PVNGS Units 1, 2, 3
Power Uprate Startup Report

Introduction

Testing was performed in Unit 2 utilizing procedure 72TI-2RC02 "Unit 2 Stretch Power Validation," Revision 0, on May 24, 1996, at 3876 megawatts thermal (Mwt) with the normal feedwater temperature of 445°F. Additionally, testing was performed in Unit 3 utilizing procedure 72TI-3RC01 "Unit 3 Stretch Power Validation," Revision 0, on May 25, 1996, at 3876 Mwt at a reduced feedwater temperature of 420-425°F. Since the PVNGS unit designs are essentially identical, these tests validate the uprate design predictions for both normal and reduced feedwater temperature modes of operation for all three PVNGS units, and no further testing is required. The reduced feedwater temperature mode of operation results in improved thermohydraulics in the steam generator dry out region thereby extending steam generator life. Operation at the normal feedwater temperature results in slightly poorer steam generator thermohydraulics (slightly increasing the dry out region) but results in an increase in megawatt output due to improved thermodynamic efficiency.

Normal Feedwater Temperature Mode of Operation at 3876 Mwt

The Unit 2 startup test was performed to validate the power uprate design predictions for the normal feedwater temperature mode of operation. The acceptance criteria required that plant parameters remained within the ranges used in the safety analyses, no pre-trip alarms were actuated, and secondary system parameters were less than the maximum design values. All acceptance criteria were met. A summary of the results is shown in Table 1.

Table 1: Results and Acceptance Criteria for Normal Feedwater Temperature Mode of Operation at 3876 Mwt

Parameter	Acceptable Range	Observed Value	Acceptance Criteria
RCS 1A Cold Leg Temp	550-560°F	554.9°F	Safety Analyses Range
RCS 2B Cold Leg Temp	550-560°F	556.8°F	Safety Analyses Range
Steam Generator #1 Pressure	>923 psia	976 psia	Greater Than Pre-Trip Value
Steam Generator #2 Pressure	>923 psia	976 psia	Greater Than Pre-Trip Value
Steam Generator #1 Feedwater Temp	>380°F	446°F	Safety Analysis Range
Steam Generator #2 Feedwater Temp	>380°F	446°F	Safety Analysis Range
Main Turbine First Stage Pressure	<738.6 psig	695 psig	Less Than Design Maximum Value
Steam Generator #1 Total Feedwater Flow	<9.05 Mlbm/hr	8.983 Mlbm/hr	Less Than Design Maximum Value

Parameter	Acceptable Range	Observed Value	Acceptance Criteria
Total Feedwater Flow			Maximum Value
Feedwater Pump A Suction Pressure	>280 psig	392 psig	Greater Than Alarm
Feedwater Pump B Suction Pressure	>280 psig	392 psig	Greater Than Alarm

Additional expected design parameters listed in Table 2, as submitted in the referenced letter, were compared to the observed values.

Table 2: Expected and Observed Plant Parameters for Normal Feedwater Temperature Operation at 3876 Mwt

Parameter	Expected Value	Observed Value
Rated Thermal Power	3876 Mwt	3876 Mwt
RCS Flow	170 Mlbm/hr	172 Mlbm/hr
Hot Leg Temperature	611°F	613°F
Cold Leg Temperature	554°F	556°F
Delta Temperature	57°F	57°F
Steam Generator Pressure	970 psia	976 psia
Feedwater Temperature	445°F	446 °F
Feedwater Flow	17.2 Mlbm/hr	17.46 Mlbm/hr
Main Turbine/Generator	1351 Mwe	1345 Mwe

As demonstrated in Table 2 and discussed below, the model accurately predicted the uprated conditions. The expected value for RCS flow was a nominal value for all three units and a small variation from this nominal value is expected. The differences between expected and observed hot leg and cold leg temperatures are within the normal operating band of plus or minus 2°F of the 611°F and 554°F respective target temperatures. The feedwater mass flow prediction did not include steam generator blowdown flow which is approximately 0.2 Mlbm/hr. This accounts for the discrepancy between the expected and observed feedwater flows. The variations between the other predicted and observed values are within the uncertainty of the instrumentation and normal operational deviations.

Reduced Feedwater Temperature Mode of Operation at 3876 Mwt

The Unit 3 startup test was performed to validate the design predictions for the reduced feedwater temperature mode of operation. The acceptance criteria also required that plant parameters remained within the ranges used in the safety analyses, no pre-trip alarms were actuated, and secondary system parameters were less than the maximum design values. All acceptance criteria were met. A summary of the results is shown in Table 3.

Table 3: Observed Value and Acceptance Criteria for Reduced Feedwater Temperature Mode of Operation at 3876 Mwt

Parameter	Acceptable Range	Observed Value	Acceptance Criteria Basis
RCS 1A Cold Leg Temp	550-560°F	554.7°F	Safety Analyses Range
RCS 2B Cold Leg Temp	550-560°F	555.7°F	Safety Analyses Range
Steam Generator #1 Pressure	>923 psia	987 psia	Greater Than Pre-Trip Value
Steam Generator #2 Pressure	>923 psia	981 psia	Greater Than Pre-Trip Value
Steam Generator #1 Feedwater Temp	>380°F	432°F	Safety Analysis Range
Steam Generator #2 Feedwater Temp	>380°F	431°F	Safety Analysis Range
Main Turbine First Stage Pressure	<738.6 psig	682 psig	Less Than Design Maximum Value
Steam Generator #1 Total Feedwater Flow	<9.05 Mlbm/hr	8.856 Mlbm/hr	Less Than Design Maximum Value
Steam Generator #2 Total Feedwater Flow	<9.05 Mlbm/hr	8.590 Mlbm/hr	Less Than Design Maximum Value
Feedwater Pump A Suction Pressure	>280 psig	342 psig	Greater Than Alarm
Feedwater Pump B Suction Pressure	>280 psig	340 psig	Greater Than Alarm

Additional expected design parameters listed in Table 4, as submitted in the referenced letter, were compared to the observed values.

