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HGP-A WELLHEAD GENERATOR
PROOF-OF-FEASIBILITY PROJECT
3 MW WELLHEAD GENERATOR

START-UP TRAINING AND OPERATING MANUAL

1981

THE RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII
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AND
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1.0

INTRODUCTION

The start-up manual is an information aid to initially familiarize plant operators with the plant operation and later be used as a reference manual while operating the plant.

This start-up manual is supplemented by the Plant Data Manual which contains a detailed description of the philosophy of operation and equipment characteristics.

The sequencing herein presents the necessary operating procedures which must be followed in order that a smooth start-up is obtained. The sequence includes, first conditioning the well and stabilizing the steam/water separations, and then bringing the operating machinery on line.

The Piping and Instrumentation Diagrams and Electrical Drawings are included under Section 12.0 and are frequently referred to in the text. Information for "trouble-shooting" is provided in the maintenance and operations manuals on all the equipment.

Environmental monitoring will be performed by LFE Environmental Analysis Laboratories who is responsible for the gathering and monitoring of air samples in and around the plant.

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The initial start-up will be supervised by Rogers Engineering staff and the plant operators will be HELCO personnel. When the plant operates to the mutual satisfaction of RCUH, Rogers Engineering and HELCO, HELCO will be totally responsible for the operation and maintenance under contract to RCUH.

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2.0

AUXILIARY SYSTEMS AND OTHER PREREQUISITES TO START-UP

OF THE POWER PLANT

In order to activate the major systems of the plant, it is necessary to start the auxiliary power system, the compressed air system for instrumentation and control, and the chemical injection system for H₂S abatement control.

2.1

Electrical System (Drawing E-08-101 - Single Line)

2.1.1

The electric system consists of the following groups of equipment:

125-V DC Power System and 120-V AC Inverter

34.5-kV Substation

4-kV Switchgear

480-V Auxiliary Power System

Emergency Generator

2.1.2

The power plant is not capable of a "cold start" and must be connected through the substation with Hawaiian Electric Light Company's system in order to provide adequate power for the plant auxiliary system.

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2.1.3 Following conditions must exist prior to formal plant start-up:

- A. The 34-kV substation, 4-kV switchgear and 480-volt Motor Control Center must be tested, protective devices set and/or calibrated and the alarm and control system must be operational.
- B. All equipment must be "tagged out" in accordance with Clearance Procedures per section 11.0.

2.1.4 The following is a check list to verify the operation of:

2.1.4.1 125-Volt DC System

- A. Battery electrolyte level correct.
- B. Charger is energized - indicating light is on and the DC voltmeter indicates _____ volts if batteries are on float charge, _____ volts if batteries are on equalizing charge.
- C. Verify operation of charger, observing charge rate ammeter.
- D. Test for DC ground at battery charger.

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E. Close DC feeder circuit breakers:

1. 34-kV Line Control
2. Transformer Circuit Breaker Control
3. Generator Control
4. Turbine Control
5. Inverter
6. Converter
7. Load Bank Control
8. Annunciator

Leave closed unless maintenance is required.

2.1.4.2 120-VAC Inverter System (Inverter is in the same cabinet as the charger).

- A. Inverter is energized. Check AC voltmeter on inverter output.
- B. Test static switch by opening circuit breaker CB3 at battery charger. (after panel P-1 is energized).
- C. Close inverter circuit breakers
 1. Caustic System Control
 2. Governor Power Supply
 3. H₂S Monitoring System Supply
 4. Control Panel Instruments
 5. Fire Alarm System

Leave closed unless maintenance is required.

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2.1.5 To Energize the 34-kV Substation:

- A. Inspect 34-kV circuit switcher for defects and the main transformer for oil levels and tap changer operation.
- B. Verify that 125-V DC control power is available. Check whether or not indicating lights are "on" either at the circuit switcher or at the Main Control Panel.
- C. Verify that 34-kV line is energized - check voltmeter on control panel.
- D. Request permission to close circuit switcher, MOS 3702, from the HELCO dispatcher. Remove tags and log in accordance with Standard Operating Procedures. Close switcher through control switch on the Main Control Panel.

NOTE: Transformer 4-kV circuit breaker is interlocked with circuit switcher and must be open.
- E. Inspect transformer and circuit switcher for problems (at initial energization or after an extended outage).

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2.1.6 To Energize 4-kV Switchgear:

- A. Inspect that switchgear is clean and that all doors are closed.
- B. Verify that 125-V DC control power is available. Check whether indicating lights for transformer circuit breaker are "on" at the Main Control Panel.
- C. Remove tags in accordance with Standard Operating Procedures.
NOTE: It is assumed here that any further operation is not under the jurisdiction of the system dispatcher except paralleling the generator.
- D. Close 4-kV transformer circuit breaker, Switch ACB-409, through the control switch and synchronizing switches on the Main Control Panel. Synchronizing selector switch to be in "MANUAL".
- E. Check bus voltmeter. If voltages are abnormally high or low, either deenergize substation and adjust manually operated tap changer settings on main transformer or change voltage regulator setting. Bus voltage should be between 3950 and 4370 volts.
- F. Inspect switchgear for signs of electrical stress.

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2.1.7 To Energize 480-volt Motor Control Center and Auxiliary Power System:

- A. Inspect auxiliary power transformer for oil leaks.
- B. Close 4-kV switch at switchgear. Switch is manually operated.
- C. Verify that all 480-volt feeder circuit breakers at the Motor Control Center and Load Bank controller are "tagged out".
- D. Verify that the manual transfer switch in the maintenance area is open and "tagged out".
- E. Remove tag and close 480 volt main circuit breaker in Motor Control Center.
- F. Check the voltmeter in Motor Control Center. If voltages are abnormal de-energize auxiliary power transformer and change taps. Voltage range should be 450 to 500 volts.
- G. Remove tag and close circuit breaker feeding transformer to 120 volt Panel P1. Close Panel P1 branch circuit breakers.

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Panel P1 supplies:

1. Lights - Control Unit
2. Lights - Switchgear/Motor Control Center Unit
3. Receptacles - Control Unit
4. Receptacles - Switchgear/Control Unit
5. Lights - Control Panel Interior
6. Inverter Bypass (alternative supply to Panel I)
7. Main Transformer Fans and Tap Changer Control
8. Auxiliary Power Transformer Fans
9. HELCO supervisory Control Equipment - Control Unit
10. Circuit Switcher Space Heater
11. Generator Space Heater
12. Turbine Supervisory Panel
13. Generator Make-up Fan
14. H₂S Abatement System
15. Receptacle - H₂S Abatement System Area
16. CO₂ System
17. Cooling Water Pump Space Heaters
18. Intercom Plant Telephone System

Leave all circuit breakers closed unless maintenance is required.

- H. Close manual transfer switch to reenergize Panel DP-1.

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- I. After individual motors are tested for the various systems, leave the motor starter circuit breakers closed unless maintenance is being performed on the equipment.

2.1.9 Standby Generator

- A. Inspect initially and periodically in accordance with manufacturer's (Onan) instructions for radiator, crankcase, and starting battery levels.
- B. Verify inverter output after load is placed on Panel I.

2.1.10 Normal Operation

For normal plant operation, whether or not the turbine-generator is in service, the 34-kV Circuit Switcher, Switch No. MOS 3702, and the incoming 4-kV circuit breaker, Switch ACB 409, shall be left in the closed position. In addition, all DC and AC low voltage circuit breakers shall also remain closed.

2.1.1.1 Abnormal Operation

- A. 125-V DC System

Low voltage or a DC ground will alarm.

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Very low DC voltage will alarm and trip the turbine, if running.

B. Inverter

Inverter failure will alarm. Inverter has a bypass switch to permit reenergizing the 120-volt Panel I.

C. 34.5-kV Substation

1. Circuit switcher will trip only on main transformer fault.
2. 4-kV transformer circuit breaker will trip on:
 - a. 34-kV line overcurrent
 - b. 34-kV line ground fault
 - c. differential relay (internal fault on transformer or connections)
 - d. transformer fault pressure (internal fault in transformer)
 - e. transformer overcurrent or bus fault
 - f. 4-kV ground fault

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3. Loss of the 34.5-kV will alarm. Tripping of the 4-kV circuit breaker has a common alarm. Individual protective devices must be checked to determine which one operated.

Switch 186T or 186L at the switchgear must be reset before reclosing the circuit breaker.

2.2 Compressed Air System (P&ID E-03-106)

Equipment Numbers and Valve Numbers are shown on the P&ID in Section 12.0.

- 2.2.1 Check Head Tank (10-13) is filled to marked level.
- 2.2.2 Start both Air Cooled Heat Exchanger Fans (12-4A & B). Start/stop push buttons are located on an adjacent pipeway support.
- 2.2.3 Check that valves V-1 through V-16 on the circulating water system are fully open. Balance the flow through each exchanger by using valves V-11 and V-12. Shut off water supply to each exchanger individually and read PI-680.

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- 2.2.4 Start up the Circulating Water Pump (14-13A or B). HAND-OFF-AUTO switches are adjacent to pumps. One pump will be on standby. Stand-by pump control switch shall be in the OFF position initially. Turn lead pump control switch to AUTO to start. Then turn stand-by pump control switch to AUTO. Failure of one pump will start the standby pump.
- 2.2.5 Check if compressor air intake charcoal filter is operational.
- 2.2.6 Check that valves V-17 through V-23 are open and that V-20 and V-24 are closed.
- 2.2.7 Check that Air Driers (16A-2A and 16-2B) are filled with dessicant. One drier is on standby. Select desired drier at random and turn ON. Indicating lights will go on. Drier failure will sound an alarm.
- 2.2.8 Check that Air Drier Prefilter and After Filter are clean.
- 2.2.9 Open drain valves on air receivers (10-5 and 10-14), drain, and close valves.

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2.2.10 Compressors have local HAND-OFF-AUTO switches and a compressor selector switch. Turn both compressor switches to AUTO. Select desired compressor at random for the lead compressor. Compressor selected will now start. Note that oil pressure must build up or compressor will shutdown automatically. Failure of one compressor will cause the standby unit to start.

2.2.11 High air temperature or low air pressure will alarm.

2.2.12 Check the following gauges against readings given below.

<u>Instrument</u>	<u>Function</u>
TI-341	Air Discharge
TI-342	Air Discharge
TI-344	Cooling Water Return
TI-345	Cooling Water Supply
TI-347	Cooling Water Supply
PI-672	Air Receiver 10-5
PI-681	Air Drier 16-2A
PI-683	Air Drier 16-2A
PI-695	Air Drier 16-2B
PI-697	Air Drier 16-2B
PI-678	Circulating Water Pump Discharge
PI-680	Circulating Water Supply
PI-665	Instrument Air Header
PI-699	Utility Air Header
PI-664	Main Control Panel Air Header

2.2.13 Crack open vent valve on Air Receiver (10-14) and obtain samples by dew cup and thermometer supplied with the driers at the Air Drier to determine air quality.

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2.2.14 - Once the desired quality of air has been obtained, at least -20°F dew point, open valve V-24 to released air into the instrument air headers. Valves V-25, V-26, V-27 and V-28 through V-31 should remain closed at this time.

2.3 Chemical Injection System (P&ID E-03-112, E-03-108, E-03-104,
E-03-102)

The chemical injection system provides caustic to various points throughout the plant for mixing with steam or water in order to chemically abate the hydrogen sulfide present in the geothermal fluids and for pH control in the condensate system.

2.3.1 Pre-start Requirements

A. Verify that instrument air is available at all the following usage points.

- 1) Steam Bypass Line
- 2) Brine to Muffler Box
- 3) Noncondensable Gas Absorber Spray
- 4) Condensate Pipeline Mixer

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B. Check that electric power is available and switched on the following pumps and instruments.

1. Power to:

Transfer Pump (14-4)

Supply Pumps (14-14A & B)

Tank Mixers (19-2A & 2B)

The above are supplied from motor starters on a local rack.

2. Power to Instrument Building and local Alarm Panel. Close feeder in Panel E2 and switch on outside of building.

3. Power for FQI-4, AY-901, FY-60 and FY-161 from Ckt. 1, Panel I.

4. Instrument air for FV-3, FV-4, PV-687 and PIC-687, LT-13 and LT-14, and LT-12. Open valve V-27.

5. Instrument air for LSL-13, LSH-13, LSL-14, LSH-14, LSH-12, LI-12, LI-13, LI-14. Open valve V-52.

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- C. Check that Caustic Dilution Tanks 10-11A and 10-11B are filled with 10% caustic solution.
- D. Check that sufficient 50% caustic is available in Caustic Storage Tanks 10-12A and 10-12B to provide batching capacity for two future mixes in dilution tanks.
- E. If dilution tanks have been standing for a period of time, in excess of 3 days, run Mixers 19-2A and 19-2B for 1/2 hour to remove any stratification which may have occurred.

Manual motor starters are located on motor starter rack adjacent to dilution tanks.

- F. Check that valves V-63 and V-65 are closed and valves V-62 and V-64 are open on Tanks 10-11 A & B, respectively.
- G. Check that valves V-58 through V-61 are closed.
- H. Check that control valves AV-965, AV-901, FV-161 & FV-160 on caustic supply lines are closed.

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- 2.3.2 The method of batch mixing caustic and water is shown in Appendix A of this manual.
- 2.3.3 Switch on selected lead Caustic Supply Pumps either 14-14A or 14-14B at caustic area switch panel. Control valve PV-687 will recirculate the caustic back to the selected tank 1011A or 1011B.
- 2.3.4 Open valves V-58 through V-61, as applicable to supply caustic to use points.
- 2.3.5 The chemical injection system is now ready for operation.
- 2.3.6 A safety instruction brochure on the handling of caustic soda is included in Appendix B.

2.4 Alarm Systems

- 2.4.1 The plant has three separate annunciators: the one on the Main Control Panel; one in the H₂S Abatement System Panel, and one for the chemical treatment area. Operation of the H₂S annunciator will cause a single alarm on the annunciator on the Main Control Panel. Operation of chemical treatment panel is repeated on the Main Control Panel.

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- 2.4.2 To energize the annunciator in the Main Control Panel close DC feeder breaker Ckt 8 and control power switch in Main Control Panel. All annunciators will go "ON". Push "Acknowledge" button.
- 2.4.3 To test annunciator push "Test" button.
- 2.4.4 After an alarm is indicated push the "Acknowledge" button to silence all audible devices. Annunciator is the "first out" type and a separate button is provided.
- 2.4.5 To silence all audible devices open the "Horn Cutout" switch. This is mandatory if the station is unattended.
- 2.4.6 Log all alarms. Indicate all first out alarms. In the case of the H₂S abatement system, the vibration and temperature monitor and generator, transformer and 34.5 kV line protective devices, log the specific device that alarmed (or tripped).

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3.0 WELLHEAD SYSTEM (P&ID E-03-102)

Initially, the Wellhead will be controlled from the instrument house adjacent to the Wellhead. When stability has been obtained the control will be transferred to the Control Module in the Power Plant. This phase of start up will be used to stabilize the well flow and evaluate the steam for particulate matter prior to admitting to the turbine.

During the startup and long term running of the wellhead, various tests and samples of the brine and steam are required, along with air quality, noise level, and other miscellaneous data. Appendix D shows these requirements.

3.1 Start-up Pre-check

3.1.1 Check that instrument air and electric power is available to the following wellhead instruments, and activate these instruments:

A. Air supply to:

LT-1, LIC-1, LIC-501, LR-1, LR-501, LSH-1, LSL-1, LSH-501,
FT-1, FY-1A, FL-1B, FR-1, FR-101, PT-1, PR-1, PR-061, PIC-1,
PIC-601A, PC-601B, PIC-601B, PY-601B, PV-1, PSH-601, FT-2,
FR-102, FIR-2, PV-601

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B. Electrical power to:

LEH-502, LSH-502, LAH-502, LAH-501, LAL-501, LAH-1, LAL-1,
PAH-601, PY-1A

C. Electrical power to:

Motor operators for HV-905, HV-906, limitorque operators
on wellhead valves.

- 3.1.2 Check that Wellhead instruments LT-1, LIC-1, LSL-1, LSH-1, PIC-1, FY-1A are on local control in the wellhead instrument house.
- 3.1.3 Check that caustic supply is available and operative to the steam and brine system and that control valves FV-161 and FV-160 respectively are fully closed.
- 3.1.4 Fully open drain valve upstream of FT-1 Venturi element to allow all accumulated water to be drained from the line. The valve is then to be partially closed to provide throttling during the initial stages of the start up when large amounts of condensate will collect in the line. Once a steady state has been reached the valve can be closed.

