DETERMINING CYCLE LEAKAGE MEGAWATT EFFECTS USING PMAX & PEPSE

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ABSTRACT

Much time and effort is expended locating and evaluating the effect of cycle leakage on heat rate and/or generator output. Sometimes the culprit is quickly found but determining the leakage through a supposedly closed valve is guesswork at best. Most PMAX models have been developed such that a manual input is required for calculating the megawatt (MW) effect of a known leakage flow. The engineer is then required to either assume a flow or select an input that returns the Unaccounted MW Deviations to a pre-leakage value.

This situation occurred twice at the Sequoyah Nuclear Plant when a condensate pump recirculation valve failed to seal off following brief outages. It appeared that the valve leakage, passing directly to the condenser, accounted for losses of 2.5 and 3.5 MW. In these cases there were no manual inputs or calculations included in the PMAX model to assess the MW effect of leakage through this path.

The purpose of this paper is to document TVA's effort to quantify and qualify pump recirculation valve leakage to the Sequoyah Nuclear Plant Unit 2 main condenser using the plant PEPSE model. In addition, the paper will discuss the modifications made to the unit's PMAX model which enables TVA to easily quantify the MW effect for any future recirculation valve leakage.

INTRODUCTION AND BACKGROUND

On January 23, 2007, Sequoyah Nuclear Plant Unit 2 tripped from 100% power. Following the return to operation at 100% power it was recognized that the unit was generating approximately 4-5 MW less than expected. By the time the unit had settled and T_{avg} was adjusted there was still a generation loss of 2-3 MW. A walkdown of the secondary side was conducted January 29-30, 2007. The pipe surface temperature (200-240°F) of the Condensate Booster Pump (CBP) recirculation line indicated that there was leakage through the line to the condenser. Since there is a common line from the three CBPs to the condenser, further investigation was required to determine that the leakage was from the 2B CBP recirculation valve.

For minimum flow protection, Sequoyah employs the Yarway 5300 Series Automatic Recirculation Control (ARC) valves to provide cooling flow through the CBPs. The ARC valves are fully mechanical in nature and operate off system pressure, flow, and hardware linkages (i.e., no electrical or pneumatic controls).

Efforts were made by the maintenance staff to persuade the valve to re-position such that the recirculation path would be isolated. Successful isolation was achieved over a two day period (January 31-February 1, 2007). During this time period the unit output increased approximately 2.5 MW. This increase also appears to have taken place gradually (i.e., in about 3-4 stages).

One other notable change during this same time period was the flow through the No. 7 Heater Drain Tank Pumps (HDTPs). The flow decreased by approximately 150 gpm following the MW recovery period. The No. 7 HDTPs process the drains collected from the nine low pressure feedwater heaters (3 strings of 3 heaters) forward in the cycle (see Figure 1).

Subsequent to the first trip, Unit 2 was manually tripped from 100% power on March 13, 2007 following a malfunction of one of the main feed pump turbines. Similarly, there was a generation loss noticed following return to 100% power; however, this time the loss was even higher (3-4 MW). Based on the previous shutdown the CBP recirculation line was suspected of leaking to the main condenser. A temperature reading was taken of the pipe with an infrared thermometer immediately upstream of the condenser. The pipe surface temperature (170°F) indicated that there was leakage through the line to the condenser; however, either the temperature measurement was incorrect or we were looking in the wrong place for the missing MWe. As before, a change in the No. 7 HDTP flow was realized. The flow had increased approximately 190 gpm above the flow seen prior to the shutdown.

The maintenance staff was unsuccessful this time in getting the valve to seal off; therefore, on-line valve maintenance was performed. Following the maintenance activity, a recovery of approximately 3.5 MW was realized.

EVALUATIONS

A multi-step evaluation was performed as follows:

1. Determine if the 2.5 MW recovered could be credited to a leaking CBP recirculation valve.
2. Determine if the recirculation valve leakage would increase the No. 7 HDTP flow 150 gpm.
3. Determine if the 3.5 MW recovered could be credited to a leaking CBP recirculation valve.
4. Determine if the recirculation valve leakage would increase the No. 7 HDTP flow 190 gpm.
5. Establish an analytical method for calculating the leakage flow to the condenser based on the pipe wall temperature.
6. Incorporate this methodology into the Sequoyah Unit 2 PMAX model.

➢ PEPSE Evaluations

The Sequoyah Unit 2 PEPSE model was configured to determine the MW impact of CBP recirculation leakage to the main condenser. The current condenser backpressure was utilized in the model. A sensitivity study was executed with the leakage flow varied over the range of 0.0 to 1.0E6 lb/hr. It was determined that a 2.5 MW loss was associated with a leakage flow of 475,000 lb/hr (1011 gpm) (see Table 1). Since this flow was less than the design flow capacity of the recirculation valve (1800 gpm), the leakage flow was considered reasonable and feasible. With this amount of leakage it would be expected that the condensate flow from the condenser hotwell to the CBPs would be increased similarly. The increased flow through the low pressure heaters would result in higher extraction flows (i.e., heaters able to condense more steam). In addition, the low pressure heater shell pressures would be reduced due to the higher extraction flows. The lower shell pressures would then drive the condensate temperatures lower. Prior to the MW recovery, System Engineering had noted that the feedwater heater outlet temperatures were down slightly. A plot of PMAX archive data showed that the No. 5 FWH outlet temperature (i.e., CBP inlet temperature) had trended up during the MW recovery time period (see Figure 2). The increased extraction flows would increase heater drain flows and ultimately the No. 7 HDTP flow. The PEPSE output showed that the No. 7 HDTP flow increased by 159 gpm for the case with a CBP recirculation leakage of 1011 gpm. This agrees closely with the field data witnessed (150 gpm decrease following valve isolation).

Based on the close agreement of unit operating data and PEPSE results it was concluded that the MW loss was the result of a leaking CBP recirculation valve.

Based on the previous results of Table 1, it was assumed that the leakage flow corresponding to 3.5 MW was in the 650,000 to 700,000 lb/hr range. An additional sensitivity study was executed with the leakage flow varied over this range. It was determined that a 3.5 MW loss was associated with a leakage flow of 669,000 lb/hr (1425 gpm). Since this flow is also less than the design flow capacity of the recirculation valve (1800 gpm), the leakage flow was considered reasonable and feasible.

Again, with this amount of leakage it was expected that the condensate temperatures throughout the low pressure heater stings would be driven lower. Figure 3 provides a plot of PMAX archive data showing the No. 5 FWH outlet temperature during the period just prior to the unit trip through the time following recirculation valve repair. This clearly shows the impact CBP leakage has on condensate temperature. Note that twice during the planning period for the on-line maintenance activity the 2B CBP was tripped and isolated. These were times during which the maintenance staff agitated the recirculation valve in an attempt to get it to reseat. Prior to opening the valve the pump discharge line between the recirculation valve and the downstream discharge isolation valve was hot tapped. Testing was then performed using the hot tap to ensure a tight shutoff of the isolation valve. The figure shows that the temperature returned to its normal value when the valve repair was complete and the recirculation leakage was isolated. The PEPSE output also showed that the No. 7 HDTP flow increased by 213 gpm for the case with a CBP recirculation leakage of 1425 gpm. This agrees fairly close with the field data difference of 190 gpm.

Again, based on the close agreement of unit operating data and PEPSE results it was concluded that the MW loss was the result of the leaking 2B CBP recirculation valve.

