PALISADES PLANT TECHNICAL SPECIFICATIONS

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Amendment No. 31, 51, 57, 85, 108,

TSP1287-0253-NL04

ATTACHMENT

Consumers Power Company
Palisades Plant
Docket 50-255

TECHNICAL SPECIFICATIONS PAGE CHANGES

REACTOR PROTECTION SYSTEM

March 25, 1988

47 Pages

TSP1287-0253-NL04

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1.1 REACTOR OPERATING CONDITIONS (Cont'd)

Axial Offset or Axial Shape Index

The difference between the power in the lower half of the core and the upper half of the core divided by the sum of the powers in the lower half and upper half of the core.

Narrow Water Gap Fuel Rod

A fuel rod adjacent to the narrow interfuel assembly water gap (a gap not containing a control rod).

Narrow Water Gap Fuel Rod Peaking Factor $-F_r^N$

The maximum product of the ratio of individual fuel assembly power to core average fuel assembly power times the highest narrow water gap fuel rod local peaking factor integrated over the total core height including tilt.

2.0 SAFETY LIMITS AND LIMITING SAFETY SYSTEM SETTINGS

2.1 SAFETY LIMITS - REACTOR CORE

Applicability

This specification applies when the reactor is in hot standby condition and power operation condition. /
/

Objective

To maintain the integrity of the fuel cladding and prevent the release of significant amounts of fission products to the primary coolant.

Specifications

The MDNBR of the reactor core shall be maintained greater than or equal to 1.17. /
/
/

Basis

To maintain the integrity of the fuel cladding and prevent fission product release, it is necessary to prevent overheating of the cladding under normal operating conditions. This is accomplished by operating within the nucleate boiling regime of heat transfer, wherein the heat transfer coefficient is large enough so that the clad surface temperature is only slightly greater than the coolant temperature. The upper boundary of the nucleate boiling regime is termed "departure from nucleate boiling" (DNB). At this point, there is a sharp reduction of the heat transfer coefficient, which would result in high-cladding temperatures and the possibility of cladding failure. Although DNB is not an observable parameter during reactor operation, the observable parameters of thermal power, primary coolant flow, temperature and pressure, can be related to DNB through the use of the XNB DNB /
Correlation."[1] The XNB DNB Correlation has been developed to predict /
DNB and the location of DNB for axially uniform and nonuniform heat flux distributions. The local DNB ratio (DNBR), defined as the ratio of the heat flux that would cause DNB at a particular core location to the actual heat flux, is indicative of the margin to DNB. The minimum value of the DNBR, during steady-state operation, normal operational transients, and anticipated transients is limited to 1.17. A DNBR of /
1.17 corresponds to a 95% probability at a 95% confidence level that /

2.1 SAFETY LIMITS - REACTOR CORE (Contd)

DNB will not occur which is considered an appropriate margin to DNB for all operating conditions.[1]

The reactor protective system is designed to prevent any anticipated combination of transient conditions for primary coolant system temperature, pressure and thermal power level that would result in a DNBR of less than 1.17[3] The XNB DNB correlation has been shown to be applicable to the Palisades Plant in Reference 2.

References

(1) XN-NF-621(P)(A), Rev 1
(2) XN-NF-709
(3) Updated FSAR, Section 14.1.

2.2 SAFETY LIMITS - PRIMARY COOLANT SYSTEM PRESSURE

Applicability

Applies to the limit on primary coolant system pressure.

Objective

To maintain the integrity of the primary coolant system and to prevent the release of significant amounts of fission product activity to the primary coolant.

Specification

The primary coolant system pressure shall not exceed 2750 psia when there are fuel assemblies in the reactor vessel.

Basis

The primary coolant system[1] serves as a barrier to prevent radionuclides in the primary coolant from reaching the atmosphere. In the event of a fuel cladding failure, the primary coolant system is the foremost barrier against the release of fission products. Establishing a system pressure limit helps to assure the continued integrity of both the primary coolant system and the fuel cladding. The maximum transient pressure allowable in the primary coolant system pressure vessel under the ASME Code, Section III, is 110% of design pressure. The maximum transient pressure allowable in the primary coolant system piping, valves and fittings under ASA Section B31.1 is 120% of design pressure. Thus, the safety limit of 2750 psia (110% of the 2500 psia design pressure) has been established.[2] The settings and capacity of the secondary coolant system safety valves (985-1025 psig)[3], the reactor high-pressure trip (≤2400 psia) and the primary safety valves (2500-2580 psia)[4] have been established to assure never reaching the primary coolant system pressure safety limit. The initial hydrostatic test was conducted at 3125 psia (125% of design pressure) to verify the integrity of the primary coolant system. Additional assurance that the nuclear steam supply system (NSSS) pressure does not exceed the safety limit is provided by setting the secondary coolant system steam dump and bypass valves at 900 psia. /

References

(1) Updated FSAR, Section 4. /
(2) Updated FSAR, Section 4.3. /
(3) Updated FSAR, Table 4-5 /
(4) Updated FSAR, Table 4-10 /

2.3 LIMITING SAFETY SYSTEM SETTINGS - REACTOR PROTECTIVE SYSTEM

Applicability

This specification applies to reactor trip settings and bypasses for instrument channels.

Objective

To provide for automatic protective action in the event that the principal process variables approach a safety limit.

Specification

The reactor protective system trip setting limits and the permissible bypasses for the instrument channels shall be as stated in Table 2.3.1.

The TM/LP trip system monitors core power, reactor coolant maximun inlet temperature, (T_{in}), core coolant system pressure and axial shape index. The low pressure trip limit (P_{var}) is calculated using the following equation. /

$$P_{var} = 1563.7(QA)(QR_1) + 12.3(T_{in}) - 6503.4$$ /

where:

$QR_1 = 0.412(Q) + 0.588 \quad Q \leq 1.0 \qquad Q = \dfrac{\text{core power}}{\text{rated power}}$ /
$\quad\;\; = Q \quad Q > 1.0$ /

$QA = -0.691(ASI) + 1.058 \quad -0.653 \leq ASI < -0.156$ /
$\quad\;\; = -0.521(ASI) + 1.085 \quad -0.156 \leq ASI < +0.162$ /
$\quad\;\; = 0.226(ASI) + 0.964 \quad +0.162 \leq ASI \leq +0.544$ /

The calculated limit (P_{var}) is then compared to a fixed low pressure trip limit (P_{min}). The auctioneered highest of these signals becomes the trip limit (P_{trip}). P_{trip} is compared to the measured reactor coolant pressure (P) and a trip signal is generated when P is less than or equal to P_{trip}. A pre-trip alarm is also generated when P is less than or equal to the pre-trip setting $P_{trip} + \Delta P$. /

TABLE 2.3.1

Reactor Protective System Trip Setting Limits

		Four Primary Coolant Pumps Operating	Three Primary Coolant Pumps Operating (4)
1.	Variable High Power (1)	≦10% above core power, with a minimum setpoint of ≦30% of rated power and a maximum of ≦106.5% of rated power	≦10% above core power with a minimum setpoint of ≦15% rated power and a maximum of ≦49% of rated power
2.	Primary Coolant Flow (2)	≧95% of Primary Coolant Flow With Four Pumps Operating	≧60% of Primary Coolant Flow With Four Pumps Operating
3.	High Pressure Pressurizer	≦2255 Psia	≦2255 Psia
4.	Thermal Margin/Low Pressure (2,3)	P_{trip} ≧ Applicable Limits	Replaced by Variable High Power Trip and 1750 Psia Minimum Low-Pressure Setting
5.	Steam Generator Low Water Level	Not Lower Than the Center Line of Feed-Water Ring Which Is Located 6'-0" Below Normal Water Level	Not Lower Than the Center Line of Feed-Water Ring Which Is Located 6'-0" Below Normal Water Level
6.	Steam Generator Low Pressure (2)	≧500 Psia	≧500 Psia
7.	Containment High Pressure	≦3.70 Psig	≦3.70 Psig

(1) The VHPT can be 30% of rated power for power levels ≦ 20% of rated power.

(2) May be bypassed below 10^{-4}% of rated power provided auto bypass removal circuitry is operable. For low power physics tests, thermal margin/low pressure, primary coolant flow and low steam generator pressure trips may be bypassed until their react points are reached (approximately 1750 psia and 500 psia, respectively), provided automatic bypass removal circuitry at 10^{-1}% rated power is operable.

(3) Minimum trip setting shall be 1750 psia.

(4) Operation with three pumps for a maximum of 12 hours is permitted to provide a limited time for repair/pump restart, to provide for an orderly shutdown or to provide for the conduct of reactor internals noise monitoring test measurements.

2.3 LIMITING SAFETY SYSTEM SETTINGS - REACTOR PROTECTIVE SYSTEM (Contd)

Basis

The reactor protective system consists of four instrument channels to monitor selected plant conditions which will cause a reactor trip if any of these conditions deviate from a preselected operating range to the degree that a safety limit may be reached.

1. Variable High Power - The variable high power trip (VHPT) is incorporated in the reactor protection system to provide a reactor trip for transients exhibiting a core power increase starting from any initial power level (such as the boron dilution transient). The VHPT system provides a trip setpoint no more than a predetermined amount above the indicated core power. Operator action is required to increase the setpoint as core power is increased; the setpoint is automatically decreased as core power decreases. Provisions have been made to select different set points for three pump and four pump operations.

   During normal plant operation with all primary coolant pumps operating, reactor trip is initiated when the reactor power level reaches 106.5% of indicated rated power. Adding to this the possible variation in trip point due to calibration and instrument errors, the maximum actual steady state power at which a trip would be actuated is 112%, which was used for the purpose of safety analysis.[1]

2. Primary Coolant System Low Flow - A reactor trip is provided to protect the core against DNB should the coolant flow suddenly decrease significantly.[3] Flow in each of the four coolant loops is determined from a measurement of pressure drop from inlet to outlet of the steam generators. The total flow through the reactor core is measured by summing the loop pressure drops across the steam generators and correlating this pressure sum with the pump calibration flow curves. The percent of normal core flow is shown in the following table:

4 Pumps	100.0%
3 Pumps	74.7%

   During four-pump operation, the low-flow trip setting of 95% insures that the reactor cannot operate when the flow rate is less than 93% of the nominal value considering instrument errors.[4]

Basis (Contd)

Provisions are made in the reactor protective system to permit operation of the reactor at reduced power if one coolant pump is taken out of service. These low-flow and high-flux settings have been derived in consideration of instrument errors and response times of equipment involved to assure that thermal margin and flow stability will be maintained during normal operation and anticipated transients.[5] For reactor operation with one coolant pump inoperative, the low-flow trip points and the overpower trip points must be manually changed to the specified values for the selected pump condition by means of set point selector switches. The trip points are shown in Table 2.3.1.

3. High Pressurizer Pressure - A reactor trip for high pressurizer pressure is provided in conjunction with the primary and secondary safety valves to prevent primary system overpressure (Specification 3.1.7). In the event of loss of load without reactor trip, the temperature and pressure of the primary coolant system would increase due to the reduction in the heat removed from the coolant via the steam generators. This setting is consistent with the trip point assumed in the accident analysis.[11]

Basis (Continued)

4. Thermal Margin/Low-Pressure Trip

The TM/LP trip set points are derived from the 4-pump operation core thermal limits through application of appropriate allowances for measurement uncertainties and processing errors. A pressure allowance of 165 psi is assumed to account for: instrument drift in both power and inlet temperatures; calorimetric power measurement; inlet temperature measurement; and primary system pressure measurement. Uncertainties accounted for that are not a part of the 165 psi term include allowances for: assembly power tilt; fuel pellet manufacturing tolerances; core flow measurement uncertainty and core bypass flow; inlet temperature measurement time delays; and ASI measurement. Each of these allowances and uncertainties are included in the development of the TM/LP trip set point used in the accident analysis.

For three-pump operation, continued power operation is limited to for a maximum of 12 hours. During this mode of operation, the high power level trip in conjunction with the TM/LP trip (minimum set point = 1750 psia) and the secondary system safety valves (set at approximately 1000 psia) assure that adequate DNB margin is maintained.[5]

5. Low Steam Generator Water Level - The low steam generator water level reactor trip protects against the loss of feed-water flow accidents and assures that the design pressure of the primary coolant system will not be exceeded. The specified set point assures that there will be sufficient water inventory in the steam generator at the time of trip to allow a safe and orderly plant shutdown and to prevent steam generator dryout assuming minimum auxiliary feedwater capacity.[9]

The setting listed in Table 2.3.1 assures that the heat transfer surface (tubes) is covered with water when the reactor is critical.

Basis (Contd)

6. Low Steam Generator Pressure - A reactor trip on low steam generator secondary pressure is provided to protect against an excessive rate of heat extraction from the steam generators and subsequent cooldown of the primary coolant. The setting of 500 psia is sufficiently below the rated load operating point of 739 psia so as not to interfere with normal operation, but still high enough to provide the required protection in the event of excessively high steam flow. This setting was used in the accident analysis.(8)

7. Containment High Pressure - A reactor trip on containment high pressure is provided to assure that the reactor is shut down before the initiation of the safety injection system and containment spray.(10) /

8. Low Power Physics Testing - For low power physics tests, certain tests will require the reactor to be critical at low temperature ($\geq$ 260°F) and low pressure ($\geq$ 415 psia). For these certain tests only, the thermal margin/low pressure, primary coolant flow and low steam generator pressure trips may be bypassed in order that reactor power can be increased for improved data acquisition. Special operating precautions will be in effect during these tests in accordance with approved written testing procedures. At reactor power levels below 10^{-1}% of rated power, the thermal margin/low-pressure trip and low flow trip are not required to prevent fuel rod thermal limits from being exceeded. The low steam generator pressure trip is not required because the low steam generator pressure will not allow a severe reactor cooldown, should a steam line break occur during these tests. /

References

(1) ANF-87-150(P), Volume 2, Table 15.0.7-1
(2) deleted
(3) Updated FSAR, Section 7.2.3.3.
(4) ANF-87-150(P), Volume 2, Section 15.3
(5) XN-NF-86-91(P)
(6) deleted
(7) deleted
(8) XN-NF-77-18, Section 3.8
(9) ANF-87-150(P), Volume 2, Section 15.2.7
(10) Updated FSAR, Section 7.2.3.9.
(11) ANF-87-150(P), Volume 2, Section 15.2.1
(12) ANF-87-150(P), Volume 2, Section 15.0.7.2

(next page is 2-13)

3.1 PRIMARY COOLANT SYSTEM

Applicability

Applies to the operable status of the primary coolant system.

Objective

To specify certain conditions of the primary coolant system which must be met to assure safe reactor operation.

Specifications

3.1.1 Operable Components

a. At least one primary coolant pump or one shutdown cooling pump with a flow rate greater than or equal to 1500 gpm shall be in operation whenever a change is being made in the boron concentration of the primary coolant and the plant is operating in cold shutdown or above, except during an emergency loss of coolant flow situation. Under these circumstances, the boron concentration may be increased with no primary coolant pumps or shutdown cooling pumps running.

b. Four primary coolant pumps shall be in operation whenever the reactor is operated continually above hot shutdown.

   Before removing a pump from service, thermal power shall be reduced as specified in Table 2.3.1 and appropriate corrective action implemented. With one pump out of service, return the pump to service within 12 hours (return to four-pump operation) or be in hot shutdown (or below) within 24 hours. Start-up (above hot shutdown) with less than four pumps is not permitted and power operation with less than three pumps is not permitted.

c. The measured four primary coolant pumps operating reactor vessel flow shall be 124.3×10^6 lb/hr or greater, when corrected to 532°F.

d. Both steam generators shall be capable of performing their heat transfer function whenever the average temperature of the primary coolant is above 325°F.

e. Maximum primary system pressure differentials shall not exceed the following:

   (1) Maximum steam generator operating differential of 1380 psi.

3.1 PRIMARY COOLANT SYSTEM (Continued)

3.1.1 Operable Components (Continued)

(2) Hydrostatic tests shall be conducted in accordance with applicable paragraphs of Section XI ASME Boiler & Pressure Vessel Code (1974). Such tests shall be conducted with sufficient pressure on the secondary side of the steam generators to restrict primary to secondary pressure differential to a maximum of 1380 psi. Maximum hydrostatic test pressure shall not exceed 1.1 Po plus 50 psi where Po is nominal operating pressure.

(3) Primary side leak tests shall be conducted at normal operating pressure. The temperature shall be consistent with applicable fracture toughness criteria for ferritic materials and shall be selected such that the differential pressure across the steam generator tubes is not greater than 1380 psi.

(4) Maximum secondary hydrostatic test pressure shall not exceed 1250 psia. A minimum temperature of 100°F is required. Only ten cycles are permitted.

(5) Maximum secondary leak test pressure shall not exceed 1000 psia. A minimum temperature of 100°F is required.

(6) In performing the tests identified in 3.1.1.e(4) and 3.1.1.e(5), above, the secondary pressure shall not exceed the primary pressure by more than 350 psi.

f. Nominal primary system operation pressure shall not exceed 2100 psia.

g. The reactor inlet temperature (indicated) shall not exceed the value given by the following equation at steady state power operation: /

$T_{inlet} \leqq 543.3 + .0575(P\text{-}2060) + 0.00005(P\text{-}2060)^{**}2 + 1.173(W\text{-}120) - .0102(W\text{-}120)^{**}2$ /
/

Where: T_{inlet} = reactor inlet temperature in F°
P = nominal operating pressure in psia
W = total recirculating mass flow in 10^6 lb/h corrected to the operating temperature conditions.

When the ASI exceeds the limits specified in Figure 3.0, within 15 minutes, initiate corrective actions to restore the ASI to the acceptable region. Restore the ASI to acceptable values within one hour or be at less than 70% of rated power within two hours. /

If the measured primary coolant system flow rate is greater than 130 M lbm/hr, the maximum inlet temperature shall be less than or equal to the T_{Inlet} LCO at 130 M lbm/hr. /

3.1.1 Operable Components (Cont'd)

h. A reactor coolant pump shall not be started with one or more of the PCS cold leg temperatures ≦ 250°F unless 1) the pressurizer water volume is less than 700 cubic feet or 2) the secondary water temperature of each steam generator is less than 70°F above each of the PCS cold leg temperatures.

i. The PCS shall not be heated or maintained above 325°F unless a minimum of 375 kW of pressurizer heater capacity is available from both buses 1D and 1E. Should heater capacity from either bus 1D and 1E fall below 375 kW, either restore the inoperable heaters to provide at least 375 kW of heater capacity from both buses 1D and 1E within 72 hours or be in hot shutdown within the next 12 hours.

Basis

When primary coolant boron concentration is being changed, the process must be uniform throughout the primary coolant system volume to prevent stratification of primary coolant at lower boron concentration which could result in a reactivity insertion. Sufficient mixing of the primary coolant is assured if one shutdown cooling or one primary coolant pump is in operation.[1] The shutdown cooling pump will circulate the primary system volume in less than 60 minutes when operated at rated capacity. By imposing a minimum shutdown cooling pump flow rate of 1500 gpm, sufficient time is provided for the operator to terminate the boron dilution under asymmetric flow conditions.[6] The pressurizer volume is relatively inactive, therefore will tend to have a boron concentration higher than rest of the primary coolant system during a dilution operation. Administrative procedures will provide for use of pressurizer sprays to maintain a nominal spread between the boron concentration in the pressurizer and the primary system during the addition of boron.[2]

The FSAR safety analysis was performed assuming four primary coolant pumps were operating for accidents that occur during reactor operation. Therefore, reactor startup above hot shutdown is not permitted unless all four primary coolant pumps are operating. Operation with less than four primary coolant pumps is permitted for a limited time to allow the restart of a stopped pump or for reactor internals vibration monitoring and testing.

Both steam generators are required to be operable whenever the temperature of the primary coolant is greater than the design temperature of the shutdown cooling system to assure a redundant heat removal system for the reactor.

Basis (Contd)

Calculations have been performed to demonstrate that a pressure differential of 1380 psi[3] can be withstood by a tube uniformily thinned to 36% of its original nominal wall thickness (64% degradation), while maintaining:

(1) A factor of safety of three between the actual pressure differential and the pressure differential required to cause bursting.

(2) Stresses within the yield stress for Inconel 600 at operating temperature.

(3) Acceptable stresses during accident conditions.

Secondary side hydrostatic and leak testing requirements are consistent with ASME BPV Section XI (1971). The differential maintains stresses in the steam generator tube walls within code allowable stresses.

The minimum temperature of 100°F for pressurizing the steam generator secondary side is set by the NDTT of the mayway cover of + 40°F.

The transient analyses were performed assuming a vessel flow at hot zero power (532°F) of 124.3 x 10^6 lb/hr minus 6% to account for flow measurement uncertainty and core flow bypass. A DNB analysis was performed in a parametric fashion to determine the core inlet temperature as a function of pressure and flow for which the minimum DNBR is equal to 1.17. This analysis includes the following uncertainties and allowances: 2% of rated power for power measurement; ±0.06 for ASI measurement; ±50 psi for pressurizer pressure; ±7°F for inlet temperature; and 3% measurement and 3% bypass for core flow. In addition, transient biases were included in the derivation of the following equation for limiting reactor inlet temperature:[4]

$$T_{inlet} \leq 543.3 + .0575(P-2060) + 0.00005(P-2060)^{**}2 + 1.173(W-120) - .0102(W-120)^{**}2$$

The limits of validity of this equation are:

$1800 \leq$ Pressure ≤ 2200 Psia

$100.0 \times 10^6 \leq$ Vessel Flow $\leq 130 \times 10^6$ Lb/h

ASI as shown in Figure 3.0

With measured primary coolant system flow rates > 130 M lbm/hr, limiting the maximum allowed inlet temperature to the T_{Inlet} LCO at 130 M lbm/hr increases the margin to DNB for higher PCS flow rates.

3.1 PRIMARY COOLANT SYSTEM (Contd)

Basis (Contd)

The Axial Shape Index alarm channel is being used to monitor the ASI to ensure that the assumed axial power profiles used in the development of the inlet temperature LCO bound measured axial power profiles. The signal representing core power (Q) is the auctioneered higher of the neutron flux power and the Delta-T power. The measured ASI calculated from the excore detector signals and adjusted for shape annealing (Y_I) and the core power constitute an ordered pair (Q, Y_I). An alarm signal is activated before the ordered pair exceed the boundaries specified in Figure 3.0. / / / / / / / / /

The restrictions on starting a Reactor Coolant Pump with one or more PCS cold legs ≦ 250°F are provided to prevent PCS pressure transients, caused by energy additions from the secondary system, which would exceed the limits of Appendix G to 10 CFR Part 50. The PCS will be protected against overpressure transients and will not exceed the limits of Appendix G by either (1) restricting the water volume in the pressurizer and thereby providing a volume for the primary coolant to expand into or (2) by restricting starting of the RCPs to when the secondary water temperature of each steam generator is less than 70°F above each of the PCS cold leg temperatures.[5]

References

(1) Updated FSAR, Section 14.3.2 /

(2) Updated FSAR, Section 4.3.7 /

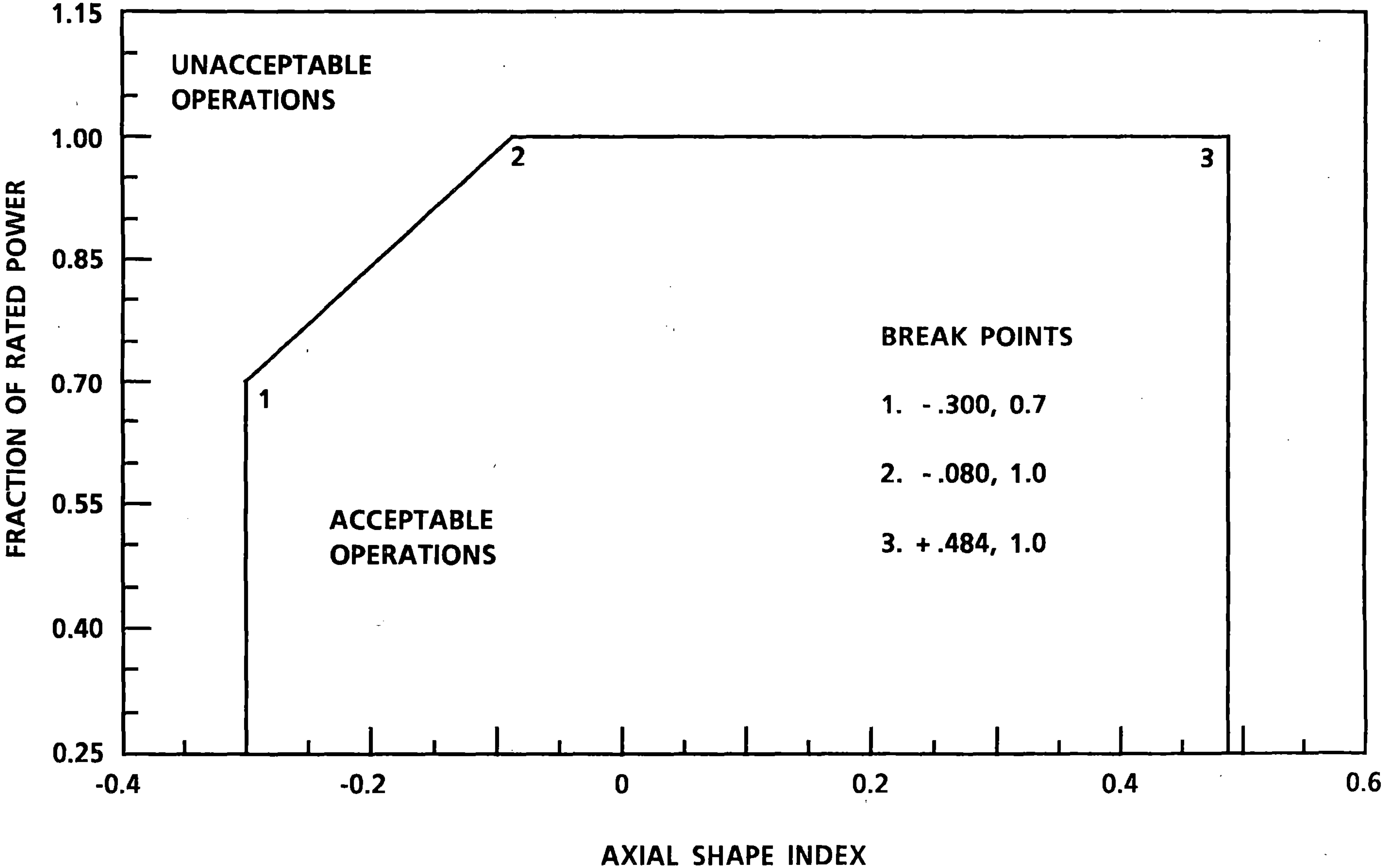
(3) Palisades 1983/1984 Steam Generator Evaluation and Repair Program Report, Section 4, April 19, 1984 / /

(4) ANF-87-150(P), Volume 2, Section 15.0.7.1 /

(5) "Palisades Plant Overpressurization Analysis," June, 1977, and "Palisades Plant Primary Coolant System Overpressurization Subsystem Description," October, 1977

(6) ANF-87-150(P), Volume 2, Section 15.4.6.3.2 /

FIGURE 3 - 0
ASI LCO FOR Tinlet FUNCTION



3.1 PRIMARY COOLANT SYSTEM (Contd)

3.1.7 Primary and Secondary Safety Valves

Specifications

a. The reactor shall not be made critical unless all three pressurizer safety valves are operable with their lift settings maintained between 2500 psia and 2580 psia (± 1%).

b. A minimum of one operable safety valve shall be installed on the pressurizer whenever the reactor head is on the vessel.

c. Whenever the reactor is in power operation, a minimum of 23 secondary system safety valves shall be operable with their lift settings between 985 psig (± 10 psig) and 1025 (± 1%) psig.