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- 3.1.5 Open all valves around steam trap, except steam trap bypass valve, upstream of control valve PV-1.
- 3.1.6 Check ANX 1, 1A, 2, 3, 4, 5 sample connections and close sample valves.
- 3.1.7 Check that 4" block valve under relief valve PSV-1 is locked open.
- 3.1.8 Check that all valves are fully open, except LV-1 bypass valve and that control valve LV-1 on brine line is open to Muffler Box (45-4) by setting LIC-1 to maximum.
- 3.1.9 Check that valve V-34 "Gas to Emergency Treatment" on line NCG-004 is closed.
- 3.1.10 Check that 2" drain valve (V-41) on Flash Separator (10-1) is fully closed.
- 3.1.11 Check that instrument wire line spool 4" valve on wellhead piping is closed.
- 3.1.12 Check that both motor operated wing valves HV-905 and LV-906 at the wellhead are closed.

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- 3.1.13 Check that 10" well "root" valve V-38 is closed.
- 3.1.14 Check that the portable blower is installed in wellhead valve pit and is ready for use. Switch on and run for 15 minutes prior to personnel entering the valve pit.
- 3.1.15 Check that muffler box drain valve is open.
- 3.1.16 Check that flash separator level indicator isolation valves are open.
- 3.1.17 Check that block valve upstream of PV-601 is closed.

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3.2 Steam Generation

- 3.2.1 Open 2" line valve V-39 & crack open valve V-40 on wellhead. Slowly warm up the well for approximately 24 hours. This allows and hot water to rise in the well bore and slowly heat up the well. Usually the well is ready to be flashed when the temperature at TI-375 reaches approximately 200°F.
- 3.2.2 Open the 10" wellhead root valve V-38 slowly. Check for any unusual occurrences, i.e., steam leaks through flanges or valve packing, etc.
- 3.2.3 The control station. located in the Instrument House, for motorized valves consists of an OPEN-CLOSE-STOP push button. Open 10" motorized wing valve (HV-906) to the vent stacks incrementally using the control station. Pressure at PI-10 shall not exceed 500 psi and temperature at TI-108 should not exceed 470°F. Pressure could rise fast in which case valve should be opened wider to control the pressure. Initially, excessive water will be present and may cause localized flooding in the wellhead area. The well can be run in this mode during daylight hours for up to 8 hours per 24 hour period. Start-up of the wellhead should normally commence at daybreak to allow sufficient time to clean the well prior to admitting well

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fluid to the separator. (NOTE: The operation of the wellhead in daylight hours without the use of H_2S abatement is acceptable through a local agreement worked out with the local residents living near the plant.)

- 3.2.4 Once a relatively steady state flow has been obtained through the line to the Vent Stacks, the system is ready for steam generation through the Flash Separator.
- 3.2.5 Fully open control valve PV-1 by operating PIC-1 on "MANUAL".
- 3.2.6 Open incrementally the 10" motorized wing valve HV-905 to the Flash Separator (10-1), similar to method used for HV-906, allowing a small quantity of steam to enter the system and warm-up the vessels and piping. During this warm-up period the caustic supply should be turned off.
- 3.2.7 After 6 hours of well bore warm-up partially open the 10" wing valve to the Flash Separator to warm-up the flash separator for approximately 2 hours, then slowly open to fully open the 10" wing valve and close the vent stack wing valve. Close valves V-39 and V-40.

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- 3.2.8 Set PIC-1 at the local panel to 160 psig and switch to AUTOMATIC.
- 3.2.9 Once the steam supply is flowing, open the drain valve on line EW-006 from the Sparger 20-2 Box. The caustic supply valve will open automatically with the opening of control valve PV-1. Initially set FV-161 for 200 gpm.
- 3.2.10 Set LIC-1 at mid range of the level column on the Flash Separator, LV-1 should move to bring the level to this setting.
- 3.2.11 Adjust caustic flow rate to the calculated value per Figure 3-1 for steam flow rates as indicated by FIR-1 on local panel. The requirement for injection of caustic into the brine flow will be determined during the initial start up. For H_2S abatement at scrubber column use 97.2 to 239 gal./hr. flow rate.
- 3.2.12 Desuperheater water may be necessary to ensure that temperature on TI-14 shows correct reading of 5°F below saturation temperature for steam pressure. See Table 3-4 - Saturated Steam Table, for pressure-temperature relationship.

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3.2.13 The system is now under full control and will be run in this mode while samples are taken to ensure that the steam quality is acceptable before allowing steam to enter the turbine. Samples will be taken at ANX-1 to check flashed steam composition. Sampling will be the responsibility of the Hawaii Institute of Geophysics. ANX-1 will also be used to check the dryness fraction. ANX-3 samples will give the effects of the caustic on the H_2S in the steam and check the effectiveness of the treatment. The same is true of ANX-4 and ANX-5 sample points. ANX-2 will be used to obtain a brine sample if required.

3.2.14 The following gives a summary of normal range readings for the Wellhead Instruments:

<u>Instrument</u>	<u>Function</u>	<u>Normal Range Reading</u>
PI-11	Separator Pressure	160 psig
TI-11	Separator Temperature	370°F
LG-11	Separator Water Level	Mid Range
TI-21	Steam Temperature	370°F
TI-12	Brine Temperature	370°F
PI-606	Brine Pressure	160 psig
LIC-1	Water Level Set Point	Mid Range
FIR-2	Brine Flow Recorder	-
TI-13	Bypass Steam Temperature	300 to 350°F
PI-13	Bypass Steam Pressure	10 to 30 psig
TI-14	Desuperheated Steam Tempt.	300 to 350°F
TI-15	Steam Temperature after Caustic Injection	250 to 300°F
PIC-1	Steam Pressure Setting	160 psig
FR-1	Steam Flow Recorder	-
PR-1	Steam Pressure Recorder	-

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3.2.15

Checking of Steam Quality for Particulate Matter

A target is installed in the bpass line to be used to measure impingements of particulate matter originating in the well. The target is installed at a right angle to the steam flow and consists of a polished surface steel plate 2" wide. Judgment as required in determining the quality of the steam from examination of the plate surface and an impingement free target will never be obtained. The targets will be installed after the well has been blown through the vent stack for 6 hours and after the 2 hours warm-up of the Flash Separator. The target should be left installed for 2 hours before removal for examination and then replaced with a new target.

GRAPH 3-1

STEAM FLOW FR-101 - VS - CAUSTIC FLOW

100,000

80,000

60,000

40,000

20,000

0

LBS PER HR STEAM FLOW

20

40

60

80

100

PERCENT OF 554 GPH. - 10% CAUSTIC SOLN.

46 U/82

KEUFFEL & ESSER CO. MADE IN U.S.A.

GRAPH 3-2

BRINE FLOW FR-102 - VS - CAUSTIC FLOW

NOTE: 100% = 120,000 lbs./hr.

PERCENT OF 554 GPH. - 10% CAUSTIC SOLN.

GRAPH 3-3

CONDENSATE FI-121 - VS - CAUSTIC FLOW RATE

NOTE: 10 = 150 GPM CONDENSATE FLOW

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TABLE 3-4

SATURATED STEAM TABLE

<u>Pressure psig</u>	<u>Temperature °F</u>
0	211
5	227
10	239
15	249
20	258
25	267
30	274
35	280
40	287

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4.0 COOLING WATER SYSTEM (P&ID E-03-105)

The next step in the start-up of the plant is to activate the Cooling Water system to ensure that cooling water is available to the condensing equipment, lube oil system cooler, the generator cooler, and the recycle gas cooler.

Prior to the initial start-up of the plant the Cooling Tower basin must be filled with water from the potable water system via line PW-019. Before commencing to fill, ensure that the basin drain valve is closed and all debris is removed from the tower basin and the trash screens are clean and in place. The fire fighting spray nozzles which are connected to the potable water system must be tested for operation and even distribution.

4.1 Pre-start Check

4.1.1 Verify that instrument air and electrical power is supplied to the following instruments on cooling water system and that the instruments are active:

A. Air supply to:

LIC-531, LV-531, TY-330, TR-330

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B. Electrical power to:

AT-901, ASH/ASL-901, ASHH/ASLL-901, AAHL-901, TY-330, PSL-640,
PAL-640, LSL-531, LAL-531, LSH-533, LAH-533, XS-903, XA-903

- 4.1.2 Check that electric power is available to Cooling Tower Fan Motors (11-1A & 11-1B) and Circulating Pump Motors 14-3A and 14-3B.
- 4.1.3 Check that all cooling water line valves V-35, V-36, V-42 through V-51 are open to equipment Main Condenser (12-1), Inter- and After-condensers (12-2, 12-3), Generator Cooler (18-1), Lube Oil Cooler, and Recycle Gas Cooler (12-6) and that discharge valve on the selected run pump (14-3A or 14-3B) is fully open.
- 4.1.4 Check that cooling tower fans are off. Verify by checking either indicating lights on tower or on the Main Control Panel.
- 4.1.5 Check that controls for Cooling Water Pumps (14-3 A and B) are off and "LOCK OUT" stop push button is unlocked. Verify through indicating lights at Main Control Panel.
- 4.1.6 Check that valves LV-521A and AV-901 (P&ID E-03-104) are closed.

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4.2 Start-up of Cooling Water System

- 4.2.1 Select either Cooling Water Pump 14-3A or 14-3B thru selector switch on the Main Control Panel. Start pump selected on "Hand" position. Open all vent connections on heat exchangers to bleed air, until only water emerges, then close vent valves. Check that pressure gauge PI-652 has a reading in the range of _____ psig and PI-655 on the generator cooling water supply line has a reading of _____ psig.
- 4.2.2 Check the differential pressure readings across heat exchangers and condensers. Compare with values shown on Table 4-1.
- 4.2.3 Check for even distribution of return flow from the Cooling Tower headers. Adjust header valves as required to give an even flow distribution down through the tower.
- 4.2.4 Make the necessary adjustments to the equipment cooling water outlet valves to produce flow rates in accordance with the values on Table 4-2. Several attempts may be necessary to achieve the correct balance of water supply.

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Actual flow readings can be obtained for the Main Condenser, Intercondenser and Aftercondensers. The balance of the cooling water flow will go through the Lube Oil Cooler, Generator Cooler and Recycle Gas Cooler. The flows through these items of equipment are best determined by adjustments to give the correct output temperatures as shown on Table 4-2.

4.2.5 Manually cycle water level control valve LV-531 on line CW-029 (overflow line) from local controller LIC-531 to make sure it will operate.

4.2.6 The cooling water system is now ready for use and should be kept running while the next system, the H₂S abatement system is brought on line.

4.2.7 For normal operation, control switches on Main Control Panel shall be turned to the "auto" position. Failure of one pump will start the standby pump automatically.

4.3 Cooling Tower Fans

4.3.1 Start one fan when main condenser discharge temperature indicated on TI-313 approaches 105°F to 110°F. Start second fan if temperature continues to rise. Control switches are at the fans and on the Main Control Panel.

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TABLE 4-1

ACCEPTABLE DIFFERENTIAL PRESSURE READING FOR COOLING WATER ACROSS
CONDENSERS AND HEAD EXCHANGERS

<u>EQUIPMENT</u>	<u>EQUIPMENT NO.</u>	<u>PRESSURE GAUGE</u>	<u>ACCEPTABLE OPERATING ΔP</u> <u>READING (PSI)</u>
Main Condenser	12-1	PI-641	0.7
Intercondenser	12-2	PI-642	0.4
Aftercondenser	12-3	PI-643	0.3
Recycle Gas Cooler	12-6	PI-639	0.5
Generator Cooler	18-1	PI-648	0.5
Lube Oil Cooler	----	PI-651	0.5

NOTE: If ΔP increases by more than 50% above the stated figures investigation should be made into the cause of the increase.

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TABLE 4-2

COOLING WATER FLOW RATES AND OUTLET TEMPERATURES

<u>EQUIPMENT</u>	<u>EQUIPMENT NO.</u>	<u>FLOW RATE (GALS/MIN)</u>	<u>OUTLET TEMPERATURE °F</u>
Main Condenser	12-1	3144	115
Intercondenser	12-2	36.8	115
Aftercondenser	12-3	34.8	115
Recycle Gas Cooler	12-6	1.0	90
Generator Cooler	18-1	76.0	92
Lube Oil Cooler	----	41.0	89

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5.0

HYDROGEN SULFIDE ABATEMENT SYSTEM (P&ID E-03-108)

In order to meet the design requirements for H_2S removal it is necessary to have the H_2S abatement system operating prior to introduction of steam into the turbine and condensers. However when starting up the plant the emergency H_2S treatment system will be used until a stablized load is established. The emergency system is described in Paragraph 5.2.

The H_2S abatement system is comprised of an Incinerator or Thermal Oxidizer (10-18) and Absorber Column (10-9). The Absorber Column has a ceramic packing section for gas scrubbing. The Recycle Pumps (14-12A and B) circulate water and caustic soda through the scrubber. An emergency gas treatment system which directs the noncondensable gas to the brine line is also available in the event the H_2S abatement system is down.

5.1

Pre-start Requirements

5.1.1

Check that Instrument Air supply and electrical power are available to the following instruments.

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Air supply to:

XV-961A, XV-961B, FT-171B, FFIC-171, FT-171A, FV-179, PIC-692, PV-692, LT-571, LIC-571, LV-571, AV-965, AIC-965, AY-965

Electrical power to:

PSL-750, PAL-750, PSH-752, PAH-752, PSL-754, PAL-754, XE-963, XS-963, XA-963, PSL-755, PAL-755, XV-962A, XV-962B, XV-962C, TE-390, TSL-390, TISH-390, TAL-390, TAH-390, BE-964, BS-964, BA-964, TE-391, TSH-391, TE-392, TI-392, LAL-571, LAH-571, FSL-173, FAL-175, FSL-175, FAL-173, AT-965, AY-965, PSL-694

- 5.1.2 Electrical power to pump 14-12A & B and blower motor 14-16 and instruments is switched on.
- 5.1.3 Caustic supply to spray header in Absorber Column is available and control valve AV-965 is closed.
- 5.1.4 Potable water supply to spray heads in Absorber Column is available.

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5.1.5 Water level in bottom of Absorber Column (10-9) is filled to Normal Water Level by operating the potable water spray. Read on LIC-571 the actual level of water in the column. Pointer should read at mid range.

5.1.6 Propane Tank (10-19) is full and block valve V-3 and V-4 are open. PCV-756 should be set for a pressure of 18 psig.

5.1.7 Control Valve XV-961B to bypass system is closed.

5.1.8 System Supply Pressures:

1. Instrument Air - 20 psig
2. Caustic Solution - 20 psig
3. Propane - 7-10 psig
4. Noncondensable Gas - 2 psig

5.1.9 System Piping - verify that all piping systems have been purged of any accumulated material which could foul or plug valve trim, orifices, or other small openings in instruments.

5.2 Scrubber Recirculation System

With the Initial Systems Controls check completed, the Scrubber Recirculation System must be brought on line before lighting the

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burner to begin the refractory cure. The following components are to be started as follows:

- 5.2.1 Open potable water supply to the absorber column thru V-20. Fill packed column base section.
- 5.2.2 Open the Instrument Air Supply Valves to the Level Transmitter (T-571), the Level Indicating Controller (LIC-571), the Level Control Valve (LV-571), and move the LIC-571 set point to midscale. As the level reaches the Low Level Alarm Point, LAL-571, will go out, and the Level Indicator will begin to register.
- 5.2.3 As soon as the Scrubber reaches minimum level, the recycle system must be started so that liquid can be discharged from the system to maintain level control. Open the suction valve (V-14 or V-15) and discharge avlve (V-16 or V-17) on one of the recycle pumps. Open V-18 and V-19 on recycle line. Depress the pump start pushbutton. The Low Flow (FAL-173 and FAL-175) Alarm Light should go off as the flow quickly reaches minimum conditions.
- 5.2.4 Start Combustion Air Blower
- 5.2.5 Pumps 14-12A & B are 100% pumps. One pump is operational while the other is on automatic standby, in the event of the failure of the lead pump.

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5.3 Start-Up Procedure

The Initial Firing and Refractory Cure can now proceed.

5.3.1 Switch the Panel Power Off-On Switch to the "ON" position and verify that the white "PANEL POWER ON" light is lit.

5.3.2 Depress the "LAMP TEST" button to determine that all annunciator alarm point lights are operable. The following lights should remain lit after releasing the "LAMP TEST" button:

- A. Waste Gas Pressure High (PAH-752)
- B. Flame Failure (BA-964, BA-963)
- C. T. O. Temperature High (TAH-390)

5.3.3 Open all instrument isolation valves and all manual valves except those closest to the burner.

5.3.4 Set Ratio Controller FFIC-171 in manual position and open control valve FV-171 approximately 20% open. Open pilot manual valve V-4.

5.3.5 Press the "PURGE START" pushbutton. The blue "PURGING" light on the panel will light. At the end of the purging period (two minutes) the amber "PURGE COMPLETE" light will light and the "PURGING" light will go off.

