INTERNAL TECHNICAL REPORT

Title: SOFTWARE REQUIREMENTS AND DESIGN GUIDE FOR THE SMW(e) RAFT RIVER PILOT PLANT

Organization: Mini Systems Division
Project Office

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Checked By: G. Ross

Approved By: Ed Felty

RECEIVED
MAY 15, 1980
T. L. RASMUSSEN
Simmons, Patty

From: Dale J Claflin [Dale.Claflin@inl.gov]
Sent: Thursday, December 07, 2006 8:43 AM
To: Simmons, Patty
Cc: Claflin, Dale; Flynn, Vesta; Ponce, Linda
Subject: Re: EG&G Idaho Geothermal Reports
Attachments: EG&G Patent Docs.doc

Patty,

The 13 reports listed are all OK for unrestricted release. Please remove (cover up) the patent caution wording, as well as any other statements concerning restricted distribution. We don't have a concern with the "Internal Technical Report" words, but if you feel it would eliminate confusion by removing that term, please do so. Let me know if you need anything else.

Dale Claflin
Idaho National Laboratory
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Dale,

OSTI has been working on a project for the last year or so to collect geothermal documents. At the STIP meeting in April, I sent out a plea to the DOE labs to identify and send to OSTI any geothermal documents that we did not already have in our database. I have a problem with a group of reports from EG&G Idaho. I am not sure you are the person correct person to ask for help on this issue. If not, maybe you can direct me to the responsible individual.

Attached is a list of documents that were sent to OSTI as part of that special geothermal project. All of the documents in this list have a patent caution as well as 'Internal Technical Report' stamped on the front of the report. The date on each of the documents is well past the sunset date for patentable material. If there is no other reason for control, I would like permission to cover up the patent caution and release each as unlimited. Would we also need to cover 'Internal Technical Report'?

If you need me to, I will be happy to fax you a copy of the covers of the reports.

Please let me know if you can help me out with this problem, or advise if I should communicate with someone
else - and who

Thanks ahead for your help,
Patty

Patty Simmons
U.S. DOE Office of Scientific and Technical Information
simmons.p@osti.gov
865-576-1290

12/7/2006
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SOFTWARE REQUIREMENTS AND DESIGN GUIDE FOR THE 5MW(e) RAFT RIVER PILOT PLANT

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DATE: 4/17/80

5MW(e) PROJECT MANAGER: K. K. Rasmussen

DATE: 5/12/80
SOFTWARE REQUIREMENTS AND DESIGN GUIDE
FOR THE RAFT RIVER 5MW(e) PILOT PLANT

1. SCOPE

This document defines the software requirements for the Raft River 5MW(e) Pilot Plant. It constitutes Part II of a three-part overall document which will contain the software requirements for the Supply and Injection Control System as Part I and the software requirements for the Data Processing System as Part III.

This document also provides a functional design guide for the required computer program modules. The design guide is intended to provide management with an overview of the form and function of the modules, and to be a working level outline for the software generation task.

Parts I and III of the overall documents will be issued at later date.
PART II

THE 5MW(e) PLANT

5. OVERVIEW

The 5MW(e) electrical generating plant is a demonstrational unit intended to provide engineering data basic to improvement of geothermal-electric technology. It is anticipated that the plant will operate on a production basis after initial testing, and that periodic re-testing will be done to measure the effects of fouling in heat exchanges and aging generally. The initial tests will confirm engineering estimates of performance, and will identify optimum feasible operating conditions and maximum power generating capacity. They will also identify any anomalous plant behavior not foreseen. Several tests will lead to quantification of constant and variable terms used in thermodynamic relationships descriptive of plant and subsystem behavior. Because the product of the testing will be confirmatory engineering data heretofore unavailable, the plant has been carefully instrumented, with either explicit or implicit instrumentation redundancy for most parameters to be measured. The 5MW(e) data system collects the data directly from the instrumentation. Enhancements such as on-line analytical routines may be added later, but initially, data capture shall be the sole activity of the data system.

