Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

BBS Ltr #43-75

Dresden Nuclear Power Station
R. R. #1
Morris, Illinois 60450
January 27, 1975

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
AEC DOCKET NUMBER 50-237

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

2) Notification of Region III of NRC Regulatory Operations
Telephone: Mr. P. Johnson, 0900 hours on December 28, 1975

Report Date: January 27, 1975

Occurrence Date: December 27 and 28, 1974

Facility: Dresden Nuclear Power Station, Morris, Illinois

IDENTIFICATION OF OCCURRENCE

The cracks discovered in the feedwater spargers constitute an unusual event because they present a substantial variance from performance specifications contained in the safety analysis report.

CONDITIONS PRIOR TO OCCURRENCE

The cracks were discovered during a scheduled feedwater sparger inspection while the unit was in a Refueling outage.

DESCRIPTION OF OCCURRENCE

A feedwater sparger inspection was performed in response to a General Electric recommendation (FDI #397/57145). The inspection consisted of using an underwater TV camera to examine areas including: 1) welds of six inch schedule 40 header pipes to the eleven inch junction box pipe, 2) weld of junction box to thermal sleeve, 3) contact of bearing bars to vessel wall, 4) pin engagement with clevis



1071

ends of each sparger and 5) cladded feedwater nozzle blend radii area on the reactor vessel. The inspection was performed from 4 P.M. December 27 to 4 A.M. December 28, 1974 and was recorded on video tape.

The inspection revealed two cracks. The first crack was located on the upper part of the right side header pipe to junction box weld area of the southwest quadrant sparger. The crack (see Figures I and II) appeared to be relatively straight, extending about 90 degrees around the pipe circumference. The second crack was located on the upper part of the left side header pipe to junction box weld area of the northeast quadrant header. This crack (see Figures I and II) appeared to be a little more jagged than the first crack, near the weld area and extending about 200 degrees around the pipe circumference.

It was also discovered that the bearing bars (preload spacer), on the right side of the southeast quadrant sparger and on the right side of the northwest quadrant sparger were not in contact with the vessel wall. No other discrepancies were observed.

The existance of the cracks was confirmed by additional personnel. The cracks were viewed by Commonwealth Edison metallurgists and a copy of the video tape of the inspection was given to General Electric for their review.

DESIGNATION OF APPARENT CAUSE OF OCCURRENCE

The TV inspection and the General Electric cold flow tests indicated that the primary cause of the cracking was that the design of the feedwater spargers rendered them susceptable to a condition of flow induced vibration. Installation/Construction and varying service conditions may also have been contributing causes of the cracking.

ANALYSIS OF OCCURRENCE

Based on the underwater TV inspection, the predominate failure mode appears to be fatigue cracking. The video tapes of the sparger inspection were also viewed by General Electric personnel and concensus of opinion was that the Dresden 2 sparger cracks looked very similar to the sparger cracks at another BWR plant (Ref. #2). The cracked spargers at this other BWR plant were metallurgically examined and determined to be transgranular (fatigue cracks).

As viewed through the underwater TV camera, the bearing bar on each of two spargers appeared to be out of contact with the vessel wall by a slight amount. Although there are several possible explanations for this, the actual cause is not known at the present time. This condition has been observed at other BWR plants and its presence does not alter the conclusion that the sparger cracks are caused by fatigue due to flow induced vibrations.

Numerous full-scale cold-flow tests (Ref. #1) 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 (see FigureIV) 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 roll 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. (See figure I).

Although the Dresden 2 thermal sleeve was designed to allow only a 0.003-inch radial gap, the error band of the stability boundaries (Figure IV), 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 2 spargers experienced flow induced vibration. The actual radial gaps found on another BWR unit with cracked spargers (Ref. #2) 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 broked 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 #2. 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 sybsystem 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. #2). 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 and the successful inspection of the Dresden 3 spargers during the previous refueling outage, it is concluded that the renewed operation of Dresden 2 and the continued operation of Dresden 3 are 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) further inspect the old Dresden 2 spargers and determine the actual radial gap when they are removed, 3) replace all four Dresden 2 spargers this outage with new spargers of the new design (very similar to the Design 4 spargers in Ref 2), 4) inspect the feedwater spargers during its next scheduled refueling outage and 5) inspect (including a liquid penetrant examination of the nozzle blend radii) the Dresden 3 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) Scheduled 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 design which increases the stability margin (See Figure IV).