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- 5.3.6 Press the "IGNITION START" pushbutton. Pilot gas solenoid valves (XV-962A, XV-962B) and Vent Valve (XV-962C) will be energized. Green "PILOT GAS ON" light will be lit. Within 15 seconds, the green "PILOT PROVED" light will be illuminated indicating successful pilot ignition. After 15 seconds, the ignition timer will time out and the amber "PURGE COMPLETE" light will go out.
- 5.3.7 If the pilot flame is not detected within 15 seconds, the ignition timer will time out dropping power to the pilot gas and ignition circuits. Repurge will be mandatory before pilot lighting can be attempted again.
- 5.3.8 To repurge and attempt to re-ignite, repeat Steps 5.3.5 and 5.3.6.
- 5.3.9 If lighting problems persist, refer to the "Pilot Lighting Troubleshooting" List.
- 5.3.10 Once lit, the Pilot can be operated indefinitely.

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NOTE: The following curing should be scheduled to be started three days before anticipated usage.

- 5.3.11 The temperature should now be increased per the "Initial Refractory Curing Schedule (Table 5-2) by slowly increasing gas pressure on pilot as indicated by PI-757. The temperature can also be increased by decreasing the combustion air flow by controller FFIC-171.
- 5.3.12 Each incremental change in temperature must be made while observing that the flame remains stable.
- 5.3.13 After the Refractory Cure-out has been completed noncondensable gas can be added to the system. However there must be sufficient non-condensable gas available to maintain flame temperature, until such time the noncondensable gas will be directed to the emergency system. First activate the pH Control System, put FFIC on automatic control and set point at 7.
- 5.3.14 Open Waste Block Valve, V-27. Depress "WASTE GAS START" pushbutton. This will activate the Waste Gas Solenoid Valve (XY-961) which will open Control Valve (XV-961A) and close Control Valve (XV-961B). In 15 seconds, Waste Gas Timer (3TR) will time out and de-energize Pilot Gas System.

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5.4 Normal Shutdown

5.4.1 Reduce the Oxidizer temperature 200°F (93°C) per hour until 300°F (149°C) is reached by slowly closing V-27. The combustion air damper will have to be adjusted to maintain burner stability.

5.4.2 When 300°F (149°C) is reached, push "WASTE GAS STOP" pushbutton.

5.4.3 Close all waste and pilot gas manual valves.

5.4.4 After the temperature drops below 200°F (93°C), shut off the combustion air blower and close the manual dampers.

5.4.5 Allow Quench recycle to continue until Oxidizer temperature is below 150°F (65°C).

5.5 Temporary Shutdown

5.5.1 Push Waste Gase "STOP" pushbuttons

5.5.2 When 800°F (427°C) is reached, shut off the combustion air blower and close the manual dampers to hold heat in the system.

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5.5.3 Allow Quench recycle to continue.

5.6 Emergency Shutdown

5.6.1 Turn the panel power circuit breaker to the OFF position.

5.6.2 When 800°F (427°C) is reached, shut off the combustion air blower and close the manual dampers to hold heat in the system.

5.6.3 Allow Quench recycle to continue.

5.7 Emergency Gas Treatment System

The emergency gas treatment system is used as a back-up system to the H₂S abatement system in the event that the system should fail. The emergency system consists of a Suction Surge and Moisture Separator (10-17), a Gas Booster Blower (14-15), and a Recycle Gas Cooler (12-6).

5.7.1 Standby/Ready Requirements

The system must be ready at all times to start automatically.

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This system will be used to abate the H_2S gas during low noncondensable gas flows which exist prior to start up of the turbine. The system will also continue to be used until the load on the turbine is stablized.

- A. Check that electrical power is available to the Gas Blower (14-15) and control switch is in AUTO position.
- B. Check that cooling water valves are open to and from the Recycle Gas Cooler (12-6).
- C. Check that control valve FV-179 on Gas Blower discharge is closed.

5.7.2 In the event that the emergency system is required, control valve XV-961B on the bypass line from the H_2S abatement system will automatically open thereby signalling the Gas Blower to start and, hence, put the system into operation.

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TABLE 5-1

START-UP AND SHUTDOWN SCHEDULE

Cold Start-Up After Initial Cure-Out

Heat system with pilot for 10-12 hours, then follow schedule below.

<u>Time-Hours</u>	<u>Oxidizer Temperature</u>
1- 4	Hold at 500°F (260°C)
5- 5	Raise to 600°F (315°C)
5- 6	Raise to 800°F (427°C)
6- 7	Raise to 1000°F (538°C)
7- 8	Raise to 1200°F (649°C)
8- 9	Raise to 1400°F (760°C)
9-10	Raise to 1600°F (871°C)

NOTE: If the unit has been shutdown in excess of one month, the initial curing schedule should be followed.

Hot Start-Up After Temporary Shutdown

Over a period of one hour, gradually increase the temperature to 1000°F (538°C). Hold this temperature for one hour. Gradually increase the temperature 200°F (93°C) per hour until 1600°F (871°C) is reached.

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TABLE 5-2

INITIAL REFRACTORY CURING INSTRUCTIONS

The Thermal Oxidizer should be heated up according to the following Time-Temperature Schedule, after a minimum of one day of Air Curing.

<u>Time-Hours</u>	<u>Oxidizer Temperature</u>
0- 1	Raise to 300°F (149°C)
1- 7	Hold at 300°F (149°C)
7- 8	Raise to 350°F (177°C)
8- 9	Raise to 400°F (204°C)
9-10	Raise to 450°F (232°C)
10-11	Raise to 500°F (260°C)
11-12	Raise to 550°F (288°C)
12-13	Raise to 600°F (316°C)
13-14	Raise to 650°F (343°C)
14-15	Raise to 700°F (371°C)
15-16	Raise to 750°F (399°C)
16-17	Raise to 800°F (427°C)
17-18	Raise to 850°F (454°C)
18-19	Raise to 900°F (482°C)
19-20	Raise to 950°F (510°C)
20-21	Raise to 1000°F (538°C)
21-31	Hold at 1000°F (538°C)
31-32	Raise to 1200°F (649°C)
32-34	Raise to 1400°F (760°C)
34-36	Raise to 1600°F (871°C)

NOTE: Once the curing is started, the Thermal Oxidizer should not be turned off until curing is complete.

If the unit has been shutdown for any length of time, the following schedule should be followed to prevent excessive damage to the refractory.

- (1) Extended shutdown one month or longer: Complete cure in compliance with initial curing cycle.
- (2) One week to one month shutdown: Heat system with pilot only for 24 hours. Raise temperature per Cold Start-Up Schedule in Table 5-1.
- (3) Maximum shutdown one week: Heat system for one hour with pilot. Raise temperature per Cold Start-Up Schedule in Table 5-1.

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6.0

LUBE OIL SYSTEM (P&ID E-03-107)

The Lube Oil System is critical to the long life running of the turbine and generator. The system must provide clean, particle free, correct temperature oil to all bearings and to the hydraulic control system and governor control system. For this purpose a centrifuge is provided to clean the oil and a heater and cooler provided to control the lube oil temperature.

The system is divided into two subsystems - one for lubrication and one for the control system. The control system operates at a higher pressure than the lubrication system. The lubrication system supplies oil to all the bearings on the turbine, gearbox and generator. The control oil system supplies oil to the steam trip and control valve actuators which are operated by the Woodward electronic governor.

6.1

Pre-start Requirements

- A. Check that electrical power and air supply are available to all motors and instruments and heaters listed below as required.

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Electrical power to: Note, only basic element is indicated in some cases, marked *, supplying power to basic element activates other instruments associated with the basic element.

TC-382, LSL-542, LSH-542, LAH-542, TSH-383, TAH-383, TSH-386, TAH-386, PSL-724, PAL-724, PSL-725, PSL-726, PAL-726, TE-363*, TE-358*, TE-357*, TE-355, TE-356*, TE-362*, TE-359*, TE-360*, XE-914*, XE-913*, XE-912*, XE-911*, ST-922*, TSH-355, TAH-361, TSH-356, TAHH-361, PSL-706, PSL-709, PAL-709, PSL-710, PAL-710, Lube Oil Heater, Lube Oil Centrifuge, Auxiliary Lube Oil Pump, Control Oil Pumps and Oil Reservoir Exhauster Fan

- B. Check that Lube Oil drums are ready for loading via the centrifuge and into the reservoir (initial fill only).

Air supply to:

PV-704, PIC-704, Lube Oil Pump

- D. Check that 3" reservoir dump valve is closed.

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- E. Check that Lube Oil Filter elements on the reservoir and are installed (initial fill only).
- F. Check that all Lube Oil Piping has been thoroughly cleaned, flushed and dried (initial fill only). This procedure is extremely important and must be carried out per the Elliott Manual instructions reproduced for convenience in Appendix "C". If for any reason the unit has been shut down for an extended period of time, it would be advisable to clean and flush the lines prior to returning the turbine to service per Appendix "C".
- G. Check that cooling water is available at the Lube Oil Cooler.
- H. Check that all valves to and from centrifuge are open.

6.2

When initially filling the system, pump the lube oil from the storage barrels using the air operated Lube Oil Transfer Pump (14-8) to the Centrifuge (18-2). Care must be taken to adjust the transfer pump flow rate to match the centrifuge discharge rate. This method will ensure that the lube oil enters the system at maximum cleanliness.

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6.3 Start the electric heater in the lubricating oil reservoir.

6.4 A. Start the Lube Oil Auxiliary Pump (18-5) from the Turbine Supervisory Panel when the correct temperature of 85°F has been reached as indicated on TI-381.

NOTE: This pump is used instead of the Main Oil Pump because the Main Oil Pump (18-6) is shaft driven from the turbine and cannot deliver sufficient flow or head until it reaches a high speed.

B. Start vapor exhauster (18-8) from Turbine Supervisory Panel.

C. Check ΔP across reservoir filters by reading PDI-723. See Table 6-1.

D. Visually check for oil flow at the 5 bearing flow glass gauges.

6.5 System is now ready for turbine start.

6.6 To activate the control oil system, start the main control oil pump (18-9) on the Turbine Control Oil Skid from the Turbine

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Supervisory Panel. Observe all pressure and temperature indicators shown on Table 6-1 and check that values are within acceptable limits. Start control oil system shortly before operating trip valves.

6.7

During normal running of the unit, the lube oil shall be circulated from the reservoir through the centrifuge and back to the reservoir. This ensures that the oil is kept at maximum cleanliness during operation.

6.8

If for any reason the reservoir must be emptied, a dump tank (10-16) is provided into which the contents of the reservoir can be drained thru a 3" drain line. A block valve is provided for this purpose.

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TABLE 6-1

LUBRICATION AND CONTROL SYSTEM DATA

Reservoir Capacity:			
Charging		2271 litres	600 U. S. gal.
Working		874 litres	231 U. S. gal.
Main Pump:			
Vendor:	Tuthill	Model:	5RCFA
Output:	3.8 l/s @ 4.1 bar		69.5 gpm @ 59 psig
Driver:	Elliott Gear		
Auxiliary Pump:			
Vendor:	DeLaval-IMO	Model:	C3EBF-162
Output:	3.3 l/s @ 4.1 bar		52.5 gpm @ 59 psig
Driver:	Electric Motor		
Main Pump - Control Oil:			
Vendor:	DeLaval-IMO	Model:	A6DB-187
Output:	4.7 l/s @ 37.3 bar		74 gpm @ 540 psig
Driver:	Electric Motor		
Auxiliary Pump - Control Oil:			
Vendor:	DeLaval-IMO	Model:	A6DB-187
Output:	4.7 l/s @ 37.3 bar		74 gpm @ 540 psig
Driver:	Electric Motor		
Oil Cooler(s):			
Vendor:	Whitlock	Model:	8A78
Water Flow @ Inlet:	5.3 l/s @ 29°C		84 gpm @ 85°F
Oil Filter(s):			
Vendor:	Cuno	Model:	6SL2
Media Size:	10 Micrometers (microns)		
Clean Oil Filter Pressure Differential:			.3 bar 5 psi
Oil Filter(s) - Control Oil:			
Vendor:	Cuno	Model:	3SL3
Media Size:	19 Nucrineters (microns)		
Clean Oil Filter Pressure Differential:			.3 bar 5 psi
Relief Valve Setting			4.8 bar 69 psig
Relief Valve Setting - Control Oil			41 bar 594 psig

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7.0 TURBINE INLET LINE, TURBINE HEAT UP AND CONDENSATE SYSTEM

7.1 Condensate System

The condensate system disposes of the condensed steam from the Main Condensers and Inter and After Condensers. P&ID E-03-104 shows the condensate system.

7.1.1 Pre-start Requirements

- A. Check that electrical power and air supply are available to motors and instruments and control valves as required.

Electrical Power to:

LSH-523, LSL-523, LAHL-523, LSL-521, LAL-521, LSH-521, LAH-521, LSL-524, LSH-524, LSHL-524, LSL-526, LSH-526, LAHL-526, Condensate Pumps 14-2A and 14-2B.

Air supply to:

LT-521, LIC-521, LV-521A, LV-521B, LT-524, LIC-524, LV-524, LT-526, LIC-526, LV-526, FT-121, FI-121

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- B. Check that temporary line strainers are installed upstream of the pumps (14-2A & B).
- C. Check that Condenser Boot is filled with water to Normal Working Level by filling with potable water through the vacuum breaker connection.
- D. Check that suction and discharge valves around pumps and control valves are open.
- E. Check that caustic supply to control valves AV-901 is available.
- F. Check that rupture disc PSE-618 is installed on the overhead ducting.

7.2

Turbine Inlet Line and Turbine Heat Up

The main steam system is composed of the high pressure steam piping from the wellhead area through the Moisture Separator (10-2) and thru the trip valves and then thru the control valves into the turbine. Auxiliary systems include the steam supply to the ejectors (15-1, 15-2, & 15-3) and the gland steam seal system.

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When the turbine is ready for start up it is necessary to transfer control of the wellhead steam supply from the Local Control Panel in the Instrument Building to the Main Control Panel. This is achieved by manually switching the three-way air signal valves at the wellhead local panel thereby diverting the air signals to the control module. Controllers at the Main Control Panel should have the same set point or manual output setting as the respective instrument at the Local Control Panel. Prior to switching the control signal from PIC-1 (Local Panel) to PIC-601A (Main Control Panel) the steam piping must be preheated as described in this section. Concurrently the Moisture Separator Control LIC-1 must be transferred to LIC-501.

Explanatory Note:

Additional information on the operation of the Woodward Governor Controller and the duplicate controls on the Local Supervisory Panel are pending from Woodward Co. and Elliott Corporation.

It is anticipated that this additional data will be available prior to the plant start-up.

The following test covers the current understanding and original design philosophy of the Turbine-Generator unit and represents Rogers Engineering Co.'s input from past experience in the start-up and operation of similar geothermal power plants.

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The initial step in the start-up of the Turbine is preliminary heat up of the Turbine Inlet Line and valving and the turbine and condensing system in order to prevent excessive stress due to rapid temperature changes.

7.2.1 Pre-start Requirements (Initial Start)

- A. Check that steam is available at specified pressure from the wellhead.
- B. Check that all lines have been drained of all previous condensate.
- C. Verify that instrument air and electrical power is supplied to the following instruments on the inlet steam line and vessels and that the instruments are active:

Air supply to:

PV-601, LT-511, LY-511, PDT-612, PT-615

Electrical power to:

TI-313, PR-615, LY-511

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- D. Check that rupture disc PSE-618 has been removed.
- E. Install a temporary blind flange at inlet to Main Condenser.
- F. Check that gland sealing steam control valve PCV-613 is open.
- G. Check that all interstage turbine drain valves are open.
- H. Check that drain connection on Condensate Drain Tank is open.
- I. Check that all control of the wellhead has been transferred to the Main Control Panel.
- J. Check that all Turbine Control Valves are in closed position.
- K. Verify that Lube Oil Auxiliary Pump (18-5) is switched on thru switch at the Turbine Supervisory Panel.
- L. Verify that Main Control Oil Pump is switched on through switch at the Main Control Panel.

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M. Verify that Bently Nevada vibration and bearing temperature equipment is in service. Check read out on the meter on the Main Control Panel for each point in service. Bearing temperature units can be checked by reading temperature. Vibration monitor units have indicating lamps that will be on.

N. Verify that Woodward Governor is energized and reset. Indicating lamps are provided for this purpose, and will light up when the governor is energized.

7.3 Manually open Control Valve PV-601 using controller in Main Control Panel to admit small amount of steam into inlet line.

7.4 Manually open gland sealing steam control valve, PCV-613. Read PI-614 on turbine skid to check pressure range of 3-5 psig.

7.5 Operate ramp control at turbine supervisory panel for trip valve No. 1 to slowly open the valve and admit steam to the inlet pipe. Open synchronizing valve until turbine starts turning. Watch the speed carefully and stop opening synchronizing valve when speed reaches 500 rpm.