The 5MW(e) plant converts the energy of geothermally heated water to electrical energy conforming to 60 Hz commercial power standards. The plant capacity is sufficiently large to be useful in a demonstrational sense, but is limited to a capacity conservative of the geothermal energy resource, which hasn't been fully explored. The 5MW(e) plant will continue on a regular production basis after completion of the testing. Additional production units may be added at a later time.
5.1 *Geothermal Water Loop Overview*

The supply of geothermally heated water has been discussed in PART I. The geothermally heated water entering the plant is pressurized by pumps and may give up heat energy to the plant working fluid, isobutane, at two boilers and preheaters. The heated water flows thru the high pressure boiler, the high pressure preheater, the low pressure boiler, and the low pressure preheater. Each of the heat exchange elements in the cascade is engineered for successively lower temperature water input requirements for efficient use of the geothermal resource. After the usable heat energy has been extracted, the water is routed to the injection wells. The initial water temperature is 290°F. The temperature after the energy extraction is 140°F. Flow rate is 2250 gpm under normal operating conditions.

5.2 *Isobutane Loop Overview*

The plant working fluid, isobutane, is routed in essentially a closed loop. Within the loop liquid isobutane is pumped from a condensate storage tank to the low pressure preheater. The stream is divided, with part of the stream routed to the low pressure boiler, and part to the high pressure preheater. The stream through the high pressure preheater is routed to the high pressure boiler. The streams from the boilers consist of pressurized isobutane vapors, and the streams drive a turbine which has a high pressure and a low pressure stage. The vapors yield mechanical energy in the turbine, and the vapor exhaust of the two turbine stages is merged and routed to a condenser, where the isobutane gives up thermal energy and is condensed. The slightly subcooled liquid is returned to the condensate storage tank. Bypass paths around each of the preheaters help to regulate the input temperatures of the isobutane to the boilers. A water separator treatment element is also part of the isobutane loop.

5.3 *Condenser Coolant Loop Overview*

The condenser requires a cooled water stream, which picks up heat from the isobutane, and yields heat to ambient air by partial evaporation.
Water treated for mineral removal and for the prevention of scaling in the condenser is pumped to a tower for cooling by a dripping process that uses trays with holes to direct flow through a fan driven ambient air stream. The water losses by evaporation are replaced by a makeup stream from the treatment system. The water continually cycles gaining heat energy from the isobutane in the condenser and yielding heat to the environment in the cooling tower. The condenser function impacts overall plant efficiency, as it is the means of reducing backpressure at the turbine. Ambient air temperature and humidity content affect the water cooling function, which affects the condenser's heat transfer ability which in turn affects the turbine performance via the back pressure effects.

5.4 Turbine-Generator Overview

The turbine-generator unit is the electrical production element of the 5MW(e) plant. The instrumentation of this unit will be monitored by the data system for measurement of performance and general well-being. The turbine-generator combination is a conventional element of most thermal power generating plants. About 80 sensors measuring performance of the turbine generator will be assigned multiplexer connectors into the data system.

5.5 Data System Configuration Overview

The 5MW(e) data system consists of a DEC PDP 11/34 computer system having a VT100 CRT, and a controller for magnetic tape with one PERTEC drive, and two RL01 disks. Plant instrumentation is interfaced through an ANALOGIC analog and digital channel multiplexer. Exclusive of the turbine-generator unit instrumentation, about 130 analog signals are monitored by the data system.

