SECTION 3B

Using PMAX and R*TIME to Monitor Reactor Heat Balance Input Parameters

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Using PMAX and R*Time to Monitor Reactor Heat Balance Input Parameters At Oyster Creek Station

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An ongoing investigation regarding unit MWe output differences at a large dual unit Nuclear station, identified an apparent Unit 1 overpower condition. This condition was unidentified for an extended period due to its gradual increase in magnitude over a long period of time (6 months). Data indicates the magnitude of the overpower condition to be 0.2 – 0.4% (7 - 14 MWt) above licensed thermal power.

A detailed root cause investigation was performed. Apparent causes of this event are as follows:

- No long term trending of critical parameters related to thermal power
- Inadequate system manager trending of parameters
- No process for daily thermal calculation verification

Six fleet corrective actions were assigned to address the issue.

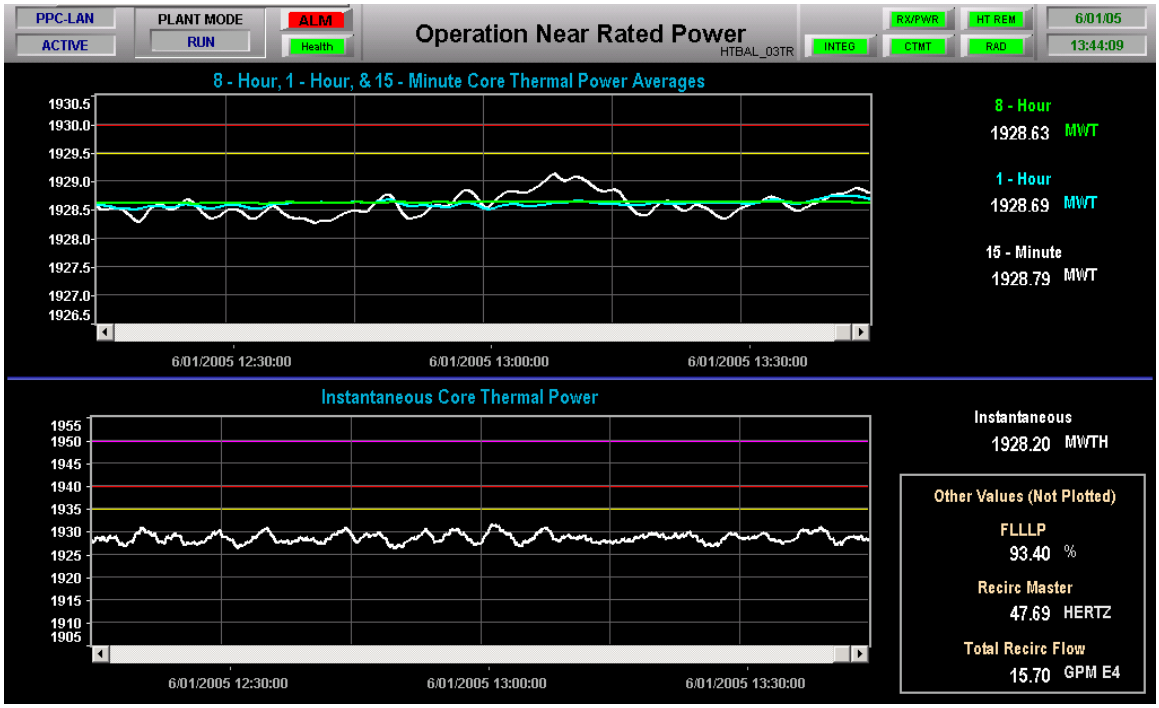
Corrective Action 2, which is the basis for this paper, follows:

2. For stations with units operating at or above 99% reactor power, perform nominal* daily review of Heat Balance Calorimetric Parameters, and other plant parameters (e.g. turbine control valve position, turbine first stage pressure, main steam flow, and condensate flow) as required, for adverse trends and perform trending over previous 6 month minimum period to ensure no slowly progressing trend exists which could have the effect of increasing reactor power above licensed limit. *Nominal means the goal is daily monitoring with allowance for personnel illness, training, etc. but must be performed at least weekly.

   Responsibility: Site Thermal Performance Engineer

The paper discusses how Oyster Creek responded to the corrective action, using dedicated RTime displays, and a set of seven, PMAX generated plant parameter ratios.

Operations and Reactor Engineering are responsible for monitoring and maintaining Core Thermal Power (CTP). A plant process computer display showing various CTP average power over time is used (shown below).



In order to supplement Operations and Reactor Engineering monitoring of Core Thermal Power (CTP), the thermal performance engineer monitors and trend plant parameters that are input to the CTP Calorimetric and additional BOP parameters to supplement these inputs. The goal in watching these parameters is to identify as quickly as possible adverse plant conditions that may lead to reactor overpower. Additionally, long-term trends are performed, the following trends were proposed:

1. Retrieve the RFW flow and trend the difference in FW flows. Establish the expected values and expected bounds based upon data coming out of an outage (30 days at 100% RTP following a refuel outage).

2. Retrieve the 1st stage turbine pressures and trend the full power values. Use this as confirmation for changes in FW flow.

3. Retrieve the feedwater temperatures and trend the full power values and the differences between maximum-minimum for the inputs to the heat balance and difference between the averages of HP heater outlet temperatures and the four inputs to heat balance and the averages of the backup FW temperatures to the inputs to the heat balance. These can be used to identify drifting FW temperature signals and confirm an indication of reactor overpower. If FW flow is drifting, it is expected that all the FW temperatures will trend

together. If a FW temperature is drifting, it is expected that the differences will show a change.

4. Retrieve the RWCU flows, and the recirculation suction temperatures. Trend the ratio of RWCW flow rates, the difference between the inlet and outlet temperatures, and the RWCU inlet temperature and the Recirc suction temperatures.

5. Retrieve the CRD flow rate and the estimate of CRD temperature and trend.

6. Retrieve the pressure input (SPDS) and the reactor pressure indicators that are input into SPDS and trend the difference between the maximum pressure indication and the minimum pressure indication.

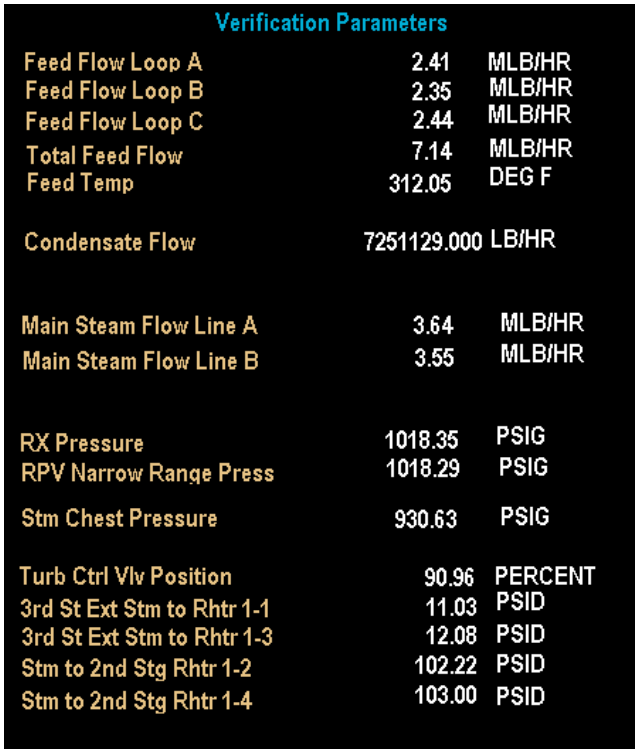
7. Retrieve the Recirculation pump powers and the recirculation pump speeds. The pump power should be a cubed function of the recirculation pump speed. Trend the ratio of pump power divided by the cube of the recirc pump speed.