The fourth design feature will increase the strength of the spargers by increasing the thickness of the pipe walls.

FAILURE DATA

Previous inspections of the Dresden 2 and 3 spargers did not reveal any sparger damage. Sparger damage has been noted in at least one other BWR unit (Ref 2).

The cracks were found in the area where six inch schedule 40 header pipes are welded to the junction box pipe (see figures I, II, and III). The spargers are made of 304 stainless steel (schedule 40).

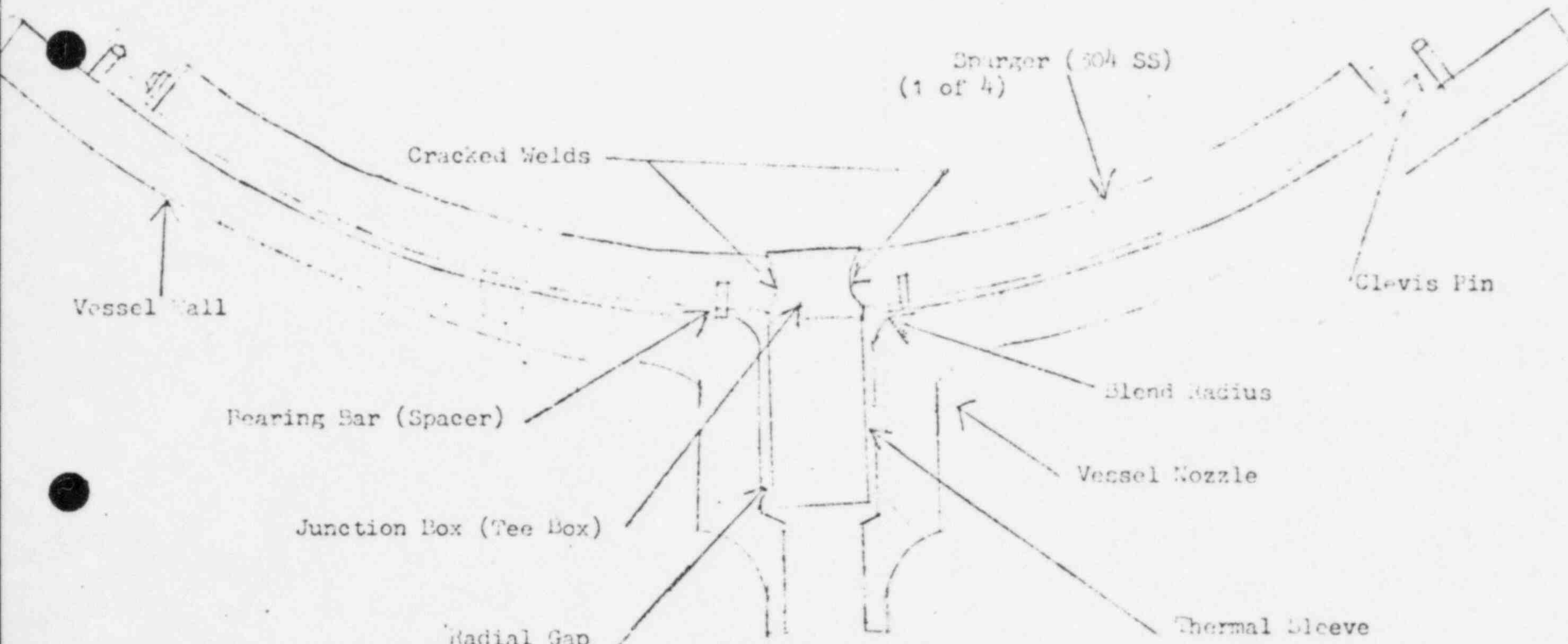
The documents references in the letter are:


1. General Electric "Feedwater Sparger Cold Flow Vibration Tests" (NEDO-20554, June 197[illegible]).

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

## Figure I

## Old Dresden II Feedwater Spargers




Note: Sparger arms are not of equal length

Figure II Pictures of Crack (SW Sparger)

Note: These two pictures of the same crack are mirror images of the actual sparger and therefore, do not indicate the correct orientation.

