893/17 8-2
See Rto. Dth. 2/14/77
893/17 8-2

OPERATION AND MAINTENANCE MANUAL

MASTER

**ELECTROMAGNETIC
PUMP
MODEL 18 EPA 38A01
14,500 GPM**

ERDA CONTRACT AT(04-3)-893, TASK 17

AT03-76SF76017

GENERAL ELECTRIC

**FAST BREEDER REACTOR DEPARTMENT
SUNNYVALE, CALIFORNIA**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

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.

EFFECTIVE PAGES

<u>Page</u>	<u>Date</u>	<u>Page</u>	<u>Date</u>
i	12/17/76	3-i	12/17/76
ii	12/13/76	3-1	12/14/76
iii	12/16/76	3-2	12/13/76
iv	12/17/76	3-3	12/13/76
v	12/14/76	3-4	12/13/76
1-1	12/14/76	4-i	12/17/76
1-2	12/15/76	4-1	12/13/76
1-3	12/13/76	4-2	12/13/76
1-4	12/13/76	4-3	12/13/76
1-5	12/11/76	4-4	12/13/76
1-6	12/11/76	4-5	12/10/76
1-7	12/4/76	4-6	12/13/76
1-8	12/13/76	4-7	12/13/76
1-9	12/13/76	4-8	12/13/76
		4-9	12/13/76
		4-10	12/14/76
		4-11	12/10/76
		4-12	12/10/76
2-i	12/17/76	5-i	12/17/76
2-1	12/13/76	5-1	12/14/76
2-2	12/15/76	5-2	12/14/76
2-3	12/15/76	5-3	12/14/76
2-4	12/15/76	5-4	12/15/76
2-5	12/4/76	5-5	12/10/76
2-6	12/13/76	5-6	12/14/76
2-7	12/13/76	5-7	12/16/76
2-8	12/13/76	5-8	12/14/76
2-9	12/15/76	5-9	12/15/76
2-10	12/13/76	5-10	12/15/76
2-11	12/13/76	5-11	12/14/76
2-12	12/13/76	5-12	11/13/76
2-13	12/13/76		
2-14	12/13/76	6-i	12/17/76
2-15	12/14/76	6-1	12/17/76
2-16	12/13/76	6-2	12/15/76
2-17	12/13/76	6-3	12/16/76
2-18	12/13/76	6-4	12/15/76
2-19	12/13/76	6-5	12/16/76
2-20	12/15/76	6-6	12/16/76
2-21	12/13/76	6-7	12/16/76
2-22	12/13/76	6-8	12/16/76
2-23	12/13/76	6-9	12/17/76

DISCLAIMER

This book 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.

A-1	12/15/76
A-2	12/15/76
A-3	12/15/76
A-4	12/15/76
B-1	12/16/76

NOTICE REGARDING THIS MANUAL

This manual is a serialized document issued by General Electric, Fast Breeder Reactor Department, EM Pump Engineering. The distribution is listed in Appendix B. Revisions will be on a page-by-page basis. With each revision a new list of effective pages, with latest date will be supplied.

The manual contains information and requirements relevant to the installation, operation, and maintenance of General Electric ELECTROMAGNETIC PUMP Model 18EPA38A01 at the Liquid Metal Engineering Center, Santa Susana, California. Other uses of this manual are not authorized, and General Electric Company assumes no responsibility for any unauthorized use.

The instructions in this manual do not purport to provide for every possible contingency in connection with pump installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the operator's purpose, the matter should be referred to the General Electric Company, Fast Breeder Reactor Department, EM Pump Engineering, 310 DeGuigne Drive, P. O. Box 5020, Sunnyvale, California 94086, Mail Code S-23.

SAFETY PRECAUTIONS

WARNING

HIGH VOLTAGE, TEMPERATURE, AND PRESSURE CAN CAUSE SERIOUS OR FATAL INJURY. THE OPERATION OF ELECTRIC MACHINERY CAN BE HAZARDOUS. HANDLING OF LIQUID SODIUM CAN BE UNDULY HAZARDOUS UNLESS PERFORMED BY SPECIALLY QUALIFIED PERSONNEL. ALL PHASES OF PUMP INSTALLATION, OPERATION AND MAINTENANCE SHOULD BE PERFORMED ONLY BY EXPERIENCED AND AUTHORIZED PERSONNEL WHO HAVE READ AND UNDERSTOOD THE CONTENTS OF THIS MANUAL.

FOR THE EQUIPMENT COVERED BY THIS MANUAL, IT IS IMPORTANT TO OBSERVE SAFETY PRECAUTIONS TO PROTECT PERSONNEL FROM POSSIBLE INJURY OR DEATH. AMONG THE MANY CONSIDERATIONS, PERSONNEL SHOULD:

- AVOID CONTACT WITH ENERGIZED CIRCUITS
- AVOID CONTACT WITH SURFACES AT ELEVATED TEMPERATURE
- NEVER BYPASS OR RENDER INOPERATIVE ANY SAFEGUARDS OR PROTECTIVE DEVICES, WITHOUT THE SPECIFIC CONSENT OF THE TEST REQUESTER,
- USE PROPER CARE AND PROCEDURES IN HANDLING, LIFTING, INSTALLING, OPERATING AND MAINTAINING THE EQUIPMENT.

SAFE MAINTENANCE PRACTICES AND QUALIFIED PERSONNEL ARE IMPERATIVE. BEFORE BEGINNING ANY MAINTENANCE TASK, BE SURE THAT ALL POWER SOURCES ARE DISCONNECTED FROM THE MACHINE AND ACCESSORIES, AND GROUNDING SWITCHES AT CAPACITOR EQUIPMENT ARE CLOSED TO AVOID ELECTRIC SHOCK.

FAILURE TO PROPERLY GROUND THE FRAME OR CASES OF ALL ELECTRICAL EQUIPMENT COVERED BY THIS MANUAL MAY CAUSE SERIOUS INJURY TO PERSONNEL. GROUNDING SHOULD BE IN ACCORDANCE WITH THE NATIONAL ELECTRIC CODE AND CONSISTENT WITH SOUND LOCAL PRACTICE.

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	
1.1 General Information	1-1
1.2 Principles of Operation	1-6
2.0 DESCRIPTION	
2.1 EM Pump	2-1
2.2 Stator Cooling Unit	2-8
2.3 Power Supply	2-12
2.4 Instrumentation	2-13
3.0 RECEIVING, HANDLING AND STORAGE	
3.1 General	3-1
3.2 Cooling Unit	3-3
3.3 Power Supply	3-4
4.0 ASSEMBLY AND INSTALLATION	
4.1 Pump	4-1
4.2 Cooling Unit	4-2
4.3 Power Supply	4-3
4.4 SPTF Readiness	4-11
5.0 OPERATION	
5.1 Power Supply System	5-1
5.2 Pump Operation	5-5
5.3 Sodium Fill	5-6
5.4 First Time Operation	5-7
5.5 Operating Characteristics of the Pump	5-7
5.6 Operating Limits	5-11
5.7 Normal Shutdown	5-12
5.8 Emergency Procedures	5-12
6.0 MAINTENANCE	
6.1 Periodic Inspection	6-1
6.2 Trouble Shooting	6-3
6.3 Spare Parts	6-9
APPENDICES:	
A. Instrument Designation Cross Reference List	
B. Distribution	

LIST OF ILLUSTRATIONS

<u>Figure No.</u>		<u>Page</u>
1-1	EM Pump in FFTF Tank (SPTF)	1-2
2-1a	EM Pump, Lower Section	2-2
2-1b	EM Pump, Middle Section	2-3
2-1c	EM Pump, Upper Section	2-4
2-2	EM Pump Cooling System	2-9
2-3	Sodium Leak Detector Schematic	2-20
5-1	Calculated Normal Pump Operation at 20 Hz	5-9
5-2	Calculated Pump Operation at 60 Hz	5-10

LIST OF TABLES

<u>Table No.</u>		
1-1	Rated Performance	1-3
1-2	Dimensions and General Data	1-3
1-3	Electric Supply	1-4
1-4	Stator Cooling Unit	1-4
1-5	Miscellaneous	1-5
4-1	Protective Device Settings	4-9
5-1	Operator's Control Functions	5-3
5-2	Nominal Operating Conditions at 20 Hz	5-8
5-3	Nominal Operating Conditions at 60 Hz	5-8
5-4	Limits of Operation	5-11
6-1	Trouble Shooting Guide	6-4
6-2	Reaction to Alarms and Trips	6-5

1.0 INTRODUCTION

1.1 General Information

This manual contains a description of the major components and instructions for operating and maintaining electromagnetic pump Model 18EPA38A01. Frequent reference is made to the following documents which should be at hand if the manual is to be fully understood:

GE Spec 22A3938, Test Request
GE Spec 23A2068, EM Pump Installation
GE Spec 23A2154, Shipping & Receiving
LMEC SDD-48-SA-001

The pump is designed for installation in the FFTF pump tank located in the SPTF at LMEC which has been used for testing the FFTF prototype mechanical pump.

The pump is illustrated schematically in Figure 1-1. Sodium enters from the side near the bottom, flows upward through an annulus where the pumping forces are delivered, and returns downward through a central passage to exit at the bottom. The annulus is surrounded by the stator, a set of circular coils in slots in a stack of laminated steel punchings.

The complete installation includes, (1) the pump, (2) an MG set which delivers 3-phase electric power to the stator, (3) switchgear and controls, (4) capacitors for power factor correction, (5) an induction voltage regulator, and (6) a cooling unit.

Power is delivered to the stator of the pump under normal operation at 20 Hz from the generator of an M-G set. Power can alternatively be delivered to the stator of the pump at 60 Hz through an induction voltage regulator (IVR) for operation at low flow, equivalent to pony-motor operation of a mechanical pump.

The cooling unit contains a gas blower and a gas-to-chilled-water heat exchanger. The blower circulates nitrogen through the stator and the chilled water heat exchanger. The chilled water system rejects the heat to the atmosphere.

Figure 1-1. EM Pump in FFTF Tank (SPTF)

TABLE 1-1

RATED PERFORMANCE

<u>Fluid</u>	<u>Flow</u>	<u>Developed Head</u>	<u>Inlet Head</u>	<u>Fluid Temp.</u>
Sodium	14,500 gpm	183 psi	12 psia	858°F

TABLE 1-2

DIMENSIONS AND GENERAL DATA

Dimensions

<u>Component and Ref. Dwg. no.</u>	<u>Height inches</u>	<u>Width diameter inches</u>	<u>Depth inches</u>	<u>Weight pounds</u>	
EM Pump 852E274	516	102		126,000	
M-G Set 852E650	170	500	113	160,000	
Cooling Unit 852E649	335	121	122	35,000	
Switchgear & Control					
852E657 Input Section	50	169	74	22,000	
852E656 Output Section	90	152	74	17,000	
Capacitor Equipment					
852E659					
Rack with Switch	125	130	55	4,050	
Rack without Switch	72	96	55	2,350	
Termination Box	90	68	60	6,000	<u>HOLD</u>
Induction Voltage					
Regulator (IVR) 852E658	130	85	56	13,000	

TABLE 1-3

ELECTRIC SUPPLY

	<u>VOLTS</u>	<u>AMPS</u>	<u>FREQ</u>	<u>PHASES</u>	<u>POWER</u>
M-G Set Drive Motor	4160	775*	60	3	6000 Hp
EM Pump Stator (Phase)**	4000	500	20	3	
Induction Voltage					
Regulator Primary***	4160	30	60	3	200 Kva
Secondary	2000	60	60	3	200
Cooling Unit Blower					
Motor	460	227	60	3	200 Hp
Cooling Unit Damper					
Motor	120	5	60	1	0.25 Hp
EM Pump Vent Pipe					
Heaters	277	17	60	1	4.5 Kva
Freeze Vent Heater Power	120	3	60	1	380 Va
Chilled Water Control					
Power	120	5	60	1	600 Va
Sodium Pressure Trans-					
mitter	+ 15	1	DC	3-wire	30 Va
Nitrogen Pressure					
Transmitters	120	1	60	1	120 Va
Instrument Control &					
Light on Cooling					
Unit	120	30	60	1	3.6 Kva

TABLE 1-4

STATOR COOLING UNIT

Construction: Structural steel clad with weatherproof skin

Mounting: Angle brackets on two sides

RATED PERFORMANCE
(at 2000 ft elevation)

Flow Rate	90,000 lb/hr
Inlet Pressure	5 inches of water gauge
Discharge Pressure	32 inches of water gauge
Pressure gain	27 inches of water gauge
Inlet gas temp.	100 deg F
Discharge gas temp.	56 deg F

* Inrush, 1800 amps max.

** Pump is delta-connected, Generator is wye-connected with high-impedance ground

*** Primary and secondary of IVR are wye connected.

Water-to-Nitrogen Heat Exchanger

Max heat rejection	1.4 million Btu/hr
Water inlet temp	40 deg F
Water exit temp	56 deg F to 65 deg F (est.)
Water flowrate	160 to 250 gpm
Water press. inlet	50 psig
Pressure loss	15 psig

Nitrogen Supply Requirements

Normal Makeup	1000 scf/day, continuous
Purge	700 scfm for 6 hours
Pressure	5 inches of water gage
Impurity Limits	TBD

TABLE 1-5

MISCELLANEOUS

Cover Gas Requirements

Argon at 5 psia
to 20 psig

Vacuum System Requirements

Evacuate sodium passages to TBD (see SDD) mm Hg at 400 deg. F.

EM Pump Stator Cooling Requirements

SPTF to provide 40 deg F water at 160 gpm to remove 1.4 million Btu/hr
Makeup Nitrogen 1000 scf/day
See Table 1-2.

Sodium Cooling Requirements

Heat rejected to the sodium by the pump over its complete operating range may be as large as 8.0 million Btu/hr at low flow, high developed head, and low sodium temperature. For test purposes the power input to the pump will be adjusted within the capability of the LMEC SPTF sodium cooler as shown in Figure 3 of the Test Request, Spec. 22A3938. Section 5.6 amplifies this and describes some exceptions.

TABLE 1-5 (continued)

Normal Performance Range

Fluid	Liquid sodium up to 1000 deg F max
Electric Supply	0 to 4000 volts, 20 Hz, 3 phase
Flow	0 to 16,000 gpm
Discharge Pressure	0 to 215 psig
Inlet Pressure	12 psia to 120 psig
Alt. Power Source (IVR)	0-2000 volts, 60 Hz, 3 phase

Some combinations of these limits are not available; for more details of performance see Section 5.0.