➢ Analytical Method for Determining Leakage Flow

Based on information provided by General Electric (GE) and partially documented in Ken Cotton's book "Evaluating and Improving Steam Turbine Performance" (see pages 296-298), the pipe wall temperature can be used to estimate the leakage flow through the valve(s). This methodology was used to validate the leakage flow calculated with PEPSE.

The methodology is as follows:

Required Inputs:
(Note that upstream and downstream notations are in relation to the leaking valve. Data following the return to operation (January 23, 2007 trip) was used for this example)

Downstream Pipe Temp	230.0	°F	(pipe wall temperature just off condenser wall)
P_{sat} based on Pipe Temp	20.78	psia	(determined from Steam Tables)
Pipe Inside Diameter	8.0	inches	(pipe diameter at temperature measurement)
Pipe Area	50.0	$inches^2$	(calculated)
Upstream Temperature	263.0	°F	(from plant computer or PMAX)
Upstream Pressure	500.0	psia	(from plant computer / PMAX / or assumed)
Average Condenser BP	1.65	in Hg	(from plant computer or PMAX)

Steam Leakage is calculated as follows:

$$Ws = Ap \times N \times w/Pp \times Pp \qquad \text{(Equation 1)}$$

where
Ws = Steam part of leakage flow (lbm/hr)
Ap = Area of pipe (in^2)
N = Restriction Factor (Always 1 for Critical Flow, i.e., $P1/P2 \geq 1.83$)
w/Pp = Flow Function (Figure 4 - See either Page 297 of Cotton or Fig. 14, ASME Steam Tables (1967), page 301)
Pp = Pressure in pipe downstream of valve (psia), this is Psat based on Pipe Wall Temperature reading (Note that this pressure must be at

least two times as great as the pressure in the receiving tank – i.e., critical pressure ratio, thus critical flow)

Determine the value of w/Pp based on the steam enthalpy at Pp (Figure 4).

H_g = 1157.053 Btu/lbm (Hg based on Pp = 20.78 psia)

w/Pp = 53.77 lbm/hr/in²/psia (Based on Pp and H_g)

Using Equation 1, calculate the steam leakage

Ws = (50 in²) x (1.0) x (53.77 lbm/hr/in²/psia) x 20.78 psia)

Ws = 55,890.53 lbm/hr

Total Leakage is calculated as follows:

(Wt)(hbv) = (Ws)(Hs) + (Ww)(hav) (Equation 2)

and

Wt=Ws + Ww (Equation 3)

Combining Equations 2 and 3 produces the following

Wt = Ws x (Hs - hav) / (hbv - hav) (Equation 4)

where Wt = Total Leakage Flow past the valve (lbm/hr)
Ws = Steam part of leakage flow (lbm/hr) - calculated above
Ww = Water part of leakage flow (lbm/hr)
hbv = Water enthalpy before the valve (btu/lbm)
Hs = Steam enthalpy after the valve (btu/lbm) (based on Pp)
hav = Water enthalpy after the valve (btu/lbm) (based on Pp)

and hbv = 232.75 Btu/lbm (Based on 263.0°F and 500.0 psia)
Hs = 1157.053 Btu/lbm (same as H_g above)
hav = 198.33 Btu/lbm (h_f at Pp = 20.78 psia)

Wt = (55,890.53) x (1157.053 – 198.33) / (232.75 – 198.33)

Wt = 1,556,866 lbm/hr

Water Leakage is calculated using Equation 3

Ww = 1,556,866 – 55,890.53

Ww = 1,500,976 lbm/hr

The following information related to moisture correction is based on a paper offered on the EPRI Plant Performance Enhancement Program (P2EP) web site as document 0073.0-460 “Water Leakage to the Condenser” (http://www.epriq.com/pse/Library/Library/P2ep/460.pdf). The paper is dated April 24, 1996 and is listed as a systems procedure. The paper has no author listed.

Figure 4 used earlier to determine the Flow Function (w/Pp) assumes that either the moisture content is zero or all moisture is accelerated to steam velocities. Moisture under these conditions (i.e. leaking through a valve) is not accelerated to the high steam velocities. Using the curve supplied by GE “Effect of Moisture in the Flow of Steam through Various Restrictions” (see Figure 5), the true flow can be approximated. The GE curve was drawn from experimental data and reflects the effects from the slower velocity moisture. Using the steam/water mixture moisture percentage, an additional flow factor to correct for the moisture can be determined.

Total Flow Corrected for Moisture is calculated as follows:

Determine moisture of steam/water mixture downstream of the valve.
%M = Ww / Wt
%M = 1,500,976 lbm/hr / 1,556,866 lbm/hr
%M = 0.9641 x 100
%M = 96.41

Determine the flow factor as a function of percent moisture (see Figure 4)

Wc = Wt x fc (Equation 5)

where Wc = Corrected leakage flow rate (lbm/hr)
Wt = Total Leakage Flow past the valve (lbm/hr)
fc = Flow Correction based on Vapor Flow in the presence of water

From Figure 5

fc = 0.305

Wc = (1,556,866 lbm/hr) x (0.305)
Wc = 474,844 lbm/hr or 1011.4 gpm

This flow (1011.4 gpm) is almost identical to the flow previously calculated by PEPSE (1011 gpm) for a generation loss 2.5 MWe.

To validate the methodology further the data collected for the March 13, 2007 trip was used to calculate the leakage flow through the valve.

Based on the fact that a pipe surface temperature of 170°F had been measured following the second return to service, it was clear the calculated leakage would be much less than the PEPSE predicted flow of 1425 gpm. As previously stated, either the temperature measurement was incorrect or we were looking in the wrong place for the missing MWe. The flow calculations were performed at 170°F and the resulting leakage flow was only 213 gpm. It was further calculated that a temperature of ~240° would result in a flow commensurate with the PEPSE estimated flow of 1425 gpm. Since the flow and temperature changes associated with the low pressure heaters (i.e., No. 7 HDTP Flow and No. 5 FWH Outlet Temperature) indicate and support a major leakage through the CBP recirculation line, it was decided to go back out in the plant and get a new temperature reading off the pipe. System Engineering performed the temperature measurement with a contact thermometer. The temperature reading was 246 ±5°F; therefore, the estimated flow of 1425 gpm predicted by PEPSE is substantiated and the methodology to predict leakage flow using the pipe wall temperature is validated.

- Incorporating Analytical Methodology Into PMAX

To incorporate the analytical methodology into PMAX the following steps were taken:

STEP 1
The PMAX model was reviewed to determine the point number of each plant parameter required to perform the calculations. Table 2 lists the existing point numbers that were identified for use.

STEP 2
New PMAX point numbers were assigned for Manual Input of the Pipe Wall Temperature and for each calculation result. Table 3 provides a listing of the new point numbers.

STEP 3
The flow function and flow correction factors taken from Figures 4 and 5 were incorporated into Bogey Curves LEAKFF, LEAKCF. The enthalpy utilized as the X value in Figure 4 is the enthalpy at saturated vapor conditions (Hg or Hs). This allows the data from Figure 4 to be simplified into one curve by determining the corresponding Hg for each possible pressure line. Then a single Flow Function value is read from the figure based on the saturation pressure value (see Table 4). Table 5 provides the curve values for Figure 5. The MW Effects curve (LEAKMW1) was created by running PEPSE at various leakage flows and power levels (see Table 6).