8. Retrieve Main Turbine Control Valve Positions and trend the full power values.

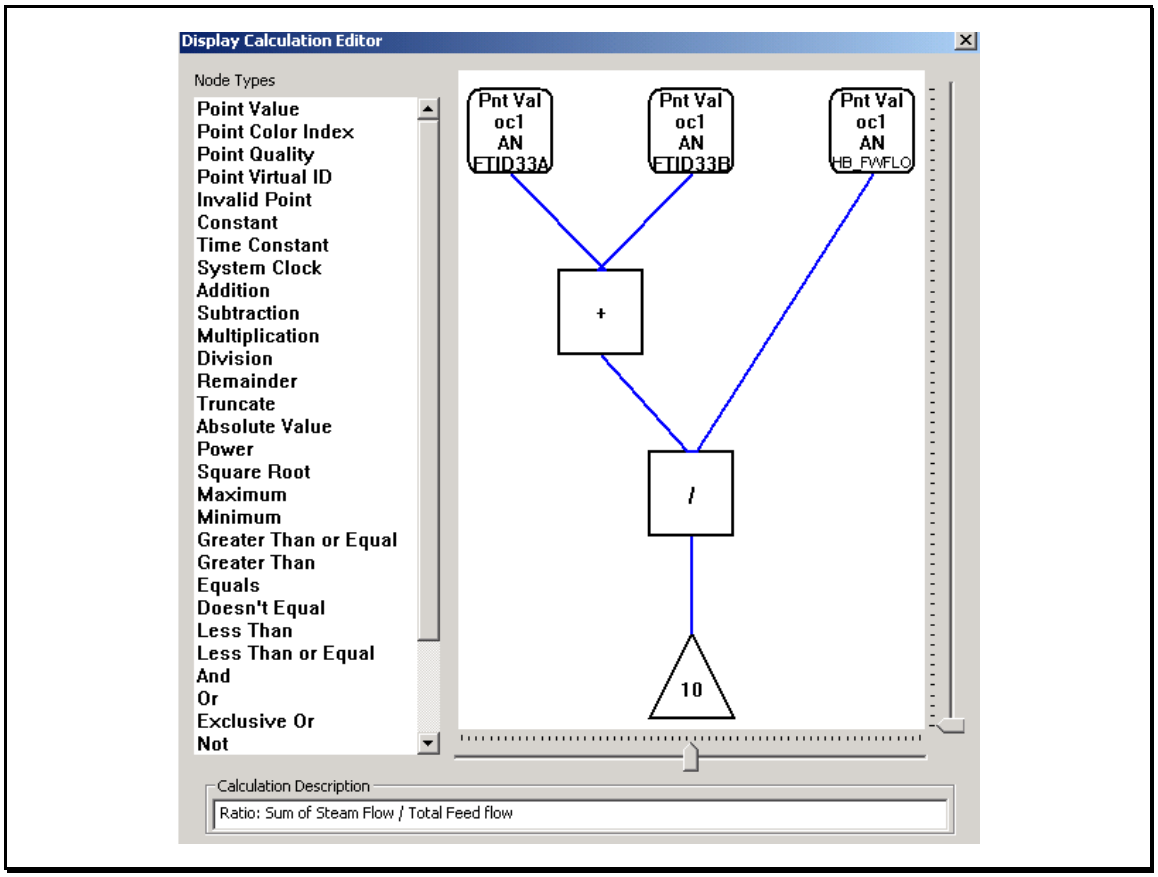
The above parameters are augmented with the following ratios as recommended in EPRI TR-107422, Vol. 2, Page 2-85) *(Ratios can be customized for each plant based on parameter availability, however trending a minimum of two to three ratios is recommended):*

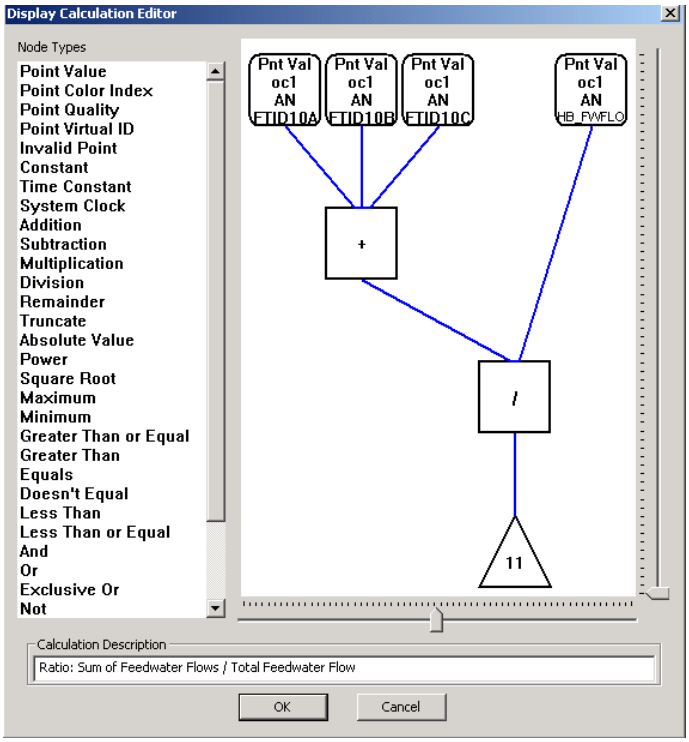
1. Main Steam Flow/FW Flow
2. Condensate Flow/FW Flow
3. HP Turbine Inlet Pressure (or 1st Stage pressure)/FW Flow
4. Heater Drain Flow/FW Flow
5. Other Turbine Stage Pressures/ Feedwater Flow