OPERATING PRECAUTIONS

OPERATION OF THE PUMP SHOULD AT ALL TIMES BE STRICTLY IN ACCORDANCE WITH THE INSTRUCTIONS IN THIS MANUAL AND G.E. APPROVED TEST AND OPERATING PROCEDURES. THE OPERATING PRECAUTIONS AND OPERATING LIMITS MUST BE STRICTLY OBSERVED. ALL DEVIATIONS FROM APPROVED SPECIFIED PROCEDURES AND ALL UNEXPECTED RESULTS SHALL BE PROMPTLY REPORTED TO THE FAST BREEDER REACTOR DEPARTMENT, 310 DEGUIGNE DRIVE, P. O. BOX 5020, SUNNYVALE, CALIFORNIA 94086.

THE FOLLOWING PRECAUTIONS SHOULD ALWAYS BE OBSERVED WHEN OPERATING OR PREHEATING THE PUMP.

1. DO NOT APPLY MORE THAN 200 VOLTS TO THE PUMP STATOR UNLESS THE SODIUM DUCT IS COMPLETELY FULL OF SODIUM.
2. DO NOT APPLY MORE THAN 250 VOLTS UNLESS THERE IS POSITIVE INDICATION OF SODIUM FLOW. IF FLOW IS UNCERTAIN, RETURN TO 200 VOLTS OR LESS.
3. NO STATOR WINDING TEMPERATURE SENSOR SHALL EXCEED 340 DEG. F. REDUCE STATOR VOLTAGE AS NECESSARY TO MAINTAIN MAX. COIL TEMPERATURE SENSOR UNDER 340 DEG F.
4. THE PUMP STATOR SHOULD HAVE COOLING GAS SUPPLIED TO IT AT ALL TIMES.
5. DO NOT OPERATE THE PUMP IN THE REVERSE FLOW MODE UNTIL THE SPTF HAS BEEN MODIFIED FOR IT. THE PUMP IS CAPABLE OF DEVELOPING FULL PRESSURE IN THE REVERSE DIRECTION AT FULL VOLTAGE, AND THIS COULD DAMAGE THE SPTF PUMP SUCTION SYSTEM AND EXPANSION TANK.
6. IF ANY OPERATING PARAMETER FOR THE PUMP, M-G SET, STATOR COOLING SYSTEM OR OTHER ACCESSORIES CANNOT BE KEPT WITHIN THE OPERATING LIMITS SHOWN IN TABLE 5-4, THE PUMP SHOULD BE SHUT DOWN ACCORDING TO NORMAL SHUTDOWN PROCEDURES IN SECTION 5.7.

1.2 PRINCIPLES OF OPERATION

Electromagnetic Pump Model 18EPA38A01 is an annular linear induction pump which pumps liquid sodium at temperatures up to 1000 deg F, at flows up to 16,000 gpm and developed pressures up to 215 psi. Calculated performance at 858 deg F is shown in Figures 5-1 and 5-2.

The pump itself is hermetic and has no moving parts. Pressure results from the electromagnetic force produced by the interaction of the electric current induced in the sodium and the magnetic field which moves upward at a speed of 63 ft/sec. This field is produced by an arrangement of circular coils carrying 3-phase electric current. In normal operations these coils are supplied with 3-phase electric power at 20 Hz from the generator of a motor generator set. The voltage delivered by the generator is adjustable from about 80 volts to 4000 volts. The motor of this MG set is a squirrel-cage motor supplied by 60 Hz, 4160 volt, 3-phase power.

Flow rate of the sodium is controlled by varying the voltage of the electric power coming from the generator. Power input and developed pressure at a particular flow vary approximately as the square of the voltage. Direction of flow and pressure can be reversed by reversing the phase sequence of the power from the generator to the pump.

For very low flow 60 Hz, 3-phase power, varied by an induction voltage regulator (IVR), can be applied to the EM Pump. The IVR is provided to simulate pony motor operation of a mechanical pump. Provision is made for switching to 60 Hz power for emergency conditions or long-time decay heat removal and to provide for power supply diversity. Interlocks prevent simultaneous application of both power sources.

The electrical coils are thermally insulated from the sodium duct by a thermal barrier assembly consisting of a high efficiency inorganic insulation sandwiched between thin stainless steel enclosures. (Dwg. 261R175.) The heat conducted across this insulation plus the winding heat generated in the electrical coils is removed by a separate closed circuit cooling system, consisting of a gas blower and a gas-to-water heat exchanger with the necessary instrumentation and control. The cooling gas is nitrogen. The cooling water is provided by a water chiller and an evaporative cooling tower which are not a part of the equipment furnished with the pump.

Because the EM Pump has no moving parts, there are no critical operating clearances, no dynamic seals, no bearings, no wear rings, and no impellers. Hence the pump requires no maintenance.

These features, also mean that the EM Pump is much more able than mechanical pumps to accommodate thermal dilatation and transients of all kinds including temperature, flow, pressure, and power transients. As a result operation over the entire flow range from zero to 100% rated is simple and extremely reliable.

Operation of the pump should at all times be strictly in accordance with the instructions in this manual. The OPERATING PRECAUTIONS AND OPERATING LIMITS must be strictly observed. All deviations from the specified procedures and all unexpected results shall be promptly reported to the Fast Breeder Reactor Department, 310 DeGuigne Drive, P. O. Box 5020, General Electric Company, Sunnyvale, CA 94086.

2.0 DESCRIPTION

	<u>Page</u>
2.1 EM Pump	2-1
2.1.1 Duct and Center Iron	2-1
2.1.1.1 Duct	2-5
2.1.1.2 Center Iron	2-5
2.1.2 External Support Vessel	2-6
2.1.3 External Thermal Insulation	2-6
2.1.4 Stator Guide Cylinder	2-6
2.1.5 Coolant Gas Manifold	2-7
2.1.6 Stator	2-7
2.1.7 Duct Thermal Insulation	2-8
2.2 Stator Cooling Unit	2-8
2.2.1 Structural Arrangement	2-10
2.2.2 Fan and Drive Motor	2-10
2.2.3 Heat Exchanger	2-11
2.2.4 Instrumentation and Controls	2-11
2.3 Power Supply and Control System	2-12
2.3.1 Motor Generator Set	
2.3.2 Induction Voltage Regulator	
2.3.3 Capacitor Equipment	
2.3.4 Switchgear & Control	
2.4 Instrumentation	2-13
2.4.1 Temperature	2-13
2.4.2 Vibration	2-14
2.4.3 Sodium Leak Detection	2-15
2.4.4 Strain Gages	2-17
2.4.5 Magnetic Flux Monitoring	2-17
2.4.6 Pressure	2-18
2.4.7 Miscellaneous	2-19
2.4.8 Calibration	2-20

2.0 DESCRIPTION

2.1 ELECTROMAGNETIC (EM) PUMP

The 41,500 gpm EM pump is designed to be installed in the pump tank originally designed for the primary mechanical pump of the Fast Flux Test Facility. The principal dimensions and weights of the pump and its components as depicted on G.E. Dwg. 261R165, are listed below. Figures 2-1a,b,c illustrate the functions and configurations of the pump.

Dimensions:

- a. The maximum diameter of the external support vessel flange supported by the FFTF pump tank is 93.0 inches.
- b. The height of the pump from the bottom bellows surface to the top of the vent pipe is 43 ft. 3 inches.
- c. The maximum protrusion diameter approximately 4 ft below the external support vessel flange is 82.9 inches.
- d. The maximum protrusion diameter in a zone below item c, extending down to 24 ft. 6 in. below the external support vessel flange, is 74.8 inches.
- e. The pump tapers to a 58 inch diameter below item d in the region of the 28 inch diameter inlet nozzle.
- f. Below the inlet plenum of the pump a 38.2 inch diameter flange supports the bellows assembly.
- g. The outlet nozzle extending down through the bellows assembly is a 16 inch diameter pipe.
- h. The four coolant manifold flanges have a maximum diameter of 32 inches.

<u>Component</u>	<u>Weight (lbs)</u>
EM Pump Assembly Complete	120,000
Stator Assembly	37,000
External Support Vessel	34,000
External Thermal Insulation	10,100
Stator Guide Cylinder	8,500
Pump Duct Insulation	1,150
EM Pump Duct	21,000
Coolant Gas Manifold	9,100
Bolt Ring	2,100

2.1.1 Duct and Center Iron

2.1.1.1 Duct

The duct (Fig. 2-1 a,b,c) has a pressure boundary which has conventional pressure vessel features. It was designed and fabricated in accordance with the existing ASME Code Section III and the high temperature code cases. The duct is designed for an inlet pressure of 120 psig and an outlet pressure of 225 psig.

Figure 2-1a. EM Pump, Lower Section

Figure 2-1b. EM Pump, Middle Section

Figure 2-1c. EM Pump, Upper Section

The pump configuration with the center return duct has two important advantages. First, with both inlet and outlet sodium pipes at the same end of the pump, the stator can be removed over the other end of the duct without disturbing the sodium piping. The second advantage is that differential thermal expansion between the duct and the stator is accommodated, because the duct is free to expand or contract without restraint. Another feature of the duct is the variation in the area of the annulus along the length of the duct. The greater flow area at the entrance and the exit reduces electromagnetic end-effects while the higher velocity at the center enhances effective pressure development.

The duct is composed of cylinders of several diameters, transition pieces, an inlet tee, upper and lower heads, a support skirt and a flange. The center iron is enclosed in the pump duct between the center return pipe and the inner shell of the pumping annulus. Surfaces in contact with sodium are 316H stainless steel.

The duct is 24 ft. 5 in high and 6 ft. 2 in. in diameter at the support flange. Through the stator pumping region it is 24.4 in. in diameter. It weighs 21,000 pounds.

The duct support flange has a machined register for fit with the lower external support vessel flange. The upper part of the duct is an axial slide fit within the duct thermal insulation support cylinder. This provides lateral support for the duct while permitting the axial motion which results from temperature changes.

The vent line for the duct extends from the upper head to the freeze vent. The vent line is a 2 inch diameter pipe for the lower 11 ft. and a 1 inch dia. pipe for the upper section which continues on to the freeze vent. A tee in the 1 inch pipe contains a pressure sensor to monitor pump discharge pressure.

Near the bottom of the 16 in. outlet pipe a bellows is bolted to the 38.25 in. diameter flange which provides the seal to the bottom of the pump tank in the same manner as for the FFTF mechanical pump.

2.1.1.2 Center Iron (Fig. 2-1a)

The center return pipe-to-duct outer shell has three lateral connecting support points. Two of these support points are in the transition cone region just above the inlet nozzle and one is near the top of the duct just below the 180 degree turn around piece. These support points raise the natural frequency and limit the stress level due to vibration to a satisfactory value.

The duct and vent pipe instrumentation includes 23 thermocouples, one tri-axial and one uni-axial accelerometer, three leak detectors, 14 strain gauges and one sodium discharge pressure sensor. See Table V, Test Request 23A3938.

2.1.2 External Support Vessel (Fig. 2-1a)

The external support vessel provides the structural interface to which the duct support flange and the associated duct assembly elements are mounted. The external support vessel also provides the EM Pump mounting interface with the FFTF primary pump tank through its upper flange, and provides a portion of the sodium and cover gas pressure boundary around the pump internal parts. The vessel is composed of cylinders of two diameters, 79.00 inches OD at the upper end and 73.75 inches OD at the lower end, connected by a forged transition section, and having forged flanges at either end. Complying with the ASME BPVC, Section III, it is designed for an external pressure of 120 psi at an operating temperature of 1050 deg F, which reflects the FFTF primary pump requirements. Construction is of 316H stainless steel plate and forgings. The lower flange has a machined register for fit with the duct support flange, and a welding preparation for the omega-shaped welded seal which excludes sodium from the pump stator annulus. The transition section includes a series of tapped holes which are used for mounting the external thermal insulation assembly. The lower surface of the top flange rests upon the FFTF pump tank flange and is positioned on that flange by two pins.

2.1.3 External Thermal Insulation (Fig. 2-1a,b)

The external thermal insulation assembly consists of two subassemblies: steel supporting and alignment cylinders, and the thermal insulation assembly. The steel cylinder subassembly has two sections; the upper section is carbon steel. It supports the insulation and the lower stainless steel cylinder and serves as the outer boundary of cooling gas supply to the stator. The stainless steel alignment cylinder fits at its lower end into a machined diameter on the inside of the duct support cone flange.

The external thermal insulation assembly isolates the stator region from the hot lower duct surfaces and external support vessel surfaces at sodium temperatures.

The 316 stainless steel alignment cylinder operates at the temperature of the sodium at its lower end, and 200 deg F at its upper end, and thus sustains a substantial thermal gradient. It provides lateral support to the stator through sliding fits at its upper and lower ends, and also accommodates the differential thermal expansion which occurs.

2.1.4 Stator Guide Cylinder (Fig. 2-1a,b)

The stator guide cylinder provides high accuracy positioning and lateral support interfaces for the pump stator, and serves as one part of the stator cooling gas distribution system. The stator guide cylinder has high accuracy sliding fits at its lower end with the flange of the external thermal insulation assembly on the outside, and the stator lower end support flange on the inside. At the upper guide there is another close tolerance fit with the upper end of the stator. Both of these features align the stator to the duct, and provide support for the stator, accommodating lateral loads so that the stator does not move laterally in relation to the duct.

The stator guide cylinder also provides for the centering and guiding of the stator during its installation, to prevent inadvertent contact of the stator and duct as the stator is being lowered into place.

Inlet cooling gas flows down the outer wall of the stator guide cylinder, through 2 inch distribution holes, into the stator. Gas flow out of the stator goes up the inside of the cylinder and out nozzles at the top through sleeves.

2.1.5. Coolant Gas Manifold (Fig. 2-1c)

The coolant gas manifold is a carbon steel structural part which mounts to the external support vessel, and through a separate bolt ring, clamps the pump assembly to the pump tank. The stator guide cylinder bolts to the upper flange of the manifold. The manifold supports the weight of the stator and the stator guide cylinder and transfers it to the external support vessel flange and to the pump tank flange.

The manifold also contains four flanged parts, or nozzles. Two nozzles accommodate inlet cooling gas flow, the other two provide outlet gas flow through self-centering sleeves from the stator guide cylinder nozzles.