Basis

The primary and secondary safety valves pass sufficient steam to limit the primary system pressure to 110 percent of design (2750 psia) following a complete loss of turbine generator load without simultaneous reactor trip while operating at 2650 MW_t.[1]

The reactor is assumed to trip on a "High Primary Coolant System Pressure" signal. To determine the maximum steam flow, the only other pressure relieving system assumed operational is the secondary system safety valves. Conservative values for all system parameters, delay times and core moderator coefficient are assumed. Overpressure protection is provided to the portions of the primary coolant system which are at the highest pressure considering pump head, flow pressure drops and elevation heads.

If no residual heat were removed by any of the means available, the amount of steam which could be generated at safety valve lift pressure would be less than half of one valve's capacity. One valve, therefore, provides adequate defense against overpressurization when the reactor is subcritical.

The total relief capacity of the 24 secondary system safety valves is 11.7×10^6 lb/h. This is based on a steam flow equivalent to an NSSS power level of 2650 MW_t at the nominal 1000 psia valve lift pressure.

At the power rating of 2530 MW_t, a relief capacity of less than 11.2×10^6 lb/h is required to prevent overpressurization of the secondary system of loss of load conditions, and 23 valves provide relieving capability of 11.2×10^6 lb/h.[1,2]

The ASME Boiler and Pressure Vessel Code, Section III, 1971 edition, Paragraph NC-7614.2(a) allows the specified tolerances in the lift pressures of safety valves.

References

(1) Updated FSAR, Section 4.3.9.4. /
(2) ANF-87-150(P), Volume 2, Section 15.2.1 /

BASIS

The Steam and Power Conversion System is designed to receive steam from the NSSS and convert the steam thermal energy into electrical energy. A closed regenerative cycle condenses the steam from the main turbine and returns the condensate as heated feedwater to the steam generators. Normally, the capability to supply feedwater to the steam generators is provided by operation of the turbine-driven main feedwater pumps.

A reactor shutdown from power requires removal of core decay heat. Immediate decay heat removal requirements are normally satisfied by the steam bypass to the condenser, or by steam discharge to the atmosphere via the main steam safety valves or power operated relief valves.[1,2] If the main feedwater pumps are not operating, any one auxiliary feedwater pump can supply sufficient feedwater for removal of decay heat from the Plant. The Plant is provided with two motor driven auxiliary feedwater pumps (P-8A, P-8C) and one turbine driven auxiliary feedwater pump (P-8B). The Auxiliary Feedwater System is designed so that an automatic start signal is generated to the auxiliary feedwater pumps upon low secondary side steam generator level. Upon low secondary side steam generator level, auxiliary feedwater pump P-8A would be the first auxiliary feedwater pump to receive an automatic start signal. If pump P-8A failed to start or establish flow within a specified period of time, auxiliary feedwater pump P-8C would receive an automatic start signal. If both pump P-8A and pump P-8C failed to start or establish flow within each pump's specified period of time, auxiliary feedwater pump P-8B would receive an automatic start signal. All three auxiliary feedwater pumps normally take suction from the condensate storage tank. The minimum amount of water in the condensate storage tank and primary coolant system makeup tanks combined is the amount needed for 8 hours of auxiliary feedwater pump operation. If the outage is more than 8 hours, Lake Michigan water can be used, by utilizing a fire pump to supply water to the auxiliary feedwater pumps P-8A and P-8B, or by utilizing a service water pump to supply water to auxiliary feedwater pump P-8C.

Three fire pumps are provided, one motor driven and two diesel driven, each capable of delivering 1500 gpm at 125 psig. Three service water pumps are provided, all of which are motor driven, each capable of delivering 8000 gpm at 60 psig.

REFERENCES

(1) Updated FSAR, Section 10.2.1 /
(2) ANF-87-150(P), Volume 2, Section 15.2.7 /
/

3.10 CONTROL ROD AND POWER DISTRIBUTION LIMITS

Applicability

Applies to operation of control rods and hot channel factors during operation.

Objective

To specify limits of control rod movement to assure an acceptable power distribution during power operation, limit worth of individual rods to values analyzed for accident conditions, maintain adequate shutdown margin after a reactor trip and to specify acceptable power limits for power tilt conditions.

Specifications

3.10.1 Shutdown Margin Requirements

a. With four primary coolant pumps in operation at hot shutdown and above, the shutdown margin shall be 2%.

b. With less than four primary coolant pumps in operation at hot shutdown and above, boration shall be immediately initiated to increase and maintain the shutdown margin at ≧ 3.75%.

c. At less than the hot shutdown condition, boron concentration shall be greater than cold shutdown boron concentration for normal cooldowns and heatups, i.e., non-emergency conditions. /

d. If a control rod cannot be tripped, shutdown margin shall be increased by boration as necessary to compensate for the worth of the withdrawn inoperable rod.

e. The drop time of each control rod shall be no greater than 2.5 seconds from the beginning of rod motion to 90% insertion.

3.10.2 (Deleted) /

3.10.3 Part-Length Control Rods

The part-length control rods will be completely withdrawn from the core (except for control rod exercises and physics tests).

3.10.6 Shutdown Rod Limits

a. All shutdown rods shall be withdrawn before any regulating rods are withdrawn.

b. The shutdown rods shall not be withdrawn until normal water level is established in the pressurizer.

c. The shutdown rods shall not be inserted below their exercise limit until all regulating rods are inserted.

3.10.7 Low Power Physics Testing

Sections 3.10.1.a, 3.10.1.b, 3.10.3, 3.10.4.b, 3.10.5 and 3.10.6 may be deviated from during low power physics testing and CRDM exercises if necessary to perform a test but only for the time necessary to perform the test.

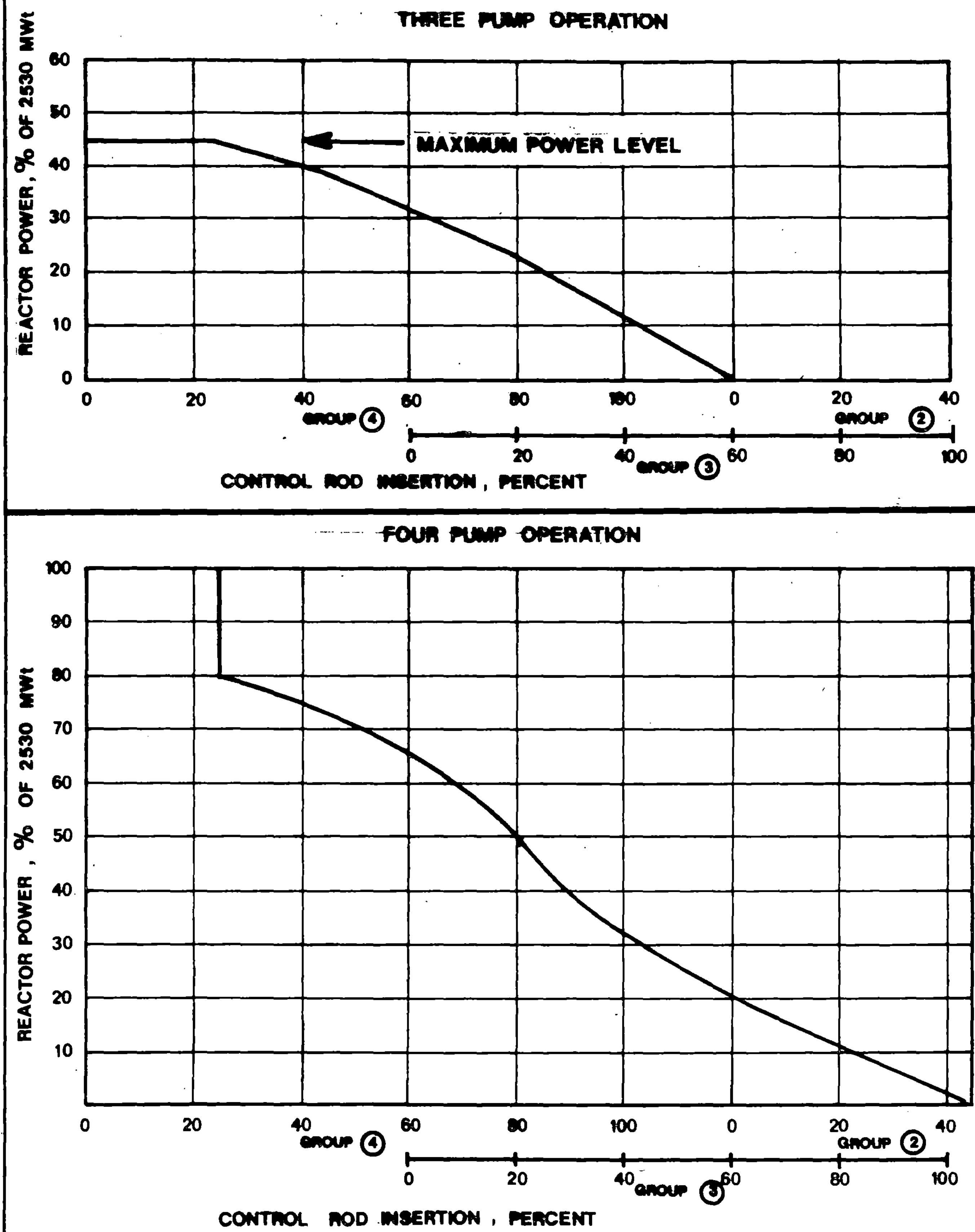
3.10.8 Center Control Rod Misalignment

The requirements of Specifications 3.10.4.1, 3.10.4.a, and 3.10.5 may be suspended during the performance of physics tests to determine the isothermal temperature coefficient and power coefficient provided that only the center control rod is misaligned and the limits of Specification 3.23 are maintained.

Basis

Sufficient control rods shall be withdrawn at all times to assure that the reactivity decrease from a reactor trip provides adequate shutdown margin. The available worth of withdrawn rods must include the reactivity defect of power and the failure of the withdrawn rod of highest worth to insert. The requirement for a shutdown margin of 2.0% in reactivity with 4-pump operation and of 3.75% in reactivity with less than 4-pump operation is consistent with the assumptions used in the analysis of accident conditions (including steam line break) as reported in Reference 1 and 2 and additional analysis. Requiring the boron concentration to be at cold shutdown boron concentration at less than hot shutdown assures adequate shutdown margin exists to ensure a return to power does not occur if an unanticipated cooldown accident occurs. This requirement applies to normal operating situations and not during emergency conditions where it is necessary to perform operations to mitigate the consequences of an accident. The change in insertion limit with reactor power shown on Figure 3-6 insures that the shutdown margin requirements for 4-pump operation is met at all power levels. The 2.5-second drop time specified for the control rods is the drop time used in the transient analysis.[2]

The insertion of part-length rods into the core, except for rod exercises or physics tests, is not permitted since it has been demonstrated on other CE plants that design power distribution envelopes can, under some circumstances, be violated by using part-length rods. Further information may justify their use. Part-length rod insertion is permitted for physics tests, since resulting power distributions are closely monitored under test conditions. Part-length rod insertion for rod exercises (approximately 6 inches) is permitted since this amount of insertion has an insignificant effect on power distribution.



CONTROL ROD INSERTION LIMITS	PALISADES TECHNICAL SPECIFICATION	FIGURE 3-6

Amendment No ~~31~~

Basis (Contd)

For a control rod misaligned up to 8 inches from the remainder of the banks, hot channel factors will be well within design limits. If a control rod is misaligned by more than 8 inches, the maximum reactor power will be reduced so that hot channel factors, shutdown margin and ejected rod worth limits are met. If in-core detectors are not available to measure power distribution and rod misalignments >8 inches exist, then reactor power must not exceed 75% of rated power to insure that hot channel conditions are met.

Continued operation with that rod fully inserted will only be permitted if the hot channel factors, shutdown margin and ejected rod worth limits are satisfied.

In the event a withdrawn control rod cannot be tripped, shutdown margin requirements will be maintained by increasing the boron concentration by an amount equivalent in reactivity to that control rod. The deviations permitted by Specification 3.10.7 are required in order that the control rod worth values used in the reactor physics calculations, the plant safety analysis, and the Technical Specifications can be verified. These deviations will only be in effect for the time period required for the test being performed. The testing interval during which these deviations will be in effect will be kept to a minimum and special operating precautions will be in effect during these deviations in accordance with approved written testing procedures.

Violation of the power dependent insertion limits, when it is necessary to rapidly reduce power to avoid or minimize a situation harmful to plant personnel or equipment, is acceptable due to the brief period of time that such a violation would be expected to exist, and due to the fact that it is unlikely that core operating limits such as thermal margin and shutdown margin would be violated as a result of the rapid rod insertion. Core thermal margin will actually increase as a result of the rapid rod insertion. In addition, the required shutdown margin will most likely not be violated as a result of the rapid rod insertion because present power dependent insertion limits result in shutdown margin in excess of that required by the safety analysis. /

References

(1) XN-NF-77-18 /
(2) ANF-87-150(P), Volume 2 /

POWER DISTRIBUTION INSTRUMENTATION

3.11.2 EXCORE POWER DISTRIBUTION MONITORING SYSTEM

LIMITING CONDITION FOR OPERATION

The excore monitoring system shall be operable with:

a. The target Axial Offset (AO) and the Excore Monitoring Allowable Power Level (APL) determined within the previous 31 days using the incore detectors, and the measured AO not deviated from the target AO by more than 0.05 in the previous 24 hours.

b. The AO measured by the excore detectors calibrated with the AO measured by the incore detectors.

c. The quadrant tilt measured by the excore detectors calibrated with the quadrant tilt measured by the incore detectors.

APPLICABILITY:

(1) Items a., b. and c. above are applicable when the excore detectors are used for monitoring LHR.

(2) Item c. above is applicable when the excore detectors are used for monitoring quadrant tilt.

(3) Item b., above is applicable for each channel of the TM/LP trip and the Axial Shape Index (ASI) alarm. /

ACTION 1:

With the excore monitoring system inoperable, do not use the system for monitoring LHR.

ACTION 2:

If the measured quadrant tilt has not been calibrated with the incores, do not use the system for monitoring quadrant tilt.

ACTION 3: /

When the measured AO uncertainty is greater than specified in Specification 4.18.2, the TM/LP trip function and the ASI alarm setpoints shall be conservatively adjusted within twelve (12) hours or that channel shall be declared inoperable. The operability requirements for TM/LP and ASI are given in Table 3.17.1 and 3.17.4, respectively. /

Basis

The excore power distribution monitoring system consists of Power Range Detector Channels 5 through 8.

The operability of the excore monitoring system ensures that the assumptions employed in the PDC-II analysis[1] for determining AO limits that ensure operation within allowable LHR limits are valid.

3.11.2 EXCORE POWER DISTRIBUTION MONITORING SYSTEM

LIMITING CONDITION FOR OPERATION

Basis (Contd)

Surveillance requirements ensure that the instruments are calibrated to agree with the incore measurements and that the target AO is based on the current operating conditions. Updating the Excore Monitoring APL ensures that the core LHR limits are protected within the ± 0.05 band on AO. The APL considers LOCA based LHR limits, and factors are included to account for changes in radial power shape and LHR limits over the calibration interval.

The APL is determined from the following:

$$APL = \left[\frac{LHR(Z)_{TS}}{LHR(Z)_{Max} \times V(Z) \times E_p(Z) \times 1.02} \right]_{Min} \times \text{Rated Power}$$

Where:

(1) $LHR(Z)_{TS}$ is the limiting LHR vs Core Height (from Section 3.23.1),

(2) $LHR(Z)_{Max}$ is the measured peak LHR including uncertainties vs Core Height,

(3) V(Z) is the function (shown in Figure 3.11-1),

(4) $E_p(Z)$ is a factor to account for the reduction of allowed LHR in the peak rod with increased exposure (Figure 3.23.2) such that:

For fuel rod burnups less than 27.0 GWd/MT - $E_p = 1.0$

For fuel rod burnups greater than 27.0 GWd/MT but less than 33.0 GWd/MT - $E_p = 1.0 + 0.0064 \times LHR$

For fuel rod burnups greater than 33.0 GWd/MT - $E_p = 1.0 + 0.0012 \times LHR$

Where LHR is the measured fuel rod average LHR in kW/ft,

3.12 MODERATOR TEMPERATURE COEFFICIENT OF REACTIVITY

Applicability

Applies to the moderator temperature coefficient of reactivity for the core.

Objective

To specify a limit for the positive moderator coefficient.

Specifications

The moderator temperature coefficient (MTC) shall be less positive than $+0.5 \times 10^{-4}$ $\Delta\rho/°F$ at $\leq$ 2% of rated power. /

Bases

The limitations on moderator temperature coefficient (MTC) are provided to ensure that the assumptions used in the safety analysis [1] remain valid. /

Reference

(1)ANF-87-150(P), Volume 2, Section 15.0.5 /

If the bypass is not effected, the out-of-service channel (Power Removed) assumes a tripped condition (except high rate-of-change power, variable high power and high pressurizer pressure),[1] which results in a one-out-of-three channel logic. If, in the 2 of 4 logic system of either the reactor protective system or the engineered safeguards system, one channel is bypassed and a second channel manually placed in a tripped condition, the resulting logic is 1 of 2. At rated power, the minimum operable variable high power level channels is 3 in order to provide adequate flux tilt detection. If only 2 channels are operable, the reactor power level is reduced to 70% rated power which protects the reactor from possibly exceeding design peaking factors due to undetected flux tilts.

The engineered safeguards system provides a 2 out of 4 logic on the signal used to actuate the equipment connected to each of the 2 emergency diesel generator units.

Two start-up channels are available any time reactivity changes are deliberately being introduced into the reactor and the neutron power is not visible on the log-range nuclear instrumentation or above 10^{-4}% of rated power. This ensures that redundant start-up instrumentation is available to operators to monitor effects of reactivity changes when neutron power levels are only visible on the start-up channels. In the event only one start-up range channel is available and the neutron power level is sufficiently high that it is being monitored by both channels of log-range instrumentation, a startup can be performed in accordance with footnote (d) of Table 3.17.4.
The Zero Power Mode Bypass can be used to bypass the low flow, steam generator low pressure, and TM/LP trips[2] for all four Reactor Protective system channels to perform control rod testing or to perform low power physics testing below normal operating temperatures. The requirement to maintain cold shutdown boron concentration when in the bypass condition provides additional assurance that an accidental criticality will not occur. To allow low power physics testing at reduced temperature and pressure, the requirement for cold shutdown boron concentration is not required and the allowed power is increased to 10^{-1}%.

References

(1) Updated FSAR, Section 7.2.7.
(2) Updated FSAR, Section 7.2.5.2

Table 3.17.1
Instrumentation Operating Requirements for Reactor Protective System

No	Functional Unit	Minimum Operable Channels	Minimum Degree of Redundancy	Permissible Bypass Conditions
1	Manual (Trip Buttons)	2	None	None
2	Variable High Power Level	2[b,d]	1[d]	None
3	Log Range Channels	2	1	Below 10^{-4}%[e] or Above 15% Rated Power[a] Except as Noted in (c)
4	Thermal Margin/ Low-Pressurizer Pressure	2[b,f]	1	Below 10^{-4}%[e] of Rated Power[a] and greater than cold shutdown boron concentration.
5	High-Pressurizer Pressure	2[b]	1	None
6	Low Flow Loop	2[b]	1	Below 10^{-4}%[e] of Rated Power[a] and greater than cold shutdown boron concentration.
7	Loss of Load	1	None	None
8	Low Steam Generator Water Level	2/Steam Gen[b]	1/Steam Generator	None
9	Low Steam Generator Pressure	2/Steam Gen[b]	1/Steam Generator	Below 10^{-4}%[e] of Rated Power[a] and greater than cold shutdown boron concentration.
10	High Containment Pressure	2[b]	1	None

(a) Bypass automatically removed.
(b) One of the inoperable channels must be in the tripped condition.
(c) Two channels required if TM/LP, low steam generator or low-flow channels are bypassed.
(d) If only two channels are operable, load shall be reduced to 70% or less of rated power.
(e) For low power physics testing, 10^{-4}% may be increased to 10^{-1}% and cold shutdown boron concentration is not required.
(f) AO operability requirements are given in Specification 3.11.2.

Table 3.17.4 (Cont'd)

No	Functional Unit	Minimum Operable Channels	Minimum Degree of Redundancy	Permissible Bypass Conditions
8.	Pressurizer Water Level (LI-0102)	2	1	Not required in Cold or Refueling Shutdown
9.	Pressurizer Code Safety Relief Valves Position Indication (Acoustic Monitor or Temperature Indication)	1 per Valve	None	Not Required below 325°F
10.	Power Operated Relief Valves (Acoustic Monitor or Temperature Indication)	1 per Valve	None	Not required when PORV isolation valve is closed and its indication system is operable
11.	PORV Isolation Valves Position Indication	1 per Valve	None	Not required when reactor is depressurized and vented through a vent ≥1.3 sq.in.
12.	Subcooling Margin Monitor	1	None	Not required below 515°F
13.	Auxiliary Feed Flow Rate Indication	1 per flow[h] Control Valve	None	Not required below 325°F
14.	Auxiliary Feedwater Actuation System Sensor Channels	2 per steam generator[e]	1	Not required below 325°F
15.	Auxiliary Feedwater Actuation System Actuation Channels	2[f]	1	Not required below 325°F
16.	Excore Detector Deviation Alarms	1[g]	None	Not Required Below 25% of Rated Power /
17.	Axial Shape Index Alarm	2[i]	1	Not Required Below 25% of Rated Power /

(e) Auxiliary Feedwater System Actuation System Sensor Channels contain pump auto initiation circuitry. If two sensor channels for one steam generator are inoperable, one of the steam generator low level bistable modules in one of the inoperable channels must be in the tripped condition.

Table 3.17.4 (Cont'd)

(f) With one Auxiliary Feedwater Actuation System Actuation Channel inoperable, in lieu of the requirement of 3.17.2, provide a second licensed operator in the control room within 2 hours. With both inoperable, in lieu of following the requirements of 3.17.2, start and maintain in operation the turbine driven auxiliary feed pump.

(g) Calculate the Quadrant Power Tilt using the excore readings at least once per 8 hours when the excore detectors deviation alarms are inoperable, or at least once per 8 hours using symmetric incore detectors when the difference between the excore and the incore measured Quadrant Power Tilt exceeds 2%.

(h) With two flow rate indicators inoperable for a given control valve, the control valve shall be considered inoperable and the requirements of 3.5.2(e) apply.

(i) AO operability requirements are given in Specification 3.11.2.

(next page is 3-84)

3.23.1 LINEAR HEAT RATE (LHR)

LIMITING CONDITION FOR OPERATION

ACTION 3:

If the incore alarm system is inoperable and the excore monitoring system is not being used to monitor LHR, operation at less than or equal to 85% of rated power may continue provided that incore readings are recorded manually. Readings shall be taken on a minimum of 10 individual detectors per quadrant (to include 50% of the total number of detectors in a 10-hour period) within 4 hours and at least every 2 hours thereafter. If readings indicate a local power level equal to or greater than the alarm setpoints, the action specified in ACTION 1 above shall be taken.

Basis

The limitation of LHR ensures that, in the event of a LOCA, the peak temperature of the cladding will not exceed 2200°F.[1][3]

Either of the two core power distribution monitoring systems (the incore alarm system or the excore monitoring system) provides adequate monitoring of the core power distribution and is capable of verifying that the LHR does not exceed its limits. The incore alarm system performs this function by continuously monitoring the local power at many points throughout the core and comparing the measurements to predetermined setpoints above which the limit on LHR could be exceeded. The excore monitoring system performs this function by providing comparison of the measured core AO with predetermined AO limits based on incore measurements. An Excore Monitoring Allowable Power Level (APL), which may be less than rated power, is applied when using the excore monitoring system to ensure that the AO limits adequately restrict the LHR to less than the limiting values.[4]

If the incore alarm system and the excore monitoring system are both inoperable, power will be reduced to provide margin between the actual peak LHR and the LHR limits and the incore readings will be manually collected at the terminal blocks in the control room utilizing a suitable signal detector. If this is not feasible with the manpower available, the reactor power will be reduced to a point below which it is improbable that the LHR limits could be exceeded.

Basis (Contd)

The time interval of 2 hours and the minimum of 10 detectors per quadrant are sufficient to maintain adequate surveillance of the core power distribution to detect significant changes until the monitoring systems are returned to service.

To ensure that the design margin of safety is maintained, the determination of both the incore alarm setpoints and the APL takes into account a measurement uncertainty factor of 1.10, an engineering uncertainty factor of 1.03, a thermal power measurement uncertainty factor of 1.02 and allowance for quadrant tilt.

References

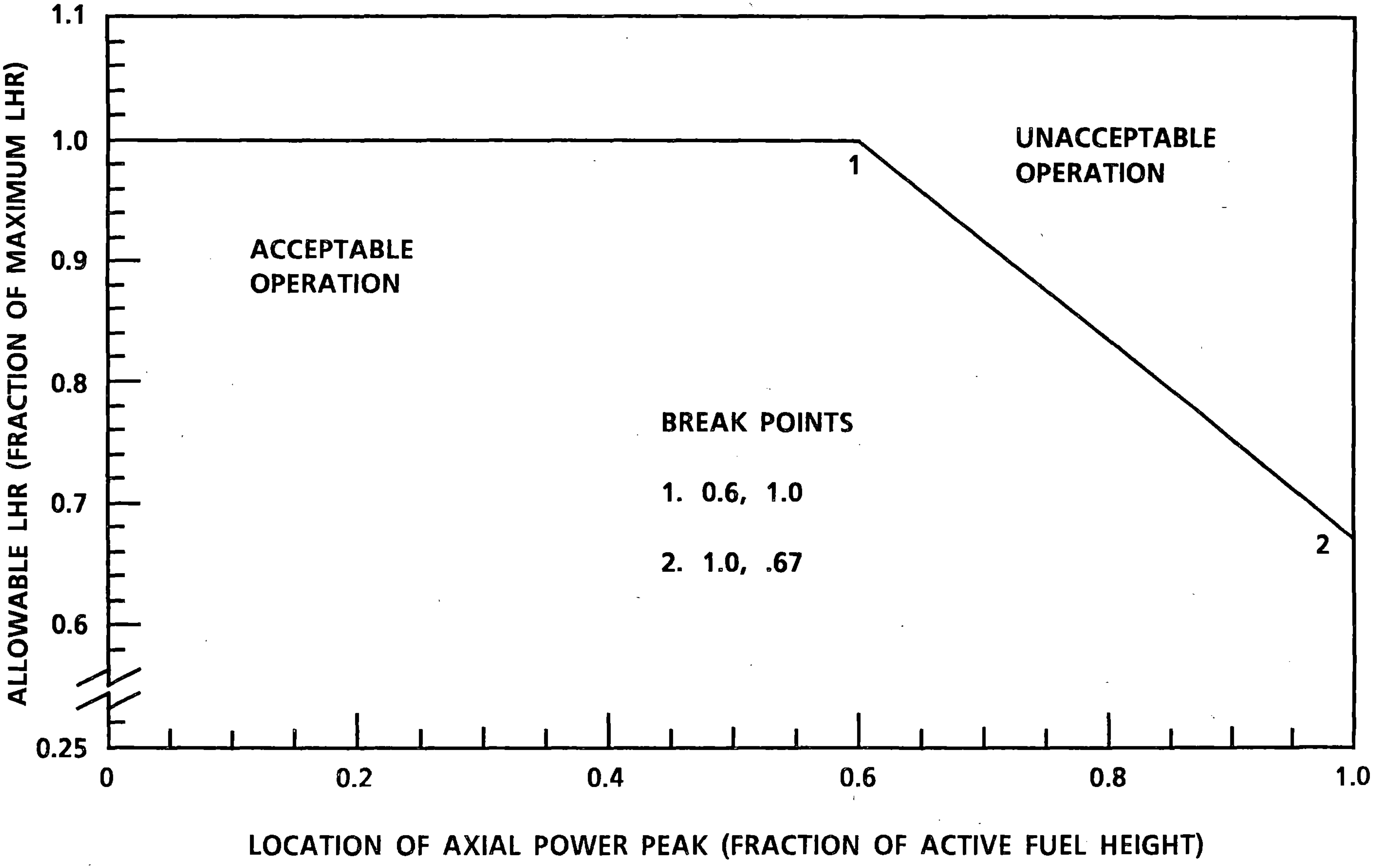
(1) XN-NF-77-24

(2) deleted /

(3) XN-NF-78-16

(4) XN-NF-80-47 /

FIGURE 3.23-1
ALLOWABLE LHR AS A FUNCTION OF PEAK POWER LOCATION



3.23.2 RADIAL PEAKING FACTORS

LIMITING CONDITION FOR OPERATION

The radial peaking factors F_r^A, F_r^T, F_r^N and $F_r^{\Delta H}$ shall be less than or equal to the value in Table 3.23-2 times the following quantity. The quantity is [1.0 + 0.3 (1 - P)] for P ≧ .5 and the quantity is 1.15 for P < .5. P is the core thermal power in fraction of rated power.