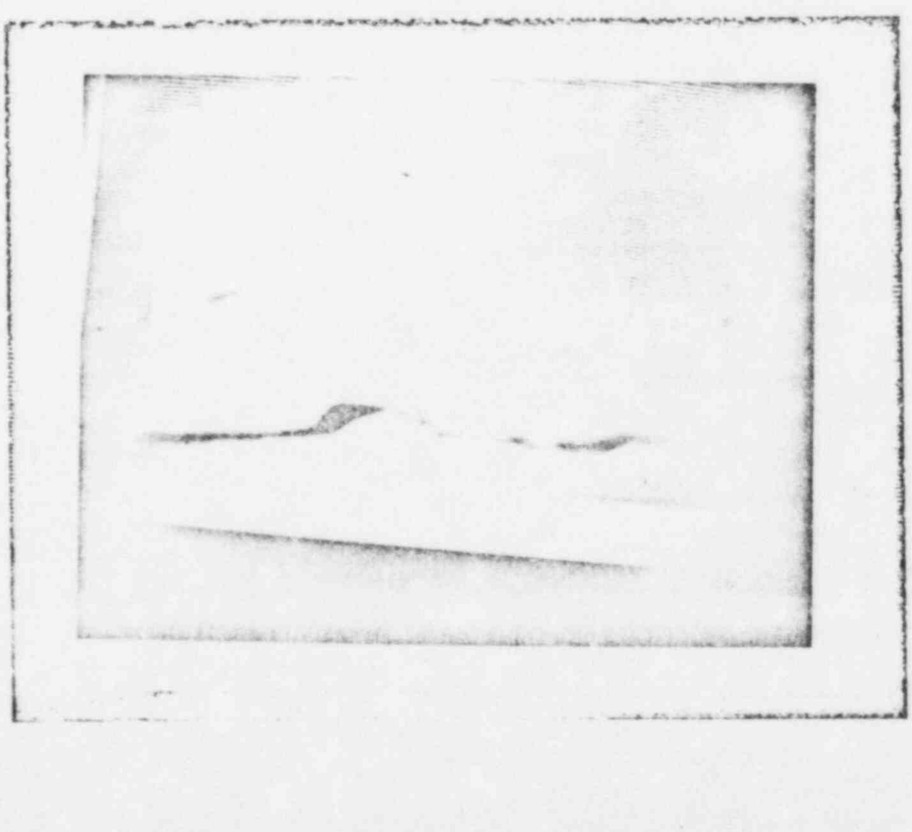


Figure III Pictures of Crack ([illegible] Sparger)

Note: These two pictures of the same crack are mirror images of the actual sparger and therefore, do not indicate the correct orientation.

