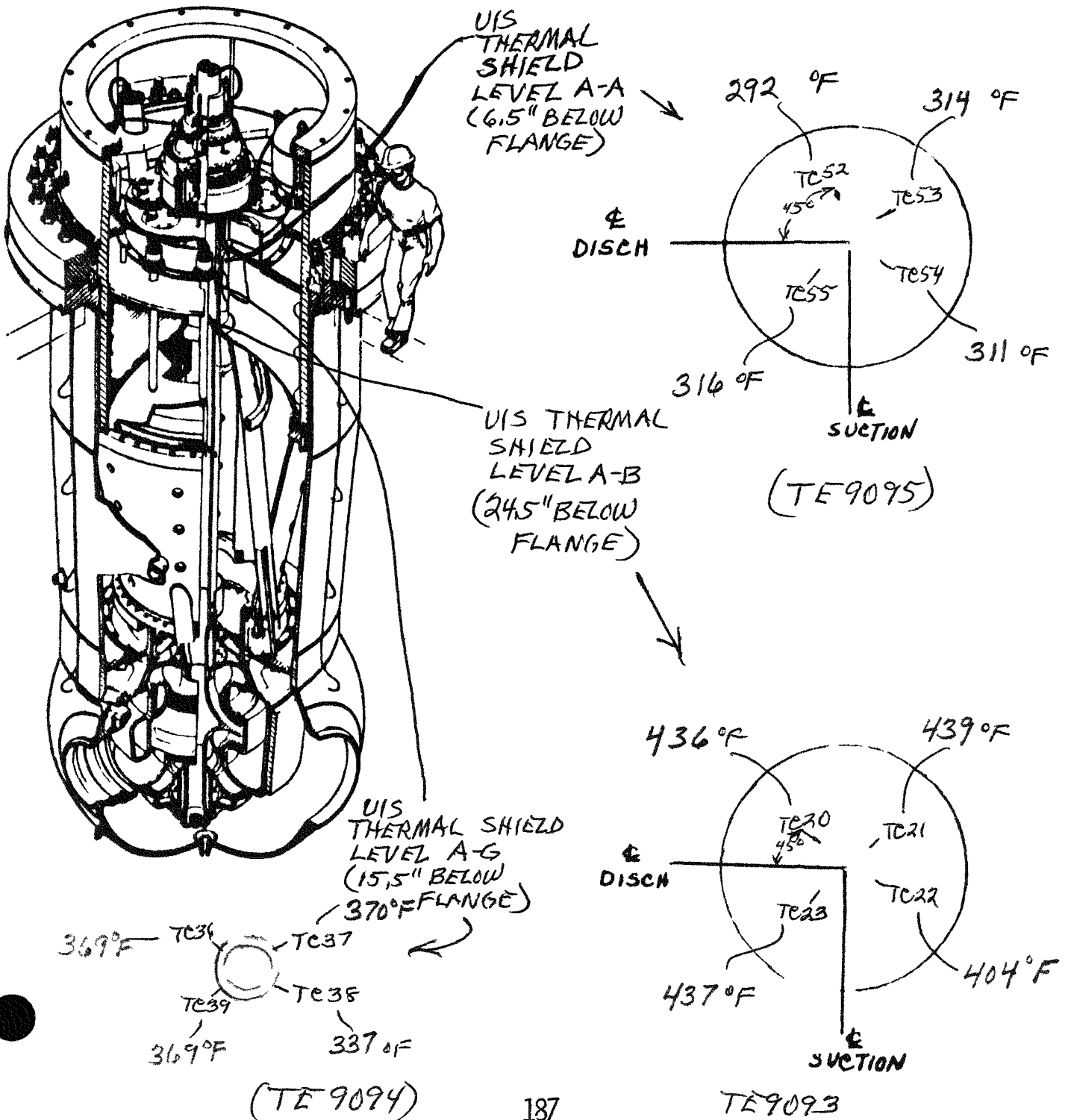
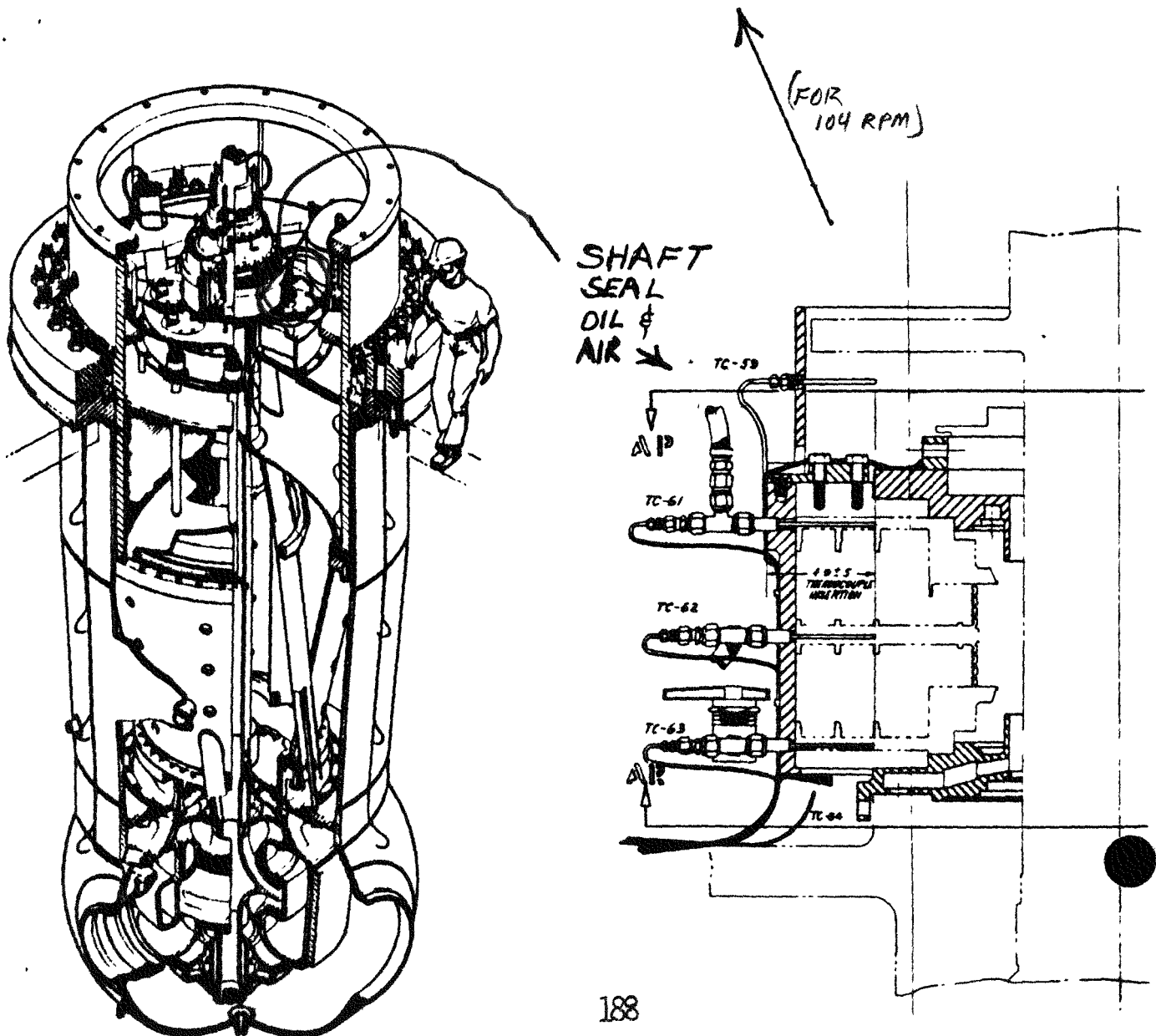


FIGURE 2.9.2 J  
IHTS PUMP TEMPERATURES

- (TE9038) TC 59 AIR INTO HX - 92°F
- (TE9034) TC 64 AIR OUT HX - 92°F
- (TE9031) TC 61 UP HX OIL IN - 118.5°F
- (TE9031A) TC 62 OIL FEED & HX OUT - 111.8°F
- (TE9031B) TC 63 LO HX OIL IN - 105.2°F



### 3.0 SUMMARY OF REQUIREMENTS & OBJECTIVES

#### 3.1 DRS 51.28 Objectives

Objectives	Results
1. Demonstrate that the pump is mechanically and hydraulically stable when separated through its full design speed and flow range and verify hydrostatic bearing performance in the sodium environment.	<ul style="list-style-type: none"><li>° At rated speed, pump and drive vibration/displacement sensors indicate low readings (less than .4g as on pump, less than 4 mils on drive). No abnormal levels experienced at intermediate speeds during Coast-down or Servo tests Bases - Segments B13, B6, B11.</li><li>° Pump has a hook in H-Q curve between R2 and shutoff on pony motor. This is out of normal operating range. See Figure 2.1.3. Basis - Segment C10.</li><li>° On main motor mapping indicates pump is hydraulically stable with negative slope from R2 through R6 at 1116 RPM. Basis A13A, B3A, C8, C10.</li><li>° Hydrostatic bearing operation satisfactory as evidenced by proximeter performance. Basis - Segments A13A, A16, B1, B2 and C8.</li></ul>
2. Determine pump hydraulic characteristics (head-flow map and efficiency) in sodium	° Mapping, with head, flow measurements and efficiency calculations were accomplished in numerous test segments for both the 37.5 inch and the 38.25 inch diameter impeller. See Figure 2.1.1, 2.1.2, 2.1.3 for mapping on pony motor, Figure 2.2.1, 2.2.2, 2.2.4, 2.2.5 for mapping on main motor. Basis: Segments A13A, A13B, A17, B3A, B8, B14, C8, C10.

3. Demonstrate that high temperature and the associated structural temperature gradients do not degrade mechanical operation or hydraulic performance
  - ° It was determined that developed head was less with the temperatures to 1000F than that predicted by the pump supplier. Assuming that the ETEC sodium instrumentation is valid, the amount of head degradation (from the prediction) has been quantified so that plant impellers may be trimmed accordingly.
  - ° It was determined that baffling between the Upper Inner Structure and the tank is necessary to mitigate tank handling caused by gaseous cellular convection in the upper part of the pump. This baffling design was confirmed by test in Segment C12. Basis: Segments A11, B1, & C12.
  - ° Thermal shield design was confirmed. The tank to support structure interface temperatures were adequately mitigated by the thermal shielding (See para. 2.9.2). Basis: Segment B13.
  
4. Demonstrate that the pump & pump auxiliaries are capable of sustained operation while pumping sodium at variable flows & speeds
 

The endurance runs, Segment B5 & B13 verify pump and shaft seal lube service sustained operation at rated speed and flow. Operation at variable flows and speeds is verified by the numerous mapping and servo testing runs.
  
5. Demonstrate pump pony motor operation; verify hydrostatic bearing performance in sodium at pony motor speed; demonstrate pony motor developed head at/near shutoff measure head flow characteristics at different hydraulic loop impedance.
 

Pony motor head/flow mapping was measured at both 600°F and 1000°F with two pony motor speeds (104 and 81.6 RPM) Shut off heads were determined. See Figures 2.1.1 and 2.1.2 for the 37.5 inch impeller head flow map, and Figure 2.1.3 for the 38.25 inch impeller performance map.

5. Continued

Hydrostatic bearing performance is demonstrated in all mapping runs and in Segment B1, the limit of the bearing capability to prevent journal touchdown on the bearing with high tank temperature differential was demonstrated. Figure 2.4.2 shows the relationship of across tank differential temperature on bearing gap.

6. Determine any deleterious structural distortion caused by convection in the gas space

There is no deleterious structural (tank) distortion at internal pressure planned for the PHTS loops. At planned IHTS loop pressure (93 psi), the pump will require baffling between the Upper Inner Structure and the tank to mitigate the bending of the tank to acceptable levels. This baffling was designed and verified in test. Basis: Test Segments A11, B1 and C12. See Para. 2.4.

7. Demonstrate ability of the pump to withstand sodium fluid temperature transients which simulate predicted plant operating and upset transients

The pump was able to handle every transient applied to it during the low temperature, the mild temperature, and the severe temperature thermal transients of Segments A16, B2, and B7. Satisfactory operability through thermal transients was demonstrated by both operation and visual inspection following tests.

8. Demonstrate capability of the standpipe bubbler to maintain adequate sodium level in the pump during steady state and operating transients

The bubbler performed excellently. Level excursions were fractions of an inch even during coastdown trips. Basis: Segments B11 and B13.

9. Verify pump drive response characteristics with the pump operating in sodium with simulated loop impedance.

Drive response to sinusoid and ramp function inputs were measured for numerous flow levels. Drive met the specified performance requirements except for stability at 725 RPM, where random speed variation was over 1%. A modification to the fluid coupler (between the MG Set Drive Motor and Generator) is required to correct the condition. The fix was not verified during sodium testing. Basis: Segment B6.

- 10 Demonstrate flow coastdown characteristics (head, flow, speed from maximum facility flow and from pony motor speed, and correlate to similar measurements made in water tests. Determine pump and motor compliance with rotating kinetic energy requirements per E-Spec Table 3.3.1.
- Flow coastdowns were quantified via some 116 coastdowns run during the test program, at different temperatures and at different loop impedances. Some were run with the pony motor tripped in advance of the main motor. The results were tabulated in normalized form and compared to the required coastdown schedule of SDD51A. See Paragraph 2.7.3. Basis is Segment B11.
11. Measure compliance with NPSH requirements.
- The pump, based on ETEC measurements in sodium has adequate NPSH performance except it is marginal regarding NPSH at the 39,100 gpm flow point with 2 loop <sup>minimum</sup> impedance ( $.1714 \times 10^{-6}$  ft/gpm<sup>2</sup>). (This requirement is on hold in SDD51A) Tests indicate with the 38.25" diameter impeller that 57 feet NPSH would be required to operate cavitation free, at the 39K/R6 point, whereas only 49.2 ft. are available. With the 37.5" impeller, pressure drop off at 39,100 gpm and R6 impedance is 4% with 49 ft. NPSH. (49 ft. is available at CRBRP). Basis: Segments A14, B9, and C11.
12. Verify applicability of IOM Manual procedures for checkout of assembly, operation, disassembly, maintenance & inspection of pump and auxiliaries.
- The pump IOM Manual was very satisfactory for all operations. For instrumentation installations, ETEC had to generate additional detail. Basis: Segments A4B, A5, B15, C1 C15.
13. Demonstrate the CRBRP prototype flow controller operation with the drive system and the CRBRP PM flowmeter.
- The flow control servo system, with drive servo and pump hydraulic head were tested for response to sinusoid, step, and ramp function commands and the results quantified. Basis: Segment B6

14. Verify that established rate of dry preheat is satisfactory as indicated by tank and internal temperature gradients.
- The test Request 22A3551 allowed 3°F/hour as the target heatup rate. ETEC used a slower schedule target of 2°F/hour. A heater element solid state relay failure caused a tank skin differential of 146°F prior to corrections but no damage was done to the pump, and bending did not cause journal to bearing touchdown. The preheat schedule at CRBRP and the tank and internal temperature gradient limits to be used should be based on the ETEC experience. The IOM Manual will define target heat up rates and limits.  
Basis: Segment A8.
15. Determine hydraulic impedance of the pump to low magnitude forward flow of sodium through the pump rotor
- The forward hydraulic impedance through the pump was quantified as being about 250 ft/W<sup>2</sup> in accordance with specified requirements.  
Basis: Segments A15 and B4.
16. Confirm performance of shaft seal regarding leak rates.
- The total shaft seal oil consumption was quantified as 3.9 cc/hr during segments B7 through B14A (October 24 through December 4, 1982, PHTS conditions)  
Basis: Segment Report B13
17. Verify suitability of the pump for subsequent use in sodium after CHCF cleaning operation.
- The pump was satisfactorily cleaned, disassembled, and reassembled between phases B&C. There are design changes being made for the plant pumps and unique features to the prototype which prevent subsequent use in the plant. Some parts required heating for stud removal. Cleaning at CHCF was adequate.
18. This item was deleted from the DRS.
19. Evaluate whether sodium migration upward or oil migration downward is a concern with purge gas feed, labyrinth and shaft seal arrangement.
- Disassembly between Phases B&C revealed some oil product deposition on the shaft SN171222 above the labyrinth, believed to be due to the incident where the seal overheated due to loss of oil tank gas pressurization. Disassembly at the end of Phase C, with a different shaft involved (SN174848) revealed no oil product deposition

20. Determine whether gas injection at the IHX return nozzle causes adverse effects on pump sodium level stability or if slug pumping occurs at the bubbler; and to measure sodium carryover. Tank sodium level stability with IHX gas injection is satisfactory as long as the bubbler discharge is not impeded or plugged. The carryover numbers quantified by ETEC were much lower than expected, and the test was considered inconclusive.

### 3.2 Test Request Performance Predictions & Criteria

The following items were tabulated in Appendix C3 of the test Request 22A3551. The items are either performance requirements from the Pump or Drive E-specification, or are predictions by the pump supplier. Where an item has been modified from its original E-Spec requirement by an approved ECP, the changed or updated requirement is listed.

#### 3.2.1 Pump Performance Items

Item	Results		
	Shaft Position	Swing Direction	Measured Clearance (mils)
1. The journal lateral swing as a pendulum within the bearing assemblies during pump internals assembly shall be within 28 to 50 mils. Predicted nominal is 40 mils. ° Source: 1E3862 ° Related Test Segment: A4B	0	0	39
	0	45	41
	0	90	35
	90	135	39
	90	0	40
	90	45	38
	90	90	38
	90	135	40
2. Upper Inner Structure to tank seal leak test shall verify that the leak rate is less than $5 \times 10^{-2}$ SCC/Second helium at a delta pressure of 5 psi. ° Source: ECP #G0855 Rev. 7 ° Related test segment: A5	Segment Report A5, plus supplementary submittal by ETEC indicated that indisputable proof of passing leak test was not forthcoming from the test, due to confusion in the labeling of pipes from the two buffer zone. One buffer passed, one did not. Unable to identify which is which.		
	3. Establish leak rate of the static (dropdown) seal during the program ° Source: Test Request ° Related Segments: A5A and B14B	Leak rate was measured with both shafts; both measurements with sodium at 600°F, the first at the start of the program in Phase A, the second at the end of Phase C. Rates are defined in Para. 2.7.5.	