APPLICABILITY: Power operation above 25% of rated power.

ACTION:

1. For P < 50% of rated with any radial peaking factor exceeding its limit, be in at least hot shutdown within 6 hours.

2. For P ≥ 50% of rated with any radial peaking factor exceeding its limit, reduce thermal power within 6 hours to less than the lowest value of:

   $$[1 - 3.33 (\frac{F_r}{F_L} - 1)] \times \text{Rated Power}$$

   Where F_r is the measured value of either F_r^A, F_r^T, F_r^N or $F_r^{\Delta H}$ and F_L is the corresponding limit from Table 3.23-2.

   Basis

   The limitations on F_r^A, F_r^T, $F_r^{\Delta H}$ and F_r^N are provided to ensure that assumptions used in the analysis for establishing DNB margin, LHR and the thermal margin/low-pressure and variable high-power trip set points remain valid during operation. Data from the incore detectors are used for determining the measured radial peaking factors. The periodic surveillance requirements for determining the measured radial peaking factors provide assurance that they remain within prescribed limits. Determining the measured radial peaking factors after each fuel loading prior to exceeding 50% of rated power provides additional assurance that the core is properly loaded.

3.23.3 QUADRANT POWER TILT - T_q

LIMITING CONDITION FOR OPERATION

The quadrant power tilt (T_q) shall not exceed 5%.

APPLICABILITY: Power operation above 25% of rated power. /

ACTION:

1. With quadrant power tilt determined to exceed 5% but less than or equal to 10%. /
   a. Correct the quadrant power tilt within 2 hours after exceeding the limit, or /
   b. Determine within the next 2 hours and, at least once every 8 hours thereafter, that the radial peaking factors are within the limits of Section 3.23.2, or /
   c. Reduce power, at the normal shutdown rate, to less than 85% of rated power and determine that the radial peaking factors are within the limits of Section 3.23.2. At reduced power, determine at least once every 8 hours that the radial peaking factors are within the limits of Section 3.23.2. /
2. With quadrant power tilt determined to exceed 10%: /
   a. Correct the quadrant power tilt within 2 hours after exceeding the limit, or /
   b. Reduce power to less than 50% of rated power within the next 2 hours and determine that the radial peaking factors are within the limits of Section 3.23.2. At reduced power, determine at least once every 8 hours that the radial peaking factors are within the limits of Section 3.23.2. /
3. With the quadrant power tilt determined to exceed 15%, be in at least hot standby within 12 hours.

Basis

Limitations on quadrant power tilt are provided to ensure that design safety margins are maintained. Quadrant power tilt is determined from excore detector readings which are calibrated using incore detector measurements.[1] Calibration factors are determined from incore measurements by performing a two-dimensional, full-core surface fit of deviations between measured and theoretical incore readings and integrating the fitting function over each core quadrant. Values of LHR and radial peaking factors are increased by the value of quadrant tilt.

b. The PCS vent(s) shall be verified to be open at least once per 12 hours when the vent(s) is being used for overpressure protection except when the vent pathway is provided with a valve which is locked, sealed, or otherwise secured in the open position, then verify these valves open at least once per 31 days.

Basis

Failures such as blown instrument fuses, defective indicators, and faulted amplifiers which result in "upscale" or "downscale" indication can be easily recognized by simple observation of the functioning of an instrument or system. Furthermore, such failures are, in many cases, revealed by alarm or annunciator action and a check supplements this type of built-in surveillance.

Based on experience in operation of both conventional and nuclear plant systems when the plant is in operation, a checking frequency of once-per-shift is deemed adequate for reactor and steam system instrumentation. Calibrations are performed to insure the presentation and acquisition of accurate information.

The power range safety channels and ΔT power channels are calibrated / daily against a heat balance standard to account for errors induced by changing rod patterns and core physics parameters.

Other channels are subject only to the "drift" errors induced within the instrumentation itself and, consequently, can tolerate longer intervals between calibration. Process system instrumentation errors induced by drift can be expected to remain within acceptable tolerances if recalibration is performed at each refueling shutdown interval.

Substantial calibration shifts within a channel (essentially a channel failure) will be revealed during routine checking and testing procedures. Thus, minimum calibration frequencies of one-per-day for the power range safety channels, and once each refueling shutdown for the process system channels, are considered adequate.

The minimum testing frequency for those instrument channels connected to the reactor protective system is based on an estimated average unsafe failure rate of 1.14×10^{-5} failure/hour per channel. This estimation is based on limited operating experience at conventional and nuclear plants. An "unsafe failure" is defined as one which negates channel operability and which, due to its nature, is revealed only when the channel is tested or attempts to respond to a bona fide signal.

TABLE 4.1.1

Minimum Frequencies for Checks, Calibrations and Testing of Reactor Protective System(5)

Channel Description	Surveillance Function	Frequency	Surveillance Method	
1. Power Range Safety Channels	a. Check	S	a. Comparison of four-power channel readings.	
	b. Check(3)	D	b. Channel adjustment to agree with heat balance calculation. Repeat whenever flux-ΔT power comparators alarms.	
	c. Test	M(2)	c. Internal test signal.	/
	d. Calibrate (6)	R	d. Channel alignment through measurement/adjustment of internal test points.	/
2. Wide-Range Logarithmic Neutron Monitors	a. Check	S	a. Comparison of both wide-range readings.	
	b. Test	P	b. Internal test signal.	
3. Reactor Coolant Flow	a. Check	S	a. Comparison of four separate total flow indications.	
	b. Calibrate	R	b. Known differential pressure applied to sensors.	/
	c. Test	M(2)	c. Bistable trip tester.(1)(4)	
4. Thermal Margin/Low Pressurizer Pressure	a. Check: (1) Temperature Input (2) Pressure Input	S	a. Check: (1) Comparison of four separate calculated trip pressure set point indications. (2) Comparison of four pressurizer pressure indications. Same as 5(a) below.)	
	b. Calibrate (1) Temperature Input (2) Pressure Input	R	b. Calibrate: (1) Known resistance substituted for RTD coincident with known pressure and power input. (2) Part of 5(b) below.	/
	c. Test	M(2)	c. Bistable trip tester.(1)	/
5. High-Pressurizer Pressure	a. Check	S	a. Comparison of four separate pressure indications.	
	b. Calibrate	R	b. Known pressure applied to sensors.	/
	c. Test	M(2)	c. Bistable trip tester.(1)	

TABLE 4.1.1

Minimum Frequencies for Checks, Calibrations and Testing of Reactor Protective System(5) (Contd)

Channel Description	Surveillance Function	Frequency	Surveillance Method
6. Steam Generator Level	a. Check	S	a. Comparison of four level indications per generator.
	b. Calibrate	R	b. Known differential pressure applied to sensors.
	c. Test	M(2)	c. Bistable trip tester.(1)
7. Steam Generator Pressure	a. Check	S	a. Comparisons of four pressure indications per generator.
	b. Calibrate	R	b. Known pressure applied to sensors. /
	c. Test	M(2)	c. Bistable trip tester.(1)
8. Containment Pressure	a. Calibrate	R	a. Known pressure applied to sensors.
	b. Test	M(2)	b. Simulate pressure switch action.
9. Loss of Load	a. Test	P	a. Manually trip turbine auto stop oil relays.
10. Manual Trips	a. Test	P	a. Manually test both circuits.
11. Reactor Protection System Logic Units	a. Test	M(2)	a. Internal test circuits.
12. Axial Shape Index (ASI)	a. Test	R	a. Known power inputs applied to Thermal Margin Calculator. / / /
13. ΔT Power	a. Check	S	a. Same as 1(a). /
	b. Check (3)	D	b. Same as 1(b). /
	c. Test	R	c. Known temperature inputs applied to Thermal Margin Calculator. / /

TABLE 4.1.1

Minimum Frequencies for Checks, Calibrations and Testing of Reactor Protective System(5) (Contd)

Channel Description	Surveillance Function	Frequency	Surveillance Method
14. Thermal Margin Calculator	a. Check	Q	a. Verify constants. /

NOTES: (1)The bistable trip tester injects a signal into the bistable and provides a precision readout of the trip set point.

(2)All monthly tests will be done on only one of four channels at a time to prevent reactor trip.

(3)Adjust the nuclear power or ΔT power until readout agrees with heat balance calculations when above 15% of rated power. /

(4)Trip setting for operating pump combination only. Settings for other than operating pump combinations must be tested during routine monthly testing performed when shut down and within four hours after resuming operation with a different pump combination if the setting for that combination has not been tested within the previous month.

(5)It is not necessary to perform the specified testing during prolonged periods in the refueling shutdown condition If this occurs, omitted testing will be performed prior to returning the plant to service.

(6)Also includes testing variable high power function in the Thermal Margin Calculator. /

FREQUENCY NOTATION

Notation	Frequency
S	At least once per 12 hours.
D	At least once per 24 hours.
W	At least once per 7 days.
M	At least once per 31 days.
Q	At least once per 92 days.
SA	At least once per 6 months.
R	At least once per 18 months.
P	Prior to each start-up if not done previous week.
NA	Not applicable.

TABLE 4.1.3

Minimum Frequencies for Checks, Calibrations and Testing of Miscellaneous Instrumentation and Controls

Channel Description	Surveillance Function	Frequency	Surveillance Method
1. Start-Up Range Neutron Monitors	a. Check	S	a. Comparison of both channel count rate indications when in service.
	b. Test	P	b. Internal test signals.
2. Primary Rod Position Indication System	a. Check	S	a. Comparison of output data with secondary RPIS
	b. Check	M	b. Check of power dependent insertion limits monitoring system.
	c. Calibrate	R	c. Physically measured rod drive position used to verify system accuracy. Check rod position interlocks.
3. Secondary Rod Position Indication System	a. Check	S	a. Comparison of output data with primary RPIS.
	b. Check	M	b. Same as 2(b) above.
	c. Calibrate	R	c. Same as 2(c) above, including out-of-sequence alarm function.
4. Area Monitors Note: Process Monitor Surveillance Requirements are located in Tables 4.24-1 and 4.24-2	a. Check	D	a. Normal readings observed and internal test signals used to verify instrument operation.
	b. Calibrate	R	b. Exposure to known external radiation source.
	c. Test	M	c. Detector exposed to remote operated radiation check source.
5. Emergency Plan Radiation Instruments	a. Calibrate	A	a. Exposure to known radiation source.
	b. Test	M	b. Battery check.
6. Environmental Monitors	a. Check	M	a. Operational check.
	b. Calibrate	A	b. Verify airflow indicator.
7. Pressurizer Level Instruments	a. Check	S	a. Comparison of six independent level readings.
	b. Calibrate	R	b. Known differential pressure applied to sensor.
	c. Test	M	c. Signal to meter relay adjusted with test device.

TABLE 4.1.3

Minimum Frequencies for Checks, Calibrations and Testing of Miscellaneous Instrumentation and Controls (Continued)

Channel Description	Surveillance Function	Frequency	Surveillance Method	
8. Control Rod Drive System Interlocks	a. Test	R	a. Verify proper operation of all manual rod drive control system interlocks, using simulated signals where necessary.	/
	b. Test	P	b. Same as 8(a) above, if not done within three months.	
9. Flux-ΔT Power Comparator	a. Calibrate	R	a. Use simulated signals.	/
	b. Test	M	b. Use simulated signals.	/
10. Calorimetric Instrumentation	a. Calibrate	R	a. Known differential pressure applied to feedwater flow sensors.	/
11. Containment Building Humidity Detectors	a. Test	R	a. Expose sensor to high humidity atmosphere.	
12. Interlocks - Isolation Valves on shutdown Cooling Line	a. Calibrate	R	a. Known pressure applied to sensor.	
13. Service Water Break Detector in Containment	a. Test	R	a. Known differential pressure applied to Sensors.	

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Amendment No 12, 30, 31, 38, 66, 81,

TSP1287-0253-NL04

4.15 Primary System Flow Measurement

Applicability

Applies to the measurement of primary system flow rate with four primary coolant pumps in operation.

Objective

To provide assurance that the primary system flow rate is equal to or above the flow rate required in 3.1.1.c.

Specification

After each refueling outage, or after plugging 10 or more steam generator tubes, a primary system flow measurement shall be made with four primary coolant pumps in operation. This measurement shall be made within the first 31 days of rated power operation.

Basis

This surveillance program assures that the reactor coolant flow is consistent with that assumed as the basis for Specification 3.1.1c.

4.18.2 EXCORE MONITORING SYSTEM

SURVEILLANCE REQUIREMENTS

4.18.2.1 At least every 31 days of power operation:

a. A target AO and excore monitoring allowable power level shall be determined using excore and incore detector readings at steady state near equilibrium conditions.

b. Individual excore channel measured AO shall be compared to the total core AO measured by the incores. If the difference is greater than 0.02, the excore monitoring system shall be recalibrated.

c. The excore measured Quadrant Power Tilt shall be compared to the incore measured Quadrant Power Tilt. If the difference is greater than 2%, the excore monitoring system shall be recalibrated.

4.19 POWER DISTRIBUTION LIMITS

4.19.1 LINEAR HEAT RATES

SURVEILLANCE REQUIREMENTS

4.19.1.1 When using the incore alarm system to monitor LHR, prior to operation above 50% of rated power and every 7 days of power operation thereafter, incore alarms shall be set based on a measured power distribution.

4.19.1.2 When using the excore monitoring system to monitor LHR:

a. Prior to use, verify that the measured AO has not deviated from the target AO by more than 0.05 in the previous 24 hours for each operable channel using the previous 24 hourly recorded values.

b. Once per day, verify that the measured Quadrant Power Tilt is less than or equal to 3%.

c. Once per hour, verify that the power is less than or equal to the APL and not more than 10% of rated power greater than the power level used in determining the APL.

d. Continuously verify that the measured AO is within 0.05 of the established target AO for at least 3 of the 4, 2 of the 3 or 2 of the 2 operable channels, whichever is the applicable case.

4.20 MODERATOR TEMPERATURE COEFFICIENT (MTC) /

SURVEILLANCE REQUIREMENTS /

4.20.1 The MTC shall be determined to be within its limits by confirmatory measurements prior to initial operation above 2% of rated thermal power, after each refueling." /

(next page is 4-90)

ATTACHMENT

Consumers Power Company
Palisades Plant
Docket 50-255

AFFIDAVIT AND
GAMMA METRICS REPORTS

AFFIDAVIT

STATE OF CALIFORNIA)
) ss.
COUNTY OF SAN DIEGO)

I, Clinton L. Lingren, being duly sworn, hereby say and depose:

1. I am Vice President, Reactor Instrumentation, of GAMMA-METRICS, a California corporation ("GM") and as such, I am authorized to execute this Affidavit.

2. I was a founder of GM in 1980 and have been continuously employed by GM as a Vice President since then. As such, I am familiar with GM's research and development activities with respect to reactivity control systems, as well as its documentation and documentation control practices and policies which govern the protection of GM's trade secrets and the control of related information.

3. I am familiar with the documents listed on Exhibit A attached hereto (the "Documents"). All of the information contained in those Documents has been classified by GM as proprietary in accordance with GM's policies established for the protection of its trade secrets.

4. The Documents contain information of a proprietary and confidential nature and are of the type customarily held in confidence by GM and not made available to the public.

5. I have engaged in research and development activities with a variety of employers for more than 20 years. Based on that experience, I state that other companies similarly situated would regard information of the kind contained in the Documents to be proprietary and confidential.

6. GM has held the Documents in confidence and has released them only (i) as necessary to comply with applicable law, and (ii) under confidential disclosure agreements. GM follows a variety of customary procedures for the safeguarding of its proprietary information, including the information set forth in the Documents.

7. GM is making the Documents available to the United States Nuclear Regulatory Commission in confidence, with the request, hereby made, that the information contained in the Documents will not be disclosed or divulged for the reasons set forth herein, which are intended to be responsive to 10 C.F.R. 2.790(b)(1).

8. The information contained in the Documents is not available in public sources.

9. GM has expended substantial amounts to create the information set forth in the Documents. That information is vital to GM's competitive advantages and would be extremely helpful to GM's competitors if it were known by them.

10. GM believes the information in the Documents is proprietary because it reveals the details of the implementation of the functions performed by the thermal margin monitor and includes information used by GM in its business which affords GM an opportunity to obtain a competitive advantage over its competitors who do not or may not know or use the information contained in the Documents.

11. The disclosure to a competitor of the proprietary information contained in the Documents would permit the competitor to reduce its research and development expenditures and thereby unfairly improve its competitive position by giving it extremely valuable insights into GM's proprietary information, resulting in substantial and irremediable harm to GM's competitive position.

The statements herein made are truthful and complete to the best of my knowledge, information and belief.

Clinton L. Lingren

Clinton L. Lingren

Sworn to and subscribed before me this 4th day of March, 1988.

OFFICIAL SEAL
JEANNEE L. CHRIST
NOTARY PUBLIC - CALIFORNIA
SAN DIEGO COUNTY
My Comm Expires Jan 6, 1989

Jeannee L. Christ

Notary Public
State of California

EXHIBIT A

List of Documents

HARDWARE SPECIFICATION
DOCUMENT NO. 056

SOFTWARE REQUIREMENTS SPECIFICATION
DOCUMENT NO. 055

SOFTWARE DESIGN DESCRIPTION
DOCUMENT NO. 089

INSTRUCTION MANUAL
DOCUMENT NO. 070, VOLUMES I, II, III & IV

TMM SOFTWARE QUALITY ASSURANCE AND DEVELOPMENT PLAN
DOCUMENT NO. 068

RCS-50 TMC QUALIFICATION TEST PLAN
DOCUMENT NO. 066

VERIFICATION PLAN
DOCUMENT NO. 067

HARDWARE-SOFTWARE INTEGRATION PLAN
DOCUMENT NO. 073

VALIDATION PLAN
DOCUMENT NO. 088

Document Number 056

Revision: 3.0

Date: July 21, 1986

General Purpose Class 1E Qualified Microcomputer Hardware Specification

THERMAL MARGIN MONITOR

for

CONSUMERS POWER COMPANY

Palisades

GAMMA-METRICS
5550 Oberlin Drive
San Diego, CA 92121
Telephone 619/450-9811

Revision Record

Revision A : R. Cram May 17, 1985

Initial release.

Revision B : R. Cram June 4, 1985

Revised and corrected several items. Added options clarification. Added section 14.0.

Revision C : R. Cram August 6, 1985

Revised and corrected several items based on meeting with Bill Staley. Added document number. Added section 15.0. Changed isolation specifications from 200 v to 600 v. Added IEEE-603 reference document. Changed consumer power company drawing numbers. Added storage time specification. Added NUREG-0700 CRT requirements. Added OBE and SSE requirements. Changed analog I/O capabilities increasing output channels to 3 and inputs to 7. Changed line voltage from 120 to 117 vac.

Revision D : R. Cram August 27, 1985

Line voltage change not picked up in Rev. C. Included change for line voltage to 117 vac.

Revision E : R. Cram Sept. 11, 1985

Corrected misspellings.

Revision F : R. Cram Sept. 24, 1985

Corrected number of key positions. Changed keyboard to key pad.

Revision G : R. Cram Oct. 15, 1985

Corrections per document review form.

Revision 3.0 J. Miller July 21, 1986

Official release with changes. Added sections 13.0 and 14.0.

Table of Contents

APPENDICES

1.0 Scope:

This document covers a description of the hardware implementation of a general purpose medium performance microcomputer to be qualified for class 1E installations in nuclear power generating stations. It covers all environmental requirements, packaging and handling requirements, I/O capabilities and a general description of the system and design goals.

2.0 Reference documents:

The following documents are invoked in the design of the system. In the event of a conflict between reference documents and this document, this specification shall be considered the governing document.

1) Consumers Power Company document J-54
2) Consumers Power Company sketch 8-JL-130 Sh. 1
3) Application Criteria for Programmable Digital Computer Systems in Safety Systems of Nuclear Power Generating Stations - ANSI/IEEE - ANS-7-4.3.2-1982
4) Qualifying Class 1E Equipment for Nuclear Power Generating Stations - IEEE-323-1974
5) Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations - IEEE-344-1975
6) Standard Criteria for Safety Systems for Nuclear Power Generating Stations - IEEE-603-1980.
7) NUREG-0700 Section 6.7.2 - Guidelines for Control Room Design - CRT Displays.

3.0 General description:

The general purpose microcomputer is to be designed to be used in class 1E installations in Nuclear Power Generating Stations. It is to be designed to withstand all of the rigors associated with power plant environment as well as exposure to radiation. The system is to be capable of handling extremes in temperature, humidity and vibration as well as being designed to have a high reliability. The system is to be easily expandable or can be reduced over the current configuration to a minimum cost solution to simple problems. This will be accomplished by the use of a standard bus architecture. The graphics display and keypad input provide for ease of operator use and dual keylocks provide a high degree of operational security.

The unit will be designed to mount in a standard 19" rack panel an occupy 8-3/4" or less of vertical rack space and is 15-3/8" deep.

4.0 Environmental Specifications:

The general purpose microcomputer shall be designed to meet all of the environmental specifications herein over the specified life of the unit of 40 years.

4.1 Temperature Specifications:

The system will be capable of being operated over temperature extremes ranging from +5 degrees celsius to +55 degrees celsius with no degradation in performance (41 deg F to 131 deg F). Additionally the unit will be capable of being stored at temperatures ranging from -25 deg celsius to +60 degrees celsius in a nonoperational status for periods of up to 5 years without degradation of the unit (-13 deg F to 140 deg F).

4.2 Shock and Vibration Specifications:

The unit shall be seismically qualified to operate with no degradation in performance to the curves shown in appendix A. These curves were selected on the basis that they envelope any known seismic requirement. The unit shall be tested to these requirements so that durability and adequacy of the design is demonstrated. Additionally the unit shall be designed to be capable of withstanding normal air, sea and land transportation without damage when properly packed. The unit will withstand 5 operating base events (OBE) and 1 safe shutdown event (SSE) per the requirements of IEEE-344-1975. Margins specified in section 3.1.5 of IEEE-323-1974 will be employed where applicable.

4.3 Humidity Specification:

The unit shall be capable of operation without degradation in performance over a relative humidity range of 5% to 95% noncondensing.

4.4 Radiation Tolerance Specification:

The unit shall be designed to be able to operate without a critical failure after being exposed to Gamma radiation to a total integrated dose of 10,000 rads. A critical failure is fully defined in the test plan. Briefly, a critical failure is a failure that causes the device to be unable to perform the defined calculation process, read the necessary inputs or produce the required outputs.

5.0 Packaging and handling requirements:

The computer shall have the following dimensions not including back panel, side panel or front panel devices such as connectors, switches, terminal blocks and mounting rails.

Depth : 15.375 inches

Width : 19 inch, rack mountable

Height : 8.75 inches

The microcomputer shall be capable of being shipped using normal commercial air, sea or land carrier with proper packing. The unit will not require any special handling or packing provisions above what is normally used for commercial packing purposes.

Connections to the microcomputer shall be via terminal blocks located on the rear of the chassis capable of accepting wire gauge sizes between AWG 14 to AWG 22.

6.0 Input/Output (I/O) Capabilities:

The following paragraphs specify the I/O capabilities of the machine. Note that additional I/O can be added by increasing the number of Isolators installed in the unit and adding more cards to the standard bus around which the system is built.

6.1 Industrial I/O Capabilities:

There will be a total of 8 digital industrial inputs or outputs available in the stock package with a capability of being expanded up to 24 inputs or outputs. These lines may be configured as either inputs or outputs however they must be specified as either input or output in blocks of 4 lines. Examples are 8 inputs and 16 outputs, 20 inputs and 4 outputs, 12 inputs and 12 outputs, etc. All industrial I/O are completely isolated from the chassis, from other I/O lines and from the computer power supplies.

6.1.1 Industrial output line specifications:

All industrial output lines will be solid state DC switches having an isolation voltage rating of 600 vac RMS minimum to any computer parts, chassis and power supplies, a current rating of 2.0 amps DC at 20 deg C., 1.5 amps DC at 45 deg C and a maximum voltage drop of 1.6 vdc at 3 amps. The off state leakage current shall be less than 2 ma and the off state blocking voltage shall be greater than 40 Vdc. As an option output lines may be configured to have solid state AC switches, a current rating of 2.0 amps AC RMS at 20 deg C., and an off state blocking voltage of 200 vac.

6.1.2 Industrial input line specifications:

All industrial input lines will be solid state DC input modules capable of handling AC or DC line inputs. The input voltage range shall be 10 to 30 vdc or 15 to 30 vac with a maximum input current at maximum line of 23 ma. The input to output isolation shall be greater than 600 vac RMS with a maximum leakage current of less than 2 ma.

The microcomputer will have an option of sensing contact closures externally. In the event an external contact closure is used, the isolation rating is decreased to 600 vac RMS or 1000 vdc. The external contact must be capable of handling 40 ma of current and have an off state blocking voltage of greater than 20 vdc.

6.2 Analog I/O Capabilities:

There will be provisions for a total of 16 analog I/O channels. Any number of those up to 18 may be analog input with 12 bit resolution and any number can be analog output up to 8 channels also with 12 bit resolution. The standard configuration will provide for 3 analog output channels and 7 analog input channels. Any variation from this standard may be provided at additional cost. Data rate capabilities will be such that the analog I/O channels can be accessed at least 100 times per second.