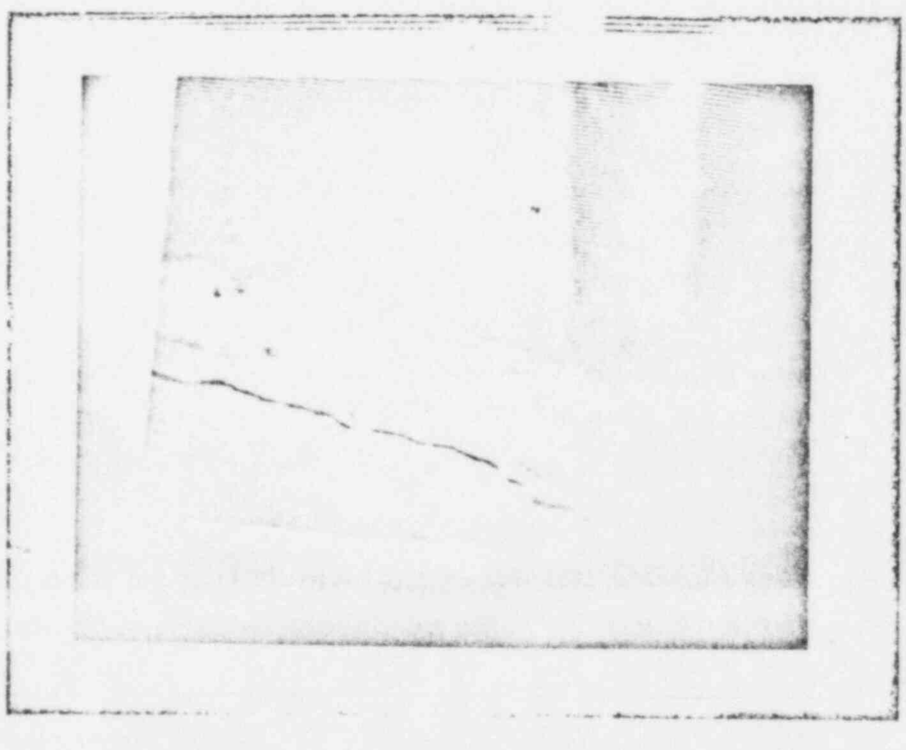


Figure IV. Conditions for Sparger Instability Based on Cold Flow Testing

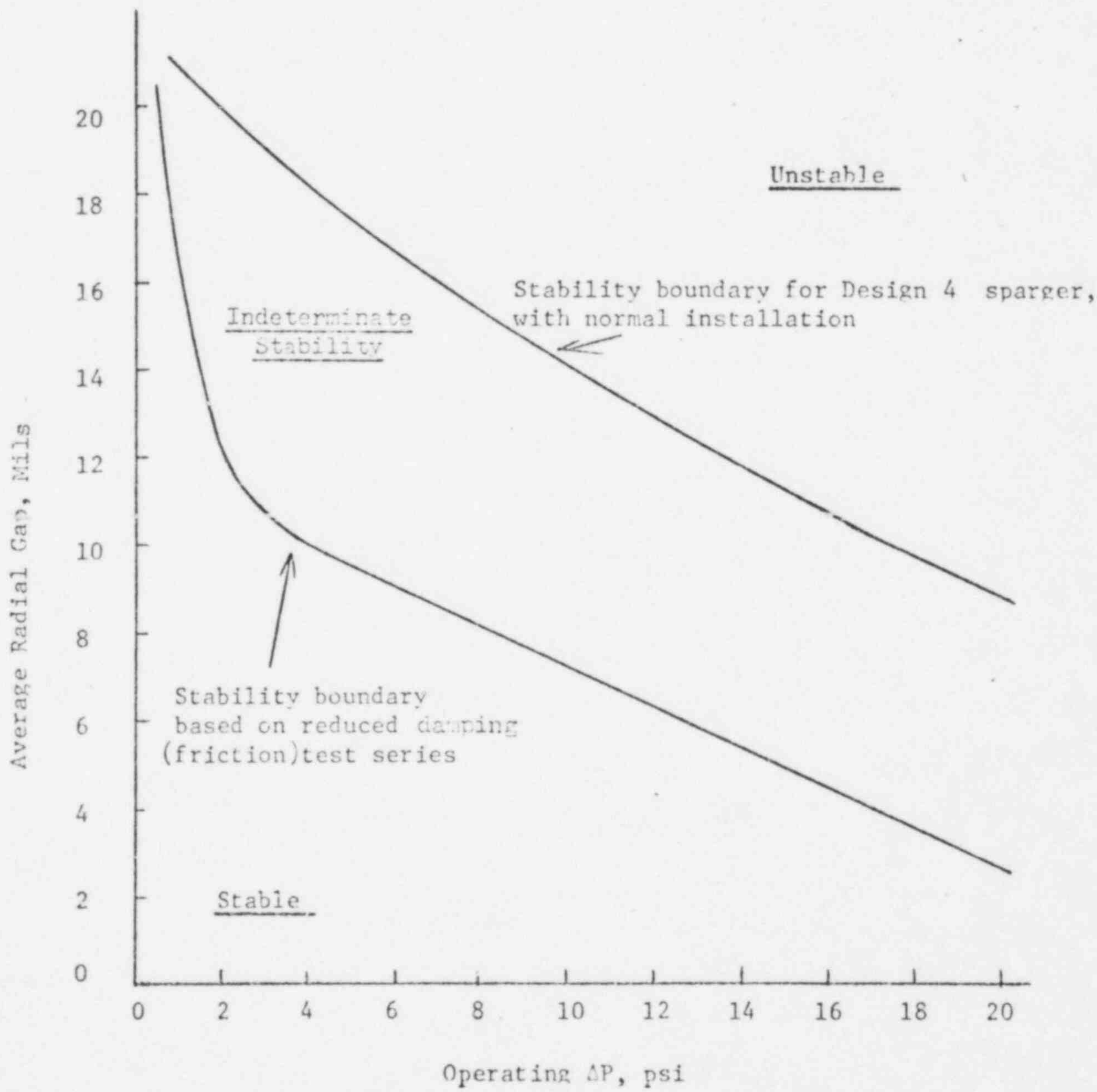
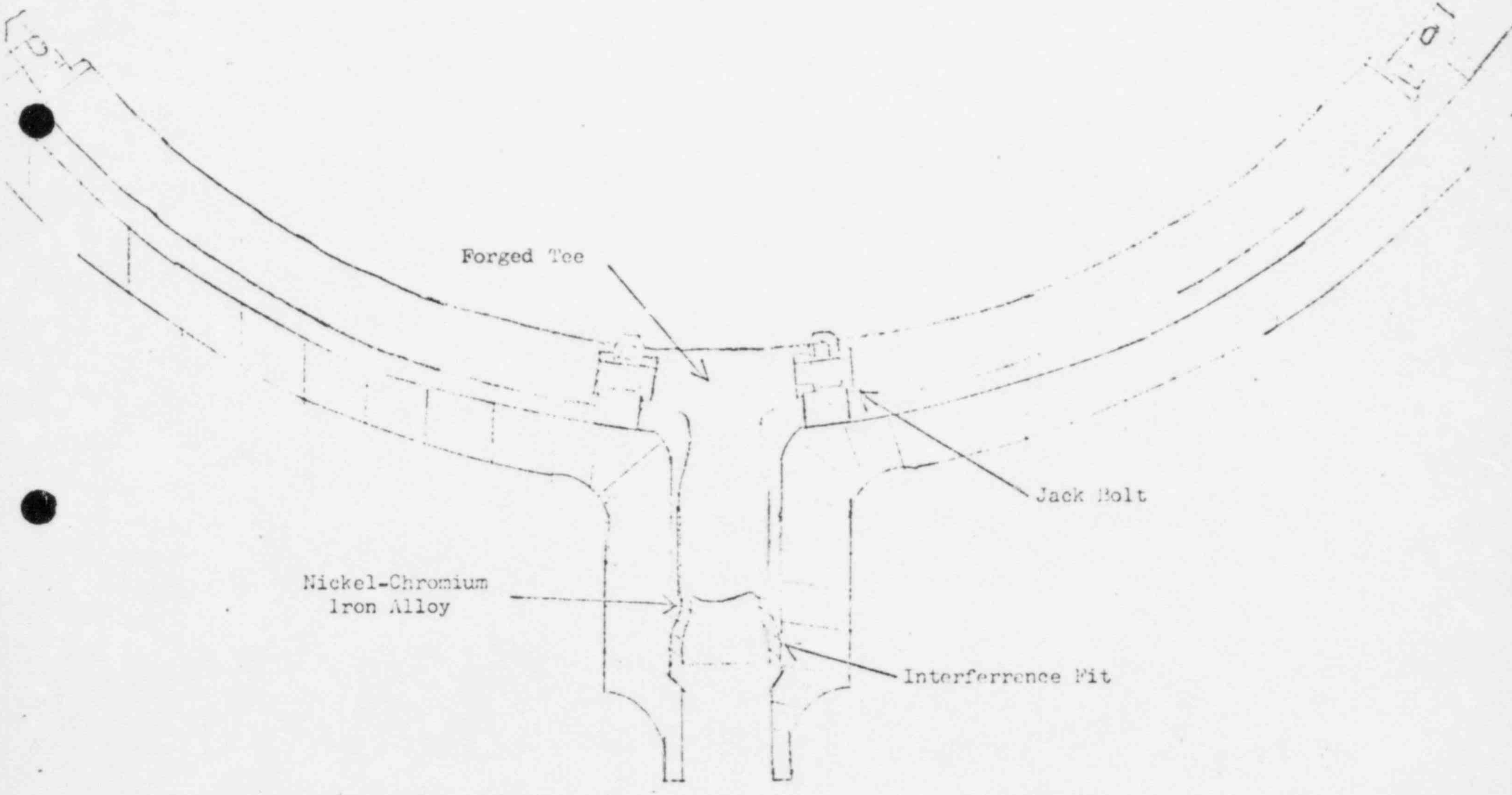


Figure V New Design Sparger



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 borken 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 concievably 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 mare 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. Effect of Large Pieces on Reactor

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.

Sincerely,

B. B. Stephenson
Superintendent
Dresden Nuclear Power Station

BBS:RWC:smp