4. Shaft seal axial travel shall be determined by measurement during assembly. Measurement was 1.96 inches.
- Source: TM9001 Para. 5.2.5.8
  - Related Segment: A4B
5. Turning torque shall be less than 260 foot-lb with VDM bearing lift pump operating. (30 to 60 ft.lb. attributable to seal, 40 to 200 ft. lb. attributable to motor bearing). This is 180 inch lb when measured at the pony motor with the 17.26 to 1 gear ratio
- Source: GEK42758
  - Related Segment: A8,B1, B13,C10
  - Source: GEK42758
- At Segment A8:  
 As measured at pony motor test  
 Breakaway: 70 to 100 in. lb  
 Running: 40 to 70 in-lb.  
 At Segment B1 with damaged shaft seal;  
 Breaking: 38 ft lb.(456 in-lb)  
 Running: 25 ft. lb.(300 in-lb)  
 At Segment B13 Endurance Run with damaged shaft seal  
 Breakaway: 75 to 80 in lb.  
 Running: 65 to 70 in lb.
- At Segment C10 (1005 F Mapping with replacement shaft seal:  
 Breakaway: 95 in lb  
 Running: 40 to 45 in lb.
6. The preheater system shall not cause a pump dry heat up rate in excess of 3 degrees F per hour. circumferential temperature gradient shall not exceed 90°F. Maximum temperature delta for thermocouples other than 180° apart shall be 120F. Temperature gradient from bearing TC's to tank skin shall not exceed 150°F during dry heat up
- Source: DRS 51.28 & Test Segment 22A3551
  - Related Segments: A8,C5
- ETEC used 2°F/hour as a target. One solid state relay failure caused 146°F tank differential, but bending was not sufficient to cause journal to bearing touchdown. No damage to pump.
- AT 10 days into preheat, bearing to tank differential was 45°F from upper bearing TE9033A to transition ring TC Average (TE9051 series). This was maximum differential during the 30 day preheat.
7. The shut off head when operating on pony motor plant PHTS design speed gear shall not exceed 5.0 ft
- Source: E-Spec 22A3444
  - Related Segment: A13B
- With 37.5 inch impeller:
- |       |          |          |
|-------|----------|----------|
| RPM   | 600F     | 1005F    |
| 103.9 | 4.63(ft) | 4.87(ft) |
| 81.6  | 2.94     | 2.92     |
- With 38.25 inch impeller
- |       |          |         |
|-------|----------|---------|
| RPM   | 600F     | 1005F   |
| 103.9 | 5.04(ft) | 5.1(ft) |
- The above is based on:  
 Gear B, 17.26/1 Ratio (103.9)  
 Gear D, 21.98/1 Ratio (81.6)

- |                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7. Continued                                                                                                                                                                                                                                                                                      | Plant pumps will likely be trimmed to a diameter between the two used for test. If a higher diameter is used, gear C (19.28 to 1 ratio yielding 93 RPM) would be appropriate.                                                                                                                                                                        |
| 8. The sodium level changes in the pump tank due to starting and stopping on pony motor with the bubbler shall be 4 inches or less <ul style="list-style-type: none"> <li>◦ Source: EM0261</li> <li>◦ Level Control Study</li> <li>◦ Related Segments A10, A12A, B13B, B3A, B11</li> </ul>        | Level changes with starts & stops from either pony motor or main motor were either not discernable or were small fractions of an inch.                                                                                                                                                                                                               |
| 9. The realized coastdown schedule for the motor & pump with loop load for 1116 RPM and R3 impedance shall be compared with the normalized schedule listed in Appendix B1 of the test Request. <ul style="list-style-type: none"> <li>◦ Source: SDD51A</li> <li>◦ Related Segments: B1</li> </ul> | Coastdown is compliant. See Para. 2.7.3 for typical coast-down schedule.                                                                                                                                                                                                                                                                             |
| 10. The measured value of H-Q reading from main motor mapping at design speed as shown in Figure 3 of 22A3444 shall not exceed acceptable deviation per Standards of the Hydraulic Institute, 13th Edition                                                                                        | Std. of Hydro Institute: Given speed & flow, the head may vary: -0% to +5% (458 to 480.9 ft.)<br><br>The 37.5 inch impeller does not meet the above requirements (441 ft., 33,700 gpm at 600°F).<br><br>The 38.25 inch impeller is just barely above the 480.9 ft. limit when data is adjusted to 33,700 gpm (483 ft. at 600F, and 488 ft. at 1005F) |
| 11. When an NPSH of 49.2 ft. (CRBRP available) is applied at 115% of flow, or when an NPSH of 50.6 ft. is applied at 100% flow, there shall be no evidence of cavitation as measured by the 3% head loss method.                                                                                  | There is no evidence of cavitation at the 100% flow conditions.<br><br>There is cavitation at R6 and and 39,100 gpm. See Para. 3.1 Item 11.                                                                                                                                                                                                          |

There shall be no cavitation when the pump is operated in the range bounded by the points 1,2,3,6,5 of Figure 3 of E-Spec 22A3444 and at suction pressures per Figure 4 of 22A3444.

See Para. 2.5 for additional details.

- Source 22A3444
- Related Segments: A14,B9,C11

12. Under locked rotor conditions, the forward flow impedance shall be equal to or less than 250 ft/W<sup>2</sup>. Under windmilling conditions, the forward flow impedance shall be equal to or less than 102 ft./W<sup>2</sup>.

Impedance of non windmilling rotor in the 10 to 50 inch W.G. differential pressure range with 600°F sodium averaged 245. With 1005F sodium and a differential pressure range of 30 to 143 inches WG, the impedance average was 250 with data scatter to 230 & 270. Since the rotor did not windmill, there is no windmilling data.

- Source: 22A3444
- Related Segments: A15&B4

13. The predicated radial gap loss at the in sodium hydrostatic bearing due to application of fluid transients:

Measurements of bearing gap by means of proximeters proved to be highly useful as a safety device during cellular convection induced tank bending. The proximeters were temperature sensitive, requiring recalibration about every 50°F.

PHTS Journal:

	Up Shock	Down Shock
Lower Bearing	Opens	-2 mils per 100°F

Upper Bearing	-2.3 mils per 100°F	opens
---------------	---------------------	-------

For IHTS Journal:

	Up Shock	Down Shock
Upper Bearing	-2.8 mils per 100F	open

Lower Bearing	Opens	-2 mils Per 100°F
---------------	-------	-------------------

- Source: Byron Jackson
- Related Test Segments: A16, B2, B7

ETEC devised a technique to modify proximeter output as a function of temperature and to display the gap change vs. time in a post transient test playback. These curves are available in the ETEC report on Seg. B7.

The pump survived all applied transients, which indicates that the analysis and design is suitable for the application.

14. The shaft seal oil leakage rate shall not exceed 10cc/hour per seal when operated at PHTS pressures.
- The leak rate for the shaft seal when operated at IHTS pressures shall not exceed 70 cc/hour total (60 cc upper seal and 10 cc lower seal).
- Source: The recap Design Review
  - Related Segment: B13
- The leak rate of both upper and lower seal while operating at PHTS pressures for 1008 hours from segments B7 through B14A was 3.9 cc/hr total drainage from the supply tank. This is about 20% of the rate which was recommended for planning the frequency of servicing.
15. With an input of .55 SCFM argon gas into the IHX return with IHX return flow stream with 200 gpm, there shall be no detectable gas entrained in the pump discharge flow.
- With an input of up to .55 SCFM argon gas into the IHX return flow stream with 200 gpm sodium flow, the magnitude of sodium carryover in the gas region of the standpipe bubbler shall be measured during sodium testing.
- Source: DRS51.28 & Test Request 22A3551
  - Related Segment: B3B
- The only way to detect entrainment is a fall off in head developed as compared to performance without IHX gas injection. There was no evidence of developed head drop off.
- Carryover measurements were completed, however, results were considered unsuccessful. See Para. 2.7.9 for details.
16. The H-Q curve slope at 1116 RPM for impedance from R2 to R6 shall be negative.
- Source: Test Request & ICD #CG52004/5
  - Related Segment: B13
- The constant speed - variable impedance curve of Head vs. Flow is negative from R2 thru R6.
17. The shaft seal heat exchanger shall maintain the seal internal oil, as measured by thermocouple TE9031A at a temperature below 225°F.
- Source: Test Request & ICD #CG52004/5
  - Related Segment: B13
- The seal oil temperature was measured as 145°F when sodium was 1005F.
- (Seal oil temperature during water test was 140F)

18. Vibration at Pump Discharge Nozzle is to be monitored during Segment A12AB and arbitrary alarm limits are to be established for subsequent tests.
- Source: Test Request
  - Related Segment: A12AB
- ETEC monitored/recorded nozzle vibration levels at Segment A12AB and in all subsequent segments after Segment A13A & A13B, a 100Hz low pass filter was added.
19. The HQ curve at pony motor speed shall have a negative slope from R2 loop impedance through R6 loop impedance
- Source: Figure 3 of 22A3444
  - Related Segment: A13A,C10
- Within the operating range of R2 to the minimum hydraulic loop impedance achievable at ETEC, the HQ curve displayed a negative slope.
- Between R2 and shutoff there is a zone where the curve has a dip, followed by a positive slope in the 1600 to 2000 gpm region. See Figure 2.1.3. This dip and positive slope is not in the CRBRP operating region.

### 3.2.2 Drive System Performance Items

Item	Results
<p>1. Drive System step function response shall be:</p> <ul style="list-style-type: none"> <li>-Less than 33.2 seconds for 22% to 30% speed</li> <li>-Less than 20 seconds for 40% to 100% speed</li> <li>◦ Source: Table 3.3.2 of</li> <li>◦ Related Segment: B6</li> </ul>	<p>All response times were within specification.</p> <p>(Response time is time from initiation of step command until output is 90% of the speed change).</p>
<p>2. Drive System overshoot shall be less than 1% of design speed for a step function speed command of 10% of design speed; for the 50% to 100% speed range, and less than 2% for the 30% to 50% speed range.</p> <ul style="list-style-type: none"> <li>◦ Source: 22A3553</li> <li>◦ Related Segment: B6</li> </ul>	<p>All overshoot tests were within specification.</p> <p>(Overshoot is the maximum transient excursion from final steady state speed following a step change).</p>
<p>3. Drive system settling time shall be less than 50 seconds for 10% step changes from 40% to 100% speeds.</p>	<p>All settling times were within specification.</p> <p>(Settling time is the time from step initiation until output is within 3% of its final value).</p>

4. Drive system steady state speed error shall be less than 1% of operating speed point.
- Source: 22A3553
  - Related SEgment: B6
- The drive system met the 1% requirement except at 726 RPM, where the system "hunted". Resolution is a Voith Fluid coupler modification. Confirmation of the fix was not accomplished during sodium tests, but is planned for the plant pump water tests.
- (Steady state speed error is the speed error remaining after a speed change transient has expired).
5. Drive System threshold requirements is  $\pm 0.27\%$ .
- Source 22A3553
  - Related SEgment: B6
- Threshold requirements were met.
6. Drive system response to sinusoidal speed commands requires that phase margin be 50 or greater and that gain margin exceed 20 decibels and that bandwidth be greater than 0.1 radian/sec.
- Phase margin, gain margin and bandwidth were met.

APPENDIX A

LIST OF TEST SEGMENTS & REPORTS

<u>TEST SEGMENT</u>	<u>SEGMENT REPORT</u>	<u>REPORT DATE</u>
A1 TANK, HEATER & INSULATION INST.	82ETEC-DRF-0723	2/17/82
A2 MG& AUXILIARY INSTALLATION	82ETEC-DRF-0724	2/17/82
A3 MG SET CHECKOUT	ETEC-TDR-82-10	6/24/82
A4A PUMP INTERNALS RECEIVING	83ETEC-DRF-4509	10/13/83
A4B INTERNALS ASSEMBLY	83ETEC-DRF-4523	10/17/83
A5 INNER STRUCTURE ASSEMBLY	83ETEC-DRF-4500	10/13/83
A5A LEAK TEST DROP DOWN SEAL	83ETEC-DRF-4048	9/9/83
A6 DRIVE MOTOR INSTALLATION	ETEC-TDR-82-10	6/24/82
A7 FINAL COLD PUMP CHECKS	82ETEC-DRF-4023	7/30/82
A8 PREHEAT & FILL	82ETEC-DRF-0497	1/3/83
A9 PURGE SUPPLY/LEVEL CONTROL	83ETEC-DRF-1963	5/19/83
A10 PONY MOTOR SNAKEDOWN	83ETEC-DRF-1999	5/23/83
A11 LOW TEMP. GAS CONVECTION CHECKS	83ETEC-DRF-2490	6/17/83
A12 INITIAL MAIN MOTOR RUN	83ETEC-DRF-4418	9/7/83
A13 BASELINE HEAD/FLOW MAPPING	83ETEC-DRF-1964	5/19/83
A13B PONY MOTOR MAPPING	83ETEC-DRF-1971	5/19/83
A14 LOW TEMP. NPSH	83ETEC-DRF-3320	7/28/83
A15 ROTOR IMPEDANCE AT 600°F	83ETEC-DRF-2151	6/3/83
A16 LOW TEMP. THERMAL TRANSIENTS	83ETEC-DRF-2126	6/1/83
A17 BASELINE RECHECK	83ETEC-DRF-1943	5/17/83
B1 HIGH TEMP GAS CONVECTION TEST	83ETEC-DRF-3156	7/18/83
B2 MILD THERMAL TRANSIENTS	83ETEC-DRF-2129	6/2/83
B3A FIRST RUN TO RATED TEMP/MAPPING	83ETEC-DRF-2186	5/26/83
B3B IHX GAS INJECTION TEST	83ETEC-DRF-3917	8/31/83
B4 ROTOR IMPEDANCE AT 1005°F	83ETEC-DRF-2311	6/9/83
B5 SHORT TERM ENDURANCE RUN	83ETEC-DRF-2380	6/17/83
B6 DRIVE & FLOW CONTROLLER SERVO TEST	93ETEC-DRF-3834	8/26/83
B7 SEVERE THERMAL TRANSIENTS	83ETEC-DRF-2538	6/29/83
B8 HIGH TEMP BASELINE RECHECK	83ETEC-DRF-1953	5/18/83
B9 HIGH TEMP NPSH	83ETEC-DRF-3104	7/13/83
B10 ONE LOOP OPER ON MAIN MOTOR	83ETEC-DRF-3909	8/30/83
B11 COAST DOWN RUNS	83ETEC-DRF-3438	8/4/83
B13 LONG TERM ENDURANCE RUN	83ETEC-DRF-3910	8/30/83
B14 BASELINE RECHECK	83ETEC-DRF-2272	6/7/83
B14A PPIF TRANSIENT (1100°F)	83ETEC-DRF-2536	6/28/83
B14B LEAK TEST DROP DOWN SEAL	NOT ISSUED	
B14C SHAFT SEAL REPLACEMENT DEMO	83ETEC-DRF-4496	10/13/83
B15 DISASSEMBLY	83ETEC-DRF-4861	11/2/83