6.2.1 Analog input specifications:

The input impedance of the analog voltage inputs shall be 1 meg ohm resistive +/- 2%. The inputs can be operated with an input of 0 to 10 vdc, -10 to +10 vdc, 0-5 vdc, 4 to 20 madc, 0-20 ma dc or special customer requirements. However, 0 to 10 vdc is to be the standard configuration. If voltage input is used, the offset shall be less than 5 mv dc or 0.075% of full scale whichever is greater. If current input is used, the offset shall be less than 0.15 madc or 0.075% whichever is greater. Line isolation voltage shall be at least 600 vac RMS or 1000 vdc. Linearity shall be better than 0.025% and gain and offset temperature drift shall be less than 100 PPM per degree C. of full scale.

6.2.2 Analog Output Specifications:

The analog outputs may take the form of 0 to 10 vdc, 4 to 20 madc, 10 to 50 madc, or 0 to 20 madc, but comes standard as 0 to 10 VDC. The maximum current that can be drawn from the analog output channels is 10 ma dc when voltage outputs are used. The output isolation voltage is 600 vac RMS or 1000 vdc minimum. The channel linearity is .05% of full scale or better. Temperature coefficient of gain and offset is less then 50 PPM per degree C of full scale range. The offset error shall be less then .075% of full scale range and gain error shall be less then .10% of full scale range.

7.0 Screen output:

In addition to the analog and industrial outputs available to the user, an integrated screen will be used to output data to the user. The screen will have a graphics capability and a minimum resolution of 300 lines horizontal and vertical.

The displays and screens will be designed to be in conformance with NUREG-0700 sections 6.7.2.1 through 6.7.2.8 inclusive, to the greatest extent possible. Sections specific to the customer's installation are excluded. No measurements of screen or character luminance or contrast will be made by Gamma-Metrics.

The screen output is not considered a safety related function of the computer.

8.0 Keypad input:

In addition to the analog and industrial inputs available to the user, an alphanumeric keypad will be an integral part of the design and may be used to communicate with the microcomputer. The keypad will be environmentally sealed against dust, dirt and noncorrosive chemicals. The keypad will be detachable so that security may be increased. Additionally, 4 front panel mounted soft keys will be included in the design to be used by operators to call up screens and provide for operation of the system.

9.0 Keylock capabilities:

Two keylocks will be installed on the front panel of the unit with one lock having three positions and the second lock having two positions. Each position will form a digital input to the system for a total of 5 digital inputs. The microcomputer will periodically scan the position of those keys to determine if a secure access to the machine is to be granted.

10.0 Peripheral equipment options:

Optionally, three outputs will be available to drive printers or other peripheral equipment that may be connected to the system. There will be provisions for two RS-232C serial interface ports available on the system and one Centronics compatible port for driving a parallel printer.

11.0 Line power requirements:

The device shall be designed to operate from 117 Vac single phase power source. Minimum line frequency is 55 Hz and maximum line frequency is 65 Hz. Line voltage may vary +/- 10% without detrimentally affecting the operation of the unit. Maximum current consumption shall be less then 2 amps AC RMS and total power consumption shall be less than 240 watts at a nominal line voltage of 117 Vac.

12.0 Battery Retention Requirements:

The computer will have provisions for battery back-up of all volatile random access memory (RAM) so that critical function may be restored immediately after a power failure without operator intervention. The retention time of the RAM will be a minimum of 1 year under all environmental extremes specified herein.

13.0 Initialization Requirements

Prior to powering the chassis, the cover must be removed and a jumper installed to enable the battery backed up RAM. When the unit must be powered off for extended periods of time, this jumper should be disconnected to prevent discharging the battery. The unit is designed to be self initializing on powering on the chassis.

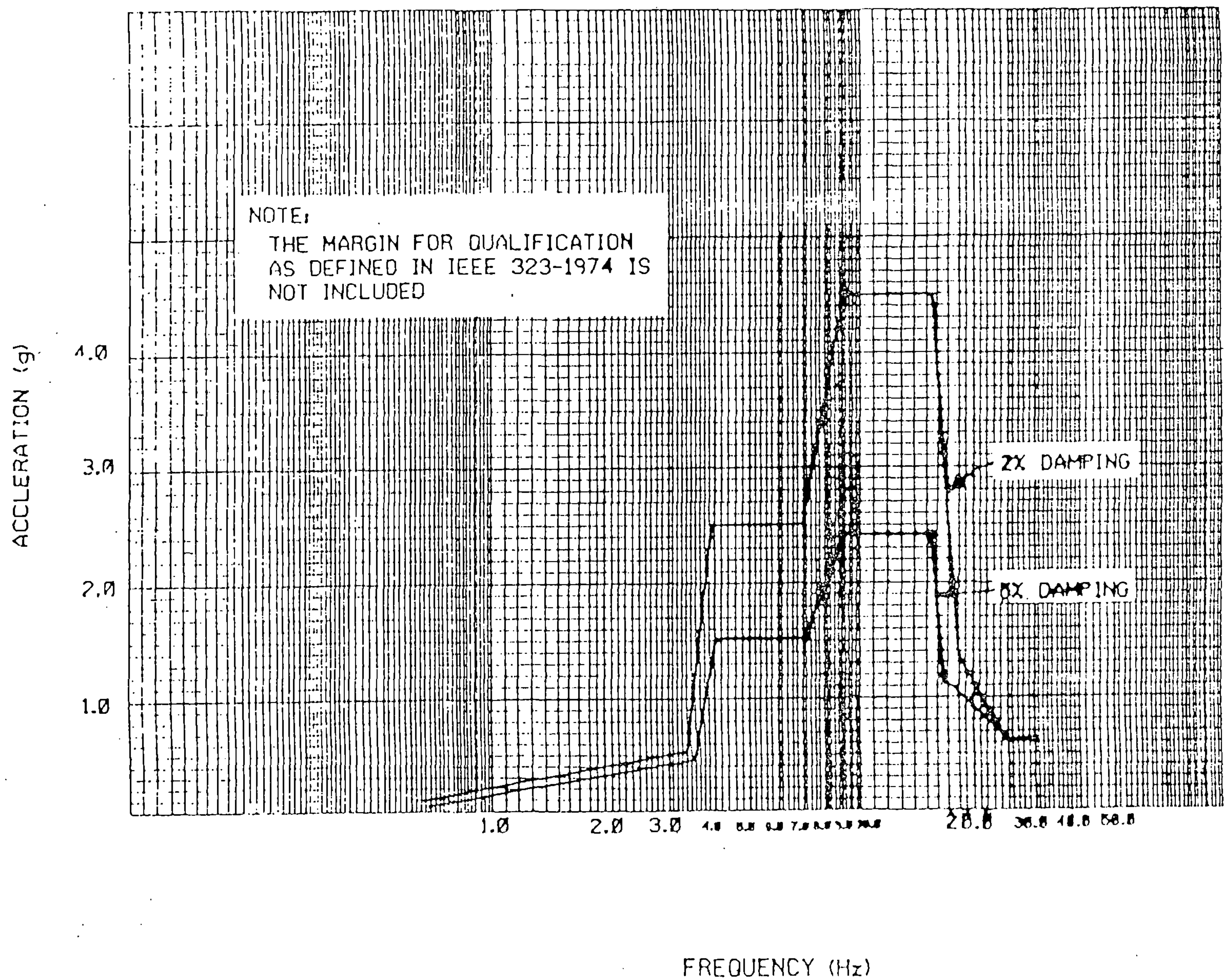
14.0 Interrupt Features

Hardware interrupt capability is obtained by the use of a momentary switch on the rear of the chassis, which causes a reset of the computer when depressed.

Appendix A

Seismic Test Envelopes

SSE = OBE x 2



CONSUMERS POWER COMPANY
JACKSON, MICH.

CONTROL PANEL C27
AUXILIARY BUILDING, EL. 625'-0"
HORIZONTAL RESPONSE SPECTRA
OPERATING BASIS EARTHQUAKE

PALISADES

PL

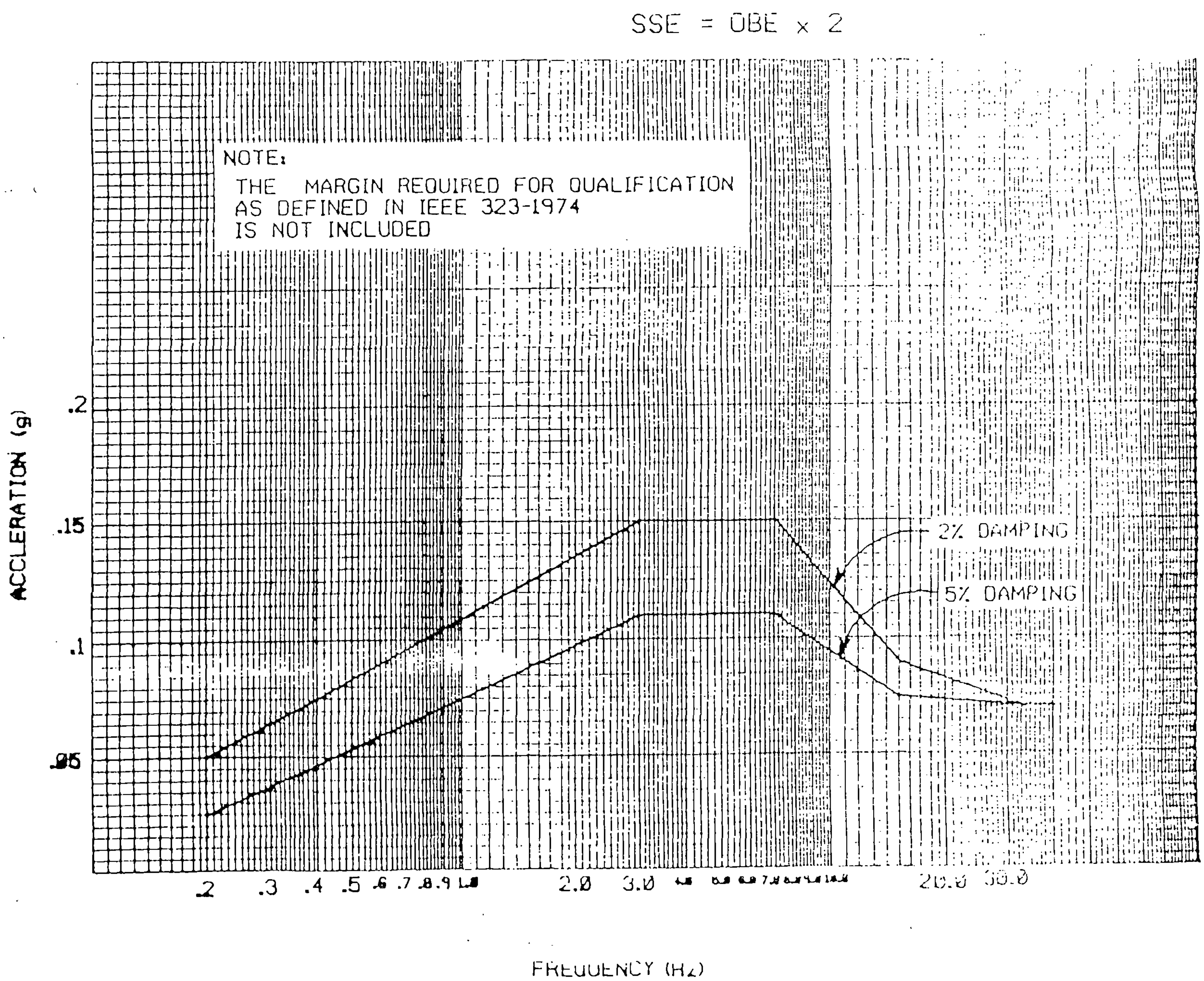
ATTACHMENT 1

PAGE ONE

PALISADES PLANT

CONSUMERS POWER COMPANY
JACKSON MICHIGAN

CONTROL PANEL C27
AUXILIARY BUILDING, EL. 625'-8"
VERTICAL RESPONSE SPECTRA
OPERATING BASIS EARTHQUAKE



GAMMA-METRICS

SOFTWARE

REQUIREMENTS SPECIFICATION

CONSUMERS POWER COMPANY
THERMAL MARGIN MONITOR

DOCUMENT# 055

JULY 9, 1986

Revision 3.0

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(CONTINUED)

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1.0 SCOPE

The purpose of this document is to provide a software specification of the GAMMA-METRICS Thermal Margin Monitor (TMM). Thus each required function of the TMM is described in detail, along with any associated inputs and outputs. In addition to the functional requirements, non-functional requirements are discussed. Among the non-functional requirements are performance constraints and life-cycle constraints.

This document does not describe any of the TMM displays or diagnostic messages. These items will be explained in an Operating Manual, which will be delivered with the product.

2.0 APPLICABLE DOCUMENTS

The following documents are referred to in this specification. This document will serve as <u>the</u> software specification for the TMM, with the reference documents serving to clarify or supplement this specification.

1) Consumers Power Company document J-54.

2) Consumers Power Company <u>LOGIC FOR TM/LP TRIP</u> drawing 8-JL-130, sheet 1.

3) America National Standard <u>Application Criteria for Programmable Digital Computer Systems in Safety Systems of Nuclear Power Generating Stations</u> - ANSI/IEEE ANS-7-4.3.2-1982.

4) GAMMA-METRICS document #056 -<u>THERMAL MARGIN MONITOR HARDWARE SPECIFICATION</u>.

5) GAMMA-METRICS document #068 - <u>TMM SOFTWARE QUALITY ASSURANCE PLAN</u>.

3.0 OVERVIEW

The GAMMA-METRICS Thermal Margin Monitor is a self-contained, microprocessor based, 19" rack-mounted product which is targeted to replace the existing ΔT and TM/LP (Thermal Margin/Low Pressure) calculators at the Palisades Nuclear Plant. The system hardware features a data entry keyboard, a video display, two security key switches, and four menu selection switches. The front panel layout will be designed for ease of use.

The TMM embedded computer program will provide those functions described in Consumers Power Co drawing JL-130. The TMM's primary function is to repeatedly calculate ΔT Power, Power Density pretrip/trip, TM/LP P_{trip} and the Variable High Power Trip. The results of these calculations affect the TMM's graphic display as well as the digital and analog outputs.

3.1 FUNCTIONAL REQUIREMENTS

This section describes each of the functions provided in the TMM and the information flow within and between each of the functions.

3.1.1 ΔT POWER FUNCTION

The ΔT Power is a function of the highest cold leg temperature, the average hot leg temperature, and a temperature differentiator. The cold leg temperatures and average hot leg temperature are read by the TMM as external analog inputs.

The ΔT Power equation is expressed mathematically as follows:

$$\Delta T\ Power = K\alpha\Delta T + K\gamma\Delta T^2 + K\beta T_C\Delta T + \tau\frac{d}{dt}(a\Delta T + T_C) + BIAS$$

The range of the calculated ΔT Power is 0 to 125% Power.

The time derivative in the above formula will be estimated as follows:

1. Once per second a "raw" value of the derivative will be calculated by simply subtracting the previous value of (a * Delta T + TC) from the present value of (a * Delta T + TC). This yields the change during the last second in degrees Fahrenheit per second.

2. These once-per-second "raw" values will be smoothed by putting them through a first order digital lag filter with an operator adjustable time constant. The time constant would typically be 5 to 10 seconds. The filter formula is:

DIFF = GAIN * RAW_DIFF + (1 - GAIN) * OLD_DIFF

where:

GAIN = reciprocal of time constant

DIFF = estimated rate of change of (a * Delta T + TC)

RAW_DIFF = change in (a * Delta T + TC) during one second

OLD_DIFF = previous value of DIFF, one second ago

Note that the operator can set the time constant to 1 second in order to cause DIFF to equal RAW_DIFF.

The TMM embedded computer program will calculate the power equation automatically, every second. The result, ΔT Power, is displayed on the front panel monitor and is also used in the TM/LP Trip function. The various terms used in this equation come from both external analog inputs and internal operator adjustable parameters.

3.1.1.1 ΔT POWER EXTERNAL ANALOG INPUTS

Three analog input parameters are used to arrive at the T_C and ΔT equation parameters: T_{C1}, T_{C2}, and T_H AVE. T_{C1} and T_{C2} are both cold leg temperatures with a DC range of 1-5V corresponding to temperatures of 515 - 615°F. T_C is equivalent to the maximum (larger number) of T_{C1} and T_{C2}. T_H AVE is an average or "active loop" hot leg temperature with a DC range of 1-5V corresponding to temperatures of 515 - 615°F. ΔT is equivalent to the difference between T_H AVE and T_C.

In summary, $T_C = MAX(T_{C1}, T_{C2})$ and $\Delta T = (T_H AVE - T_C)$.

3.1.1.2 ΔT POWER OPERATOR ADJUSTABLE PARAMETERS

Some of the parameters used in the ΔT Power equation are obtained from the internal parameter table. All parameters in this table are stored in battery backed-up volatile memory so that they can be adjusted by the Operator, yet they will not be lost upon a power failure. The volatile memory will be backed up for a minimum of 100 hours should there be a power failure. Seven parameters are used in this equation:

PARAMETER	ADJUSTABLE RANGE
$K\beta$	1×10^{-6} to 5×10^{-3}
$K\gamma$	-1×10^{-5} to 1×10^{-5}
$K\alpha$	3×10^{-2} to 1×10^{-3}
a	0 to 10.0
τ	0 to 1.0
BIAS	-0.10 to 0.10
TIME CONSTANT	1 to 30

3.1.1.3 T_C ALARM FUNCTION

An additional operation is performed on the calculated T_C value. If at any time $T_C > T_C MAX$ or $T_C < T_C MIN$, a digital output T_{CC} (contact closure) is tripped/opened. With both T_CMAX and T_CMIN, a 0.5% deadband will be used to reset (close) the contact. That is, if T_C falls below T_CMIN, T_C must rise 0.5% above the T_CMIN value to reset (close) the contact. Similarly, if T_C rises above T_CMAX, T_C must fall 0.5% below the T_CMAX value to reset (close) the contact. No Operator intervention is necessary to reset the alarm condition.

3.1.1.3.1 T_C ALARM DIGITAL OUTPUT

A single digital output (contact closure) is provided for use with this function. This contact T_{CC} is normally closed and will open upon a trip condition.

3.1.1.3.2 T_C ALARM ADJUSTABLE PARAMETERS

The parameters used in this function which can be adjusted are as follows:

PARAMETER	ADJUSTABLE RANGE
T_CMAX	515 to 700°F
T_CMIN	0 to 600°F

3.1.2 POWER DENSITY PRETRIP/TRIP FUNCTION

The purpose of the Power Density Trip function is to activate a set of contact closures (digital outputs) based upon comparing core Axial shape index (ASI) and the allowed ASI which is a function of Core Power. The ASI is derived from the deviation of linear power levels in the upper and lower portions of each quadrant divided by the average quadrant linear power level and is a measure of the power distribution between the upper and lower portions of the core. A large ASI magnitude corresponds to significant flux deviation between the upper and lower portions of the core in each quadrant. Hence, this function provides a trip if the ASI is too great for the current power level.

This function is calculated once every 100 milliseconds. The mathematical function is comprised of piecewise linear functions, a calculated LPD (Local Power Density) blocking function (defined as Q2), analog inputs, and Operator adjustable parameters. This function will open/close a PRETRIP or TRIP set of contact closures as follows:

Open **TRIP** contact if $Y \geq Y_P$ or if $Y \leq Y_N$

Open PRETRIP contact if $Y_{PP} \leq Y$ or $Y \leq Y_{NP}$

Where:

$$Y = ASIF\left(\frac{L-U}{L+U}\right)$$

$$Y_P = LPDF_p(QR_2)$$

$$Y_N = LPDF_n(QR_2)$$

$$Y_{PP} = Y_P - b$$

$$Y_{NP} = Y_N + b$$

$$QR_2 = LPF(Q2)$$

$$Q = MAX(\phi, \Delta T\ Power)$$

$$Q2 = \begin{cases} 0, \text{ if } Q \leq 14.5\%\ Power \\ MAX(\phi, \Delta T\ Power), \text{ if } Q \geq 15\%\ Power \end{cases}$$

Q2 has a 0.5% deadband in that Q must drop from 15% all the way to 14.5% Power to change from MAX (ϕ,ΔT Power) to 0. Similarly, Q must rise from 14.5% all the way to 15% Power to change from 0 to MAX(ϕ,ΔT Power).

ASIF, $LPDF_p$, $LPDF_n$, LPF are piecewise linear functions described below. L and U are linear power analog inputs described in section 3.1.2.2.

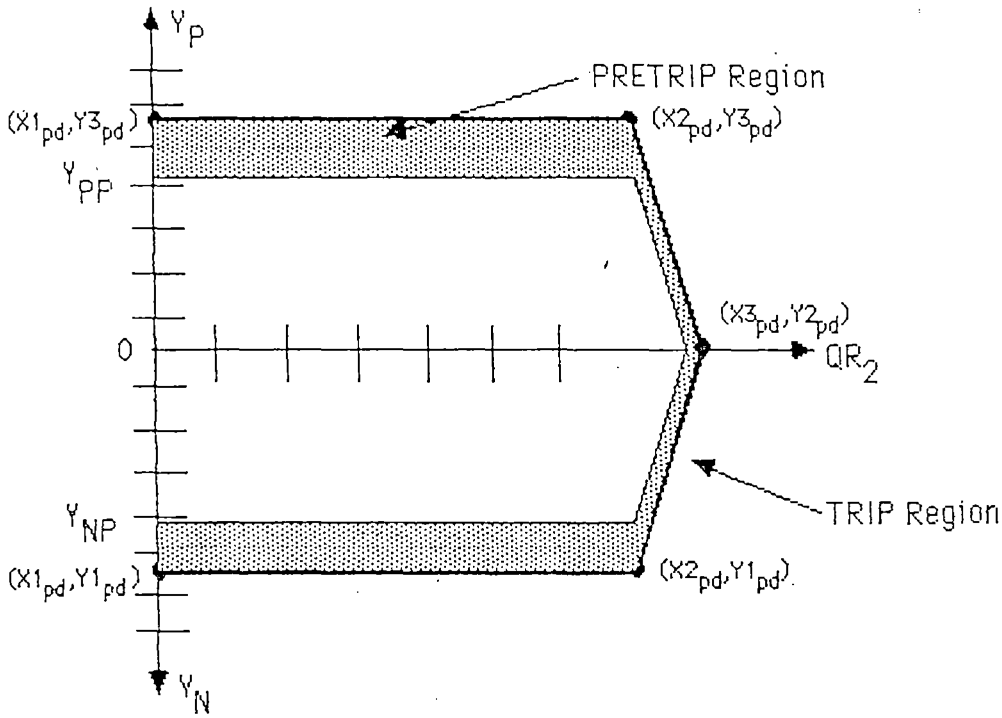
3.1.2.1 POWER DENSITY PRETRIP/TRIP PIECEWISE FUNCTIONS

There are four functions used to calculate the Power Density Pretrip/Trip function. These functions are piecewise linear since several connected line segments make up each function.

The $LPDF_p$ and $LPDF_n$ are actually the positive and negative "sides" of the <u>Local Power Density Function</u>. This function consists of four connected segments, two above and two below the X-axis. Thus the $LPDF_p$

functional value is based upon the positive portion of the function and the $LPDF_n$ functional value is based upon the negative portion of the function graph. This is depicted as follows:

LOCAL POWER DENSITY FUNCTION



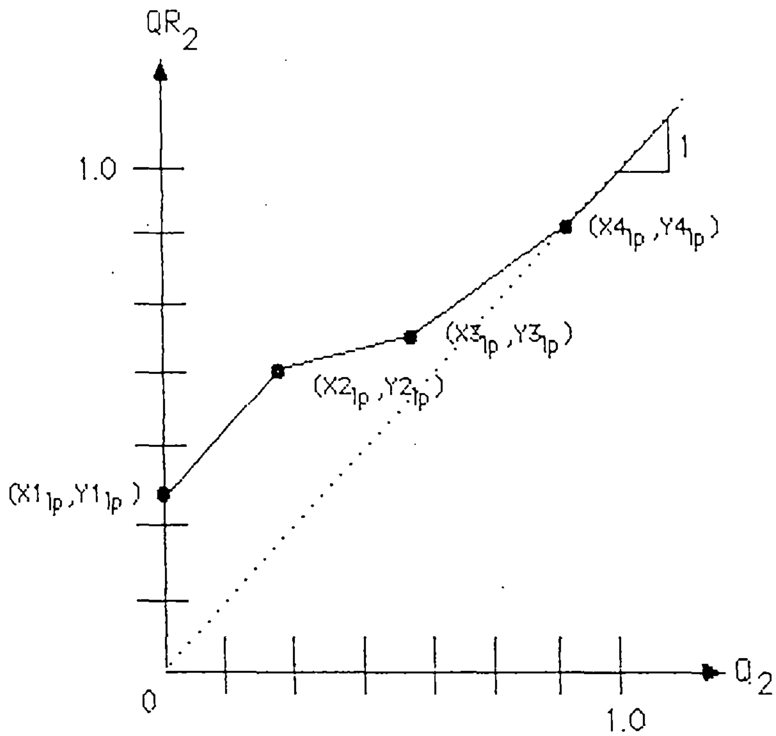
Note: $X2_{pd}$ must be less than or equal to $X3_{pd}$

The PRETRIP region is the shaded area and the TRIP region is anywhere outside the graph.

The line segment endpoints (Xi_{pd} , Yi_{pd}) are included in the internal parameter table and are Operator adjustable as described in section 3.1.2.4.

The third piecewise function is the Loca Peaking Function (LPF). The 1.0 "Q_2" value on the graph is equivalent to 100% power. This function consists of four connected line segments depicted as follows:

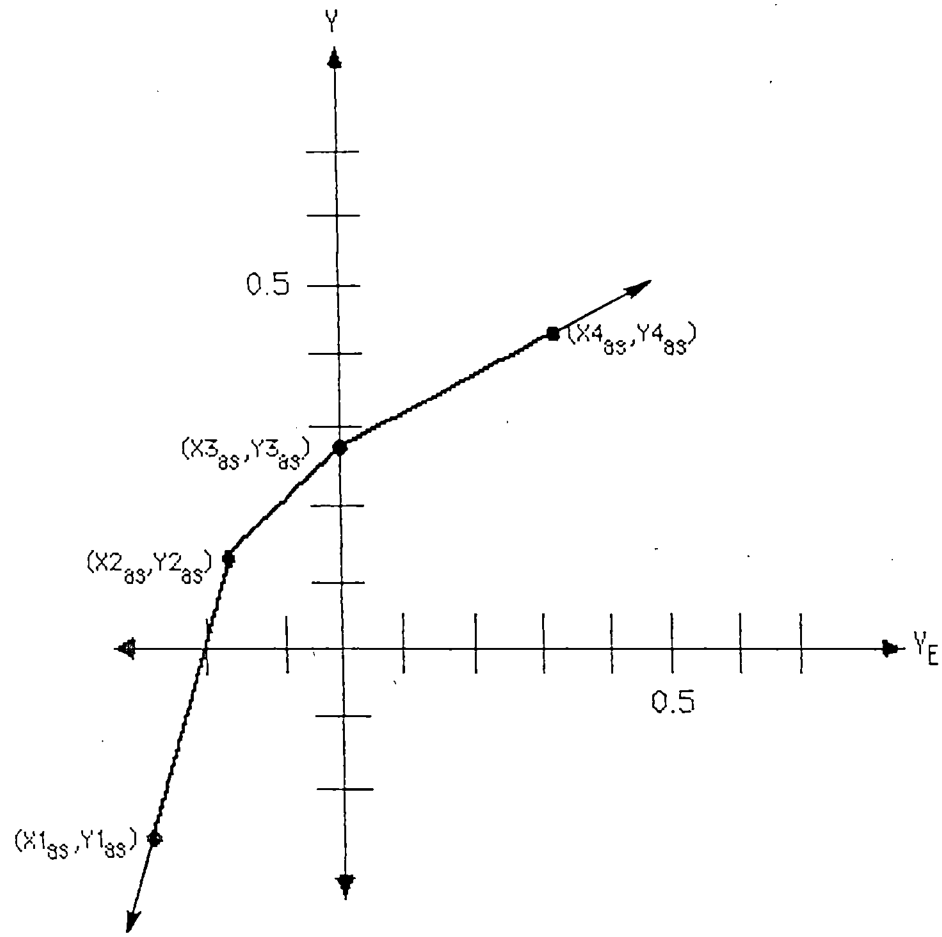
LOCA PEAKING FUNCTION



The line segment endpoints (Xi_{1p} , Yi_{1p}) are included in the internal parameter table and are Operator adjustable as specified in section 3.1.2.4.