5.6 Data System Function Overview

The 5MW(e) computer exercises no control functions, nor is there any initial requirement for calculational routines. The computer shall control
the sequence and rate of the analog and digital scanning. It will convert
analog values to engineering units as necessary, and convert digital values
to representations suitable for display. The data system shall exercise a
data compression function to exclude redundant values from archive files.
Periodic representations of single values, not more frequent than 10
minutes, shall be preserved in the steady state condition. Any significant
changes occurring shall also be recorded. For archive purposes, each
recorded value shall have either explicit or implicit identification, and
shall have an accompanying time of acquisition to full resolution of the
computer's time-of-day clock. The data system shall maintain a current
value matrix containing the latest acquired value for each active signal on
the data system. Upon operator demand, or as a timed function as
appropriate, related subsets of the plant parameters shall be displayed on
the CRT. A printed representation shall also be made, but only upon
specific operator demand.

The data system shall permit transfer of the entire current value
matrix to magnetic disk on operator command. This shall permit the
preserving of all data system monitored values at a given instant. Space
shall be allocated on the magnetic disk for up to 16 such "pictures" before
overwrite occurs. This feature is intended to assist verification of
steady state conditions. The representations shall be written to magnetic
tape on operator command.

The data system archive function shall have enable and disable states
under operator control to eliminate needless accumulation of unwanted data
during intervals between tests. When the plant becomes fully operational,
the disable feature may be removed.
Geothermal flow arriving from the S & I system at 290°F is regulated by valves. Three valves are used to control water temperature. Water in excess of the 5MW(e) plant needs may be directed into the 5MW(e) injection bypass line. (During normal operation no water bypasses the plant.) Downstream from the modulating valve, the temperature and flow rate are measured. A recirculation line has entry downstream from these two sensors. The next instrumentation downstream is a pressure sensor. Two pressurizing pumps operating in parallel are next. The pumps raise the pressure of the geothermal water by about 100 psig to near 180 psig during normal operations. The pressure is measured downstream of the pressurizing pumps. High pressure flow to the plant may be limited by a bypass. Additionally, some water may be valved to bypass the high pressure boiler and preheater.

Instruments for measuring the water properties ahead of the high pressure boiler include two for temperature, and one for pressure. Instruments immediately following likewise consist of one for pressure measurement, and two for temperatures. The instruments for each succeeding element in the cascade, namely the high pressure preheater, the low pressure boiler, and the low pressure preheater, are all similar to those for the high pressure boiler. The water is channeled through the tubes of each heat exchange element, with the isobutane routed through the shell. The geothermal water pressurization to near 180 psig ensures that the geothermal water will be in the liquid state uniformly as it cascades through the four heat exchanger elements. It also inhibits the precipitation of calcite.

Downstream of the heat exchangers flow is measured, a bypass line enters, and a re-circulation line exits. Flow is measured again downstream as the geothermal water at about 140°F is valved into the injection line. A three-way dump valve may direct the water to a pond if the rate of change in temperature is greater than the injection line can accommodate for any reason.
7. ISOBUTANE LOOP INSTRUMENTATION

Isobutane in the liquid state is held in a condensate storage tank at about 100°F. The tank is instrumented for level and temperature. The tank exit is instrumented for temperature. Two pumps in parallel pressurize the isobutane to about 430 psig, up from the tank pressure of about 66 psig. Pump work raises the temperature to about 105°F. Pressure is measured upstream and downstream of each pump. Additionally, temperature and flow downstream of each pump are measured. The density and flow rate of the isobutane stream are measured for the combined pump output. Partial flow may be valved to a water removal element. Flow through that element is measured, as is any flow valved back to the condensate storage tank.

For isobutane entering the low pressure preheater, instruments include two temperature sensors, and sensors for pressure, flow, and density. Downstream of the low pressure preheater, two sensors measure temperature and one measures pressure. The instruments for the high pressure preheater have a similar configuration. Lines to the boilers have similar instrumentation as well. Instruments for each include those for determining density, flow, and temperature. Instruments immediately preceding the boilers include a sensor for pressure and two for temperature. Pressure and liquid level are sensed in the boilers. Downstream of the boilers, two sensors measure temperature, and flow and density of the isobutane are measured. Preceding the turbine stages temperature, pressure, and flow are measured, then temperature and pressure repeated immediately preceding turbine entry. Temperature of vapors emerging from the turbine is measured, and temperature and pressure of the merged vapor streams are measured. One additional temperature sensor is imposed in the line upstream of the condenser. Pressure and level within the condenser is measured, and a temperature sensor monitors the liquid flowing from the condenser to the storage tank. Bypass lines are instrumented for pressure, temperature, and differential pressure.
8. CONDENSER COOLANT LOOP INSTRUMENTATION