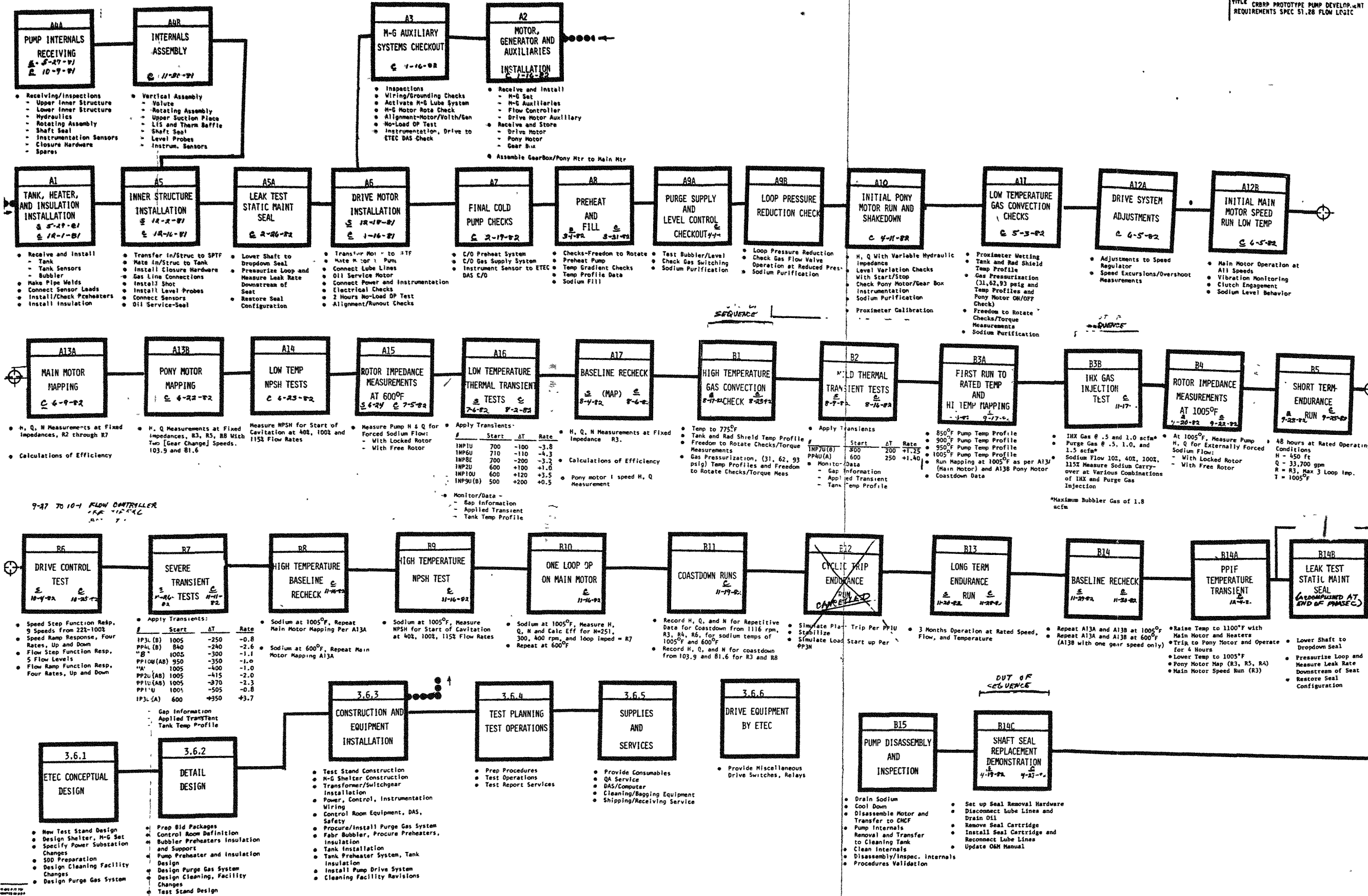
LIST OF TEST SEGMENTS & REPORTS

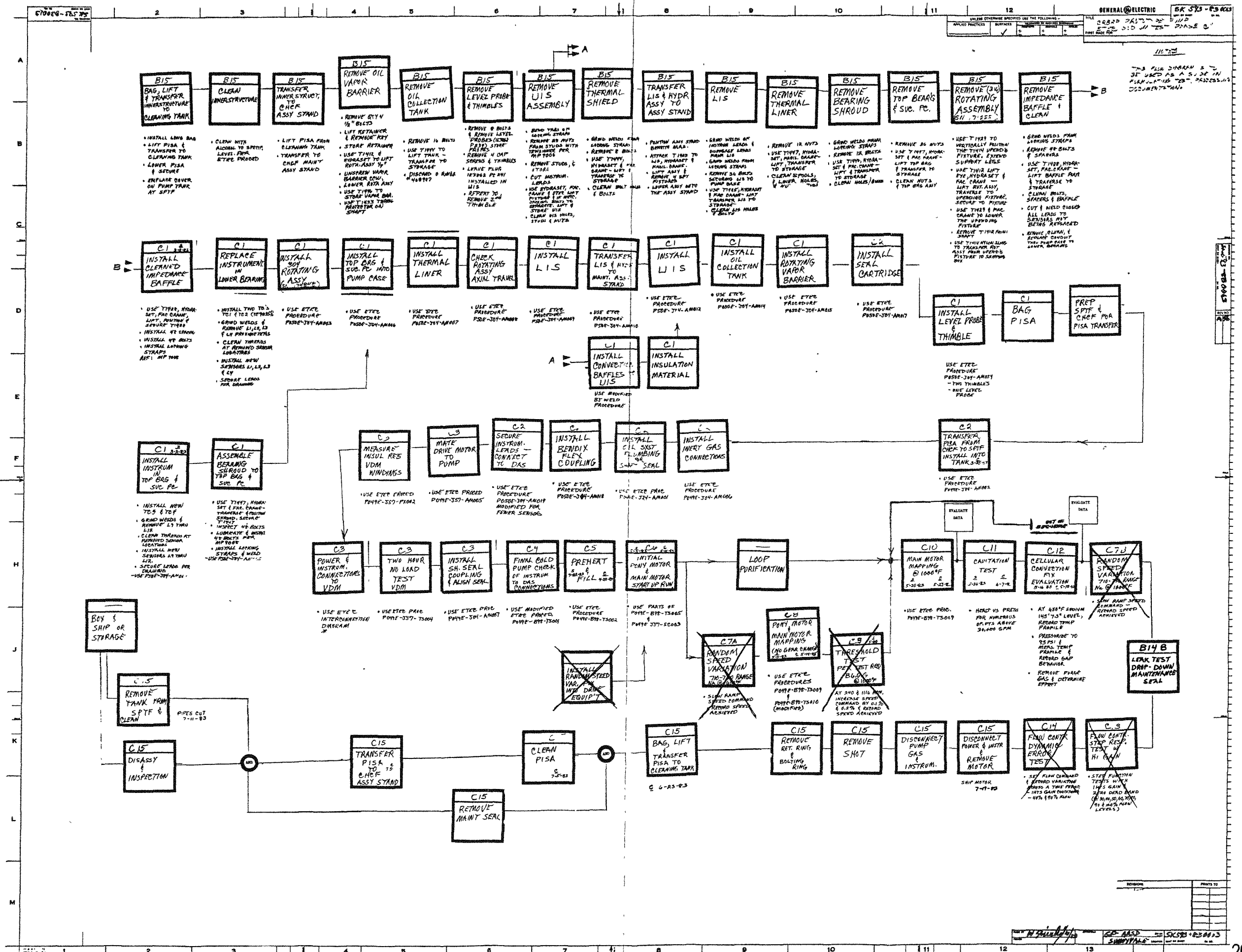
	<u>TEST SEGMENT</u>	<u>SEGMENT REPORT</u>	<u>REPORT DATE</u>
C1	REASSEMBLY	83ETEC-DRF-4302	10/5/83
C2	INNERSTRUCTURE INSTALLATION	83ETEC-DRF-4302	10/5/83
C3	DRIVE MOTOR INSTALLATION	83ETEC-DRF-4302	10/5/83
C4	FINAL COLD PUMP CHECKS	83ETEC-DRF-4302	10/5/83
C5	PREHEAT & FILL	83ETEC-DRF-4302	10/5/83
C6	PONY & MAIN MOTOR START-UP	83ETEC-DRF-4222	9/23/83
*C8	BASELINE MAPPING @600°F	83ETEC-DRF-3711	8/17/83
C9	DRIVE THRESHOLD TEST	83ETEC-DRF-4221	9/22/83
*C10	MAIN MOTOR MAPPING AT 1005°F	83ETEC-DRF-3712	8/17/83
C11	CAVITATION TEST	83ETEC-DRF-3429	8/12/83
C12	CELLULAR CONVECTION FLX EVAL.	83ETEC-DRF-3192	7/20/83
C15	DISASSEMBLY & INSPECTIONS	83ETEC-DRF-4769	10/26/83

\* The Quick Look Report is required to complete these documents:

<u>Test Segment</u>	<u>Quick Look Report</u>	<u>Date</u>
C8	83ETEC-DRF-2304	6/9/83
C10	83ETEC-DRF-2111	5/31/83

APPENDIX B





THIS PLAN IS TO BE USED AS A GUIDE IN PLANNING THE MAINTENANCE PROCESS. IT IS NOT A CONTRACT DOCUMENT.

REVISIONS

APPENDIX C

EM	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2497	Lube Oil System of MG Motor was contaminated as received.	6/2/81 ETEC Seg A2	Support bearing housing oil settling chamber not adequately cleaned.	1. Inspected bearings - OK 2. Cleaned & flushed settling chamber & piping 3. Filters checked after running.	Install per IOM procedures. Inspect sump of coupler (1st unit delivered)
2499	MG Set Motor & Generator bearings show uneven wear between upper & lower halves. Motor inboard bearing shows scoring.	6/5/81 ETEC Seg A2	Lube oil contamination as reported via NCR 2497.	1. Bearings examined by GE-I&SE 2. Bearings polished	Inspect per IOM manual. See NCR 2497
2505	MG Coupler - sludge (with consistency like butter), iron filings & a pair of safety glasses found in oil reservoir.	6/17/81 ETEC Seg A2	Improper cleaning.	Reference ETEC #81-211-19-190 1. Cleaned & flushed 2. Refilled, recirculated oil until filter examination OK visually.	Install per IOM procedures. See NCR 2497
2508	1. Hardware missing - (MG Set) o interconnect enclosure attachment hardware o power interconnect hardware o hardware for mounting internal components in enclosure 2. IOM Manual does not cover attachment of the power interconnect enclosure nor does it cover cleaning of high voltage terminals. 3. A rats nest was found in the power interconnect enclosure.	6/29/81 ETEC Seg A2	Packaging of hardware during disassembly for shipment inadequate. Power equipment enclosures are shipped separately and should have been properly identified and tagged per Tab XII of IOM #GEK42757. Assembly drawings not used.	1. ETEC replaced missing bolts 2. Enclosure cleaned per IOM Manual GEK 42757 Tab VIII 3. Corroded terminals were burnished to "bright metal" 4. Insulation resistance checked per IOM #GEK 42757 Tab III.	Install per IOM procedures. Review IOM for adequacy
2542	Approximately 20 jumpers have been located in the Voith TB #3 rather than in the ICP Panel #2 per drawing 0146D1676 Sheet 7.	10/1/81 ETEC Seg A2	Supplier discrepancy.	Accepted as is, NCR has termination list to identify the as built configuration.	1. Inspect CRBRP units to determine configuration. 2. If required, correct all units to agree with drawing.
2543	Fuses missing.	10/2/81 ETEC Seg A3	Apparently cannibalized at conclusion of water test.	ETEC furnished fuses.	None.

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
8684	<p>Coupler shims for vertical adjustment are missing.</p> <p>Electrical leads and cables are not bagged or otherwise protected (from moisture). Applies to both motor and generator.</p> <p>Ashcroft switch on motor has loose wires.</p> <p>Flex conduit damaged on coupler</p> <p>Motor inspection plate bolts missing, five from north side, four from south side.</p> <p>Generator exiter has loose wires and terminal box #4 is missing.</p> <p>Damage to top of electrical cabinet labeled "PHTS Loop 1 Panel, PPS Pump Trip BKR A".</p> <p>Pony Motor gear speed module missing.</p> <p>Speed regulator panel door screw missing.</p> <p>Panels need paint</p>	6/3/81 ETEC Seg A2	<p>No shims supplied with equipment when it came from Schenectady.</p> <p>O&amp;M Manual GEK 42757 does not require bagging the leads prior to shipment.</p> <p>Loose wires are the oil pressure switch leads to the control panel. They were not removed prior to shipment.</p> <p>Conduit damaged during shipment, possibly during initial shipment from Schenectady.</p> <p>Bolts were apparently not returned when unit was prepared for shipment.</p> <p>The unit did not have any conduit (Term. Box #4) when it came from Schenectady.</p> <p>Damage sustained during shipment.</p> <p>Speed module was removed from ICP prior to shipment.</p> <p>Possibly lost during handling</p> <p>Paint scratched during handling.</p>	<p>Shims used at BJ became rusty after 2 years and were discarded. ETEC provided new shims.</p> <p>The units, when prepared for shipment, are covered with 2 pieces of 4 mil polyethylene. This provides sufficient protection for the leads during shipment. Bagging of the leads is required only when the units are in storage. If the P.E. Box are installed and the units are idle, the heaters in each unit are energized to prevent condensation of moisture.</p> <p>The loose wires are part of the field installed wiring which do not come with the equipment. These wires were furnished by ETEC per ICD interface requirements.</p> <p>Used as is.</p> <p>ETEC replaced missing bolts.</p> <p>ETEC replaced the missing conduit (Crouse-Hinds conduit LB-37).</p> <p>Used as is.</p> <p>Removal of speed module from ICP was authorized. The analog was not functioning properly. A replacement was provided for the sodium test.</p> <p>ETEC replaced missing screw.</p> <p>Used as is at ETEC.</p>	<p>none</p> <p>none</p> <p>none</p> <p>Repair when prototype is refurbished</p> <p>none</p> <p>none</p> <p>Repair when prototype is refurbished</p> <p>none</p> <p>none</p> <p>Repair when prototype is refurbished</p>

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT B.J/ETEC	PROPOS. ACTIONS FOR CRBRP
8684	<p>PSID gage on tube oil skid is inoperative. Screws and needle are loose inside glass face.</p> <p>Front cover damaged on circuit breaker, P/N 269A6146.</p> <p>One hold-down bolt for coupler is 3/4" shorter than the others and is double-threaded.</p>	6/3/81 ETEC Seg A2	<p>Screws and needle possibly jarred loose during shipment</p> <p>Possibly damaged during shipment.</p> <p>Regular bolt appears to have been lost.</p>	<p>ETEC consulted the IBSE representative during his visit to the site. Was restored.</p> <p>Used as is at ETEC.</p> <p>ETEC replaced</p>	<p>none</p> <p><del>Repair when prototype is refurbished</del></p> <p>none</p>

210

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2544	VDM lube oil skid-flow switch covermissing. U bolt clamp missing, Conduit unscrewed & exposed to weather	10/2/81 ETEC SEG. A3	Shipping preparation carelessness	ETEC furnished replacements and repaired loose conduit.	None - Lube Skid is test equipment not provided to CRBRP
2551	VDM Lube Skid- two temperature gages and two pressure gages are missing	10/14/81 ETEC SEG A2	Supplier error (As received)	GE supplied missing parts	None - Test equipment not provided to CRBRP
2572	Plastic cooling fan at top of pony motor has a piece broken away between fan blades	11/4/81 ETEC SEG A2	Unknown (As received)	ETEC- reworked- radiused corner to blend.	Replace <del>the</del> prototype is refurbished.
2577	Drip pan missing (VDM)	11/12/81 ETEC SEG A2	Not shipped by supplier	Supplier provided a replacement.	None
2580	MG Set Instrum. Panel- Three resistors, 5125 ohms called for on drawing 0146D1676 sh 4 are missing.	11/16/81 ETEC SEG A3	Lost between use at BJ & ETEC receipt.	ETEC furnished.	None
2581	Heater fuse wiring non existant- two lines	11/19/81 ETEC SEG A3	Incomplete retrofit of a wiring change	ETEC installed the wiring	Inspect all units at CRBRP
2584	Cover plate on Voith positioner is broken. Bolt for cover is missing Strain relief box is loose, with bolt & support angle missing	11/18/81 ETEC SEG A3	Unknown (as received)	Cover plate used as is Bolt replaced Reworked attachment of strain relief box-fabr. new bracket.	None-CRBRP receiving inspection complete
2585	Identification tags for LT1-min travel, and LT2-max travel, are reversed	11/23/81 ETEC SEG A3	Unknown (As received)	Changed location of identification tags.	Inspect all units at CRBRP
(1) 2587	Thermocouple TE44B, ETEC tag # TE9260A does not operate.	11/24/81 ETEC SEG A3	Small bits of insulation from from the thermocouple extension wire were crimped under the connector pins and prevented continuity.	ETEC used alternate TC44A later Repaired TC and used it.	Inspect one set of MG-Set Voith coupler for continuity
2588	Pony motor gear speed digital indicator missing from ICP	11/24/81 ETEC SEG A3	Transducer was sent back to subtier supplier for adjustment/calibration. See NCR 2607	Returned transducer was installed.	

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2593	Lube oil skid wiring as installed does not agree with drawing # B-76-E-60 Rev'n C	12/9/81 ETEC SEG A3	Probably modification by BJ without drawing update	No action was required at ETEC ETEC NCR to BJ for plant pump tests.	None - Oil Skid is test equipment, not delivered to CRBRP.
2594	MG-Lube Oil Skid temperature sensor for scoop tube outlet is located downstream of pump 1A, should be upstream.	12/11/81 ETEC SEG A3	Supplier error  (Ref 3.623-6946 Rev1)	ETEC relocated sensor	Plant units require inspection.
2599	MG Set Hx water valves-(Ross) do not function	12/22/81 ETEC SEG A3	Prototype received with faulty pilot valve resilient seats.	ASCO solenoid pilot valve seats replaced, making them identical to plant equipment.	Inspect to be sure correct valves are used
2600	Speed Regulator Panel circuit breaker inoperative	12/22/81 ETEC SEG A3	Unknown (inoperative as received)	Inoperative unit replaced with breaker from spare speed control panel. (1) Investigate breaker at CRBRP	Inoperative breaker requires replacement on spare SRP. failure and check one unit.
2601	MG Set Motor- Winding phases were incorrectly terminated in high voltage compartment.	12/23/81 ETEC SEG A3	Supplier error	ETEC swapped the T2 & T5 connections.	Inspect all units at CRBRP
2602	VDM Terminal Box #1 - terminals are incorrectly identified	1/8/82 ETEC SEG A6	Unknown	ETEC relabled terminal strip per drawing 136D5551 Rev D	Inspect all units at CRBRP
2603	MG Set Voith Coupler oil level switches are not connected per drawing 3.60-10174	1/11/82 ETEC SEG A6	Unknown (as received condition)	Corrected wiring error. Splices were required.	Inspect all units at CRBRP
2604	Speed Regulator panel wired to bypass scoop tube lower limit switch in violation of 3232-14	1/11/82 ETEC SEG A6	Unknown (as received condition)	ETEC revised wiring to agree with drawing.	Inspect all units at CRBRP
2605	MG SET Drive Motor potential transformer PT1 is a 240:1 ratio, whereas, drawing 34D842758 Rev 1 calls for 120:1 ratio.	1/11/82 ETEC SEG A6	Unknown	Used as is. PT1 was used to monitor MG Motor line voltage in support of initial application of ETEC autotransformer; not required for test program	Inspect all CRBRP units.  Correct ETEC MG unit as prototype is refurbished.
2606	Thermocouple in VDM (ETEC Tag# TE9243B) does not work	1/12/82 ETEC SEG A6	Small bits of insulation from the thermocouple extension were crimped under connectors and prevented continuity.	ETEC used TE9243B to replace inoperative TC. Later repair TC and used it.	Inspect one set of VDM TC for continuity
2607	Pony motor speed transducer output is not linear proportional to speed.	1/13/82 ETEC SEG A6	Potential incorrect relationship between signal level and gate width	ETEC used digital display, since analog not working properly.	Pony motor speed transducer analog signal will be checked for linearity and replaced if necessary

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2608	VDM thermocouples TE9246A & D are inoperative (TE41A-B & TE44A-44B)	1/19/82 ETEC SEG A6	Small bits of insulation from the thermocouple extension wire was crimped under the connector pins & prev. continuity.	ETEC connected TE9246C to the DAS. Later repaired and used	Inspect one set of VDM.TC for continuity.
2609	Scoop tube position is unstable between two positions for one position command input	1/20/82 ETEC SEG A 6	Absence of training & startup control. Function generator not calibrated correctly. Procedure not followed.	ETEC executed procedure #3 of XL593-10550 Incorporated procedure into IOM manual	None- procedure is in IOM Manual. (1) IOM Manual has been checked and is adequate.
2610	Upon loss of reference speed command signal, the SRP drives scoop tube to maximum rather than to minimum position.	1/21/82 ETEC SEG A6	Technician error- clip lead shorted 24 volts to circuit being monitored	ETEC replaced the function generator PC boards with units from spare SRP & realigned function generator per XL 593-10550 spare function generator received from W-OR	IOM manual upgrade to add caution note. Return spare to W-OR
2611	Low oil pressure switch does not operate when adjusted per drawing	1/25/82 ETEC SEG A6	Lube oil pressure is different at ETEC due to line arrangement.	Orifice was installed to increase pressure at the switch.	None- Oil skid is test equipment not to be furnished to CRBRP
2614	Speed regulator circuitry does not permit acceleration from pony motor speed to 250RPM when MOR is set for 22.5% speed.	2/3/82 ETEC SEG A6	Design problem (Resolved)	A modified circuit was installed by the manufacturer's rep. which solved the problem.	Modify all CRBRP SRP's. Update drawings.
2615	Ross solenoid water valves do not operate unless downstream valves are about 90% closed	2/3/82 ETEC SEG A6	Insufficient MG set cooling line water pressure	ETEC designed & fabricated orifices per RFS033767 to increase delta P across valve.	See NCR2740
2617	MG Set lube oil pump-- when simulating a failure, the standby pump comes on, but "failed" pump is not deenergized	2/10/82 ETEC SEG A6	System is not designed to shut off pump with simulated "failure"	ETEC took no corrective action	None (Not an IOM manual requirement)
2623	MG Set- Cooling air at exit end of duct had rainwater when blower motor was activated.	2/18/82 ETEC SEG A6	Facility configuration	Elbow hood placed on facility building at duct interface. Meggar check made on windings	None
2624	VDM lube oil skid- two pressure relief valves leak	2/18/82 ETEC SEG A6	Valves damaged during removal for cleaning. Ref 82ETEC-DRF0286	Lower valve was replaced. Upper valve was not replaced. (Leak rate acceptable)	None. Oil skid is not delivered to CRBRP
2625	Oil level exceeds high limit under normal operating conditions	2/18/82 ETEC SEG A6	Adjustment problem with unique plumbing	Relief valve flow rate adjusted & orifice installed	None
2628	Pony motor ammeter of ICP is always pegged at full scale.	2/26/82 ETEC SEG A6	Improper CT ratio. Actual current is 31 to 34 amps.	ETEC procured a 30:5 ratio CT, and operated with jumper on ammeter until new CT was installed.	None. ICD's define proper CT ratio for CRBRP (B&R interface)

