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JAN 27 1978

269

NOTE TO: B. C. Buckley, Section Leader, Plant Systems Branch, DOR

FROM: S. D. MacKay, Plant Systems Branch, DOR

SUBJECT: OCONEE POWER OSCILLATIONS

During a visit to the Oconee power station on December 27, 1977, additional information was obtained regarding the nature and cause of reactor power oscillations on Unit No. 3 and the action taken by the licensee to reduce the magnitude of these oscillations.

The licensee had observed reactor power oscillations in Units 1, 2 and 3 at power levels between 50% and 75% of full power that had a frequency of 0.25 Hertz and a peak-to-peak amplitude of approximately 1.5% of full power. These oscillations were considered normal. However, following the first refueling outage of Unit No. 3 in the Fall of 1976, these 0.25 Hertz oscillations gradually increased in amplitude from 1.5% in November 1976 to 7% in June 1977 (see Reference 1).

In an effort to determine the cause of the oscillations and to eliminate them, the licensee gathered data on all parameters that were oscillating and checked all settings in the integrated control system. Parameters that oscillate at 0.25 Hertz include: reactor power (out-of-core detectors), reactor coolant inlet temperature, reactor coolant outlet temperature, steam generator pressures, steam generator water levels, feedwater flows, feedwater pump pressures and reheater drain level. The only abnormality noted in checking the process system parameters was that steam generator A provided 18°F less superheat than steam generator B and the least amount of superheat in any once-through steam generator. It has been pointed out that this may be related to the fact that steam generator A has an open lane three tubes wide rather than one tube wide. In assessing the effects of the integrated control system on the oscillations, the power from the steam generators was unbalanced by demanding the reactor coolant returning from steam generator B to be 2°F hotter than the reactor coolant returning from steam generator A. This unbalance stopped the oscillations but the settings were restored for normal operation. Similarly, when only three of the four reactor coolant pumps are in operation, the oscillations are not present. This and other information together with previous knowledge that the steam generator water level had a natural frequency of 0.25 Hertz led to the conclusion that the oscillations might be reduced by increasing the hydraulic resistance of the downcomer region of the steam generator. There is an adjustable orifice in the steam generator for this purpose.

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It was planned that during the October 1977 shutdown, the orifice plate position would be checked and if it were 2 1/2 inches open, the same as Units 1 and 2, it would be completely closed. During the shutdown it was found that the orifice plate was in the expected position, 2 1/2 inches open. However, attempts to close the orifice failed as the plate could be moved only 1/4 to 1/2 inches toward the closed position. It was secured in that position, between 2 and 2 1/2 inches open.

After refueling, the plant was started up on December 3rd and the amplitude of the power oscillations was less than one percent. However, after operation for three days at 75% power it was apparent that the oscillations were increasing in amplitude. Figure 1 shows that on December 18 while operating at approximately 75% power, the peak-to-peak amplitude of the power oscillations was 2.2 percent of full power.

My current knowledge of the phenomenon leads to the following qualitative understanding. The oscillatory tendency originates in the steam generator at the natural frequency of oscillation of the water levels in the downcomer and tube bundle regions. This effect may or may not be enhanced by the process system or the control system. In either case, a change in the water level in the tube bundle will cause a change in the effective heat transfer area coupling the reactor coolant system to the steam system resulting in a change in the rate of heat removal from the reactor coolant and thereby causing a change in the temperature of the coolant returning to the reactor core. The oscillating water level therefore causes the reactor water temperature to oscillate and results in reactivity changes that cause the reactor power level to oscillate. These temperature and power level changes also result in the oscillation of the reactor outlet temperature but it is not clear whether this temperature oscillation in turn significantly influences the water level in the tube bundle region.

The power level oscillations were minimal when the reactor was first placed into operation after refueling because at that point in core life the absolute magnitude of the temperature coefficient of reactivity was relatively,small, i.e., about 1/5 of that at the end of the previous cycle. However, as the fuel burned up and boron was removed from the moderator, the temperature coefficient of reactivity increased and thereby caused the reactor power oscillations to increase in amplitude. Thus, if no corrective action is taken, the amplitude would be expected to increase throughout the life and become approximately the same as that at the end of the previous cycle.

It was also noted that the power level oscillations are measured on the out-of-core neutron detectors whereas the in-core detectors indicate no oscillation. There is no in-core indication of power oscillation because the in-core power level signals are generated

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by the activation and decay of rhodium powered detectors that have an effective response time of several minutes and therefore do not respond to a 0.25 Hertz oscillation. The out-of-core detectors respond quickly to neutron flux level changes and therefore follow the 0.25 Hertz oscillations that could arise from core power level changes or changes in the density of the water in the reactor vessel downcomer between the core and the detectors. A calculation of the changes in neutron attenuation due to the oscillating temperature of the incoming water compared to an estimate of the reactivity effects of that temperature oscillation shows that the reactivity effects are predominant and therefore the out-of-core detectors indicate an actual power level oscillation.

