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VICE PRESIDENT AND GROUP EXECUTIVE
NUCLEAR OPERATIONS



Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Subject: Virgil C. Summer Nuclear Station
Docket No. 50/395
Technical Specifications

Dear Mr. Denton:

In the review of the draft Technical Specifications for the Virgil C. Summer Nuclear Station the NRC Technical Specification reviewer requested documentation be submitted to support the 1.75% measurement uncertainty value for reactor coolant flow in Technical Specification 3.2.3 (page 3/4 2-8). Originally, a value of 3.5% was submitted, however, the reduction is justified by the performance of a flow measurement calorimetric to determine total reactor flow instead of using an elbow tap reading. This eliminated the 1.5% error allowance associated with elbow tap repeatability. The remaining .25% error reduction was accomplished by statistically combining errors. Statistical combination of errors is justified by WCAP-8567 (accepted by NRC on 4-19-78 by letter from Mr. John Stolz to Mr. Clem Eicheldinger of Westinghouse.)

Specification 3.2.3, RCS Flow Rate and Nuclear Enthalpy Rise Hot Channel Factor, in the Standard Technical Specifications requires that total reactor flow (total flow through the vessel from all loops) be above some minimum value and if above that minimum value allows a trade off between rod bow penalty and reactor flow. The minimum flow value is thermal design flow corrected for flow measurement uncertainties. Historically, the uncertainty has been specified as 3.5%. Flow measurement uncertainties much less than this can be achieved however by using modern statistical error combination techniques and a calorimetric flow measurement method. The accuracy claimed for this technique depends primarily on the measurement procedure employed and on how well the instrument errors are understood and controlled by plant personnel. The calorimetric flow calculation, the measurements required and the measurement uncertainty analysis are described in the following paragraphs and tables.

Reactor coolant loop flow is determined from the steam generator thermal output, corrected for the loop's share of the net pump heat input, and the enthalpy rise ( $\Delta$ h) of the coolant. Total reactor flow is the sum of the individual loop flows. Table 1 lists the calorimetric equations and defines the terms.

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To establish the overall flow measurement uncertainty, the accuracy and relationship to flow of each instrument used for the calorimetric measurements (see Table 2) must be determined. In most cases, there are several components (transducer, converter, isolator, readout device, etc.) which contribute to the overall uncertainty of the measurement. Table 3 provides a list of typical components involved in the calorimetric loop flow measurement, a corresponding conservative instrument error allowance and the effect of the instrument error allowance on the calculated power or flow value. The overall loop flow measurement uncertainty is the statistical combination of the individual uncertainties and appears at the bottom of Table 3. Total reactor flow measurement uncertainty, which is the statistical combination of the individual loop flow uncertanties, also appears at the bottom of Table 3.

In summary, individual loop flow is determined by performance of a calorimetric and these values are summed to arrive at total reactor flow. The measurement uncertainty is determined by statistically combining individual component and loop uncertainties. A calorimetric flow measurement must be performed to take credit for this particular measurement uncertainty.

TABLE 1

REACTOR COOLANT LOOP FLOW CALCULATION

$$W_L = 8.02 \left\{ [Q_{SG} + (Q_L/N - Q_P)] \;/\; [h_H - h_C] \right\} V_C$$

Where: $W_L$ = Loop flow (GPM)
$Q_{SG}$ = Steam generator thermal output (BTU/hr.)
$Q_L$ = Primary system net heat losses (BTU/hr.)
$N$ = Number of loops
$Q_P$ = Reactor coolant pump heat adder (BTU/hr.)
$h_H$ = Hot leg enthalpy (BTU/lb.)
$h_C$ = Cold leg enthalpy (BTU/lb.)
$V_C$ = Cold leg specific volume (Cu. Ft./lb.)
$(Q_L/N-Q_P)$ = $-3.4 \times 10^7$ BTU/hr.

$$Q_{SG} = (h_s - h_f) W_F$$

Where: $h_s$ = Steam enthalpy (BTU/hr.)
$h_F$ = Feedwater enthalpy (BTU/hr.)
$W_F$ = Feedwater flow (LB./hr.)