2.1.6 Stator (Fig. 2-1a,b)

The stator consists of a laminated iron core with insulated electrical coils arranged to produce an electromagnetic field which can act upon the liquid metal in the duct. The reaction of the liquid metal to the field is to flow axially at a rate determined by the external hydraulic resistance and the force (pressure) developed by the electromagnetic field.

The stator is delta-connected. The stator winding is of a formed-coil construction similar to that used in large rotating electrical equipment. The winding insulation system meets the regulations of IEEE class H and is capable of continuous operation at hot spot temperatures up to 392 deg F. After the coils are inserted in the slots and connected, the complete stator is treated with several applications of silicone resin. When supplied with 20 Hz 3-phase power, the stator winding produces an 8 pole magnetic field travelling at 63.6 ft/sec axially in the stator bore.

The stator is cooled by nitrogen gas utilizing a straight-through ventilation pattern. Cooling gas enters the pump through the coolant gas manifold (Drawing 852E397) and is distributed to all parts of the stator by means of the perforated stator guide cylinder (Drawing 852E493). It passes through six gas inlet chambers formed by the stator guide cylinder and the exhaust gas header, and flows through cooling passages located in each stator tooth. The cooling gas flows out of the stator through six exhaust gas header ducts attached to the stator frame, and exits into the gas manifold.

Forty sheathed chromel-alumel thermocouples are provided for monitoring pump stator temperatures during operation. The thermocouples are located at (1) the coil inner diameter, (2) coil outer diameter, (3) coil face, gas inlet side, (4) the coil face gas exit side, (5) stator tooth near the inside diameter, and (6) stator laminations at the outer diameter.

Twenty eight flux coils are located along the stator to measure the stator flux distribution. Twenty four of these are located in the stator yoke and four in pairs on the stator teeth near the center of the stator.

Three platinum resistance temperature sensors are located in the exhaust gas header ducts to monitor the temperature of the stator exit cooling gas.

2.1.7 Duct Thermal Insulation (Fig. 2-1b)

The duct thermal insulation protects the stator windings from the high temperature of the sodium. The insulation is a thin cylinder located in the annulus between the duct and stator. The insulation dimensions are approximately 24 inches in diameter, 1/4 inch thick and 14 1/2 feet long. The insulation is suspended from the stator flange by a steel cylinder with about the same dimensions. The two cylinders are connected by a bolted flange joint to make the assembly shown in Figure TBD.

The insulation material is Johns-Manville flexible Min-K protected on both the inside and the outside by 0.010 inch thick stainless steel cylinders. The outer cylinder is continuous while the inner cylinder is seamed to allow for thermal expansion. Sandwiched in the insulation are 18 thermocouples and 34 magnetic flux sensors. Two additional flux sensors and 3 accelerometers are located slightly above the insulation cylinder. The instrument leads are routed along the support cylinder and terminate in the junction box mounted on the support flange.

The two radial load pads located slightly above the insulation are part of the pump duct support system. The inner load pad fits closely around the top of the pump duct and the outer load pad fits closely with the stator guide cylinder. The close-fitting surfaces are chromium carbide coated for a compatible load bearing surface.

2.2 STATOR COOLING UNIT

The EM Pump cooling unit is a combination gas mover and heat exchanger providing the necessary gas cooling to maintain the hot-spot temperature of the stator windings of the pump below a safe level. The unit is designed to deliver 90,000 lb/hr of nitrogen, using a single gas mover. The nitrogen is cooled in a nitrogen-to-water heat exchanger.

The cooling unit, which is part of a closed loop system, has minimal nitrogen leakage. The nitrogen is slightly pressurized to allow only outward leaks and prevent infiltration of air. Controls are provided for adjusting the nitrogen flow and regulating the cooling water flow through the heat exchanger. Figure 2-2 is the diagram of the cooling system.

The major components of the stator cooling unit are:

- Structure
- Fan and drive motor
- Heat Exchanger
- Instrumentation and Controls

Figure 2-2. EM Pump Cooling System

2.2.1 Structural Arrangement

The cooling unit houses the gas-to-water heat exchanger, the fan, and the water valve. The cooling unit is approximately 10 ft. wide, 10 ft. deep and 27 ft. high. Mounting angles are provided at the SPTF elevation of 175 ft. positioned to bring the blower inlet and discharge flanges to the elevation requested by LMEC. Except for the blower and motor, the structure is enclosed in corrugated galvanized iron for protection from the elements.

Ladders are provided for access to the motor-blower deck (top), plenum box hatches (middle) and the drain valve and control equipment (bottom). The blower deck ladder is outside the structure running from the 175 ft. elevation up to the motor-blower deck (about 186 ft.). A door is provided at the 175 ft. level for access to an interior deck and to the ladder to the lowest deck at about 160 ft.

Thermal insulation is applied to the plenum at and below the heat exchanger (cold area) and to the duct (39 inch diameter) running from the bottom of the plenum box to the outlet flange at the 183 ft. level. The blower and blower inlet transition section of the duct are not thermally insulated.

The carbon steel parts are protected from rust by anti-rust paint inside the plenum box, Bisonite inside the blower and anti-rust paint on all outside surfaces not otherwise protected.

2.2.2 Fan and Drive Motor

The blower is directly connected to the drive motor and a shaft seal is used to minimize the leakage of gas. A damper is located on the suction-side of the blower to allow gas flow adjustment. The damper is motor driven and manually controlled. The blower discharge includes an expansion nozzle (evase) to help distribute the gas flow through the heat exchanger. A vibration-isolation section is provided at the blower inlet and outlet flanges.

The blower is designed to deliver the required nitrogen flow and static pressure head. The drive motor is directly coupled to the gas mover impeller shaft; however, removal of the drive motor does not require disassembly of the blower. The drive motor is a totally enclosed fan-cooled squirrel cage induction motor which is controlled by a combination (non-fused) motor controller.

2.2.3 Heat Exchanger

A rated cooling capability, the heat exchanger will remove heat from the nitrogen at the rate of 1.4 million Btu/hr. The total heat to be transferred includes heat from the duct, the electrical losses in the stator, and the power required to circulate the gas. The heat exchanger is of brazed construction employing nonferrous tubing and is capable of withstanding a hydrostatic pressure of 100 psig. A manual air vent is provided at the high points in the water side of the heat exchanger for purging air from the system.

The heat exchanger tube bundles and manifolds are arranged to slide into the middle of the plenum box. The blower discharges vertically downward into the inlet plenum where a horizontal plate spreads the gas flow over the frontal area of the heat exchanger. This baffle plate has cut-outs which remove about half of the baffle area to aid the distribution of gas flow. The calculated pressure drop across this baffle plate is about 1.5 inches water gauge. Access hatches are provided in the plenum wall to allow adjustment of the baffle location (and to replace it, if necessary) and to install and inspect the heat exchanger.

2.2.4 Instrumentation and Controls

A mass flow measuring system is provided. Input electrical power at 120V AC is needed to operate the computer and pressure transducers of the system and to provide the 4-20 ma output signal analogons to mass flow. The system includes a resistance temperature detector and a manifold of pitot tubes to measure the gas velocity.

A relative humidity gauge will provide a 4-20 ma signal to the SPTF data system and to an alarm indicating a sudden change in humidity.

A three-way proportioning motor-driven water control valve, with manual override is provided at the cooling unit. A controller is provided for installation at the SPTF operator's control station. This controller positions the water control valve to maintain the temperature of the cooling gas at the outlet of the EM Pump at a constant value independent of the pump operating conditions, nominally 100 deg F. The resistance temper-ature detectors (RTD's) in the outlet section of the EM Pump stator assembly will be used for temperature feedback.

The nitrogen flow through the cooling unit is adjustable from 20% to 100% of rated flow by an electrically actuated damper. The actuator is capable of continuous adjustment with limit switches to prevent motion beyond the full open or full closed positions. A third limiting device is provided to prevent the damper from being fully closed while the blower is running. The damper also serves as a flow obstruction at the inlet to the fan while purging.

2.3 EM PUMP POWER SUPPLY

The EM pump normally operates from power obtained from a motor generator set which converts the customary electrical 60 Hz utility power to 20 Hz. Switches are provided to allow the EM pump to be connected alternatively, to an induction voltage regulator (IVR) which applies the utility frequency of 60 Hz directly to the EM pump. The output voltage of both the 20 Hz generator and the 60 Hz IVR can be adjusted by the operator in order to obtain the desired pump operating conditions.

The power supply includes the switchgear and control to start and run the MG drive motor, to manually select the generator or the IVR, and to automatically switch from the generator to the IVR whenever input power to the MG drive motor fails and speed falls below a preselected value.

The power supply includes a bank of power-factor-correcting capacitors with a switch to disconnect part of the bank when operating from the 60 Hz induction voltage regulator.

2.3.1 Motor-Generator Set

The principal components of the M-G set are the induction drive motor, a synchronous 20 Hz main generator, a fly-wheel (for energy storage), a brushless exciter for the main 20 Hz generator, a brushless 60 Hz control power generator and a tachometer generator all directly connected and mounted on a common non-self supporting fabricated steel base.

The bearings for all rotors are pedestal type sleeve bearings which are self-lubricated (with oil rings) except for the control power generator and the tachometer generator. A high pressure oil pump is installed at each bearing to provide an initial oil film at each bearing prior to start. The high pressure lube oil pumps are not used once the M-G set is running. The control power and tachometer generators each have end-shield mounted bearings and are coupled to the main M-G set shaft with flexible couplings.

The drive motor and the main 20 Hz generator are cooled by room air which enters the end of each machine and is discharged through the top of it where provisions are made for the connection of a duct to discharge this warm air outside the M-G set building. The air is moved through each machine by fins on the rotor which can develop only a limited amount of pressure at the discharge flange. Refer to the notes on the outline drawing for this limitation.

The control power generator, tachometer generator and brush-less exciter for the main generator are all self-ventilated by means of an open (drip proof) construction. The flywheel is non-ventilated and completely enclosed. Any heat developed by the windage of the flywheel within the enclosure is dissipated to the room by conduction and radiation from the enclosure. The heat developed by bearing friction is dissipated to the room by conduction and radiation from the bearing pedestals.

The power connection boxes for the drive motor and main generator are sized to provide room for current transformers for differential protection, surge capacitors, lightning arrester (drive motor only) and current transformers for relay and meter circuits (main generator only). These terminal boxes also provide space for the termination of shielded cables with stress cones.

The total weight of the M-G set and the weight of principal parts of the M-G set are given on the outline drawing.

2.3.2 Induction Voltage Regulator

The induction voltage regulator (IVR) provides ground isolation from the electric utility source and the capability of adjusting the output voltage from zero to 2000 volts. The unit is analogous to a wound-rotor induction motor arranged to have the rotor driven to and held at positions corresponding to the desired output voltage. The primary of the IVR is connected to the electric utility system and a small pilot motor positions the secondary of the IVR. The amount of voltage induced in the secondary winding is proportional to the position of the rotor. Control circuits are provided to drive the motor to raise and lower the output voltage. A voltage regulator circuit is provided to automatically maintain the output voltage of the IVR at any desired level regardless of changes of the voltage on the IVR primary.

The IVR is liquid cooled with heat radiators arranged around the outside of a sealed steel tank. Electrical connections are made to bushings located on the top of the tank which are enclosed in steel air-filled compartments. Lightning arresters are connected to the primary terminals of the IVR. The secondary is Y connected with the neutral brought out for connection to a high resistance neutral grounding resistor.

The control circuits are located within a cabinet on the side of the IVR.

2.3.3 Capacitor Equipment

The capacitor equipment consists of racks of capacitor units which are interconnected to provide the amount of power factor correction needed, grounding switches for personnel protection during maintenance periods, a switch to disconnect part of the capacitors for 60 Hertz operation and a termination box for interconnecting the capacitors with the EM pump stator leads.

The capacitor racks consist of a welded aluminum framework on which the capacitor units are mounted in two rows in an upright position. Each rack contains the number of capacitor units required for a balanced three-phase circuit. Each capacitor unit is connected to the bus through an individual current limiting fuse unit.

The capacitor units are furnished with two bushings. One bushing is connected to the phase bus and the other bushing is connected to a neutral bus. This construction electrically isolates the capacitor circuit from the aluminum frame which is connected to the facility ground network.

One three-phase rack is connected directly to the main bus of the termination box. The other two capacitor racks are connected in parallel to a disconnect switch which is, in turn, connected to the main bus of the termination box. The disconnect switch is motor operated and the control leads are routed through the termination box to the switchgear in the M-G building. Circuits in the switchgear automatically open and close the switch in accordance with the operator's selection of either the main generator or the induction voltage regulator as the power source.

The termination box is a separate free-standing compartment which houses the instrument transformers and power transducers for electrical measurements, current transformers for differential protection, disconnect links to facilitate de-energized tests on individual EM pump windings and a bus to interconnect the EM pump, incoming feeder and two capacitor lines. Terminal boards are provided for the connection of wires interconnecting with other parts of the system.

2.3.4 Switchgear and Control

The switchgear equipment consists of two sections of vertical-lift, metal-clad, 4160 voltage class indoor units with air-blast power circuit breakers.

Input Section

The Input Section serves to terminate the incoming feeder from the power source and distribute power to the IVR and to the drive motor of the M-G set. The feeder to the IVR is connected directly to the incoming line terminals. Three circuit breakers are connected as a reduced-voltage, auto-transformer type, closed transition motor starter. The autotransformer is located in one of the compartments of the Input Section. Potential and control power transformers are located in another of the five compartments.

Output Section

Circuit breakers for the IVR secondary and the main 20 Hz generator are located in the Output Section. An incoming line compartment is used to connect the EM pump feeder to the main bus and also mount one set of potential transformers. The two power circuit breakers are both mechanically and electrically interlocked to prevent simultaneous connection of the 60 Hz IVR and 20 Hz main generator to the main bus.

The voltage regulator for the main 20 Hz generator and the coastdown transfer circuitry are located in one auxiliary compartment while instrument transformers for the 60 Hz IVR are located in another compartment. In all, the Output Section consists of five compartments.

2.4 INSTRUMENTATION

The EM pump instrumentation consists of thermal sensors to monitor temperature throughout the system, strain gages and accelerometers to monitor stress and vibration of the major pump components, flux sensors to monitor the magnetic fields, sodium pressure and leak detectors, and cooling gas pressure and mass flow measuring elements.