Table 4: Expected and Observed Plant Parameters for Reduced Feedwater Temperature Operation at 3876 Mwt

Parameter	Expected Value	Observed Value
Rated Thermal Power	3876 Mwt	3876 Mwt
RCS Flow	170 Mlbm/hr	174 Mlbm/hr
Hot Leg Temperature	611°F	613°F
Cold Leg Temperature	554°F	556°F
Delta Temperature	57°F	57°F
Steam Generator Pressure	970 psia	984 psia
Feedwater Temperature	420-425°F	432 °F
Feedwater Flow	16.6 Mlbm/hr	17.3 Mlbm/hr
Main Turbine/Generator	1341 Mwe	1345 Mwe

As demonstrated in Table 4 and discussed below, the model accurately predicted the uprated conditions with the exception of feedwater temperature. The differences between expected and observed hot leg and cold leg temperatures are within the normal operating band of plus or minus 2°F of the 611°F and 554 °F respective target temperatures. The higher hot leg temperature resulted in a slightly higher than expected steam generator pressure. The predicted feedwater temperature reduction for opening the high pressure feedwater heater bypass valve was 20-25°F which would have resulted in a final feedwater temperature of 420-425°F. The actual reduction was approximately half the predicted value (13°F) with a final feedwater temperature of 432°F. The observed feedwater temperature remains within the analyzed bounds of 420-445°F and does not affect any safety analyses. The observed feedwater temperature reduction varied from the predicted value because the design model used to develop the prediction over estimated the high pressure heater bypass flow with the high pressure heater bypass valve open. The design model predicted a 22-25% high pressure heater bypass flow. The actual bypass flow was approximately 13%. The lower than expected high pressure heater bypass flow resulted in a higher feedwater temperature than predicted. This in turn affected the values predicted for feedwater flow, megawatts electric and the number of steam generator tubes in the dryout region as discussed below.

The effect of the less than anticipated feedwater temperature reduction on the feedwater mass flow prediction was an increase of approximately 0.3 Mlbm/hr in the required feedwater flow at the new thermal power. The predicted flow increases from 16.6 to 16.9 Mlbm/hr for a 13°F rather than a 25°F reduction in feedwater temperature. The increase is caused by the fact that each pound of feedwater at the higher temperature does not require as much of an increase in enthalpy to be turned to steam in the steam generators. Thus, for the constant thermal input, the rate of feedwater addition is increased. The feedwater flow prediction also did not include steam generator blowdown flow which was approximately 0.3 Mlbm/hr. Hence, the discrepancy between the expected and observed feedwater flows, after accounting for

the smaller feedwater temperature reduction, is approximately 0.1 Mlbm/hr which is within the uncertainty of the measurement.

The lower than predicted feedwater temperature reduction resulted in fewer lost megawatts electric than predicted for the reduced feedwater temperature mode of operation. Lower feedwater temperature resulted in reduced carnot cycle efficiency and less megawatts electric produced per megawatt thermal input. The original prediction was an increase of 16 Mwe for a 20-25°F reduction in feedwater temperature and 26 Mwe for no feedwater temperature reduction. The 13°F reduction in feedwater temperature gives a predicted increase of approximately 21 Mwe which was the value observed.

The less than predicted feedwater temperature reduction also affects the number of steam generator (SG) tubes potentially susceptible to corrosion in the upper tube bundle regions of the steam generator. This has no affect on the safety of operation but could potentially affect the economic life of the steam generators. The two factors which have been empirically found to affect corrosion in the upper bundle are a steam quality greater then 0.65 and a condition termed "dryout." Dryout is referred to as the region of the steam generator where an empirical correlation between steam generator quality, fluid density, and fluid velocity exceeds a value of 180 lbm/sq ft x s. Originally, the steam generator design resulted in 1600 SG tubes in a region which exceeded a quality of .65 and 3000 SG tubes in the dryout region. The increased rated thermal power and the steam generator orifice removal and feedring modifications; with a reduced feedwater temperature of 420°F, would reduce the number of tubes with a quality greater than 0.65 to 30 and the number of tubes in dryout to approximately 2600. The observed feedwater temperature of 432°F will still reduce the number of steam generator tubes in these regions from the original predictions by approximately 40 percent. Thus, the number of tubes which are predicted to remain in a region of steam quality greater than 0.65 is reduced from the as designed value of 1600 to 900 tubes. The number of tubes which are predicted to remain in the dryout region is reduced from the as designed value of 3000 to 2700. Thus the number of tubes in these two regions is reduced from the originally designed steam generator values.

The less than predicted feedwater temperature reduction resulted in the effects discussed above on the feedwater flow value, megawatts electric output, and the number of steam generator tubes in the dryout region. None of these has any safety significance and do not effect the conclusion of the safety evaluation report or the basis for the technical specification amendments for power uprate to 3876 Mwt.