STEP 4
New C-Point 2-12 was added to the model to handle all calculations associated with leakage determination. Also, C-PT 2-13 was added to set all values associated with the CBP Leak MW Effect equal to zero when required by logical test. Each C-PT contained 20 calculations.

STEP 5
C-PT 2-12, C-PT 2-13, and the three Bogey Curves were added to Sequence 2. A logical test was added to Sequence 2 so that C-PT 2-12 and the three associated bogey curves are skipped if manual input PN02961 (CBP Recirc pipe wall temp) is set to zero. A logical test for C-PT 2-13 was also added in Sequence 2 so that it is skipped when the manual input PN02961 greater than zero.

STEP 6
A new display was developed (leak-cbpr) which displays all of the calculated values associated with the leakage flow and associated MW effect. In addition, trend plots of the average No. 5 FWH outlet temperature and No. 7 HDTP flow were included on the display to provide visual indicators of possible leakage.

STEP 7
The calculated MW effect was incorporated into overall tally of MW Effects.

Figure 6 shows the layout of the new display (leak-cbpr) with trend data exhibited for the time period associated with the March 2007 trip. Figure 7 shows a simulated leakage calculation based on a wall temperature of 240°F. Note that the calculated leakage flow (1376 gpm) is less than the flow previously calculated (1425 gpm) for 240°F because the condenser backpressure is higher (1.573 psia).

CONCLUSIONS

- Based on the close agreement of unit operating data and PEPSE results it is concluded that the PEPSE model is an accurate tool for determining the required leakage for a know MW loss.
- Feedwater heater outlet temperatures and drain flows are accurate indicators of recirculation leakage flows.
- The analytical methodology presented by GE and Ken Cotton is accurate and can be employed to determine water leakage when critical flow is present.
- The PMAX model can be modified to include calculations which account for miscellaneous leakages such as a pump recirculation valve; however, a PMAX leakage module would be beneficial if additional leak paths were to be included in the model.

TABLE 1
PEPSE Sensitivity Study Output

CBP Recirculation Leakage (lb/hr)	CBP Recirculation Leakage (gpm)	Generator Output (KW)	Generator Output (MW)	Output Loss (MW)
0	0.0	1,217,980	1217.980	0.00
50,000	106.4	1,217,700	1217.700	-0.28
100,000	212.9	1,217,440	1217.440	-0.54
150,000	319.3	1,217,180	1217.180	-0.80
200,000	425.7	1,216,920	1216.920	-1.06
250,000	532.1	1,216,650	1216.650	-1.33
300,000	638.6	1,216,390	1216.390	-1.59
350,000	745.0	1,216,130	1216.130	-1.85
400,000	851.4	1,215,870	1215.870	-2.11
450,000	957.8	1,215,610	1215.610	-2.37
455,000	968.5	1,215,580	1215.580	-2.40
460,000	979.1	1,215,570	1215.570	-2.41
465,000	989.8	1,215,530	1215.530	-2.45
470,000	1000.4	1,215,510	1215.510	-2.47
475,000	1011.0	1,215,470	1215.470	-2.51
480,000	1021.7	1,215,460	1215.460	-2.52
485,000	1032.3	1,215,420	1215.420	-2.56
490,000	1043.0	1,215,410	1215.410	-2.57
495,000	1053.6	1,215,370	1215.370	-2.61
500,000	1064.3	1,215,340	1215.340	-2.64
550,000	1170.7	1,215,080	1215.080	-2.90
600,000	1277.1	1,214,820	1214.820	-3.16
650,000	1383.5	1,214,560	1214.560	-3.42
700,000	1490.0	1,214,290	1214.290	-3.69
750,000	1596.4	1,214,030	1214.030	-3.95
800,000	1702.8	1,213,770	1213.770	-4.21
850,000	1809.2	1,213,510	1213.510	-4.47
900,000	1915.7	1,213,250	1213.250	-4.73
950,000	2022.1	1,212,980	1212.980	-5.00
1,000,000	2128.5	1,212,720	1212.720	-5.26

TABLE 2
Existing Points Used

POINT NAME	DESCRIPTION	UNITS
PN02082	U2 CNDR C HOTWELL PRESSURE	PSIA
PN02150	U2 COND BSTER PMP DISCH HDR PRESS	PSIA
PN04239	U2 COND BOOSTER PUMPS HEADER OUT TEMP	DEG F

TABLE 3
New Points Created

POINT NAME	DESCRIPTION	UNITS
PN02961	U2 CBP RECIRC LINE WALL TEMP	DEGF
PN03175	U2 CBP RECIRC LEAKAGE STEAM FLOW	LB/HR
PN03176	U2 CBP RECIRC LEAKAGE TOTAL FLOW	LB/HR
PN03177	U2 CBP RECIRC LEAKAGE WATER FLOW	LB/HR
PN03178	U2 CBP RECIRC LEAKAGE MOISTURE	-
PN03179	U2 CBP RECIRC LEAKAGE CORRECTED FLOW	LB/HR
PN03180	U2 CBP RECIRC LEAKAGE UPSTREAM SPEC. VOLUME	FT3/LB
PN03181	U2 CBP RECIRC LEAKAGE FLOW IN GPM	GPM
PN03210	U2 CBP RECIRC LEAKAGE MIN. WALL TEMP	DEG F
PN03211	U2 CBP RECIRC LEAKAGE AVG. #5 FWH OUTLET TEMP	DEGF
PN03400	U2 CBP RECIRC LEAKAGE SAT. PRESSURE	PSIA
PN03401	U2 CBP RECIRC LEAKAGE MINIMUM PSAT	PSIA
PN03402	U2 CBP RECIRC PRESSURE MULTIPLIER (NO LEAKAGE)	-
PN03780	U2 CBP RECIRC LEAKAGE STEAM ENTHALPY	BTU/LB
PN03781	U2 CBP RECIRC LEAKAGE ENTHALPY BEFORE VALVE	BTU/LB
PN03782	U2 CBP RECIRC LEAKAGE WATER ENTHALPY AFTER VALVE	BTU/LB
PN03783	U2 CBP RECIRC LEAKAGE TOTAL FLOW CALC	BTU/LB
PN03784	U2 CBP RECIRC LEAKAGE TOTAL FLOW CALC	BTU/LB
PN03785	U2 CBP RECIRC LEAKAGE TOTAL FLOW CALC	-
PN03835	U2 CBP RECIRC LEAKAGE FLOW FUNCTION	-
PN03836	U2 CBP RECIRC LEAKAGE MOISTURE CORRECTION FACTOR	-
PN06065	U2 CBP RECIRC LEAKAGE MW EFFECT	MW
PN06830	U2 CBP RECIRC LEAKAGE CONSTANT	-