2.4.1 Temperature

Two types of temperature sensors are used throughout the EM pump and its service accessories; thermocouples and RTD's (resistance temperature detectors).

Thermocouples

The thermocouples used throughout the EM pump system are Type K (chromel-alumel), sheathed .04" O.D. 304 SS), ungrounded junction, mineral (magnesium oxide) insulated elements. The response time for this type of element to reach 63.2% of an instantaneous temperature change is of the order of 18 to 20 seconds. The bend radius for the sheathed element should be as large as possible but no less than twice the sheath diameter. Each conductor is a solid, #30 AWG conductor. The ANSI color code for a Type K thermocouple is yellow. The maximum recommended temperature for a 304 SS sheathed Type K thermocouple is 1700 degrees F.

Representative thermoelectric voltages produced by a Type K thermocouple are:

Temperature (deg. F)	Voltage* (Millivolts)
75	0.955
140	2.436
370	7.649
420	8.759
850	18.702
1000	22.251
1030	22.961
1050	23.435
1200	26.975

*Reference junction at 32 deg. F.

RID

The RIDs selected for monitoring the EM Pump stator cooling gas have a repeatability of 0.025%, stability of 0.2% and a response time of less than 6 seconds to reach a 63% indication of an instantaneous temperature change. The element resistance at 32 deg F is 100 ohms, the resistance element is sheathed in 0.25 inch O.D. type 316 S.S., and the lead wires are rated for operation up to 400 deg. F.

Representative resistances as a function of temperature are:

Temperature (deg. F)	Resistance (ohms)
32	100.00
40	101.74
55	104.99
60	106.07
75	109.30
100	114.68
105	115.76
120	118.97
150	125.37

2.4.2 Vibration

Two types of accelerometers are used in the EM Pump to detect vibration of the major pump components. The primary difference between the two types is their temperature survival characteristics (500 deg F and 1200 deg F). Both types of accelerometers are designed around self-generating piezoelectric crystals.

Charge converters are mounted outside of the EM pump in the ambient environment as close to the environmental interface as possible. The charge converters compensate for the low resistance of the accelerometers operation at high temperature.

Low Temperature Accelerometers (500 Deg F)

The low temperature accelerometers are ring shaped, hermetically sealed units that are held in place by a single bolt through the center. The charge sensitivity is 10 pC/g nominal the frequency response is approximately 2 to 8000 Hz with a departure from linearity of about 1% per 400 g. The transducer is insulated from ground when the special mounting screw, teflon sleeve, and anodized mounting washers supplied by the vendor are used. A low temperature, flexible cable with miniature connectors is used. The maximum acceleration limits in any direction are 1000g, sinusoidal and 300g shock.

High Temperature Accelerometers (1200 Deg F)

The high temperature accelerometers are self generating, piezoelectric, welded units capable of operating in sodium in a nuclear environment up to 1200 deg F, with reduced performance at 1400 deg F. Electrical connection is made through a hardline, Inconel 600, mineral insulated (MgO), triaxial cable terminating in a miniature coaxial receptacle. Sealing is achieved by welding the outer cable sheath to the case of the accelerometer.

The charge sensitivity is nominally 10 pC/g with a frequency response up to 5000 Hz. The amplitude linearity is 1% per 500g, 0 to 2000g. The sensing element is electrically isolated from the case. The case and outer triaxial sheath are grounded at the transducer when the transducer is mounted. The sheath is not carried electrically through the connector. The acceleration limits are 100g peak vibration in any direction and 2000g peak shock. The pressure limitation is 60 psi.

2.4.3 Sodium Leak Detection (See Dwg. #134D1615)

The sodium leak sensing scheme involves the placement of conduction probes in areas where leaking liquid sodium would be most likely to collect. The conduction probe consists of two conductors that would be shorted together by liquid sodium.

Physically, the sodium leak detector employs two two-conductor (24 AWG each conductor) mineral insulated (MgO), 1/8 inch O.D. stainless steel (304 SS) sheath cables. The two conductors in a cable are exposed at the sensing end and brazed together to form a single contact point. The liquid sodium bridges between the contact points of the two sheathed cables. Figure 2-3 is the schematic diagram.

2.4.4 Strain Gages

The strain sensors within the EM Pump are integral lead, one-half bridge resistance strain gauges equipped with stainless steel jacketed, magnesium oxide insulated, three conductor lead cables. These gauges are spot welded to the surface to be monitored.

The strain transducers are rated at a strain level of plus or minus 61000 micro-inches per inch. The basic transducer includes a 120 ohm active platinum-tungsten alloy filament and a 120 ohm reference element in a three wire, one-half bridge circuit arrangement. The natural gauge factor is 4.5. The operable temperature range for static measurements is -452 to +950 deg F (to 1200 deg F short term) and for dynamic measurements from -452 to 1500 deg F.

The excitation current for a gauge should not exceed 50 milliamperes. The stainless steel (Type 347 SS) rigid lead wire consists of three (#30 AWG) copper conductors in swaged magnesium oxide insulation, rated to 1500 deg F and 30,000 psi. Each gauge is about one inch long with a flange for spot welding to the test specimen. The strain sensing element is protected by a stainless steel tube filled with magnesium oxide insulating powder. The tube is swage sealed. The stainless steel of the gauge is chosen to match the stainless steel of the test specimen to minimize differential stress between the sensing element and the test specimen.

2.4.5 Magnetic Flux Monitoring

Airgap Flux Sensing Coils

The magnetic flux sensing elements are individual coils placed to monitor the magnetic flux produced by the stator coils of the EM Pump.

Figure 2-3. Sodium Leak Detector Schematic (Typical)

Each sensing element is a single wire bent into a rectangular shape. The oscillating magnetic field perpendicular to the plane of the rectangular coil generates in it an EMF proportional to the strength of the magnetic flux. The single wire sensing element is made as the center conductor of a coaxial, mineral insulated (MgO), stainless steel (type 304SS), sheathed (0.040" O.D.) cable. The center conductor, concentric with the sheath of the cable to within 0.003 inches, is a # TBD AWG Type 304 stainless steel wire. The sheath of the coaxial cable forms half of the signal conducting circuit. Beyond the coil, the connecting cable is a triaxial hardline such that the outerconductor of the coil coax is electrically insulated. The air gap flux sensing elements will operate within a temperature range of 70 deg. F to 1050 deg. F. The anticipated signal level is one half to one millivolt per gauss peak at 20 Hz.

Yoke and Tooth Flux Sensing Coils

The magnetic flux within the stator yoke and teeth is monitored by two-turn #20AWG copper wire coils. The copper wire is enameled and overwound with a fiberglass insulation. These coils are serviced by twisted pair, shielded cables. The coils are operable to a maximum temperature of 400 deg. F. The anticipated output from the yoke magnetic flux sensing elements is nominally 3 millivolts per gauss peak and for the tooth sensing coils, 1 millivolt per gauss peak at 20 Hz.

2.4.6 Pressure

2.4.6.1 Pressure, Sodium Discharge

The sodium pressure sensor utilizes the principle of impedance variation dependent upon the generation of decay and eddy currents. A coil is placed in close proximity to a conducting pressure diaphragm. The observed circuit impedance is a function of the position of the conductive plate.

In the design of the transducer, two coils are used, one experiences an impedance change due to variations in diaphragm position as a function of pressure, and the second experiences no change as its relationship to a second reference conducting plate is fixed. Each coil is used as an arm of an impedance bridge. This bridge arrangement makes a transducer element that is relatively insensitive to temperature.

The pressure transducer is serviced by a two-conductor (#33AWG copper), mineral insulated (MgO), stainless steel (304 SS), 0.125 inch O.D. sheathed, welded cable. A signal conditioning electronic package is mounted within the ambient environment as close to the pressure vessel as possible.

The transducer is sensitive to pressure variations between 5 and 250 psi over an operating temperature range of -100 deg. F. to 1050 deg. F. The frequency response of the system is limited by the characteristics of the diaphragm to about 8000 Hz. The output voltage from the signal conditioning electronics is 0-10 VDC corresponding to 0-250 psi.

2.4.6.2 Cooling Gas Pressure

Two types of stator cooling gas pressure transducers and transmitters are employed to help monitor the pump performance. One pressure element senses the cooling gas inlet pressure, the other senses the differential pressure between the inlet and the outlet. Both transducers measure the deflection of a diaphragm by means of a resistive strain gauge bridge. A stable voltage source, compensation and calibration elements are included in the pressure transducer/transmitter housing.

The inlet pressure monitor will sense 0 to 25 pounds per square inch absolute with a 4 to 20 milliamper output signal. The operating temperature range is 20 deg. F. to +250 deg. F. The frequency response is 0 to 2 Hz.

The differential pressure monitor will sense the pressure drop as the cooling gas is circulated through the EM Pump. The gauge is unidirectional and will sense a differential pressure of 0 to 50 inches water (0 - 1.7 psi) with a base pressure differential of 100 psi maximum. The output is a 4 to 20 milliamper DC signal.

2.4.7 Miscellaneous

2.4.7.1 Cavitation Monitor

The cavitation monitor is a self-generating piezoelectric hydrophone designed to be immersed in the liquid sodium.

The specific details of the hydrophone design and operation are TBD.

2.4.7.2 Cooling Gas: Mass-Flow Monitor

The cooling gas mass flow monitor is a complete system consisting of three transducers observing the gas stream and a mass flow computer providing a 4 - 20 Ma signal output representing the percentage of the maximum possible mass flow rate per hour for which the instrument is calibrated.

The mass-flow rate computer computes the basic equation for mass flow:

$$Q = K(P \text{ } dP/T)^{\frac{1}{2}}$$

where:

Q = Mass-flow rate (18,00090,000 lbs N₂/hr)

K = A constant

P = Absolute gas pressure (13.7 15 psia)

dP = Differential pressure (approx. 0.5 inches
water)

T = Temperature (515 565 deg. R)

providing automatic compensation for pressure and temperature variations.

2-23 Description
12/13/76

2.4.7.3 Cooling Gas - Flow Control Damper Position

The position of the flow control damper is indicated by three camactuated switches operated from the shaft of the positioning motor. Three indicator lights on the operator's control console indicate the positions of the damper, fully opened, fully closed, and less than 20% open.

2.4.7.4 Cooling Gas - Water Flow Bypass Control Valve

The water flow bypass control valve is operated automatically to control the flow of water through the water-cooled heat exchanger coil. The feedback sensor for the control unit is the RTD element monitoring the outlet gas flow from the stator assembly of the EM Pump. The valve actuator has a slide-wire position transducer feeding back to the controller at the control console. The position readout is 0-100% opening.

2.4.7.5 Cooling Gas - Humidity

The relative humidity of the cooling gas is continuously monitored, primarily to sense a water leak in the water cooled heat exchanger coils.

2.4.8 Calibration

Most of the sensors are permanently attached within the EM pump system at inaccessible locations. Therefore, NBS traceable calibration data and certification have been obtained from each sensor/transducer manufacturer. The transducers will be checked at installation for electrical performance, and these checks will be repeated each time the system is returned to a normal reproducible set of conditions. Any change in performance will be indicative of a shift in calibration.

3.0 RECEIVING, HANDLING, AND STORAGE

	<u>Page</u>
3.1 General	3-1
3.2 Cooling Unit	3-3
3.2.1 Receiving	3-3
3.2.2 Handling	3-3
3.2.3 Storage	3-3
3.3 Power Supply	3-4
3.3.1 MG Set	3-4
3.3.2 Inductions Voltage Regulator	3-4
3.3.3 Capacitors	3-4
3.3.4 Switchgear and Controls	3-4

3.0 RECEIVING, HANDLING AND STORAGE

3.1 GENERAL

Immediately upon receipt all packages and parts should be inspected for damage and evidence of exposure to weather, foreign substances, and forces which could cause deformation or breakage. This should be done in accordance with GE specification 23A2154, Procedure for Shipping and Receiving Parts and Equipment for 14,500 GPM Pump (at LMEC). This specification also includes directions for unloading and storage.

Prior to removing equipment from the carrier vehicle, receiving personnel shall perform the following:

1. Take photographs of the shipping container exterior, adequate to show how it is positioned on the truck when received. Additional photographs should be taken as evidence of damage to exterior of container or any abnormal appearance.
2. The exterior of the shipping container shall be further inspected for evidence of damage. If the container is damaged an assessment should be made to determine the probability of damage to the component. Any damage should be reported and documented on the carrier receiving record before sign-off. Minor damage to the container that does not violate the double layer of seal material shall be noted, with photographs, for record purposes. If the sealed envelope is breached, the vessel in its container, shall be removed from the carrier and the condition reported to the GE Site Representative prior to proceeding with the remainder of the receiving inspection.
3. Condition of the dessicant shall be recorded. An unsatisfactory humidity condition as shown by the indication(s) of dessicant color, collections of moisture, or stains shall be reported to the GE Site Representative.
- 4.. Check for shipping documents. Any shortages or missing documents shall be reported to the GE Site Representative.
5. Check shipment container for appropriate identification of the part or parts contained.

If the exterior of the shipping container is in good order and other items are satisfactory, place the unit in temporary storage in accordance with specification 23A2154. If components are to be delivered directly to CHCF for assembly, proceed as indicated in specification 23A2068.

Receiving inspection of all parts, vessels, and assemblies shall be performed as soon as possible after arrival of the shipment at the SPTF site.

Area Requirements

The approximate areas required to store these components within their shipping containers are provided as information.

<u>Pump Component</u>	<u>Floor Space (ft.)</u>	<u>Height (ft)</u>
Stator	320 (35x8)	7
Duct	210 (26x8)	8
External Support Vessel	240 (8x30)	8
Ext. Thermal Insulation Assembly	240 (8x30)	8
Stator Guide Cylinder	256 (8x32)	8
Coolant Gas Manifold	64 (8x8)	6
Vent Pipe Assembly	34 (17x2)	2

Crane Service Requirements

Components in storage should be handled only in their containers. Handling procedures and sling attachments shall be as described in GE Specification 23A2068.

Pump Installation

Detailed instructions for assembly and installation of the pump in the FFTF pump tank in the SPITF test loop are found in GE Specification 23A2068, starting with step 34.

3.2 COOLING UNIT

3.2.1 Receiving Inspection

Immediately upon receipt all components should be inspected for damage and evidence of exposure to weather, foreign substances, and forces which could cause deformation or breakage. If the component is not to be assembled and installed upon receipt, see paragraph 3.2.3 for storage instructions.