A good deal of additional data and some testing are necessary to confirm our present understanding of the phenomenon and allow us to quantify some of the effects that have been observed.

The licensee is continuing its evaluation of this matter, devising special tools to permit movement of the orifice plates in the steam generators and developing further tests of the instrumentation and controls. Additional data will be obtained within the first 28 effective full power days when the reactor is at 75% power for the correlation test of the in-core and out-of-core deutron detectors.

It is expected that the amplitude of the oscillations, will not exceed the value previously experienced, and there is apparently no significant safety consideration at that value. However, it is recommended that the licensee be encouraged to obtain additional data and a better quantitative evaluation of this phenomenon so that the oscillations may be eliminates or reduced to an insignificant level.

S. D. MacKay, Plant Systems Branch
Division of Operating Reactors

References

1. "Trip Report - Oconee Power Oscillations" 10/31/77, R. Woodruff, IE.
2. BAW-10002, "Once-Through Steam Generator Research and Development Report," August 1969.
3. BAW-10002, Supplement 1, June 1970.

Enclosure

Figure 1 - Oconee Unit 3 Power Level Oscillations

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JAN 27 1978

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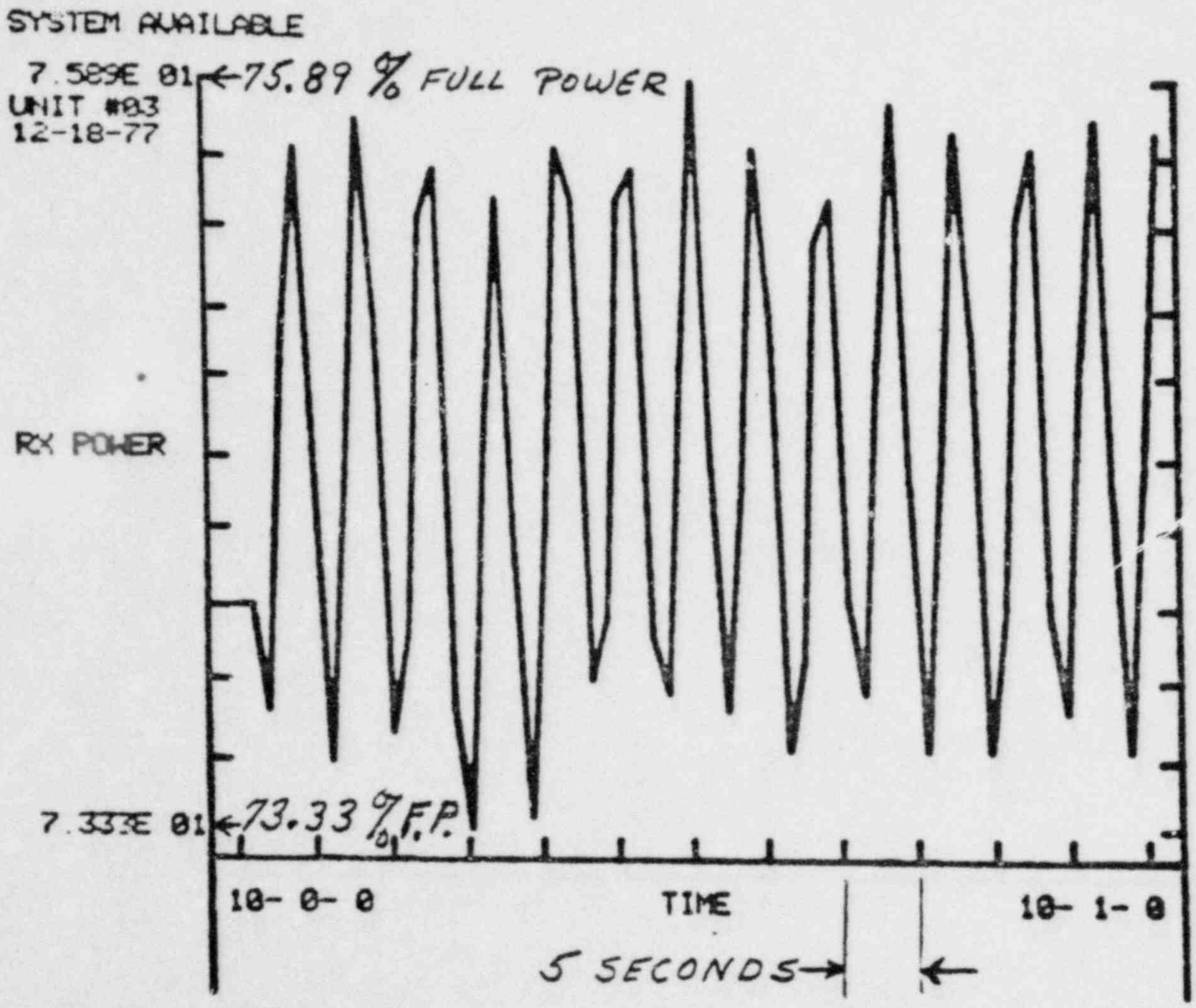
Oconee Unit 3
Power Level Oscillations



