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Dresden Nuclear Power Station
R. R. #1
Morris, Illinois 60450
June 13, 1975

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Mr. James G. Keppler, Regional Director
Directorate of Regulatory Operations-Region III
U. S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, Illinois 60137

SUBJECT: REPORT OF UNUSUAL EVENT PER SECTION 6.6.C OF THE TECHNICAL SPECIFICATIONS FEEDWATER SPARGER FAILURES

References: 1) Regulatory Guide 1.16 Rev. 1 Appendix A

2) Notification of Region III of NRC Regulatory Operations Telephone: Mr. P. Johnson 1145 hours on May 15, 1975

3) General Electric "Feedwater Sparger Cold Flow Vibration Tests" NEDO-20554, June 1974

4) Millstone Interim Report on Feedwater Sparger Failure including addendum 1, 2, 3, and 4; and special report, Chloride Intrusion Incident

Report Number: 50-249/75-27

Report Date: June 13, 1975

Occurrence Date: May 15, 1975

Facility: Dresden Nuclear Power Station, Morris, Illinois

IDENTIFICATION OF OCCURRENCE

At approximately 0800 hours on May 15, 1975, cracks were discovered in the Unit-3 feedwater spargers. These cracks constitute an unusual event because they represent a substantial variance from safety analysis report specifications.

CONDITIONS PRIOR TO OCCURRENCE

Unit-3 was in a refueling outage.

DESCRIPTION OF OCCURRENCE

A feedwater sparger inspection was performed in response to a General Electric recommendation (FDI 402/57145). Particular attention was directed towards the

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following areas:

a) Welds of header pipes to the junction box

b) Weld of the junction box to the thermal sleeve

c) Contact of the jack bolt bearing bars to vessel wall; welds of the jack bolt brackets to headers

d) Pin engagement with clevis ends of each sparger

e) Weld of cover plate to junction box

f) Cladded feedwater nozzle blend radii area on the reactor vessel

The inspection was conducted on May 15, 1975 at 0800 hours. It consisted of a combination of visual observations and dye penetrant NDE tests.

Cracks were observed on five of the eight header pipe to junction box welds and on one of four thermal sleeve to junction box welds.

<u>DESIGNATION OF APPARENT CAUSE OF OCCURRENCE</u> (Design Deficiency)

The inspection and the General Electric cold flow tests indicated that the cracking was due primarily to the design of the spargers which rendered them susceptible to flow-induced vibration.

<u>ANALYSIS OF OCCURRENCE</u>

The Unit-3 sparger cracks looked very similar to sparger cracks at other BWR plants. Sparger cracks at one BWR plant were metallurgically analyzed and were determined to be transgranular (fatigue) cracks.

Numerous full-scale cold-flow tests (Ref. #3) have been conducted at the General Electric test facility in San Jose on feedwater spargers of several different configurations to determine the cause of vibration. Results of these tests have shown that unstable flow-induced vibration occurs as a function of the following variables:

The pressure differential between the sparger inlet and discharge

The average radial gap, which permits leakage flow between the inside of the thermal sleeve and the outside of the feedwater nozzle

The amount of damping present in the system, particularly at the thermal sleeve-to-nozzle interface.

It is known from the cold-flow tests that leakage flow plays an important role in sparger vibration because the tests show that the sparger will vibrate when only leakage flow is present. However, it is not known whether the radial gap is important primarily as it affects the amount of leakage flow, or as it affects damping, since gap changes inevitably change both these variables in tests.

The importance of damping was demonstrated in a test of the spargers (without preload) in which a lifting force was applied at the tee box while the point of instability was determined.

The tests at the GE sparger test facility show that there is a relationship between thermal sleeve/nozzle leakage and sparger vibration. For the cold flow sparger tests, the vessel nozzle inside diameter at the thermal sleeve fit was increased in increments for the performance of leakage tests and corresponding full flow tests. These tests indicate that for a given sparger flow, the leakage is directly proportional to the average radial gap between the nozzle and thermal sleeve.

Although the Dresden 3 thermal sleeve was designed to allow only a 0.003-inch radial gap, the error band of the stability boundaries (Figure I), the operating pressure drop across the sparger of about 16 psi, and the methods of construction and installation which could produce a much larger radial gap than specified makes it entirely possible that the Dresden 3 spargers experienced flow induced vibration. The actual radial gaps found on another BWR unit with cracked spargers (Ref. #4) were significantly greater than specified. The unusual service and environmental conditions of changing feedwater flow rate, the temperature difference between the feedwater and the water in the vessel, and the movement of water within the vessel also contribute to the problem by producing thermal cycling, thermal stress, and effects on the damping.

This event did not cause any personnel injuries, personnel exposures, or release of radioactive materials. It is concluded that this event did not endanger the health and safety of the public.