3.2.2 Handling

All handling, lifting and supporting of the cooling unit shall be done only at the points provided for such activities.

The cooling unit shall be righted from its shipping position (horizontal) by lifting at the top two eyes on the structure and allowing the base to act as a pivot. A "tailing" line must be used to prevent rocking when nearing a vertical position.

Lifting of the structure or assembled unit shall be from all four eyes using the strongback provided.

3.2.3 Storage

If the cooling unit is not immediately installed in SPTF, and if temporary storage is required, there are two options of storage possible: assembled or disassembled.

If the unit has been assembled (motor, fan and inlet core installed) it can be stored by attaching the provided protection flange covers and closing all doors and hatches.

To store the unit in its partially assembled (shipping) condition replace all of the protective covers.

3.3 POWER SUPPLY T&D

- 3.3.1 M.G. Set
- 3.3.2 Induction Voltage Regulator
- 3.3.3 Capacitors
- 3.3.4 Switchgear and Controls

4.0 ASSEMBLY AND INSTALLATION

	<u>Page</u>
4.1 Pump Assembly	4-1
4.2 Pump Installation	4-1
4.2.1 Mechanical	4-1
4.2.2 Electrical Power	4-1
4.2.3 Instrumentation and Control	4-2
4.3 Cooling Unit	4-3
4.2.1 Checkout Cooling Unit	4-3
4.2.1.1 Water Leak Check	4-3
4.2.1.2 Gas Leak Check	4-3
4.2.1.3 Damper Operations	4-3
4.2.1.4 Blower Test	4-4
4.2.1.5 Water Control Test	4-4
4.2.1.6 Nitrogen Purge	4-4
4.2.1.7 Humidity Alarm Set-Point	4-4
4.3 Power Supply	4-5
4.3.1 Checkout Power Supply	4-5
4.3.1.1 MG Set Alignment	4-5
4.3.1.2 Airgap adjustment and measurement	4-6
4.3.2 Insulation Resistance Check	4-6
4.3.3 Winding Resistance Check	4-7
4.3.4 Switchgear Operation	4-7
4.3.4.1 MG Set Control	4-8
4.3.4.2 IVR Control	4-8
4.3.5 MG Set Startup	4-8
4.3.6 Transfer Switching	4-11
4.3.7 Check Instrumentation	4-11
4.4 SPTF Readiness	4-12

4.0 ASSEMBLY AND INSTALLATION

4.1 PUMP ASSEMBLY

Pump assembly and installation is described in GE Specification 23A2068.

4.2 PUMP INSTALLATION

4.2.1 Mechanical

Pump installation is described in GE specification 23A2068 paragraphs 4.39-4.40.

4.2.2 Electrical Power

Terminals T1 through T6 should each be connected to one or more conductors capable of carrying 500 amps at 4000 volts. Arrange the conductors in conduits or cables as shown in Dwg. 198B7817. The power terminal box, located at the top of the EM pump, contains terminals T1 through T6, and six tapped holes for grounding cable shields, if used. The top of the terminal box is a 3/8 inch thick plate which can be machined to adapt to the incoming power cables. Space is provided in the box for 6 750 mcm cables or equivalent.

Access to the terminals within terminal box is achieved by the removal of the cover and two sides of the terminal box.

Since the EM pump connections to the power cables must be insulated, the power cables must be identified with the same markings as the EM pump terminals to which they are connected, i.e., T1 to T1, T2 to T2, etc. The terminal connectors of the power cable should be identified by stamping them with 0.25 inch high characters. Also, mark the conductors with non-conducting labels beyond the point where insulation will be applied. At the other end of the cables mark conductors in a similar manner. A continuity check must be conducted on each conductor to confirm that they are properly identified.

CAUTION:

FAILURE TO IDENTIFY THE POWER CABLES PROPERLY CAN RESULT IN EITHER REVERSAL OF FLOW OR PHASE BUCKING WHEN PUMP IS CONNECTED TO INCOMING POWER.

CAUTION:

FAILURE TO CONNECT INCOMING POWER TO THE PUMP WITH THE PHASE SEQUENCE AS SPECIFIED COULD RESULT IN A REVERSAL OF FLOW AND THE DEVELOPMENT OF HIGH PRESSURE AT THE INLET. THE USER SHALL TAKE THE NECESSARY ACTION TO SEE THAT THE CORRECT POWER PHASE SEQUENCE IS APPLIED. USE OF AN ELECTRICAL PHASE SEQUENCE INDICATOR IS RECOMMENDED.

Connect the power cable at the pump terminals but not at the capacitor equipment terminal box. Assure that the EM pump stator is thermally stabilized as indicated by constant stator thermocouple output over the previous four hour period.

With a low resistance ohmmeter or bridge (1% over 0.05-0.5 ohm range) measure the resistance of each phase winding at both the EM pump terminals and at the cable-ends at the capacitor equipment terminal box.

The resistance data obtained at the EM Pump terminals should agree with factory data within $\pm 5\%$ when corrected to the same ambient temperature.

Record the resistance data for the three windings at the two places and the temperature of the windings at the time of test.

4.2.3 Instrumentation and Control

Connect thermocouples using chromel-alumel wire according to drawing TBD. The flux sensors leads should be connected per drawing TBD using standard instrument leads.

4.2 COOLING UNIT

The cooling unit will be shipped assembled and complete except for the motor and blower assembly and the inlet cone. These are to be attached as shown on GE drawing . TBD.

The installation of the cooling unit at the SPTF elevation of 175 feet shall be subject to the interfacing connections with LMEC as shown on GE drawing 852E649.

4.2.1 Checkout Cooling unit

Prior to first operation of the EM pump (prior to sodium fill), the cooling unit should be checked out as indicated in paragraphs 4.2.1.1 through 4.2.1.7.

The EM pump stator cooling unit shall be checked for proper operation and adjustment range of cooling gas flow. For this test electrical power must be available to the cooling unit and the water chiller and evaporative cooling towers must be operational.

4.2.1.1 Water Leak Check

Turn on the chilled water pumps and throttle return as is necessary to maintain a pressure (up to 50 psig) at the cooling unit. Inspect all piping, heat exchanger headers and heat exchanger tubes for water leaks. Use the access doors in the side of the cooling unit plenum to enter the plenum and inspect for tube and header water leaks.

4.2.1.2 Gas Leak Check

With all vents closed, pressurize the gas cooling system with nitrogen at the highest possible pressure up to 1.7 psig. Check for leaks and seal as necessary to minimize nitrogen consumption.

4.2.1.3 Damper Operation

Use the damper control switch in the SPTF control room to run the damper actuator throughout the full range. Visually verify that the actuator does move the vanes all the way and the control room position indicating lights correspond to the fully closed, 20% open and 100% open positions of the damper vanes. Verify that the 20% limit switch stops the actuator and that the bypass switch can be used to fully close the damper if the blower motor is not energized.

4.2.1.4 Blower Test

Pressurize the cooling system with nitrogen at 5 inch (water) gage. Run the damper actuator to the 20% open position and start the blower motor. Verify that the damper closing bypass switch is disabled when the blower motor is running. Check for proper direction of blower rotation and correct if necessary. Check the mass flow meter for an indication of appropriate gas flow. When normal operation is obtained, adjust the damper position to produce increasing steps of about 10,000 pounds (gas) per hour and manually record damper position, mass flow and blower motor voltage, current and power. With motor current at rated value record all data. Reduce the gas flow to values which repeat those used when increasing flow, and record the same data. Return the damper to the open position corresponding to operation at rated motor current and proceed directly to the test of water controls.

4.2.1.5 Water Control Test

At the indicator-controller in the SPTF control room, operate the manual switches to verify that the chilled water control valve can be opened and closed. With automatic operation, move the set-point to correspond to temperatures above and below the cooling gas temperature. Verify that appropriate movement of the valve is obtained for each set-point condition. Move the set-point to 100 degrees F. and allow the blower to raise the gas temperature to this level. Verify that stable temperature regulation is obtained; adjusting, if necessary, the proportional, reset and rate adjustments of the controller.

4.2.1.6 Nitrogen Purge

Stop the blower motor and fully close the damper. At the top of the cooling unit near the damper, open the purge valve (NOTE - the purge valve may be used to throttle the expelled gas and control the inlet nitrogen flow up to the limit of the nitrogen makeup supply rate). Continue to purge until the exhaust gas contains less than 2% oxygen. Close the purge valve and return the damper to 20% open.

4.2.1.7 Humidity Alarm Set-Point

Set the humidity meter-relay to close the alarm circuit at a relative humidity 5 percentage points above the level then measured in the cooling gas system.

Record the verification of completion of the water and gas leak checks, damper operation, water control test and purge operation. The data for the blower test shall also be recorded.

4.3 POWER SUPPLY*

Installation of the power supply equipment including switch-gear, M-G set, capacitor equipment, and IVR will follow normal industrial practice for similar equipment. Installation procedures will be supplied in GE Technical Manual TBD.

4.3.1 Checkout Power Supply - No Load

4.3.1.1 M-G Set Alignment

The shafts of the motor and generator must be properly aligned in order to avoid shaft flexure and excessive vibration. The base must be firmly anchored to floor/foundation and supported at load-bearing areas before proceeding.

With maximum separation of coupling-halves, measure the separation at eight points equally spaced around and near the outer circumference of the coupling face. Move or shim one or both of the machines to make the faces parallel and make all eight readings 0.001 inch or less.

With a dial indicator, measure the runout of one coupling with respect to the other. Move or shim one or both of the machines to reduce the run-out and align the shaft centers. Check and, if necessary, correct the parallelism. Repeat until the coupling faces are parallel within 0.001 inch when measured as described above, and the total indicator run-out for shaft centering does not exceed 0.002 inch.

Record final data giving eight values of separation and the total indicator run-out.

*All of section 4.3 is preliminary.

4.3.1.2 Air Gap Adjustment and Measurement

The air gap around the periphery of the rotor of the motor and generator must be equalized as described herein. Before proceeding, the shafts of all units must have been aligned in accordance with paragraph 4.6.1.1. Bearing pedestals must be secured to the base and oil lift pumps checked out and operating.

Using a step- or wedge-type gap guage, measure the air gap between the rotor and stator at four points at each end of the rotor. Shift and shim the stator as required to reduce the difference to less than 0.020 inch. Mark a point on the rotor and rotate this mark to each of the vertical and horizontal centerline positions and to the four intermediate positions (45 degrees apart) and at each point measure the air gap on each end of the rotor. Shift and shim the stator to reduce the difference between diametral pairs to less than TBD inch.

The air gap is set when the rotating air gap differential criterion is satisfied.

Record the final rotating air gap measurements as taken at both ends of the rotor.

4.3.2 Insulation Resistance Check

The insulation resistance of the power and control conductors shall be measured as described herein before application of normal power in order to avoid short circuits.

Before proceeding see that all ground conductors, all potential transformers, all electronic solid-state control equipment and all power factor correcting capacitors are disconnected during the test. The operating voltage of the insulation resistance meter shall be at least 1000 volts for both power and control circuits.

With the EM pump stator power cables disconnected from the rest of the system and with the phases not interconnected measure the insulation resistance between each phase and from each phase to ground.

Switches may be closed to interconnect for test purposes as much of the electrical circuit as possible except that machine, pump, and IVR windings shall be checked separately. Systematic measurements shall be made to assure checkout of all parts of the circuit.

The insulation resistance shall be measured between the three phase conductors and from each phase conductor to ground.

The insulation resistance shall not be less than 5 megohms.

Record the insulation resistances and ambient temperature of the motor, generator IVR and EM pump and the lowest insulation resistance observed on the rest of the system.

4.3.3 Winding Resistance

The electrical resistance of the main windings of the electrical apparatus must be measured with a precision ohmmeter in order to verify both the circuit continuity and the status of the circuit as compared with data from similar factory tests.

Before proceeding with the test see that the apparatus is thermally stable at ambient temperature conditions.

Measure the resistance of all windings of the drive motor, main generator, control power generator and induction voltage regulator.

All data must agree with factory data within plus or minus 10% when corrected to the same ambient temperature.

Record all data.

4.3.4 Switchgear Operation

All circuit-breaker coils and control and protective circuits are to be connected to electrical power and checked as described below.

Before proceeding with the test see that (1) in both the input and output sections, all circuit-breakers are in the "test" position (primary contacts disconnected); (2) all switches are in the open position; (3) the insulation resistance (4.1.2) is satisfactory; (4) all circuits are cleared for operation and 4160 volts are applied to the motor starter section; and (5) the switchgear battery is connected and charged.

4.3.4.1 M-G Set Control

Simulate a motor start (motor not connected) and verify that the circuit-breakers operate with the correct sequence and timing. Refer to the M-G Set O & M Manual. In turn, actuate each protective relay and verify that the RUN circuit breaker opens.

During a simulated motor starting sequence when in the START condition, actuate the starting overcurrent relay and verify that the START circuit-breaker opens and the motor starting sequence is terminated

Close the generator circuit-breaker and actuate each protective relay to verify generator trip control.

4.3.4.2 IVR Control

Close the induction voltage regulator primary and secondary circuit-breakers to the OPERATING position. Verify that the output voltage can be adjusted throughout the range given by the nameplate. Restore both circuit breakers to the TEST position.

Verification of proper operation should be recorded.

4.3.5 M-G Set Startup

Verify that the M-G set operates properly with correct rotation, generates a potential and that the voltage regulator for the generator operates as described below.

Before proceeding verify that the M-G set is aligned (4.6.1), resistance data (4.6.2 and 4.6.3) are satisfactory, switchgear is operative (4.6.4), bearing lube oil levels are correct, lube rings are free, oil lift pumps are operating and generator output circuit breakers are open.

With an observer stationed to observe the M-G set, jog the drive motor to verify direction of rotation. Because acceleration is rapid, continue to observe as motor coasts to stop to verify direction of rotation. Observe and record the starting current inrush and line voltage just after starting. Verify that the motor starter sequences to apply full line voltage to the motor and the inrush current does not exceed 1800 amps. Check all bearing pedestals for proper operation of the lubricating oil rings, as indicated by TED.

Check entire set for satisfactory operation in accordance with the M-G set operation and maintenance manual. Energize the voltage regulator for the control power generator and check the output voltage of the control power generator. Energize the voltage regulator for the main generator, manually raise the generator voltage to rated voltage, and check output phase sequence.