Upstream and downstream from the condenser two sensors measure temperature and one measures pressure. Instruments on lines exiting or entering through valves downstream of the condenser measure flow rate during blowdown, and the flow rate of makeup water. Pressure, temperature, and flow rate of the input stream to the cooling tower are monitored, and atmospheric pressure and wet and dry bulb temperature are measured for ambient air. Wet and dry bulb temperature instrumentation is also mounted in the cooling tower stack. The cooled water in the storage pond is measured for temperature and depth. After the cooling water is pressurized by pumping from the pond, the pressure and flow are measured upstream of the condenser.

9. TURBINE-GENERATOR INSTRUMENTATION

The turbine-generator combination is instrumented to measure working fluid parameters, performance, and operating condition. Instruments monitoring the operating condition or well-being of the turbine-generator unit in general have alarm setpoints. The two stage turbine is instrumented for flows, pressures, and temperatures of the isobutane vapors. The high pressure and low pressure stages of the turbine are supplied by separate headers. Each header has a throttle/stop valve for control of the flow rate, and flow is metered in each header. Pressure, temperature, and flow rate of both of the isobutane vapor streams are measured upstream of the throttle/stop valves, and pressure and temperature are measured downstream from the valves. At the impeller inlet and outlet, the isobutane pressure and temperature are measured. At the exhaust vanes, pressure and temperature are measured similarly. Temperature and pressure of the common exhaust are also measured. Temperature of the isobutane bypass at the balance piston is measured for each stage.

The generator performance instrumentation consists of devices to measure AC output volts, power, power factor, and volt-amperes reactive
(VARs). Measurement is also made of field current and voltage. Temperature of the stator is sensed by resistance temperature detectors at six points, with alarms activated on excessive temperature.

Instrumentation for monitoring vibration in the bearings of the generator, gear box, and turbine is switch selected manually from an Elliot panel. One of ten devices may be selected. The data system monitors the switch position. The devices actually measure proximity, deriving a frequency value for deviations that are cyclic. The signal level is a function of frequency.

The lubricating oil temperature and the temperature of the journal and thrust bearings is monitored with alarm functions. Bearings of the turbine, gear box, and generator are monitored. Oil temperature at the oil cooler outlet and for points downstream from each of the major bearings is measured.

10. DATA SYSTEM INSTRUMENTATION CONFIGURATION

The data system terminal assignments using the ANALOGIC instrumentation interface subsystem is contained in the following section, which provides the terminal assignment (MUX) the signal and transmitter identifications, and the primary and secondary instrumentation ranges. The information has been gathered from the P&IDs listed.

FSEC DRAWINGS:

699-0701-50-274, P-2, Rev-B
699-0701-30-274, P-3, Rev-B
699-0201-50-274, P-5, Rev-A
699-0201-50-274, P-6, Rev-C
699-0201-50-274, P-7, Rev-B
699-0201-50-274, P-8, Rev-A
699-0701-28-274, I-2, Rev-A
699-0701-28-274, I-3, Rev-A
699-0701-28-274, I-4, Rev-A
699-0701-28-274, I-5, Rev-A
699-0701-28-274, I-6, Rev-A
699-0701-28-274, I-7, Rev-A
ABBREVIATIONS