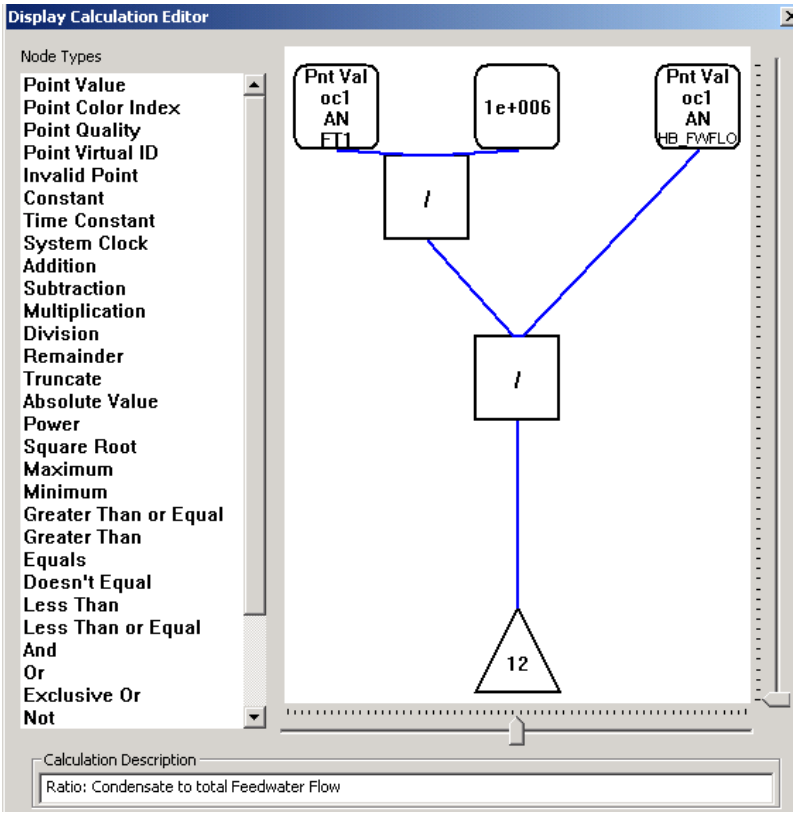
The parameters selected for Oyster Creek are shown below:



Ratios were calculated using the display calculation capability of the R*Time Display Builder as shown below. The ratios were embedded into a Reactor Heat Balance Plant Parameter Verification Display also shown below.




Display Calculation Editor
Node Types
Point Value
Point Color Index
Point Quality
Point Virtual ID
Invalid Point
Constant
Time Constant
System Clock
Addition
Subtraction
Multiplication
Division
Remainder
Truncate
Absolute Value
Power
Square Root
Maximum
Minimum
Greater Than or Equal
Greater Than
Equals
Doesn't Equal
Less Than
Less Than or Equal
And
Or
Exclusive Or
Not
Pnt Val oc1 AN FTID10A
Pnt Val oc1 AN FTID10B
Pnt Val oc1 AN FTID10C
Pnt Val oc1 AN HB_FWFLO
+
/
11
Calculation Description
Ratio: Sum of Feedwater Flows / Total Feedwater Flow
OK
Cancel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Addition
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Absolute Value
Power
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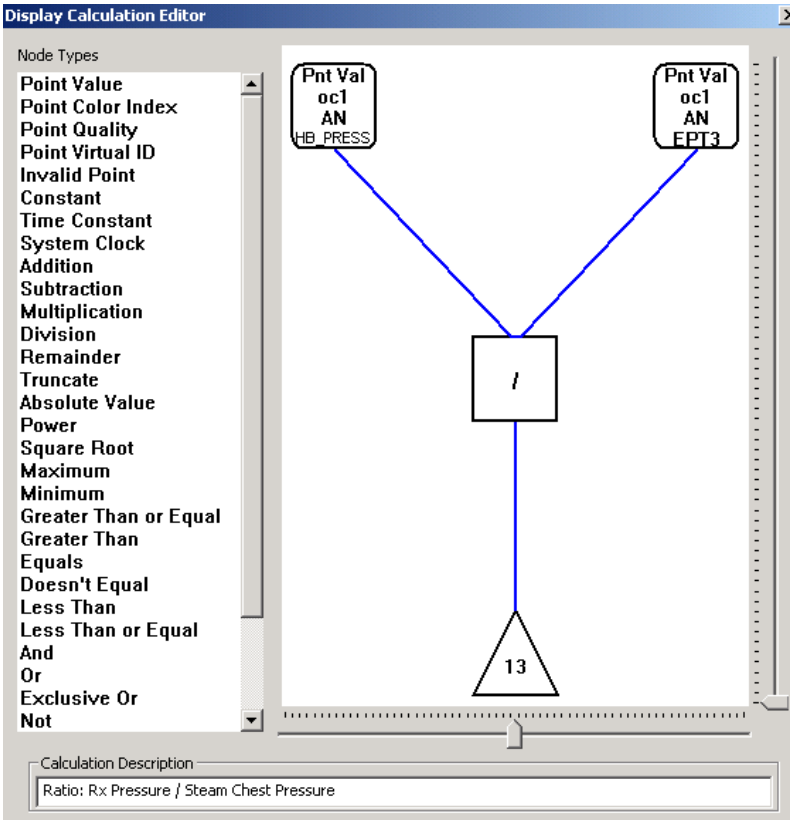
Maximum
Minimum
Greater Than or Equal
Greater Than
Equals
Doesn't Equal
Less Than
Less Than or Equal
And
Or
Exclusive Or
Not
Pnt Val oc1 AN FT1
1e+006
Pnt Val oc1 AN HB_FWFLO
/
/
12
Calculation Description
Ratio: Condensate to total Feedwater Flow


Display Calculation Editor
Node Types
Point Value
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Point Virtual ID
Invalid Point
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Time Constant
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Addition
Subtraction
Multiplication
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Truncate
Absolute Value
Power
Square Root
Maximum
Minimum
Greater Than or Equal
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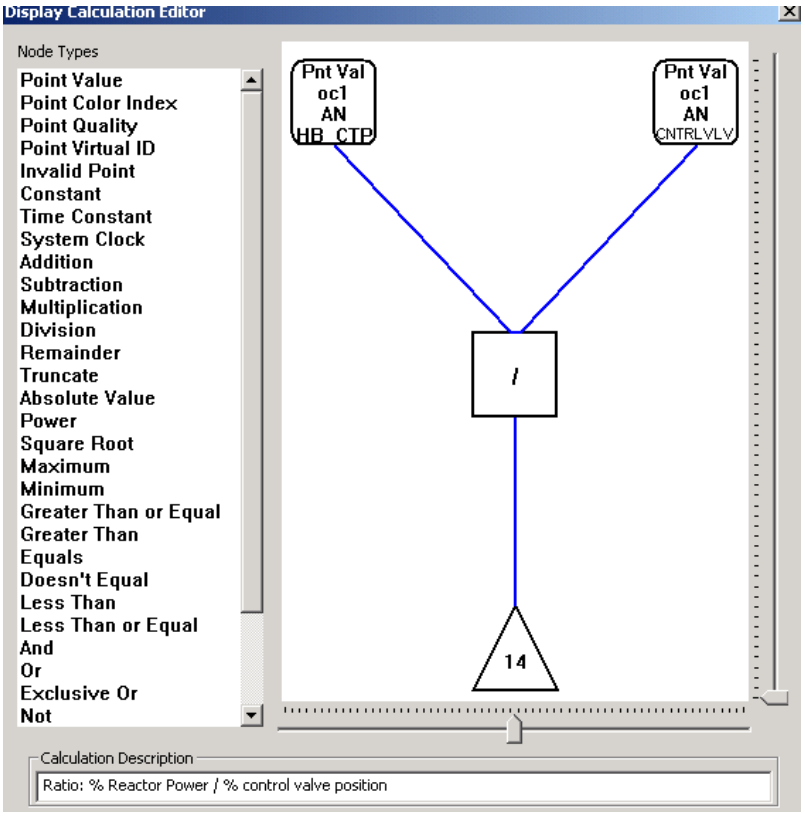
Equals
Doesn't Equal
Less Than
Less Than or Equal
And
Or
Exclusive Or
Not
Pnt Val
oc1
AN
HB_PRESS
Pnt Val
oc1
AN
EPT3
/
13
Calculation Description
Ratio: Rx Pressure / Steam Chest Pressure