Check output voltage of the tachometer generator. Check all features of the voltage regulator including the automatic voltage reduction with speed which occurs upon loss of electrical power to the drive motor. Set all protective devices in accordance with the following list:

TABLE 4-1

Protective Device Settings

		<u>Nominal Set Point</u>	<u>Relay Tap</u>	<u>Setting Time Dial</u>
<u>Drive Motor Protective Devices</u>				
Function: Interrupts Drive Motor power				
50/51-DMR-A/B/C	Motor Running Current High	800 amp	TBD	TBD
50/51-DMS-A/B/C	Motor Starting Current High	1800 amp	TBD	TBD
50GS-DM	Motor Ground Current High	15 amp	TBD	TBD
27/47-DM	Motor Supply Voltage Low or			
	Phase Sequence Reversed	3400 volt	TBD	TBD
87-DM	Motor Differential Current			
	High	20 amp	TBD	TBD
<u>Induction Voltage Regulator Protective Devices</u>				
Function: Interrupts IVR primary power				
50/51-IVRP-A/B/C	IVR Primary Current High	50 amp	TBD	TBD
	IVR Primary Ground Current			
50/41N-IVRP	High	15 amp	TBD	TBD
24/47-IVRP	IVR Primary Voltage Low	1000 volt		
<u>EM Pump Protective Devices</u>				
Function: Interrupts power to EM pump from either the Main Generator or IVR. Leaves the IVR energized and the M-G set running except 87-GEN which also stops the M-G set.				
50/51-IVRS-A/B/C	IVR Secondary Current High	75 amp	TBD	TBD
	IVR Secondary Ground			
50G-IVRS	Current High	10 amp	TBD	TBD
	EM Pump, Differential			
87-EMP	Current High	20 amp	TBD	TBD
	Generator Differential			
87-GEN	Current High	20 amp	TBD	TBD
50/51-GEN-A/B/C	Generator Current High	1000 amp	TBD	TBD
59-GEN	Generator Voltage High	4100 amp	TBD	TBD
509-GEN	Generator Ground Current High	10 amp	TBD	TBD

* Contact closure for alarm in SPTF Control Room

Certification of proper operation should be recorded

4.3.6 Transfer Switching (HOLD)

Check operation of capacitor switches and the circuit breakers in the output section of the switchgear as the M-G set coasts to switching speed and switches over to the IVR and the IVR continues to supply power in a simulated coastdown.

During this test all switchgear output section power circuit breakers shall be in the "test" position (load contacts disconnected). Start the M-G set. Connect a chart recorder, or use the Data Acquisition System (DAS), to record the status (open/close) of the capacitor switches, the main generator breaker and the induction voltage regulator secondary circuit breaker and the output voltage of the main generator. Raise the main generator voltage to 1000 volts. Simulate a loss of power to the M-G set drive motor. Refer to the M-G set operation manual for instructions to set the timing of the coast-down transfer circuit.

Preserve the chart recording (or DAS printout) of the transfer switching. Record the time scale, the voltage scale and the status condition (open/close).

4.3.7 Check Instrumentation

Check all sensors for output as appropriate for the existing conditions. The sensors are identified on the following drawings:

852E274	ICD - EM Pump (Sheet 4)
852E649	ICD - EM pump Cooling Unit
852E650	ICD - Motor Generator Set
852E656	ICD - Switchgear and Control-Output Section
852E657	ICD - Switchgear and Control-Input Section
TBD	ICD - Termination Box

4.4 SPTF READINESS

Before attempting to operate the EM pump, installation of all equipment must be completed in accordance with Section 3. In addition, SPTF facilities and services must be modified as described in SDD 48-SA-001 (SPTF) because of certain requirements which differ from requirements of the FFTF mechanical pump test. These major modifications are:

- a. The EM pump requires a surge tank connected to nozzle N-6 of the pump tank to compensate for the smaller gas volume caused by the displacement of the EM pump in the FFTF pump tank. The surge tank must be equipped with a sodium level sensor and provisions to add and control inert cover gas.
- b. The stator cooling unit for the EM pump will require chilled water at 40 deg. F from the existing SPTF water chiller. The heat rejection will be 1.4 million Btu/hr. For further details see ICD 852E649.
- c. The motor-generator set requires indoor installation on an appropriate concrete foundation. For further details see ICD 853E650.
- d. The induction voltage regulator, and the metal-clad switchgear must also be installed as part of the pump power supply system, see ICD's 852E658, 852E656 and 852E657.
- e. The power capacitor bank must be installed near the EM pump in a safety enclosure. For further details see ICD 852E659.
- f. Interfaces for the EM pump are found on ICD 852E274.
- g. In addition to the major apparatus mentioned above the EM pump test will require the data channels listed in Table V of Test Request, GE Spec. 22A3938.
- h. A submersible hydrophone (to be supplied by ANL). to detect bubble collapse noise due to cavitation, must be installed in the line connecting the FFTF pump tank to the surge tank.

5.0 OPERATION

	<u>Page</u>
5.1. Power Supply System	5-1
5.2 Pump Operation	5-5
5.3 Sodium Fill	5-6
5.4 First Time Operation	5-7
5.5 Operating Characteristics of the Pump	5-7
5.6 Operating Limits	5-11
5.7 Normal Shutdown	5-12
5.8 Emergency Procedures	5-12

5.0 OPERATION

5.1 POWER SUPPLY SYSTEM

5.1.1 Basic Functions

The basic functions to be controlled by the operator are:

1. Starting and adjusting the stator cooling unit, water chiller, evaporative cooler, and those auxiliary systems associated with the SPTF,
2. Starting the M-G set,
3. Closing the generator circuit breaker to connect the M-G set to the EM pump, and
4. Adjusting the output voltage of the main generator.

The pump pressure and flow are changed either by adjusting the voltage applied to the EM pump or by changing the hydraulic resistance in the SPTF sodium loop. These instructions are limited to pump voltage adjustment; for adjustment of hydraulic resistance, refer to LMEC instruction for SPTF operation.

The devices available to the operator for EM pump control are listed in Table 5.1-1. For test facility controls, refer to LMEC instructions for SPTF operation.

5.1.2 M-G Set Start and Run

The M-G drive motor starter is interlocked so that the oil-lift pumps must be running before the drive motor can be started. The oil-lift pump motor control is located at the switchgear input section within the M-G building.

Before starting the oil-lift pumps, check the M-G set and nearby area to be certain that all is ready for M-G set operation. After starting the oil-lift pumps, check each bearing for adequate oil flow.

The oil-lift pumps are started by pushbuttons located on the incoming line unit of the switchgear input section.

CAUTION: THE EM PUMP MUST BE DISCONNECTED
DURING THE STARTUP OF THE M-G SET.

It is recommended that the M-G set drive motor be started from the control switch at the switchgear input section and not from the SPTF control room even though provisions are made for the installation of a control switch in SPTF and the switch is listed in Table 5.1-1. The control switch at the switchgear allows the operator to observe and hear the startup and, consequently, to de-energize the motor if any abnormal conditions develop during start-up.

To start the M-G set drive motor, turn the control switch from the center position to START and then release the handle. The handle will return to the center position, for details of the motor starter sequential action in response to the control switch operation, refer to ---TBD---.

After the M-G set is running, check the bearing lubrication, the control power generator voltage and the operation of the main generator excitation system.

- o At each of the six bearing pedestals, remove the cover and check the oil ring. The oil ring should be turning with the shaft; if not, use a clean, smooth, wooden dowel to dislodge and start the ring.
- o At the switchgear output section, check the voltage of the control power generator. The voltage should be in the range of 220 to 260 volts. If the voltage is not within this range, refer to ---TBD---.
- o Before energizing the pump, turn the control generator transfer switch to LOCAL and gradually raise the main generator output voltage by turning the GEN VOLTS ADJ control. Bring the voltage to 4000 volts and turn switch to REMOTE. If the generator output voltage does not respond, refer to ---TBD---.

TABLE 5-1 OPERATOR'S CONTROL FUNCTIONS

<u>FUNCTION</u>	<u>DEVICE</u>	<u>DESCRIPTION</u>
Pump Voltage Control, Generator Power	Multi-turn Potentiometer	Turn-counter with logging scale dial, Zero position interlock with Generator Breaker
Pump Voltage Control, IVR Power	Multi-turn Potentiometer	Turn-counter with logging scale dial. Zero position interlock with IVR Breaker.
Power Source Selection (IVR/Generator)	Rotary Switch	3-position, IVR-OFF-GEN, for control of 52-IVRS and 52-GEN
IVR Primary Circuit Breaker Control	Rotary Switch	3-position, spring return to center (TRIP- CLOSE with center not marked.
M-G Drive Motor Starter	Rotary Switch	3-position, spring return to center (START-STOP with center not marked.)
Status Indication, Pump Power Circuit Breakers (IVR and GEN)	Indicating Lights (one pair for each circuit breaker)	Red for breaker closed, Green for breaker opened, (recommended colors)
Status Indication M-G Drive Motor Starter	Indicating lights (one light for STARTING, one for STOP)	Red for Stopped, Amber for Starting, Green for Running (recommended colors)
IVR Control Transfer SPTF/M-G Building)	Selector Switch	2-position, LOCAL- REMOTE - allows (IVR operation in M-G Building (for main- tenance purposes only)
IVR Mode Selection (Manual/Automatic)	Selector Switch	2-position, MANUAL-AUTO
Blower Motor Control	Pushbuttons (2)	Momentary contact, START-STOP

TABLE 5-1 (continued)

<u>FUNCTION</u>	<u>DEVICE</u>	<u>DESCRIPTION</u>
Pump Cooling Gas Flow Control	Switch	3-position, spring return to center, RAISE -* -LOWER * BLANK
Pump Cooling Gas Temperature Control	Process Controller	Position regulator for the Chilled Water Control Valve (in Cooler Unit) with proportional, reset adjustments. Valve (in Cooler Unit) with proportional, reset and rate controls and adjustments. Feedback from RTD in Pump Cooling Gas Outlet.
Indication, Cooling Gas Humidity	Analog Readout with Alarm Contacts	Input: 4-20 ma Scale: 5% to 95% RH
Indication, Blower Motor Power	Analog Readout	Input: 4-20 ma Scale: 0 to (250) kW HOLD
Indication, Generator Electrical Output	Analog Readout (Volts, Amperes)	Input: 4-20 ma Scale: Per instrument transformer ratios
Indication, IVR Electrical Output	Analog Readout (Volts, Amperes)	Input: 4-20 ma Scale: Per instrument transformer ratios

5.2 PUMP OPERATION

5.2.1 Preheat of Pump

The pump must be preheated before being filled with liquid sodium. The pump vent pipe is heated by electric resistance elements which obtain power and temperature control from SPTF facility apparatus. The external support vessel is heated by radiation and convection from the pump tank which, in turn, is heated by the SPTF trace heating system. The lower pump duct is heated by conduction through the metal from the upper duct and also by radiation and convection from the pump tank. The part of the pump duct within the stator is inaccessible for external heat sources and must be heated from within by induction from the stator windings.

The magnetic flux of the stator induces an electric current in the walls of the duct. This current, passing through the electrical resistance of the duct material, generates heat. Some of this heat is normally transferred to the stator cooling gas and much of the heat is normally removed by the sodium. But when the duct is empty the heat transfer is slow and the magnetic flux must be limited to prevent overheating. Since the power is proportional to voltage squared, the applied voltage during preheat must be kept low, below 200 volts.

The pump should be preheated according to the following steps:

- a. The pump duct will be filled with a high purity inert gas such as argon having less than 10 ppm of contaminants.
- b. Stator cooling unit must be operating with minimum gas flow (minimum damper setting).
- c. Turn on pump tank and vent pipe heaters and energize the pump stator at minimum voltage (not more than 145 V) 20 Hz. Raise the voltage by 25 volt increments every 12 hours up to 200 volts.
- d. As the duct heats, adjust the tank and vent pipe heaters so their hottest thermocouple is always at a lower temperature than the hottest duct thermocouple and is not more than 25 deg. F below it.
- e. When the hottest duct thermocouple reaches 400 deg. F (about 3 days), adjust stator voltage as required to maintain 400 deg. F until sodium is loaded.

CAUTION: THE MAXIMUM SPREAD OF TEMPERATURE INDICATED BY ALL DUCT THERMOCOUPLES SHALL NOT EXCEED 150 DEG F DURING DUCT PRE-HEAT. IF THIS SPREAD IS EXCEEDED, REDUCE STATOR VOLTAGE TO NEXT LOWER VOLTAGE WHICH WILL MAINTAIN CONDITIONS WITHIN ALL LIMITS.

5.3 SODIUM FILL

5.3.1 Prior to Sodium Fill:

- o Leak check the pump and pump tank per LMEC procedure.
- o Purge the loop of oxygen and inert with argon (SDD-48-SA-001, Vol. II, paragraph 3.2.1).
- o Preheat the duct and the vent pipe according to paragraph 5.2.1. The temperature shall be checked on sensors 105A, 1C1-6, 1C1-9, 1C1-14, and 1C1-16.*
- o Assure that the freeze vent is clear of sodium for the start of the sodium fill operation and that inert gas passes through it freely.
- o Shut off power to the heater in the freeze vent (VH5).* The temperature on the freeze vent pipe (1C1-1) should read less than 120 deg F.
- o Verify that the sodium leak detectors (107A and B, 109A and B, 112A and B) circuits have correct continuity. The two leads 107A shall indicate continuity; the same is true for 107B, 109A, 109B, 112A and 112B. Verify that continuity is not indicated between 107A and 107B or between 109A and 109B or between 112A and 112B.*

5.3.2 Sodium Filling

The filling of the main flow loop (MFL) in SPTF with sodium shall be done in accordance with LMEC SDD-48-SA-001, Vol. II, paragraph 3.2.3.

When sodium freezes in the freeze vent line, the vent line isolation valves should be closed, and the cover gas system returned to normal control. The levels in the pump tank and expansion tank should be established within the normal operating range.

* (For LMEC designations see App. A).

5.4 FIRST TIME OPERATION

IN ALL CASES WHERE TURNING VOLTAGE ON OR OFF IS REQUESTED OR WHERE STARTUP OR SHUT-DOWN IS REQUESTED, CONTROL MUST BE EXERCISED THROUGH THE M-G SET VOLTAGE REGULATOR. THE PUMP CIRCUIT BREAKERS MUST NOT BE OPENED OR CLOSED WITH POWER ON. (SEE TEST SEGMENT B9, TABLE IV, GE SPEC 22A2068 TEST REQUEST).