In October and November of 1972, General Electric and Commonwealth Edison jointly performed an evaluation and wrote a report concerning the Dresden and Quad Cities feedwater spargers. The report included evaluation of the consequences of a feedwater sparger failure. This evaluation, given in its entirety in Appendix A, specifically considers enthalpy variation at the core inlet, the blockage of a fuel element, and effect of broken pieces on the core spray header. The evaluation concluded that the consequence of sparger cracking when position is maintained is not of safety significance. Even gross failure of the sparger would not result in an immediate safety concern.

An independent safety evaluation of a sparger failure from incipient through complete failure was given in reference #4. In this reference, the safety consequences of the following events were considered:

1. Fuel bundle flow blockage by small pieces;
2. Damage of ECCS core spray line due to a broken sparger falling against it;
3. Damage to the jet pump from a falling sparger;
4. Disengagement of the thermal sleeve from the feedwater nozzle;
5. Operation of the HPCI subsystem with a failed feedwater sparger.

There are no major changes in the new Design 4 sparger (to be discussed in the next section) from a safety standpoint. The conclusion is still that the safety consequences of a feedwater sparger failure are acceptable.

The cause of feedwater sparger cracking has been essentially determined by the GE cold-flow tests and the special instrumentation on the Design 3 spargers of another BWR plant (Ref. #4). The design features of the Design 4 spargers and their successful operation, as indicated by the special instrumentation, show that a solution has been found for the identified problem. Based on the above analyses, it is concluded that the renewed operation of Dresden is justified with the corrective actions to be taken as specified in the next section.

CORRECTIVE ACTION

The program for corrective action is to 1) liquid penetrant examine the accessible portion of the nozzle blend radius of each feedwater nozzle, 2) replace all four Dresden 3 spargers this outage with new spargers to the new design (very similar to the Design 4 spargers in Ref 2), and 3) inspect the feedwater spargers during its next scheduled refueling outage.

The salient design features of the Design 4 feedwater sparger are (see figure V):

1) Interference fit between the sparger thermal sleeve and vessel safe end.

2) Forged-welded tee between the thermal sleeve and the sparger headers.

3) Different size and location of exit holes in the sparger

4) Schedule 80 rather than schedule 40 304 stainless steel spargers.

The first design feature was based on several tests showing there was no vibration under any flow conditions when the thermal sleeve was tightly fitted to the safe end (small radial gap).

The second design feature reduces peak stress levels in the tee by a factor of 4 due to smaller stress concentrations. This is due to the use of full penetration welds, more uniform sections, and large radii at the junction of the header pipes and the thermal sleeve.

The third design feature was incorporated to lower the pressure drop at rated flow from 16 psi for the first designs to 11 psi for the new designs which increases the stability margin (See Figure I).

FAILURE DATA

Previous inspections of the Unit-3 sparger revealed no cracks. The previous inspection on the Unit-2 sparger revealed cracking similar to that encountered on Unit-3 during this outage.

B. B. Stephenson
Superintendent

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APPENDIX A

Consequences of Feedwater Sparger Failure

The safety aspects of Feedwater Sparger failure are addressed as follows:

A. Enthalpy variation at the core inlet.

B. Possibility of small pieces of the sparger blocking a fuel element orifice.

C. Effect of large pieces of the broken sparger on the core spray header.

A. Non-Uniformity in Core Inlet Enthalpy

If one or more Feedwater Spargers should partially or completely break, there will be a non-uniform temperature distribution of the coolant in the downcomer annulus. Because of incomplete mixing in the lower plenum, non-uniformity in the core inlet enthalpy would exist. As stated in references (1) and (2) core power assymetries would result. The references also conclude that these assymetries do not present a safety problem. The rationale for this conclusion is that the calculation of MCHFR in the highest power region will be in the conservative direction, i.e., calculated MCHFR will always be less than the actual MCHFR. This is further explained in the following paragraph.

If a particular region in the core is supplied with coolant at an enthalpy lower than the average inlet enthalpy, the power in that region will be greater than the average power. Because incore instrumentation indicates actual power and MCHFR is calculated using the average inlet enthalpy, the MCHFR in the region of higher power will always be calculated at a value less than actual. This calculation always results in a conservative MCHFR and assures adequate margin for all transients and postulated accidents.

B. Effect of Small Pieces in the Reactor

If the sparger junction box should separate from one of the sparger arms, a small piece could conceivably break loose. A concern with a small piece is that associated with potential fuel bundle flow blockage. Since the piece must be sucked in through the annular passage around the jet pump nozzle, the maximum size of the piece would be less than $2\frac{1}{2}$" by $2\frac{1}{2}$", by $\frac{1}{4}$" thick. The chances of the piece flowing into the jet pump are small. However, for purposes of determining potential consequences, this is assumed to occur.

The safety analysis for this piece is considered to be identical to the safety analysis and test performed for the Quad Cities jet pump washer and was used as a guide in performing the sparger piece evaluation discussed below.