The Axial Shape Index Function (ASIF) is a piecewise function consisting of three connected line segments:

ASI FUNCTION



The resulting Y value is called the "Axial Offset", and is compared with the positive and negative outputs of the Local Power Density Function. The Axial Shape Index Function is determined by the four points (Xi_{as}, Yi_{as}). These points are included in the internal parameter table and are Operator adjustable as described in section 3.1.2.4.

3.1.2.2 POWER DENSITY ANALOG INPUTS

Three analog input parameters are used in the Power Density Pretrip/Trip function: U, L, and ϕ. U and L are linear power readings and have a DC range of 0 to 10V corresponding to a power range of 0 to 125% power. ϕ is <u>calibrated nuclear power</u>, and has a DC range of 0 to 10V corresponding to a power range of 0 to 125% power. The analog inputs U and L are used in the calculation of "subchannel deviation" $Y_E = \left(\frac{L-U}{L+U}\right)$ and are used in the calculation of Y as defined in section 3.1.2. The input variable ϕ is used in the "Local Power Density Block" Function. For power levels below 15% calibrated nuclear power, Local Power density trips are inhibited.

3.1.2.3 POWER DENSITY DIGITAL OUTPUTS

Two digital outputs (contact closures) are provided for use with this function. These are the TRIP and PRETRIP contacts described in section 3.1.2.

3.1.2.4 POWER DENSITY OPERATOR ADJUSTABLE PARAMETERS

The endpoints used to make up the piecewise linear functions, the points determining the Linear Function, and the PRETRIP factor b are stored in the internal parameter table and can be adjusted by the Operator. The following is a list of the Operator adjustable parameters used in the Power Density pretrip/trip function:

PARAMETER	ADJUSTABLE RANGE	WHERE USED
$X1_{pd}$	0 to 0	Local Power Density Func.
$X2_{pd}$, $X3_{pd}$	0 to 2.0	Local Power Density Func.

$Y1_{pd}$	-1.0 to 0	Local Power Density Func.
$Y2_{pd}$	0 to 0	Local Power Density Func.
$Y3_{pd}$	0 to 1.0	Local Power Density Func.
b	0 to 1.0	Local Power Density Func.
$X1_{lp}$	0 to 0	Loca Peaking Function
$X2_{lp}$, $X3_{lp}$, $X4_{lp}$	0 to 1.2	Loca Peaking Function
$Y1_{lp}$, $Y2_{lp}$, $Y3_{lp}$, $Y4_{lp}$	0 to 1.2	Loca Peaking Function
$X1_{as}$, $X2_{as}$, $X3_{as}$, $X4_{as}$	-1.0 to 1.0	ASI Function
$Y1_{as}$, $Y2_{as}$, $Y3_{as}$, $Y4_{as}$	-1.0 to 1.0	ASI Function

3.1.3 TM/LP (P_{TRIP}) FUNCTION

The purpose of the Thermal Margin/Low Pressure function is to provide an analog output pressure signal P_{TRIP}, derived from an equation using temperature, power, and some Operator adjustable parameters used in piecewise linear functions. This analog output has a DC range of 10 to 50ma and corresponds to a pressure between 1500 and 2500 PSIA. P_{TRIP} is described mathematically as follows:

$P_{TRIP} = MAX\ (\ P_{VAR}\ ,\ P_{MIN}\ ,\ P_{ASGT}\ )$

$P_{VAR} = \lambda Q_{DNB} + \beta T_{CAL} + \gamma$

$Q_{DNB} = QR_1 * Q_A$

$T_{CAL} = T_C + K_C B$

$T_C = MAX\ (\ T_{C1}\ ,\ T_{C2}\ )$. Also used in the ΔT Power Function

B = Computed ΔT Power with a range of 0 to 1.25 equivalent to 0 to 125% Power.

$Q_A = AF\ (\ Y\ )$

Y = "Axial Offset" obtained from the ASI Function and is used in the Local Power Density Trip function.

$QR_1 = PPF\ (\ Q_1)$

$$Q1 = \begin{cases} \phi, \text{ if } \Delta T \text{ Power Block contact is } \underline{open} \\ MAX(\phi, \Delta T \text{ Power}), \text{ if } \Delta T \text{ Power Block contact is } \underline{closed} \end{cases}$$

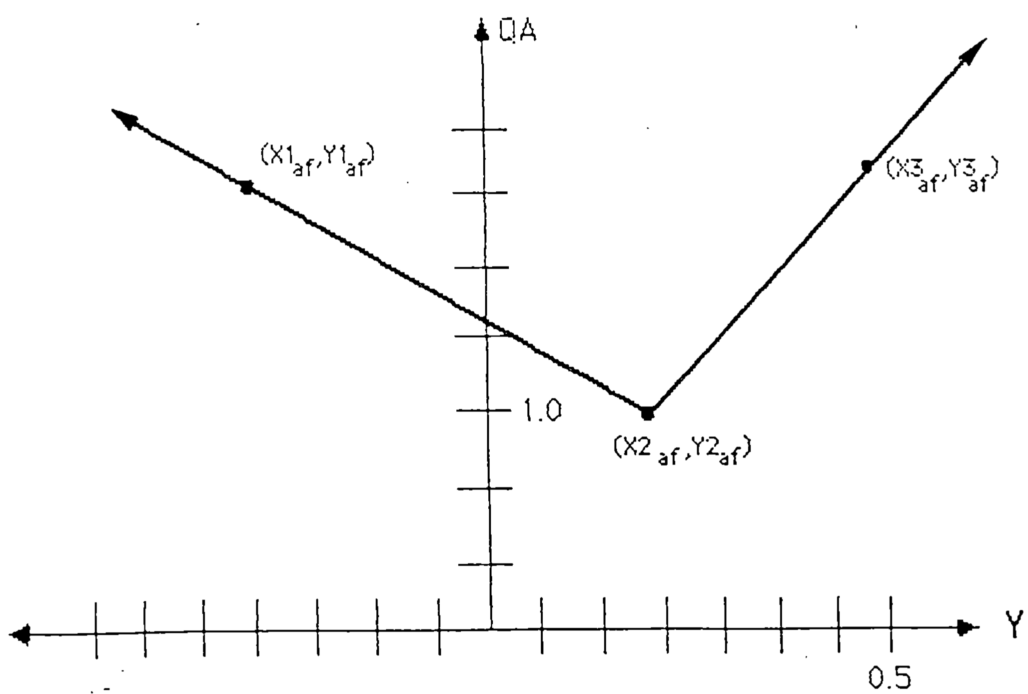
PPF and AF are piecewise linear functions described in section 3.1.3.1. λ, β, γ, P_{MIN}, and K_C are Operator adjustable constants described in section 3.1.3.5. P_{ASGT} is a pressure analog input described in section 3.1.3.3.

3.1.3.1 P_{TRIP} PIECEWISE FUNCTIONS

There are two piecewise linear functions used in the P_{TRIP} calculations- namely the <u>Axial Function</u> (AF) and the <u>Power Peaking Function</u> (PPF).

The <u>Axial Function</u> consists of two line segments, which meet at a vertex:

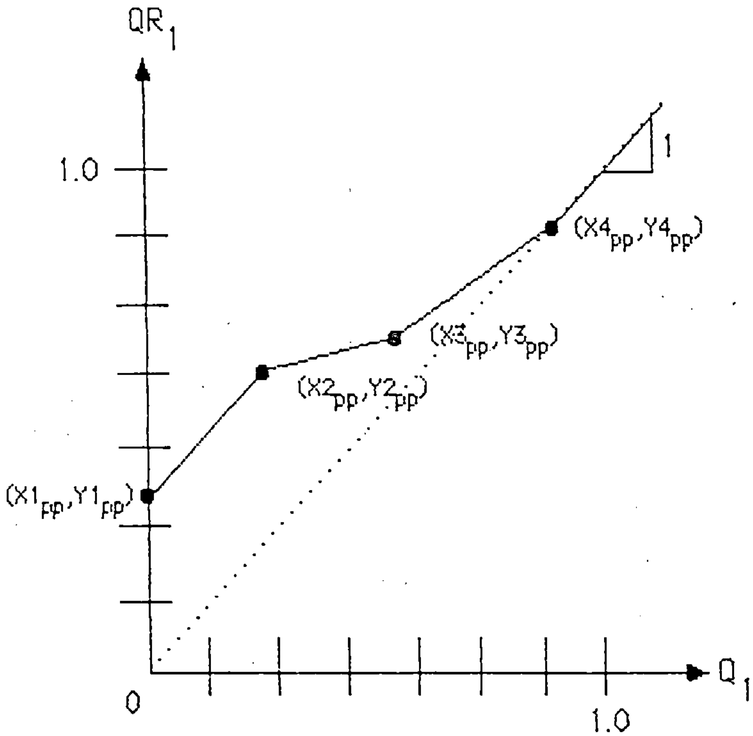
AXIAL FUNCTION



The two lines are determined by three points- one of which is the vertex ($X2_{af}$,1). All three points are included in the internal parameter table and are Operator adjustable as specified in section 3.1.3.5.

The Power Peaking Function 1.0 "Q_1" axis value corresponds to 100% power. This function consists of four connected segments :

POWER PEAKING FUNCTION



The line segment endpoints (Xi_{pp} , Yi_{pp}) are included in the internal parameter table and are Operator adjustable as described in section 3.1.3.5.

3.1.3.2 P_{TRIP} ANALOG OUTPUT

A single analog output "P_{TRIP}" is provided by this function. The P_{TRIP} analog output has a DC range of 10 to 50 mA which corresponds to a pressure range of 1500 to 2500 PSIA.

3.1.3.3 P_{TRIP} EXTERNAL ANALOG INPUTS

The calibrated nuclear power input ϕ is used by this function. ϕ is the same signal described in section 3.1.2.2. which has a DC range of 0 to 10V corresponding to a power range of 0 to 125% power. This function indirectly uses T_{C1}, T_{C2}, and T_HAVE as used by the ΔT Power Function, which is described in section 3.1.1.1.

In addition, P_{ASGT} is used in the MAX select portion. P_{ASGT} has a DC range of 0 to 10 V corresponding to a pressure range of 1500 to 2500 PSIA.

3.1.3.4 P_{TRIP} EXTERNAL DIGITAL INPUTS

One external digital input (contact closure) is sensed for this function, namely the ΔT Power Block. This contact can be either open or closed and is controlled by existing plant equipment. The ΔT Power Block contact is closed at $\geq 10^{-4}$% power.

3.1.3.5 P_{TRIP} OPERATOR ADJUSTABLE PARAMETERS

The endpoints used to make up the piecewise linear functions and the various multipliers used in this function are stored in the internal parameter table and can by modified by the Operator. The following is a list of the Operator adjustable parameters used in the P_{TRIP} function:

PARAMETER	ADJUSTABLE RANGE	WHERE USED
$X1_{pp}$	0 to 0	Power Peaking Func.
$X2_{pp}$, $X3_{pp}$, $X4_{pp}$	0 to 1.2	Power Peaking Func.
$Y1_{pp}$, $Y2_{pp}$, $Y3_{pp}$, $Y4_{pp}$	0 to 1.2	Power Peaking Func.
$X2_{af}$	-0.5 to 0.5	Axial Function
$X1_{af}$	-1.0 to 0	Axial Function
$X3_{af}$	0 to 1.0	Axial Function
$Y2_{af}$	1.0 to 1.0	Axial Function
$Y1_{af}$, $Y3_{af}$	1.0 to 2.0	Axial Function
K_C	0 to 0.1	TM/LP P_{TRIP} Function
β	10 to 30	TM/LP P_{TRIP} Function
λ	1000 to 3000	TM/LP P_{TRIP} Function
γ	-13000 to -4000	TM/LP P_{TRIP} Function
P_{MIN}	1500 to 2000	TM/LP P_{TRIP} Function

See Appendix A for the complete Internal Parameter Table.

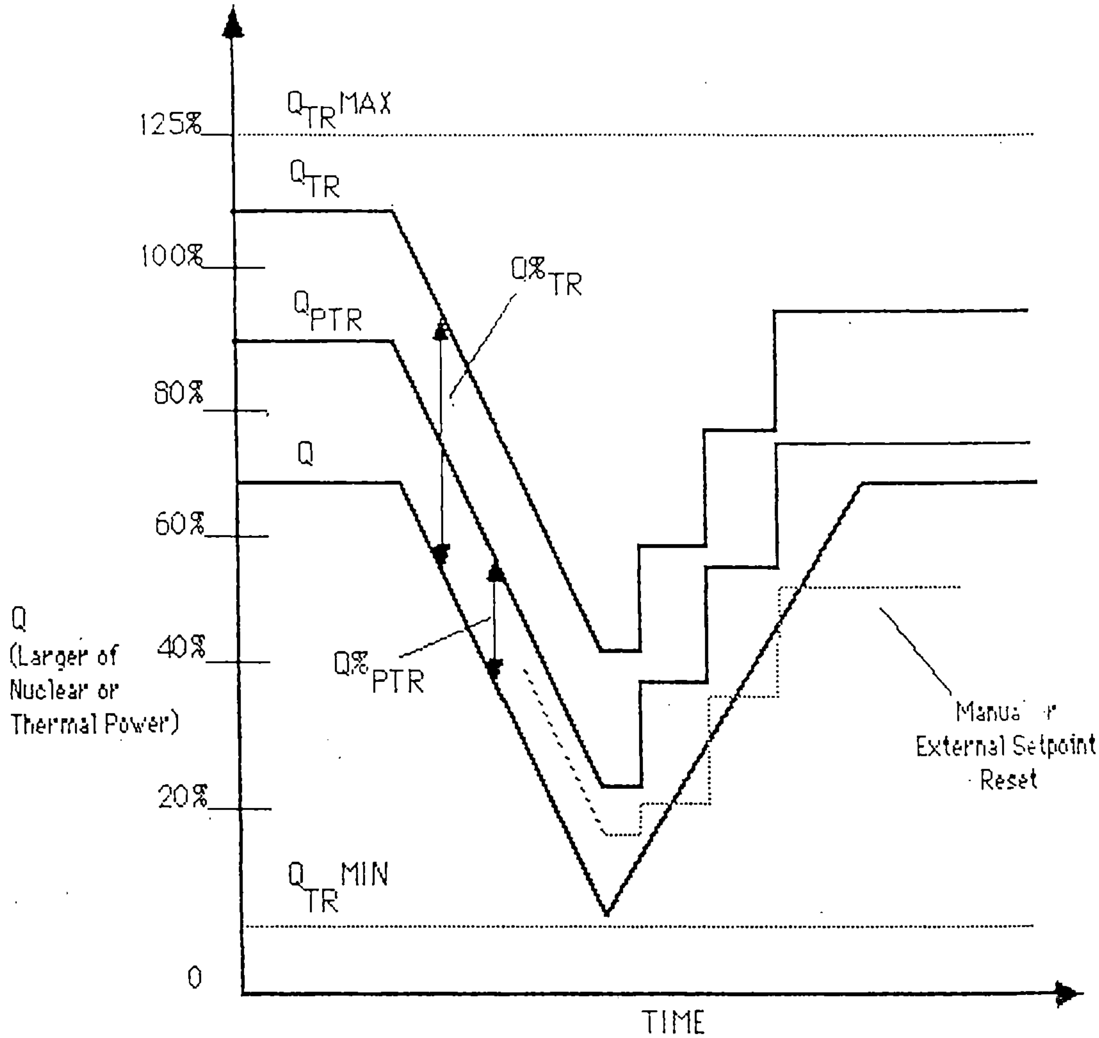
3.1.4 METER RELAY ANALOG OUTPUT

An additional parameter "ϕ-B" is calculated every 100 milliseconds and is provided as a TMM analog output, at the rear of the device. "ϕ" is calibrated nuclear power and B is the calculated ΔT Power. "ϕ-B" has a DC range of 0 to 10.0 V corresponding to a power deviation span of -10.0% to +10.0%.

3.1.5 VARIABLE HIGH POWER TRIP ALARM (VHPT)

A Dynamic alarm monitoring system is provided which gives trip signals based upon "Q", which is the maximum of ΔT Power or Nuclear Power (see figure below). The alarm monitor calculations are performed every 100 milliseconds. Q is measured against the two setpoints Q_{PTR} and Q_{TR}. Q_{PTR} is the Q Pretrip alarm level which is set to a percentage "$Q\%_{PTR}$" above the current Q value. Q_{TR} is the Q Trip alarm level which is set to a percentage "$Q\%_{TR}$" above Q. Q_{PTR} is between Q and Q_{TR} (e.g. $Q \leq Q_{PTR} \leq Q_{TR}$). In addition, Q_{TR} is constrained to be between Q_{TR}MIN and Q_{TR}MAX. Q_{TR}MIN, Q_{TR}MAX, $Q\%_{TR}$, and $Q\%_{PTR}$ are Operator adjustable parameters.

VARIABLE HIGH POWER TRIP ALARM



The VHPT Alarm provides two contact closures for use by Plant equipment. The first contact, "Q_{PCC}," is opened (tripped) when Q rises above the Pretrip setpoint Q_{PTR}. The second contact, "Q_{TCC}," is opened (tripped) when Q rises above the Trip setpoint Q_{TR}. These contacts will be reset (closed) when Q falls below the corresponding Trip or Pretrip deadband. These deadbands are set to 0.5% below the current Q_{TR} and Q_{PTR} values. The contact closures will open/close <u>without</u> Operator intervention.

As the power level "Q" is dropping, both the Q_{PTR} and Q_{TR} limits will be updated, and will track Q using the corresponding $Q\%_{PTR}$ and $Q\%_{TR}$ values. As Q is rising, the Q_{TR} and Q_{PTR} values will remain fixed at their current levels until either the Operator presses the SETPOINT RESET pad on the TMM front panel or an EXTERNAL SETPOINT RESET is received. If Q_{TR} reaches Q_{TR}MAX, then Q_{PTR} will not rise any further. The External reset is provided from existing Plant equipment and is a "digital input" to the TMM. The setpoint cannot be reset at all when the alarm is in the TRIP condition. In addition, the Operator must wait at least ten seconds between subsequent alarm resets. The TMM will deactivate the reset capability for ten seconds following an Operator TMM reset.

3.1.5.1 VHPT ALARM ANALOG INPUTS

A single analog input "ϕ" is used in the dynamic alarm system. This is calibrated nuclear power and has a DC range of 0 to 10V corresponding to a power range of 0 to 125% power.

3.1.5.2 VHPT ALARM DIGITAL OUTPUTS

Two digital outputs (contact closures) Q_{PCC} and Q_{TCC} are provided. These are used to signal other equipment of the alarm condition.

3.1.5.3 VHPT ALARM ANALOG OUTPUTS

A signal proportional to Q_{TR} is output to the VHPT setpoint analog output.

3.1.5.4 VHPT ALARM DIGITAL INPUTS

A single digital input is used as the External Setpoint Reset. This input will be connected to a momentary push button switch, external to the TMM.

3.1.5.5 VHPT ADJUSTABLE PARAMETERS

The following is a list of the Operator adjustable parameters used by the VHPT Alarm :

PARAMETER	ADJUSTABLE RANGE
$Q\%_{TR}$	0 to 20% above Q
$Q\%_{PTR}$	0 to 20% above Q
$Q_{TR}MIN$	0 to 50% Power
$Q_{TR}MAX$	0 to 125% Power

3.1.6 HISTORICAL TRENDING

The TMM performs a seven day historical trending of ten parameters. Specifically those parameters tracked are 1) Axial Offset, 2) Diff Output, 3) Q_{DNB}, 4) QA, 5) QR_1, 6) QR_2, 7) T_C, 8) T_HAVE, 9) P_{TRIP}, and 10) P_{VAR}. The system will archive each parameter once per hour. This hourly data is saved for the most recent 24 hours. The data for hours divisible by four is saved for the most recent 7 days.

In summary, the archive maintains a FIFO queue of the latest 24 hours of data (once per hour) as well as a FIFO queue of the last 7 days of data (once per four hours).

The TMM will continually track all ten parameters internally, but only four parameter tables can be displayed on a single screen. The Operator can dynamically select which four he wishes to display. All the entries in each table will be time and date stamped for clarity.

3.1.7 ON-LINE SYSTEM TESTING

The GAMMA-METRICS TMM software provides for three types of system testing. A test is performed automatically by the TMM upon initial powerup or system reset. The second test feature allows the Operator to initiate system test functions with the TMM in an off-line state. In addition, ROM and RAM testing is carried on as a background task during normal mode operation.

3.1.7.1 POWERUP INITIAL TEST

A self-test is performed by the system automatically upon power up or system reset (via the rear panel reset button). This self-test consists of a volatile system memory test as well as a checksum test of the system PROMs. The self-test will not take longer than ninety seconds. If any problems are encountered, the TMM will attempt to write a diagnostic message on the display and then will "trip" to a fail-safe condition, as described in section 3.2.2.2. If no problems are found, the TMM will function normally and no error messages will be written to the display.

3.1.7.2 OPERATOR INITIATED SELF-TEST

The Operator can initiate various TMM self tests by switching Keylock# 1 into the TEST position. When the TMM is put into self test mode, all primary functions are disabled. In this mode the Operator can select among a menu of tests displayed on the screen. These tests include 1) An analog I/O test, 2) A digital I/O test, and 3) A keypad test. Results of each test are displayed on the TMM screen.

3.1.7.2.1 ANALOG I/O TEST

The analog I/O test is used to verify the operation of all the analog inputs and outputs which are accessible from the rear panel. This test will set the "ϕ-B" analog output to 7.5 VDC and the P_{TRIP} output to 25mA. The display will also indicate as DC voltages, the readings of T_{C1}, T_{C2}, T_{H}AVE, U, L, and ϕ analog inputs.

3.1.7.2.2 DIGITAL I/O TEST

The digital I/O test will verify the operation of all the digital inputs and outputs accessible from the TMM rear panel. The Operator can select any digital output and set its state to open or closed. Required digital outputs are LPD/PRETRIP, LPD/TRIP, Q_{TCC}, Q_{PCC}, and T_{CC}. The TMM will also display the current state of the VHPT Alarm Setpoint Reset and ΔT Power Block digital inputs as open or closed.

3.1.7.2.3 KEYPAD TEST

The keypad test allows the Operator to verify the functionality of the keypad. In this test the Operator connects the keypad to the TMM and presses the various keys. If the keypad is functional, then the corresponding numbers and characters will be displayed on the screen.

3.2 NON-FUNCTIONAL REQUIREMENTS

Non-Functional requirements discuss the various constraints placed on the system by either Consumers Power Company or GAMMA-METRICS. This specification will cover Interface, Performance, Operating, and Life-Cycle Constraints.

3.2.1 INTERFACE CONSTRAINTS

The interface constraints define the way the TMM and its environment interact. The TMM environment consists of the Operators, the TMM hardware and the TMM software.

3.2.1.1 TMM OPERATORS

The TMM needs <u>no Operator intervention</u> to perform its normal operating functions. These functions are:

1) ΔT Power calculation
2) T_C Alarm Function
3) Power Density Pretrip/Trip Function
4) TM/LP P_{TRIP} Function
5) Meter Relay "ϕ-B" output
6) VHPT Pretrip/Trip function

The Operator may view the various displays at will, but needs a key to modify any of the internal constants. The Operator interacts with the TMM hardware by viewing the display, switching between displays, and by adjusting parameters using the keypad.

3.2.1.2 TMM HARDWARE

The TMM hardware is contained in a 19" rack chassis and includes an embedded computer system, a front panel display, a keypad, two keylocks, four front panel selection keys, and a system reset button located on the rear panel.

For a detailed description of the TMM hardware requirements, see the GAMMA-METRICS document <u>THERMAL MARGIN MONITOR HARDWARE SPECIFICATION</u>.

3.2.1.2.1 TMM EMBEDDED COMPUTER

The embedded computer system is the "core" of the TMM. The computer must react quickly and correctly to the various external and internal events. The computer is microprocessor based and is <u>dedicated</u> to the execution of the TMM software programs.

3.2.1.2.2 FRONT PANEL CRT DISPLAY

The front panel screen is not only used to display the various items such as ΔT Power, VHPT Alarm, and the adjustable constants, but also to verify the operation of the unit by displaying test results. This display will augment the TMM basic functions by providing real-time visual feedback; however, the TMM can perform its <u>basic</u> functions without any CRT screen display.

3.2.1.2.3 KEYPAD

The removable keypad will be used for the entry or alteration of the internal constants. The keypad will contain both numbers and characters (alphanumeric) so that various numeric parameters can be entered in both standard and scientific notation. In addition, the keypad will contain keys for "Enter" and "Clear." Note that the internal constants can only be changed if the Operator has Keylock#1 in the "DATA MODIFY" position as described below.

3.2.1.2.4 KEY SWITCHES

Two Chicago-Lock style, key switches will be available at the front panel. Key switch#1 is used to select between three operation modes: TEST, NORMAL, and DATA MODIFY. The key will be removable <u>only</u> in the NORMAL position. The NORMAL position is the standard position for the TMM - the TMM will perform its functions and update its display without Operator intervention. The TEST position is used for Operator initiated TMM self tests. The DATA MODIFY position allows the Operator to adjust any of the internal constants by using the keypad.

Key switch#2 has two defined positions: 4 PUMP and 3 PUMP. The 4 PUMP is the standard position for normal operation of the TMM. The 3 PUMP position causes the TMM to use a <u>seperate set</u> of adjustable constants. The Operator can switch between either position at any time; however, no action will be taken unless Keyswitch#1 is in the DATA MODIFY position.

3.2.1.2.5 SELECTION KEYS

There are four selection keys on the TMM front panel. These keys are not directly labelled in that their functions are defined by text on the TMM screen. The selection keys are located directly beneath the CRT display. The corresponding text labels are placed at the bottom of the CRT display, directly above each key. These keys will be used to switch between displays, select menu options, reset alarm conditions, and to scroll tabular data.

3.2.1.3 TMM SOFTWARE

The TMM software consists of the main program software and the Operating System software. Both portions will be placed in firmware or non-volatile memory. All the software in the TMM is encoded as binary numbers as required by the embedded computer system.