214

	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2636	Current Transformers installed with polarity marks on winding side of generator. 34D842755 indicates polarity should be with marker on motor side	3/5/82 ETEC SEG A6	Hardware miswired	CT's #1 to 6 were left in position as is. CT's 4,5,6 were rewired to to drawing	None- Plant units have been confirmed to be correct.
2638	VDM lube oil pump is inoperative (lower bearing)	3/5/82 ETEC SEG A8	Pump ingested a rag of unknown origin	ETECdisassembled pump for removal of rag.	Inspect piping installation per construction routine
2642	VDM lower bearing thermocouples TE9243B and TE9243D inoperative	3/9/82 FTEC SEG A8	Unknown. 9243D shorted, 9243B open	TE9243A was used to ICP alarm. TE9243C was used for DAS & for rate of rise alarm.	TC to be checked when prototype is refurbished. Investigate TC failure at ETEC
2668	MG Set field thermal overload relay (FTOL) did not operate when field current was applied @ 8amps for 5 minutes	4/1/82 ETEC SEG A8	Absence of training & startup control. Incorrect adjustment	ETEC readjusted to meet the 55 to 110 sec IOM criteria	None
2669	Pony motor overspeed trip does not function when wired per 0146D1676	4/6/82 ETEC SEG A 10	Unknown	Wiring was changed to achieve functional operation. NCR defines revision	CRBRP units to be inspected to verify configuration GE/ARSD to check with vendor to determine if drawing requires update.
2671	Orifices installed per NCR2615 to make Ross valves operate cause cavitation in facility piping	4/16/82 ETEC SEG A11	Loop water pressure. (Piping not prototypical of CRBRP)	Operating condition was accepted after unsuccessful experimentation with another orifice change	None See NCR2740

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2675	VDM Lube Oil Pressure Switches for lower bearing could not be adjusted to a high level of 20 psig increasing.	4/22/82 ETEC	Loop related	Accepted as received with a cosmetic redress of wiring	None This is part of test equipment, not to be shipped to CRBRP.
2678	MG Set start up for A6 no-load test was aborted with alarms on scoop tube control power loss and TAH9206 bearing temp rate of change. Rate of rise in excess of 10°F/min.	4/26/82 ETEC Seg A6	Wiring diagram LJP-03-16-82 incorrect. ETEC procedure was too restrictive.	1. Wiring changed per GE direction. 2. Procedure changed to start sequence to allow time for lubricant to reach bearings.	See MCR 2614 for disposition
2680	Actuator valve for heat exchanger B does not open fully after reaching operating temperature.	4/27/82 ETEC Seg A6	Leak in Hx temp sensing bulb (Not prototypical)	Oil mix valve locked in closed position (routing all oil through HxA) and HxB used for emergency only. Sensor was replaced.	Actuator valve to be made prototypical for CRBRP when unit is refurbished. Delivered CRBR plant unit; use valves from different vendor and will be inspected to confirm this. None
2687	Oil mix valve actuator broken while attempting to block in closed position	5/5/82 ETEC Seg A12	Excessive force applied	scrapped part and replaced.	None
2688 2690	Abnormal noise from Voith Coupler. Wire found in unit.	5/6/82 ETEC Seg A12	A support bracket weld was broken allowing vapor shield to contact rotating part.	Used bolt to reposition part.	Voith at ETEC was originally welded - others at CRBRP were bolted. Inspect one unit at Oak Ridge. None
2693	Lower VDM bearing lube system operates with noise. upper bearing system does not.	5/12/82	Unknown	Noise disappeared before valve could be disassembled for inspection.	None
2697	VDM and MG trip when attempting a VDM start - several instances between 5/5/82 through 5/14/82.	5/17/82 ETEC Seg A12	Circuit problem. The timer which controls scoop tube withdrawal activates based on MG Set start rather than VDM sequel. Thus, timer was timed out prior to start of VDM.	1. ETEC used manual start pending circuit change. 2. Circuit change was made per LJP 06-16-82.	IOM Manual must be updated. CRBRP units must be modified.
2699	Speed drifted to 1132 rpm.	5/21/82 ETEC Seg A12	Inadequate training and procedure implementation	ETEC reset speed. Problem did not recur.	None

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2704	When Hx transferred, only the oil, not the water switched. (See NCR 2740)	6/2/82 ETEC Seg A12	Piston size in Ross valves incorrect.	Parts revised with replacements forwarded from Ross brought to CRBRP configuration.	None
2705	GE-ICP status lights do not indicate correct position of valves related to heat exchanger.	6/3/82	Supplier error.	Circuitry rewired.	Units at CRBRP must be modified. Drawings must be updated (014601722)
2706	Pinion shaft fell during a gear change. Three gear teeth damaged.	6/10/82 ETEC A138	Operator inexperience	1. Procedure revised. 2. Damaged gear reworked.	Add caution note to IOM
2707	Gouge on surface of seal No. 1213815. (gear box assembly)	6/10/82 ETEC Seg A138	Unknown	Raised metal and removed by hand, blending.	None
2709	Lube oil "C" Pump would not start. (See NCR 2754)	6/14/82 ETEC Seg A13A	A vent valve and piping configuration caused loss of oil prime. Vent valve was found open causing "C" pump to pump air.	1. Replaced pump. 2. Revised procedures to check on vent valve.	None Vent valve is peculiar to ETEC.
2711	Rag visible in tygon tubing used as sight gage on VDM lower bearing.	6/25/82	Improper cleaning operation	Oil checked and foreign material removed.	Install per IOM Manual
2714	When VDM is started, MG set trips.	7/1/82 ETEC Seg A15	Off normal activity triggered protective circuitry.	1. At ETEC, Pony Motor was stopped to reset the relay logic. No other action needed.	None
2715	MG Set tripped with over-voltage/regulator fault annunciator alarm	7/8/82	Power transistor Q4 shorted causing full power to be applied to the exciter.	1. ETEC replaced transistor Q4 with new unit.	See NCR 2746
2722	Power reading at generator output is suspect.	7/16/82 ETEC Seg A16	GE drawing 2H9016T for ETEC installation was in error.	1. Potential transformer's wiring reversed.	None
2724	VDM tripped at 1702 hours on 7/26/82	7/27/82 ETEC Seg A16	Transistor Q4 shorted.	ETEC replaced Q4	See NCR 2746

217

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2726	Circuit breaker for speed regulator panel power supply is intermittent through the auxiliary contacts. When open, "speed reg/scoop tube power loss." alarm is experienced.	2/2/82 ETEC Seg A16	Component failure, cause unknown.	1. ETEC removed and replaced faulty module with spare. 2. Faulty unit was to be repaired/returned to supplier for repairs.	Circuit breaker in spare SRP to be replaced (1) Inspect one SRP for proper latching of this circuit breaker. Vendor investigation found no failure.
2730	MG Set Voith Coupler bearing thermocouple TE9200B is erratic Redundant TC- TE9260A is inoperative. (TE41 A&B)	8/12/82 ETEC Seg B2	Same as NCR 2587	ETEC deleted this readout from the DAS. Can be checked visually by temp. gage TS08A (temp switch will shutdown on over temperature). Later repaired and used TC.	Same as NCR 2587
2732	VDM: Unusual noise is present during acceleration (sounds like core noise).	8/16/82	Unknown	ETEC was instructed to continue to use VDM as is. GE LM&G representative says "No problem"	Troubleshoot and fix <del>the</del> prototype is refurbished
2731	VDM tripped unexpectedly at 1830 hours on 8/20/82	8/20/82 ETEC Seg B1	Power transistor Q4 shorted, causing full power to be supplied to the exciter.	1. Q4 replaced with new 2N6151 transistor. 2. Installed a .22 mfd capacitor. 3. Installed a fan in the ICP panel for added cooling.	See NCR 2746
2740	Upon command, Hx B will transfer to A, but A will not transfer to B at all without assistance. This problem persists after action per NCR 2704 has been completed. Other related NCR's 2599, 2615, 2671, 2704, 0324.	8/25/81 ETEC Seg B1	May be a design problem Cooling water pressure differential across transfer valve was too low at ETEC.	ETEC requested to continue to operate with HxB as the primary unit and HxA as backup.	Ross Valve Representative determined chief cause of problem is low pressure min operating pressure to be defined to CRBRP
2745	VDM tripped unexpectedly at 1328 hours on 8/26/82	8/26/82 ETEC Seg B3A	Power transistor Q4 failed.	ETEC replaced both Q4 and resistor R10	See NCR 2746
2746	VDM tripped during a start attempt at 1726 hours on 8/26/82	8/27/82 ETEC Seg B3A	Basler Voltage regulator faulty (other NCR's: 2715, 2724, 2731, 2745).	Voltage regulator unit replaced with one from the CRBRP storage facility. Failure analysis completed.	Replace unit removed from storage in Oak Ridge. Replace the failed voltage regulator with a new one.
2754	During MG start-up, Lube oil pump B failed to prime itself and would not pump oil. Failing to pump oil, it didnot shut itself off.	9/3/82 ETEC SEG B3A	Air in loop resulting from local piping. ETEC has a vent valve between sump and oil pump, which is believed to be source of air.	ETEC handled the problem administratively by running the Lube oil skid prior to the normal start-up sequence.	None. (There are no vent valves on the oil pump suction lines at CRBRP)

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE REF NCR	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2753	Low lube oil level alarm sounds intermittently even though lube oil level is within operating limits.	9/13/82 ETEC SEG.83A	Level switch needs recalibration or is defective or changing operating conditions cause alarm.	Proper lube oil level is verified periodically with MG set stopped using a dipstick. Will request ETEC to recalibrate oil level switch and monitor unit to determine if any particular operating conditions trigger alarm.	Action for CRBRP is pending further investigation by ETEC
2766	Loss of Main Pump Drive Motor Alarm	10/6/82 ETEC SEG.86	Combination of the ETEC application and the oil test rig which is not CRBRP equipment.	Clean the pressure switches to be sure any remaining rag fragment don't inhibit switch plunger movement. Continue to operate since the system will be protected by the minimum value pressure switch and/or the thermal switches on the VDM bearings.	Oil pressure switch which initiated the alarm signals is not CRBRP equipment. CRBRP application will be reviewed to determine the best pressure switch value to avoid false alarm.
	Main Pump Drive Motor vibration alarm which is triggered by either "Pony Motor" or "Pony Motor Reduction Gear Frame" sensors.	10/6/82 ETEC SEG.86	ETEC application causes considerable fluctuation in the vibration level on the "Pony Motor" or "Pony Motor Reduction Gear Frame" sensors at speed above 1100 rpm.	Continue to operate provided that RMS level does not exceed 5 mils.	None, problem is unique to ETEC test structure & flow control.
2767	Oil leaks at various joints in MG set oil Tube system were observed during daily inspection.	10/6/82 ETEC SEG.86	Oil leaks in the Ross Valve are caused by seal deterioration due to expiration of normal seal life. Oil leaks in the piping are caused by leaking joints.	Continue to operate. Replenish oil as required. ETEC is to keep the area around the MG set as clean as practical. ETEC will be requested to repair oil leaks and replace valve seal during shut-down for pump baffle installation	Seal replacement to be identified in O&M Manual spare part list. Repair procedure is already identified.

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE REF NCR	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT B3/EETC	PROPOSED ACTIONS FOR CRBRP	TARGET DATE	VERIFICATION
2770	Vertical Drive Motor will not start. HARTMAN-BRAUN electronic module does not function properly.	10/13/82 EETC SEG.B6	Test Engineer accidentally applied 24V to zener diode in function generator while using previously prohibited test points. Reference NCR 2610.	Replace shorted zener diode. Rewire test points to terminal block to prevent reoccurrence.	OMM Manual will identify the use of equipment locations which will eliminate the possibility of applying 24V to function generator output terminals.	Note D GL4226	N/A
2777	Vertical Drive Motor circuit breakers tripped out on startup	10/28/82 EETC SEG.B7	Oil pressure switch PSVM-U2 failed to operate due to sticky plunger switch in the oil test rig.	Rework switch and return to service.	N/A, this component is part of the oil test rig and not CRBRP equipment.	N/A	N/A
2783	Speed regulator panel provides uncommanded Pump speed changes.  RPM changes from 1116 to 1128 have been observed.	11/2/82 EETC SEG.B7	Voltage at test point TSM1-8 is changing causing VDM speed to change.  Occurrence is random & intermittent. Test evaluation identified a defective part 2240001.	Defective component was replaced and pump operated successfully for at least 24 hours under close monitoring for this event and drive performance was satisfactory  Repair failed unit. Provide failure analysis.	Replace Speed Regulator card removed spare speed regulator panel	(2)Note B GL4225	(2)Note G GL4227
2791	Volts per hertz ratio is not constant over vertical drive motor speed range of approx. 223 RPM to 1116 RPM, volts per hertz varies from approx. 75.4 to 66.0 respectively.	11/15/82 EETC SEG.B8	Equipment received from supplier in this condition. Incorrect location of capacitor C25.	Adjusted volts/hertz regulator to establish volts/hertz versus exciter field current curve within permissible range. Later C25 capacitor was relocated and V/Hz improved to 72.5 at 234 RPM to 68.5 at 1116 RPM.	Modify location for C25 capacitor on all plant units.	Note B GL4225	Note G GL4226
2796	Pump speed cannot be controlled within $\pm 0.3\%$ as required.	11/17/82 EETC SEG B11	Same problem as EETC identified in NCR 2783.	See NCR 2783.	See NCR 2783.	Note D GL4226	N/A

APPENDIX D

ITEM	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS RBRP
2523	Tank thermocouples are Class 1 (grounded), whereas component spec. calls for Class 11 (ungrounded)	8/11/81 ETEC SEG A4A	Component supplier error	Sheath ground at the DAS system was disconnected.	None required. Specification calls for Class 11 (Ungrounded) components.
2529	Rotating Element Handling Fixture towing hitch was not shown on drawing. Several rungs were damaged. Phenolic liners of cradle were damaged	9/2/81 ETEC SEG A4A	(as received condition) Supplier discrepancy	Accepted as is for use. Discrepancies are minor, and have no impact on test article	Refurbish by supplier for plant use.
2530	Pump Case & Bearing Cage Assy has light score marks on ID of sodium bearing surface, & tool marks around outside surface, & one dimple	9/2/81 ETEC SEG A4A	(as received condition) Supplier discrepancy	Accepted as is for use. Discrepancies are minor and have no impact on test program.	None required
2533	Interface between ETEC supplied tank cover and bolt heads used to secure pump maintenance seal ring.	9/10/81 ETEC SEG A1	Design of cover did not accommodate pump design change which added the maintenance seal ring	While cover was used, the maintenance seal was held down with only two reworked bolts	None required
2535	Lower cradle of Rotating Element Handling Fixture has a distorted hinge & a bent hinge pin.	9/15/81 ETEC SEG A4A	(as received condition) Supplier discrepancy	Reworked- replaced hinge pin and assembly.	Refurbish by supplier for plant use
2536	Rotating Assembly has several nicks, gouges, and 4 jaw chuck marks	9/15/81 ETEC SEG A4A	(as received condition) Supplier handling	One gouge was polished, all other used as is.	None required
2538	Spare thermocouples are Class 1 (grounded)-should be Class 11 (ungrounded)	9/24/81 ETEC SEG A4A	Component supplier error. See NCR2523	No immediate action.	None required
2545	Cable support cap has sharp edges Drawing calls for rounded edge	10/2/81 ETEC SEG A4B	Supplier discrepancy	Caps were removed, reworked, and reinstalled.	None required. The plant pump equivalent part is #B2000018 & has generous countersinks
2557	Thermocouples used on pump internals are Class 1 (grounded) should have been Class 11.	10/21/81 ETEC SEG A4A	Component supplier error	Sheath ground at the DAS system was disconnected.	None required
2558	Nut galled on its stud	10/21/81 ETEC SEG A4B	Unknown	Replaced one stud and two nuts.	None required
2563	Fillet weld on oil level probe flange interferes with ID of instrument hole; one bolt has interference with holes in seal	10/27/81 ETEC SEG A4B	Supplier error	ETEC machined fillet weld & cut bolt.	None required. Plant pumps will not have valves mounted on collection tank cover

221

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTION APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2565	Fillet weld on oil level probe interferes with ID of instrument hole	10/30/81 ETEC SEG A4B	Supplier error	ETEC machined fillet weld.	Pump supplier has designed a new level probe mount assembly - Dwg. #B200013.
2571	Thermocouple and proximeter probes have leads which are too short. Upper seal adjusting lugs do not align with holes in seal.	11/4/81 ETEC SEG A4B	Design error by supplier	Thermocouple extension leads provided by ETEC. Elongated hole in bracket of seal adjusting lugs.	None required
2575	Flange of sodium level probe plug interferes with motor mounting flange.	11/6/81 ETEC SEG A4B	Design error. Part was not used during water test.	Plug was returned to supplier for rework.	Sodium level probe plug design has been eliminated on plant pumps. A thimble drawing #340592 has a smaller diameter than the prototype.
2583	Oil service valve brackets holes do not align with holes in valve Ref: 294817 & 437009	11/17/81 ETEC SEG A4B	Supplier error	Bracket holes were elongated.	None required. Interconnections between oil supply tank & seal cartridge were redesigned.
2596	Pull box associated with the supply tank level probe interferes with the vertical drive motor.	12/17/81 ETEC SEG A6	Design error	ETEC removed the conduit box & employed softwire to level probe electronics.	Redesign eliminates pull box. A flexible conduit goes from the level probe to the electronics. See Plant Dwg. 2E2531/2E2532 Sheet 4. No action required
2619	Split ring of motor half coupling OD is oversize, causing interference between ring and shaft groove	2/11/82 ETEC SEG A6	Supplier manufacturing error	Returned to BJ for remachining	Factory QA program should prevent recurrence.
2621	IOM manual illustration for split ring installation is incorrect	2/17/82 ETEC SEG A6	Supplier artwork error	IOM illustration ignored	
2622	Piping schematic 2E2519 Rev B shows a valve in the lube system shaft seal vent line which does not exist.	2/18/82 ETEC SEG A5A	Supplier error	Drop down seal leak test was run with a fitting loosened.	Plant pump drawing 1E4061 & 1E4062 Sheet 1, Zone C-20 shows the valve. No action required.
2650	Seal oil supply tank level sensor inoperative	3/18/82 ETEC SEG A8	Preamplifier module failure	ETEC procured a new preamplifier.	None required
2653 2655	Shot loading not complete. Actual was 28,650 lb; required was 32,000 lb.	3/19/82 ETEC SEG A5	Unable to deflect shot to outside edge of shot cavity with gravity pour method.	Accepted loading as is	A tool which would facilitate loading to outside edges of the UIS is required
2654	IOM Manual calls for use of the vacuum shot transfer tool for loading, whereas the tool does not have capability for loading-only for unloading	3/19/82 ETEC SEG A5	IOM manual in error	Shot was loaded using the HEDL tilt fixture.	Tooling (tilt fixture, sling, funnel) for gravity assisted loading is required
2658	Torque required to turn pump & YDM exceeds limit of ETEC procedure	3/22/82 ETEC SEG A8	Variable drag of floating shoe bearings in the YDM Limit was set too low	Accepted as is	Plant procedure torque limit will be based on ETEC experience.
2660	Pump tank insulation not installed per drawing	3/23/82 ETEC SEG A8	Construction contractor error.	Construction contractor reworked.	None required.