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- 7.6 Turbine can now be left running at this speed to clean out turbine interior and warm up pipelines. Careful attention must be given to any unusual occurrences, such as vibration or rubbing noises.
- 7.7 Heat up and cleaning period should last approximately one hour if no problems occur.
- 7.8 Woodward manual, chapter ____, gives details of the control valve ramp controls and governor operation; a copy of pertinent sections of this manual are contained in Section 8.0.
- 7.9 During the initial warm up of the turbine and inlet piping the steam is exhausted to atmosphere in order that all perservative materials coated on the internal parts of the turbine are not redeposited on the condenser tubes.

The turbine can be exhausted to atmosphere through the rupture disc connection PSE-618; however, there are no permanent provisions to block off the condenser from the steam flow. Field arrangement must be made to block the steam path during intial start up of the unit by means of a temporary blind placed in the inlet to the condenser. During the venting to atmosphere maintain a very low steam flow rate sufficient to operate turbine at a running speed of 500 rpm.

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- 7.10 After completing the above close PV-601, and allow turbine to coast down. When exhaust duct temperature permits re-install rupture disk PSE-618 and remove the temporary blind at the condenser inlet.
- 7.11 The next procedure is to repeat the warm up, but to exhaust the steam into the condenser.
- 7.12 On initial start up of the system, start the condensate pumps during the warm up period for the turbine. During initial warm up of the turbine steam piping a small amount of condensate is produced which will be added to the water in the Main Condenser Boot.
- 7.13 To start condensate pumps, select either pump (14-2A or 14-2B) thru switch on Main Control Panel. Start pump selected on "Hand" position then turn both pump control switches to "Auto".
- 7.14 The control valve LV-521A in condensate pump discharge line (C-005) is normally closed on initial start up and the water from the boot is recirculated through control valve LV-521B. Control valve LV-521A will gradually open as the level rises in the Main Condenser Boot.
- 7.15 Start up the vacuum system. The first stage ejector is started by manually opening the inlet steam valve to the ejector. Initially the ejector may experience a lack of gases from the condenser caus-

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ing surging of the ejector. This can be overcome by opening the bypass valve V-32 on line E5-010. Check readings should be made of PI-631. The vacuum will slowly increase until an operating vacuum of 4" Hg is obtained. It may not be possible to obtain this value until the 2nd ejector is activated and steam flow to the system is increased .

- 7.16 Maintaining the turbine speed at 500 rpm, turn the level controller LIC-521 to automatic. This will bring control valves LV-521A and LV-521B under automatic control. The level in the condenser should remain constant at the normal water level point.
- 7.17 The second ejector is now brought into action by manually opening the steam valve to that ejector. Once again surging may be experienced, and the bypass valve around the ejector (V-33) should be opened to control this situation. Control valves LV-524 (intercondenser) and control valve LV-526 (aftercondenser) should be put into AUTOMATIC on LIC-524 & LIC-526, respectively. The bypass valves on both ejectors should be slowly closed as the system stabilizes.
- 7.18 The condensate system is now fully activated and ready for an increased steam load.

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8.0 TURBINE AND GENERATOR OPERATION

8.1 Prerequisite Conditions

- 8.1.1 Check that turbine control valves for System #1 and #2 are closed and that the trip valve for System #1 and #2 are closed.
- 8.1.2 Check that Cooling Water and Condensate systems are in operation.
- 8.1.3 Verify that control circuits have been tested.
- 8.1.4 Verify that all protective relays are set and operational.
- 8.1.5 Verify that generator insulation resistance readings are acceptable and have been consistent during initial operation or after extended shutdown.
- 8.1.6 Verify that manual and automatic voltage regulators are operational and set for manual operation. (Manual operation for initial start-up, testing and back-up).
- 8.1.7 Verify that instrumentation is calibrated properly and zeroed.

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- 8.1.8 Supervisory control Transfer Switch (143 RE) in Main Control Panel shall be in "local" position. White light on panel will be on.
- 8.1.9 Verify that governor has been energized and allowed to warm up for 10 minutes.
- 8.2 Start generator makeup fan.
- 8.3 Set PIC-601A to 160 psig and change from MANUAL to AUTOMATIC.
- 8.4 Turbine-Generator Start-up
 - 8.4.1 Start the Auxiliary Oil Pump (18-5) and the Main Control Oil Pump (18-9) using selector switches SS-4 and SS-3 on Turbine Supervisory Panel No. 1. These pumps supply lube and control oil to the turbine and the five hydraulic amplifiers on the trip and control valves.
 - 8.4.2 Depress System 1 transfer button on Main Control Panel. This will transfer the trip, synchronizing and control valve ramp controls from the governor control in the Main Control Panel to the Turbine Supervisory Panel.
 - 8.4.3 Depress the "ON" buttons for fail safe override speed and kW sensor, and "reset" buttons for governor and trip valves on the governor control in the Main Control Panel.

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- 8.4.4 Set the governor in a droop mode of operation by opening the "Droop Mode Switch" located adjacent to the governor control in the Main Control Panel.
- 8.4.5 Operate System 1 Trip Valve Ramp Switch (SS-5) to ramp fully open the System 1 trip valve.
- 8.4.6 Using "ramp" control switch (SS-7) for the synchronizing valve in the Supervisory Panel adjacent to the turbine, slowly open the synchronizing control valve and increase the turbine speed.
- 8.4.7 Bring turbine slowly up to first critical speed of 3,300 rpm then pass quickly through first critical speed range by ramping the synchronizing valve open until synchronous speed, 5,800 rpm, is reached.
- 8.4.8 Transfer control to the governor in the Main Control Panel by depressing the "OFF" side of System 1 transfer buttons.
- 8.5 To Place Generator In Service
 - 8.5.1 Bring generator to 60 cps through operation of speed or Raise-Lower switch on governor panel.

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- 8.5.2 Place voltage regulator control switch on Main Control Panel in "Manual" position.
- 8.5.3 Increase generator voltage slowly to 4 kV using manual regulator.
- 8.5.4 To transfer to automatic voltage regulator turn transfer switch to "Auto". Normal operation will be through the automatic regulator which is controlled through Switch 70V-CS.
- 8.5.5 Run unloaded (in conjunction with turbine). Check generator for water flow and temperature, oil temperature, vibration, and winding temperature.
- 8.5.6 Check phase rotation (initial operation only).
- 8.5.7 Obtain clearance from dispatcher to parallel generator with system.
- 8.5.8 Two methods of synchronizing are provided, manual and automatic. For manual operation turn selector switch 143 SS to "manual" position. To parallel with system close synchronizing switch. Match voltage and frequency. Close 4 kV generator circuit breaker when synchroscope is a "24-o'clock" position. For automatic operation turn

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selector switch to "auto" position and push SPM button on governor. A synchronizing relay which is part of the governor will automatically match frequency and voltage and close the generator circuit breaker.

- 8.5.9 After synchronization, the generator is loaded by ramping open System 1 control valve to approximately 300 kW of load to stabilize turbine operation. Hold this load for 10-20 minutes.
- 8.5.10 Advise dispatcher that generator is paralleled. Request permission to take load. The turbine-generator shall be loaded at a rate not exceeding 0.1 MW/minute.
- 8.5.11 Ramp synchronizing valve closed after fully loading the generator.
- 8.5.12 Pick-up minimum var load to cover reactive requirements of auxiliary power system. Add additional var load as directed by system dispatcher.
- 8.6 The Turbine-Generator is now ready for synchronized operation with the HELCO power system.

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8.7 Normal Operation Parameters

8.7.1 The following control panel meter readings will be indicated at generator design load:

Wattmeter:	3000 kW
Varmeter:	1176 kvar
Ammeter:	520 Amperes
Voltmeter:	4.16 kV (119V-voltmeter is secondary reading)

Temperature:	
Stator Windings:	Less than 120°C
Inlet Air:	40°C Maximum
Outlet Air:	Less than 100°C

8.7.2 During normal operation at rated conditions:

Inlet Cooling Water Temp.	29.4°C (85°F)
Temperature Rise Across Coolers:	5°C (10°F)
Outlet Cooling Water	34.4°C (94°F)
Bearing Oil Discharge Temperature:	Less than 60°C (140°F)
Vibration:	0.005 in. peak-to-peak

8.7.3 Limitations:

Voltage:	± 5% or 4,370 Maximum
Frequency:	± 5% or 57 to 63 cps

8.7.4 For operation at other loads see Reactive Capability curve, Fig. 8-1 which indicates permissible loading with different power factors and megawatt output.

8.7.5 Four methods of generator loading are available:

1. Load sharing with other sources on system where generator loading increases and decreases proportionate to system load

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LEADING

FIG. 8-1 APPROXIMATE REACTIVE
CAPABILITY CURVE
FOR OVER EXCITED
REGION.

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and governor speed droop characteristics. Enabling switch is located adjacent to governor. Normally this switch will be open.

2. Constant load utilizing the Woodward governor. Set point controls and an enabling switch marked kW Sensor are available on governor control panel in the Main Control Panel.
3. Constant var output or constant power factor. Enabling control switch is on the Main Control Panel. Set point rheostat is located on the Main Control Panel.
4. Constant frequency control. Turbine-generator will operate isochronously. For normal operation this will not be used. For continuous operation as an isolated plant this mode may be used. Frequency control switch is located on the governor panel in the Main Control Panel.

8.7.6 Normal Operation

- A. The intent of the system is to operate normally carrying a constant 3000 kW load. The 34.5-kV system may not require or be capable of absorbing 3000 kW. To absorb the difference

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between 3000 kW and HELCO requirements, use the load bank. Control switch is located on the Main Control Board for adjusting the load bank controller.

- B. Generator can be operated manually if the power plant is attended. However remote control over the generator voltage adjusting rheostat and the load bank controller and generator circuit breaker will be through HELCO's supervisory control equipment. To transfer control, turn switch 143 RE to "REMOTE"; an amber light adjacent to the switch will go on.
- C. Should the plant be separated from the power system. Plant operation can continue independently, but at a reduced load of approximately 1800 kW consisting of 1600 kW on the load bank controller plus auxiliary power load.

8.8 Transfer of load between System 1 and System 2.

8.8.1 While System 1 is on load, ramp fully open the System 2 trip valve.

8.8.2 Depress the Frequency Control maintained pushbutton and the kW sensor "ON" button.

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- 8.8.3 Ramp open the System 2 control valve.
- 8.8.4 Slowly ramp closed the System 1 control valve.
- 8.8.5 Ramp closed the System 1 trip valve.
- 8.8.6 Turn off frequency control and kW sensor.
- 8.8.7 For transfer from System 2 to System 1 exchange systems in the above procedure.

8.9 Stem Free Test

The purpose of the Stem Free Test is to assure that both the trip valve and the turbine control valve on each system will operate smoothly and quickly in the event of an emergency.

Stem Free Test shall be made on trip and control valves and shall be made shortly after the turbine is started, shortly before normal shutdown and at least once daily.

- 8.9.1 Transfer turbine governor control to System 2 as described in Paragraph 8.8.

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- 8.9.2 Verify that synchronizing valve, System 1 control valve and System 2 trip valve are closed.

- 8.9.3 Depress Synchronizing Valve Stem Test pushbutton. Button will latch in and light up. Synchronizing valve will automatically open and close in 7 seconds. Observe Actual Position indicator on governor control panel to insure that valve moves through its entire range. Release pushbutton by depressing a second time.

- 8.9.4 Depress System 1 Control Valve Stem Test pushbutton. Control valve will cycle as described for synchronizing valve in Paragraph 8.9.3.

- 8.9.5 Ramp the System 1 trip valve fully open and observe that "OPEN" light on governor control panel comes on. Then ramp trip valve closed and observe that "CLOSED" light comes on.

- 8.9.6 Transfer turbine governor control to System 1 and repeat the above steam test procedure for System 2 control valve and trip valve.

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9.0

LOAD BANK OPERATION

9.1

Load bank provides up to 1600 kW of dummy load on the generator. Control is either local, through a control switch on the main control panels, or through the HELCO supervisory control system.

9.2

To Energize Load Bank

9.2.1

Close fan motor starter circuit breakers at motor control center.

9.2.2

Start load bank resistor cooling fans from push button on Terminal Box 6. Indicating lights are provided locally and at the motor control center. Note that each resistor circuit breaker can not be closed unless the fan is operation first. Each resistor is provided with an air flow switch and temperature switch to protect the resistor against over temperature.

9.2.3

Control Power Circuit Breaker

A. 1LA will light.

B. 1L4, 1L5, 1L5, 1L7, 1L8, will not light until BCB turned "ON"

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- C. AR will be de-energized and in alarm state.
- D. Digital voltmeter will read "ZERO"

9.2.4

Close Main Circuit Breaker

- A. 1LB will light. Set PCM control to "local" and set point to "minimum."
- B. Push "set point button and turn" set point knob until DVM reads "ZERO"
- C. Set "manual power adjust" to minimum and "auto-manual" selector to "manual."

9.2.5

Close Resistor Circuit Breaker (BCB1)

- A. 1L1 will light.
- B. Adjust SCR1 "bias" until voltmeter reads "ZERO"
- C. Turn "manual" adjust to maximum and adjust SCR1 "gain" until wattmeter reads maximum kW (approximately 400 kW).
- D. Reduce "manual" adjust to minimum and trip circuit breaker.

9.2.6

Repeat Paragraph 9.2.5 in turn with BCB2, BCB3 and BCB4.

9.2.7

Automatic Load Bank Control

- A. Set PCM to desired kW as indicated on meter
- B. Set PCM to "auto"
- C. SCR's soft-start feature will increase load to preset value.

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- D. PCM 3-mode control function will regulate load as measured by PT to hold preset load level.
- E. Partial or total loss of any load bank will be compensated by the PCM within the capacity of the remaining active load banks.
- F. The load bank kW will be continuously displayed on both the load bank controller and on the main control panel.

9.2.8

Main Circuit Breaker will be tripped if the generator is tripped through operation of any protected device. Lockout relay 186G on switchgear must be reset prior to closing the circuit breaker.

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10.0

NORMAL AND EMERGENCY SHUTDOWN - MECHANICAL AND ELECTRICAL

Several systems have emergency shutdown trips to prevent damage to the plant equipment and provide overall safety of operation. Normal shutdown is defined as any shutdown which is premeditated and not caused by an emergency condition. An example of normal shutdown would be a maintenance shutdown for routine inspection and repair.

The following procedure should be used for normal shutdown.

10.1 Normal Shutdown (Attended Station)

- 10.1.1 Request permission of dispatcher to drop load (if shutdown is required by plant internal problems)
- 10.1.2 Reduce load at a rate not to exceed 0.1 MW/min. The Generator load removal will cause a partial closing of the turbine control valve resulting in a rise in pressure in the incoming steam line which will activate the bypass valve PV-1 allowing steam to be dumped to the rock muffler. As PV-1 opens PV-601 closes. Once PV-601 is fully closed, the block valve upstream of PV-601 should be manually closed.

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- 10.1.3 Trip generator circuit breaker.
- 10.1.4 Reduce voltage to zero through voltage regulator.
- 10.1.5 Make final running inspection. Check water and oil temperatures, and for excess vibration.
- 10.1.6 Depress "Shutdown" button on Governor Control Panel in Main Control Panel.
- 10.1.7 Stop generator makeup fan after turbine is tripped
- 10.1.8 Make inspection after shutdown in accordance with manufacturer's check list.
- 10.1.9 Verify generator space heater is in operation.
- 10.1.10 Shut off valves to ejectors to inter-and after-condensers and condensate drain.
- 10.1.11 Shut off caustic supply valve AV901 to condensate system.
- 10.1.12 Shut off seal steam supply to turbine glands.

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- 10.1.13 Turbine will now roll to a halt in approximately 15 minutes.
- 10.1.14 When speed drops below 1000 rpm or oil pressure drops below 18 psig, the Auxiliary Lube Oil Pump will automatically start to supplement the main lube oil pump which is shaft driven.
- 10.1.15 Shut off all plant load, i.e., cooling water pumps, condensate pumps, cooling tower fans etc. except for air compressors and H₂S abatement system.
- 10.1.16 When speed drops below 1,000 rpm, open the vacuum dump valve on the main condenser. This will increase the deceleration of the machine.
- 10.1.17 During the period of shutdown of the machine the H₂S system and all other caustic injection points except the Wellhead steam bypass line should be shutdown.
- 10.1.18 By the time the turbine has rolled to a halt, all systems should be shut down or in the process of being shutdown. If shutdown is for a short duration, it may be required to keep the H₂S abatement system active and ready for a restart of the plant. In this case the propane pilot light should be kept active to maintain the temperature in the incinerator, see Section 5.0 H₂S Abatement System.