The main program software causes the TMM to perform all its functions. This software will be developed by GAMMA-METRICS. This software is automatically invoked (executed) by the TMM upon a system RESET or powerup.

The Real-Time Executive software supports the main program software by providing an interface to the system hardware. The Executive Software will be multitasking to allow for optimal use of the microprocessor resource as well as to provide synchronization of the various tasks in the system software.

3.2.2 PERFORMANCE CONSTRAINTS

The TMM performance constraints include throughput rates and operation of the TMM during a TMM hardware failure.

3.2.2.1 THROUGHPUT RATES

The most critical items are the normal operating functions described in section 3.2.1.1. The Delta T Power and TC alarm functions are repeated once per second. The other functions must be performed every 100 milliseconds. Secondary to this is the updating of the various displays. Any display which is providing dynamic information will be updated every several seconds, although the actual calculations are performed more frequently.

3.2.2.2 SYSTEM POWER CYCLING BEHAVIOR

The RAM memory, in which the operator adjustable parameters are stored, has its own batteries, and will be normally retain these values when power is off. When power is resumed an integrity check of this data will be performed. If the data is not valid, it will be replaced with a default set of values stored in nonvolatile memory.

When the computer system has no power, the digital outputs will be in a high resistance state and will therefore be seen as in the open circuit condition by external hardware. Similarly, the P_{trip} analog output will not generate any current. External hardware may interpret this as a zero reading or an error condition.

3.2.2.3 REPEATABILITY

The TMM reads external inputs (e.g. temperatures, pressures) and uses a microcomputer to perform the various calculations based upon the inputs. If the inputs remain unchanged, the TMM will perform the successive calculations with $\pm$0.1% repeatability, with the exception of "ϕ-B" calculations which have $\pm$0.5% repeatability.

3.2.3 OPERATING CONSTRAINTS

The Operating.Constraints include available Keyswitch data entry techniques, Operator Skill level considerations, and Front panel component spatial distribution. For environmental specifications see GAMMA-METRICS document - THERMAL MARGIN MONITOR HARDWARE SPECIFICATION.

3.2.3.1 KEYPAD DATA ENTRY

The keypad supplied allows the Operator to modify the internal system constants. The Operator gains security access to these parameters by using Keylock# 1. Any numerical data entered with the keypad may be in standard decimal or scientific notation form.

3.2.3.2 OPERATOR SKILL LEVEL CONSIDERATIONS

The TMM display can be viewed by any appropriate plant personnel. Privledges to use the front panel switches and to alter any internal parameters should be given only to those who are qualified to use such nuclear instrumentation.

3.2.3.3 ERGONOMIC FACTORS

All the front panel controls will be laid out in functionally similar groups, so that the Operator need not focus on two seperate areas of the panel when using the device. The primary display (ΔT Power and VHPT Setpoint) will be viewable from a distance of 20 feet. In addition, the various screen layouts will be designed to minimize eye movement. The NUREG 0700 standard will be used as a guideline for CRT display design whenever feasable, as determined by GAMMA-METRICS.

3.2.4 LIFE-CYCLE CONSTRAINTS

The life-cycle constraints for the TMM include System Maintainability, and Resource Availability. In addition, the Methodological standards including Design Techniques, Software Quality Assurance, Validation and Verification, and Programming Standards will be stated herein and followed for the duration of this project.

3.2.4.1 MAINTAINABILITY

The software system will be maintained by qualified GAMMA-METRICS Software Engineers and Programmers. The software will be written in a microcomputer dialect of the PASCAL programming language. The programmers will use the standard language features whenever possible to enhance portability and maintainability. Program documentation including source code comments and pseudocode will be maintained by GAMMA-METRICS.

3.2.4.2 RESOURCE AVAILABILITY

All software will be designed, written, and maintained by GAMMA-METRICS Software Engineers and Programmers. Software Validation will be performed by qualified software professionals not involved in either the software design or development phases. These personnel may or may not work for GAMMA-METRICS. For further information regarding Validation and Verification, see doc# IEEE-ANS-7-4.3.2-1982.

3.2.4.3 VALIDATION AND VERIFICATION (V&V)

V&V will be performed in accordance with section 6 and 7 of document number IEEE-ANS-7-4.3.2-1982 and the Software Quality Assurance Plan. Software Verification will be performed from the Requirements phase to the Hardware/Software Integration Phase. Validation will be performed on the computer system as a whole, in accordance with a formal test plan. Verification is performed by individuals who did not participate in the system design. Validation is performed by individuals who did not participate in the design or implementation.

3.2.4.4 PROGRAMMING STANDARDS

GAMMA-METRICS software personnel will code most of the system using Intel Pascal86. To achieve higher speed and a better interface to the TMM hardware, certain modules will be written in assembly language. These assembly language modules will be documented to include register usage and pseudocode for complex functions. For more detailed programming standards, see the TMM SOFTWARE QUALITY ASSURANCE PLAN.

APPENDIX A
OPERATOR ADJUSTABLE PARAMETERS

PARAMETER	ADJUSTABLE RANGE	WHERE USED
$K\beta$	1×10^{-6} to 5×10^{-3}	ΔT Power Calculation*
$K\gamma$	-1×10^{-5} to 1×10^{-5}	ΔT Power Calculation*
$K\alpha$	3×10^{-2} to 1×10^{-3}	ΔT Power Calculation*
a	0 to 10.0	ΔT Power Calculation*
τ	0 to 1.0	ΔT Power Calculation*
BIAS	-0.10 to 0.10	ΔT Power Calculation*
TIME CONSTANT	1 to 30	ΔT Power Calculation
T_CMAX	515 to 700°F	T_C Alarm Function
T_CMIN	0 to 600°F	T_C Alarm Function
$X1_{pd}$	0 to 0	Local Power Density Func.
$X2_{pd}$, $X3_{pd}$	0 to 2.0	Local Power Density Func.
$Y1_{pd}$	-1.0 to 0	Local Power Density Func.
$Y2_{pd}$	0 to 0	Local Power Density Func.
$Y3_{pd}$	0 to 1.0	Local Power Density Func.
b	0 to 1.0	Power Density Pretrip/Trip
$X1_{lp}$	0 to 0	Loca Peaking Function
$X2_{lp}$, $X3_{lp}$, $X4_{lp}$	0 to 1.2	Loca Peaking Function
$Y1_{lp}$, $Y2_{lp}$, $Y3_{lp}$, $Y4_{lp}$	0 to 1.2	Loca Peaking Function
$X1_{as}$, $X2_{as}$	-1.0 to 1.0	ASI Function
$X3_{as}$, $X4_{as}$	-1.0 to 1.0	ASI Function
$Y1_{as}$	-1.0 to 1.0	ASI Function
$Y2_{as}$, $Y3_{as}$, $Y4_{as}$	-1.0 to 1.0	ASI Function
$X1_{pp}$	0 to 0	Power Peaking Func.
$X2_{pp}$, $X3_{pp}$, $X4_{pp}$	0 to 1.2	Power Peaking Func.
$Y1_{pp}$, $Y2_{pp}$, $Y3_{pp}$, $Y4_{pp}$	0 to 1.2	Power Peaking Func.
$X1_{af}$	-1.0 to 0	Axial Function
$X2_{af}$	-0.5 to 0.5	Axial Function
$X3_{af}$	0 to 1.0	Axial Function
$Y1_{af}$, $Y3_{af}$	1.0 to 10	Axial Function

$Y2_{af}$	1.0 to 1.0	Axial Function
K_C	0 to 0.1	TM/LP P_{TRIP} Function*
β	10 to 30	TM/LP P_{TRIP} Function*
λ	1000 to 3000	TM/LP P_{TRIP} Function*
γ	-13000 to -4000	TM/LP P_{TRIP} Function*
P_{MIN}	1500 to 2000	TM/LP P_{TRIP} Function
$Q\%_{TR}$	0 to 20% above Q	VHPT Alarm Function
$Q\%_{PTR}$	0 to 20% above Q	VHPT Alarm Function
$Q_{TR}MIN$	0 to 50% Power	VHPT Alarm Function
$Q_{TR}MAX$	0 to 125% Power	VHPT Alarm Function

*These parameters can be entered outside their adjustable range after a warning message is issued by the TMM.

APPENDIX B
ANALOG AND DIGITAL I/O

PARAMETER	TYPE	VOLTAGE RANGE	WHERE USED
T_{C1}	ANALOG INPUT	1 to 5VDC	ΔT Power Calc.
T_{C2}	ANALOG INPUT	1 to 5VDC	ΔT Power Calc.
$T_H AVE$	ANALOG INPUT	1 to 5VDC	ΔT Power Calc.
L	ANALOG INPUT	0 to 10VDC	High/Low Trip Func.
U	ANALOG INPUT	0 to 10VDC	High/Low Trip Func.
ϕ	ANALOG INPUT	0 to 10VDC	High/Low Trip Func.
P_{ASGT}	ANALOG INPUT	0 to 10VDC	TM/LP P_{TRIP} Func.
P_{TRIP}	ANALOG OUTPUT	10 to 50 mADC	TM/LP P_{TRIP} Func.
ϕ-B	ANALOG OUTPUT	0 to 10VDC	Meter Relay Output
VHPT Setpoint	ANALOG OUTPUT	0 to 10VDC	VHPT Alarm
ΔT Power Block	DIGITAL INPUT	0VDC/5VDC	TM/LP P_{TRIP} Func.
Ext Setpt. Reset	DIGITAL INPUT	0VDC/5VDC	VHPT Alarm
T_{CC}	DIGITAL OUTPUT	0VDC / 5VDC	T_C Alarm Function
LPD/PRETRIP	DIGITAL OUTPUT	0VDC / 5VDC	High/Low Trip Func.
LPD/TRIP	DIGITAL OUTPUT	0VDC / 5VDC	High/Low Trip Func.

Q_{PCC}	DIGITAL OUTPUT	0VDC/5VDC	VHPT Alarm
Q_{TCC}	DIGITAL OUTPUT	0VDC/5VDC	VHPT Alarm

SOFTWARE
DESIGN DESCRIPTION

THERMAL MARGIN MONITOR

CONSUMERS POWER COMPANY

Palisades

DOCUMENT #089

GAMMA-METRICS
5550 Oberlin Drive
San Diego, CA 92121

(619) 450-9811

Revision No. 3
July 09, 1986

EQUIPMENT WARRENTY

Unless otherwise agreed in writing between the parties, the following warranty terms and conditions apply.

(a) Warranty. GAMMA-METRICS warrants to the Buyer that the equipment is free from defects in design, material, and workmanship.

(b) Warranty period. GAMMA-METRICS warranty is in effect for one year after shipment to the Buyer. For items which, under normal industry practice, have a shorter warranty period, the applicable warranty period shall be such shorter period. Such items shall include, but not be limited to: light bulbs, fuses, gaskets, photo-multipliers, tubes, disposable items, and all components with a specified wear-out period.

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1.0 SCOPE

The purpose of this document is to present a software design description (SDD) of the GAMMA-METRICS Thermal Margin Monitor (TMM) to the software development team. This document initially provides a system overview. and the software implementation is discussed at a high level with the description of the tasks to be used in the multitasking system. Descriptions of the important supporting procedures and functions are included, as well as descriptions of the data structures used. Finally, the system displays are described.

2.0 APPLICABLE DOCUMENTS

These documents were used in preparation of this document:

1) Consumers Power Company document J-54.
2) Consumers Power Company document LOGIC FOR TM/LP TRIP drawing 8-JL-130 sheet 1.
3) AMMA-METRICS document #055 - THERMAL MARGIN MONITOR SOFTWARE REQUIREMENTS SPECIFICATION.
4) GAMMA-METRICS document #056 - THERMAL MARGIN MONITOR HARDWARE REQUIREMENTS SPECIFICATION.
5) GAMMA-METRICS document #073 - TMM HARDWARE/SOFTWARE INTEGRATION REQUIREMENTS.

3.0 SYSTEM OVERVIEW

The GAMMA-METRICS Thermal Margin Monitor is a self-contained, microprocessor based, 19" rack-mounted product which is targeted to replace the existing DeltaT and TM/LP (Thermal Margin/Low Pressure) calculators at the Palisades Nuclear Power Plant. The system hardware features a data entry keypad, a video display, two security keyswitches, and four menu selection keys (softkeys or function keys). The front panel layout has been designed for ease of use.

The TMM embedded computer program provides those functions described in Consumers Power Co. drawing JL-130. The TMM's primary function is to repeatedly calculate DeltaT Power, Power Density pretrip/trip, TM/LP Ptrip and the Variable High Power Trip. The results of these calculations affect the TMM's graphic display as well as the digital and analog outputs.

The TMM will operate in three basic modes as indicated by the mode select keyswitch: 1) Normal, 2) Test, and 3) Data Modify. The standard mode of operation is Normal, in which the TMM performs all the safety functions listed in the TMM Software Requirements Specification (SRS). The operator can view the results of these functions on the CRT display and can change displays by pressing the function keys.

With the Mode Select keyswitch in the "Test" position, the TMM disables all safety functions and calculations. In this mode, the operator can run tests on the TMM hardware including the analog I/O, digital I/O, memory, and keys. The test results are displayed on the CRT.

The "Data Modify" mode is used to change the Operator Adjustable parameters for either the 3 or 4 pump configuration. The safety functions and calculations are disabled in this mode. In addition, the operator can change the real-time clock time and date. In data modify mode, all numeric data is entered via the data entry keypad. This is the only mode in which the keypad is used by the operator. By switching the Pump Select Key from 3Pump to 4Pump, while in Data Modify mode, the operator may select the "pump configuration" which will subsequently be used in normal mode.

The TMM software used to perform these functions is multi-tasking and executes under the VRTX86 real-time executive. Five tasks will execute in real time to handle the calculations, front panel controls, graphics display, trend data capture, and real-time diagnostics.

For further details on the TMM requirements and functions refer to the Software Requirements Specification (SRS). Portions of that document are to be considered a part of this design, namely the mathematical formulas described therein. Many of those formulas constitute algorithm designs that are directly implementable in Pascal source code.

The software is mostly written in PASCAL86; appropriate portions are in ASM86. (These are both products of INTEL Corporation.) Floating point math calculations are performed by INTEL's software emulation of their 8087 processor. The software also includes the VRTX real-time executive, a product of Hunter & Ready, Inc.

3.1 Global Variables and data structures

The calculation tasks produce many results which are needed by the operator and trend tasks (see below). The required communication will be accomplished by the use of global data which is accessible to all of the tasks. Only one task will be allowed to alter the contents of each global variable, but any task may read them.

Global Data:

The operator adjustable parameters

The results of the calculation tasks

Trend Archive tables and indices (see Trend Storage task)

VRTX "mailboxes" for intertask signaling

State variables, which must persist between procedure calls

The Parameter Table consists of two arrays, one for each pump configuration. Each of these is an array of records, one record for each parameter. Each record consists of: a) the current value of the parameter, b) the minumum Value of the parameter, and c) the maximum value. The Parameter Table is separate from the working set of parameters. Those are individual variables; they are loaded from the Parameter Table. The Parameter Table is modified by the Modify Parameters procedure. (see data flow diagram)

The Name Table is an array of character strings, one string for each parameter. The strings will be loaded at cold start time with the names of the parameters. An asterisk character will be in position ten for those parameters that are allowed to be outside of the range specified by the minimum and maximum values in the Parameter Table.

3.2 Integer Arithmetic and Scaling

Integer arithmetic, even with 32-bit integers, is about one hundred times faster than Intel's floating point math library, which is why it is used for the Neutron Task calculations. In order to succeed with this approach each integer variable must have a range of values which is small enough to not cause overflow in math operations, while large enough to have good resolution, or accuracy. This is achieved by the careful choice of a scale factor for every quantity that is represented by an integer variable. In each case we choose the scale factor so that the maximum value of the variable is about 32,000. This gives us very good resolution, while ensuring that the product of two such variables will still be within the 32-bit range. A pair of examples may be sufficient to illustrate this:

maximum power = 1.25. let MAXINT represent 1.25, then the scale factor equals 32,767 / 1.25 = 26213.6. (MAXINT = 32,767)

maximum pressure = 2500. let MAXINT represent 2500, then the scale factor equals 32,767 / 2500 = 13.107.

Two convert a floating point value to a long integer we multiply by the scale factor, and then round the result. To convert a long integer to floating point we divide by the scale factor.

Where 16-bit integers are used, a unique scale factor must be chosen. For this project a factor of eight happens to be ideal for converting between long and short integer forms of the same value. This is because the 16-bit versions arise only where ADC or DAC data is involved. This data has a maximum value of 4095, which is one eighth of MAXINT, to a high degree of accuracy. Hence, to produce the long integer form of Phi, which is a power quantity, we merely multiply the input value by 8.

With integer math, we cannot multiply by a decimal fraction, nor can we divide without serious loss of precision. Both of these problems are handled by the use of a function which we will name FracFinder. This function multiplies a given number by a given numerator, and then divides by a given denominator. We can then multiply by fractions as long as we create an explicit numerator and denominator rather than using a decimal fraction. The same holds for division. In both cases the result may require a different scale factor than the original number in order to avoid truncation error while keeping the multiplication step from overflowing the 32-bit range.

3.3 Smoothing of Analog Input Noise

In order to have more stable outputs in the presence of analog input noise, the low level routines which read the ADC inputs will actually use the ADC several times in rapid succession, and the return the average of the values read. The readings will be far enough apart so that their noise components are not correlated. The group of values that are averaged together must be within a time span of less than 100 milliseconds in order not to reduce the speed of response of the system.

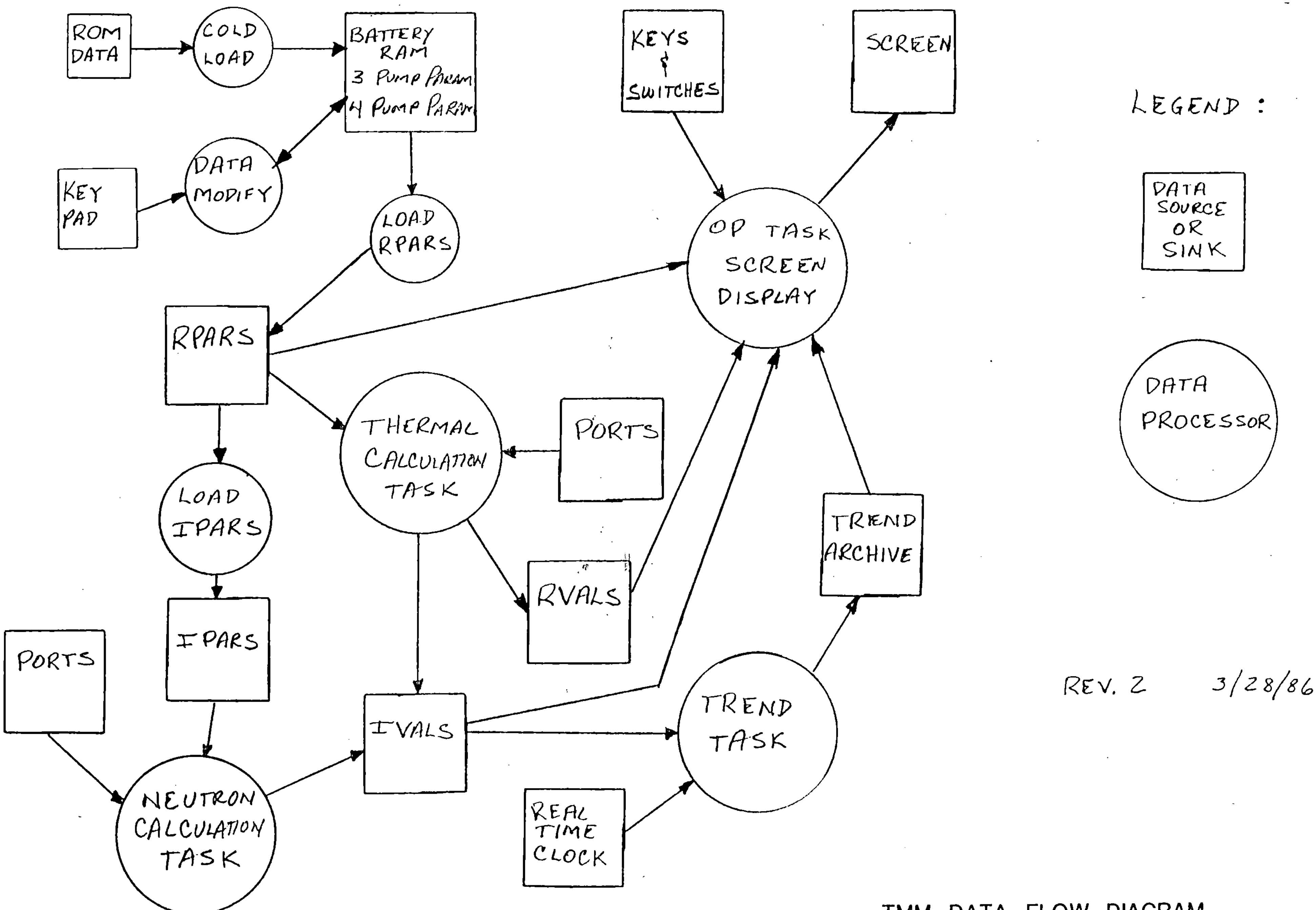
3.4 Error Handling

Detectable error conditions are handled by branching to a procedure that sends an "open" command to all the digital outputs, sets the PTrip analog output at its maximum voltage, sets the other analog outputs to zero, and displays the message "ERROR xxx" where xxx is a number. No further processing takes place, as the processor will be in a halted state with interrupts disabled. The error numbers will be defined in the user's manual.

3.5 RAM and ROM

There are two physically distinct areas of RAM. The 64 K of battery backed-up RAM, at addresses 10000 through 1FFFF, will be referred to as Application RAM. All global variables are in Application RAM. The 8 K from address 0 through 1FFF will be called System RAM. This area contains the VRTX workspace, plus a 1 K stack for each task. Pascal variables defined within procedures and functions occupy space in the stack of the calling task; the space is released when the procedure or function completes execution.

Physical ROM addresses range from E0000 through FFFFF for a total of 128 K. VRTX occupies the first 6 K of this, followed by the TMM code. Execution begins at FFFF0, as required by the 8088 processor. The last two bytes of ROM contain a 16-bit value to be matched against a CRC value by the ROM test procedure. This valued must be computed and programmed into the ROM at address FFFFE. The computation is best handled by using an emulator to execute the ROM test procedure in order to determine what value is calculated.



TMM DATA FLOW DIAGRAM

4.0 TASK DESCRIPTIONS

The TMM software uses a multi-tasking architecture so that the calculation and monitoring function can be continuously performed while still allowing the operator to interact with the machine. This also enables memory testing to occur automatically during normal operation. The five tasks that comprise the TMM software are described below. These five tasks are supported by the VRTX real-time executive, which permits them to execute concurrently and asynchronously. (The concurrency is an illusion, of course, since there is only one processor, but it is the appropriate conceptual framework for understanding the operation of the software. The tasks should be thought of as separate programs that run at the same time.) VRTX also provides priority-based scheduling, so that lower priority tasks do not execute unless higher priority tasks have satisfied all of their immediate processing needs.

The five tasks, in priority order, are:

1. The Neutron Calculations Task (highest priority)
2. The Thermal Calculations Task
3. The Operator Interface Task
4. The Trend Storage Task
5. The On-line Diagnostics Task (lowest priority)

Shorter names, namely Neutron Task, Thermal Task, Operator Task, Trend Task, and Diagnostic Task will often be used below.

The Neutron Calculations task handles all of the calculations that proceed from the measurements of neutron flux density. The Thermal Calculations task handles all of the calculations that proceed from temperature measurements. All of the measurement, calulation, and output (not CRT output) functions are divided between these two tasks. Computed values needed by other tasks are stored in RAM as global variables.

In order to achieve the 100 millisecond repetition rate for the Neutron Task it is necessary to eliminate any use of floating point arithmetic from this task. 32-bit integers will be used instead, even though this creates difficulties involving scaling and fractions.

The Operator Interface task processes operator keystrokes and presents displays to the operator. It updates those same displays, copying data from global RAM as needed. It is the only task that reads the keyboard or writes to the display. (Except in the case of the ERROR display mentioned in section 3.1. Any task may execute the error handling procedure, after which there will be no further processing.)

The Trend Storage task stores data every hour so that it can be reviewed at a later time, by operator request. A structure called the Trend Archives, in global RAM, is the repository of this data. The display of the trend data is part of the Operator Interface task.

The On-line Diagnostics task tests RAM and ROM memory.

4.1 System Architecture

The TMM Data Flow Diagram, attached, will be used to explain System Architecture, including startup issues. This requires a brief explanation of some naming conventions. The operator adjustable parameters, stored as 32-bit floating point variables, and representing values in user units, all have "RPAR" as a suffix (short for Real PARameter). They are collectively referred to as the "RPARS". Many of these will be converted to a 32-bit integer form for internal computations. These have the suffix "IPAR" and are referred to as the "IPARS" (Integer PARameters). Computed results which are meant to used by other tasks are similarly referred to as the "RVALS" and "IVALS" (Real and Integer VALues).

The data flow diagram shows data objects as rectangles, and processing elements as circles or ovals. Arrows represent data being copied from the tail to the head. Neither the sequence nor the cause of the data flow is shown in the diagram.

Upon initial startup, with unused RAM, the procedure called ColdLoad copies the default values of the operator adjustable parameters, both the 3 pump and 4 pump sets, into Application RAM. There they remain unchanged unless the Data Modify procedure is used to changed them. After ColdLoad finishes, the Load_RPars procedure copies one set of parameters into the RPARS. The pump select keyswitch position determines which set. Next the Load_IPars procedure scales and converts the RPARS into their corresponding IPARS.

If the system is restarted, with valid data in battery backup-up RAM, The ColdLoad procedure is not executed, but Load_RPars and Load_IPars will execute. The validity of RAM is determined by a CRC check of the 3 and 4 pump parameter sets. If the computed CRC word does not match a stored value, also in battery back-up RAM, then ColdLoad is executed. The stored CRC values is updated whenever the Data Modify procedure is exited.

The data flow diagram only applies to normal mode. If the system is started with the mode key not in NORMAL, then only the operator task will be active, until the key is moved to NORMAL. In normal mode the Neutron Task executes about ten times per second, each time reading appropriate input ports, calculating new values for various IVALS, and writing data to appropriate output ports. Many of the IPARS are used in these calculations, but they are not modified. Similarly, The Thermal Task executes once per second, reading input ports, and using some of the RPARS to performs its calculations. Results are written to some of the RVALS and IVALS, and data is output to certain ports.

The Trend Task is activated on the hour, it reads the ten designated IVALS and stores the values in the Trend Archives. It also reads the Real Time Clock, storing that data also to accomplish time & date stamping.

The operator task updates the current display every few seconds by reading the appropriate RVALS and IVALS, computing a character sequence, and sending that to the screen controller hardware. If the user presses a function key the operator task will respond as required, either drawing a different display, changing the function key label, or performing some procedure, such as a VHPT Reset.

The Diagnostic task operates independently, testing RAM and ROM. It will send data to the display screen if it detects an error; this will cause the machine to halt with an error message as described in section 3.4, error handling.

Details of all the tasks follow, described in prose and pseudocode.

Note: When "Delay" is referred to below, it means the VRTX delay call which allows lower priority tasks to execute until a specified number of clock ticks have occurred. The clock ticks are 15 ms apart.