5.4.1 First Time Operation

Verify that all auxiliary systems (power supply, cooler, instrumentation and protection) are operating properly and that the pump is correctly connected. After sodium is loaded verify that the sodium level in the tank is within system limits, inlet pressure is 15 psig, stator cooler is on full flow and the loop hydraulic resistance is at the lowest setting (#R11 in Spec #22A3938).

Verify that flow is in the correct direction (not reversed) by making a combination of checks including pressure, flow, and temperature indications.

When forward flow is confirmed, increase voltage by 50 volt increments to 1000 volts, review all instrument readings, and compare with calculated factory data.

CAUTION: DO NOT APPLY MORE THAN 250 VOLTS UNLESS THERE IS A POSITIVE INDICATION OF FLOW IN THE FORWARD DIRECTION.

5.4.2 Routine Startup

Startup of the pump will always be from minimum voltage (approx. 80 volts) which will normally be assured by a control interlock.

5.5 OPERATING CHARACTERISTICS OF THE PUMP

The EM pump is normally powered by the M-G set and the hydraulic output of the pump is adjusted by changing the voltage of the main generator/EM pump power circuit. This voltage is controlled by the setting of a potentiometer on the operator's control panel.

Pump voltage, and consequently the pressure developed by the pump, is increased by turning the potentiometer clockwise. The calculated pressure flow characteristics for 20 Hz and 60 Hz operation at a sodium temperature of 858 deg. F are shown in Figs. 5-1 and 5-2. A summary of the pump operating characteristics is given in Tables 5-2 and 5-3.

TABLE 5-2

Calculated Nominal Operating Conditions at 20 Hz

14,500 gpm - 183 psi Developed Head - 12 psia Inlet Head

		<u>400 deg F</u>	<u>600 deg F</u>	<u>858 deg F</u>	<u>1000 deg F</u>
Line Voltage	V	3055	3080	3235	3470
Pump Phase Current*	A	509	473	435	378
Generator Line Current**	A	663	610	598	463
Pump Power Input	KW	2450	2455	2520	2535
Pump KVA Input	KVA	4660	4370	4220	3950
Generator KVA Output	KVA	3505	3255	3075	2785
Pump Efficiency	%	47.1	47.1	45.8	45.5
Pump Power Factor	%	52.6	56.0	59.6	69.2
Generator Power Factor	%	69.9	75.5	82.0	91.1
Pump Power Output	KW	1155	1155	1155	1155
Heat Input to Sodium	KW	2220	2240	2320	2370
Heat Input to Nitrogen	KW	233	211	195	167

TABLE 5-3

Calculated Nominal Operating Conditions at 60 Hz

1,450 gpm - 1.83 psi Developed Head

		<u>400 deg F</u>	<u>600 deg F</u>	<u>800 deg F</u>	<u>1000 deg F</u>
Line Voltage	V	1835	1695	1525	1295
Pump Phase Current*	A	130	121	108	90.6
IVR Line Current**	A	34.2	35.1	38.1	41.2
Pump Power Input	KW	107	103	100	92.0
Pump KVA Input	KVA	722	617	498	359
IVR KVA Output	KVA	108	103	100	92.0
Pump Efficiency	%	1.08	1.12	1.15	1.25
Pump Power Factor	%	14.7	16.7	20.1	25.6
IVR Power Factor	%	98.7	99.8	99.7	100
Pump Power Output	KW	1.15	1.15	1.15	1.15
Heat Input to Sodium	KW	61.3	54.7	45.9	36.6
Heat Input to Nitrogen	KW	45.4	48.8	54.3	55.5

* Pump is delta-connected

** Generator is wye-connected

Figure 5-1. Calculated Normal Pump Operation at 20 Hz (858°F)

Figure 5-2. Calculated Pump Operation at 60 Hz (858°F)

5.6 OPERATING LIMITS

Table 5-4 gives limits to be observed for all pump operations. If parameter values outside these limits are requested for a particular test, such values may be used only for that test, it being further provided that if any other parameter, which has not been specified to be outside these limits, does exceed them, the test shall be immediately terminated and all parameters brought within permissible limits without delay.

TABLE 5-4

Limits of Operation

<u>EM Pump</u>	<u>Maximum Limit</u>
Outlet Pressure, Sodium	215 psig
Inlet pressure, sodium	125 psig
Inlet sodium temp.	1030 deg F
Duct temp.	1050 deg F
Duct Insulation Temp	700 deg F
Duct Stress	7000 psi
Sodium level, high	241.9 inch*
Sodium level, low	92.9 inch (min)*
Coil O.D. (slot bottom) temp	370 deg F
Radial vibration	1.1 g
<u>Vent Pipe</u>	
Vent pipe temp.	1050 deg F
Vent Pipe Heater Temp.	1400 deg F
Freeze seal temp transient	160 deg F per min.
<u>Stator Cooling Unit</u>	
Nitrogen makeup pressure setting	1-7 psig relief valve
Nitrogen temp at outlet of pump.	200 deg F max
Nitrogen pressure, makeup supply	1.7 psig (specified relief valve setting)
Nitrogen Relative Humidity	10 percentage points above initial condition.

* above centerline of inlet nozzle

5.7 NORMAL SHUTDOWN

Normally the EM pump will be energized continuously to maintain flow in SPTF in order to maintain uniform sodium temperature and avoid stagnation which could cause buildup of impurity concentrations or gas pockets or lead to localized freezing or hot spots. Therefore, when not operating under prescribed test conditions "idling" flow should be set somewhere in the range of 1000 to 3000 gpm with the stator cooling system maintaining all stator coil thermocouples below 340 deg F.

When it is necessary to remove all stator power, reduce pump voltage to minimum, open the circuit breakers, and drain sodium to a level below the pump tank.

If it is necessary to de-energize the pump without draining it promptly, special procedures approved by GE in advance must be followed.

5.8 EMERGENCY PROCEDURES

Instructions for reaction to alarms and shutdown signals may be found in 22A3938.

6.0 INSPECTION AND MAINTENANCE

	<u>Page</u>
6.1 Periodic Inspection	6-1
6.1.1 EM Pump	6-1
6.1.2 Stator Cooling Unit	6-2
6.1.3 Power and Control System	6-2
6.1.4 Instrumentation	6-2
6.2 Trouble Shooting	6-3
6.2.1 Alarms and Trips	6-5
6.3 Spare Parts	6-9

6.0 MAINTENANCE

6.1 PERIODIC INSPECTION

6.1.1 EM Pump

Components of the pump are described in drawings as follows:

<u>Pump Component</u>	<u>GE Dwg #</u>
EM Pump	261R165
Stator	261R174
External Support Vessel	852E379
External Thermal Insulation	852E400
Stator Guide Cylinder	852E493
Pump Duct Insulation	261R175
Pump Duct	261R125
Coolant Gas Manifold	852E397
Bolt Ring	164C6328

WARNING: BEFORE INITIATING THE PERIODIC INSPECTION CHECKS,, DISCONNECT ALL POWER SOURCES TO THE PUMP AND ACCESSORIES TO AVOID SERIOUS INJURY TO PERSONNEL. DO NOT TOUCH OR HANDLE ANY UNINSULATED LEADS OR TERMINALS ON THE PUMP WINDINGS AT ANY TIME UNTIL THE POWER IS DISCONNECTED AND THE CAPACITORS ARE DISCHARGED BY CLOSING THE GROUND SWITCHES, ONE AT EACH CAPACITOR STACK-RACK.

Visual Inspection

Visually inspect for any sign of mechanical damage to the stator or electrical degradation such as from arcing or tracking in the terminal box region.

Stator Insulation Resistance Check

Insulation resistance should be checked during each pump maintenance shutdown. The insulation resistance of the stator windings should be checked using a 500 volt D.C. insulation resistance meter ("Megger"). In the terminal box at the capacitor equipment, open the disconnect links and remove the pump conductors from the bar-type current transformers. The insulation resistance should be at least [5] megohms when measured at room temperature (70 degrees F) at the pump conductors.

HOLD

If the insulation resistance is low, the cause may be moisture on the stator winding or leads. This moisture may be removed by slowly heating the stator to 200 degrees F. by energizing the stator windings with not more than 200 volts, and holding for several hours at this temperature. Recheck insulation resistance, and continue heating until the resistance is within the acceptable range.

6.1.2 Stator Cooling Unit

The periodic maintenance requirements for components of the Stator Cooling Unit are given in the manufacturer's publications given in Appendix TBD. The publications cover:

- a. Blower and Drive Motor
- b. Damper and Damper Actuator
- c. Cooling Coil
- d. Controller, Blower Motor
- e. Mass Flow Computer System
 - Computer
 - Annubar (Pitot tube manifold)
 - Pressure Transmitter, Absolute
 - Pressure Transmitter, Differential
 - Temperature Sensor, RTD type
- f. Moisture Detector

6.1.3 Power and Control System

Refer to Preliminary Instructions, 750BR052.

6.1.4 Instrumentation

Refer to Appendix TBD for manufacturer's publications for the pressure transmitters in the instrument terminal boxes of the EM pump.

For instrumentation of the Power and Control System, refer to Preliminary Instructions 750BR052.

6.2 TROUBLE SHOOTING

Troubles in the EM pump include electrical shorts, opens, grounds, and sodium leakage from the duct. Conventional devices monitor these faults and disconnect electric power to limit damage due to electric arcs and short circuits. In the case of sodium leakage, power is also removed to reduce the possibility of forced sodium ejection and the ignition of spray jet fires. For all foreseeable troubles, special protective circuitry provides alarms and trips. Additionally, certain other manifestations, if they develop, may provide advance warning of conditions which, if not corrected, could lead to eventual failure. Hence, most of the instrumentation is surveillance type whose alarms signal a need to investigate and correct abnormal conditions. Table 6-2, Reaction to Alarms and Trips, performs part of the functions of a trouble shooting guide.

The trouble shooting guide (Table 6-1) deals with a) unforeseen conditions, including those imposed by the loop on the pump, and b) conditions which might worsen after the protective surveillance instruments and controls have acted.

TABLE 6-1
Trouble Shooting Guide

<u>Observed Condition</u>	<u>Possible Causes</u>
Pump energized; no flow	<ul style="list-style-type: none"> o Low sodium level in loop causing gas bubble in duct, (pump not primed) o Valve closed in loop. o Flow blocked by obstruction or freezing.
Pump energized; low flow and pressure	<ul style="list-style-type: none"> o Stator coils interconnected improperly o Center iron laminations shorted by sodium
Low electrical insulation resistance	<ul style="list-style-type: none"> o Moisture or other contaminants o Insulation damage
Sodium aerosols, liquid or solid deposits in stator or coolant cavity	<ul style="list-style-type: none"> o Sodium leak from pump duct
Change in customary sound level or frequency of vibration	<ul style="list-style-type: none"> o Structural distortion or creep of duct, pump tank, or other parts o Cavitation
Sodium or sodium oxide visible at support flange at top of pump tank	<ul style="list-style-type: none"> o Leakage of argon cover gas
Coolant gas temperature rises more than customary for given operation	<ul style="list-style-type: none"> o Thermal insulation in pump duct or tank deteriorating or damaged o High sodium level in pump tank o Low chilled water flow or low gas flow
Internal trace heaters inoperative	<ul style="list-style-type: none"> o Sodium leakage from pump duct or tank o Excessive applied voltage o Inoperative sheath temperature limiter
Helium in cover gas	<ul style="list-style-type: none"> o Leak in center iron sheath

6.2.1 Alarms & Trips

The following table (Table 6-2) is intended as a guide for the operator in reacting quickly to alarm and trip signals. The actions taken, in the case of alarms, should prevent a trip from occurring or in the case of trips will prevent possible damage to the pump (i.e., freezing). These recommendations will apply under all normal operating conditions. There may however, be a number of instances where the Test Request (22A3938) requires operation beyond normal operational alarm settings. The exceptions in 22A3938 will apply only for the purpose of that particular test.

The list in the table is for pump-initiated alarms and trips only, and does not cover perturbations in the power supply, stator cooling system, or the SPTF system.

Note: All trips signals will result in automatically driving the MG set exciter to zero (a few seconds) and the pump cannot be restarted until the generator voltage has been reduced to its minimum value (about 80 volts)

Table 6-2
REACTION TO ALARMS & TRIPS

<u>Sensor</u>	<u>Reaction to Alarm</u>	<u>Reaction to Trip</u>
Temperature,Duct,High alarm	Reduce Pump Voltage	Restart & run at idle* until cooled below setting.
Temperature, Freeze Seal, High	Reduce Heater Voltage	Reduce heater voltage, reduce suction pressure to 10 psig, restart and run at idle until cooled below alarm setting.
Temperature,Vent Pipe	Reduce Heater Voltage	Restart & run at idle until cooled below alarm setting.
Temperature, Stator Winding, High	Reduce Pump Voltage	Increase Nitrogen flow. Restart and run at idle until cooled below alarm setting.
Temperature, Cooling Gas,Outlet,High	Increased cooling Reduce Pump Voltage	N/A
Vibration, Duct (Radial), High	Reduce Pump Voltage	Restart and run at idle, Resume test at lower levels.
Vibration, Duct Insulation support Cylinder, High	Reduce Pump Voltage	Restart and run at idle, Resume test at lower levels
Sodium Leak Detector	1.Shutdown pump (normal shutdown) 2.Lower Na level below pump 3.Check circuits 4.Check for sodium vapor in nitrogen, sodium volume, etc., Excessive moisture	Drain Pump
Strain, Duct, High	Reduce Pump Voltage	N/A
Mass Flow, Cooling Gas, Low	Reduce Pump Voltage Increase Mass Flow	Restart blower or open damper, Restart pump and resume test

*"Idle" is steady-state operation at 1500 gpm $\pm$ 500 gpm.