A detailed study of flow blockage in a BWR has been made in a GE Topical Report (1) on file in the Public Document Room. As stated in that report, based on analyses of high power density fuel operating at 18.5 kw/ft:

a) It would take more than a 90% area blockage to cause a MCHFR less than 1.0: therefore, no fuel rod damage occurs.

b) If the blockage were more than 90%, clad melt and fuel crumbling would occur. This would lead to high radiation sensed by the main steam line radiation monitors which would scram and isolate the reactor. Offsite doses remain less than 10CFR20 limits.

Based on the information concerning the maximum size of the sparger piece, the following conclusions are drawn:

1) Because the fuel bundle orifice diameters are 1.425 and 2.262" and the maximum surface of the sparger piece is 2.5 inches square, it is possible for significant blockage to occur if the piece were carried to the orifice properly oriented.

2) The most likely resting place of the piece is in the reactor vessel on the bottom of the outer anulus. It may have found its way into the recirculation loop. It is possible for the lost piece to enter the lower plenum through the jet pump nozzle and therefore, it could be in the bottom plenum.

3) The fluid velocities in the lower plenum in the vicinity of the orifice region is a maximum of 3fps and is not high enough to lift the piece up toward the core inlet orifices. The vertical velocity to suspend but not lift the Quad Cities washer (2.25 inch diameter) was 5-6 fps as determined by test. However, even this presupposes the area is inserted into the upward velocity field. This can occur only with much higher velocities required to lift the washer from the bottom of the reactor vessel. The maximum upward velocity in the reactor lower plenum is about 6 fps.

4) If the piece is introduced into the lower plenum during operation, it will have a high (17 fps) downward velocity which will drive it to the bottom surface of the plenum. Further, the piece cannot easily negotiate the 180° turn to upwards toward the core. Due to its higher density, it will tend to move radially away from the turn and hence into the lower velocity points at the center and remain there. For the piece to be scooped up would require a much higher surface velocity than actually exists in the vertical direction. Therefore, it is concluded that the piece will remain in the bottom plenum if it is introduced there during operation or if it is there already.

5) The possibility of the piece becoming lodged at the core inlet is considered to be so highly improbable that operation can continue without safety concerns.

There is no way, because of the physical barrier which encompasses the CRD, for the piece to find its way into the control rod drive itself.

C. <u>Effect of Large Pieces on Reactor</u>

The feedwater Sparger could fail in various ways. For the purpose of this analysis it is assumed that both arms of the sparger header separates from the junction box but the thermal sleeve remains attached to the junction box. The main concern is the possible interaction between the failed pieces and the internal core spray distribution piping.

If the Feedwater Sparger fails as described above the jet of the feedwater would force the junction box against the shroud head bolts. A lateral movement of the tee box of approximately four inches would result. Since the thermal sleeve to the junction is 27 inches long, this assembly will not disengage from the pressure vessel. If the junction box (11 inches in diameter) were properly oriented it could pass through the space (15 inches) between two studs. In this event the junction box would travel an additional five inches and butt up against the steam separator standpipes. The junction box still could not separate from the pressure vessel.

The Feedwater Sparger arms and the internal core spray distribution piping (both 6" schedule 40 pipes) are separated 14 inches center to center or approximately 7 inches wall to wall. If the failed feedwater sparger arms should sag from its restraining brackets and rub against the internal core spray distribution piping, the resultant fretting action could in time wear a hole in this distribution piping. However, the wall thickness of the header is 0.280 inches so that some time would be required for this to occur.

Failure Detection

The immediate effect of a crack in a Feedwater Sparger junction box is a leakage path for feedwater flow. The leakage flow or its effect cannot be detected nor has safety significance unless there is a gross failure. For a gross change in flow pattern, downcomer flow distribution anomalities maybe detected by a change in the vessel water level indication and/or the core neutron flux instrumentation. The pattern and magnitude of these observed changes are unknown and can vary depending on the type of failure (e.g. one or two arms broken), exact location of the failure relative to the instrumentation, and plant operating conditions. In short, some change is expected but the magnitude of these changes cannot be quantified.

FOOTNOTES

(1) Consequences of a Postulated Flow Blockage Incident in a Boiling Water Reactor' NEDO-10174.

(2) Quad Cities has a maximum linear heat generation rate limit of 17.5 kw/ft.

REFERENCES

(1) "Reactor Asymmetrical Neutron Flux Distribution", Dresden Nuclear Power Station Unit 2 Special Report No. 6, March, 17, 1971.

(2) Supplementary Information to Special Report No. 6, February 17, 1972.

(3) "Consequences of a Postulated Flow Blockage Incident in a Boiling Water Reactor", NEDO-10174, May 1970.

BRS:RWC:smp

Figure I . Conditions for Sparger Instability Based on Cold Flow Testing