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRRBP
2662	Pump tank differential temperature was 146°F, where limit was 60°F	3/25/82 ETEC SEG A8	Loss of facility heater control, & personnel failure to heed an alarm	ETEC replaced defective power relays and examined wiring. Tank - use as is.	None required
2665	Tank nozzle insulation- gaps have appeared at several locations	3/29/82 ETEC SEG A8	Lack of expansion joints	ETEC added blanket insulation material.	None required
2666	Seal oil supply tank level probe not operating after installation of new preamplifier.	3/29/82 ETEC SEG A8	High capacitance & too long a cable between sensor & preamplifier causing loss of signal.	Moved preamplifier & used a low capacitance cable.	Plant pumps will have preamplifier located about 1 foot from level probe.
2667	Temperature gradient on pump tank exceeded Test Request maximum.	3/29/82 ETEC SEG A8	Improper limit defined in the Test Request.	Accepted as is. Test Request changed.	None required. IOM manual will define limit for CRRBP.
2713	Seal Vibration sensor VE9014C and sodium bearing sensor VE9012A are inoperative	7/1/82 ETEC SEG A15	Loose connection in one case. Unknown in other.	VE9012A had a loose connector & was reworked.	The plant pump has no vibration sensor on the in-sodium bearing. Plant pump seal cartridge has a total of 3 vibration sensors (redundant 3 axis).
2734	Facility pressure relief valve PSV973 failed to reseal after an overpressure condition. This caused a short term oil over temp cycle of 330°F	8/19/82 ETEC SEG B1	Foreign material in facility gas line. See UOR# ETEC82-08-SPTF-83-03	Technician opened the valve then returned to normal. Foreign material was expelled. After test, valve was removed for inspection.	Plant should alarm on high oil temperature. Plant Sys. 82 alarms on loss of pressure to pump oil supply tank interface #13. An ECP will propose adding #8 alarm to Table #5-4 of CG52004 & CG52005.
8679	Many tank bolts have nicks & scratches	5/12/81 ETEC SEG AAA	Improper or lack of preshipment inspection by supplier	Part were reworked Part were replaced	None required
8680	Tank rust streaks internal (vertical streaks). Exterior has roller streaks	5/15/81 ETEC SEG AAA	Unknown- Probably from water test or post test cleaning	Stains were cleaned, roller marks- use as is.	None required
2798	Uncontrolled Sodium temperature excursion to 1056°F was applied to the sodium pump	11/22/82 ETEC SEG B13	The loop's sodium cooler fan E102 failed due to motor brush failure	B13 is the long term endurance run. ETEC stopped the pump immediately. They also reset the alarm TAN-120 to 1005°F.	None required
2836	Miscellaneous scratches, gauges, rubmarks, & weld spatter on the SS304 water test impeller as received for the start of phase C Test	3/1/83 ETEC SEG C1	Inflicted during water test at pump suppliers facility	Use as is at ETEC	None required
2738	Broken swage lock fitting & possible flexible oil have damage, oil supply tank	3/10/83 ETEC SEG C1	Improper binding of tank to pellet while tank was in storage	Swage lock assembly replaced Hydro tested drain hose.	None required

## PUMP PROBLEM TABULATION

ITEM #	PROBLEM DESCRIPTION SYMPTON/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTIONS FOR CRBRP
2840	IOM Manual Para. 7.2.2.6 procedure for seal cartridge removal could not be followed. It was necessary to disassemble shaft seal in order to remove it.	3/11/83 ETEC SEGB15	Seal sleeve was locked to the shaft, and bumper bearing surfaces grooved. Cause was loss of gas pressurization of the oil supply tank and the high cross tank differential temperature being induced by pump internal cellular convection. See NCR #2734 for ETEC facility event which was the initiator of this problem. Additional details provided in unusual occurrence Report #ETEC-83-01-SPTF-83-01	Seal was disassembled piece by piece. Rubbing faces of top seal were destroyed to gain access to seal sleeve. Torch heat was applied to sleeve to release it from shaft. A replacement seal cartridge was then used for subsequent testing	CRBRP must provide a reliable gas supply or provide an alarm and administrative procedure which will get the pump shut down before the seal overheats.
2806	Shaft failed to drop down when coupling bolts were loosened (NCR's 2806 & 2840 & 2734 are common failure items)				
2846	Accelerometer connector is bent	3/22/83 ETEC SEG B15	Unknown	Used as is	None required
2833	LIS to hydraulic bolts 648963 have galled threads and scratches on shank	2/23/83 ETEC SEG C1	Supplier furnished (as received condition)	Used as is	None required
2807	Test Segment B14B, Leak Test of Drop Down Seal could not be run when scheduled	12/14/82 ETEC SEG B14B	Bumper bearing was grooved & locked axially. Initiator of problem was loss of gas pressure on oil supply tank. See NCR's 2734, 2840&2806	Segment B14B was subsequently run at the end of Phase C tests, with replacement shaft seal in place.	See NCR 2840
2803	The vacuum shot transfer tool inoperative	12/15/82 ETEC SEG B15	Bearing seizure	Substitute equipment used	None required
2786	Sodium purity out of limits	11/4/82 ETEC SEG B8	New sodium had been added to loop for transient testing of segment B7	Cold trapping continued	None required
2787	PPIOU transient applied at a rate higher than permissible (exceeded tolerance of $\pm 30\%$ of specified rate)	11/8/82 ETEC SEG B7	Facility feed valve controller failed to follow the valve opening program	ETEC stationed an operator to manually override the automatic program for valve positioning	None required
	Alarm ZAH90036, Pump Bearing	9/20/82	Proximeter component ZE9005C/D failure. Failure cause unknown	CRT display at SPTF changed to show lower bearing gap sensors	

ITEM #	PROBLEM DESCRIPTION SYMPTOM/DAMAGE	DATE/REF	LIKELY CAUSE(S)	CORRECTIVE ACTIONS APPLIED AT BJ/ETEC	PROPOSED ACTION FOR CRBRP
2756	Alarm ZAH90036, Pump bearing orbit was activated	9/20/82 ETEC SEG B4	Proximeter component ZE9005C/D failure. Failure cause unknown	CRT display SPTF changed to show lower bearing gap sensors	None required Proximeter not used at CRBRP
2880	Thermocouple data during part of cooldown period was not valid	6/10/83 ETEC SEG C15	Reference junction in SPTF Data Acquisition System was temporarily disconnected for maintenance of other equipment	None required other than to recognize that TC data invalid for 8 hours on 6/10/83	None
2876	H/Q data at R3 omitted from test at end of mild thermal transitional test	8/16/82 ETEC SEG B2	Documentation error (discovered after the fact)	No procedural changes needed	None
2886	A partial cut of 36" pipe was initiated at wrong location (and final cut was made at correct location)	7/11/83 ETEC SEG C15	Personnel error in dwg. interpretation (dwg. has two centerlines)	Use as is. BJ is to repair saw mark as necessary	None required
2889	First three threads on a tank mounting bolt are stripped	7/20/83 ETEC SEG C15	Unknown	None required	None
2898	Cracks in hardfacing of upper journal of shaft used in Phase C tests	8/5/83 ETEC SEG C15	Improper manufacture which allowed hardface material to extend to end of journal	None required The journals used in Phases A&B did not experience this problem	None Control of hardface dimension will prevent this condition
2854	Mechanical interference between motor shaft extension and new split collar	4/ /83 ETEC Seg C3	Supplier manufacturing error	ETEC remachined the original split collar used previously with rotating assembly #171222	None

APPENDIX E

THE INFORMATION IN APPENDIX E WAS PREPARED BY  
THE ENERGY TECHNOLOGY ENGINEERING CENTER



---

9. Description of Occurrence (cont'd)

test article. The decision was made by the Test Requester to permit testing to continue. The operators reset the oil seal reservoir pressure to 108 psig by operating the pressure controller in the automatic mode (to set a fixed pressure rather than a delta pressure above pump tank pressure) and testing was continued. Subsequently, the oil seal reservoir sight gage has been closely monitored and no evidence of oil leakage or seal degradation has been observed.

---

10. Operating Conditions of Facility at Time of Occurrence

A special test in support of Test Segment B1 of the CRBK pump test program was in progress at the request of, and under the surveillance of the Test Requester Site Representative and a representative of the pump manufacturer. The following conditions existed at the time of the incident.

Sodium Temperature	-	775°F
Sodium Flow Rate	-	7860 gpm
Pump Tank Pressure	-	93 psig
Pump Speed	-	260 rpm

---

11. Immediate Evaluation

Apparently the cascade mode function of the oil seal reservoir pressure regulator failed to function properly and allowed regulated pressure to drift high enough to relieve the pressurizing line relief valve. The relief valve failed to reseat allowing the pressure in the oil seal reservoir to decay below the pressure in the pump tank. The minimum recorded pressure in the reservoir was 72 psig. After some work on the valve, including a second lift to clear any obstruction, the operators were successful in reseating the relief valve. There was no indication of what the object was that was apparently preventing the relief valve from seating.

A decrease in measured seal temperature (approximately 8°F) was observed coincident with opening of the relief valve and decay in pump tank pressure. These observations suggest that there was leakage of clean pump tank sweep gas through the oil seal reservoir (for a period of possibly 3 minutes). There was a sharp increase (to approximately 265°F) in oil and seal temperatures approximately 18 minutes after the relief valve opened and a sharp increase (to 330°F) in another oil temperature when the relief valve closed. The temperature increases have not yet been explained. A grab sample of oil was analyzed and compared with new DTE-24 oil. There was no evidence of contamination or decomposition of the oil taken from the oil seal reservoir. The reservoir oil has been submitted for particulate analysis.

November 1, 1982

---

**12. Immediate and/or Temporary Corrective Action Taken and Results**

The relief valve was reset to something above the operating pressure level of 108 psig in the oil seal reservoir. On completion of the special test, the relief valve will be removed, inspected, cleaned and reset and re-installed in the facility system.

The oil seal reservoir pressure controller has not yet been checked out in the cascade mode because the controller is still being used in the automatic mode to provide a set pressure to the oil seal reservoir. The controller will be checked out after completion of the current test.

---

**13. Is Further Evaluation and/or Corrective Action Necessary? No. Except as noted in Item 14.**

---

**14. Final Evaluation and/or Corrective Action Taken**

Results of the immediate evaluation of the incident indicated that there was a possibility of back flow of cover gas from the pump tank, past the shaft seal, and through the oil reservoir when the oil reservoir pressure relief valve unseated. Further evaluation of the incident reinforces the initial conclusion that there was flow of cover gas from the pump tank past the shaft seal, however, the most likely flow path is now considered to be through the seal oil vent line to the oil reservoir rather than through the oil supply line as first speculated.

The pump manufacturer has not reviewed this analysis, but has stated that the shaft seal was designed to prevent back flow of gas in the event of pressure reversal, i.e., pump tank pressure higher than oil reservoir pressure.

Pressure and temperature time histories for the incident are presented in Figures 1 and 2. A description of the events indicated in Figures 1 and 2 is presented in Table 1. It can be seen from Figure 1 that the shaft seal oil reservoir pressure decayed to a value approximately 22 psi below the pump tank pressure after the relief valve opened. Figure 2 shows evidence of perturbations in the seal and oil temperature measurements coincidental with the relief valve opening. The initial volume of gas flow from the pump tank was probably near-ambient sweep gas from the shaft annulus in the upper inner structure causing only slight, but perceptible, temperature perturbations. As the pump tank cover gas continued to vent through the shaft seal, hotter gas from the pump tank ullage was drawn up through the annulus and vented through the shaft seal and into the oil reservoir pressurization (and vent) line. Evidence of hot gas flow through the seal can be seen in Figure 2 at Events 3 and 4. The upper seal and inlet oil temperatures begin to increase at Event No. 3. All three seal and inlet oil temperatures begin to rise rapidly at Event No. 4 indicating that hot gas from the pump tank ullage was passing through the seal.

These temperature excursions were only observed during the period when the pump tank pressure exceeded the oil reservoir pressure. Figure 1 shows that the reverse pressure condition existed from the time that the relief valve opened (Event No. 1) until the relief valve was manually closed (Event No. 5), a period of approximately 28 minutes. The reverse pressure condition also existed for approximately 3 minutes between Events No. 5 and 6. After the relief valve was closed while the operators were

November 1, 1982

14. Final Evaluation and/or Corrective Action Taken (cont'd)

attempting to re-establish the pressure balance between the pump tank and the oil reservoir. After the proper pressure balance was restored, the seal and oil inlet temperatures returned to their normal values. No further anomalous seal temperature excursions have been observed. Another data observation can be made from Figure 1 to support the conclusion that pump tank cover gas vented through the shaft seal. Note that the pump tank pressure decayed when the relief valve opened at Event No. 1 and tended to follow the decay in oil reservoir pressure until Event No. 2. The operators began to manually pressurize the pump tank at Event No. 2 to bring the pump tank pressure back to the target value of 93 psig. It can be seen from Figure 1 that the oil reservoir pressure also increased at the same rate during this period, although the operators took no action to vary the oil reservoir pressure. The conclusion drawn from this observation was that increasing pump tank pressure resulted in increased gas leakage flow past the shaft seal into the oil reservoir pressurization line causing an increase in oil reservoir pressure. Note also that when the relief valve closed at Event No. 5, there was a corresponding increase in pump tank pressure as a result of higher than normal sweep gas flow (initiated at Event No. 2) and cessation of cover gas leakage past the seal (when the oil reservoir pressure exceeded the pump tank pressure).

The oil reservoir pressure dropped below the pump tank pressure between Events No. 5 and 6, however, there was no corresponding disturbance in pump tank pressure. The relief valve was closed during that period and there was evidently not enough gas leakage past the seal to perturbate the pump tank pressure. Figure 2 shows that there was a sharp increase in upper seal temperature between Events No. 5 and 6. This is interpreted to be evidence that there was hot gas leakage from the pump tank past the shaft seal.

Following completion of the special high pressure pump tank test, the oil reservoir relief valve was reset in-place to relieve at 125 psig to expedite further pump testing. The relief valve was then tested to ensure satisfactory operation. The valve would repeatedly relieve at 125 psig allowing the inlet pressure to drop to approximately 70 psig and it would then reset. This operation is similar to its operation at the time of the incident, except for failure to reseat at that time. Cover gas flow from the pump tank through the shaft seal vented through the same line that the oil reservoir vents through (this is also the oil reservoir pressurization line). The additional gas flow through the oil reservoir vent line may have been sufficient to keep the pressure at the relief valve high enough to prevent reseating. This appears to be a possible explanation of why the relief valve did not reseat during the incident. The relief valve cannot be conveniently removed from the system for further checkout while pump testing is in progress. The oil reservoir pressure is normally operated at approximately 30 psig. One more test at high pump tank pressure is scheduled. It is planned to gag the oil reservoir relief valve

November 1, 1982

**14. Final Evaluation and/or Corrective Action Taken (cont'd)**

for that test and provide argon bottle bank pressure at no greater than 125 psig. These steps, combined with an existing 150 psig relief valve in the argon system, will provide adequate protection against recurrence of this incident.

The oil reservoir pressure controller was checked out after completion of high pressure pump tank test. The regulator was found to operate satisfactorily in cascade mode throughout its normal operating pressure range (up to 50 psig). It was noted that the controller tended to deviate when operated above the normal pressure range. The conclusion drawn was that the controller should not be used in the cascade mode at higher than normal operating pressure (50 psig for this controller). The operating pressure was approximately 130 psig at the time of the incident. The cascade mode maintains a desired delta-P between two pressure points. The controller will be operated in the automatic mode (maintaining a desired set pressure at one point rather than a delta-P between two points) any time it is necessary to pressurize the oil reservoir above approximately 50 psig. No further checkout of the controller is deemed to be necessary.

**15. Programmatic Impact**

None

**16. Impact Upon National Codes and Standards**

None

**17. Similar Unusual Occurrence Report Numbers**

None

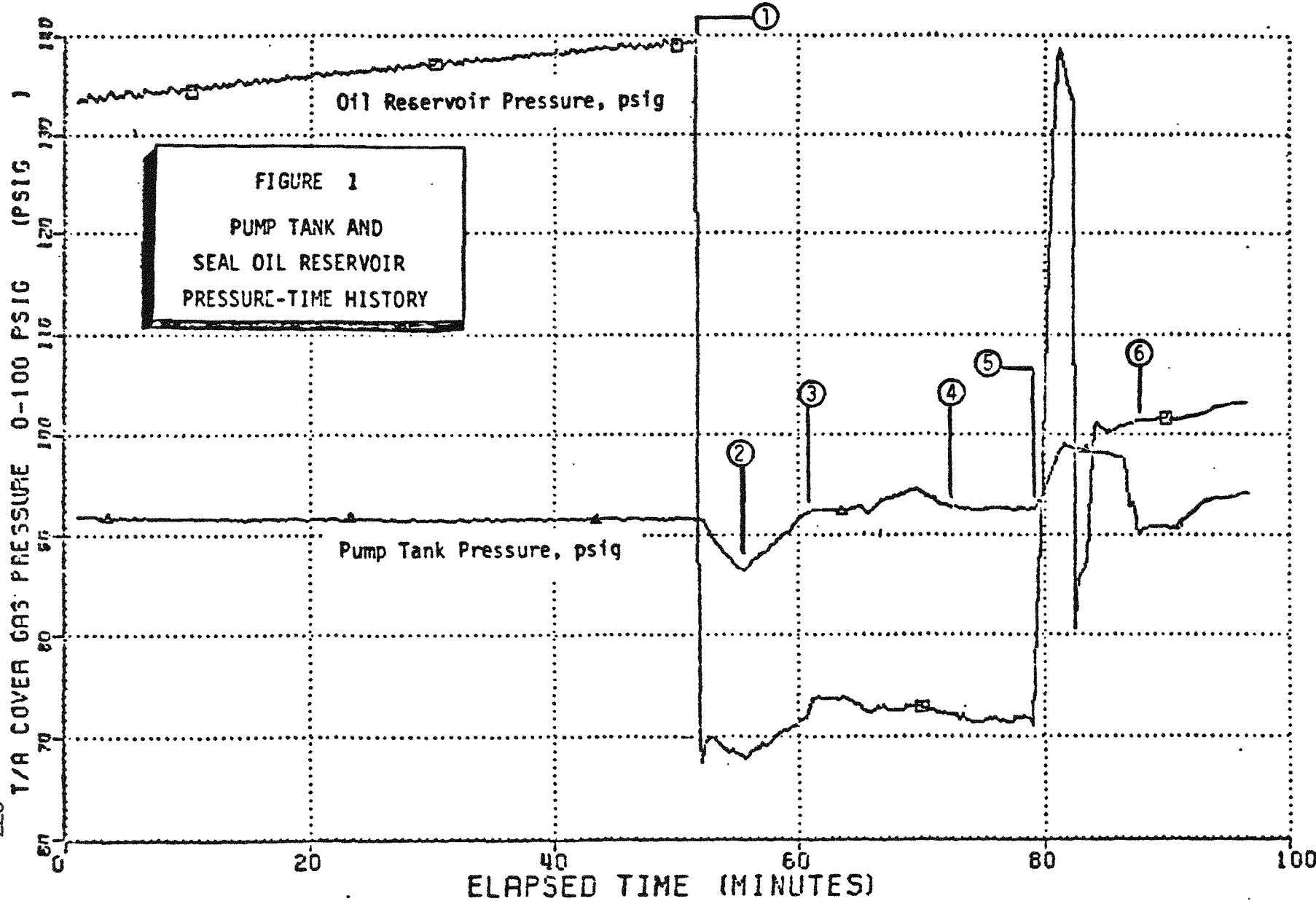
**18. Signatures**

Originator	<u>W. H. Munyon</u> W. H. Munyon - Manager - SPTF	Date	<u>11-2-82</u>
Cognizant Manager	<u>W. H. Munyon</u> W. H. Munyon - Manager - SPTF	Date	<u>11-2-82</u>
Engineering	<u>R. E. Fenton</u> R. E. Fenton - Manager - Test Engineering	Date	<u>11-3-82</u>
Quality Assurance	for <u>L. B. Copeland</u> L. B. Copeland - Manager - QA	Date	<u>11-5-82</u>
Test Requester	<u>J. L. Grimaldi</u> J. L. Grimaldi - GE Site Representative at ETEC	Date	<u>11-22-82</u>
Operations Manager	<u>W. S. DeBear</u> W. S. DeBear - Manager - Operations Dept,	Date	<u>11-8-82</u>

TABLE IDESCRIPTION OF TIME EVENTS

<u>Event No.</u>	<u>Time of Day, Hours</u>	<u>Event Description</u>
1	2351.0 (8-18-82)	Relief valve in the oil reservoir pressurizing line unseated and failed to reseal. Disturbances noted in oil temperature measurements.
2	2354.7 (8-18-82)	Operators began to pressurize pump tank manually after noting that pressure had decayed below target value.
3	2359.7 (8-18-82)	Pump tank pressure returned to target value. Oil temperature start to show increase.
4	0012.2 (8-19-82)	Shaft seal inlet oil and upper seal temperatures increase rapidly as much as 130F. Lower seal temperature also shows an increase.
5	0018.0 (8-19-82)	Operators manually reseated relief valve.
6	0027.0 (8-19-82)	Balance restored between pump tank and oil reservoir pressures. Seal and oil temperatures experience excursions while adjusting pressures. Oil reservoir pressure dropped below pump tank pressures during the period between Event 5 and 6.

