H. L. Price, Director
Division of Licensing and Regulation

JUN 1 6 1960

Marvin M. Mann, Assistant Director
Division of Inspection

Signed by M. M. Mann

WESTINGHOUSE TESTING REACTOR

SYMBOL: INS:VAW:PAM

Attached is Division of Inspection Report CF-174 concerning a recent visit to the subject reactor. We make no recommendation at this time, but offer the following comments:

1. It appears that Westinghouse's technical analysis and review of the safety of the reduced flow-boiling experiments that preceded their execution were incomplete. Hemmerle and Pressesky had not seen Lowdermilk's research before it was shown to them on this visit. (This work is directly applicable to the conditions imposed during the Westinghouse tests.) Furthermore, it appears that the full WTR Safeguards Committee had not considered the particular test that resulted in meltdown.

2. In our opinion, the license condition that allows one per cent of the total core volume to be void is not sufficiently conservative. At the present state of the art of detecting boiling (real boiling, not single, large gas bubbles) and of predicting flow instabilities and burnout, it is not possible to predict the consequences of voids in a reactor. An alternate condition - practiced at the MTR - might be in order; i.e., when any boiling is observed, the reactor power level is to be lowered ten per cent.

3. We note that in the absence of detailed flow distribution measurements (which Westinghouse does not plan), it probably never will be known whether the fuel element melting was initiated by "boiling disease" (flow decay) or a manufacturing defect in the element. We feel that the uncertainty in the burnout correlations for similar reactor conditions needs to be emphasized and brought to the attention of other reactor operators. A separate memorandum to you, reporting a brief survey of the present state of the art, and containing recommendations on this subject, is in preparation.

Attachment:
Div. of Inspection
Report CF-174, Copy 2

cc w/attach:

W. F. Finan, ACRS	Cy 1
Dr. C. K. Beck, DIR	Cy 3
L. E. Johnson, DLR	Cy 4
C. F. Eason, CO	Cy 5
R. C. Hageman, CH	Cy 6
R. H. Engelken, SAN	Cy 7
J. R. Sears, NY	Cy 8
V. A. Walker, ID	Cy 9
Files	Cy 10

OFFICE ▶	INS	INS	INS
SURNAME ▶	PAMorris:bh	MMMann	CANelson
DATE ▶	6- -60	6-15-60	6- -60

Form AEC-318 (Rev. 9-53) U. S. GOVERNMENT PRINTING OFFICE 16—62761-3

A/32

U. S. ATOMIC ENERGY COMMISSION
DIVISION OF INSPECTION
REPORT CF-174

By: Vincent A. Walker, Inspection Specialist
Division of Inspection, Headquarters

Date: JUN 16 1960

Title: WESTINGHOUSE TESTING REACTOR

SUMMARY

The Westinghouse Testing Reactor site was visited on June 1, 1960. The purpose of this visit was to discuss the heat transfer calculations associated with the fuel element meltdown experienced on April 3, 1960, and to ascertain the calculations and literature search that had been made prior to the "boiling detector calibration."

DETAILS

I. Scope of Visit

John R. Sears, Inspection Division, New York Operations Office, and Vincent A. Walker, Division of Inspection, AEC Headquarters, visited the Westinghouse Testing Reactor, Waltz Mill, Pennsylvania, on June 1, 1960. Discussions were held with the following Westinghouse personnel:

M. A. Schultz	-	Engineering Manager, WTR
A. Pressesky	-	Manager, Scientific Support Section
E. H. Hemmerle	-	Supervisor, Technical Assistance

The heat transfer analysis done by W. J. Gambill, ORNL, and performed independently by Vincent A. Walker, was reviewed in detail. The differences in interpretation of the results of the calculations were emphasized.

An attempt was made to determine the extent of detailed analysis performed by Westinghouse prior to the execution of the "boiling detector calibration."