TABLE 4
Flow Function (Bogey Curve LEAKFF)

```
BOGEY CURVE LIST OF DATA BASE CONTENTS
DATA BASE NAME :  LEAKFF
DATA BASE TITLE:  U2 LEAKAGE FLOW FUNCTION
                    NAME          PTID
                  --------      --------
INPUT VARIABLE :    PRESSURE    PN03400
OUTPUT VARIABLE:    FACTOR      PN03835
NUMBER OF PRESSURE/FACTOR VALUES IN THE TABLE:   13

********************* LEAKFF   DATA BASE *********************
PRESSURE   1 =      0.0000          FACTOR     1 =      0.0000
PRESSURE   2 =      0.2000          FACTOR     2 =     61.2000
PRESSURE   3 =      0.5000          FACTOR     3 =     59.8000
PRESSURE   4 =      1.0000          FACTOR     4 =     58.8000
PRESSURE   5 =      2.0000          FACTOR     5 =     57.8000
PRESSURE   6 =      5.0000          FACTOR     6 =     56.2600
PRESSURE   7 =     10.0000          FACTOR     7 =     55.0000
PRESSURE   8 =     20.0000          FACTOR     8 =     53.8000
PRESSURE   9 =     50.0000          FACTOR     9 =     52.5000
PRESSURE  10 =    100.0000          FACTOR    10 =     51.5000
PRESSURE  11 =    200.0000          FACTOR    11 =     50.7500
PRESSURE  12 =    500.0000          FACTOR    12 =     50.0000
PRESSURE  13 =   1000.0000          FACTOR    13 =     50.2500
```

TABLE 5
Flow Correction (Bogey Curve LEAKFC)

```
BOGEY CURVE LIST OF DATA BASE CONTENTS
DATA BASE NAME :  LEAKCF
DATA BASE TITLE:  U2 MOISTURE CORRECTION FACTOR
                    NAME          PTID
                  --------      --------
INPUT VARIABLE :    MOISTURE    PN03178
OUTPUT VARIABLE:    FACTOR      PN03836
NUMBER OF MOISTURE/FACTOR VALUES IN THE TABLE:   18

********************* LEAKCF   DATA BASE *********************
MOISTURE   1 =      0.0000          FACTOR     1 =      1.0000
MOISTURE   2 =      0.2000          FACTOR     2 =      0.9600
MOISTURE   3 =      0.4000          FACTOR     3 =      0.9080
MOISTURE   4 =      0.5500          FACTOR     4 =      0.8450
MOISTURE   5 =      0.6500          FACTOR     5 =      0.7910
MOISTURE   6 =      0.7000          FACTOR     6 =      0.7600
MOISTURE   7 =      0.7250          FACTOR     7 =      0.7400
MOISTURE   8 =      0.7500          FACTOR     8 =      0.7200
MOISTURE   9 =      0.7750          FACTOR     9 =      0.6950
MOISTURE  10 =      0.8000          FACTOR    10 =      0.6700
MOISTURE  11 =      0.8250          FACTOR    11 =      0.6400
MOISTURE  12 =      0.8500          FACTOR    12 =      0.6000
MOISTURE  13 =      0.8750          FACTOR    13 =      0.5550
MOISTURE  14 =      0.9000          FACTOR    14 =      0.5050
MOISTURE  15 =      0.9250          FACTOR    15 =      0.4400
MOISTURE  16 =      0.9500          FACTOR    16 =      0.3700
MOISTURE  17 =      0.9750          FACTOR    17 =      0.2500
MOISTURE  18 =      1.0000          FACTOR    18 =      0.0000
```