Display Calculation Editor
Node Types
Point Value
Point Color Index
Point Quality
Point Virtual ID
Invalid Point
Constant
Time Constant
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Subtraction
Multiplication
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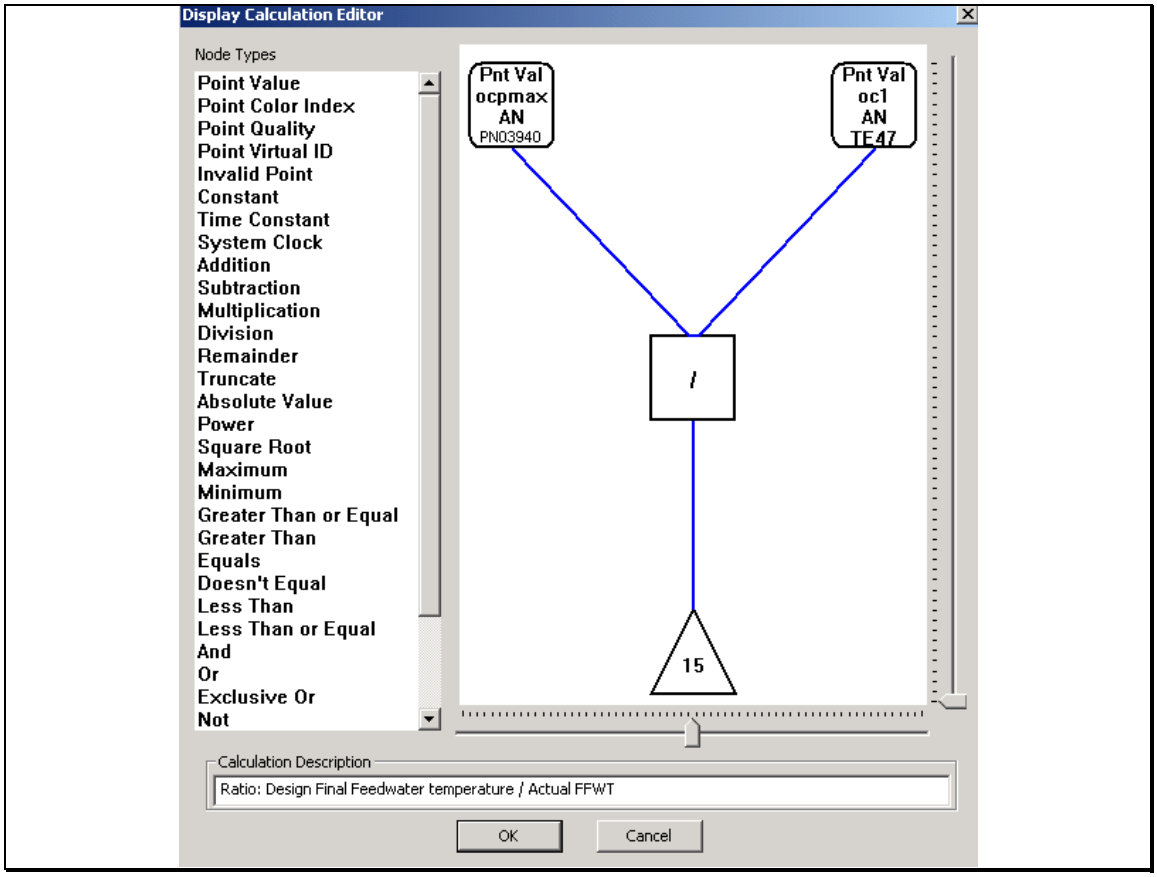
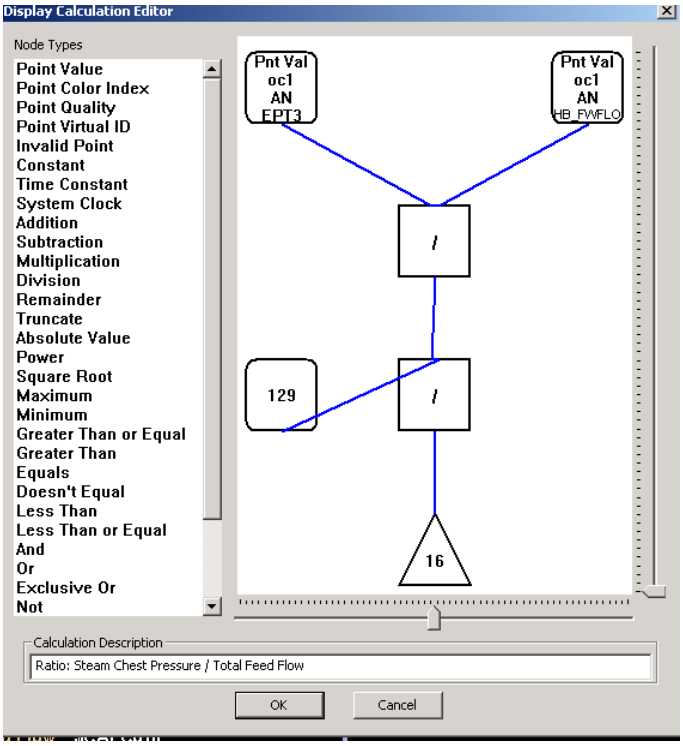
Truncate
Absolute Value
Power
Square Root
Maximum
Minimum
Greater Than or Equal
Greater Than
Equals
Doesn't Equal
Less Than
Less Than or Equal
And
Or
Exclusive Or
Not
Pnt Val
oc1
AN
HB_CTP
Pnt Val
oc1
AN
CNTRLVLV
/
14
Calculation Description
Ratio: % Reactor Power / % control valve position


Display Calculation Editor
Node Types
Point Value
Point Color Index
Point Quality
Point Virtual ID
Invalid Point
Constant
Time Constant
System Clock
Addition
Subtraction
Multiplication
Division
Remainder
Truncate
Absolute Value
Power
Square Root
Maximum
Minimum
Greater Than or Equal
Greater Than
Equals
Doesn't Equal
Less Than
Less Than or Equal
And
Or
Exclusive Or
Not
Pnt Val
ocpmax
AN
PN03940
Pnt Val
oc1
AN
TE47
/
15
Calculation Description
Ratio: Design Final Feedwater temperature / Actual FFWT
OK
Cancel