4.2 Neutron Calculations Task

The purpose of the Neutron Task is to read the neutron and pressure sensors ten times per second, calculate all quantities which might change as a result of these readings, and write to any outputs that depend on these calculations. This task does no floating point calculations. (i.e., it uses no Pascal REAL values)

Procedure:

    calculate constants that depend on adjustable parameters
    initialize state variables
    initialize other variables as may be required
    Delay about one half second to assure that Thermal Task completes
        (This is so the BetaTCal term will be available)
    repeat indefinitely:
        read analog inputs from three neutron monitors
        read analog input Pasgt from pressure sensor
        read the delta-T power block digital input
        scale these inputs to produce long integer representations
        compute Local Power Density Trip formulas
        output to trip & pre-trip digital outputs
        compute and output a value to meter relay
        compute TM/LP formulas
        output Ptrip value to analog output port
        read VHPT reset digital input, also check VHPT reset mailbox
        perform reset logic

maybe alter VHPT trip and pretrip setpoints

compute VHPT trip formulas

output VHPT setpoint to analog output

output to VHPT digital outputs

Delay (just long enough to produce ten reps per second)

(End of Loop)

4.3 Thermal Calculations Task

The purpose of the thermal task is to read the temperature sensors every second, compute those quantities that depend on the temperature readings, and output to any relevant outputs. This task uses floating point math because the Delta-T Power calculation would be very difficult to do in integer form, and because there is enough time available at the one second rep rate. Two items are computed as REALS and then converted to integer form for use by the neutron task; these are Delta-T Power and the BetaTCal term of the TM/LP formulas.

The repetion rate of the Thermal task is controlled by the real time clock, which is initialized so as to produce a one second interrupt. This is a separate capability from that of its normal timekeeping function. The interrupt service routine then sends a message to the VRTX mailbox named AlmMail. The thermal calculations begin again whenever this message is received.

This task also handles the responsibility for restarting the Trend Storage task on the hour. This is accomplished by reading the hours register of the real time clock and noting when it changes. When this occurs a VRTX "resume" call is made to awaken the Trend Task.

Procedure:

calculate constants that depend on adjustable parameters

initialize state variables

initialize other variables as may be required

repeat indefinitely:

wait for message to be received by AlmMail mailbox

read analog inputs from water temperature sensors

compute Tc alarm conditions, if there is a change, then:

output to Tc alarm digital output

compute an estimated rate-of-change of (A*DeltaT+Tc)

compute Delta-T Power

compute BetaTCal

calculate long integer forms of those two variables

read the hours register of the real time clock

if the hour has changed, then:

awaken Trend storage task with VRTX "resume" call

save the hour for the next comparison

(End of Loop)

4.4 Operator Interface Task

The Operator Interface task is responsible for updating the current display with the results produced by the calculation tasks. It also monitors the softkeys and keyswitches and takes appropriate action if it finds a change in their state. After doing any required activity it suspends itself for 1/5 of a second with a "delay" call. Most of the time there is no required activity, so the delay is merely repeated. This task is the only one that writes on the display or pays attention to the operator's input.

Some floating point math is necessary, for scaling, and to produce character string representations of real variables. Interrupts are disabled during these periods, to prevent interruption by the higher priority Thermal Task, which also does floating point math. (The INTEL floating point library is not re-entrant.)

This task is also responsible for starting the other four tasks. The TMMAIN procedure, which executes first at system reset, leaves the other four tasks suspended when it hands control to VRTX. Since only the Operator task is initialy active, VRTX gives it all the CPU time. If the mode switch is not in NORMAL mode, the other tasks will not be started, hence Test or Data Modify can be used without running any of the other software. The Operator task also handles the startup RAM and ROM tests and the Cold vs. Warm start logic.

The displays are actually drawn by the graphics display card (see hardware description). In order to draw a display on the screen the lower level routines of the Operator Task must send sequences of 8-bit codes to the graphics card. The graphics card does not process these codes as fast as the computer can generate them, hence status testing is necessary. The graphics card sets a "ready" bit when it can accept another byte; the software tests this bit and does not send the next byte until the card is ready. If the card is not ready a Delay of 1 clock tick is executed. This allows other tasks to execute for about 15 milliseconds before status is tested again.

Many of the display screens take several seconds to draw. In order to provide for faster response to operator function key requests, the function key port is polled whenever "not ready" status is found. If there is an operator request pending a global flag called NewOpReq will be set. Higher level code can then check NewOpReq at various points and abort prematurely if it is set. This greatly reduces the response time to operator function key request. The screen is left in incomplete state, which is no problem if the operator understands the phenomenon. This only happens when a function key is pressed before the screen is drawn; in most cases the operator's request cause a new screen to be drawn anyway.

Procedure:

```
    Initialize graphics hardware
    Test Ram & ROM
       if not pass, execute error procedure
    Initialize variables as req'd

    Calculate CRC for the operator adjustable parameters in RAM
    If not the same as the stored value, then:
        display"COLD START IN PROGRESS"
        Load op. adj. params from ROM
        Set time and date to default values
        Calculate CRC word and store in RAM
        Initialize the trend archives
        Other cold start initialization
    End if

    Other warm start initialization
```

```
Poll Key Switches
WHILE mode switch is not in NORMAL:
  Poll Key Switches
  IF mode = TestMode, then:
      Perform Test Mode procedure
  IF mode = Data Modify, then:
      perform Data Modify procedure
end WHILE

Load the active set of op. adj. params (RPARS)
    (i.e., 3 pump or 4 pump, depending on pump switch)
Calculate long integer form of op. adj. params (IPARS)
Awaken the other four tasks with VRTX "resume" calls
set current screen to primary screen, with first menu bar

Repeat Indefinitely:   { MAIN LOOP OF OPERATOR TASK }
   Poll Key Switches
   IF mode = TestMode, then:
       Suspend background tasks
       Perform Test Mode procedure
       Resume background tasks
   end IF
   IF mode = Data Modify, then:
       Suspend Background Tasks
       perform Data Modify procedure
       Calculate CRC word and store in RAM
       Load the active set of op. adj. params (RPARS)
           (i.e., 3 pump or 4 pump, depending on pump switch)
```

```
        Calculate long integer form of op: adj. params (IPARS)
        Resume Background Tasks
    end IF

    { Read the function key port.  If there's a new keypress, act on it. }
    { provide about one second of polling without update              }
    Repeat this loop up to about five times:
        Poll the function key port
        if there is an operator request, then
            leave this loop.
        else Delay about .2 second
    end loop

    IF there is an operator request pending, then:
        clear the NewOpReq flag.
        Call the command interp procedure to act on the request.

    IF there is not an operator request pending, then:
        Call the update procedure to update the current screen.

  END MAIN LOOP
```

4.5 Trend Storage Task

This task awakens every hour on the hour to store the latest values of ten of the global variables. The values are stored in two data structures, one of which has a full day of hourly data, and the other has seven days of data taken every four hours. The Operator Interface task has access to these data structures, and will show their contents in response to an operator request.

There is also a separate initialization procedure, called only on a cold start, which sets the indices to 1, and sets all the hours to -1. The -1 is a signal to the display procedure that this is an empty record.

Data Items: (these are all global data)

two arrays of records, one for a day of data and one for a week.

The day array has 25 records.

The week array has 43 records.

Each record has the time and date of the data in that record, plus an array of ten values, the actual data.

An index variable for each array, to indicate current record.

variables to store the time of last trend storage (for both 7 day and 24 hour trend archives)

procedure:

Repeat Indefinitely:

Read the real time clock for the time and date.

IF more than 30 minutes have elapsed since last hourly trend storage, then store the time, date, and the ten values.

Store this time of last hourly trend storage.

IF the hour is a multiple of four, AND its been more than two hours since the time of last 7 day trend storage, then:

Store the time, date, and ten values.

Advance the 7 day trend index. (circular fashion)

Store this time of last 7 day trend storage.

End IF

Advance the hourly trend index. (circular fashion)

```
        End IF
        Suspend this task with the VRTX "suspend" call.
        (The Thermal Task will resume it, on the hour.)
    End loop
```

4.6 On-line Diagnostic Task

Most of the code for this task is written in assembly language, both for speed of execution and for control over interrupts. RAM is tested for minimally correct operation by write-read-compare operations on every word of RAM. The original contents of each word are restored. ROM is tested by computing a 16-bit CRC word over all but the last word of ROM and comparing it with a value stored in the last word.

```
procedure:
    Repeat Indefinitely:
        Test ROM, if not pass then execute error procedure
        Test System RAM, if not pass then execute error procedure
        Test Application RAM, if not pass then execute error proc.
    End Loop.
```

5.0 PROCEDURE/FUNCTION DESCRIPTIONS

5.1 Startup code executing prior to any task execution.

Initial Startup procedure (TMMAIN)

Initialize Interupt Vectors.

Initialize floating point error handler.

Start 15 ms periodic interrupts.

Set alarm channel of real time clock for 1 second interrupt.

Other initialization.

Create the five tasks with the VRTX "create" call.

Suspend all but Operator Task.

Jump to VRTX entry point.

End Startup procedure.

5.2 Neutron Task code

5.2.1 Local Power Density procedure

(This procedure calculates the Power Density Pretrip/Trip function and the Meter Relay Analog Output function. For a complete description of the calculations of the Power Density Pretrip/Trip Function and the Meter Relay Analog Output Function, see the SRS.)

Read the three neutron flux sensor inputs, L, U, and Phi

Scale Phi reading to produce long integer version of Phi.

Calculate scaled, long integer version of Ye from L and U.

(If L+U is less than .75 volt, set Ye to zero.)

Calculate Y using Ye as input to the ASI function.

Set Q, the power level, to the maximum of Phi and Delta-T Power.
(Delta-T Power is available from the Thermal Task.)

Compute Phi minus Delta-T Power.

Scale and limit the result for DAC output, write it to the DAC.

IF Q > 15% power then set Q2 equal to Q.

IF Q < 14.5% power then set Q2 to zero.

(no change in Q2 if Q is between 14.5 and 15 percent power)

Calculate QR2 using Q2 as input to the LOCA Peaking function.

Calculate Yp using QR2 as input to the LPD Positive function.

Calculate Yn using QR2 as input to the LPD Negative function.

Calculate Ypp and Ynn by adding/subtracting b to/from Yp and Yn.

IF Y exceeds Yp or is less than Yn, then:

    Open the LPD trip digital output.

    set the status to TRIP.

ELSE

    Close the LPD trip digital output.

    set the trip status to OK.

End IF-ELSE

IF Y exceeds Ypp or is less than Ynn, then:

    Open the LPD pre-trip digital output.

    set the status to PRETRIP.

ELSE

    Close the LPD pre-trip digital output.

set the pre-trip status to OK.

End IF-ELSE

END Local Power Density procedure

5.2.2 TM/LP PROCEDURE

(This procedure calculates the Thermal Margin/Low Pressure Function and provides an analog output pressure signal PTrip. For a complete description of the calculations of the Thermal Margin/Low Pressure Function, see the SRS.)

Read PAsgt analog input.

Scale it to produce long integer version.

Read the Delta-T Power block digital input.

IF its open, then set Q1 equal to neutron flux power, Phi.

ELSE set Q1 to greater of Phi or Delta-T Power.

Calculate QR1 using Q1 as input to the Power Peaking function.

Calculate QA using Y as input to the Axial function.

(Y is calculated in the Local Power Density procedure.)

Calculate QDNB as a scaled product of QR1 and QA.

Calculate Lambda*QDNB as a scaled product of Lambda and QDNB.

Calculate PVAR as the sum of Lambda*QDNB, Gamma, and BetaTCal.

(BetaTCal is from the thermal task, Lambda and Gamma are operator adjustable parameters.)

Set PTrip to the maximum of PVAR, PMin, and Pasgt.

(PMin is an operator adjustable parameter.)

Scale Ptrip for output to the DAC, the write it to the DAC.

END TM/LP procedure

5.2.3 VHPT Procedure:

(This procedure changes the VHPT trip and pre-trip setpoints, outputs the trip setpoint to the VHPT analog output, and sets the VHPT trip and pre-trip digital outputs.)

```
IF VHPT Reset function key pressed OR VHPT Reset digital input, then:
   IF the VHPT Trip is not in tripped state, then:
      Read the current system tick count.
      IF over ten seconds have elapsed since last VHPT reset, then:
         Reset the VHPT trip and pretrip levels.
         Save the current power level.
         Save the tick count as time of last VHPT reset.
      End IF
   End IF
End IF

IF power level has decreased since last VHPT reset, then
   Reset the VHPT trip and pretrip levels.
   Save the current power level.
End IF

convert and scale LONGINT value of VHPT setpoint to an INTEGER
for output to the DAC, then write value to the DAC.

IF VHPT trip state is TRIPPED then
    IF power level is less than setpoint - deadband, then:
```

```
            Change trip state to OK.
         End IF
      ELSE
         IF power level is greater than setpoint, then:
            Change trip state to TRIPPED.
         End IF
      End IF-ELSE

      IF VHPT pre-trip state is TRIPPED then
         IF power level less than pre-trip setpoint - deadband, then:
            Change pre-trip state to OK.
         End IF
      ELSE
         IF power level is greater than pre-trip setpoint, then:
            Change pre-trip state to TRIPPED.
         End IF
      End IF-ELSE

      Output VHPT trip state to QTCC digital output.

      Output VHPT pre-trip state to QPCC digital output.
   END VHPT Procedure
```

5.2.4 Reset VHPT Trip/Pretrip procedure

(This procedure changes the value of the VHPT trip and pretrip setpoints. The symbols are taken from the SRS, section 3.1.5.)

```
      Qtr = Q + Q%tr

      IF Qtr > QtrMAX THEN
```

```
        Qtr = QtrMax
        Qptr = QptrMax
    ELSE
        IF Qtr < QtrMin THEN
            Qtr = QtrMin
            Qptr = QptrMin
        ELSE
            Qptr = Q + Q%ptr
        End IF-ELSE
    End IF-ELSE
End Reset VHPT Trip/Pretrip procedure
```

5.3 Thermal Task Code

5.3.1 TC Alarm procedure

(This procedure reads the temperature sensors and handles the TC Alarm calculations, all with integer math. Then floating point values needed for Delta-T Power are computed. Static BOOLEAN variables LoState and HiState are needed. LoState will be set when the temperature is too cold and HiState will be set when the temperature is too hot. They will be initialized to FALSE and thev TC alarm digital output will initially be closed.)

Read the temperature sensor analog inputs: TC1, TC2, and THAve.

Set TC to the larger of TC1 and TC2.

IF LoState is TRUE, then:

```
    IF TC now exceeds minimum temperature plus deadband, then
        Set LoState to FALSE.
        Close the TC Alarm digital output.
    End IF
ELSE
    IF TC is below the minimum temp, then
        Set LoState to TRUE.
        Open the TC Alarm digital output.
    End IF
End IF-ELSE

IF HiState is TRUE, then:
    IF TC is now below maximum temperature minus deadband, then
        Set HiState to FALSE.
        Close the TC Alarm digital output.
    End IF
ELSE
    IF TC is above the maximum temp, then
        Set HiState to TRUE.
        Open the TC Alarm digital output.
    End IF
End IF-ELSE

(Preceding calculation were all in integer)
Compute floating point versions of TC and Delta-T for use in
Delta-T Power calculation.
END TC Alarm procedure
```

5.3.2 Delta-T Power procedure

(This procedure performs the Delta-T Power calculation. Delta-T Power is a function of the highest cold leg temperature, the average hot leg temperature, and a temperature differentiator. The cold leg temperature and average hot leg temperature are available from the TC Alarm procedure. For further information on the Delta-T Power Calculation, see the SRS.)

Calculate Z = A * Delta-T + TC

Subtract previous value of Z to get change in last second, ZDOT.

Compute derivative estimate as GAIN * ZDOT + (1-GAIN) * OldDiff

(where OldDiff is the previous value of the derivative estimate.)

Save current value of Z for use in one second.

Save derivative estimate as OldDiff for use in one second.

Compute Delta-T Power per formula in SRS.

Compute BetaTCal per formula in SRS. (see PVAR equation, TM/LP)

Scale Delta-T Power and BetaTCal and convert to long integer.

(These global variables will be used by the Neutron Task.)

END Delta-T Power procedure

5.4 Operator Task Code

5.4.1 Command Interpreter procedure:

```
IF the "MORE" key was pressed, then execute the MoreKey procedure
    to determine the next menu bar and draw it on the bottom line.
ELSE
    IF the key requests a procedure be performed, then do it.
    IF there is no new request pending from the operator, then:
        Use the Command Table to determine the next display screen
        and menu bar.
End IF-ELSE

IF The display is being changed
AND there is no new operator request, then:
    Draw the new screen.
    IF there is no new operator request then:
        Draw the menu bar on the bottom line.
ELSE
    IF The menu bar is being changed
    AND there is no new operator request, then:
        Draw the menu bar on the bottom line.
End IF-ELSE
End Command Interpreter procedure.
```

5.4.2 The "MORE" Key in Normal Mode

There are 16 different menu bars which can appear on the bottom line of the display in Normal mode. These menu bars, also referred to as function key labels, provide labels to indicate the action of the function keys. Initially, the primary screen is displayed, and the menu bar is:

PRESSURE ALARMS STATUS MORE

If the "MORE" key is pressed repeatedly, the following menu bars will appear:

PWR DENS	PWR PEAK	LOCA PEAK	MORE
AXIAL	ASI	ADJ PARAM	MORE
24 HR TRND	7 DAY TRND	TR SELECT	MORE

These four menu bars will repeat in the same sequence if the "MORE" key action is continued. If the PRESSURE key is selected from the first menu bar, the Pressures Screen will appear, and the menu bar will change to:

PRIMARY ALARMS STATUS MORE

The ALARMS selection will obtain the Alarms Display and this menu bar:

PRIMARY STATUS VHPT RESET MORE

Here is the complete list of menu bars, along with a reference name for each:

PRESSURE	ALARMS	STATUS	MORE	(P1)
PWR DENS	PWR PEAK	LOCA PEAK	MORE	(P2)
AXIAL	ASI	ADJ PARAM	MORE	(P3)
24 HR TRND	7 DAY TRND	TR SELECT	MORE	(P4)
PRIMARY	ALARMS	STATUS	MORE	(1A)
PRIMARY	STATUS	VHPT RESET	MORE	(1B)
PRIMARY	ALARMS	PRESSURE	MORE	(1C)
PRIMARY	PWR PEAK	LOCA PEAK	MORE	(2A)
PRIMARY	PWR DENS	LOCA PEAK	MORE	(2B)
PRIMARY	PWR DENS	PWR PEAK	MORE	(2C)
PRIMARY	ASI	ADJ PARAMS	MORE	(3A)
PRIMARY	AXIAL	ADJ PARAMS	MORE	(3B)
PRIMARY	AXIAL	PAGE	MORE	(3C)
PRIMARY	UP	DOWN	MORE	(4A)
PRIMARY	UP	DOWN	MORE	(4B)
SELECT	DISPLAY	CLEAR	MORE	(4C)

P1 is the first menu bar of the primary display. P2, P3, and P4 rotate in sequence as the "MORE" key is repeated. "P" is for Primary, and these four menu bars form the Primary sequence, or "PATH". The concept of PATH is introduced in order to create an algorithm for this sequencing. P1 - P2 - P3 - P4 is PATH 0.

If another key is pressed (not "MORE") then a new screen may be displayed. This happens unless a function is selected, the functions being VHPT Reset, UP, DOWN, PAGE, SELECT, DISPLAY, and CLEAR. When a new screen is displayed, a new menu bar will also be written. When going to a new screen and menu bar from the primary screen, the following table indicates which menu bar is next:

	function KEY 1 = A	SOFTKEY 2 = B	SOFTKEY 3 = C
menu bar			
P1	1A	1B	1C
P2	2A	2B	2C
P3	3A	3B	3C
P4	4A	4B	4C

This action also changes the PATH, from PATH 0, to PATH 1,2,3 or 4. The PATH number is the same as the number in the menu bar name. For example, if we are looking at the primary screen, and the menu bar P3, and we press softkey 2, we will obtain the ASI function display, and menu bar 3B, which also puts us on PATH 3.

The "MORE" key never changes the PATH; it moves the menu bar along the current path. The complete list of paths is:

PATH NO.	Sequence
0	P1 - P2 - P3 - P4
1	1X - P2 - P3 - P4
2	P1 - 2X - P3 - P4
3	P1 - P2 - 3X - P4
4	P1 - P2 - P3 - 4X

Where the X means either A, B, or C. Which letter the X represents is determined by the menu bar that was displayed when the new path was established. For instance, in the example above the new menu bar was 3B, hence B will be used for X as long as we sequence around this path with the "MORE" key. A variable called AltMenu will be used in the software to store this information. The "MORE" key procedure will have logic representing the above table, and will make use of the state variables PATH and AltMenu in order to select the next menu bar. When a key other than "MORE" is hit the Command Interpreter procedure will either execute one of the directly selectable functions, or it will call the Command Table procedure to select the next display, menu bar, PATH, and AltMenu.

The above scheme lets us navigate fairly quickly among the available options, and with minimal demands on the user. If the user's desire is not seen on the menu bar he can usually find it simply by hitting the "MORE" key until he sees it. If that doesn't work he can select PRIMARY, which appears on almost all menu bars.

One deviation from the above scheme will be made to avoid an inconvenient situation: After the operator uses the TREND SELECT screen to choose parameters for display, it would be difficult to get to a trend display screen in order to view the selected data. We will modify the More key procedure so that a different path is selected by the "MORE" key in this situation. When the Path is 4 and the menu bar is 4C, then the "MORE" key will go to PATH 1 and menu bar P4 with Altmenu 1A.

5.4.3 Command Table procedure:

(The command table procedure uses the current menu bar and the softkey that was pressed as inputs to a look-up table in order to return the new menu bar and display screen. It also changes two state variables that are used by the "MORE" key procedure; these are AltMenu and Path. This procedure will not be called when the softkey pressed is the "MORE" key. In order that the table be in ROM, the procedure consists entirely of CASE statements, the branches of which are assignment statements. Pascal provides no direct way of constructing a table in ROM.)

5.4.4 Data Modify Procedure:

WHILE mode = Data Modify DO

Set variables to establish initial state.

Draw the initial screen display. (Modify Param Display)

Read the pump select switch.

Show the current pump selection.

Draw the first page of parameters.

WHILE NOT Full_Init DO BEGIN

Repeatedly poll the function keys and switches until an operator action is detected:

Act according to the kind of event:

function Key 1: Draw next page of parameters.

function Key 2: Perform Set Date and Time procedure.

Set Full_Init flag to exit inner loop.

PumpSwitch: Show the current pump selection.

Re-draw the current page of parameters.

ModeSwitch: Set Full_Init flag to exit inner loop.

KeyPadChar: Perform character handler procedure.

(otherwise take no action)

End inner WHILE loop.

End outer WHILE loop.

End Data Modify procedure

5.4.5 Character Handler procedure

Act depending on kind of character:

BACKARROW: Back-Space Delete procedure.

CLEAR:

Blank the two data entry fields. (item and value)

Setup to accept an item.

Initialize appropriate variables.

PLUS, MINUS, PERIOD, EXPONENT:

IF the data entry mode is VALUE, then:

accept the character into the input buffer.

NUMERALS, 0 thru 9:

accept the character into the input buffer.

ENTER:

Action depends on data entry mode: (ITEM, VALUE, or Time-Date)

ITEM:

Verify that entry consists of one or two decimal digits.

IF SO, then:

Convert entry to integer.

IF that item not on current parameter page, then:

redraw parameter page.

Remove the cursor from the item entry field.

Change entry mode to VALUE.

Put cursor in VALUE field.

Initialize appropriate variables.

End IF SO

VALUE:

IF entry string is a valid floating point number, then:

Store the new value in the Parameter Tables

Clear the data entry fields.

Change entry mode to ITEM.

Redraw the parameter page to show the new value.

Initialize appropriate variables.

End IF

Time-Date:

Perform AcceptTime Procedure which will convert data entry string into (up to) three integers, and switch the time entry mode between DATE and TIME.

End Character Handler procedure.

5.4.6 Test Mode procedure

ALLOWS THE USER OF THE TMM TO RUN DIAGNOSTIC ROUTINES THAT WILL TEST THE SYSTEM RAM AND ROM, THE ANALOG INPUTS AND OUTPUTS, THE SOFT KEYS, PANEL SWITCHES AND KEYPAD, AND THE DIGITAL INPUTS AND OUTPUTS

TESTMODE: DO THIS ROUTINE UNTIL THE MODE CHANGES FROM TESTMODE TO ANOTHER MODE

WAIT FOR AN INPUT EVENT TO OCCUR FROM THE GET_EVENT PROCEDURE WHICH WILL HAVE STORED IN A VARIABLE WHICH EVENT OCCURED.

TEST TO SEE IF A SOFT KEY HAS BEEN PRESSED AND IF IT HAS THEN SET THE PROPER FLAGS TO INDICATE THE PROPER DIAGNOSTIC FUNCTION TO BE PERFORMED, SUCH AS GOING TO ANALOG, DIGITAL, OR KEYS TEST.

TEST TO SEE IF KEYPAD HAS BEEN PRESSED; IF SO, SET KEYPAD FLAG.

TEST TO SEE IF THE PUMPSWITCH HAS BEEN CHANGED IN A NEW POSITION AND IF SO SET THE APPROPRIATE FLAG

TEST THE FLAGS AS THEY WERE SET IN ABOVE AND CALL ON THE APPROPRIATE ROUTINES TO ACCOMPLISH THE DESIRE RESULT. THE ROUTINES WILL BE INVOLKED AS THE TABLE LISTED BELOW BASED UPON THE APPROPRIATE FLAGS.

NOTE: THE FIRST FIVE SOFT KEY EVENTS SIMPLY PRINT THE SOFT KEY PRESSED WHEN FIRST ENTERING THE KEYS TEST. THEN THE TABLE BELOW

WILL APPLY FOR THE EVENT AND THE CURRENT TEST AS APPROPRIATE.

FLAG TABLE

CURRENT TEST	EVENT OCCURRED	ACTION TAKEN
1. KEYPAD	SOFT KEY 1	INVOKE ANALOG TEST
	SOFT KEY 2	INVOKE DIGITAL TEST
	SOFT KEY 3	INVOKE MEMORY TEST
	PUMP SWITCH	DISPLAY PUMP SWITCH #
	KEY PAD	DISPLAY KEY PRESSED
2. ANALOG	SOFT KEY 1	INVOKE DIGITAL TEST
	SOFT KEY 2	INVOKE MEMORY TEST
	SOFT KEY 3	INVOKE KEYPAD TEST
	SOFT KEY 4	REREAD ANALOG INPUTS
3. DIGITAL	SOFT KEY 1	SELECT NEXT DIGITAL OUTPUT
	SOFT KEY 2	CHANGE CURRENT DIGITAL OUTPUT TO INVERSE VALUE
	SOFT KEY 3	INVOKE KEYPAD TEST
4. MEMORY	SOFT KEY 1	INVOKE ANALOG TEST

SOFT KEY 2 INVOKE DIGITAL TEST

SOFT KEY 3 INVOKE KEY TEST

AFTER THE APPROPRIATE FLAG HAS CAUSED THE APPROPRIATE ACTION TO BE TO BE TAKEN, CONTROL IS RETURNED TO THE BEGINNING OF TESTMODE AND THE ROUTINE CONTINUES TO WAIT FOR AN EVENT TO OCCUR UNLESS THE MODE HAS CHANGED.

