HAZARDS ANALYSIS BY THE RESEARCH AND POWER REACTOR SAFETY BRANCH

DIVISION OF REACTOR LICENSING

IN THE MATTER OF

CONSUMERS POWER COMPANY

BIG ROCK POINT

PROPOSED CHANGE NO. 1 - NATURAL CIRCULATION FLOW TESTS

Introduction

Consumers Power Company, pursuant to 10 CFR 50.59, requested by letter dated March 26, 1964, authorization of "Proposed Change No. 3 to the Technical Specifications for the Big Rock Point Nuclear Plant." The proposal identified 47 separate items which are currently being evaluated. Two of the items, Item 13 and Item 46, request changes to permit operation of the reactor with "natural circulation flow" instead of a minimum flow of 6×10^6 lbs/hr. This change, designated Proposed Change No. 1 to the Technical Specifications appended to License No. DPR-6, dated May 1, 1964, relates only to Item 13 and Item 46. Supplemental information regarding the natural circulation tests was provided by letter dated May 21, 1964, and by TWX dated May 29, 1964.

Scope of Natural Circulation Tests

Consumers has proposed to add a new Section 8.2.4 to the Technical Specifications to describe and define the Phase II R&D Program natural circulation tests to be performed. This section pertains only to the 84-bundle core. Natural circulation tests with 44 assemblies could be performed, in our opinion, only after an evaluation of 84 assembly natural circulation test results and new minimum permissible natural circulation "Flow vs. Power" data have been submitted for further evaluation by the Division of Reactor Licensing. Section 8.2.4 of the Technical Specifications proposed by Consumers as modified by the Staff to incorporate a requirement that such tests shall be performed prior to September 1, 1964 reads as follows:

"8.2.4 Natural Circulation Tests*

During Phase II of the R&D Program, selected tests may be conducted under conditions of natural circulation. These tests may be performed with the 84-bundle core loading and within the range of variable as specified in Section 8.2.1. In all cases, any mode of natural circulation operation shall have been shown analytically to be within the following limits for the specific flow rate applicable to the given operating conditions. In addition, as established during Phase I tests, testing will be performed at increasing increments of power to compare analytical calculations with actual conditions.

* Such tests shall be performed prior to September 1, 1964.

8.2.4.1(a) Operating Limits

Minimum Overpower Burnout Ratio	1.5
Maximum Heat Flux at Overpower, Btu/Hr-Ft^2	530,000
Maximum Steady State Heat Flux, Btu/Hr-Ft^2	434,000
Maximum Fuel Rod Power at Overpower, Kw/Ft	17.2
Maximum Steady State Fuel Rod Power, Kw/Ft	14.2
Stability Criterion: Maximum Zero-to-Peak Flux Amplitude, Percent of Average Operating Flux	20
Maximum Steady State Power Level, Mwt	That Permitted By Other Operating Limits
Maximum Reactor Pressure During Power Operation, psig	1485

(b) Power vs. Minimum Permissible Natural Circulation Flow to assure that the minimum burnout ratio is 1.5 or greater for 84 Fuel Assembly Core.

Power	Minimum Flow Permitted	Predicted Flow
MW (t)	lbs/Hr x 10^{-6}	lbs/Hr x 10^{-6}
90	1.7	4.2
110	2.3	4.4
130	3.2	4.6
156	5.0**	4.8

(c) The maximum operating level will be that which corresponds to 100% where the calculated limiting conditions are considered as 122% overpower.

(d) Set Point changes in plant instrumentation are essentially only the picoammeter set points which will be adjusted to be compatible with the new operating power level dictated by any of the above operating limitations.

8.2.4.2 General Procedure

Phase II natural circulation tests will begin from a normal forced circulation mode in the following general steps:

a. Trip both recirculation pumps from an initial steady operating condition, not to exceed 157 Mwt.

** Maximum permissible natural circulation flow for stable operation (no oscillations) is greater than 5.6 x 10^6 lbs/hr at 155 MW(t).

b. After power coast-down has settled out, increase power in approximately 20 Mwt steps, while measuring power level, flow rate and flux noise amplitude to confirm observance of specified operating limits.

c. At selected operating points, perform Phase II tests such as rod oscillator tests.

d. Upon termination of natural circulation tests, restore forced circulation mode after reducing power level to that obtained in Step b. above after tripping pumps."

Evaluation

Additional detailed analyses have been performed recently for the specific 84-bundle core configuration to be operated for the initial Phase II tests. This core includes 18 developmental assemblies and the selective use of B_4C poison rods in 12 of these assemblies. The following thermal-hydraulic and stability data have been calculated for this core over the natural circulation test operating range. The limiting case based on the steady state burnout ratio limit of 1.5 is presented below.

Reactor Thermal Power at Overpower, Mw_t	190
Reactor Pressure, Psia	1,250
Maximum Overpower Heat Flux, Btu/Hr-Ft^2	305,000
Minimum Overpower Burnout Ratio	1.51
Fuel Rod Power at Overpower, Kw/Ft	9.95
Inlet subcooling, Btu/Lb	38.6
Average Inlet Velocity, Ft/Sec	1.75
Maximum Inlet Velocity, Ft/Sec	1.82
Stability Phase Margin at Overpower, Degrees	55.6
Recirculation Flow Rate, Lb/Hr	5.0×10^6

The analytical method employed incorporates significant inherent conservatism and power distributions assumed are adequate for the period of predicted core operation up to September 1964. Since the power shaping in the reactor is dependent on fuel depletion, further calculations would be required to properly evaluate natural circulation tests beyond that date.

The burnout ratio increases during natural circulation as power decreases, though the recirculation flow also decreases. To illustrate this, examples of three calculated power levels are listed below, including the limiting overpower case of 190 MW(t).