Display Calculation Editor
Node Types
Point Value
Point Color Index
Point Quality
Point Virtual ID
Invalid Point
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Time Constant
System Clock
Addition
Subtraction
Multiplication
Division
Remainder
Truncate
Absolute Value
Power
Square Root
Maximum
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Greater Than or Equal
Greater Than
Equals
Doesn't Equal
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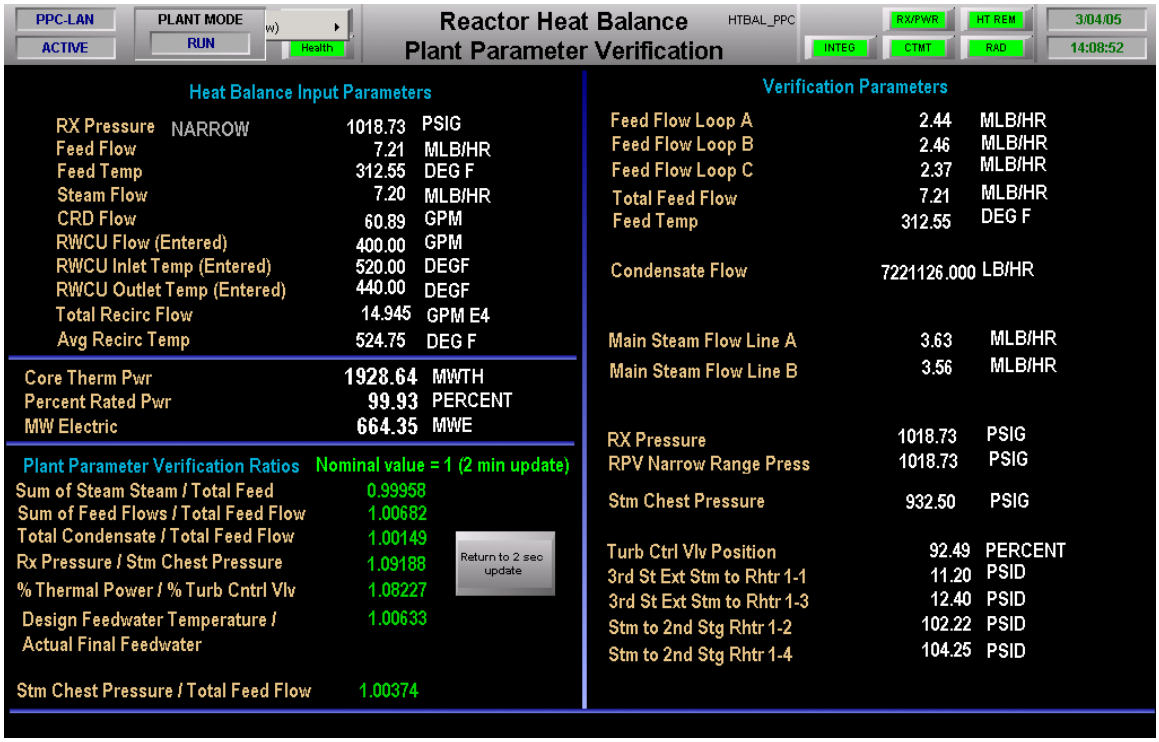
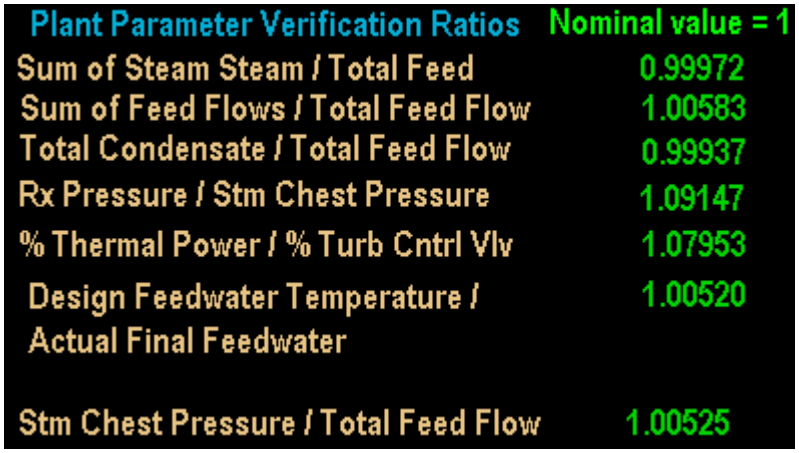
And
Or
Exclusive Or
Not
Pnt Val
oc1
AN
EPT3
Pnt Val
oc1
AN
HB_FWFLO
/
129
/
16
Calculation Description
Ratio: Steam Chest Pressure / Total Feed Flow
OK
Cancel

Using PMAX modeler, the Plant Parameter Verification Ratios were programmed and added to the PMAX model EU table. The ratios remain close to a constant value of 1 when reactor power is near (>99%) the license reactor thermal limit. A Reactor Heat Balance Plant Parameter Verification display was developed using the R*Time Display Builder (shown below).