TABLE 6
MW Effects (Bogey Curve LEAKMW1)

```
BOGEY CURVE LIST OF DATA BASE CONTENTS

DATA BASE NAME :  LEAK1MW
DATA BASE TITLE:  U2 CBP RECIRC LEAKAGE MW EFFECT

                           NAME          PTID
                         --------      --------
FIRST INPUT VARIABLE :    FLOW          PN03179
SECOND INPUT VARIABLE:    MW THERM      PN02501
OUTPUT VARIABLE      :    MW EFF        PN06065

NUMBER OF FLOW     VALUES IN THE TABLE:     8
NUMBER OF MW EFF   VALUES IN THE TABLE:    40

              *     MW THERM  1    MW THERM  2    MW THERM  3    MW THERM  4    MW THERM  5
    FLOW      *      2591.6250      2764.3999      3109.9500      3455.5000      3801.0500
    ************************************************************************************
              *
     0.0000   *         0.0000         0.0000         0.0000         0.0000     0.0000E+00
              *
200000.0000   *        -0.9446        -0.9808        -1.0470        -0.9950    -1.0180E+00
              *
400000.0000   *        -1.8882        -1.9604        -2.0910        -1.9900    -2.0360E+00
              *
600000.0000   *        -2.8303        -2.9381        -3.1380        -2.9850    -3.0550E+00
              *
800000.0000   *        -3.7706        -3.9168        -4.1830        -3.9790    -4.0740E+00
              *