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- 10.1.19 A decision on shutdown of the wellhead would depend on the reason for the plant shutdown. However, any period of shutdown anticipated to be in excess of one week would require a decision within three days on Wellhead shutdown.

10.2 Emergency Shutdown

By nature of this condition no planning is involved in an emergency shutdown and usually a trip function on the turbine or other major piece of equipment has caused the shutdown.

- 10.2.1 The annunciator will indicate the reason for the shutdown. An emergency shutdown could trip out several systems; however, the annunciator panel has a first down signal system enabling the operator to identify the original cause of the problem.

- 10.2.2 Any trip signal will close the control and emergency stop valves on the steam inlet line to the turbine, causing a pressure rise in the steam line and an opening of the bypass control valve, thereby dumping steam to the rock muffler.

- 10.2.3 The operator must then follow through with decisions on the action necessary based on the data available for the cause of the tripout. A minor problem could be easily fixed and the system brought back

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onto line in short time. Other situations could be more serious and require complete plant shutdown as described in paragraph 10.1.

10.2.4 The generator and the turbine will automatically trip on the following (see also P&ID E-03-103).

1. Low dc battery voltage
2. Reverse power
3. Field failure
4. Excess negative sequence current
5. Excess phase overcurrent
6. Neutral fault
7. Differential current (internal fault)
8. Ground fault
9. Underfrequency
10. Winding overtemperature
11. High air temperature causing CO₂ injection
12. Excess vibration
13. Bearing overtemperature
14. Turbine problems - See Section 8.0
15. Pushing of either of the "Shutdown" buttons on the Governor Control Panels in the Main Control Panel

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Except for vibration, bearing over-temperature and carbon dioxide injection, other trips sound a common alarm. Vibration and bearing over-temperature alarm is combined with that of the turbine trip alarm.

- 10.2.5 Lockout relay 186G on the switchgear must be reset before reenergizing the generator but only after operation of any of the devices is investigated and corrections or repair made.

10.3 Safety

Throughout all aspects of plant shutdown the operator must observe all safety rules and apply safety techniques in shutting down the equipment.

- 10.3.1 A tagging system provided by Hawaiian Electric Company is to be used exclusively throughout the plant and all operators are required to familiarize themselves with the safety system. This system is covered under Section 11.0.

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11.0

CLEARANCE PROCEDURES

11.1

Clearance procedures during plant start-up will be in accordance with Hawaiian Electric Light Company procedure except as modified below.

11.2

Hawaiian Electric Light Company red, yellow, and blue tags shall be used.

11.3

All tags shall be signed by the supervising operator or engineer or his designee until such time as the plant is accepted. A log will be maintained of tags issued.

11.4

A red tag shall be placed on equipment at such time as the supervising operator or engineer believes that the equipment is operational and removed only for system testing.

11.5

Yellow tags (mechanical) or blue tags (electrical) shall be used when equipment is taken out of service for adjustment or maintenance.

11.6

The above procedure shall also be used during the final construction phases and start-up testing of the plant.

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LIST OF DRAWINGS

<u>Drawing No.</u>	<u>Description</u>
E-41-001	Key Plan Mechanical
E-17-110	Key Plan Electrical
E-03-101	P&ID Legend
E-03-102	P&ID Wellhead Steam System
E-03-103	P&ID Steam System
E-03-104	P&ID Condensate and N/C Gas System
E-03-105	P&ID Cooling Water System
E-03-106	P&ID Compressed Air System
E-03-107	P&ID T/G Lube and Control Oil Systems
E-03-108	P&ID Hydrogen Sulfide Abatement
E-03-109	P&ID Ponds & Potable Water Systems
E-03-112	P&ID Chemical Feed System
E-08-101	Single Line Diagram
E-08-102	Single Line Meter & Relay Diagram
54146-D0226 (Gould)	General Arrangement
00509B (ECS)	GBB/LFE Panel Assembly
00509 (Sht. 1) (ECS)	Plant Control Panel Assembly
00509 (Sht. 2) (ECS)	Plant Control Panel Assembly
00509 (Sht. 3) (ECS)	Plant Control Panel Assembly
E-08-103	Logic Diagram Power Plant Protective System

LINE IDENTIFICATION

COMMODITY DESIGNATION

AS	AUXILIARY HIGH PRESSURE STEAM
C	CONDENSATE
CO	LUBE OIL (CLEAN)
CW	COOLING WATER
DO	LUBE OIL (DIRTY)
ES	EXHAUST STEAM
HS	HIGH PRESSURE STEAM
IA	INSTRUMENT AIR
NCS	NON-CONDENSABLE GAS
CH	CHEMICAL
PH	POTABLE WATER
UA	UTILITY AIR
ACW	COOLING WATER
EW	EFFLUENT WATER
TP	TWO PHASE

INSTRUMENT IDENTIFICATION LETTERS

(BASED ON ISA STANDARD 5.5.1)

LETTER	MEASURED OR VARIABLE (FIRST LETTER)	PASSIVE OR OUTPUT FUNCTION (SUCCEEDING LETTERS)
A	ANALYSIS	ALARM
C	CONDUCTIVITY	CONTROL
D	DENSITY OR DIFFERENTIAL	ELEMENT
E	VOLTAGE	
F	FLOW OR FRACTION (RATIO)	GLASS (UNCALIBRATED)
G	GAGING	HIGH
H	HAND OR MANUAL	INDICATE
I	CURRENT	
J	POWER OR BEAM	
K	TIME OR SCHEDULE	CONTROL STATION
L	LEVEL	LIGHT OR LOW
M	MOISTURE OR HUMIDITY	MIDDLE OR INTERMEDIATE
N		SAMPLE ORIFICE
O	PRESSURE OR VACUUM	INTEGRATE
P	QUANTITY OR EVENT	RECORD OR PRINT
R	SPEED OR FREQUENCY	SAFETY OR SWITCH
S	TEMPERATURE	TRANSMITTER
T	MULTIVARIABLE	
U	VISCOSITY	VALVE, DAMPER OR LOOPER
V	WEIGHT OR FORCE	WELL
X	VELOCITY	CONNECTION OR TAP
Y		RELAY OR COMPUTE
Z	POSITION	DRIVE OR ACTUATE

EXAMPLE:

RT - FLOW TRANSMITTER
LIC - LEVEL INDICATING CONTROLLER
PR - PRESSURE, RECORDER

ABBREVIATIONS

AS	INSTRUMENT AIR SUPPLY
AUX	AUXILIARY
AVG	AVERAGE
D	DERIVATIVE
DIFF	SUBTRACT
DIA	DIRECT ACTING
ES	ELECTRIC SUPPLY
FC	FAIL CLOSED
FI	FAIL INTERMEDIATE
FL	FAIL LOCKED
FO	FAIL OPEN
I	INTERLOCK
M	MOTOR
MAX	MAXIMIZING
MIN	MINIMIZING
R	AUTOMATIC RESET
REV	REVERSE ACTING
RTD	RESISTANCE TEMPERATURE DETECTOR
S	SOLENOID
STR	STRAINER
T	TRAP
UG	UNDERGROUND
VALV	VALVE
PP	PERSONNEL PROTECTION
DR	DRAIN
NCS	NON-CONDENSABLE GAS
CO	CHAIN OPERATED
E/E	END TO END

SYMBOLS

SYMBOLS CONT.

INSTRUMENT TYPE	INSTRUMENT IDENTIFICATION LETTERS
LOCALLY MOUNTED INSTRUMENT SYMBOL	INSTRUMENT LOOP NUMBER LOCALLY MOUNTED INSTRUMENT SYMBOL
100 SERIES - EXISTING INSTRUMENTS	
200 SERIES - NOT ASSIGNED	
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LOCALLY MOUNTED INSTRUMENT SYMBOL	INSTRUMENT LOOP NUMBER LOCALLY MOUNTED INSTRUMENT SYMBOL
100 SERIES - EXISTING INSTRUMENTS	
200 SERIES - NOT ASSIGNED	
300 SERIES - TEMPERATURE INSTRUMENTS	
400 SERIES - NOT ASSIGNED	
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600 SERIES - PRESSURE INSTRUMENTS	
700 SERIES - PRESSURE INSTRUMENTS	
800 SERIES - NOT ASSIGNED	
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INSTRUMENT TYPE	INSTRUMENT IDENTIFICATION LETTERS
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NOTE:
EQUIPMENT AND MATERIALS WITHIN DASHED BOX
ARE OWNER FURNISHED

CONDENSATE PUMPS
(1 PUMP ON 100% STANDBY)
14-2A
14-2B
100 HP @ 3600 RPM
3.00 HP @ 3600 RPM AVAILABLE
3 HP

PIPELINE MIXER
20-14C

THESE DRAWINGS WERE PREPARED BY ME OR UNDER MY SUPERVISION AND CONSTRUCTION OF THIS PROJECT WILL BE UNDER MY PERSONAL SUPERVISION.
[Signature]

REVISIONS 1. REVISED FOR PLANT 2. REVISED FOR PLANT 3. REVISED FOR PLANT 4. REVISED FOR PLANT 5. REVISED FOR PLANT				REVISIONS 1. REVISED FOR PLANT 2. REVISED FOR PLANT 3. REVISED FOR PLANT 4. REVISED FOR PLANT 5. REVISED FOR PLANT				REVISIONS 1. REVISED FOR PLANT 2. REVISED FOR PLANT 3. REVISED FOR PLANT 4. REVISED FOR PLANT 5. REVISED FOR PLANT				REVISIONS 1. REVISED FOR PLANT 2. REVISED FOR PLANT 3. REVISED FOR PLANT 4. REVISED FOR PLANT 5. REVISED FOR PLANT			
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HCP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
PIPING & INSTRUMENTATION DIAGRAM
CONDENSATE AND NC GAS SYSTEM
JOB NO. 11016
DATE 11/29/73
PAGE 3

NOTE
EQUIPMENT AND MATERIALS WITHIN DASHED BLOCK
ARE SUPPLIED BY OWNER

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION AND I AM A LICENSED PROFESSIONAL ENGINEER IN THE STATE OF HAWAII.

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII		HCP-A WELLHEAD GENERATOR PROOF-OF-FEASIBILITY PROJECT PIPING AND INSTRUMENTATION DIAGRAM COMPRESSED AIR SYSTEM	
DESIGNED & DRAWN FOR: _____ CHECKED BY: _____ APPROVED BY: _____		DATE: _____ SCALE: _____ SHEET NO. 3

NOTES

1. ITEMS MARKED WITH AN ASTERISK ARE FURNISHED & INSTALLED BY THE OWNER. TRANSFORMERS PROVIDE REMOTE METERING TO KILD CITY. POSITION STATUS OF CIRCUIT BREAKERS 152B 1, 154T, 154T2, 154T3, & 154T4 TRIP. ALL OTHERS TRANSFERRED TO KILD CITY. (ITEMS NOT IN CONTRACT)
2. FOR CYCLOIDS NOT IDENTIFIED SEE DWS, E-00-18.
3. ALL VOLTAGE & CURRENT TRANSFORMER SOUNDS ARE AT 4KV SWITCHGEAR.
4. DOUBLE SECONDARY WINDING.
5. BREAKER SYNCHRONIZER REGULATES ALL DISCONNECT METER AND CONTROL DEVICES ARE LOCATED ON CONTROL PANEL AND ALL RELAYS, WITHOUT METER & PROTECTIVE DEVICES ARE IN SWITCHGEAR OR MOTOR CONTROL CENTER.
6. DESIGN GOVERNOR PROVIDES VOLTAGE SPEED MATCHING AND AUTOMATIC SYNCHRONIZING FUNCTIONS.

HGP-A WELL HEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
SINGLE LINE
METER & RELAY DIAGRAM
E-08-102 6

1-- OVERALL SHIPPING DIMENSIONS ARE NOT LIMITED TO HOUSING DIMENSIONS SHOWN. SHIPPING SECTIONS MAY BE INCREASED BY EXTENSIONS OF BUSKINGS, BUS ETC. ON EITHER OR BOTH ENDS OF SPLIT. IF DIMENSIONS OF SHIPPING SECTIONS ARE CRITICAL, REFER TO HOME OFFICE FOR FIRM OVERALL DIMENSIONS.

2-- REFER TO DWG. 637638 FOR STANDARD SINGLE LINE SYMBOLS.

3-- STANDARD GOULD-V-T-E FINISHES (UNLESS OTHERWISE SPECIFIED)
INDOOR-LIGHT GRAY BAKED SYNTHETIC ENAMEL, ASA61

4-- ACB WEIGHTS x 950 LBS

5-- SEE 54146-D1861 FOR PLAN VIEW

GENERAL ARRANGEMENT

UNOOR SWGR - 4700V - 1200A - 250MMH - 30 JW - 60 HZ
RESEARCH CORPORATION - UNIVERSITY OF HAWAII - NGFA WELLHEAD PROJECT

GOULD	SHITTEGEAR DIVISION	54146 - 00226	2
---	------------------------	---------------	---

MANUFACTURER OF LTV EQUIPMENT		ENTERING		DATE IN	
BOX 5844297	BY VIET D	CHR E MORGAN	APR 19 1982		
BOX 37-3416	DATE 9-20-83	DATE 5-21-83	DATE 5-21-83	DATE	
THE DRAWING IS THE PROPERTY OF SOURCE AND DOES NOT CONTAIN INFORMATION AND CONFIDENTIAL DATA FROM SOURCE MUST NOT BE DISSEMINATED OR BE SUBJECT OF OTHER PUBLICATIONS WITHOUT INFO OF SOURCE.					

FRONT VIEW

NO	REVISIONS
----	-----------

4

Journal of Interpersonal Violence 26(10)br/>© The Author(s) 2011
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LEFT END VIEW

FRONT VIEW

RIGHT END VIEW

NAMER PLATES - BLACK W/WHITE 3/4" LTR 5/16" WITH SCREEN HOLES

- 50 - MANUAL VOLTAGE REGULATOR
- 51 - TEMPERATURE SWITCH
- 52 - GENERATOR BREAKER CONTROL SWITCH
- 53 - GOVERNOR CONTROL SWITCH
- 54 - GENERATOR TEMPERATURE
- 55 - GENERATOR WATTS
- 56 - LOAD BANK WATTS
- 57 - PLANT OUTPUT WATTS
- 58 - BUS VOLTS
- 59 - SYNCHROSCOPE
- 60 - GENERATOR AMPS
- 61 - GENERATOR VARS
- 62 - PLANT OUT AMPS
- 63 - PLANT OUT VARS
- 70 - INCOMING VOLTS
- 71 - FREQUENCY
- 72 - LOAD BANK BREAKER CONTROL SWITCH
- 73 - TRANSFORMER BREAKER CONTROL SWITCH

- 74 - RECORDING VOLTMETER
- 75 - RECORDING WATTMETER
- 76 - 24KV LINE
- 77 - BUS VOLTMETER SWITCH
- 78 - CIRCUIT SWITCHER CONTROL SWITCH 207CS
- 79 - GENERATOR AMMETER SWITCH
- 80 - GENERATOR SYNCHRONIZING SWITCH
- 81 - GENERATOR VOLTAGE REGULATOR SWITCH
- 82 - PLANT OUT AMMETER SWITCH
- 83 - TRANSFORMER SYNCHRONIZING SWITCH
- 84 - SUPERVISORY CONTROL TRANSFER SWITCH
- 85 - POWER FACTOR VAR SELECTOR SWITCH
- 86 - GENERATOR PARALLELING SWITCH
- 87 - VAR CONTROLLER ADJUST RHEOSTAT
- 88 - GENERATOR OVER TEMPERATURE
- 89 - AUTO-MANUAL SYNCHRONIZING SELECTOR SWITCH

VENDOR DRAWING REVIEW	
Review is for General Compliance with Contract Documents. No responsibility is assumed by this review. Contractor or Supplier has complete responsibility for design, performance and compliance with Contract Documents, Drawings, Specifications and Purchase Orders.	
1	As Executed
2	Revised
3	As Issued
4	As Issued and Forwarded
5	As Issued and Forwarded
6	As Issued and Forwarded
ROGERS ENGINEERING CO., INC.	
2100 20th St. San Francisco, Calif. 94133	
By: [Signature] Date: 1/18/81	

ITEM 107 ADDED BY ROGERS ENGINEERING Co. Inc.	1/20/81
REVISIONS	BY APPD. DATE

VENDOR PRINT NO.

40-10-7-7

CUST. RESEARCH CORP. UNIV. OF HAWAII

CUST. PO. NO. 434425 ECS. SO. NO. 005095

ECS ENGINEERED CONTROL SYSTEMS
ONE KELLY COURT, BERKELEY, CALIFORNIA 94701

TITLE: HAWAIIAN WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
DESIGNS PANEL ASSEMBLY

SCALE (1/4"=1')	DATE	DWG. NO.
DFTM. JK	8-25-80	005095
ENGR. [Signature]	1-25-81	01
CHKD. [Signature]		SHEET NO. (1 OF 2) REV.