$$W_F = K F_a (P_F \Delta P)^{1/2}$$

Where: $K$ = Feedwater venturi flow coefficient
$F_a$ = Feedwater venturi correction for thermal expansion
$P_F$ = Feedwater density (LB./cu. ft.)
$\Delta P$ = Feedwater venturi pressure drop (inches $H_2O$)

TABLE 2

MEASUREMENTS REQUIRED

| | Parameter | Instrument | Function |
|---|---|---|---|
| 1. | Feedwater venturi pressure differential | Barton gauge | Feedwater flow |
| 2. | Feedwater temperature | RTD | Feedwater enthalpy and density<br>Venturi thermal expansion |
| 3. | Steam pressure | Transducer | Steam enthalpy |
| 4. | Reactor coolant $T_{hot}$ | Narrow range RTD | RCS hot leg enthalpy |
| 5. | Reactor coolant $T_{cold}$ | Narrow range RTD | RCS cold leg enthalpy<br>RCS specific volume |
| 6. | Reactor coolant pressure | Transducer | RCS enthalpy and specific volume |

Other information required for the calculation is as follows:

7. Feedwater venturi coefficient from vendor calibration.

8. Steam generator blowdown secured during the measurement.

9. Primary system heat losses and pump heat input obtained from calculations. This quantity is the difference between the NSSS Power 2,785 $MW_t$ and the Reactor Power 2,775 $MW_t$.

TABLE 3

CALORIMETRIC FLOW MEASURMENT UNCERTAINTIES

| Component | Instrument Uncertainty | Uncertainty % Power or %Flow |
|---|---|---|
| Feedwater Flow | | |
| Venturi K | ±0.5% K | ±0.5% |
| Thermal Expansion coefficient | | |
| Temperature | ±2.0°F | |
| Material | ±5.0% | ±0.06% |
| Density | | |
| Temperature | ±2.0°F | ±0.09% |
| Pressure | ±60 psi | |
| DP Cell Calibration | ±0.5% | ±0.39% |
| DP Cell Reading Uncertainty | ±1.0% | ±0.78% |
| Feedwater Enthalpy | | |
| Temperature | ±2.0°F | ±0.28% |
| Pressure | ±60 psi | |
| Steam Enthalpy | | |
| Transducer Calibration | ±18 psi | ±0.07% |
| Isolator Calibration | ±18 psi | ±0.07% |
| Moisture Carryover | ±0.25% | ±0.22% |
| Primary Enthalpy | | |
| $T_H$ RTD | ±0.2°F | ±0.38% |
| $T_H$ R/E Converter | ±0.6°F | ±1.13% |
| $T_H$ Readout | ±0.1°F | ±0.19% |
| $T_H$ Temperature Streaming | ±1.2°F | ±2.27% |
| $T_H$ Pressure Effect | ±30 psi | ±0.24% |
| $T_C$ RTD | ±0.2°F | ±0.31% |
| $T_C$ R/E Converter | ±0.6°F | ±0.94% |
| $T_C$ Readout | ±0.1°F | ±0.16% |
| $T_C$ Pressure Effect | ±30 psi | ±0.06% |
| Net Pump Heat Addition | ±20% | ±0.085% |
| Total Loop Flow Uncertainty | $(\sum e)^{1/2}$ | ±2.974% |
| Total Reactor Flow Uncertainty | | |
| 4-loop | | ±1.5% |
| 3-loop | | ±1.75% |
| 2-loop | | ±2.1% |

TABLE 3 (Continued)

ASSUMPTIONS

The values in Table 3 are based on some specific assumptions about the instruments and readouts.

1. Feedwater flow is obtained from several readings of Barton differential pressure gauges installed on the feedwater venturi.

2. The measurement is performed soon after a calibration eliminating consideration of instrument drift.

3. Credit was taken for the 3 tap scoop RTD bypass loop in reducing uncertainties due to streaming.

This information, which should be provided to the Technical Specification reviewer and the Core Performance Branch, should be sufficient to justify this change for our plant. If you have any questions, please let us know.

Very truly yours,

T. C. Nichols, Jr.

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RBC:TCN:lkb

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