 1.0000E+06   *        -4.7110        -4.8922        -5.2260        -5.0030    -5.0930E+00
              *
 1.2000E+06   *        -5.7108        -5.8660        -6.2680        -6.1020    -6.1120E+00
              *
 1.4000E+06   *        -6.7082        -6.8352        -7.3090        -7.2040    -7.1310E+00
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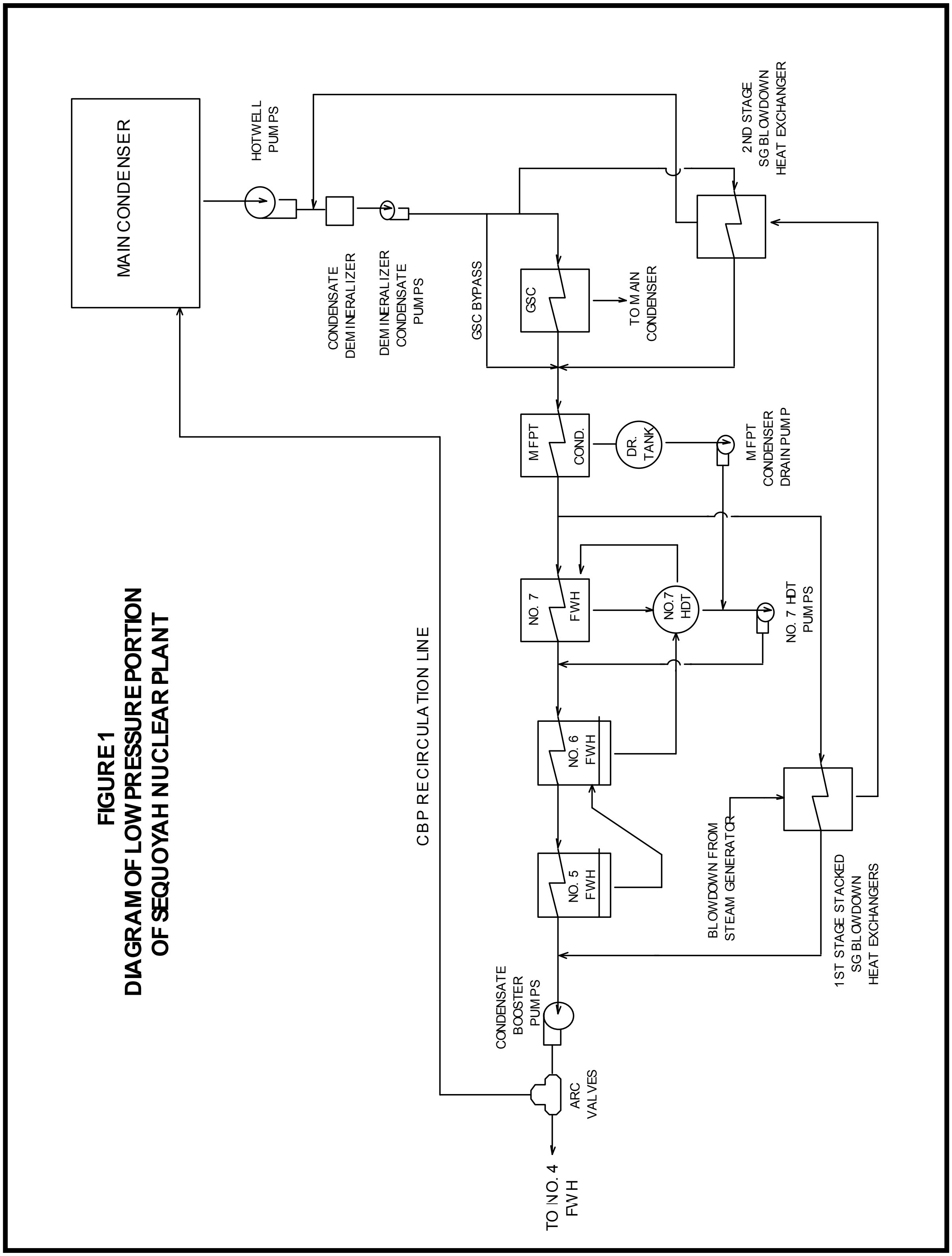


FIGURE 1
DIAGRAM OF LOW PRESSURE PORTION OF SEQUOYAH NUCLEAR PLANT

FIGURE 2

NO. 5 FWH Average Outlet Temperature

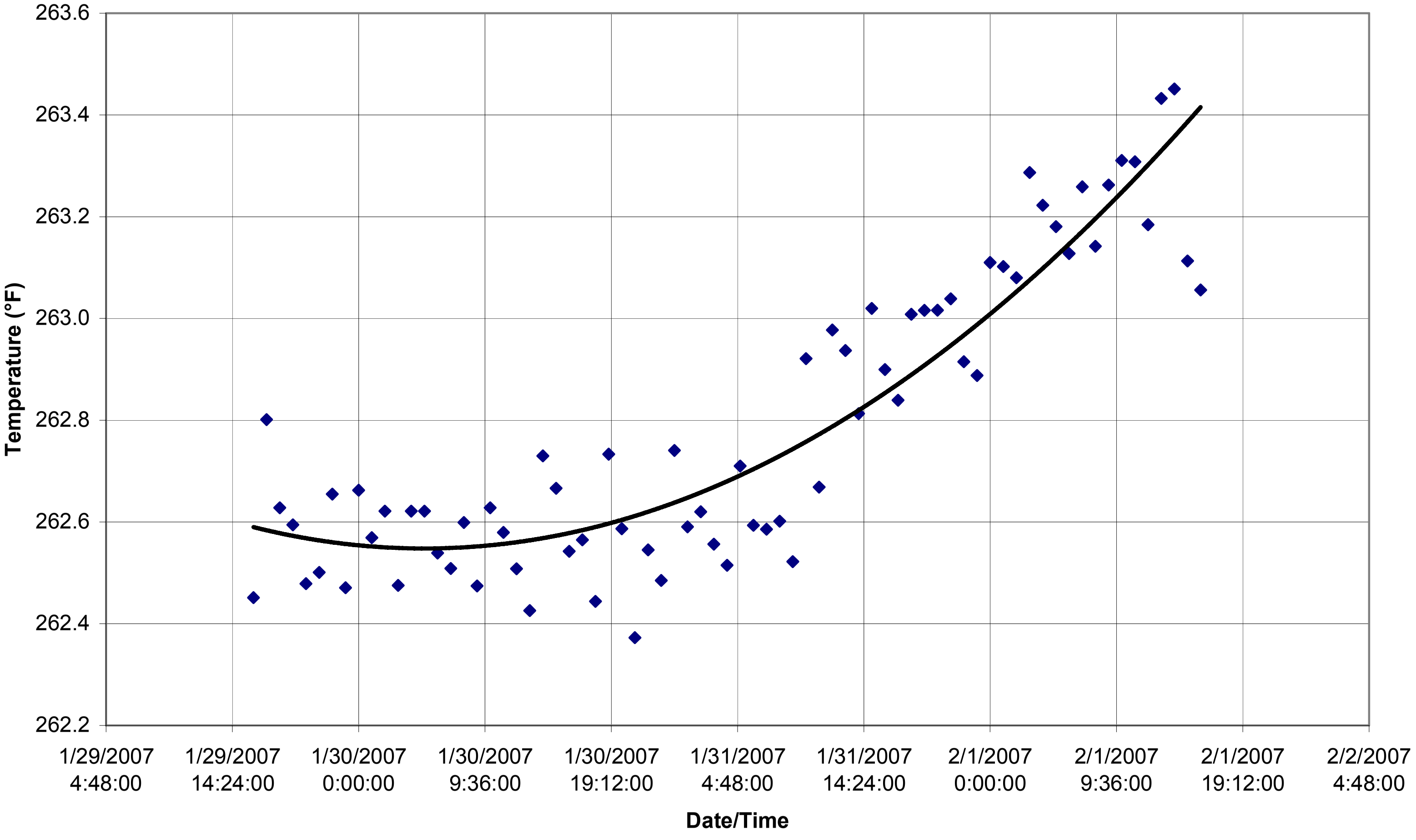


FIGURE 3
NO. 5 FWH Average Outlet Temperature

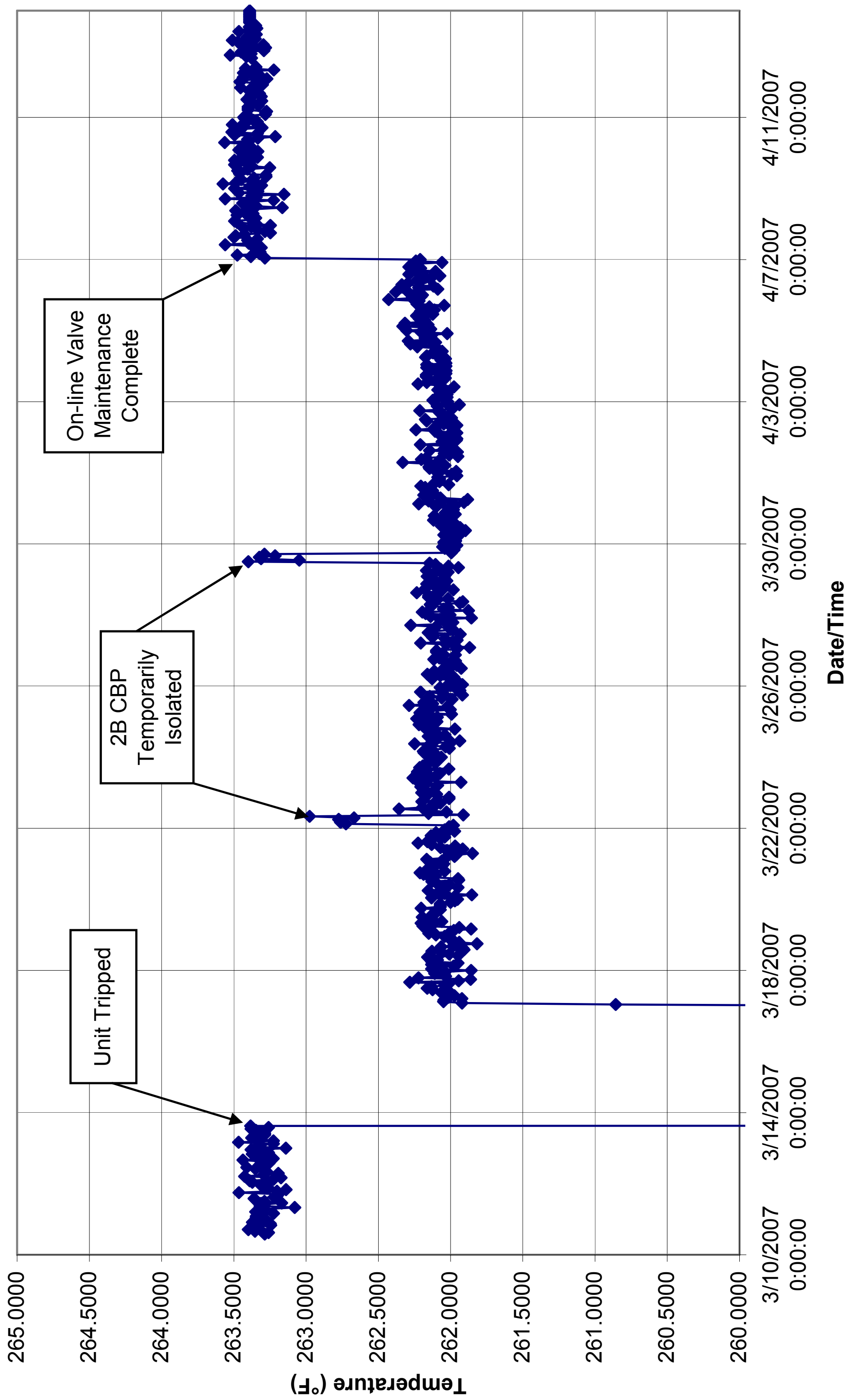


FIGURE 4

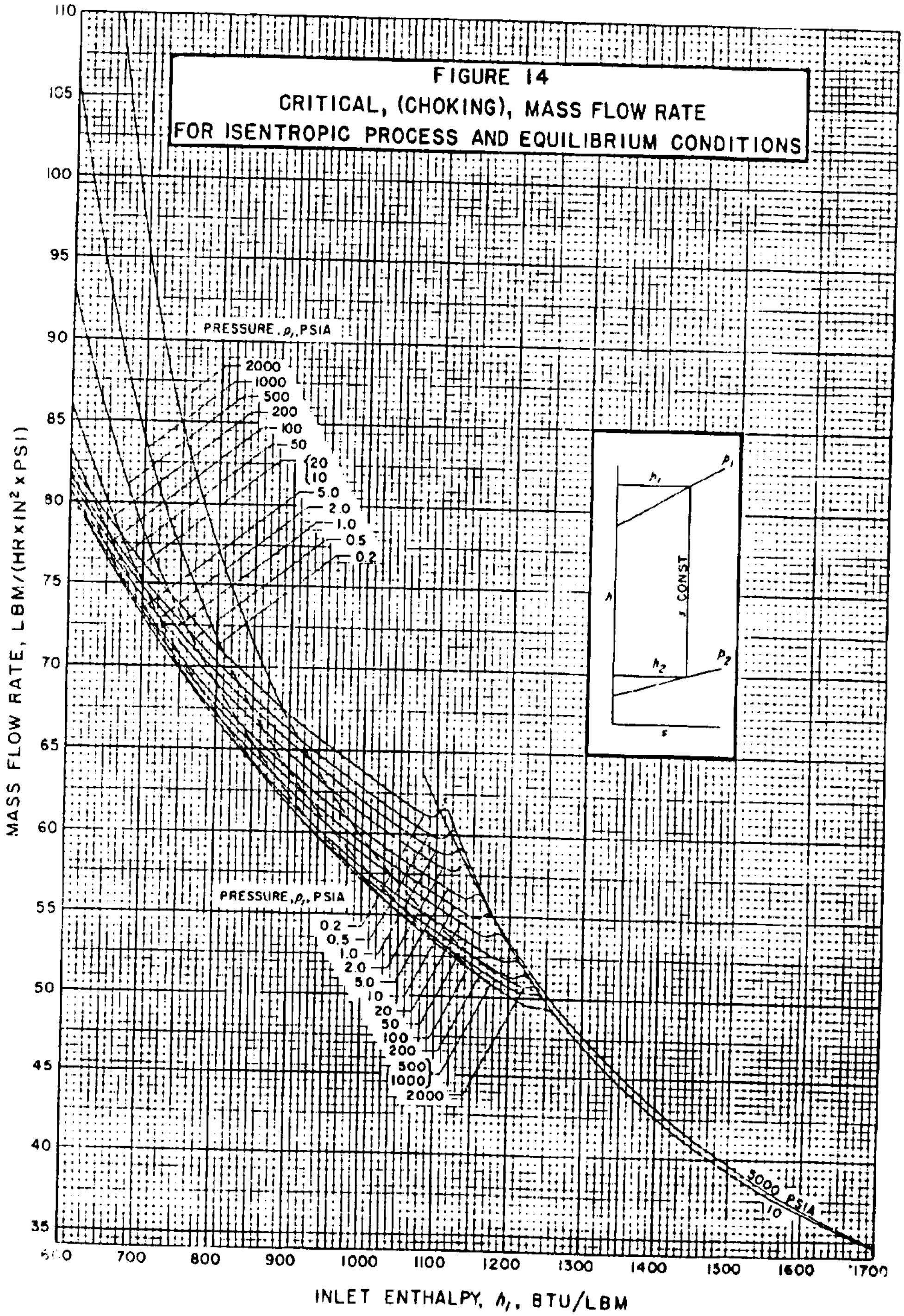


FIGURE 14
CRITICAL, (CHOKING), MASS FLOW RATE
FOR ISENTROPIC PROCESS AND EQUILIBRIUM CONDITIONS

FIGURE 5

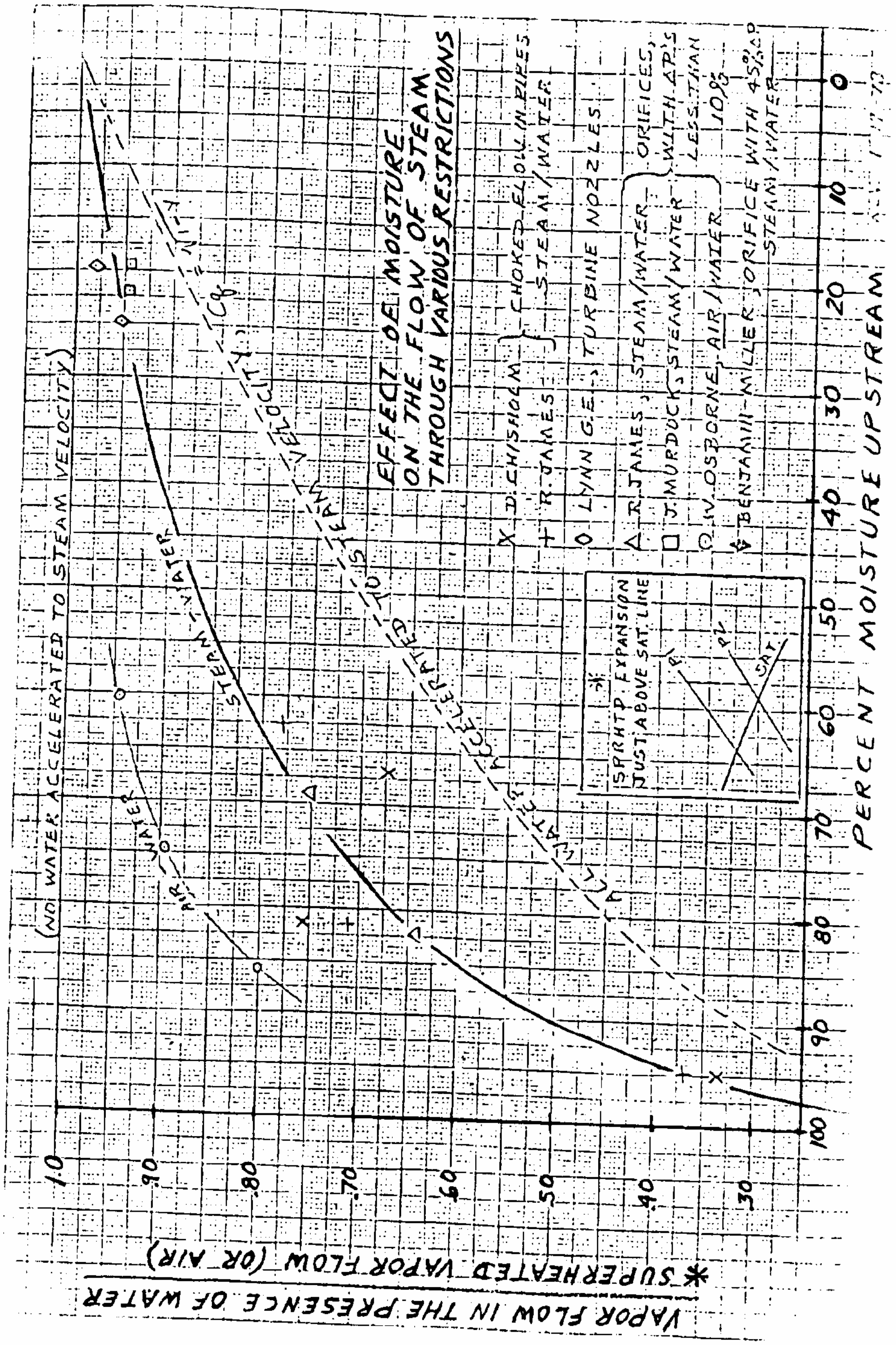
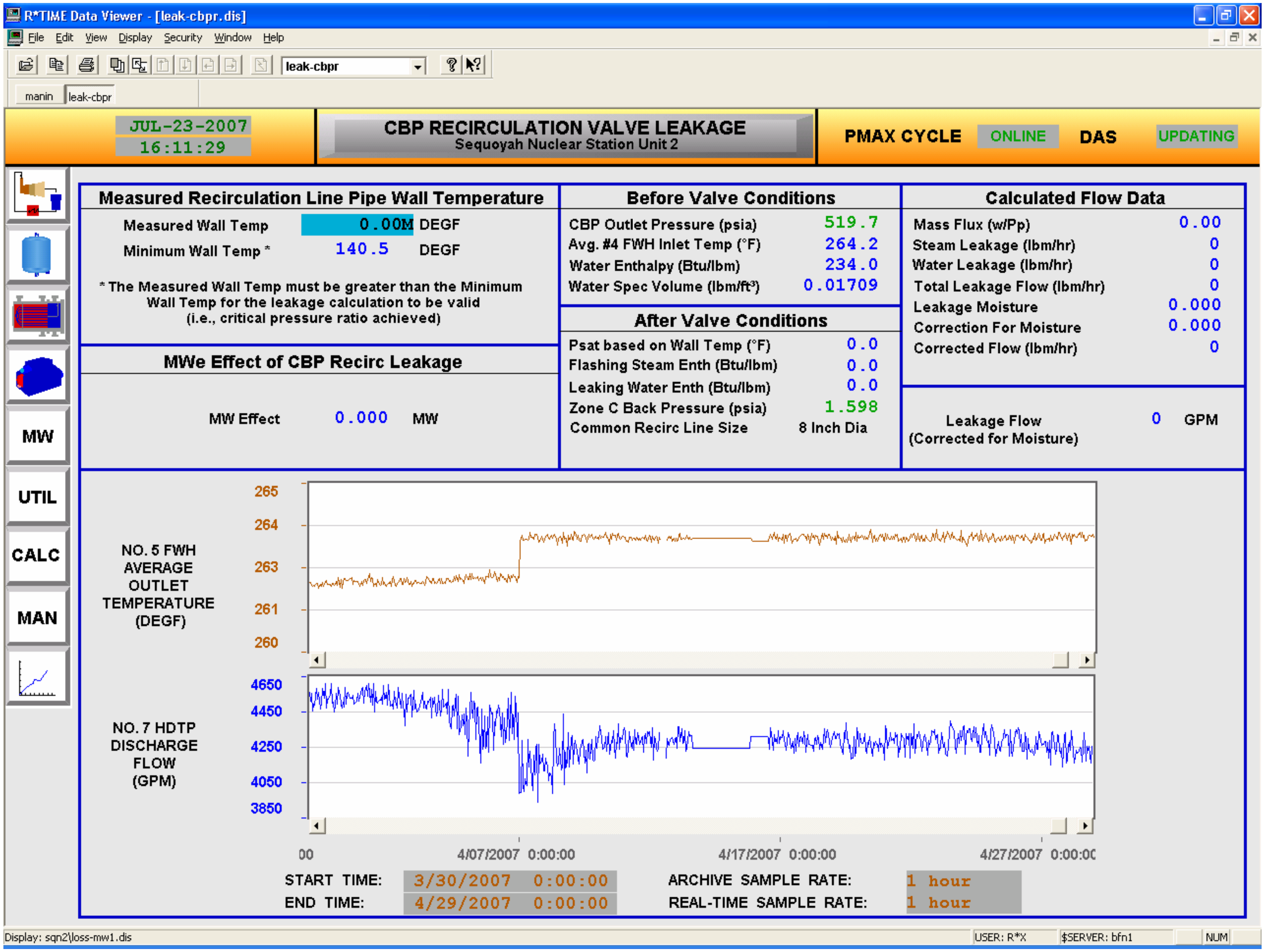

EFFECT OF MOISTURE ON THE FLOW OF STEAM THROUGH VARIOUS RESTRICTIONS
X D. CHISHOLM } CHOKED FLOW IN PIPES
+ R. JAMES } STEAM/WATER
O LYNN G.E. TURBINE NOZZLES
△ R. JAMES } STEAM/WATER
□ J. MURDOCK } STEAM/WATER
O W. OSBORNE AIR/WATER
} ORIFICES, WITH ΔP'S LESS THAN 10%
◇ BENJAMIN-MILLER ORIFICE WITH 45% STEAM/WATER
* SPRHTD. EXPANSION JUST ABOVE SAT. LINE
P1
P2
SAT.
(NO WATER ACCELERATED TO STEAM VELOCITY)
AIR-WATER
STEAM-WATER
AIR-WATER