RBT = RESISTANCE BULB TRANSMITTER
SCT = SIGNAL CONVERTER TRANSMITTER
FDT = FREQUENCY TO D. C. TRANSMITTER
DCA = DIRECT CURRENT ALARM
DT = DENSITY TRANSMITTER
PT = PRESSURE TRANSMITTER
LT = LEVEL TRANSMITTER
ZT = POSITION TRANSMITTER
TE = TEMPERATURE ELEMENT
FT = FLOW TRANSMITTER
TDT = DIFFERENTIAL TEMP TRANSMITTER
PDT = DIFFERENT PRESSURE TRANSMITTER
MUX = MULTIPLEXOR
H.P. = HIGH PRESSURE
L.P. = LOW PRESSURE
TBV = TURBINE BYPASS VALVE
TBS = TO BE SPECIFIED

TAG NUMBER IDENTIFICATION

The digits following the sensor abbreviation identify the subsystem where the measurement is located. For example: TE 127 is a temperature measurement located in the Isobutane Condensate Sybsystem. For the thermal loop the following number blocks identify the subsystems shown:

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<tr>
<th>Number Block</th>
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<tr>
<td>100</td>
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<tr>
<td>200</td>
<td>Isobutane Fluid</td>
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<tr>
<td>300</td>
<td>Isobutane Vapor</td>
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<tr>
<td>800</td>
<td>Geothermal Fluid</td>
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<td>900</td>
<td>Cooling Water</td>
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<td>MUX CHANNEL</td>
<td>DESCRIPTION</td>
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<td>1. Pressure H. P. Preheater Outlet</td>
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<td>2. Temperature H. P. Preheater Discharge</td>
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<tr>
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<td>3. Temperature H. P. Preheater Discharge</td>
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<td>4. Temperature H. P. Preheater Suction</td>
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<td></td>
<td>5. Flow Differential Isobutane to H. P. Preheater</td>
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<td>6. Pressure H. P. Preheater Inlet</td>
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<td>7. Temperature L. P. Preheater Discharge</td>
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<td>8. Pressure L. P. Preheater Outlet</td>
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<td>11. Flow Differential Isobutane to L. P. Preheater</td>
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<td>12. Pressure L. P. Preheater Inlet</td>
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<td>13. Temperature L. P. Boiler Discharge</td>
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<td>14. LEVEL Isobutane L. P. Boiler</td>
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<td>15. Temperature L. P. Boiler Discharge</td>
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<td></td>
<td>16. Pressure L. P. Boiler</td>
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<td>17. Temperature L. P. Boiler Suction</td>
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<td>18. Pressure L. P. Boiler Inlet</td>
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<td>19. Position Isobutane L. P. Boiler Valve</td>
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<td>20. Flow Isobutane to L. P. Boiler</td>
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<td>22. Temperature H. P. Boiler Discharge</td>
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<td>23. Temperature H. P. Boiler Suction</td>
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<td></td>
<td>24. Level Isobutane H. P. Boiler</td>
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<td>25. Temperature H. P. Boiler Suction</td>
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<td></td>
<td>26. Pressure H. P. Boiler Inlet</td>
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<td>27. Position Isobutane H. P. Boiler</td>
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<td>28. Differential Pressure P across WA 213</td>
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MU X

CHANNEL

DESCRIPTION

TAG NO.