### SPTF REAL-TIME PLOT



233

JAY 8/18/82	6/18/82	8/18/82	8/18/82	8/19/82	8/19/82 DAY
22:55	23:19	23:39	23:59	0:19	0:39 H:M
0.000	0.000	0.000	0.000	0.001	0.001 SEC

ELEC-82-08-SPTF-82-03  
November 1, 1982



ENERGY TECHNOLOGY ENGINEERING CENTER

UNUSUAL OCCURRENCE REPORT

Page 1 of 4

1. Report Number ETEC-82-09-SPTF-82-04  
 2. Status and Date ( ) Initial 08-25-82  
 ( ) Interim \_\_\_\_\_  
 ( X ) Final 11-01-82

3. Division or Project

Energy Technology Engineering Center (ETEC)

4. Facility, System, and/or Equipment

Sodium Pump Test Facility (SPTF)  
 Motor Generator (MG) Voltage Regulator

5. Date of Occurrence

8-20-82

6. Time of Occurrence

1830

7. Subject of Occurrence

CRBR MG Voltage Regulator Failure

8. Apparent Cause

Design  X  Material \_\_\_\_\_ Personnel \_\_\_\_\_  
 Procedure \_\_\_\_\_ Other \_\_\_\_\_ (Explain in Item 14)

9. Description of Occurrence

The vertical drive motor (VDM) was driving the CRBR pump at minimum main motor speed during a special high cover-gas pressure test of the pump tank per a procedure approved by the Test Requester.

Before the special high pressure test was completed, the Basler voltage regulator (a component of the test article) for the motor-generator (MG) failed causing the VDM to trip.

The pony motor was manually tripped and the high pressure test was completed with the pump stopped per procedural instructions.

10. Operating Conditions of Facility at Time of Occurrence

A special pump tank high cover gas pressure test was being performed at the time of the incident. The plant conditions are summarized below:

Sodium Temperature	-	775°F
Pump Speed	-	260 rpm
Pump Tank Pressure	-	93 psig
Sodium Flow Rate	-	7860 gpm

11. Immediate Evaluation

A power transistor (identified as Q-4 on GE Drawing 9117900910) in the Basler voltage regulator for the MG was immediately suspected because it had failed twice before during operation at ETEC. Checkout of the voltage regulator

November 1, 1982

11. Immediate Evaluation (cont'd)

confirmed that Q-4 power transistor had failed.

Several observations were made which suggest that failure of the Q-4 power transistor is temperature related. There are four power transistors in the regulator all mounted on the same heat sink. The Q-4 transistor is mounted near the center of the heat sink, probably the location of highest temperature. A review of the previous failures revealed that they occurred during the highest ambient temperature time of the day. Outside ambient temperatures at the times of failure were in the range of 88-95°F. Ambient temperature in the MG room (where the Instrument Control Panel (ICP) and voltage regulators are installed) is not controlled and is usually higher than outside air temperature when the MG is operating. Also, the VDM was operating at or near minimum speed at the time of each failure. The power transistors dissipate more energy when the main motor is operating at low speed than at high speed, thereby causing the transistors to operate hotter.

12. Immediate and/or Temporary Corrective Action Taken and Results

The Q-4 power transistor has been replaced with one that was purchased earlier as a spare.

The Test Requester (GE) has requested that ETEC also install a capacitor (identified as C-25 on GE Drawing 9117900910) in the Basler voltage regulator. The voltage regulator did not include this capacitor in the as-delivered configuration but the capacitor does appear on the component drawings.

ETEC has concurrence from the Test Requester Site Representative to install a fan near the voltage regulator to provide convective cooling of the heat sink and power transistors for the remainder of the test activity at ETEC.

13. Is Further Evaluation and/or Corrective Action Necessary? No, Not by ETEC

14. Final Evaluation and/or Corrective Action Taken

The voltage regulator power transistor, Q4, failed six times during the test series. This regulator was replaced and testing continued with no further regulator failures. A brief summary of the voltage regulator test history follows:

July 8, 1982, 1859 hours.

VDM trip at 457 rpm, ambient air temperature approximately 88F. Notified Test Requester (GE) and Basler Corp. Transistor Q4 determined to have failed ...replaced Q4.

July 26, 1982, 1702 hours.

VDM trip at 260 rpm, ambient air temperature approximately 96F. Notified GE and Basler Corp. Transistor Q4 had failed...replaced Q4.

4. Final Evaluation and/or Corrective Action Taken (cont'd)

August 20, 1982, 1830 hours.

VDM trip at 260 rpm ambient air temperature approximately 96F. Notified GE and Basler Corp. Transistor Q4 failed. Replaced Q4 and installed capacitor C25 per request of Test Requester (GE). Installed a fan to increase convective cooling of heat sink on voltage regulator. UOR written.

August 26, 1982, 1328 hours.

VDM trip at 357 rpm after 1 hour of operation since replacement of transistor Q4 and capacitor C25 on 8-20-82. Ambient air temperature approximately 92F. Notified Test Requester. Transistor Q4 failed...replaced Q4.

August 26, 1982, 1726 hours.

VDM trip while attempting VDM startup. Ambient air temperature approximately 85F. Notified Test Requester. Transistor Q4 found to have failed. Replaced Q4 and checked components associated with the transistor Q4 circuit (capacitor C9, diode CR28, and resistor R10) per request of the Test Requester. Associated components were not faulty. Replaced R10 however, per instructions from the Test Requester.

August 27, 1982, 1816 hours.

VDM trip while attempting VDM startup. Ambient air temperature approximately 86F. Notified GE. Again found transistor Q4 to have failed. Removed the Basler voltage regulator from the Instrumentation Control Panel (ICP) per instruction from the Test Requester.

All components in the regulator were checked and found to be in satisfactory condition. Transistor Q4 was replaced and the regulator reinstalled in the ICP for the purpose of making more instrumentation diagnostic measurements.

August 28, 1982

Measured output voltage from Basler regulator while running the regulator test mode on an oscilloscope. Measurement revealed a voltage spike with a peak magnitude of 400 volts on the leading edge of the chopped 200 volt output voltage. This spike could have been a significant contributor to the last three failures and may have been caused by the addition of capacitor C25.

August 31, 1982.

Installed a new Basler voltage regulator in the (ICP). The output of the Basler regulator was again measured with an oscilloscope while the generator was running in the voltage regulator test mode. No voltage spikes were observed on leading edge of the chopped output voltage.

NOTE: All VDM trips described above were indicated by the "Generator Over-voltage and/or Voltage Regulator Fault and/or B Exc FLD TOL" window on ICP panel.

14. Final Evaluation and/or Corrective Action Taken (cont'd)

The new Basler voltage regulator behaves somewhat differently than the previous regulator from the standpoint of Volts per Hertz output. The slope of the Volts per Hertz output versus speed is steeper for the new regulator. The consequence is that the Volts per Hertz is out of Test Requester specifications at both high speed and low speed operation. The Test Requester factory representative made adjustments to the regulator, but was not successful in bringing the Volts per Hertz output within specifications over the entire speed range. The Test Requester has provided operating limits of Volts per Hertz over the normal range of exciter current values. The voltage regulator can be adjusted to provide operation in an acceptable region of Volts per Hertz and exciter field current for sustained high speed or low speed operation.

The original Basler voltage regulator was returned to the Basler Corp. for evaluation to determine the cause of repeated failure of the power transistor Q4. This evaluation has not yet been completed.

The replacement voltage regulator is still in service and has not experienced failure such as was encountered with the original regulator.

15. Programmatic Impact

Failure of the Basler voltage regulator resulted in loss of approximately five days test time to perform diagnostic testing and servicing. Operation with the replacement voltage regulator does not significantly impact the SPTF operation since adjustments can be made to assure satisfactory operation within Test Requester specified limits.

Programmatic impact on CRBR plant operations has not been determined.

16. Impact Upon National Codes and Standards - None

17. Similar Unusual Occurrence Report Numbers - None

18. Signatures

Originator	<u>W. H. Munyon</u> W. H. Munyon - Manager - SPTF	Date	<u>Nov. 2, 1982</u>
Cognizant Manager	<u>W. H. Munyon</u> W. H. Munyon - Manager - SPTF	Date	<u>Nov. 2, 1982</u>
Engineering	<u>R. E. Fenton</u> R. E. Fenton - Manager - Test Engineering	Date	<u>11-3-82</u>
Quality Assurance	<u>R. B. Copeland</u> R. B. Copeland - Manager - QA	Date	<u>11-5-82</u>
Test Requester	<u>J. L. Grimaldi</u> J. L. Grimaldi - GE Site Representative at ETEC	Date	<u>Nov 8, 1982</u>
Operations Manager	<u>W. S. Deledro</u> W. S. Deledro - Manager - Operations	Date	<u>11-8-82</u>

ENERGY TECHNOLOGY ENGINEERING CENTER

UNUSUAL OCCURRENCE REPORT

ES DRP 1365

Page 1 of 5

1. Report Number ETEC-83-01-SPTF-83-01

2. Status and Date ( ) Initial 1-7-83  
( ) Interim \_\_\_\_\_  
(X) Final 3-28-83

3. Division or Project:

Energy Technology Engineering Center (ETEC)

4. Facility, System, and/or Equipment: Sodium Pump Test Facility  
CRBR Sodium Pump Shaft Seal

5. Date of Occurrence: 8-18-82  
(Problem identified on 1-3-83)

6. Time of Occurrence: 2351

7. Subject of Occurrence:

Damage to CRBR Sodium Pump Shaft Seal Bumper

8. Apparent Cause:

Design \_\_\_\_\_ Material \_\_\_\_\_ Personnel \_\_\_\_\_  
Procedure \_\_\_\_\_ Other X (Explain in Item 14)

9. Description of Occurrence:

Damage to the CRBR pump shaft seal sleeve bumper and bumper bushing was discovered upon removal of the bumper sleeve and bumper bushing from the pump shaft. Disassembly of the shaft seal was performed on 1-3-83, following completion of the scheduled CRBR sodium pump test program, during preparation for pump modification. The shaft seal sleeve bumper and bumper bushing are described on Byron Jackson (BJ) Drawing No. AB 2F1819 as Part Numbers 437002 and 340541, respectively. The sleeve bumper is fabricated from 316 CRES and the bumper bushing is fabricated from ASTM B-584 cast bronze alloy.

Bushing material was found to have been galled from the bearing surface and was deposited in the bushing oil supply holes. The redeposited material has the general appearance of having been scuffed or shaved off and layered. It could not be determined positively whether the material had been melted during the galling action since the bronze bushing was a casting.

March 28, 1983

---

9. Description of Occurrence: (cont'd)

Difficulty was experienced in removing the bumper sleeve from the pump shaft until BJ fabricated a special tool for its removal. In addition, heat was applied to the outer surface of the sleeve to expand it away from the shaft. The seal housing was removed without further difficulty after removal of the bumper sleeve.

A significant overheat pattern was present on the outer surface of the bronze bushing in an area corresponding to the bushing-to-sleeve rubbing area on the inside surface of the bushing. The bumper sleeve and bumper bushing were removed from the pump shaft as a unit and were immediately returned to the pump manufacturer for inspection and evaluation. No further information regarding the BJ evaluation results of the bumper sleeve and bushing is available at this time. An overheat pattern was also evident on the surface of the seal housing (Part Number 509618) in the area which was adjacent to the overheat area on the bumper bushing.

---

10. Operating Conditions of Facility at Time of Occurrence:

The most likely time of occurrence of damage to the pump shaft seal sleeve bumper and bumper bushing was during a special pump tank high pressure test which was performed in support of Test Segment B1 of the CRBR pump test program. That test was performed on 8-18-82. At that time a relief valve in the shaft seal oil reservoir pressurizing line unseated allowing the seal oil reservoir pressure to decay below pump tank pressure. This condition persisted for approximately 28 minutes.

The special test was being performed under the direct surveillance of the Test Requester Site Representative and a BJ representative. Since the pressure reversal had no apparent effect on pump operation, neither party requested that testing be discontinued at the time of the occurrence. The following conditions existed at the time of the pressurant gas relief valve incident.

Sodium Temperature - 775F  
Sodium Flow Rate - 7860 gpm  
Pump Tank Pressure - 93 psig  
Pump Speed - 260 rpm

March 28, 1983

---

10. Operating Conditions of Facility at Time of Occurrence: (cont'd)

A complete description of the pressurant gas relief valve incident is presented in the referenced UOR of Item 17.

---

11. Immediate Evaluation:

The apparent cause of seal bumper damage was displacement of the oil supply in the seal due to back flow of cover gas from the pump tank through the seal during the relief valve unseating incident. The test data showed that hot gas from the pump tank was detected by the thermocouples in the seal oil inlet and the upper and lower seal oil passages in the seal housing. The seal oil reservoir liquid level increased during the aforementioned relief valve incident providing conclusive evidence that oil has been displaced from the seal housing. It appears that the seal bumper could have been run without adequate lubrication for as long as 28 minutes before the oil reservoir pressure relief valve was closed.

There appears to be no apparent design deficiency of the shaft seal, other than failure to prevent backflow of cover gas through the seal in the event that pump tank pressure exceeds the seal oil reservoir pressure. This apparent deficiency can be overcome by procedural changes which would require pump shutdown in the event of pressure reversal between the pump tank and the seal oil reservoir. The seal oil reservoir normally is operated at pressure 20-50 psi above pump tank pressure.

---

12. Immediate and/or Temporary Corrective Action Taken and Results:

Aside from correction of the pressure reversal at the suspected time of this occurrence, no additional corrective action was taken since there was no apparent evidence of a seal problem or other reason to suspect that the main motor should be shutdown. The pump was run, without problem, for an additional four months after the relief valve incident. It was not apparent that a seal problem existed until after seal removal from the pump shaft.

The GE Test Requester and the BJ pump manufacturer were notified of an apparent overheat area on the pump shaft after seal removal on 1-3-83.

March 28, 1983

---

13. Is Further Evaluation and/or Corrective Action Necessary? No

---

14. Final Evaluation and/or Corrective Action:

Based on this incident it is apparent that the oil side cover gas pressure must be maintained for reliable seal operation. The intermediate pumps are the most critical since for these units the pump tank cover gas pressure is to be carried at 93 psig and a loss of oil side cover gas pressure can produce a larger reverse pressure than can be generated in the primary system where the normal pump tank cover gas pressure is of the order of 3 psig. It appears desirable in the case of the intermediate pumps to design a very reliable seal oil cover gas pressure system and further to institute a prompt pump shutdown if the pressure balance becomes reversed. While a reversed pressure may not be sufficient to open the seal faces, some overpressure on the oil side is desirable to maintain a thin film of oil between the moving parts and thus reduce friction heating. No changes to the pump seal design are recommended as a result of this incident. The fact that the seal continued to perform its sealing function for several months after having experienced this incident is indicative of an adequate seal design. At SPTF the relief valve PSV-973 has been gagged and appropriate procedural changes incorporated. The argon supply is limited to a maximum design pressure of the seal oil system. The corrective action procedures have been modified to require pump shutdown should the low differential pressure alarm (PDAL 9030) activate and the condition not be immediately correctable by adjusting controls on the console. PDAL 9030 is set to alarm if the seal oil cover gas pressure is less than 15 psi above pump cover gas pressure.

---

15. Programmatic Impact:

None

---

16. Impact Upon National Codes and Standards, Including RDT Standards:

None

---

17. Similar Unusual Occurrence Report Numbers:

Refer to UOR ETEC-82-08-SPTF-82-03 for a description of an incident believed to have caused the damage described in this UOR.

18. Signatures:

Originator *D.K. Darley* Date 3-29-83  
D. K. Darley - Senior Operations  
Engineer, SPTF

Cognizant Manager *W. H. Munyon* Date March 29, 1983  
W. H. Munyon - Manager SPTF

Engineering *M. J. Tessier* Date Mar 30, 1983  
M. J. Tessier - Acting Manager  
Test Engineering

Quality Assurance *R. Fuhrer* Date March 30, 1983  
R. Fuhrer - Acting Manager  
QA

Test Requester J. L. Grimaldi - DRF No. 1346 Date April 4, 1983  
Per Telecon  
J. L. Grimaldi - GE  
Representative at ETEC

Operations Manager *W. S. DeBear* Date 4-4-83  
W. S. DeBear - Manager

## ENERGY TECHNOLOGY ENGINEERING CENTER

UNUSUAL OCCURRENCE REPORT

Page 1 of 5

1. Report Number: ETEC-82-06-SPTF-82-02
2. Status and Date: ( ) Initial 06-03-82  
 ( ) Interim \_\_\_\_\_  
 (X) Final 09-29-82

## 3. Division or Project:

Energy Technology Engineering Center (ETEC)

- |                                                          |                        |                        |
|----------------------------------------------------------|------------------------|------------------------|
| 4. Facility, System, and/or Equipment:                   | 5. Date of Occurrence: | 6. Time of Occurrence: |
| Sodium Pump Test Facility (SPTF)<br>Motor Generator (MG) | May 30, 1982           | 2030 hours             |

## 7. Subject of Occurrence:

CRBR MG Oil Heat Exchanger Anomaly

## 8. Apparent Cause:

Design X Material \_\_\_\_\_ Personnel \_\_\_\_\_ Procedure \_\_\_\_\_Other X (Explain in Item 14)

## 9. Description of Occurrence:

The motor-generator (MG) oil coolant system utilizes redundant oil/water heat exchangers. The system is designed to automatically switch both the oil flow and the heat exchanger water coolant flow to the alternate exchanger if the active exchanger overheats.