<u>Sensor</u>	<u>Reaction to Alarm</u>	<u>Reaction to Trip</u>
Chiller	Reduce Pump Voltage Check chiller (see LMEC instructions)	N/A
Vibration, Pump Tank, High	Reduce Voltage	Restart and run at idle
Vibration, MFL High	Reduce Voltage	Restart and resume test
Cavitation, MFL High	Reduce Voltage	Restart and resume test
Blower Motor Power Loss	N/A	Restart blower motor Restart and resume test
Loss of MC Power	N/A	Restart and run at idle on IVR
Loss of IVR Power	N/A	Restart and run at idle on MG set.
Generator Breaker Open	N/A	Restart and run at idle on IVR, if possible
IVR Secondary Breaker Open	N/A	Restart and run at idle on MG set if possible
Loss of Gen. Field Excitation	N/A	Restart and run at idle on IVR

<u>Sensor</u>	<u>Reaction to Alarm</u>	<u>Reaction to Trip</u>
Chiller	Reduce Pump Voltage Check chiller (see LMEC instructions)	N/A
Vibration, MFL High	Reduce Voltage	Restart and resume test
Cavitation, MFL High	Reduce Voltage	Restart and resume test
Blower Motor Power Loss	N/A	Restart blower motor Restart and resume test
Loss of MG Power	N/A	Restart and run at idle on IVR
Loss of IVR Power	N/A	Restart and run at idle on MG set.
Generator Breaker Open	N/A	Restart and run at idle on IVR, if possible
IVR Secondary Breaker Open	N/A	Restart and run at idle on MG set if possible
Loss of Gen. Field Excitation	N/A	Restart and run at idle on IVR

6.3 SPARE PARTS

6.3.1 Construction Spares

Fasteners provided by GE for the various EM pump assembly operations at the CHCF and the SPTF will have approximately 10% spares. When the number of items provided is less than 10, engineering judgment will be used to determine if a spare is provided.

6.3.2 Operation Spares

Since the test period duration is short compared to the design lifetime of the pump, spares will be limited to those which might be needed during the test period.

6.3.2.1 Pump Assembly

6.3.2.2 Auxiliary Equipment

6.3.2.3 Stator Cooler

APPENDIX A

INSTRUMENT DESIGNATION CROSS-REFERENCE LIST

A1 GENERAL ELECTRIC TO LIQUID METAL ENGINEERING CENTER

<u>GE</u>	<u>LMEC</u>	<u>GE</u>	<u>LMEC</u>	<u>GE</u>	<u>LMEC</u>
4A	TE 1-1	84C	TE 1-36	118A	TE 1-56
4B	TE 1-2	84D	TE 1-37	119A	TE 1-140
5C	TE 1-3	86E	TE 1-38	119B	TE 1-141
5D	TE 1-4	96C	TE 1-39	119C	TE 1-142
6E	TE 1-5	96D	TE 1-40	119D	TE 1-143
12A	TE 1-6	105A	TE 1-49	120R	VE 1-4R
12B	TE 1-7	105B	TE 1-50	121A	TE 1-144
12C	TE 1-8	105C	TE 1-51	121B	TE 1-145
13D	TE 1-9	106A	WE 1-7	122R	VE 1-5R
14E	TE 1-10	106B	WE 1-8	123A	TE 1-57
28A	TE 1-11	106C	WE 1-9	124A	TE 1-146
28B	TE 1-12	106D	WE 1-10	124B	TE 1-147
29C	TE 1-13	106E	WE 1-11	124C	TE 1-148
29D	TE 1-14	106F	WE 1-12	124D	TE 1-149
30E	TE 1-15	107	XE 1-1	125A	TE 1-58
36A	TE 1-16	108R	VE 1-2R	125B	TE 1-59
36B	TE 1-17	109	XE 1-2	126A	TE 1-151
36C	TE 1-18	110A	TE 1-52	126B	TE 1-152
36D	TE 1-19	110B	TE 1-53	126C	TE 1-153
38E	TE 1-20	110C	TE 1-54	127	PTI-101
53C	TE 1-21	111A	VE 1-1A	128	PDTI-101
53D	TE 1-22	111R	VE 1-1R	175A	VE 1-3A
54E	TE 1-23	111T	VE 1-1T	175-R	VE 1-3R
60A	TE 1-24	112	XE 1-3	175-T	VE 1-3T
60B	TE 1-25	113A	WE 1-13	233-L-I	TE 1-70
60C	TE 1-26	113B	WE 1-14	233-L-O	TE 1-71
61D	TE 1-27	113-L-I	TE 1-64	233-M-I	TE 1-68
62E	TE 1-28	113-L-O	TE 1-65	233-M-O	TE 1-69
76A	TE 1-29	113-M-I	TE 1-62	233-U-I	TE 1-66
76B	TE 1-30	113-M-O	TE 1-63	233-U-O	TE 1-67
77C	TE 1-31	113-U-I	TE 1-60	353-L-I	TE 1-76
77D	TE 1-32	113-U-O	TE 1-61	353-L-O	TE 1-77
78E	TE 1-33	114	TE 1-55	353-M-I	TE 1-74
84A	TE 1-34	116A	TE 1-138	353-M-O	TE 1-75
84B	TE 1-35	116B	TE 1-139	353-U-I	TE 1-72
				353-U-O	TE 1-73
				BNC FE	BNC-MA

APPENDIX A (Continued)

INSTRUMENT DESIGNATION CROSS-REFERENCE LIST

A1 GENERAL ELECTRIC TO LIQUID METAL ENGINEERING CENTER

<u>GE</u>	<u>LMEC</u>	<u>GE</u>	<u>LMEC</u>	<u>GE</u>	<u>LMEC</u>
F1	NE 1-25	IC 1-7	TE 1-44	Y14	NE 1-14
F2	NE 1-26	IC 1-8	TE 1-45	Y15	NE 1-15
F3	NE 1-27	IC 1-9	TE 1-46	Y16	NE 1-16
F4	NE 1-28	IC 1-10	TE 1-47	Y17	NE 1-17
F5	NE 1-29	IC 1-11	TE 1-48	Y18	NE 1-18
F6	NE 1-30	IC 1-12	WE 1-3	Y19	NE 1-19
F7	NE 1-31	IC 1-13	WE 1-4	Y20	NE 1-20
F8	NE 1-32	IC 1-14	TE 1-78	Y21	NE 1-21
F9	NE 1-33	IC 1-15	TE 1-79	Y22	NE 1-22
F10	NE 1-34	IC 1-16	TE 1-80	Y23	NE 1-23
F11	NE 1-35	IC 1-17	TE 1-81	Y24	NE 1-24
F12	NE 1-36	IC 1-18	TE 1-82		
F13	NE 1-37	IC 1-19	TE 1-83		
F14	NE 1-38	IC 1-20	WE 1-5		
F15	NE 1-39	IC 1-21	TE 1-84		
F16	NE 1-40	IC 1-22	WE 1-6		
F17	NE 1-41	IC 1-23	TE 1-85		
F18	NE 1-42	IC 1-24	TE 1-86		
F19	NE 1-43	IC 1-25	PT 1-2		
F20	NE 1-44	R-1	NE 1-63		
F21	NE 1-45	RDT-1	TE 1-154		
F22	NE 1-46	RTD-2	TE 1-155		
F23	NE 1-47	RTD-3	TE 1-156		
F24	NE 1-48	T1	NE 1-61		
F25	NE 1-49	T2	NE 1-62		
F26	NE 1-50	T3	NE 1-59		
F27	NE 1-51	T4	NE 1-60		
F28	NE 1-52	Y1	NE 1-1		
F29	NE 1-53	Y2	NE 1-2		
F30	NE 1-54	Y3	NE 1-3		
F31	NE 1-55	Y4	NE 1-4		
F32	NE 1-56	Y5	NE 1-5		
F33	NE 1-57	Y6	NE 1-6		
F34	NE 1-58	Y7	NE 1-7		
IC 1-1	TE 1-86	Y8	NE 1-8		
IC 1-2	TE 1-41	Y9	NE 1-9		
IC 1-3	WE 1-1	Y10	NE 1-10		
IC 1-4	TE 1-42	Y11	NE 1-11		
IC 1-5	WE 1-2	Y12	NE 1-12		
IC 1-6	TE 1-43	Y13	NE 1-13		

APPENDIX A (Continued)

INSTRUMENT DESIGNATION CROSS-REFERENCE LIST

B1 LIQUID METAL ENGINEERING CENTER TO GENERAL ELECTRIC

<u>LMEC</u>	<u>GE</u>	<u>LMEC</u>	<u>GE</u>	<u>LMEC</u>	<u>GE</u>
TE 1-1	4A	TE 1-36	84C	TE 1-71	233-L-O
TE 1-2	4B	TE 1-37	84D	TE 1-72	353-U-I
TE 1-3	5C	TE 1-38	86E	TE 1-73	353-U-O
TE 1-4	5D	TE 1-39	96C	TE 1-74	353-M-I
TE 1-5	6E	TE 1-40	96D	TE 1-75	353-M-O
TE 1-6	12A	TE 1-41	IC 1-2	TE 1-76	353-L-I
TE 1-7	12B	TE 1-42	IC 1-42	TE 1-77	353-L-O
TE 1-8	12C	TE 1-43	IC 1-6	TE 1-78	IC 1-14
TE 1-9	13D	TE 1-44	IC 1-7	TE 1-79	IC 1-15
TE 1-10	14E	TE 1-45	IC 1-8	TE 1-80	IC 1-16
TE 1-11	28A	TE 1-46	IC 1-9	TE 1-81	IC 1-17
TE 1-12	28B	TE 1-47	IC 1-10	TE 1-82	IC 1-18
TE 1-13	29C	TE 1-48	IC 1-11	TE 1-83	IC 1-19
TE 1-14	29D	TE 1-49	105A	TE 1-84	IC 1-21
TE 1-15	30E	TE 1-50	105B	TE 1-85	IC 1-23
TE 1-16	36A	TE 1-51	105C	TE 1-86	IC 1-1
TE 1-17	36B	TE 1-52	110A	TE 1-138	116A
TE 1-18	36C	TE 1-53	110B	TE 1-139	116B
TE 1-19	36D	TE 1-54	110C	TE 1-140	119A
TE 1-20	38E	TE 1-55	114	TE 1-141	119B
TE 1-21	53C	TE 1-56	118A	TE 1-142	119C
TE 1-22	53D	TE 1-57	123A	TE 1-143	119D
TE 1-23	54E	TE 1-58	125A	TE 1-144	121A
TE 1-24	60A	TE 1-59	125B	TE 1-145	121B
TE 1-25	60B	TE 1-60	113-U-I	TE 1-146	124A
TE 1-26	60C	TE 1-61	113-U-O	TE 1-147	124B
TE 1-27	61D	TE 1-62	113-M-I	TE 1-148	124C
TE 1-28	62E	TE 1-63	113-M-O	TE 1-149	124D
TE 1-29	76A	TE 1-64	113-L-I	TE 1-151	126A
TE 1-30	76B	TE 1-65	113-L-O	TE 1-152	126B
TE 1-31	77C	TE 1-66	233-U-I	TE 1-153	126C
TE 1-32	77D	TE 1-67	233-U-O	TE 1-154	RTD-1
TE 1-33	78E	TE 1-68	233-M-I	TE 1-155	RTD-2
TE 1-34	84A	TE 1-69	233-M-O	TE 1-156	RTD-3
TE 1-35	84B	TE 1-70	233-L-I		

APPENDIX A (Continued)

INSTRUMENT DESIGNATION CROSS-REFERENCE LIST

B1 LIQUID METAL ENGINEERING CENTER TO GENERAL ELECTRIC

<u>LMEC</u>	<u>GE</u>	<u>LMEC</u>	<u>GE</u>	<u>LMEC</u>	<u>GE</u>
VE 1-1A	111A	NE 1-7	Y7	NE 1-42	F18
VE 1-1R	111R	NE 1-8	Y8	NE 1-43	F19
VE 1-1T	111T	NE 1-9	Y9	NE 1-44	F20
VE 1-2R	108R	NE 1-10	Y10	NE 1-45	F21
VE 1-3A	175A	NE 1-11	Y11	NE 1-46	F22
VE 1-3R	175R	NE 1-12	Y12	NE 1-47	F23
VE 1-3T	175T	NE 1-13	Y13	NE 1-48	F24
VE 1-4R	120R	NE 1-14	Y14	NE 1-49	F25
VE 1-5R	122R	NE 1-15	Y15	NE 1-50	F26
XE 1-1	107	NE 1-16	Y16	NE 1-51	F27
XE 1-2	109	NE 1-17	Y17	NE 1-52	F28
XE 1-3	112	NE 1-18	Y18	NE 1-53	F29
WE 1-1	IC 1-3	NE 1-19	Y19	NE 1-54	F30
WE 1-2	IC 1-5	NE 1-20	Y20	NE 1-55	F31
WE 1-3	IC 1-12	NE 1-21	Y21	NE 1-56	F32
WE 1-4	IC 1-13	NE 1-22	Y22	NE 1-57	F33
WE 1-5	IC 1-20	NE 1-23	Y23	NE 1-58	F34
WE 1-6	IC 1-22	NE 1-24	Y24	NE 1-59	T3
WE 1-7	106A	NE 1-25	F1	NE 1-60	T4
WE 1-8	106B	NE 1-26	F2	NE 1-61	T1
WE 1-9	106C	NE 1-27	F3	NE 1-62	T2
WE 1-10	106D	NE 1-28	F4	NE 1-63	R-1
WE 1-11	106E	NE 1-29	F5	NE 1-64	NE 1-64
WE 1-12	106F	NE 1-30	F6		
WE 1-13	113A	NE 1-31	F7		
WE 1-14	113B	NE 1-32	F8		
PT 1-2	IC 1-25	NE 1-33	F9		
PE 1-101	127	NE 1-34	F10		
PDE 1-101	128	NE 1-35	F11		
NE 1-1	Y1	NE 1-35	F12		
NE 1-2	Y2	NE 1-37	F13		
NE 1-3	Y3	NE 1-38	F14		
NE 1-4	Y4	NE 1-39	F15		
NE 1-5	Y5	NE 1-40	F16		
NE 1-6	Y6	NE 1-41	F17		

APPENDIX B - Distribution

Copy Number

1-10	LMEC
11	J. D. Nulton, RDD-ERDA
12-13	J. S. Muhlestein, ERDA-SAN
14	R. A. Erickson
15	A. F. Gacs
16	K. E. Carpenter/J. Key
17	R. R. Asamoto/D. Drumm (1)
18	R. Beames
19	C. N. Craig/P. E. Bohaboy (1)
20	E. R. Craig
21	R. Wheeler/F. E. Vanslager
22	L. Peterson
23	T. Gleason
24	J. Kliman
25	G. Brynsvold
26	F. Tippetts
27-40	J. F. Settle