PERCENT MOISTURE UPSTREAM
0
10
20
30
40
50
60
70
80
90
100
1.0
.90
.80
.70
.60
.50
.40
.30
VAPOR FLOW IN THE PRESENCE OF WATER
* SUPERHEATED VAPOR FLOW (OR AIR)

FIGURE 6



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CBP RECIRCULATION VALVE LEAKAGE

Sequoyah Nuclear Station Unit 2

PMAX CYCLE ONLINE DAS UPDATING

Measured Recirculation Line Pipe Wall Temperature

Measured Wall Temp	0.00M	DEGF
Minimum Wall Temp *	140.5	DEGF

* The Measured Wall Temp must be greater than the Minimum Wall Temp for the leakage calculation to be valid (i.e., critical pressure ratio achieved)

MWe Effect of CBP Recirc Leakage

MW Effect 0.000 MW

Before Valve Conditions

CBP Outlet Pressure (psia)	519.7
Avg. #4 FWH Inlet Temp (°F)	264.2
Water Enthalpy (Btu/lbm)	234.0
Water Spec Volume (lbm/ft³)	0.01709

After Valve Conditions

Psat based on Wall Temp (°F)	0.0
Flashing Steam Enth (Btu/lbm)	0.0
Leaking Water Enth (Btu/lbm)	0.0
Zone C Back Pressure (psia)	1.598
Common Recirc Line Size	8 Inch Dia

Calculated Flow Data

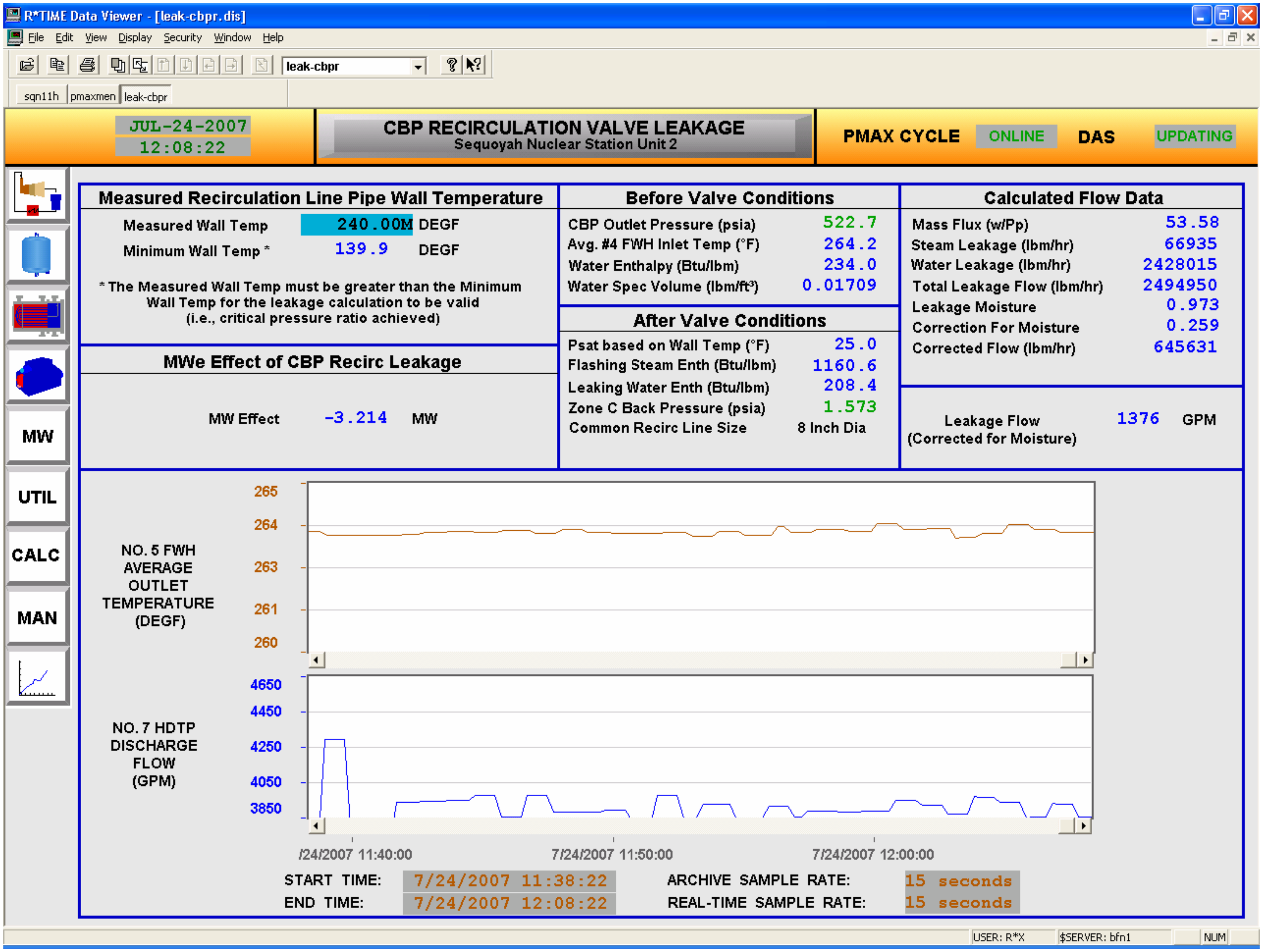
Mass Flux (w/Pp)	0.00
Steam Leakage (lbm/hr)	0
Water Leakage (lbm/hr)	0
Total Leakage Flow (lbm/hr)	0
Leakage Moisture	0.000
Correction For Moisture	0.000
Corrected Flow (lbm/hr)	0

Leakage Flow (Corrected for Moisture) 0 GPM

START TIME: 3/30/2007 0:00:00
END TIME: 4/29/2007 0:00:00