II. Results of Visit

It was agreed that the heat transfer analysis was correct. For the decay of the flow to that required for burnout, it was necessary to assume that the flow through the element which melted was significantly less (of the order of ten to twenty per cent) than the velocity through an average channel. The Westinghouse personnel do not believe that the flow distribution tests made previously are sufficiently accurate to allow their use in this situation. They agree that the data do indicate that the minimum

Distribution:
H. L. Price, DLR
Dr. C. K. Beck, DLR
L. E. Johnson, DLR
General Counsel (Mr. Eason)

Approved: Marvin M Mann
Acting Director

Results of Visit (Continued)

velocity may be up to forty per cent less than the average. They argue, however, that a thermocouple on an element in the same ring, two elements away, gave temperature indications that showed adequate flow, and that there would be symmetry of flow between this element and the one that melted. During the discussion, the bulk water temperature for a velocity of 3.7 ft/sec, a reactor power of 38 Mw, and inlet water temperature of 130° F was calculated; at the exit from the hot channel, it was agreed that the bulk water temperature exceeded the saturation temperature at the exit pressure. The use of Mirshak's correlation * for burnout under these conditions was discussed and the inspectors pointed out that this correlation does not apply at temperature subcoolings of less than about 10° F. The data obtained by Lowdermilk ** were discussed and it was evident that the Westinghouse personnel were not aware of this research.

The possibility of an inherent flow maldistribution among the fuel assemblies of the inner fuel ring was qualitatively examined. The WTR personnel indicated the locations of the inlet (there are two) and outlet lines with respect to the fuel element which melted down and stated that the flow streams impinge upon a large round tube housing the shim-rod drive rods; qualitatively, it appears that no flow maldistribution should be present, but actual measurements at this low flow rate are needed. The WTR staff does not intend to make any flow distribution tests in the reactor at this time.

At the conclusion of these discussions, Mr. Pressesky agreed that failure through the mechanism of flow decay caused by the increased pressure drop when in local boiling was a good candidate for the cause. However, he was of the opinion that calculating the flow distribution would be very difficult and measurements would be more satisfactory.

The recordings obtained during the period boiling was occurring in the MTR were shown to the WTR personnel. It was pointed out that boiling did not become evident abruptly as was the case for the tests reported by ORNL. The traces obtained in WTR at 40 Mw and full flow were not available when requested by the inspectors.

The previous technical efforts on the "boiling detector calibration" tests were summarized in a report (WTR-25) and Westinghouse test specifications. The latter documents are Exhibits B and C of Report CF-169. In WTR-25, the heat transfer considerations involved in raising the WTR power to 60 Mw are presented; e. g., hot spot -- hot channel calculations are made comparing the WTR with the MTR and the ETR. The most significant paragraph from WTR-25 is:

"EFFECT OF NUCLEATE BOILING ON PRESSURE DROP

The pressure drop across a given flow channel may be divided into several components as follows:

P = entrance loss + friction loss + elevation loss + acceleration loss + exit loss.

Under the operating conditions of the WTR, the entrance loss, elevation loss and acceleration loss for a given mass flow are approximately constant.

---

* DP-355, S. Mirshak, et al Heat Flux at Burnout, February, 1959.

** NACA-TN-4382, W. H. Lowdermilk, et al Investigation of Boiling Burnout and Flow Stability for Water Flowing in Tubes, September 1958.

Results of Visit (Continued)

As the bulk water temperature rises, the exit loss becomes greater but the effect on ΔP is quite small and can be neglected.

The friction loss up to the onset of nucleate boiling can be computed by Fanning's equation:

$$\Delta P_f = \frac{2f\ L\ v^2}{g\ D_{eq}}$$

where $f = G(\frac{1}{Re^{.2}})$

In the above calculation, the change in the viscosity (a factor in the Reynolds Number, Re) and the density are the dominating factors affecting the change in pressure drop for a given mass flow. As the temperature rises, the viscosity and the density decrease. The net effect under WTR conditions is approximately a 10% decrease in pressure drop from inlet water conditions up to the onset of nucleate boiling. What occurs at the onset of nucleate boiling is difficult to analyze. If it is assumed that nucleate boiling has a net unfavorable effect on the friction factor, the pressure drop across the channel will begin to rise as nucleate boiling increases, reducing the flow to a small extent. However, it is well known that there is a substantial increase in heat transfer efficiency with nucleate boiling and the reduction in flow would undoubtedly be more than offset by this factor."

It is evident from the paragraph that is quoted above that a thorough quantitative analysis of the possibility of flow decay and its consequence was not made.