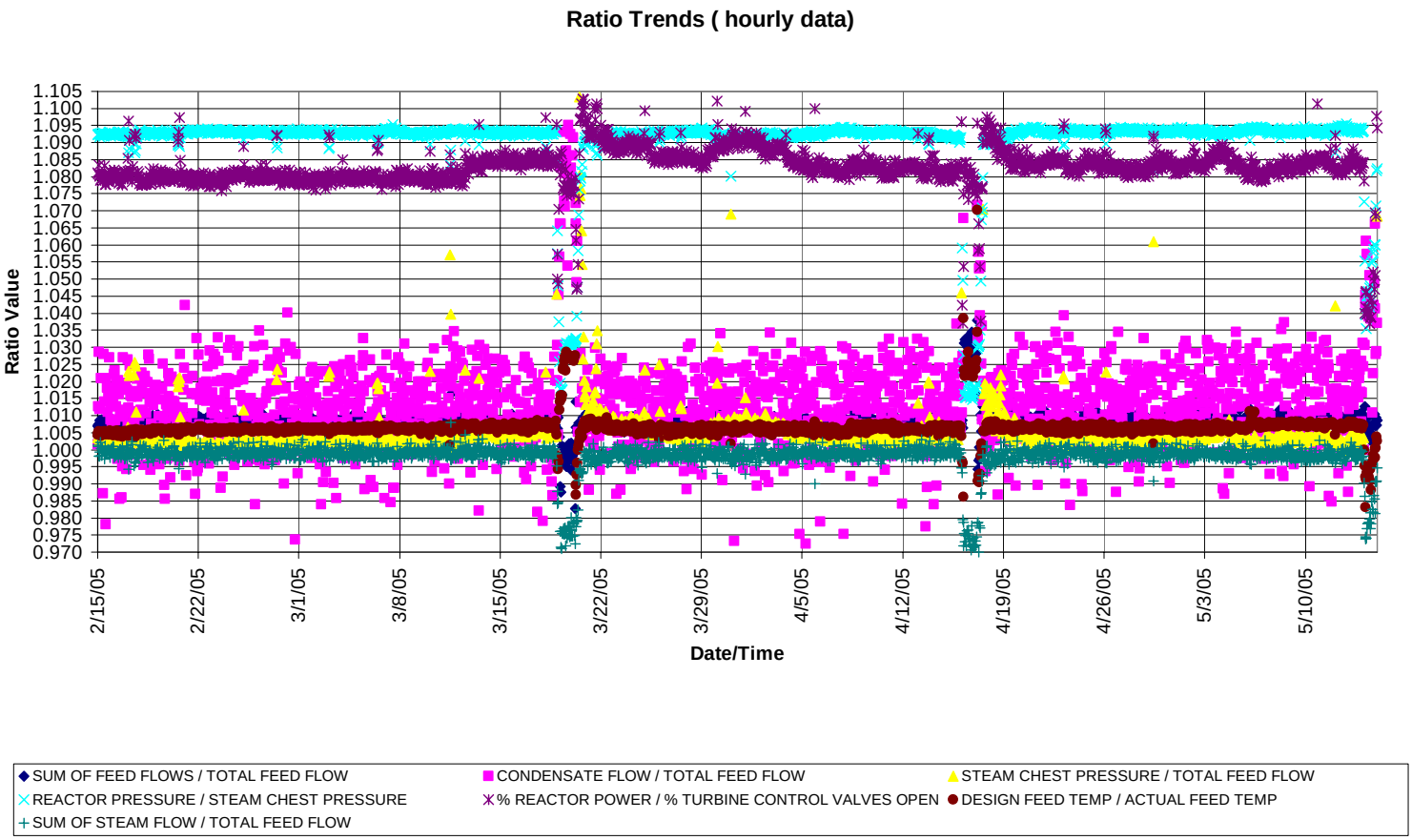


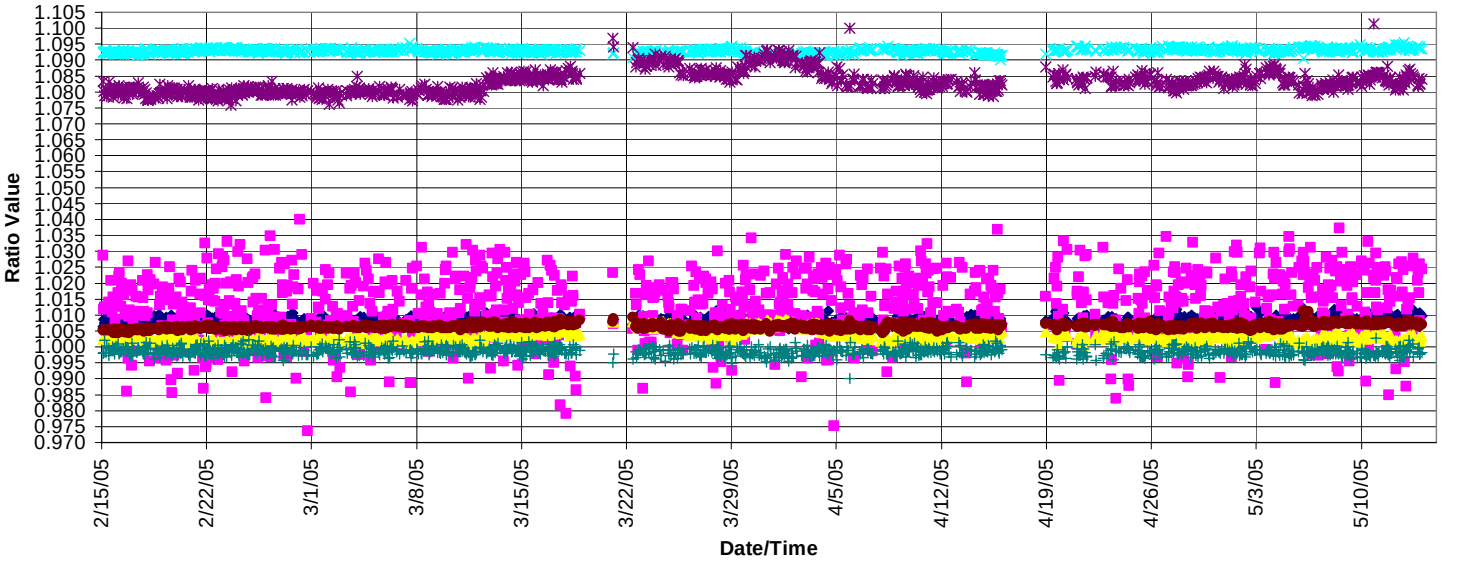
A listing of the trended ratios and representative values is shown below.



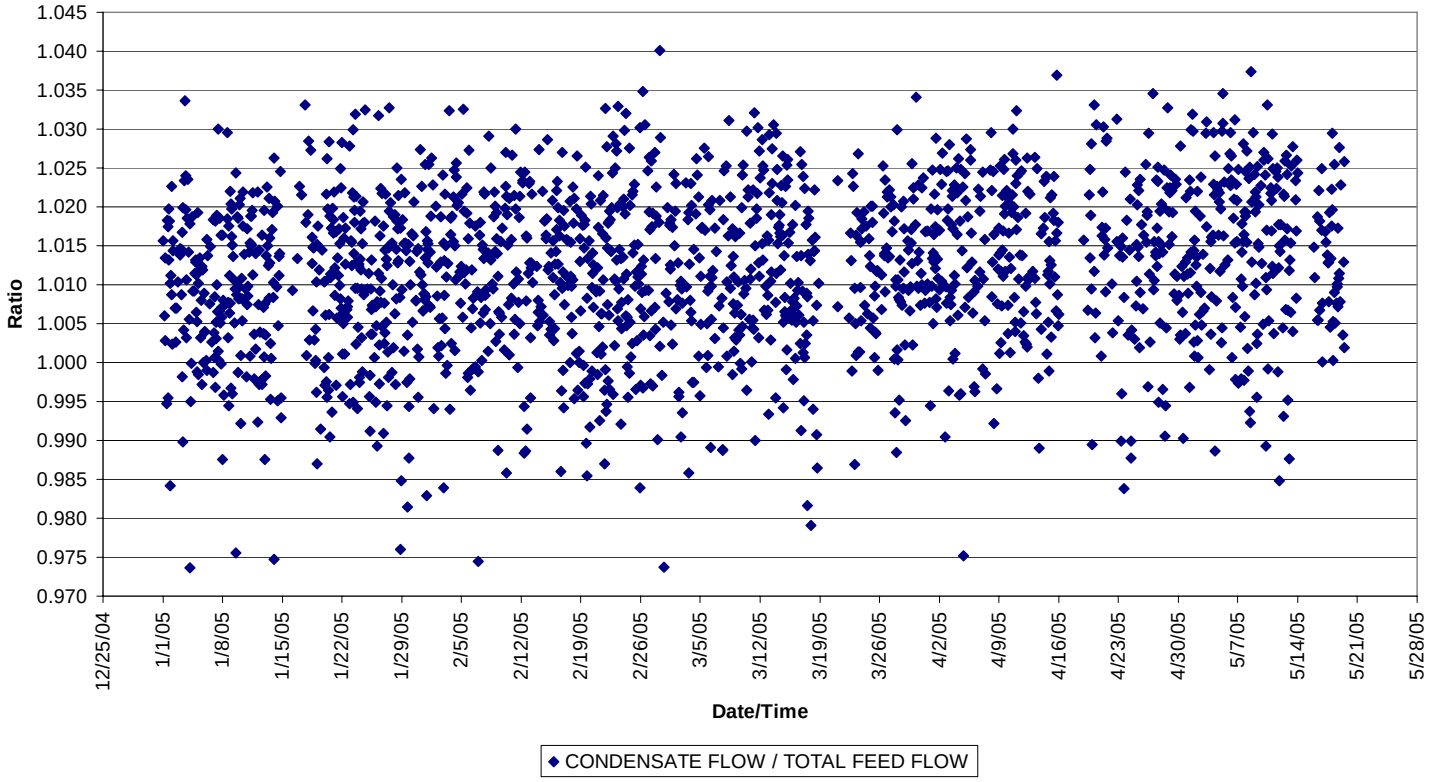
Trends

The following Plant Parameter Verification Ratios trends are for the period 12/15/04 – 5/20/05. The intent is to trend the most recent six months of data.