LEFT END VIEW

FRONT VIEW

RIGHT END VIEW

NAMEPLATES: BLACK W/WHITE ENGRAVING

- A - COOLING TOWER FAN #1
- B - COOLING TOWER FAN #2
- C - COOLING WATER PUMP A
- D - COOLING WATER PUMP B
- E - CONDENSATE PUMP A
- F - CONDENSATE PUMP B
- G - ALARM SYSTEM
- H - TEMPERATURE INDICATOR
- I - SELECTOR
- J - VIBRATION MONITOR
- K - GOVERNOR CONTROLLER
- M - COOLING WATER PUMP SELECTOR
- N - CONDENSATE WATER PUMP SELECTOR
- O - SYSTEM 1
- P - SYSTEM 2
- Q - TURBINE EMERGENCY TRIP

DETAIL OF H/P 'L'

- 1 - TESIS-1 MAIN STEAM
- 2 - TESIS-2 CONDENSER NON-CONDENSIBLE GAS
- 3 - TESIS-3 INTERCONDENSER NON-CONDENSIBLE GAS
- 4 - TESIS-4 AFTER CONDENSER
- 5 - TESIS-5 CONDENSATE DISCHARGE
- 6 - TESIS-6 MAIN CONDENSER COOLING WATER DISCHARGE
- 7 - TESIS-7 INTER CONDENSER
- 8 - TESIS-8 AFTER CONDENSER
- 9
- 10

REVISIONS

1	AS BUILT	DATE	12-6-80
2		DATE	
3		DATE	
4		DATE	
5		DATE	
6		DATE	
7		DATE	
8		DATE	
9		DATE	
10		DATE	

Capco Engineering Co., Inc.
San Francisco
RECEIVED
JAN 15 1981
FAC. NO. R-12
OS NO. 120000-31

VENDOR PRINT NO.
40-110-1-1

CUST. RESEARCH CORP. UNIV. OF HAWAII
CUST. PO. NO. 4844245 E.C.S. SO. NO. 00509

ECS ENGINEERED CONTROL SYSTEMS
ONE KYLE COURT WOODBURY, CALIFORNIA 94025

TITLE
HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
PLANT CONTROL PANEL ASSEMBLY

SCALE 1/8" = 1"	DATE	DWG. NO.
DTM	6-18-80	00509
ENGR	2-1-81	
CHKD		

SHEET NO. 1 OF 3

REV. NO.	REVISIONS	BY	APPRO.	DATE	CHD.	REV.
1	AS BUILT	KFK		12-6-80		1
2						
3						
4						
5						
6						
7						
8						
9						
10

SECT. D-D

INTERIOR VIEW (PANEL FRONT)

☐ ITEM # FOR CORD SETS

SECT. E-E

Rogers Engineering Co., Inc.
SAN FRANCISCO
RECEIVED
JAN 15 1980
FILE NO. R.E.
JOB NO. 575090-1

REVISIONS	
1	As Shown
2	As Shown
3	As Shown
4	As Shown
5	As Shown
6	As Shown
7	As Shown
8	As Shown
9	As Shown
10	As Shown

VENDOR PRINT NO.

40-110-1-1
CUST. RESEARCH CORP. UNIV. OF HAWAII
CUST. PO. NO. 4844245 ECS. SO. NO. 00509

ECS ENGINEERED CONTROL SYSTEMS
ONE KESTY COURT, SEEDS PARK, CALIFORNIA 94075

TITLE H&P-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
PLANT CONTROL PANEL ASSEMBLY

2	AS BUILT	BY	DATE	12-8-80	SCALE 1/8" = 1"	DATE	01/15/80	DWG. NO.	00509	2
1		BY	DATE	10/3-80	DFTM.	7-8-75				
REV. NO.	REVISIONS	BY	APPRO.	DATE	CHKD.			SHEET NO. 2 OF 3		REV.

REAR VIEW (INTERIOR)

Rogers Engineering Co., Inc.
SAN FRANCISCO
RECEIVED
JAN 15 1960
FROM: RIF
ON NO. 3-78070-31

VENDOR DRAWING REVIEW	
Review is for General Compliance with Contract Documents. No responsibility is assumed by this review. Contractor or Supplier has complete responsibility for design, performance and compliance with Contract Documents, Drawings, Specifications and Purchase Orders.	
1	No Exceptions Taken
2	Make Corrections Noted
3	Rejected
4	Send and Assembly
5	Send Certified Drawing
6	Fabrication May Proceed
ROGERS ENGINEERING CO., INC. ENGINEERS-ARCHITECTS P.O. Box 278070-31, San Francisco, Calif. 94101	

VENDOR PRINT NO.

40-10-1-1	
CUST. RESEARCH CORP. UNIV. OF HAWAII	
CUST. PO. NO. 48442A3	E.C.S. SO. NO. 00509
ECS ENGINEERED CONTROL SYSTEMS ONE KILLY COURT WIND PARK, CHICOPEMA 04228	
TITLE HGP-A WELL HEAD GENERATOR PROOF OF FEASIBILITY PROJECT PLANT CONTROL PANEL ASSEMBLY	
SCALE 1/8" = 1"	DATE 12-8-60
DFTM. K	6-23-60
ENGR. J. J. J.	00509
CHKD. J. J. J.	SHEET NO. (3) OF 8
REV.	REV.

REV. NO.	REVISIONS	DATE
1	AS BUILT	12-8-60

LEGEND

- ELECTRICAL CONNECTION
- HYDRAULIC CONNECTION
- OR
- NOT
- AND
- ALARM ON ANNUNCIATOR IN CONTROL PANEL
- TIME DELAY ENERGIZED
- TIME DELAY DEENERGIZED
- STATUS INDICATION TO SUPERVISORY CONTROL SYSTEM

NOTES

- EQUIPMENT NOTE SHOWN IS STOPPED MANUALLY.
- LOCATION SYMBOLS FOR DEVICES OR EQUIPMENT:
 - (CP) CONTROL PANEL
 - (EX) EXCITATION CUBICLE
 - (L) LOCAL
 - (MOC) MOTOR CONTROL CENTER
 - (S) SWITCHGEAR
 - (SC) SUPERVISORY CONTROL EQUIPMENT
 - (T) TRANSFORMER-CIRCUIT SWITCHING UNIT
 - (TU) TURBINE
- THIS DIAG. IS FOR INFORMATION ONLY TO THE CONTRACTOR IN PROVIDING A WORKING SYSTEM.
- RELAYS HAVE INDIVIDUAL ALARM TARGET

THIS WORK WAS PROVIDED BY THE UH OR UH FOR BY SUPERVISORY CONTROL CONSTRUCTION OF THIS PROJECT UNDER THE UH POLICY.

E-08-103 F&ID - WELL HEAD STEAM SYSTEM		E-08-107 T/S LINE & CONTROL OIL SYSTEM 5	
E-08-104 F&ID - STEAM SYSTEM		E-08-108 HYDROGEN SULFIDE ABATEMENT	
E-08-105 F&ID - CONDENSATE & GAS SYSTEM		E-08-109 CHEMICAL FEED SYSTEM	
E-08-106 F&ID - COOLING WATER SYSTEM			
E-08-103 SINGLE LINE METER & RELAY DIAGRAM			
E-08-104 ELEMENTARY DIAGRAMS			

REVISION	1	2	3	4	5	6	7	8	9	10
DATE										
BY										
CHKD										
APPV										

ISSUED FOR INFORMATION	DATE	3-13-78
ISSUED FOR CONSTRUCTION	DATE	
REVISION	DATE	
REVISION	DATE	

RESEARCH CORPORATION	OF THE	UNIVERSITY OF HAWAII
HGP-A WELLHEAD GENERATOR		
PROOF OF FEASIBILITY PROJECT		
LOGIC DIAGRAM		
POWER PLANT PROTECTIVE SYSTEM		
JOB NO.	E-08-103	3
DATE	3-13-78

Rogers

APPENDIX A

BATCH MIXING OF CAUSTIC & WATER FOR H₂S ABATEMENT SYSTEM

- 1.0 Start at the LAL (Low Level Alarm) condition on Tank 10-11A or 10-11B or a reading of 13.5 inches on LI-13 or LI-14.
- 2.0 Set water meter FQI-4 at a setting of 2,579 gallons and pull control knob. Water supply valve FV-4 will open. When water is added to tank it will give a reading of 86.99 inches on gauge LI-13 or LI-14.
- 3.0 Turn on Lightning Mixer 19-2A or 19-2B.
- 4.0 Set Caustic Meter FQI-3 at a setting of 421 gallons of 50% caustic and pull control knob. This will start the Caustic Transfer Pump 14-4, and automatically open supply valve FV-3. When the caustic is added the new gauge reading will be 109.1 inches on LI-13 or LI-14.

Temperature gauges TI-19 and TI-20 should show a small temperature rise as the caustic is added. However, the temperature should stabilize at ambient or below.

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APPENDIX "A" (Cont'd)

- 5.0 Continue operating mixer 19-2A or 19-2B for 30 minutes after completion of batching.
- 6.0 Turn off mixer and take a sample for Tank 10-11A or 10-11B. Test sample with hygrometer to check for Specific Gravity of 1.1.
- 7.0 The caustic solution is now at a 10% concentration and ready for use in the injection system.

IMPORTANT: It is extremely important that the above method be observed in mixing a caustic/water solution. UNDER NO CIRCUMSTANCES must the caustic be added first, as the introduction of water into concentrated caustic will cause a rapid temperature increase with potentially dangerous consequences.

APPENDIX "A"

QUICK ESTIMATE CHART FOR ESTIMATING AMOUNTS OF WATER AND CAUSTIC FOR BATCH MIXING

METHOD: ESTIMATE AMOUNT OF 10% SOLUTION REQUIRED TO MAKE UP WORKING CAPACITY. SELECT THIS VALUE ON SCALE A. READ ACROSS TO SCALE B. THIS GIVES QUANTITY OF WATER. PROJECT LINE FROM SCALE B HORIZONTALLY TO CURVE. PROJECT VERTICALLY FROM CURVE TO SCALE C. THIS GIVES QUANTITY OF CAUSTIC REQUIRED.

EXAMPLE: 2500 GAL. OF 10% SOLUTION REQUIRED.
READ 2500 ON SCALE A
READ 2150 GAL. WATER ON SCALE B
READ 350 GAL CAUSTIC ON SCALE C.

APPENDIX: 'B'

Chemical Safety Data Sheet SD-9

PROPERTIES AND ESSENTIAL INFORMATION

FOR

SAFE HANDLING AND USE

OF

CAUSTIC SODA

ADOPTED 1947

Chemicals in any form can be safely stored, handled or used if the physical, chemical and hazardous properties are fully understood and the necessary precautions, including the use of proper safeguards and personal protective equipment, are observed.

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ROGERS ENGINEERING CO., INC.

By _____

MANUFACTURING CHEMISTS ASSOCIATION

1825 CONNECTICUT AVENUE, N. W.

WASHINGTON, D. C. 20009

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Chemical Safety Data Sheet

Manual
Sheet
SD-9

CAUSTIC SODA

Adopted April, 1947

1. NAME

Chemical Name: Sodium Hydroxide
Common Names: Caustic Soda, Liquid Caustic Soda, Lye
Formula: NaOH

2. PROPERTIES

2.1 Grades and Strength

- 2.1.1 Aqueous solutions, commonly called liquid caustic, containing about 50 per cent and about 73 per cent sodium hydroxide by weight.
- 2.1.2 Anhydrous (dry) solid, flake, ground, and powdered forms, containing from 70 per cent to about 99 per cent sodium hydroxide.
- 2.1.3 CP pellet or stick.

2.2 Important Physical and Chemical Properties

- 2.2.1 **LIQUID CAUSTIC SODA** (aqueous solutions)
Color: Water white; occasionally gray.

Aqueous Solutions of Caustic Soda

	50% Solution	73% solution
Boiling Point (760 mm):	142° to 148°C (288° to 298°F)	188° to 198°C (370° to 388°F)
Crystallization begins at:	+12° to +15°C (54° to 59°F)	+63°C (145°F)
Solidifies at:	+5°C (41°F)	+62°C (144°F)

Flash Point: None.

Ignition Temperature: None. Not combustible.

Hazardous to Health: Yes.

Corrosive: Non-corrosive to rubber at atmospheric temperatures. Slowly corrosive to iron, copper, and Monel metal: solutions may pick up harmful quantities of these metals. Corrodes clothing and a few metals, such as aluminum, tin, lead and zinc, and alloys containing these metals. Destroys living tissue.

Dangerously Reactive: Yes; boiling point can be attained in diluting 73 per cent liquid caustic with water.

Heat of Dilution of liquid caustic is considerable and variable, depending upon initial and final caustic concentrations.

- 2.2.2 **ANHYDROUS (DRY) FORMS OF CAUSTIC SODA** — Solid, Flake, Ground and Powdered.

Color: White or light gray.

Boiling Point: White heat.

Melting Point: 310° to 320°C (590° to 608°F)

Hazardous to Health: Yes.

Corrosive: Non-corrosive to rubber at atmospheric temperatures. Slowly corrosive to iron, copper, and Monel metal: solutions may pick up harmful quantities of these metals. Corrodes clothing and a few metals, such as aluminum, tin, lead and zinc, and alloys containing these metals. Destroys living tissue.

Dangerously Reactive: Yes. Considerable heat is generated when water is added to caustic soda; boiling and spattering of hot caustic solution may result.

Hygroscopic: Yes.

Deliquescent: Yes.

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2.3 Hazardous Properties

2.3.1 HEALTH HAZARDS (See 8. Health Hazards and Their Control). Caustic soda is a strong alkali and is dangerous when improperly handled. The solid caustic and concentrated solution are destructive to tissues with which they come in contact, producing severe burns. Contact with the eyes, either in solid form or in solution, causes severe damage to the eye. Inhalation of dust or mist of this compound is capable of causing injury to the entire respiratory tract. Swallowing usually results in severe injury.

For detailed description of health hazards and their control, see Section 8.

2.3.2 FIRE HAZARD. Caustic soda and its solutions will neither burn nor support combustion.

3. USUAL SHIPPING CONTAINERS

Liquid caustic soda is classified by the Interstate Commerce Commission as a corrosive liquid. As such, it must be packed in ICC specification containers when shipped by rail, water, or highway, and all of the ICC Regulations regarding loading, handling, and labeling must be followed.

Anhydrous (dry) forms of caustic soda are not regulated by the ICC.

3.1 Type and Size

3.1.1 FOR LIQUID CAUSTIC SODA:

Tank cars, ICC Spec. 103, 103-W.

Tank motor vehicles, ICC Spec. MC310.

Steel Drums, returnable, ICC Spec. 5 or 5A, 55 gallon.

3.1.2 FOR ANHYDROUS (DRY) CAUSTIC SODA:

Steel drums, non-returnable. Consolidated Freight Classification Rule 40, usually containing:

700 to 760 pound solid caustic

400 to 425 pound flake caustic

or about 500 pound ground caustic.

3.2 Label or Identification

3.2.1 Each container (including tank cars) should carry an identifying label or stencil.

3.2.2 Each container (excluding tank cars) should be labeled **FOR MANUFACTURING USE ONLY** if the caustic soda is intended for use in the manufacture of a drug product.

3.2.3 Each container (excluding tank cars) should be labeled **FOR TECHNICAL USE ONLY** if the caustic soda is intended solely for non-drug use.

3.2.4 The Manufacturing Chemists' Association recommends the following in addition to, or in combination with, any label warnings required by statutes, regulations or ordinances: (See page 5).

3.2.5 Tank cars must bear the ICC **DANGEROUS** placard.

3.2.6 Tank motor vehicles must bear either the words **CORROSIVE LIQUID**, or **FOR CAUSTIC SODA, LIQUID, ONLY**.

3.2.7 Each drum containing liquid caustic soda must bear the ICC white **CORROSIVE LIQUID** label.

3.3 Disposal and Return Precautions

3.3.1 TANK CARS. Before returning empty tank cars, proceed as detailed in M.C.A. Manual Sheet TC-3, Section 6. Return empty cars as promptly as possible in accordance with instructions received from the shipper. Shipper's routing instructions should always be followed strictly.

3.3.2 RETURNABLE DRUMS. Empty returnable drums should be completely drained before returning. Interior of drums must *not* be washed. Bungs must be replaced. The ICC white **CORROSIVE LIQUID** label must be removed, obliterated or covered with the ICC **EMPTY** label. Caustic soda spilled on the outside of the drum should be washed off.

3.3.3 NON-RETURNABLE DRUMS. Single trip drums stripped from solid caustic soda, or similar drums from which flake, ground, or powdered caustic soda has been removed, should be washed free from adhering caustic soda before disposal as scrap metal.