ARCHIVE SAMPLE RATE: 1 hour
REAL-TIME SAMPLE RATE: 1 hour

Display: sqn2\loss-mw1.dis USER: R*X $SERVER: bfn1 NUM

FIGURE 7



JUL-24-2007
12:08:22

CBP RECIRCULATION VALVE LEAKAGE
Sequoyah Nuclear Station Unit 2

PMAX CYCLE ONLINE DAS UPDATING

Measured Recirculation Line Pipe Wall Temperature

Measured Wall Temp	240.00M	DEGF
Minimum Wall Temp *	139.9	DEGF

* The Measured Wall Temp must be greater than the Minimum Wall Temp for the leakage calculation to be valid (i.e., critical pressure ratio achieved)

MWe Effect of CBP Recirc Leakage

MW Effect -3.214 MW

Before Valve Conditions

CBP Outlet Pressure (psia)	522.7
Avg. #4 FWH Inlet Temp (°F)	264.2
Water Enthalpy (Btu/lbm)	234.0
Water Spec Volume (lbm/ft³)	0.01709

After Valve Conditions

Psat based on Wall Temp (°F)	25.0
Flashing Steam Enth (Btu/lbm)	1160.6
Leaking Water Enth (Btu/lbm)	208.4
Zone C Back Pressure (psia)	1.573
Common Recirc Line Size	8 Inch Dia

Calculated Flow Data

Mass Flux (w/Pp)	53.58
Steam Leakage (lbm/hr)	66935
Water Leakage (lbm/hr)	2428015
Total Leakage Flow (lbm/hr)	2494950
Leakage Moisture Correction For Moisture	0.973 0.259
Corrected Flow (lbm/hr)	645631

Leakage Flow (Corrected for Moisture) 1376 GPM

START TIME: 7/24/2007 11:38:22
END TIME: 7/24/2007 12:08:22
ARCHIVE SAMPLE RATE: 15 seconds
REAL-TIME SAMPLE RATE: 15 seconds