The active MG oil heat exchanger ("A") was given a signal to switch to the alternate heat exchanger ("B") for reasons unknown at this time. There was no indication of excessive temperature or other data recorded to indicate that the oil heat exchanger should have been automatically switched. The active heat exchanger ("A") oil valves switched to the alternate heat exchanger ("B"); however, the water coolant valves (both "A" and "B") failed to switch. The result was that oil flow was diverted through to the "B" heat exchanger while coolant water was still flowing through the "A" heat exchanger. Consequently, the MG bearings heated to approximately 243°F due to oil heatup before the MG was shutdown by the operations crew. Normal oil temperature during operation is 140-175°F.

---

10. Operating Conditions of Facility:

The main motor had been driving the CRBR pump until tripped due to high level facility valve vibration (unrelated to this incident). The pump was running on pony motor at the time of the incident. The MG was operating, but was not driving the main vertical drive motor (VDM). The temperature of sodium in the loop was 600°F.

---

11. Immediate Evaluation:

Checkouts of the MG heat exchanger Ross water valves were made following the incident. Neither valve would operate when the heat exchangers were switched from one to the other, although the oil valves consistently operated as intended. The Ross Valve Co. was contacted and given a description of the problem encountered with the water valves. Ross Valve Co. offered to supply replacement piston and cylinder assemblies for the two water valves. They explained that the water valve configuration provided to ETEC was designed for throttling service rather than for the intended shutoff service; the replacement piston assemblies reconfigure the valves to CRBR configuration and provide greater operating force. Replacement valve parts were received by ETEC and both water valves were disassembled, cleaned, and the replacement cylinders installed. The replacement piston/cylinder assemblies are larger than those originally installed and will provide greater operating force in the closing direction only...the operating force in opening direction will be lessened. Reliable opening of the valves is more critical than reliable closing.

The MG heat exchanger water valves were found to be inoperable when originally received and installed by ETEC. Per direction of General Electric (GE), the test requester, the valves were disassembled, cleaned, and reassembled by ETEC personnel. The valve internal parts were found to be heavily coated with calcium deposit scale upon disassembly. After cleaning, the valves did operate, although sluggishly. Replacement parts for the Asco solenoid valves were installed at the same time that the water valves were cleaned and checked out. The heat exchanger oil and water switch-over systems were checked out per test procedures in accordance with directions from GE and were deemed to be satisfactory for initial MG startup.

Facility circuitry to preclude tripping the MG when the VDM is tripped was recently installed to prolong the useful life of Plant Protection System (PPS) circuit breakers. One inherently undesirable feature of the new trip circuitry is that the MG is without facility PPS alarm protection from the time of VDM trip until a relay is reset manually on the Instrumentation Control Panel (ICP). The relay must be reset in the MG room by means of

---

11. Immediate Evaluation (continued)

a rotary switch to restore facility PPS protection to the MG set. Had the VDM not tripped, or if the relay had been manually reset after VDM trip, the facility PPS system would have provided an alarm in the control room when the heat exchangers switched. The facility PPS system would also have provided an alarm when the oil temperature reached 239°F or a trip of the MG would have occurred when bearing temperature reached 194°F. Because of the temporary loss of facility PPS protection to the MG set, coincident with the trip of the VDM, the alarm and trip capability was disabled.

---

12. Immediate or Temporary Corrective Action:

When VDM trip occurred, (at 1915 hours) attention was directed toward analyzing the problem and getting back into test. The operations crew entered the MG room on routine surveillance at 2033 hours and noted that the oil temperature gauges were reading approximately 250°F. The MG set was immediately shutdown. Records were made of all alarm lights, maximum oil temperature readings, valve positions, and general oil heat exchanger status to aid in diagnosing the cause of erroneous heat exchanger switch-over. Oil samples were procured and analyzed and compared with samples of new oil. No degradation of the oil was found.

The heat exchanger crossover circuit was electrically jumpered (after the status was recorded) to preclude automatic crossover and to allow completion of the test series being performed.

A timer circuit was installed which will shutdown the MG set if the relay on the ICP panel is not manually reset in the MG room within 7 minutes after a VDM trip. This will preclude operation of the MG set for long periods of time without PPS alarm protection.

---

13. Is Further Evaluation and/or Corrective Action Necessary? No (Not by ETEC)

---

14. Final Evaluation and/or Corrective Action Taken:

The records of alarm lights, temperature readings and valve positions following the incident were reviewed. The data were inconclusive as far as isolating the cause of heat exchanger crossover, i.e. high oil delta-P or high oil temperature. The heat exchanger crossover circuitry was jumpered (with Test Requester concurrence) to prevent crossover during the remainder of the test series underway at the time of the incident. The circuit was restored to its original configuration after completing that test series.

The heat exchanger alarm signals (high delta pressure and high oil

---

14. Final Evaluation and/or Corrective Action Taken: (cont'd)

temperature) have been separated and have been wired to individual annunciator windows for the remainder of the pump test program at SPTF. Since this is test article hardware this change was made with the concurrence of the Test Requester. ETEC will restore the alarm signals to their original configuration at the completion of pump testing.

Water samples from the facility coolant system were analyzed for mineral content (Fe, SiO<sub>2</sub>, Ca, and Mg), pH, and conductivity. The water quality was satisfactory for heat exchanger service, except for being slightly hard. Blowdowns of the facility water cooling tower evaporator were performed to remove precipitated calcium from the system. There was no evidence of algae formation in the water system which includes a Chemicator to inhibit algae growth.

A schedule of daily MG water valve switchover was initiated to exercise the valves and lessen the likelihood of scaling of the valve pistons and other critical components. Despite this program the valves operated normally only for a few days and then became increasingly sluggish and unreliable.

The SPTF facility water pumps provide approximately 500 gpm flowrate at 40 psig to the MG oil heat exchanger system. The water valves presently do not operate reliably at 40 psig, but can be made to operate by throttling the heat exchanger water outlet valves to increase pressure to approximately 60 psig. However, heat exchanger system cannot be operated continuously under throttled flow conditions due to the reduced cooling capability at lower water flowrate.

In summary, attempts to determine the cause of the crossover incident through data analysis and failure simulation have not been successful. Heat exchanger delta-P and temperature signals will continue to be monitored separately to assist in problem diagnosis should a similar event occur in the future. The piston and cylinder assemblies provided by the Ross Valve Company to reconfigure the valves to CRBR configuration have not improved valve operability and the valves no longer switch reliably upon command. Since both the control circuitry and the water valves are test-article related and the valves are now in CRBR configuration, ETEC has, in essence, completed all of the corrective actions and final evaluation permissible under the scope of ETEC responsibility. The Test Requester has been advised of the operational status of the MG oil heat exchanger system and the diagnostic tests performed at ETEC by means of Reference 1. Further corrective actions are being resolved by the Test Requester in conjunction with the valve manufacturer.

---

14. Final Evaluation and/or Corrective Action Taken: (cont'd)

Reference 1: 82-EETC-DRF-4765, "MG Set Lube Oil Cooling System - Automatic Valve Switching," dated September 13, 1982

---

15. Programmatic Impact:

There was no significant impact of this occurrence on the CRBR pump test program at ETEC. The possibility of a similar occurrence at CRBR, and the associated impact, is indeterminate.

---

16. Impact Upon National Codes and Standards:

None

---

17. Similar Unusual Occurrence Report Numbers:

None

---

18. Signatures:

Originator W. H. Munyon Date 10-1-82  
W. H. Munyon - Manager - SPTF

Cognizant Manager W. H. Munyon Date 10-1-82  
W. H. Munyon - Manager - SPTF

Engineering R. E. Fenton Date 10-4-82  
R. E. Fenton - Manager - Test  
Engineering

Quality Assurance L. B. Copeland Date 10-6-82  
L. B. Copeland - Manager - QA

Test Requester J. L. Grimaldi Date 10-06-82  
J. L. Grimaldi - GE Site Rep at ETEC

Operations Mgr. W. S. DeBear Date 10-7-82  
W. S. DeBear - Operations Dept. Mgr.

APPENDIX F

R E F E R E N C E S

1. XL-593-20247, GE (L. Salerno) to ETEC (\*H. Wieseneck) "CRBRP; Hydraulic Performance Measurement Meeting Notes", dated August 17, 1982.
2. XL-593-20557, GE (L. Salerno) to W (W. Purcell), "GE Plan of Action to Resolve Head/Flow Data from Sodium Test at ETEC", dated October 1, 1982.
3. XL-593-20561, GE (L. Salerno) to W (W. Purcell), "CRBRP; Prototype Pump transmittal of Meeting Notes, Data Review Meeting at ETEC of October 8, 1982", dated October 13, 1982.
4. XL-593-20289, GE (R. Michalak) to W (W. Purcell), "CRBRP; Prototype Pump Performance, GE Plan to Resolve Head Flow Problem", dated December 10, 1982.
5. XL-593-830014, GE (R. Michalak) to W (W. Purcell), "CRBRP; Main Sodium Pump Head Flow Meeting Recommendation, GE Action Plan", dated February 2, 1983.

A P P E N D I X G

D A T A T A B U L A T I O N

# Energy Technology Engineering Center

Operated for the U.S. Department of Energy  
by Energy Systems Group, Rockwell International

P.O. Box 1449, Canoga Park, California 91304

Telephone (213) 341-1000

## RECORD OF TRANSMITTAL

SUBJECT RP Prototype Pump (DSP)	DATE October 31, 1983	DRF NO. 83ETEC-DRF-4811
DISTRIBUTION	ACTION: <input type="checkbox"/> APPROVAL <input checked="" type="checkbox"/> INFORMATION <input type="checkbox"/> COMMENTS	
Mr. W. L. Frisby ✓ General Electric Company Advanced Reactor Systems Department P. O. Box 3508 Sunnyvale, California 94088  S-17  <u>w/o enclosure</u>  J. T. Cochran, GE-ARSD, Sunnyvale G. G. Glenn, GE-ARSD, Sunnyvale  <u>INTERNAL DISTRIBUTION (w/o encl)</u>  P. Archbold D. K. Liu M. J. Tessier D. J. Zweng DRF Control	DESCRIPTION  Supplementary Pump Test Data Tabulations in Response to GE Informal Request dated 9/12/83 (18 pages)	
PREPARED BY: <i>J. Boardman</i> J. Boardman, Test Cognizant Engineer	APPROVAL SIGNATURE: <i>M. J. Tessier</i> M. J. Tessier, Actg. Mgr., - Test Engineering /am	

37.5-INCH IMPELLER  
 PERFORMANCE IN 600°F SODIUM  
 TEST SEGMENT A13A

R2 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	517.2	23699	4052	3200.8	1114.7
1092.0	495.3	23462	3772	3014.1	1092.2
1000.0	416.5	21403	2908	2307.8	999.6
892.8	331.6	19133	2098	1651.8	893.1
802.0	267.5	17152	1509	1201.9	802.4
669.6	186.5	14387	848	712.9	672.0
446.4	83.2	9595	236	216.8	446.2
251.0	26.2	5412	---	---	246.4

R3 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	441.0	33560	4715	3652.4	1115.5
1092.0	421.9	32930	4392	3414.2	1090.4
1000.0	351.4	30448	3304	2634.5	998.9
892.8	282.9	26902	2365	1878.2	893.1
802.0	228.4	24288	1729	1365.7	802.6
669.6	161.2	20108	977	803.6	671.9
446.4	72.8	13444	267	241.1	446.3
251.0	23.1	7511	---	---	246.6

R4 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	394.2	38111	4905	3817.8	1116.3
1092.0	377.3	37316	4608	3567.6	1091.5
1000.0	316.6	34243	3443	2739.2	999.4
892.8	252.3	30612	2456	1954.8	892.4
802.0	203.8	27581	1803	1422.6	802.3
669.6	143.2	22952	1030	839.9	671.7
446.4	65.2	15228	282	252.4	446.1
251.0	20.8	8555	---	---	246.3

A13ATAB

A 13A CONTINUE-

R5 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	351.0	41240	4956	3899.2	1116.1
1092.0	334.6	40558	4713	3658.6	1092.3
1000.0	284.6	36988	3538	2808.8	1000.7
892.8	228.4	33031	2499	1999.6	893.3
802.0	184.7	29722	1841	1461.1	803.6
669.6	128.7	24896	1061	853.8	669.7
446.4	57.9	16576	292	259.8	445.9
251.0	18.5	9240	---	---	246.5

R6 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	NOT ATTAINABLE				
1092.0	NOT ATTAINABLE				
1000.0	187.0	40062	3489	2783.1	1001.1 (20 psig)
892.8	177.1	36042	2545	2038.3	893.1
802.0	144.0	32448	1836	1473.8	801.6
669.6	104.8	27109	1079	867.3	670.0
446.4	49.6	18104	296	264.0	446.4
251.0	16.3	10198	---	---	246.3

A13ATAB

37.5-INCH IMPELLER  
PERFORMANCE IN 1000°F SODIUM  
TEST SEGMENT B3A

**R2 SPEED SCAN**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	515.5	24227	3948	3135.1	1116.4
1092.0	493.4	23601	3690	2950.2	1094.4
1000.0	414.9	21703	2813	2245.6	999.7
892.8	331.0	19297	1988	1606.7	894.3
802.0	266.2	17349	1443	1165.5	801.8
669.6	185.8	14494	835	682.2	669.5
558.0	130.1	12126	456	394.0	558.1
446.4	83.1	9742	220	205.9	445.5
335.0	46.9	7267	85.3	89.7	335.3
251.0	26.5	5493	25.9	32.4	247.6

**R3 SPEED SCAN**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	444.9	33294	4452	3498.5	1113.9
1092.0	426.1	32540	4156	3292.4	1092.3
1000.0	358.0	29819	3172	2524.0	999.7
892.8	285.3	26648	2247	1797.6	892.1
802.0	230.6	24032	1620	1305.6	801.8
669.6	161.6	20095	944	722.6	671.5
558.0	112.7	16816	524	440.5	558.2
446.4	71.7	13352	254	231.3	446.2
335.0	40.6	10105	99	100.5	335.3
251.0	22.9	7537	33	39.7	251.1

**R4 SPEED SCAN**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	405.4	37503	4623	2590.0	1116.4
1092.0	385.7	36695	4327	3418.3	1091.8
1000.0	323.3	33662	3296	2641.5	1002.6
892.8	256.8	30076	2338	1968.9	892.2
802.0	207.5	27124	1687	1360.8	802.3
669.6	144.4	22750	982	803.0	671.4
558.0	102.4	18862	547	456.5	558.1
446.4	64.8	15032	266	239.9	446.4
335.0	37.0	11340	103	104.0	335.2
251.0	20.6	8463	34	39.1	247.1

B3A (Continued) -

R5 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	369.9	40628	4709	3704.8	1115.1
1092.0	353.3	39712	4416	3490.0	1092.2
1000.0	300.1	35995	3360	2674.7	1000.6
892.8	237.2	32232	2389	1915.6	894.9
802.0	193.2	29005	1720	1386.3	802.3
669.6	134.6	24294	998	816.7	671.5
558.0	94.8	20342	560	465.6	558.1
446.4	60.3	16387	271	243.9	446.6
335.0	34.3	12231	106	106.0	335.3
251.0	19.1	9202	34	39.2	247.0

R6 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	326.6	43469	4796	3705.8	1108.4
1092.0	---	---	---	---	---
1000.0	262.3	39038	3425	2722.0	1000.2
892.8	209.8	34948	2420	1936.7	892.9
802.0	169.1	31410	1756	1421.3	803.5
669.6	119.5	26255	1018	831.8	671.1
558.0	83.6	22157	572	474.3	558.1
446.4	53.4	17723	280	249.7	446.2
335.0	30.7	13418	108	107.9	335.2
251.0	16.9	9968	36	40.1	247.0

**R3 SPEED SCAN - 37.5" IMPELLER  
(AFTER SEVERE TEMPERATURE TRANSIENT)  
TEST SEGMENT B8**

**600°F**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	447.5	33405	4472	3534.7	1116.2
1092.0	428.5	32735	4188	3309.6	1091.5
1000.0	360.8	29925	3198	2567.1	1002.8
892.8	287.0	26773	2265	1831.3	895.6
802.0	231.5	24078	1642	1329.4	803.2
669.6	161.7	20089	957	782.0	671.7
558.0	112.5	16764	545	445.6	558.1
446.4	72.1	13425	264	236.4	444.9
335.0	41.5	10135	103	107.3	338.9
251.0	23.2	7598	39	48.9	260.4

**1000°F**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	453.5	33510	4278	3354.1	1112.6
1092.0	434.7	32845	4009	3186.5	1093.1
1000.0	364.9	30136	3056	2420.0	997.8
892.8	290.8	26947	2168	1752.0	895.2
802.0	234.5	24297	1574	1275.1	803.0
669.6	163.7	20335	920	752.3	671.5
558.0	114.9	16797	513	435.8	559.3
446.4	73.5	13528	248	226.5	446.0
335.0	41.7	10127	96	99.2	336.2
251.0	23.5	7635	38	54.2	273.2

**R3 SPEED SCAN - 37.5" IMPELLER  
(PRIOR TO SEVERE TEMPERATURE TRANSIENTS)**

SPEED(RPM)	600°F (A13A)		1005° (B3A)	
	HEAD(FT)	FLOW(GPM)	HEAD(FT)	FLOW(GPM)
1116.0	441.0	33560	444.9	33294
1092.0	421.9	32930	426.1	32540
1000.0	351.4	30448	358.0	29819
892.8	282.9	26902	285.3	26648
802.0	228.4	24288	230.6	24032
669.6	161.2	20108	161.6	20095
558.0	-----	-----	112.7	16816
446.4	72.8	13444	71.7	13352
335.0	-----	-----	40.6	10105
251.0	23.1	7511	22.9	7537

37.5-INCH IMPELLER  
 PERFORMANCE IN 600°F SODIUM  
 TEST SEGMENT B14

**R3 SPEED SCAN**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	445.8	33630	4477	3546.0	1117.1
1092.0	430.0	32594	4173	3297.0	1091.4
1000.0	360.5	29934	3193	2546.4	1000.6
892.8	287.0	26827	2265	1814.6	892.6
802.0	231.4	24158	1640	1322.9	802.2
669.6	161.4	20246	959	774.2	668.6
558.0	113.3	16742	543	453.9	558.0
446.4	72.8	13460	262	239.3	447.9
335.0	41.2	10082	101	101.6	334.2
251.0	23.2	7623	39	50.6	263.6

**R4 SPEED SCAN**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	405.5	37694	4656	3682.5	1116.9
1092.0	388.2	36875	4357	3436.6	1091.3
1000.0	326.8	33699	3324	2656.9	1001.8
892.8	260.0	30132	2358	1886.5	892.5
802.0	209.6	27103	1706	1374.5	802.0
669.6	146.0	22618	997	810.0	670.0
558.0	102.2	18915	576	474.3	559.5
446.4	64.9	15111	276	247.7	446.6
335.0	36.8	11367	107	107.8	336.2
251.0	20.5	8458	41	54.9	267.2