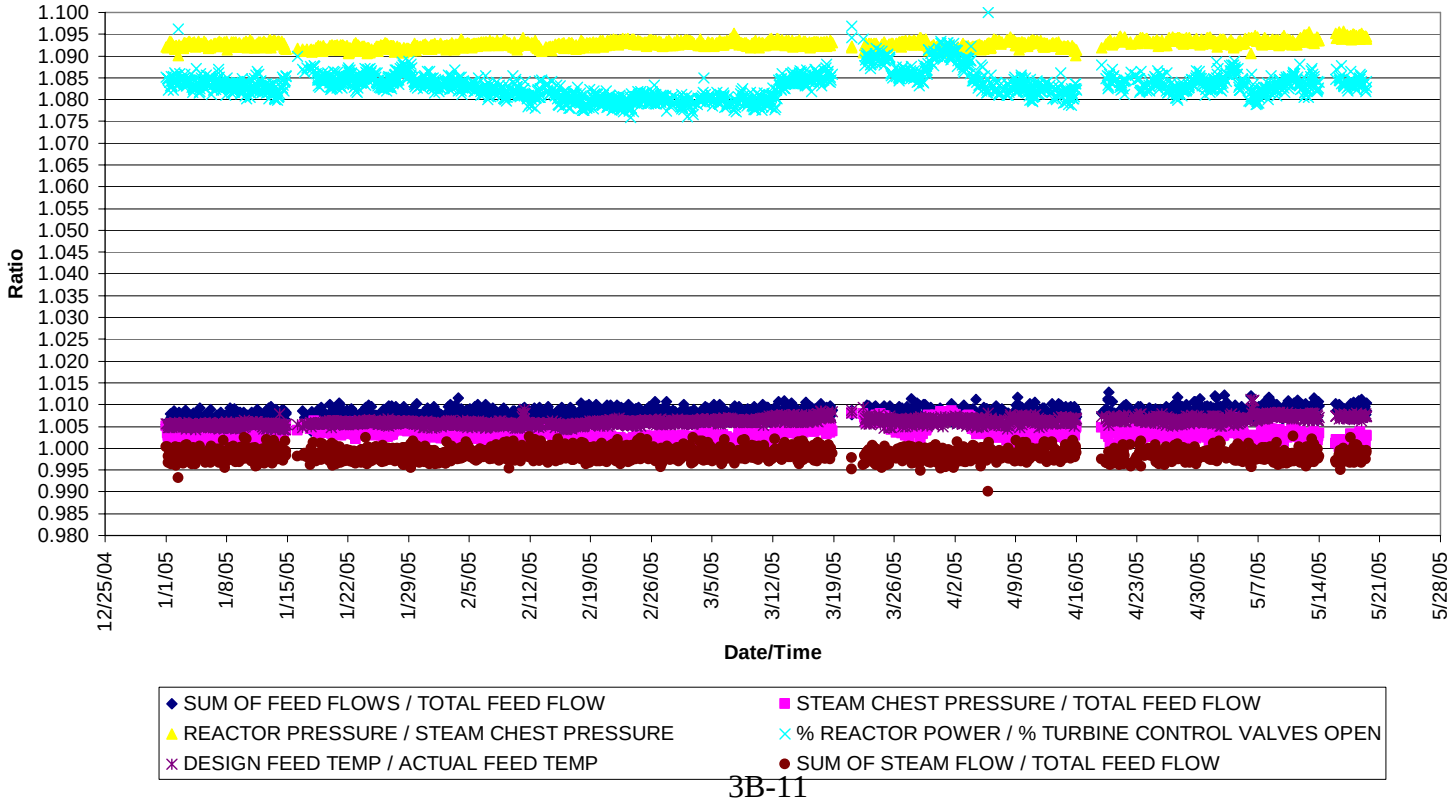




CONDENSATE FLOW / TOTAL FEED FLOW
Ratio Trends (> 1928 MWth - hourly data)



Ratio Trends (> 1928 MWth - hourly data)
WITHOUT CONDENSATE FLOW / TOTAL FEED FLOW