4. UNLOADING AND EMPTYING

4.1 Health Hazards (See 8. Health Hazards and Their Control).

4.2 Fire Hazard. None.

4.3 Tank Cars

4.3.1 Handle and unload tank cars in accordance with the recommended procedure detailed in M.C.A. Manual Sheet TC-3. See also ICC Regulations governing tank car unloading.

SODIUM HYDROXIDE

(CAUSTIC SODA)

DANGER! CAUSES SEVERE BURNS TO SKIN AND EYES

Do not get in eyes, on skin, on clothing.

Do not take internally.

When handling, wear goggles or face shield. While making solution, add slowly to surface of solution to avoid violent spattering.

In case of contact, immediately flush skin with plenty of water; for eyes, flush with plenty of water for at least 15 minutes and get medical attention.

**IN THE CASE OF PROPRIETARY COMPOUNDS CONTAINING
CAUSTIC ALKALI:**

(_____)
Name of Product

**DANGER! CONTAINS CAUSTIC ALKALI
CAUSES SEVERE BURNS TO SKIN AND EYES**

Do not get in eyes, on skin, on clothing.

PRECAUTIONS

*(Use Same Precautions as for Sodium Hydroxide,
Substituting Name of Product for Sodium Hydroxide.)*

4.3.2 Shipper's instructions for unloading should always be followed, and all caution markings on both sides of tank or dome should be read and observed.

4.4 Tank Motor Vehicles. The ICC Regulations referred to below apply to shipments made by way of common and contract carriers by public highway.

4.4.1 When loading into or unloading from a tank truck, the hand brake should be securely set, and all other reasonable precautions should

be taken to prevent motion of the vehicle during such loading or unloading process; see ICC Regulations, Section 824, par. (a) (5).

4.4.2 Under no circumstances should a tank motor vehicle be left unattended during the loading or unloading process. The delivery hose, when attached to the motor vehicle, is deemed to be a part thereof; see ICC Regulations, Section 824, par. (a) (9).

4.4.3 Procedure in case of disabled motor vehicles transporting caustic soda, or other accident thereto, is contained in ICC Regulations,

Sections 814 and 827, and paragraphs (d) (1) to (d) (2) (c), inclusive, of Section 828.

4.5 Drums

4.5.1 RETURNABLE DRUMS

4.5.1.1 Handle and empty returnable drums of liquid caustic soda in accordance with the procedure detailed in M.C.A. Manual Sheet D-31 insofar as it applies.

4.5.1.2 Returnable drums containing liquid caustic soda may be found to contain crystals if they have been exposed to low temperatures. Crystals may be redissolved by placing the drums in a warm room for a few hours.

4.5.1.3 Stand drum on end and carefully loosen the end bung to equalize internal and external atmospheric pressure. Replace bung with a standard pipe nipple provided with an all iron valve.

4.5.1.4 Return drum to horizontal position, with side-bung uppermost. Loosen side-bung sufficiently to prevent air-binding while emptying, controlling flow by the valve. Unloading by gravity is recommended. The use of compressed air is unsafe and should never be used.

4.5.2 NON-RETURNABLE DRUMS

4.5.2.1 Non-returnable drums containing solid caustic soda, may have contents removed by one of the following methods:

- (a) Dissolving out the caustic soda by perforating the drum and placing it on a rack in a dissolving tank. This requires the usual precautions to avoid splashing and spattering of agitated or recirculated solution and later handling the empty drum wet with caustic solution.
- (b) Removing the drum metal from the solid caustic is accomplished by placing the drum on its side with the seam uppermost. Then, by means of a crowbar inserted in the center of the seam, followed by rocking back and forth while working the bar toward either end, the entire seam can be opened. The heads will then come off easily and caustic soda can be rolled out in one solid piece.

If desired, the solid piece can be broken into smaller pieces by sledge or suitable crusher or may be placed directly into a dissolving tank.

If it is necessary to hoist or lift the solid caustic soda in one piece into dissolving tank or crusher, be especially careful since damp caustic is very slippery, and floors wet with it are slippery even to rubber boots.

- (c) Breaking the solid caustic soda into smaller pieces before removal from the drum can be done by placing the drum on its side, and by repeated blows with a sledge or an air hammer along its full length and completely around the circumference.

The drum steel can then be split lengthwise and the ends removed by means of a crowbar or an axe; after which the broken caustic may be removed readily.

- (d) One head of the drum can be removed by means of a simple can-opener type drum opener, then the drum is suspended on a rack or chain hoist above and near the surface of the solution tank. Water or dilute solution from the tank is then pumped into the open end of the drum, in the form of a stream or spray. If proper splash protection is provided around the tank and drum area, this method will remove the entire contents of the drum quickly and safely and, in addition, the drum can be completely cleaned in the same position by rinsing with a small amount of water.

4.5.2.2 Hot water must not be used when dissolving caustic soda. Eyes, face, neck and hands must be protected. Respiratory protection is advisable. (See 8.3 Personal Protective Equipment).

4.5.2.3 Empty drums and stripped drum metal must be handled with care until washed and rinsed to remove all adherent caustic soda in preparation for disposal. (See 3.3.2).

4.5.2.4 Drums used for flake, ground, and powdered forms of caustic soda have 10 or 12 inch diameter drum caps which are readily removed by prying with a flat, sharpened instrument, made for this work. Drum caps should be replaced firmly after removing portions of drum contents.

4.5.2.5 In making solutions, always add flake or granular forms of caustic soda slowly in small portions to avoid violent boiling and spattering. (See 2.2 Important Physical and Chemical Properties).

5. STORAGE

5.1 Hazards

5.1.1 HEALTH HAZARDS (See 8. Health Hazards and Their Control).

5.1.2 FIRE HAZARD. None. Caustic soda and the aqueous solutions do not support combustion.

5.2 Conditions of Storage

5.2.1 Storage tanks ranging in capacity from a few hundred gallons to about 150,000 gallons are in use.

5.2.2 Closed cylindrical tanks, either horizontal or vertical, are considered satisfactory.

5.2.3 Extra heavy metal is preferred for such tanks, and only the best materials and workmanship should be employed, as unevenly stressed or excessively stressed steel has been known to fail through so called "caustic embrittlement", upon prolonged contact with hot caustic solutions.

5.2.4 The body and dished heads should be made of steel meeting ASTM specification No. A.7-42, or of lower carbon, and of not less than $\frac{3}{8}$ inch thickness for tanks containing upwards of 1,000 gallons.

5.2.5 Fusion welded tanks, if properly stress-relieved and otherwise of good workmanship, are considered superior to riveted tanks for caustic soda service. However, well constructed riveted tanks, caulked inside and out, are serviceable.

5.2.6 The design and construction of such tanks and their supports should not be undertaken without the services of engineers experienced in tank construction.

5.2.7 A manhole at least 22 inches in diameter, protected by a suitable grill and cover, should be provided, as well as a vent pipe for venting the top of the tank to the atmosphere.

5.2.8 Storage in containers does not require unusual precautions. Drums should be stored in a dry location to prevent rusting. The metal in non-returnable containers is thin and may be weakened by rusting, so as to spill the contents upon handling.

6. HANDLING

6.1 Health Hazards (See 8. Health Hazards and Their Control).

6.2 Fire and Explosion Hazards. None. Caustic soda and the aqueous solutions neither burn nor support combustion.

6.3 Spills and Leakage. Wherever caustic soda is stored, unloaded, handled, or used, abundant water, preferably running water, should be available for emergency use in dissolving or diluting and flushing away spilled caustic. Spilled solid forms of caustic may be shovelled up, followed by flushing with water. Dilute acid, preferably acetic acid, may be used to neutralize the final traces of caustic remaining after flushing. Washing or mopping up small leaks may be followed by a liberal cover of sodium bicarbonate for removing the last traces of caustic.

6.4 Employee Education and Training

6.4.1 Workers who handle caustic soda or who may be exposed to this compound in any form or in any concentration should be thoroughly instructed in the hazards involved and in the accepted methods of proper handling to avoid spilling, splashing, or flying particles. Safe methods for handling this compound are described elsewhere in this manual.

6.4.2 All workers handling or potentially exposed to this compound should be acquainted thoroughly with the purpose, use and maintenance of personal protective equipment, and should be provided with accepted, adequate protective clothing and approved accessory safety equipment. (See 8.3 Personal Protective Equipment).

6.4.3 All workers should be familiar with the location of safety showers, bubbler drinking fountains for flushing the eyes, and hose lines.

6.4.4 All workers should be thoroughly familiar with first aid measures and should realize the necessity for prompt and thorough application of these principles in case of exposure to caustic soda. (See 8.4 First Aid and Medical Treatment).

6.5 Personal Protective Equipment. Equipment for the protection of individuals handling caustic soda is described in 8.3 Personal Protective Equipment.

6.6 Engineering Controls

6.6.1 To minimize accidental leakage, spilling or splashing of caustic solutions through

apparatus failures, only the best materials and workmanship should be employed. Improperly designed or improperly stress-relieved fusion welded steel equipment is subject to "caustic embrittlement" upon prolonged contact with hot concentrated caustic solutions.

6.6.2 Storage tanks should be located so as to favor as short pipe lines as possible. The number of joints should be reduced to a minimum and these should be flanged rather than screwed connections.

6.6.3 Pipe lines in the open or exposed to temperatures below the crystallizing point of the caustic solution to be handled should be bound to a steam line and wrapped with a common non-combustible heat insulation. Pipe lines should be installed with sufficient gradient to permit complete drainage after use. They may be of iron, nickel, nickel-iron or nickel-copper alloys; but copper, brass, bronze, zinc, lead or aluminum in valves or fittings must not come in contact with caustic.

6.6.4 Asbestos base gaskets are recommended.

6.7 Tank and Equipment Cleaning and Repairs

6.7.1 Tank cleaning should be under the direction of a thoroughly trained foreman who is fully familiar with all of the hazards, and the safeguards necessary for the safe performance of the work.

6.7.2 Be sure tank can be left by original entrance.

6.7.3 One man on outside of tank should keep the men in the tank under observation and at least two men should be available to aid in rescue if any of the men in the tank are overcome.

6.7.4 Entering any tank or piece of equipment to make repairs, or for thorough cleaning, may be hazardous regardless of the material which the tank formerly contained. In addition to the precautions generally recommended for tank work, such as procurement of written approval of supervision, testing for oxygen deficiency, use of rescue harness or life belt and life line, provision of grounded equipment in good condition for portable lights and power tools, and stationing of "watchers" outside of the tank entrance; additional precautions are recommended as follows:

- (a) When it becomes necessary to enter any tank or equipment in caustic soda

service, the apparatus should be pumped or drained as dry as possible followed by thorough flushing with clean hot water.

- (b) All pipe lines into or out of the tank or other apparatus should be disconnected, preferably by removing a complete small section. Valves, cocks and blank flanges should not be relied upon.
- (c) Adequate fresh air supply should be provided, preferably handled by a special small blower. Compressed air may be dangerous for this purpose, and should not be used.
- (d) Use of proper personal protective equipment is recommended. (See 8.3).
- (e) Danger signs should be placed suitably to indicate when workmen are in the tank or other apparatus.
- (f) Pipe lines should be drained as much as possible and washed out with hot water before making repairs.

6.8 Repackaging

Only the dry forms of caustic soda, such as solid, flake, granular, ground or powdered, need be considered. These forms of caustic soda readily form dust particles upon crushing or grinding and handling in mixing and packaging equipment. The small particles are hygroscopic and become wet with solution, thus adhering to clothing and exposed parts of the body.

Therefore, only dust tight apparatus should be used, or the operations conducted in specially ventilated equipment, and the workmen properly protected.

6.8.1 **CONTAINERS.** Repackers use the large drums referred to in 3. Usual Shipping Containers, and smaller containers of the sizes distributed to laboratories and households. The latter comprise the 1 to 5 pound bottles of specially molded forms of chemically pure anhydrous caustic soda used in chemical laboratories, and cans of up to 25 pounds of ground caustic soda, known as "lye", packed in outside boxes for shipment.

6.8.2 **LABELS.** These smaller packages of caustic soda are all subject to the labeling provisions of the Federal Caustic Poison Act and the various State Caustic-Acid Statutes.

7. WASTE DISPOSAL

7.1 Waste disposal of caustic soda depends to a great extent upon local conditions. Be sure that all Federal, State, and local regulations regarding health and pollution are followed.

7.2 Waste caustic soda solution should not be discharged directly into sewers or streams. The caustic should first be converted to a neutral salt, as by neutralization with acid, and then well diluted with water to render the waste less harmful.

7.3 Strong alkali tends to diminish bacterial activity needed for proper sewage disposal by increasing the alkalinity to unfavorable levels.

8. HEALTH HAZARDS AND THEIR CONTROL

This section includes not only recognized first aid procedures and information of interest to the layman, but also suggestions which may be of value to the attending physician.

8.1 Hazards. Caustic soda is dangerous when improperly handled. Whether in solid form or in solution, marked corrosive action results from contact with all tissues of the body. Since signs and symptoms of irritation are frequently not evident immediately after contact with caustic soda, injury may result before one realizes that the chemical is in contact with the body. Therefore, adequate protection against such exposure should be provided for all parts of the body.

8.1.2 ACUTE TOXICITY

8.1.2.1 *Systemic Effects.* No general or systemic effects are noted, except those associated with shock or those secondary to tissue damage, as described in 8.1.2.2.

8.1.2.2 Local Effects

Caustic soda is a strong alkali and is dangerous when improperly handled. It exerts a marked corrosive action on those tissues with which it comes in contact, with resulting burns, frequently deep ulceration and ultimate scarring. Severe burns result not only from contact with the solid alkali, but also from solutions of this compound. Even dilute solutions, on prolonged contact, exert a destructive effect on tissues. This chemical is a strong, primary irritant. Multiple small burns may result from ex-

posure to dust or mist of this compound. Contact with the eyes, either in solid form or in solution, very rapidly causes severe damage to the delicate eye tissues.

Ingestion, either of the solid form or of the solution, results in severe damage to the mucous membranes or deeper tissues with which contact is made. As a result, perforation of these tissues may follow, or there may occur subsequent severe and extensive scar formation. Obviously, death may result if penetration into vital areas ensues. Scarring may so constrict or destroy damaged tissues, that extensive corrective surgery may be required.

Inhalation of the dust or concentrated mist of this compound may cause damage to the upper respiratory tract and even to the lung tissue proper, depending upon the severity of the exposure. The effects of inhalation may vary accordingly from mild irritation of the nasal mucous membranes to severe pneumonitis.

8.1.3 CHRONIC TOXICITY

8.1.3.1 *Systemic Effects.* None, except those secondary to tissue damage. These can be minimized or prevented by prompt first aid measures.

8.1.3.2 *Local Effects.* The chronic local effects, i. e., those arising from repeated contact with dilute solutions, may be those of multiple areas of superficial destruction of the skin in the form of primary irritant dermatitis. Similarly, inhalation of the dust or mist of this compound may result in varying degrees of irritation of the respiratory tract tissues.

8.2 Prevention and Control. Caustic soda may be handled safely, provided workers so engaged are fully and adequately instructed and supervised in approved methods and in the rigid execution of proper safety precautions. If such precautions are ignored and carelessness is tolerated, caustic soda is capable of producing serious injury or death.

8.2.1 EMPLOYEE EDUCATION (See 6.4 Employee Education and Training)

8.2.1.1 It is necessary to provide those who are regularly employed in processes in which caustic soda is used, with instructions describing the hazards, prevention and control measures, and recommended first aid treatment.

8.2.1.2 Food should never be stored nor eaten near caustic soda nor in the work area in which it is handled.

8.2.2 VENTILATION. No maximum allowable concentrations for dust or mist of this compound have been established. However, ventilating equipment should be installed if there is recognizable contamination of the work room atmosphere.

8.2.3 SAFETY SHOWERS AND EYE BATHS. A readily accessible, well-marked, rapid action safety shower should be available in the area where caustic soda is being handled. Special eye washing fountains or a ready source of running tap water such as a bubbler drinking fountain or a hose with a soft, gentle flow of water should be available for eye irrigation. All safety equipment should be inspected periodically at fixed intervals to insure its being in working condition at all times.

8.3 Personal Protective Equipment

8.3.1 To secure safe working conditions, personal protective equipment is an essential supplement to, but not a substitute for, other precautionary measures such as careful and intelligent conduct on the part of the employees. The correct usage of personal protective equipment requires education of the worker in the proper employment of the materials available to him. Under conditions which are sufficiently hazardous to require personal protective equipment, the use of it should be supervised.

8.3.2 Employees who may be exposed to caustic soda should be provided with proper eye, respiratory, skin, and mucous membrane protection as follows:

- (a) Close fitting industrial goggles,
- (b) Rubber gloves and apron,
- (c) Rubber safety-toe shoes or boots (Tops should be covered by the trousers),
- (d) Cotton coveralls, which should fit snugly at neck and wrists,
- (e) Respirator of approved type, if dust or mist is present,
- (f) Do not depend on protective creams or ointments to afford protection from this compound,
- (g) Rescue harness and life line for those entering tanks or closed storage spaces.