B14 600F (Continued) -

**R5 SPEED SCAN**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	375.4	40392	4762	3741.6	1114.8
1092.0	359.4	39558	4452	3497.5	1090.1
1000.0	301.3	36308	3397	2708.2	1001.2
892.8	240.4	32409	2406	1930.1	893.5
802.0	194.2	29174	1739	1391.0	800.2
669.6	135.9	24360	1015	822.4	669.4
558.0	94.4	20338	580	480.2	558.0
446.4	60.8	16202	283	250.6	445.3
335.0	34.2	12212	110	110.3	335.9
251.0	19.4	9241	40	41.1	241.8

**R6 SPEED SCAN (NORMAL COVER GAS PRESSURE)**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	320.8	43265	4847	3826.3	1116.9
1092.0	309.6	42518	4541	3586.6	1092.4
1000.0	262.0	39135	3466	2762.6	1001.3
892.8	210.2	35092	2453	1962.7	893.0
802.0	170.0	31577	1772	1429.5	802.7
669.6	119.4	26482	1030	842.4	671.3
558.0	83.2	22160	592	448.5	558.0
446.4	53.6	17705	290	259.1	447.6
335.0	30.6	13352	111	109.8	334.5
251.0	17.1	9975	41	43.5	245.5

**R6 SPEED SCAN (20 PSIG COVER GAS PRESSURE)**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	329.4	43647	4844	3799.0	1114.3
1092.0	316.5	42787	4538	3571.5	1091.1
1000.0	266.3	39267	3466	2755.8	1000.5
892.8	213.5	35200	2454	1969.7	893.9
802.0	171.4	31622	1777	1422.4	800.5
669.6	120.2	26415	1032	833.0	668.5
558.0	83.9	22091	593	490.0	558.2
446.4	---	---	---	---	---
335.0	---	---	---	---	---
251.0	---	---	---	---	---

B14 1000F (Continued) -

**R5 SPEED SCAN**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	377.3	40753	4569	3602.7	1115.5
1092.0	364.0	40045	4272	3371.6	1091.3
1000.0	306.2	36622	3265	2610.3	1001.7
892.8	245.0	32746	2313	1847.5	891.9
802.0	197.0	29484	1670	1357.5	804.3
669.6	137.9	24614	973	788.7	669.3
558.0	96.4	20463	558	465.9	558.5
446.4	61.7	16391	271	245.2	447.7
335.0	34.8	12397	104	104.6	334.8
251.0	19.8	9298	39	43.0	247.7

**R6 SPEED SCAN (NORMAL COVER GAS PRESSURE)**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	317.8	43980	4663	3679.8	1116.1
1092.0	314.1	42879	4366	3445.5	1091.6
1000.0	266.8	39423	3337	2661.4	1001.1
892.8	213.5	35155	2358	1888.0	892.8
802.0	171.4	31833	1702	1381.7	804.1
669.6	121.8	26661	993	806.5	669.9
558.0	84.9	22205	572	474.1	558.0
446.4	54.0	17803	274	247.6	447.6
335.0	30.3	13332	106	106.2	334.5
251.0	17.1	10219	40	44.2	248.4

**R6 SPEED SCAN (20 PSIG COVER GAS PRESSURE)**

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	334.9	44166	4661	3677.0	1116.0
1092.0	319.7	43337	4360	3451.2	1092.7
1000.0	269.1	39586	3333	2659.7	1001.3
892.8	215.3	35486	2357	1894.7	894.0
802.0	174.0	31947	1706	1384.2	804.0
669.6	122.2	26712	996	807.4	669.4
558.0	84.5	22357	570	468.8	556.2
446.4	---	---	---	---	---
335.0	---	---	---	---	---
251.0	---	---	---	---	---

37.5 IMPELLER  
 PERFORMANCE IN 1000°F SODIUM  
 TEST SEGMENT B14

R3 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	453.7	33605	4284	3392.3	1116.3
1092.0	434.3	32918	4012	3182.9	1092.4
1000.0	364.5	30186	3066	3453.4	1001.4
892.8	291.1	26940	2170	1732.0	891.2
802.0	234.4	24274	1571	1260.8	800.5
669.6	163.9	20258	916	748.5	670.9
558.0	114.2	16846	517	435.0	557.6
446.4	73.6	13524	250	230.0	447.1
335.0	41.6	10207	97	97.7	333.7
251.0	23.4	7624	35	39.3	245.1

R4 SPEED SCAN

SPEED(RPM)	HEAD(FT)	FLOW(GPM)	SHP(HP)	MGG POWER(KW)	ACTUAL SPEED
1116.0	418.0	37378	4439	3481.9	1113.2
1092.0	400.5	36613	4158	3297.1	1092.7
1000.0	334.0	33773	3180	2547.5	1002.1
892.8	266.4	30193	2253	1797.4	891.3
802.0	214.8	27146	1629	1320.1	803.3
669.6	150.0	22710	949	777.2	671.8
558.0	104.4	18934	538	449.2	557.3
446.4	67.0	15164	260	235.8	446.6
335.0	37.7	11473	101	100.1	332.6
251.0	21.2	8652	39	53.1	267.7

37.5 Inch Impeller  
600°F Performance  
at 1116 RPM, R3

<u>Segment</u>	<u>Head (ft)</u>	<u>Flow (gpm)</u>	<u>MGG Power (kw)</u>	<u>SHP (HP)</u>	<u>H/Q<sup>2</sup></u>		
A13A	443.6	33,301	3643	<del>4695</del> 4630	.4000	70.6	① Recalc SHP
A17	444.5	33,335	3631	<del>4632</del> 4615	.4000	71.0	② Pump EFF
B8	447.5	33,405	3534	<del>4472</del> 4491	.4010	73.4	
B14	447.5	33,449	3546	<del>4477</del> 4507	.4000	73.5	

37.5 Inch Impeller  
1000°F Performance  
at 1116 RPM, R3

<u>Segment</u>	<u>Head (ft)</u>	<u>Flow (gpm)</u>	<u>MGG Power (kw)</u>	<u>SHP (HP)</u>	<u>H/Q<sup>2</sup></u>		
B3A	444.9	33,294	3499	<del>4452</del> 4447	.4013	49.2	
B5	444.6	33,338	3544	<del>4454</del> 4504	.4000	48.4	
B8	453.5	33,510	3385	<del>4280</del> 4302	.4039	73.4	
B13	451.4	33,593	3394	<del>4275</del> 4313	.4000	73.1	
B14	453.2	33,660	3392	<del>4284</del> 4311	.4000	73.4	

VDM Efficiency at full power should be .9478. The recalculated shaft horsepower column is based on using .9478 for each case ①.

The resulting Pump efficiency as listed in Column ② is derived from:

$$EFF = \frac{H \times Q \times SpGr}{3960 \times SHP}$$

$$\text{where } SHP = \frac{MGG \text{ Power} \times .9478}{.7457}$$

TEST SEGMENT C8

83ETEC-DRF-2017  
Page 11 of 15  
5-23-83

R2 SPEED SCAN (.88 x 10<sup>-6</sup> ft<sup>3</sup>/60min<sup>3</sup>)

DATA SHEET

Speed (ft)	Head (ft)	Flow (gpm)	SHP (HP)	EFF. % (overall)	EFF. % (Pump)	XLR (x 10 <sup>6</sup> ) (ft/gpm <sup>2</sup> )	M49 POWER (KW)	ACTUAL SPEE (rpm)
251.0	28.0	5686	32.8	65.7	<del>6</del>	.8645	37.5	246.0
335.0	49.3	7502	91.6	65.0	90.2	.8249	94.9	335.2
446.4	87.7	10041	238.7	65.7	81.5	.8695	219.0	445.3
558.0	136.6	12326	496.8	66.1	75.2	.8901	424.3	559.2
669.6	192.5	14937	887.5	67.0	73.1	.8807	720.6	669.2
802.0	281.0	17940	1529	67.3	72.8	.8732	1230.2	801.0
892.8	348.4	19926	2116	67.3	72.5	.8776	1694.3	891.9
1000.0	436.9	22234	2990	67.1	71.8	.8837	2391.8	1001.0
1092.0	520.2	24215	3914	66.8	71.1	.8872	3100.6	1091.6
1116.0	543.4	24821	4193	66.9	71.0	.8821	3317.9	1115.8

R3 SPEED SCAN (.4X 10<sup>-6</sup> ft<sup>3</sup>/60min<sup>3</sup>)

251.0	24.5	7834	39.5	69.2	<del>0</del>	.3992	44.7	280.1
335.0	43.6	10416	109.0	68.9	92.1	.4020	108.7	335.1
446.4	76.9	13868	281.9	69.9	83.6	.4001	249.4	445.1
558.0	120.0	17354	584.2	71.0	78.3	.3988	477.7	558.8
669.6	172.3	20757	1026	70.8	77.1	.3998	832.9	669.7
802.0	246.7	24920	1763	71.4	77.1	.3973	1417.1	801.6
892.8	306.0	27655	2440	71.4	76.6	.4000	1960.9	894.2
1000.0	382.8	30927	3455	71.1	75.8	.4002	2742.4	999.9
1092.0	457.3	33650	4519	71.1	75.2	.4039	3564.4	1091.8
1116.0	477.7	34354	4828	71.0	75.1	.4047	3790.5	1114.7

TEST SEGMENT C8

83ETEC-DRF-2017  
Page 12 of 15  
5-23-83

DATA SHEET

R4 SPEED SCAN L XLR = .286 x 10<sup>-6</sup> ft<sup>3</sup>/gpm<sup>2</sup>

Speed (rpm)	Head (ft)	Flow (gpm)	SHP (HP)	EFF % (overall)	EFF % (Pump)	XLR (ft/gpm <sup>2</sup> )	MAJ POWER (KW)	TURN (rpm)
251.0	29.7	11725	42.6	68.4	88.8	.2830	47.4	250.4
335.0	39.7	11725	115.9	67.4	88.8	.2885	114.3	335.3
446.4	70.1	15624	301.4	68.2	80.5	.2872	262.4	444.9
558.0	109.0	19549	620.6	69.0	75.9	.2852	512.6	559.2
669.6	157.0	23387	1073	69.5	75.7	.2872	868.9	669.1
802.0	223.5	27990	1848	69.4	74.2	.2853	1493.9	803.5
892.8	276.4	31182	2562	69.5	74.7	.2843	2040.9	892.0
1000.0	307.7	34802	3623	69.5	73.9	.2870	2860.5	998.6
1092.0	414.1	37961	4740	69.3	73.2	.2871	3732.9	1091.9
1116.0	433.0	38848	5072	69.4	73.2	.2869	3983.1	1115.4

R5 SPEED SCAN (XLR = .229 x 10<sup>-6</sup> ft<sup>3</sup>/gpm<sup>2</sup>), 20 PSI

251.0	20.9	9525	43.5	67.4	86.7	.2307	47.1	248.1
335.0	37.0	12694	119.7	66.2	86.7	.2295	117.8	335.9
446.4	65.5	16848	310.2	67.1	78.7	.2308	269.7	445.6
558.0	101.7	21085	637.3	67.8	74.5	.2288	525.4	559.3
669.6	146.3	25204	1100	68.2	74.2	.2304	894.3	670.2
802.0	210.8	29727	1889	68.1	73.4	.2385	1514.7	801.5
892.8	259.3	33278	2620	68.1	72.9	.2342	2081.0	891.3
1000.0	327.0	37078	3697	68.3	72.5	.2378	2924.8	999.5
1092.0	390.5	40414	4845	68.3	72.0	.2391	3807.7	1091.5
1116.0	407.8	41324	5180	68.3	71.9	.2388	4081.2	1117.1



# ATA SHEET

TEST SEGMENT C10

83ETEC-DRF-2111

Page 10

5-27-83

Speed (rpm)	Head (ft)	Flow (gpm)	SHP (HP)	EFF. % (overall)	EFF. % (Pump)	XLR <sup>x10<sup>6</sup></sup> (ft/gpm <sup>2</sup> )	Mega POWER (KW)	ACTUAL SPEED rpm	
				R2 SPEED	SCAN				
251.0	23.1	5679	33	63.7	⊖	.8718	50.6	274.3	
335.0	49.3	7537	79.1	63.0	87.7	.8774	94.2	336.9	
446.4	87.6	9999	228	63.9	80.0	.8761	212.7	446.4	
558.0	136.9	12444	476	64.9	74.5	.8843	411.3	559.9	
669.6	196.9	14958	853	65.8	71.9	.8800	700.9	671.5	
802.0	281.1	17873	1480	65.2	70.7	.8800	1194.3	801.7	
892.8	348.6	19904	2047	65.4	70.5	.8799	1647.9	893.3	
1000.0	437.4	22266	2888.6	65.5	70.1	.8822	2304.8	999.8	
1092.0	521.7	24277	3784	65.4	69.6	.8853	3018.7	1093.8	
1116.0	545.1	24843	4044	65.5	69.6	.8832	3201.0	1115.4	
				R3 SPEED	SCAN				
251.0	24.9	7875	40.5	68.5	⊖	.4017	57.9	274.3	
335.0	43.9	10449	105.5	67.7	71.1	.4017	106.8	337.0	
446.4	77.1	13875	273	67.7	81.5	.4005	244.7	446.3	
558.0	120.6	17365	561	69.6	77.6	.3998	470.7	559.9	
669.6	173.0	20886	986	70.0	76.2	.3965	803.4	670.0	
802.0	248.6	24905	1694	70.3	76.0	.4008	1364.5	801.7	
892.8	302.3	27631	2349	70.2	75.4	.4056	1887.3	893.3	
1000.0	385.4	31132	3318	70.4	75.1	.3976	2639.0	999.8	
1092.0	459.6	33869	4350	70.2	74.4	.4006	3438.4	1092.0	
1116.0	480.3	34631	4657	70.2	74.2	.4005	3686.8	1117.0	
				267					



# DATA SHEET

TEST SEGMENT C10

83ETEC-DRF-2111

Page 12

5-27-83

Speed (rpm)	Head (ft)	Flow (gpm)	SHP (HP)	EFF (overall)	EFF (Pump)	XLR $\times 10^{-6}$ (ft/gpm <sup>2</sup> )	MGG POWER (KW)	ACTUAL
				R4 SPEED	SCAN (20	PSIG COVER	GAS PRESSURE)	
251.0	22.7	8910	43.0	67.7	⊖	.2860	60.5	274.3
335.0	40.4	11897	109.0	68.4	91.7	.2851	106.8	333.0
446.4	71.0	15703	287	67.9	80.8	.2878	255.5	446.8
558.0	110.3	19579	593	68.5	75.8	.2877	487.0	557.2
669.6	159.0	23359	1030	62.9	75.0	.2914	838.4	670.3
802.0	226.7	28086	1775	68.9	74.6	.2874	1425.2	801.4
892.8	281.5	31167	2453	69.3	74.3	.2897	1969.2	892.3
1000.0	352.4	34934	3468	69.3	73.8	.2888	2749.7	999.5
1092.0	419.4	38181	4548	69.1	73.1	.2877	3582.1	1091.4
1116.0	437.0	39103	4862	69.1	73.0	.2858	3803.4	1113.4
				R5 SPEED	SCAN (20	PSIG COVER	GAS PRESSURE)	
251.0	21.0	9566	44.5	65.5	⊖	.2297	62.0	274.3
335.0	38.3	12940	113.4	68.7	90.9	.2286	113.7	336.9
446.4	65.2	16846	292	66.0	78.3	.2298	258.2	446.3
558.0	101.9	21043	605	66.8	73.7	.2302	501.6	559.4
669.6	146.3	25319	1052	67.3	73.2	.2282	865.5	670.1
802.0	208.9	30392	1818	67.6	72.9	.2269	1471.1	803.6
892.8	259.7	33677	2512	67.6	72.4	.2270	2008.1	892.3
1000.0	327	37676	3550	67.7	72.0	.2303	2827.5	1001.1
1092.0	389.2	41149	4659	67.6	71.5	.2299	3656.5	1090.4
1116.0	407.3	41935	4978	67.6	71.4	.2316	3895.3	1113.9

# DATA SHEET

TEST SEGMENT C10

83ETEC-DRF-2111

Page 13

5-27-83

Speed (m)	Head (ft)	Flow (gpm)	SHP (HP)	EFF (overall)	EFF (Pump)	XLR (ft/gpm <sup>2</sup> )	M64 POWER (KW)	ACTUAL SPEED ( )
R6 SPEED SCAN (NORMAL COVER GAS PRESSURE)								
251.0	19.0	10337	45.4	62.7	⊖	.1776	63.2	274.3
335.0	32.6	14151	117.8	63.3	83.2	.1662	116.2	335.8
446.4	53.2	18401	305	62.2	73.1	.1720	266.1	445.6
558.0	91.1	22933	625	63.2	69.6	.1732	515.2	558.8
669.6	131.0	27460	1081	63.6	69.2	.1738	878.1	669.8
802.0	186.3	32714	1857	63.3	68.2	.1741	1498.7	803.1
892.8	228.4	36438	2574	62.4	66.8	.1720	2060.3	893.4
1000.0	283.9	40619	3636	61.9	65.9	.1720	2870.8	998.6
1092.0	335.2	44028	4750	61.1	64.5	.1729	3754.2	1093.3
1116.0								
R6 SPEED SCAN (20 PSIG COVER GAS PRESSURE)								
251.0	18.6	10448	45.5	62.4	⊖	.1707	65.8	278.3
335.0	33.3	13934	117.0	62.7	82.4	.1715	116.6	336.9
446.4	58.0	18305	303	61.8	72.8	.1732	265.7	446.9
558.0	90.0	22993	625	62.6	68.9	.1703	515.9	559.3
669.6	129.9	27593	1078	63.5	69.1	.1707	877.1	670.3
802.0	186	33017	1859	63.7	68.7	.1706	1492.7	801.7
892.8	229.3	36689	2574	63.4	68.0	.1703	2071.9	895.0
1000.0	286.8	40970	3638	63.1	67.1	.1708	2893.1	1001.1
1092.0	341	44617	4766	62.8	66.3	.1713	3761.2	1092.9
1116.0	355	45574	5094	62.6	66	.1709	3917.2	1107.6
						.1715	3970.7	1112.9
R7 SPEED SCAN								
251.0	16.1	11226	46.3	56.9	81.2	.1279	64.2	251.0

A P P E N D I X H  
P O W E R E F F I C I E N C I E S

POWER EFFICIENCIES

<u>Pump Motor (VDM) Output (Pump Input), HP</u>	<u>5000</u>	<u>3750</u>	<u>2500</u>
Pump Motor Efficiency	94.78%	94.3%	92.85%
Generator Output (Pump Motor Input), KW	3935	2966	2009
Generator Efficiency	97.2%	97.3%	97.1%
Fluid Coupler Output (Generator Input), KW	4048	3048	2069
Fluid Coupler Efficiency	92.8%	91.1%	87.4%
Drive Motor Output (Fluid Coupler Input), KW	4362	3345	2367
Drive Motor Efficiency	95.25%	94.3%	92.9%
Drive Motor Input, KW	4580	3542	2548
Overall Efficiency	.814	.788	.732