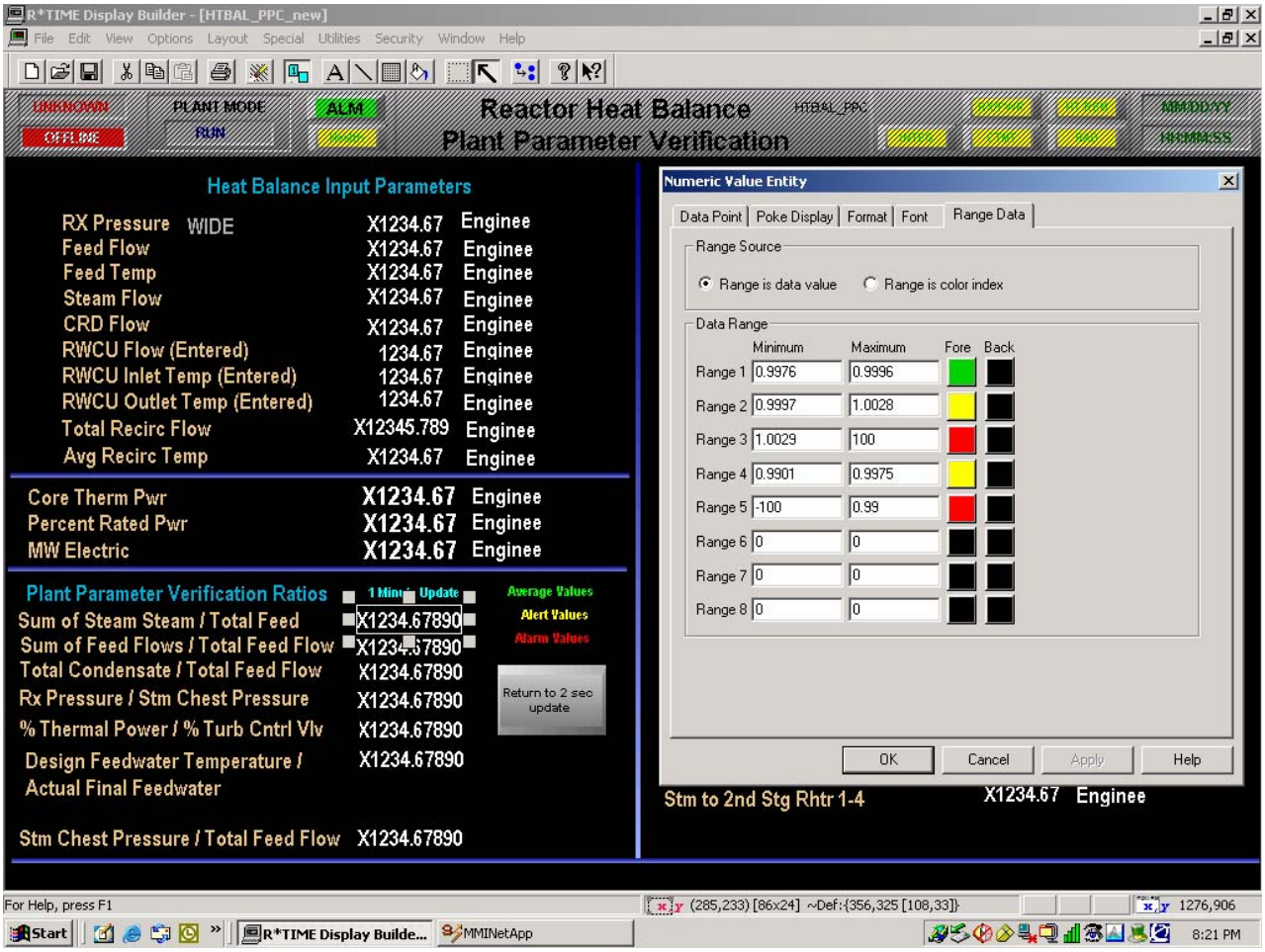


The next step was to establish alert and action alarm set points for each of the Plant Parameter Verification Ratios. The ratios were trended back to an initial date of 12/14/04 to the most current data. A minimum, a maximum, and an average value were determined for each ratio based upon data obtained when reactor power was greater than 99.9% of the licensed thermal power limit.

Date Range	SUM OF FEED FLOWS / TOTAL FEED FLOW	CONDENSATE FLOW / TOTAL FEED FLOW	STEAM CHEST PRESSURE / TOTAL FEED FLOW	REACTOR PRESSURE / STEAM CHEST PRESSURE	% REACTOR POWER / % TURBINE CONTROL VALVES OPEN	DESIGN FEED TEMP / ACTUAL FEED TEMP	SUM OF STEAM FLOW / TOTAL FEED FLOW
1/1-5/19							
average	1.008	1.012	1.003	1.093	1.083	1.006	0.999
max	1.013	1.040	1.009	1.096	1.139	1.011	1.003
min	1.004	0.974	1.000	1.090	1.076	1.004	0.990

Using R*Time Display Builder and the Numeric Value Entity, Range Data tab, alarm colors were assigned for values as shown below. A green color was assigned to the average value that was determined from the trend. Yellow was assigned as the alert color and red as the alarm color. Note alert and alarm levels were assigned for values above and below the nominal Green value.

	SUM OF FEED FLOWS / TOTAL FEED FLOW	CONDENSATE FLOW / TOTAL FEED FLOW	STEAM CHEST PRESSURE / TOTAL FEED FLOW	REACTOR PRESSURE / STEAM CHEST PRESSURE	% REACTOR POWER / % TURBINE CONTROL VALVES OPEN	DESIGN FEED TEMP / ACTUAL FEED TEMP	SUM OF STEAM FLOW / TOTAL FEED FLOW
AVERAGE							
RANGE 1- min	1.0069	1.0108	1.0024	1.0918	1.0823	1.0051	0.9976
RANGE 1 - max	1.0089	1.0128	1.0044	1.0938	1.0843	1.0071	0.9996
ABOVE Average							
RANGE 2 - min	1.0090	1.0129	1.0045	1.0939	1.0844	1.0072	0.9997
RANGE 2 - max	1.0129	1.0401	1.0090	1.0957	1.1391	1.0113	1.0028
RANGE 3 - min	1.0130	1.0402	1.0091	1.0958	1.1392	1.0114	1.0029
RANGE 3 - max	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000
Below Average							
RANGE 4 - min	1.0036	0.9737	0.9996	1.0901	1.0758	1.0039	0.9901
RANGE 4 - max	1.0068	1.0107	1.0023	1.0917	1.0822	1.0050	0.9975
RANGE 5 - min	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RANGE 5 - max	1.0035	0.9736	0.9995	1.0900	1.0757	1.0038	0.9900



Summary

The trends above are essentially constant and indicate no adverse trends. There are steam chest pressure/total feedwater flow data points outside the trend band. These data points correlate to downpower events. It is evident that there is considerable scatter in the Total Condensate flow/Total Feedwater flow trend data. This is expected due to fluctuations in condensate flow measurement. The display below showing actual data indicates two ratios in the alarm condition. The steam flow parameter is indicating high and the steam chest pressure is indicating low. These parameters are currently being investigated.


R*TIME Data Viewer - [HTBAL_PPC_NEW]
File Edit View Display Security Window Help
HTBAL_PPC_NEW
htbal_ppc_new
PPC-LAN
ACTIVE
PLANT MODE
RUN
ALM
Health
Reactor Heat Balance
Plant Parameter Verification
HTBAL_PPC
RX/PWR
INTEG
CTMT
HT REM
RAD
6/12/05
20:47:42
Heat Balance Input Parameters
RX Pressure NARROW 1019.42 PSIG
Feed Flow 7.20 MLB/HR
Feed Temp 312.43 DEG F
Steam Flow 7.23 MLB/HR
CRD Flow 62.29 GPM
RWCU Flow (Entered) 420.00 GPM
RWCU Inlet Temp (Entered) 520.00 DEGF
RWCU Outlet Temp (Entered) 440.00 DEGF
Total Recirc Flow 15.421 GPM E4
Avg Recirc Temp 526.19 DEG F
Core Therm Pwr 1929.49 MWTH
Percent Rated Pwr 99.97 PERCENT
MW Electric 615.80 MWE
Plant Parameter Verification Ratios
1 Minute Update
Average Values
Alert Values
Alarm Values
Sum of Steam Steam / Total Feed 1.00578
Sum of Feed Flows / Total Feed Flow 1.01179
Total Condensate / Total Feed Flow 1.03669
Rx Pressure / Stm Chest Pressure 1.09586
% Thermal Power / % Turb Cntrl Vlv 1.08886
Design Feedwater Temperature / Actual Final Feedwater 1.00629
Stm Chest Pressure / Total Feed Flow 1.00153
Return to 2 sec update
Verification Parameters
Feed Flow Loop A 2.41 MLB/HR
Feed Flow Loop B 2.39 MLB/HR
Feed Flow Loop C 2.46 MLB/HR
Total Feed Flow 7.20 MLB/HR
Feed Temp 312.43 DEG F
Condensate Flow 7323637.500 LB/HR
Main Steam Flow Line A 3.68 MLB/HR
Main Steam Flow Line B 3.58 MLB/HR
RX Pressure 1019.42 PSIG
RPV Narrow Range Press 1019.42 PSIG
Stm Chest Pressure 929.69 PSIG
Turb Ctrl Vlv Position 91.80 PERCENT
3rd St Ext Stm to Rhtr 1-1 11.18 PSID
3rd St Ext Stm to Rhtr 1-3 12.11 PSID
Stm to 2nd Stg Rhtr 1-2 102.68 PSID
Stm to 2nd Stg Rhtr 1-4 105.81 PSID
Display: oc1\main_menu.dis
USER: None
$SERVER: oc1
Start
Using PMAX to...
MMINetApp
R*TIME Data...
Exelon Nuclear...
AOL Spyware ...
8:47 PM