29. Flow Isobutane to L. P. Boiler (FDT-296)
30. Pressure L. P. T.S.V. Inlet (PT-284)
31. Flow Isobutane Vapor to H. P. (FT-153)
32. Temperature L. P. T.S.V. Inlet (TE-154)
33. Differential Pressure Across L. P. T.S.V. (PDT-156)
34. Position Isobutane L. P Turbine Valve (ZT-303)
35. Temperature L. P. T.S.V. Outlet (TE-158)
36. Pressure H. P. T.S.V. Inlet (PT-263)
37. Flow Isobutane Vapor to L. P. Turbine (FDT-150)
38. Differential Pressure (P across H. P. T.S.V.) (PDT-148)
39. Position Isobutane H. P. Turbine Valve (ZT-304)
40. Temperature (H. P. T.S.V. Outlet) (TE-152)
41. Temperature Condensor Inlet (TE-146)
42. Temperature Condensate Storage Tank (TE-144)
43. Level Condensate TK101 (LT-145)
44. Level TK101 and HX101 (LT-162)
45. Position Pump Bypass Flow Control (ZT-278)
46. Flow Differential Turbine to Bypass Condensor Storage (FDT-160)
47. Temperature Condensor Outlet (TE-143)
48. Pressure Condensor HX-102 (PT-141)
49. Pressure Pump 101 Suction (PT-159)
50. Temperature Pump 101 Discharge (TE-135)
51. Pressure Pump 101 Discharge (PT-139)
52. Temperature H. P. Boiler Discharge (TE-263A)
53. Flow Pump 101 Discharge (FT-134)
54. Flow Pump 102 Discharge (FT-133)
55. Flow Pump 101 and 102 Discharge (FT-278)
56. Pressure Pump 102 Discharge (PT-131)
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<td>Pressure Pump 102 Suction</td>
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<td>(PT-878)</td>
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<td>Temperature H. P. Boiler Suction</td>
<td>(TE-840A)</td>
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<td>Temperature H. P. Boiler Discharge</td>
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<td>87. Flow Bypass</td>
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<td>88. Flow To Injection</td>
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<td>Temperature difference condensate storage tank inlet-outlet</td>
<td>As above</td>
<td>1-5 V D.C. Range 0-150°F</td>
</tr>
<tr>
<td>TDT 934</td>
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</tr>
<tr>
<td>SCT 934</td>
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</tr>
<tr>
<td>MUX 102</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>FT 930</td>
<td>Flow blowdown treatment plant</td>
<td>As above</td>
<td>1-5 V D.C. Range (Set 0 - 50&quot;) (Adj 0 - 150&quot;)</td>
</tr>
<tr>
<td>SCT 930</td>
<td></td>
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</tr>
<tr>
<td>MUX 101</td>
<td></td>
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</tr>
<tr>
<td>FT 956</td>
<td>Flow combined pump discharge</td>
<td>As above</td>
<td>4-20 MA Range (Set 0 - 300&quot;) (Adj 0 - 750&quot;)</td>
</tr>
<tr>
<td>SCT 956</td>
<td></td>
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<tr>
<td>MUX 98</td>
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<tr>
<td>FT 933</td>
<td>Flow make up water pretreatment plant</td>
<td>As above except no video display</td>
<td>1-5 V D.C. Range (Set 0 - 100&quot;) (Adj 0 - 150&quot;)</td>
</tr>
<tr>
<td>SCT 933</td>
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<tr>
<td>MUX 97</td>
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</tr>
<tr>
<td>FT 959</td>
<td>Flow cooling tower inlet</td>
<td>As above</td>
<td>1-5 V D.C. Range (Set 0 - 300&quot;) (Adj 0 - 750&quot;)</td>
</tr>
<tr>
<td>SCT 959</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>MUX 93</td>
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<tr>
<td>Equipment</td>
<td>Description</td>
<td>Destination</td>
<td>Units</td>
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<td>-------------</td>
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<tr>
<td>TE 963</td>
<td>Temperature cooling tower inlet</td>
<td>As above</td>
<td>1-5 V D.C. Range +30 -150°F</td>
</tr>
<tr>
<td>RBT 963</td>
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<tr>
<td>SCT 963</td>
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<tr>
<td>MUX 92</td>
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<tr>
<td>TE 256</td>
<td>Temperature HP Preheater</td>
<td>As above</td>
<td>1-5 V D.C. Range 125-250°F</td>
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<td>RBT 256</td>
<td>discharge</td>
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<td>SCT 256</td>
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<tr>
<td>MUX 2</td>
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**NOTE:**
1. Turbine/Generator measurements will be included in Revision-1.
2. MUX channels 125 through 129 will be included in Revision-1.