NOTE: THIS IS NOT AN ANALOG RECORD.
DATA IS PLOTTED AT ONE SECOND INTERVALS.

FIGURE 1

JAN 27 1978

ADDENDUM TO NOTE OF 1-27-78 TO B. BUCKLEY

SDM

Oconee Oscillations

1. Response of Resistance Temperature Detector (RTD) to 0.25 Hertz temperature oscillations.

On January 18, 1977, I learned from a B&W employee that the response time of the RTDs was three to four seconds but might be as high as five seconds. Using four seconds as the time constant, we obtain

$$\omega T = 2 \pi (0.25) 4$$

$$= 6.28 \text{ radians}$$

A calculation of the response of this simple lag system shows an attenuation of 16 dB and a phase lag of 81°.

This shows that the RTD element will experience a temperature oscillation that is 16% as great as the oscillation in reactor coolant temperature at the 0.25 Hertz frequency. Thus the indicated temperature oscillation of 0.18°F (peak to peak) observed on December 18, 1977 at 10 am. reflected an actual temperature oscillation of 0.18/0.16 or 1.13°F.

2. Reactor Response to Oscillation of Inlet Water Temperature

The transfer function of a PWR is fairly flat in the region of 0.25 Hertz and the reactor should respond with nearly full amplitude to reactivity oscillations at this frequency. Since the fuel temperature oscillations will be very small, reactor power will respond to T inlet directly. Thus the power level response is estimated to be approximately

$$\frac{dn}{n\Delta K} \times \frac{\Delta K}{\Delta T} = \frac{dn}{n\Delta T} = 10^4 \times \frac{\Delta K}{\Delta T}$$

percent power per °F.

Thus a 1°F rise in downcomer water temperature will cause the neutron detectors to indicate a 0.3% power level increase. This accounts for part of the amplitude of the oscillations.

4. Phase Relationship Between Power Level and Downcomer Density

The effective transport time from the downcomer to the core is approximately one and a half seconds. The power level will lag the reactivity change slightly and the total lag time between a downcomer density increase and a power level rise will approach two seconds. With a two-second lag, the power level will be 180° out of phase with the downcomer density, i.e., when the power level is maximum, the density will be minimum and therefore the two effects will be additive to produce the maximum neutron level reading.

The moderator temperature coefficient $\frac{\Delta K}{\Delta T}$ for cycle 3 has been reported to be -0.53×10^{-4} Beginning of cycle and -2.55×10^{-4} at end of cycle. Thus if the temperature coefficient were -1.2×10^{-4} on December 18 when the temperature oscillation was 1.13°F, the resultant power level oscillation should have been about 1.4 percent power. The data shows however, that the power level oscillations were approximately 2.2% power. A temperature power transfer coefficient of 1.8% power per °F would be needed to explain this behavior.

Although this calculation is neither sophisticated nor very accurate, it does indicate that the power level oscillations observed could result directly from the inlet temperature oscillations.

3. <u>Neutron Detector Response to Downcomer Water Temperature Oscillations</u>

The downcomer annulus contains a layer of water 8 1/4 inches (21 cm) thick between the reactor core and the neutron detector. For this thickness of water, the effective attenuation length will be approximately 10 cm (3 meV neutrons) and the change in attenuation per 1°F will be

$$\frac{dN}{N} = -\frac{1}{L}\,dx = -\frac{x}{L}\,\frac{d\rho}{\rho}$$

where $\frac{d\rho}{\rho} = -0.0014$ per °F at 550°F at 2000 psi

$$\frac{dN}{N} = \frac{21}{10} \times 0.0014 = 0.0030 \text{ per °F}$$

$$= 0.3 \text{ percent per °F}$$

JAN 27 1978

OCONEE UNIT 3
COLD LEG TEMPERATURE