5.5 Utilities and Supporting Routines

5.5.1 PLFunc - Piecewise Linear Function Evaluator

PLInit - Initialization of a P.L.F. (needed to use PLFunc)

PLFunc receives an array POINTS, an integer N, and a value INVAL. POINTS describes a particular piecewise linear function, N is the number of points, and INVAL is a value of the independent variable. The function returns the value of the dependent variable.

PLInit is a procedure that is called when a new P.L.F. is defined, and again if any of its points are changed. (It will be called at startup and after Data Modify.)

The array POINTS is an array of records. Each record consists of a value X and value Y. These are the cartesian coordinates of a point. The order of the points corresponds to moving from left to right, or increasing values of X.

When INVAL is less than the first X value, we will assume that the first line segment is extensible to the left. Similarly, if INVAL is greater than the Nth X value, we extend the last segment to the right.

In the description below, let X[i] and Y[i] refer to the coordinate values, with 0 <= i < N. Let SLOPE[i] refer to the slope of the segment joining POINT[i] with POINT[i+1], for i < N-1.

Algorithms: There is an initialization and an execution algorithm. The initialization algorithm must be performed whenever the POINTS array is created, or changed. It consists of calculating, and storing, the slopes of the line segments. The PLInit procedure must perform this operation, storing the SLOPE array so that PLFunc can use it. The calculation is, for all i from 0 through N-2:

```
SLOPE[i] = (Y[i+1] - Y[i]) / (X[i+1] - X[i])
```

PLFunc does the following:

```
if N < 2 it is an error condition. otherwise:

set i to 1
set LIMIT to N-1

WHILE (i not equal to LIMIT) and (INVAL > X[i])
DO  increment i
End WHILE

decrement i

result = Y[i] + SLOPE[i] * (INVAL - X[i])
(done, return the result)
```

Modifications required for integer math: Instead of SLOPE[i] we use

NUMER[i] and DENOM[i] where NUMER[i] and DENOM[i] are both integers and NUMER[i] / DENOM[i] = SLOPE[i]. PLInit stores the NUMER and DENOM arrays. The result formula of PLFunc uses the FracFinder function on the (INVAL - X[i]) term, using NUMER[i] and DENOM[i] as the numerator and denominator. SLOPE is nowhere explicitly used.

5.5.2 Graphics Status procedure

(This procedure is called by any routine that wants to send data to the graphics card, prior to so doing. It reads the Status Port to determine whether the graphics hardware is ready to accept data. It does not return to the caller until this is the case. If the graphics card is not ready, the VRTX call delay(1) is done, allowing other tasks to execute. It also empties the key pad of any pending characters, placing them in a RAM buffer. In addition it may set the NewOpReq flag; it does so if it detects that the operator has just pushed a function key.)

```
    Buffer any characters from numeric keypad.
    Set retry limit.
    Read the graphics status port.
    WHILE status is NOT READY and retry limit not exceeded, DO:
        VRTX Delay for one clock tick.
        Poll the function keys, maybe set NewOpReq flag.
        Increment the retry counter.
        Read the graphics status port.
    End WHILE
    IF the retry limit is exceeded, then jump to error procedure.
End Graphics Status procedure
```

5.5.3 RAMTEST

RAMTEST is an assembly language routine that is designed to be called from any pascal module as a function that will return a boolean value that indicates to the calling program whether the ramtest failed or succeeded. In order to write a routine that is both thorough and fast in execution time, this routine makes extensive use of the internal registers of the 8088 microprocessor. In addition, this routine must reside in ROM in order to work properly as it does not relocate itself in order to check the adress space where it resides.

```
Function ramtest
        (lowoff:word;lowseg:word;upoff:word;upseg:word) : boolean;

  move all but the lower four bits of the lower order offset
     into the lower segment in order to get ready for a
     segment by segment test of the ram.

  move all but the lower four bits of the upper offset as above


     if lower segment is greater then upper segment then indicate
     error by returning boolean false to the calling program

  call TESTRAM subroutine until both the lower offset = upper offset
     this is done to used both the lower segment and upper segment
     to control the TESTRAM as it does a segment by segment test


Main: call TESTRAM to check another 16 bytes of data
```

increment the lower segment count

if lower segment = upper segment then exit with a return value of true boolean to the calling program

otherwise jump to MAIN and continue the ramtest

TESTRAM: set counter with 16 for 16 byte ramtest

move first byte and store a copy in an index register with a working copy in the ax register

xor the byte with FFH and store this new value of in order to test in order to store the bitwise inverse of the initial value

read the byte again and compare byte read with value written if the values are not the same than indicate an error, return a boolean false

write the initial value that was stored in the index register to the byte location and read it back to insure that the value is the initial one

decrement 16 byte counter and return to calling code otherwise jump to testram to continue the ramtest

5.5.4 ROMTEST

ROMTEST is an assembly language routine that is callable from any pascal module as a function that will return a boolean value where false indicates that the romtest failed. this routine is actually only a setup routine that calls on the following routine called CRCHECK and passes it the address parameters that crcheck needs in order to complete crc of the ROM. The returned crc value from the routine crcheck is compared against the value in ROM at FFFF:E.

5.5.5 CRCHECK

CRCHECK is an assembly language routine that is designed to be called from any pascal module as a function that will return a crc value that indicates to the calling program the value of the crc In order to write a routine that is both thorough and fast in execution time, this routine makes extensive use of the internal registers of the 8088 microprocessor.

move all but the lower four bits of the lower order offset
   into the lower segment in order to get ready for a
   segment by segment crc of the rom.

move all but the lower four bits of the upper offset as above

   if lower segment is greater than upper segment then indicate
   error by returning boolean false to the calling program

call crcl subroutine until both the lower offset = upper offset
   this is done to used both the lower segment and upper segment
   to control the crcl as it does a segment by segment crcl

set the crc initially to zero.

Main: call crcl to continue the crc check on another 16 bytes of data

increment the lower segment count

if lower segment = upper segment then exit with a return value of the crc value in the form of a word to the calling program

otherwise jump to MAIN and continue the crc

CRC1: set counter for 16 byte count

move next memory byte into ax register

get polynomial X**16 + X**15 + X**2 + 1.
(This is just the 16-bit word 8003 hex)

save byte in register cx

generate the new crc by shifting the data byte and the crc left eight times ; after each shift the crc is XORed with the polynomial if the XOR of the data bit and the crc's most significant bit is a 1.

decrement the byte counter and return to MAIN if counter = 0.

otherwise jump to crcl and continue the CRC.

6.0 DISPLAY DESCRIPTIONS

This section describes the displays used in the operation of the TMM.

The operator moves from display to display by using the four softkeys located beneath the display. The function key functions are labelled on the CRT above the keys. For example, to go to the AXIAL display from the current display, the operator simply presses the function key labelled "AXIAL." On most displays the rightmost key is labeled "MORE". By pressing this key, a new set of labels is displayed for the three other keys. Thus, if the desired display is not seen on the existing softkey labels, the operator can locate it by using the "MORE" key to display new labels.

Displays that present dynamically changing values will be updated every several seconds.

The following 13 displays are for Normal Mode:

6.1 PRIMARY DISPLAY

The Primary Display presents the Delta-T Power and the VHPT Setpoint in large, easy to read numbers. Also, the time and date are presented as feedback that the TMM is operating. The softkeys at the bottom of the display are labeled with the available options for other displays. Both of the large numbers being presented have a range of 0 to 125, representing % power. The active pump configuration is also shown, 3 Pump or 4 Pump.

6.2 PRESSURES DISPLAY

The Pressures Display presents the Ptrip pressure as computed from the TM/Lp function. In addition, the Pmin (operator adjustable parameter), Pvar (based on cold leg temperature and axial offset), and Pasgt (asymetrical steam generator trip analog input) are displayed. All pressures are displayed in units of PSIA.

6.3 AXIAL FUNCTION DISPLAY

The Axial Function Display presents a graph of the piecewise axial function as determined from three points. Along with the graph are the numerical values for the three points and the current values for QA and Y. QA is the axial function result of Y. Y is the axial offset obtained from the ASI function.

6.4 POWER PEAKING DISPLAY

The Power Peaking Display presents a graph of the piecewise power peaking function as determined from four points. Along with the graph are the numerical values for these points and the current values of QR1 and Q1. QR1 is the power peaking functional result of Q1. Q1 is equivalent to the maximum of Phi or Delta-T Power if the Delta-T Power Block is closed, or Phi if the Delta-T Power Block is open.

6.5 ALARMS DISPLAY

The Alarms Display indicates the status of the variable high power trip (VHPT) and temperature alarms. The VHPT information includes the current power level (Max of Phi or Delta-T) ranging from 0 to 125% power, the trip status as OK, Pretrip, or Trip, the VHPT trip setpoints (Qptr and Qtr), and the operator adjustable parameters for the percentage above power that the trip setpoints should be set. The "VHPT RESET" function key is used to reset the VHPT setpoints after a trip. The external setpoint reset (external to the TMM) performs the same function.

The temperature information includes the current Tc value as obtained from the maximum of the cold leg temperatures Tc1 and Tc2, the temperature trip status as OK or Trip, and the minimum and maximum trip setpoints TcMIN and TcMAX (operator adjustable).

6.6 24 HOUR TREND DISPLAY

The 24 Hour Trend Display shows the values of the selected trend parameters in tabular form. The UP and DOWN function keys are used to scroll through the trend data, ten lines at a time. No information is automatically updated on this display.

6.7 SEVEN DAY TREND DISPLAY

The 7 Day Trend Display is identical to the 24 hour trend display except that the data source is the trend 7 day archives, rather than the 24 hour archives.

6.8 TREND PARAMETER SELECT DISPLAY

The Trend Parameter Select Display allows the operator to select which trend parameters to display on the 24 Hour or 7 Day Trend Display. The current displayed parameters are presented along with a menu of all the trend parameters available. Several function keys are used to choose which parameters to display. The SELECT function key moves a cursor through the selections thus allowing the operator to choose one. The DISPLAY key is used to add the SELECTed parameter to the current displayed list (if there is space on the screen). The CLEAR key is used to remove the last selected parameter from the current selection list.

6.9 SYSTEM STATUS DISPLAY

The System Status Display provides the operator with a dynamic report on system operability. Specifically, these variables are: TC1, TC2, TC, THAve, L, U, Phi, Phi-B, PTrip, and Pasgt. Also shown are the states of the five digital outputs, Tcc, LPD/trip, LPD/pretrip, Qtcc, and Qpcc. (see SRS - DOC #055)

6.10 POWER DENSITY DISPLAY

The Power Density Display presents a graph of the two local power density (LPD) functions as determined by the five operator adjustable points. In addition, the trip status of the Power Density Pretrip/Trip function is displayed as OK, Pretrip, or Trip; the five point pairs are displayed numerically, as are the current Y and QR2 values. Y is the result of the ASI function and QR2 is the functional result of the Loca Peaking function. Also shown are Yn and Yp, the outputs of the LPD piecewise linear functions.

6.11 LOCA PEAKING DISPLAY

The Loca Peaking Display presents a graph of the piecewise linear Loca Peaking function as determined from the four operator adjustable points. Along with the graph are the numerical values for these points and the current values of QR2 and Q2. QR2 is the Loca Peaking functional result of Q2. Q2 is equivalent to Q (the maximum of Phi or Delta-T power) if Q is greater than or equal to 15.0% power, or equal to 0 if the Q is less than or equal to 14.5% power. (see SRS - DOC #055 for more detailed definition of Q2)

6.12 ASI DISPLAY

The ASI (Axial Shape Index) Display presents a graph of the piecewise linear ASI function as determined from the four operator adjustable points. Along with the graph are displayed the numerical values for these points and the current values of Y and Ye. Y is the ASI functional result of Ye. Ye is the subchannel deviation computed from the U and L linear power readings.

6.13 ADJUSTABLE PARAMETERS DISPLAY

The Adjustable Parameters Display allows the operator to view the adjustable parameters. The PAGE function key is used to scroll through the parameter list, ten at a time. Note that no parameters can be modified here. If the operator needs to change these parameters, he must have the mode select keyswitch in the Data Modify position and use the Modify Parameters Display described below.

The following two displays are seen when the mode keyswitch is in the Data Modify position:

6.14 MODIFY PARAMETERS DISPLAY

The Modify Parameters Display allows the operator to view and modify the operator adjustable parameters. The current parameters are displayed for the pump selected via the keyswitch. The operator can scroll the parameters by pressing the PAGE key. New parameters are entered using the data entry keypad. First the parameter number is entered. The TMM will then wait for a new value to be entered by the operator. Once the new value has been entered, the TMM will wait for another parameter number. Any valid parameter number may be entered; if a number is entered for a parameter not shown on the screeen, then the appropriate page of parameters will be displayed.

6.15 SET DATE AND TIME DISPLAY

The Set Date and Time Display allows the operator to change the date and time stored in the TMM battery-backed up clock. The current date and time are displayed at the top of the screen and are updated once per second. The DATE softkey is used to enter a new system date and the TIME softkey is used to set the system time. The date and time digits are entered using the data entry keypad.

The following four displays are used in conjunction with the mode keyswitch in the Test Mode:

6.16 MEMORY TEST DISPLAY

The Memory Test Display allows the operator to perform ROM and RAM tests. The results of these tests are indicated on the display as either PASS or FAIL. The IN PROCESS message appears while the test is currently being performed.

6.17 DIGITAL TEST DISPLAY

The Digital Test Display provides status on all the external digital inputs and outputs as being open or closed. The current values of the digital inputs are displayed; they are updated when the user pressed the READ INPUTS softkey. The operator can use the softkeys to change the state of the digital outputs. The SELECT key is used to choose which output to change. The OPEN/CLOSED key is used to toggle the state of the selected item as open or closed. The displayed state of each digital output is updated each time the operator changes it.

6.18 ANALOG TEST DISPLAY

The Analog Test Display provides the current values of all the TMM analog inputs and outputs. The analog inputs Tc1, Tc2, THave, L, U, Phi, and Pasgt are displayed as 0 to 10 VDC. They are updated whenever the user presses the READ INPUTS function key. The analog outputs Phi-B, Ptrip, and VHPT Setpoint are preset to 7.50VDC, 30.0mA, and 5.00VDC respectively.

6.19 KEYS TEST DISPLAY

The Keys Test Display allows the operator to test the functionality of the pump select keyswitch, softkeys, and data entry keypad. The pump select keyswitch switch position is displayed as "3Pump" or "4Pump" and is updated if the switch is moved. Upon each keypad keypress, the associated character is displayed in the keypad data area. The function keys will display 1, 2, 3, or 4.

APPENDIX A

RUN TIME SUPPORT CONSIDERATIONS

run-time Support Libraries and their interfacing to the Thermal Margin Monitor operating system.

INTRODUCTION:

Some of the Intel software development tools, such as their Pascal compiler, require the addition of common compiler functions that are found in the various Run-Time Support Libraries provided by Intel. This feature provides a method to allow the software developer the ability to configure the application to eliminate or include various features as necessary.

There are two classes of libraries for the Intel Pascal compiler:

1. Those that support functions that use the 8087 Numeric Data Processor (NDP) or the 8087 NDP Emulator.

2. Those that deal with non-mathematical data processing.

In addition to the various functions that the Run-Time Support Libraries add to the basic Pascal compiler (and that it requires), there are a number of functions that these libraries will require from the actual operating system that the program(s) will run under in order to insure the proper operation of the program(s). The type of functions that the operating system is required to provide include Heap Memory Management, file I/O such as floppy disks or hard disks systems provide, and other device I/O such as printers and serial ports. Both the hardware and the software environment that defines the operating system and the requirements of the system application will determine the degree of implementation of the supporting functions provided to the Run-Time Support Libraries by the operating system.

The operating system chosen for the Thermal Margin Monitor is a combination of VRTX (a multi-tasking executive for the 8086/88) and various software routines written by the software development team at GAMMA-METRICS to provide those functions that the VRTX operating system and the various Run-Time Support Libraries require. These software routines include functions to initialize and to provide drivers for the various hardware devices such as the real time clock, counter timer circuit and parallel port. In addition, there are routines to support the run-time exception handling systems for both the compiled Pascal modules and for the 8087 support libraries. In the case of the 8087, the Thermal Margin Monitor will be using the Emulator 8087 NDP software package which contains the routines that fully emulates the 8087 NDP co-processor.

VRTX enables the software developer the ability to provide an integrated method of providing a multitasking environment with little support software overhead. However VRTX, as received from Hunter and Ready, does not directly support the ability to have its various software functions called from a higher language, such as Pascal, as a defined and recognized function or procedure within the specifications of that language. As received, VRTX is only usable through assembly language routines that pre-set various registers for their use by VRTX and translates the return values contained in predefined register upon return from VRTX. However, an assemble language module that can interface Intel Pascal routines with the VRTX operating system would provide the software support to allow the control of the VRTX system from Pascal software modules. This interface will be written to allow all of the VRTX system calls to be available to the programmer directly from Pascal as a set of predefined procedures and functions will various input parameters and returned values where necessary and as defined in the VRTX User's Guide. The VRTX support manual, "Interfacing Vrtx to a language" will be used extensively to develop this software interface.

Since VRTX is a multitasking environment, any task that will be defined to run under VRTX and any support software to these tasks must be reentrant. This is crucially important as far as the Run-Time Support Libraries are concerned since any of the tasks supported by VRTX may at any given time call any of the various routines in the support libraries as a natural course of the Pascal compiled routines that use these libraries. Since the 8087 Run-Time Support Libraries are not reentrant, the multitasking abilities of VRTX are disabled while any one task is using these support libraries. However, VRTX's multitasking capabilities are fully utilized for a majority of the remaining program code of the Thermal Margin Monitor. Because of this, all routines that are to be used in the Run-Time Support libraries and all routines that provide support to the individual tasks must be reentrant. The following sections will address the necessary steps in order to ensure that all aspects of the Run-Time Support Libraries, the VRTX operating system, and the hardware software support drivers are covered in the overall Thermal Margin Monitor software architecture in order to fulfill the necessary software requirements for this system.

In order to fulfill the necessary functions and global references needed by the support libraries which are to be supplied by the operating system, the null library RTNULL.LIB is linked in with all the object modules and after these modules to insure that any unsupported feature of the run-time system will have all external and global references resolved at link time. RTNULL.LIB will insure that these references will be resolved, however, it will perform little if any actual tasks towards supporting the run-time system and will in most case simply put the processor in a halted state if any of the support procedure labels are called inadvertently. If the labels are resolved by either a library or object module that is linked ahead of RTNULL.LIB then that global reference will accepted by the linker as the legitimate label and that which resides in RTNULL.LIB will be ignored.

The interrupt handling system of the Thermal Margin Monitor provides interrupt handlers for interrupts caused by the run-time system by initializing the appropriate interrupts vectors with the handler addresses. These handlers will take the appropriate action such as print an error number to the monitor's screen or providing VRTX with its time base for its multitasking system. Upon start-up, a routine will initialize each group of 16 interrupts from interrupt 0 to 255 with a vector that will trap all interrupts that are not later handled by specific handlers. Then after this initialization, the interrupts directly supported by the Pascal run-time system ,the 8087 NDP run-time, and VRTX are handled by other interrupt handlers that will take care of the specific requirements of each interrupt and their respective vectors will over-write the previously placed default interrupt handler routines. Interrupts such as interrupt 0, 4, 5, 16, and 17 which correspond to divide exception, overflow, range check, floating-point exception, and case range/ procedure stack overflow respectively are interrupts that indicate unrecoverable errors in the monitor software system and therefore will cause a system "hang up" after the appropriate error number has been written to the monitor's screen. The previously mention set of interrupts are the interrupts that will indicate to the operating system that a specific run-time exception has occurred. All other run-time Pascal exceptions are handle by the compiled modules individually by their calling a supplied exception handler routine that is called PASHAN.

PASHAN is the abbreviated name for Pascal handler and it is the global label for the Thermal Margin Monitor's main Pascal run-time exception handler. The previous paragraph covered the exceptions not included in this handler where the system uses interrupts to handle a few of the run-time exceptions. When the compiled Pascal modules (especially those compiled with the CHECK option, see page 10-10 of the Pascal-86 User's Guide 121539-005 hereafter mentioned as the Pascal user's guide) detect an exception they call a procedure named TQGETERH which is supplied by an assembly language routine that will place in a pointer variable the address of the Pascal exception handler named PASHAN. After the routine has the address of PASHAN, it will call this exception handler with data parameters that will indicate such information as the exception code that corresponds to the exception as listed on pages 14-1 through 14-4 of the Pascal user's guide. The procedure PASHAN will translate the information provided to it by the calling program to an error number that has been defined by the monitor's operating system.

The 8087 NDP exception handling routine works in a very similar method to the above Pascal exception handler except that the handler is invoked by code produced by the Emulator 8087 NDP. This software will copy the address that resides at location 040h , the interrupt 16 vector which is reserved for 8087 exceptions, to a location that is defined by the 8087 run-time support libraries with a jump instruction (OEAH) before the address. When an exception involving the Emulator 8087 occurs, the emulator code will jump to the jump instruction that contains the address of the 8087 exception handler and then the exception handler will print the appropriate error code on the monitor's screen as it did in the Pascal exception handler. There is a slight modification to this system when code is written to reside in ROM. There currently is no code in the Intel run-time support libraries that will place the jump instruction (OEAH) before the exception handler address and this jump instruction will only be in the program code if both the code section and the data of the program are loaded into memory at the same time. In the ROM version, the only data that resides in the data section of the monitor's memory is that which the program loads into it. The above information was verified by Alfred Wong and Chung Lew of Intel's software development group (phone 408-987-7816) and they indicated that if the system will place the jump instruction in memory sometime during initialization, then the 8087 run-time support library will function properly. Listed below is the set of error codes that will be printed on the screen for the corresponding run-time exceptions involving the Emulator 8087 and the compiled Pascal code.

The following is a list of the error codes that will be displayed on the Thermal Margin Monitor:

1) UNINITIALIZED INTERRUPTS. before the tmm program is started,

a routine calles resetl will be run that will group the 256 interrupts into 16 groups of 16 members and each group will have its own exception handler and will display a different code on the tmm screen.

group 0 - 80

group 1 - 81

group 2 - 82

.

.

.

etc

group 15 - 95

2) PASCAL EXCEPTIONS. These exceptions will occur as a result of the Pascal run-time system. Pascal will report these as a four digit number starting with a 8000, for ex. 8000 for divide by zero as defined in the Pascal reference manual. however, errorhang will display this information as an integer and therefore the screen would display the value -0 for a divide by zero.

divide by 0 -0	RUN-TIME PASCAL INTEGER ZERO DIVIDE: 8000
integer overflow -1	RUN-TIME PASCAL INTEGER OVERFLOW: 8001
heap exception - 1151	
heap exception - 1152	
heap exception - 1153	
set exception - 1131	
set exception - 1132	
set exception - 1133	
set exception - 1134	
set exception - 1135	
range exception -6	run-time exception 8006
range exception -17	run-time exception 8017

3) 8087 EXCEPTIONS- These exceptions occur as a result of the 8087 emulator They can be cumulative in that a precision error can occur at the same time as an invalid operation error and errorhang would display the summation of the two error numbers as found below and the above errors would result in a number 33 being displayed.

Invalid operation - 1

Denormalized operand - 2

Zero divide - 4

Overflow - 8

Underflow - 16

Precision - 32

NOTE: The error numbers from 1 to 63 have been reserved for the 8087 because the above exceptions can occur in combinations and the exception handler will display these all at once. For example if both a precision (error number 32) and an overflow exception (error number 8) occurred then the error number 40 would be display to indicate that both of these exceptions occurred simultaneously.

4) MACHINE LEVEL EXCEPTIONS. These exceptions occur due to the conditions described by each exceptions.

interrupt 0 - 96	divide by zero
interrupt 1 - 97	single step
interrupt 2 - 98	NMI (non-maskable interrupt)
interrupt 4 - 99	interrupt on overflow
interrupt 5 - 75	array out of range
interrupt 17 - 76	integer out of range

The remaining support functions that the operating system is expected to provide the run-time support libraries are not implemented by the Thermal Margin Monitor because these various function are not used by the system. There are no file I/O support routines because the monitor does not have any file devices such as floppy disk or hard disk. In addition, the memory management system that supports the heap are not provided because the Pascal routines NEW and DISPOSE are not invoked in this software system. The Intel Pascal compiler provides the ability for very extensive and powerful file I/O routines and command line processing. These capabilities enable very powerful operating systems such as MSDOS, Intel intellec III, and Intel IRMX which are based upon the 8086/88 to be fully used as regard to their various characteristics. However, when applying the Intel Pascal software environment to a stand-alone target system with no file I/O devices and no direct human interface that allows for example the inputing to the operating program a command line or direct input, the need for and the implementation of these extensive routines do not exist. As seen in the "Run-Time support Manual for iAPX 86,88 Applications" from pages B-8 to B-47, there are a great number of these routines that ,except for the exception handling routines, deal with the type of routines that have been previously discussed. These routines that deal with file I/O, memory management (heap), and other routines that support interfacing to a complex operating system are not support directly but instead are linked with the code in RTNULL.LIB as discussed previously and if inadvertently called, will in almost every case cause the processor to halt. Therefore the Thermal Margin Monitor has been designed to provide only the minimum degree of support from the operating system to the run-time support libraries and only in the case of the Pascal exception handler support routine TQGETERH is the support libraries supported at all. The software was designed with no calls to any of the Pascal routines that would invoke the remaining routines that the operating system is expected to provide. The following is a list of those routines that the operating system does not support for the Run-Time Support Libraries.

1) TQ$FILE$DESCRIPTOR

2) TQ$DEVICE

3) TQ$INITIALIZE

4) TQGETPRECON

5) TQ$EXIT

6) OPEN

7) CLOSE

8) READ

9) WRITE

10) SEEK

11) SKIP

12) END RECORD

13) REWIND

14) BACKSPACE

15) END FILE

16) TQSETERH

17) TQ$ALLOCATE

18) TQ$FREE

19) TQGETSMALL$HEAP

For further details on the above functions please read appendix B of the "Run-Time Support Manual for iAPX 86,88 Applications". This appendix will also indicate the action taken when these functions are invoked and the RTNULL.LIB is linked in place of routines usually provided for by the operating system.

In review, the operating system of the Thermal Margin Monitor which is composed of the multitasking VRTX system and support routines provided by programmers at GAMMA-METRICS supports only the exception handling responsibilities of the requirements of the logical record system as defined by the "Run-Time Support Manual for iAPX 86,88 Applications" as specified in appendix B. These exception handlers include those necessary for both the compiled Pascal code , the 8087 NDP, and the processor level exception interrupts. Figure B-1 of the run-time support manual shows a diagram which gives a graphic display of providing run-time support without an operating system. Page B-2 of the same manual shows a complete break down of what a standard interface called the "Logical Record Interface" should provide in order to fully implement the features of the Intel Pascal compiler. Of these various supporting software routines, only TQGETERH is provided. If in the future, added hardware devices are added that can support file I/O or if management of the heap is needed due to the use of the procedures NEW and Dispose, then it will become necessary to provide an added amount of support from the operating system in the form of procedures that are listed on page B-2 of the run-time support manual.