Power MW(t)	Flow - Lb/Hr	Min B.O.R.
177	4.9×10^6	1.89
190	5.0×10^6	1.51
206	5.1×10^6	1.29

The stability of the 84-bundle core was evaluated for two cases, i.e., that corresponding to the burnout limiting overpower case of 190 Mwt, 1250 psia, and its corresponding nominal operating power of 156 Mwt. The results are presented as frequency vs. phase and magnitude curves in Consumer's application.

Power Level	Gain Margin	Phase Margin
190 Mwt	10.6 Db	55.6 Deg
156 Mwt	10.9 Db	59.8 Deg

Both operating points demonstrate a substantial margin above instability and indicate little sensitivity to changes in operating power levels.

The thermal hydraulic analyses are based on methods developed by General Electric Company and have been verified in the operation of many natural and forced circulation reactor systems. The stability studies are based on methods developed as part of the Consumers R&D Program and reported in the topical and quarterly reports of that program. (1)

Phase II tests which involve natural circulation will begin from a normal forced circulation mode and follow these general steps:

1. Trip both recirculation pumps from an initial steady operating condition of 157 Mwt.

2. Power coast down will settle out at about 90 Mwt, while flow will drop to about 4.1 million pounds per hour. This condition is far from limiting with respect to any conceivable operating limit.

3. Power will be increased in approximately 20 Mwt steps, while measuring the power level, flow rate, and flux noise amplitude to confirm continued observance of specified operating limits before proceeding to next higher power.

4. At selected operating points, Phase II tests such as rod oscillator tests will be performed.

5. On termination of the tests, the forced circulation mode will be restored from a reduced power level.

The application shows a curve for a typical case where both recirculation pumps are tripped. The case is the nominal 1250 psia, 157 Mwt initial power situation referred to in the preceding procedure. Shown on the graph are the time responses

(1) GEAP-3795 - "Consumers Big Rock Point Nuclear Power Reactor Stability Analysis" by J. M. Case and L. K. Holland.

of heat flux, recirculation flow rate, and minimum burnout ratio. These data reflect substantial information gained during the Phase I tests where pump trips were performed from various initial operating levels and therefore reflect a high confidence level in their adequacy.

We have evaluated Consumer's analyses of the hazards associated with the proposed operation of the reactor on natural circulation and agree with its conclusion with respect thereto as set forth below:

1. Maximum Credible Accident - The maximum credible accident analysis (MCOA) is based on an initial power level of 240 Mwt and an initial pressure level of 1500 psia. Since the proposed operation will be at 157 Mwt and 1250 psia, the effects of the MCOA from that operating condition are less severe than the effects for the case analyzed and reported previously.

2. Accidental Pump Start Accident - Starting a recirculation pump during natural circulation will be prohibited by test procedures. Nevertheless, it has been determined that accidentally starting a pump, causing reduced steam voids, lower reactor temperature and consequent rapid reactivity insertion is less severe than the 100°F cold water accident analyzed for forced convection.

3. Reactivity Insertion Accident - Because of programmed overpower protection and the more negative void coefficient, the reactor overpower resulting from the maximum rate of reactivity insertion will be limited to values less than for normal operating conditions.

4. Plant Transient Performance - The most important parameters which influence plant transient performance are the void reactivity feedback coefficient and the inherent pressure rate following a sharp steam shutoff. The void coefficient was estimated to be slightly higher than the case studied for 240 Mwt operation. However, the pressure rate of the plant for this proposed operating condition is about 37% less than the pressure rate for the 240 Mwt case due to the lower steam flow rate in the proposed condition (610,000 vs 972,000 lb/hr).

The resultant transient reactor responses expected from the various turbine trips and load rejections are less than those determined and reported for normal operation.

Technical Specifications

To provide authorization of Proposed Change No. 1, Sections 5.3.1(b) and 8.2.1 of the Technical Specifications of License DPR-6 should be amended as follows:

"5.3.1(b) Reactor Operation; change the minimum recirculation flow rate specification to the following:

Minimum Recirculation Flow Rate, Lb/Hr (Except during pump trip tests or natural circulation tests as outlined in Section 8) 6×10^6"

"8.2.1 Core Performance and Transient Tests; change the specification on recirculation flow rate as follows:

Variable	Range
Recirculation Flow Rate	Natural Circulation to Full 2 Pump Flow"

8.2.4 Natural Circulation Tests as proposed by Consumers Power and quoted earlier in this hazards analysis should be added to the Technical Specifications of License DPR-6.

Summary

The following is a summary of the considerations regarding the natural circulation flow tests at the Big Rock Point nuclear plant:

1. Predicted natural circulation flows in the test range are above the minimum flows where the burnout is 1.0, and below the values where reactor instabilities could be expected.

2. The operational restrictions on flow and the protection afforded by the reactor overpower scram circuit minimize fuel rod failure possibilities.

3. The analytical methods used to predict flow during natural circulation have been verified at low power levels by comparing flow predictions to flow measurements obtained during Phase I pump trip tests.

4. Tests will be performed at steady state conditions. (No Transient Tests during natural circulation except for oscillator tests which cause only minor perturbations.)

5. The power distributions assumed in the core performance calculations relating to the proposed tests are adequate for the period of predicted core operation up to September 1, 1964.

Conclusion

On the basis of the foregoing considerations, we have concluded that Proposed Change No. 1 does not present significant hazards considerations not described or implicit in the hazards summary report and that there is reasonable assurance that the health and safety of the public will not be endangered.

Accordingly, we believe the Technical Specifications of License No. DPR-6 should be revised as indicated herein to allow the conduct of natural circulation flow tests at the Big Rock Point plant, as proposed, for the time period not exceeding September 1, 1964.

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Date: June 15, 1964