8.4 First Aid and Medical Treatment

8.4.1 GENERAL PLAN

Speed in removing caustic soda is of primary importance.

First aid treatment should be started at once in all cases of contact with caustic soda in any form or serious injury may result. *Refer all injured persons to a physician even when the injury appears to be slight.* Give the physician a detailed account of the accident.

8.4.2 SPECIFIC ACTIONS

8.4.2.1 General First Aid. Of prime importance is the copious and prolonged application of water to all affected areas at the first instant after exposure. Contaminated clothing should be removed promptly. *Irrigation and prolonged application of water to the affected areas should be continued for as long as one to two hours.* If 5 per cent ammonium chloride or 5 per cent zinc chloride solutions are on hand, wash the affected areas promptly and thoroughly with these solutions. However, if they are not immediately available, no time should be lost awaiting them, but copious amounts of water should be used. It is generally accepted that prolonged, copious irrigations with water are less damaging to tissues than are attempts at chemical neutralization. It should be borne in mind that in severe burns and those involving a large area of body surface, shock may supervene at any time. This should be treated promptly by placing the patient in a supine position and keeping him reasonably warm until the physician arrives. No oil or ointment of any kind should be applied to burned areas within the first 24 hours after contact or subsequently without the sanction of the attending physician. A physician should be called in attendance at the earliest possible moment.

8.4.2.2 Contact With Eyes

8.4.2.2.1 FIRST AID. If even minute quantities of caustic soda, either in solid form or in solution, enter the eyes, they should be irrigated immediately and copiously with water for a minimum of 15 minutes. The eye lids should be held apart during the irrigation to insure contact of water with all the tissues of the surface of the eye and lids. A physician should be called in attendance at the first possible moment, preferably an eye specialist. If a physician is not immediately available, the eye irrigation should be continued for a second period of 15 minutes. After the first 15 minute period of irrigation is completed, it is permissible as a first aid measure to instill two or three drops of an 0.5 per cent pontocaine solution or an equally effective aqueous topical anesthetic. No oils or oily ointments should be instilled unless ordered by the physician.

8.4.2.2.2 Ophthalmologists may be interested in a method of treatment for chemical burns of the eye described by Ralph S. McLaughlin, "Chemical Burns of The Human Cornea", American Journal of Ophthalmology, 29:1355, 1946.

8.4.2.3 *Taken Internally.* Ingestion of caustic soda causes severe burns of the mucous membranes of the mouth, throat, esophagus and stomach. Here, since copious irrigation is not as feasible as on surface tissue, chemical neutralization may be attempted. Dilute vinegar or a 5 per cent solution of ammonium chloride may be administered freely if at hand. Unless they are immediately available, their use should not be contemplated, but the patient should be encour-

aged to drink a large quantity of water without delay. After free caustic soda has been diluted with water or chemically neutralized, whites of eggs or mineral oil may be administered for their demulcent or soothing effect. A stomach tube should not be inserted, except by the attending physician.

8.4.2.4 *Dermatitis.* Dermatitis of the primary irritant type may occur following single or repeated exposure to dilute solutions. This merely represents a relatively mild inflammatory response of tissues to exposures of low concentration. Repeated exposures result in an eczematoid condition of the skin, which may require prolonged treatment by a dermatologist.

The medical information in this publication has been supplied by the Medical Advisory Committee of the Manufacturing Chemists' Association

CHEMICAL SAFETY DATA SHEETS

*Acetaldehyde	(1952)	SD-43
Acetic Acid	(1951)	SD-41
Acetic Anhydride	(1952)	SD-15
*Acetone	(1952)	SD-87
Acetylene	(1957)	SD-7
*Acrolein	(1951)	SD-85
*Acrylonitrile	(1954)	SD-31
Aluminum Chloride	(1956)	SD-62
Ammonium Dichromate	(1952)	SD-45
*Ammonia Anhydrous	(1952)	SD-8
*Ammonia Aqua	(1947)	SD-13
*Aniline	(1963)	SD-17
Antimony Trichloride		
(Anhydrous)	(1956)	SD-66
Arsenic Trioxide	(1956)	SD-60
*Benzene	(1950)	SD-2
*Benzyl Chloride	(1957)	SD-69
Benzoyl Peroxide	(1950)	SD-81
Betanaphthylamine	(1949)	SD-32
Boron Hydrides	(1961)	SD-84
*Bromine	(1952)	SD-49
*Butadiene	(1954)	SD-55
*n-Butyllithium in		
Hydrocarbon Solvents	(1956)	SD-91
*Butyraldehydes	(1950)	SD-78
Calcium Carbide	(1943)	SD-23
Carbon Disulfide	(1943)	SD-12
Carbon Tetrachloride	(1953)	SD-3
*Caustic Potash	(1947)	SD-10
*Caustic Soda	(1947)	SD-9
*Chlorine	(1950)	SD-80
Chloroform	(1952)	SD-89
*Chlorosulfonic Acid	(1949)	SD-33
Chromic Acid	(1952)	SD-44
*Cresol	(1952)	SD-48
*Cyclohexane	(1957)	SD-68
*Diethylenetriamine	(1959)	SD-76
*Dimethyl Sulfate	(1947)	SD-19
Dinitrotoluenes	(1955)	SD-93
*Ethyl Acetate	(1953)	SD-51
*Ethyl Chloride	(1953)	SD-50
*Ethyl Ether	(1955)	SD-29
*Ethylene Dichloride	(1947)	SD-18
*Ethylene Oxide	(1951)	SD-38
Formaldehyde	(1950)	SD-1
*Hydrochloric Acid	(1951)	SD-39
Hydrocyanic Acid	(1961)	SD-67
*Hydrofluoric Acid	(1957)	SD-25
*Hydrogen Peroxide	(1955)	SD-53
Hydrogen Peroxide		
(Not Exceeding		
52%)	(1951)	SD-53—Sup. A
Hydrogen Peroxide		
(High Strength)	(1951)	SD-53—Sup. B
Hydrogen Sulfide	(1950)	SD-36
*Isopropylamine	(1959)	SD-72
Lead Oxides	(1956)	SD-64
Maleic Anhydride	(1952)	SD-88
Methyl Acrylate and		
Ethyl Acrylate	(1950)	SD-79
*Methanol	(1948)	SD-22
Methylamines	(1955)	SD-57
*Methyl Bromide	(1949)	SD-35
*Methyl Chloride	(1951)	SD-40
Methylene Chloride	(1952)	SD-86
*Methyl Ethyl Ketone	(1951)	SD-83
*Mixed Acid	(1955)	SD-65
Naphthalene	(1956)	SD-58
*Nitric Acid	(1951)	SD-5
*Nitrobenzene	(1948)	SD-21
Ortho-Dichlorobenzene	(1953)	SD-54
Paraformaldehyde	(1950)	SD-6
paraNitroaniline	(1956)	SD-34
Perchloroethylene	(1949)	SD-24
Perchloric Acid Solution	(1955)	SD-11
*Phenol	(1954)	SD-4

Phosphoric Acid	(1958)	SD-70
Phosphoric Anhydride	(1943)	SD-23
*Phosphorus, Elemental	(1947)	SD-15
*Phosphorus Oxichloride	(1948)	SD-25
*Phosphorus Pentasulfide	(1958)	SD-71
*Phosphorus Trichloride	(1949)	SD-27
Phthalic Anhydride	(1956)	SD-61
Propylene	(1955)	SD-59
Sodium Chlorate	(1952)	SD-42
Sodium Cyanide	(1949)	SD-30
*Sodium, Metallic	(1952)	SD-47
Sodium and Potassium		
Dichromates	(1952)	SD-45
Styrene Monomer	(1951)	SD-37
Sulfur	(1959)	SD-74
Sulfur Chlorides	(1950)	SD-77
*Sulfur Dioxide	(1953)	SD-52
*Sulfuric Acid	(1953)	SD-20
Tetrachloroethane	(1949)	SD-34
*Toluene	(1956)	SD-63
Toluidine	(1951)	SD-32
Tolylene Diisocyanate	(1959)	SD-73
1, 1, 1-Trichloroethane	(1955)	SD-60
Trichloroethylene	(1956)	SD-14
*Vinyl Acetate	(1959)	SD-75
*Vinyl Chloride	(1954)	SD-56
Zirconium and Hafnium		
Powder	(1956)	SD-92

* Chem-Cards available

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- Electrical Equipment in Hazardous Areas SG-19

CLEANING & FLUSHING OF LUBE OIL SYSTEM

LUBRICATION SYSTEM FLUSHING

All units employing forced feed oiling systems should have the entire lubrication system thoroughly flushed before operation. The importance of this step cannot be over-emphasized. All dirt, rust, scale, weld slag or other contaminants that have been introduced into the oil system during storage, transportation and/or fabrication at the jobsite must be removed by a continuous flushing operation or in extreme cases by pickling, neutralizing and spraying with a rust-preventative oil.

Oil piping supplied by Elliott Company is acid cleaned and neutralized, then coated (fogged) with oil to protect against rust formation. The open ends are plugged before shipment. Piping not supplied by Elliott Company must also be acid cleaned and neutralized before it is connected into the system.

Flushing should begin as soon as the system is assembled and a lubricating oil pump can be operated. The flushing should continue until inspection of the filters indicates that all contaminants have been removed.

If the system remains idle for a period of time it should be flushed before operation. An alternate method, is to circulate oil through the system at regular intervals during the idle period and to flush the system clean just before startup.

When the oil system services a compressor which uses a mechanical contact or oil film seal (Iso-Carbon or Iso-Sleeve, temporary bypass lines should be used to isolate the seals during the flushing operation.

If a continuously lubricated coupling is used, the oil supply tubing should be disconnected during oil system flushing.

Gear manufacturer's instruction should be referred to for specifics. In general it is recommended that temporary bypass lines be installed to isolate gears during the flushing operation. Gear cases, inspection covers and plugs should be opened only under the direct supervision of the gear manufacturer's representative.

Install blanks at the connecting flanges to block off piping to the topworks on hydraulic diaphragm actuators, pressure-reducing valves, back-pressure regulators and similar control devices.

CAUTION

Be sure to remove blank-offs and to replace any piping or tubing sections removed before placing the system into operation.

13. Check the pressure gage readings and sight flow indicators for an indication of flow restriction.
14. Periodically vent the oil coolers, strainers or filters of trapped air. Manually lift relief valves to flush piping sections between the relief valves and oil reservoir.
15. Check the oil return lines for free flow back to the oil reservoir.
16. Continue oil circulation until there is no evidence of contaminants in the filters.
17. Stop oil circulation and install felt, muslin or gauze pads (40 micrometers or less) backed with fine stainless steel screen in the bearing oil supply lines on the downstream side near the bearing housings. Restart circulation of lube oil.
18. Check filter pads installed in Step 17 at hourly intervals. The system can be considered clean if inspection of filters and filter pads shows no evidence of contaminants at three consecutive hourly checks.
19. Blanked off parts of the system should then be flushed clean after removing the blanks.
20. When flushing is completed discontinue the oil heating but continue circulating the oil until the temperature is approximately 50°C (120°F) at cooler outlet. When this temperature is reached, remove the flushing oil from the system. Open oil lines at lowest points, allow the reservoir and oil lines to drain completely.

After satisfactory system cleanliness is obtained:

1. Remove all temporary strainers, pads and back up screens from the system.
2. Remove all traces of flushing oil and contaminants deposited by the flushing operation from the bearing housing, filters, and system low points. Install new filter elements.
3. Remove the oil reservoir cover and clean the reservoir using lint-free wiping cloths. Replace cover and immediately fill reservoir with clean oil.
4. Remove and clean the lower half journal bearing liners and retainers.
5. Install all orifices in their proper locations.
6. Replace the journal and thrust bearings, making up the bearing housing joints with an oil resistant sealant.
7. Prime main and auxiliary oil pumps. Operate the main pump, bleed the system of any air. Check for oil leaks at all fittings and connections. Operate the auxiliary oil pump and repeat venting the system.
8. After venting, check for leaks, set and check all pressure control valves, controls, and safety devices for proper operation before initial startup. (Refer to Table 5-1, Schematic Oil Flow Diagram, Oil Piping Drawing and Bill of Material for settings).

NOTE

All checks should be made with the oil system at normal operating temperature.

Flushing The Lubrication System

1. Thoroughly inspect all accessible areas of the system. If contamination is found, it should be removed prior to charging with flushing oil.
2. Install clean oil filter elements.
3. Remove and clean the top halves of the journal bearings and both halves of the thrust bearing. Rotate the lower half journal bearing liners, exposing the oil supply ports. Remove and tag all lube oil orifices.
4. Align the oil pumps to the drivers and lubricate the couplings. (Refer to Chapter 2 for alignment procedure). Check overspeed trips, and adjust if necessary on turbine driven pumps before placing them in service.
5. Fill the oil reservoir to the minimum operating level with a suitable flushing oil to properly flush the system and maintain pump suction. Although special flushing oils are available and are recommended, a standard lubricating oil may be used for flushing.

CAUTION

Flushing oils containing petroleum solvents, such as kerosene, or non-petroleum solvents, such as carbon tetrachloride and solutions containing water, caustic compounds or other active materials must not be used for flushing.

6. To prevent entrainment of air, the vents on the filters and coolers, the vent at the system's high point (if not on the filter or cooler) and the vents on control sensing lines must be opened and air bled from the system while under pressure. Close the vents when all air has been vented.
7. Start either the main or auxiliary lube oil pump and circulate lube oil. If pumps cannot be operated, some temporary means must be provided to circulate the flushing oil.
8. Gradually heat the lube oil to 65 to 70°C (150 to 160°F), do not exceed 70°C (160°F). Maintain this temperature throughout the flushing operation. To heat the oil, inject heated water into water side of oil cooler approximately 7.5m (25 feet) upstream of cooler. Do not inject live steam directly into the cooler.

CAUTION

If steam is used to heat the water, a temperature alarm and relief valve must be installed.

9. An alternate means of heating the oil is to make a coil of copper tubing and submerge in the oil reservoir. Pass a controlled amount of steam through the coils to maintain the desired oil temperature. Make sure that tubing does not leak.
10. Attach mechanical vibrators to the piping, particularly at joints and flanges, to dislodge any scale or other contaminants from the inside of the piping. If vibrators are not available the piping can be hammered periodically.
11. Flush through control valves and control valve bypasses alternately. Open all key valves and needle valves.
12. Experience has shown that most foreign matter is collected in the filters during the first few hours of flushing. During this time, if a noticeable increase in the pressure differential occurs .35 bars differential (5 psi) across the filters, the filters should be cleaned. This may occur as frequently as every 15 minutes.

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APPENDIX "D"

SUMMARY OF TESTS AND SAMPLING REQUIREMENTS

The following tests and sampling will be performed by LFE Environmental Analysis Laboratories or Hawaiian Institute of Geophysics during plant operation:

A. Warm-up and Initial 8-Hour Flow Period

1. Ambient Air Monitoring - Various Points
2. Well Water Sampling

B. Flow Stabilization Period (about 2 weeks)

1. Ambient Air Sampling
2. Discharge Water Sampling for Hg, As, B, F (weekly)
3. Noise
4. Silica Precipitation Pond Sampling for Inlet and Outlet, Analysis of Silica and pH
5. Emission H₂S Sampling
6. Sparger Exhaust H₂S Sampling Inside Sparger Box
7. Sparger Drain Sampling and Analysis
8. Steam Quality Analysis or Chloride Analysis in Steam (5 ppm maximum)
9. Noncondensable Gas Composition and Total Amount
10. Chloride Analysis in Brine

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APPENDIX "D" (Cont'd)

C. Start-up Period (about 2 weeks)

1. Ambient Air Sampling
2. Emission H₂S Sampling at Zink System
3. Emission H₂S Sampling at Brine Flash Chamber
4. Discharge Water Sampling for Hg, F, B, As (weekly)
5. Noise
6. Steam Quality or Chloride in Steam
7. Noncondensable Gas Content and Composition
8. Condensate pH
9. Cooling Water Basin pH
10. Silica Precipitation Pond Sampling for Inlet and Outlet. Analysis
of Silica and pH
11. Zink System Fluid Discharge for Total Sulfur Content
12. Chloride Analysis in Brine
13. Lube Oil - HELCO

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APPENDIX "D" (Cont'd)

D. Long Term Plant Operation Period

1. Ambient Air Sampling
2. Emission H₂S Sampling
3. Noise
4. Discharge Water Analysis for Hg, B, F, As
5. Steam Quality
6. Noncondensable Gases
7. Silica Pond Inlet/Outlet
8. Chloride in Brine
9. Lube Oil - HELCO