STANDARD FORM NO. 64

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TO : Peter A. Morris, Chief, Reactor Inspection Branch
Division of Inspection, AEC Headquarters

DATE: June 7, 1960

FROM : Vincent A. Walker, Inspection Specialist, Division of Inspection, AEC Headquarters

SUBJECT: WESTINGHOUSE TEST REACTOR INCIDENT

Vincent A. Walker

SYMBOL: INS:VAW

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The report summarizing the discussions with WTR personnel regarding the heat transfer analysis of the incident and the technical effort performed prior to the incident is attached.

In my opinion, the technical effort expended prior to the incident was inadequate. Hemmerle and Pressesky had never seen Lowdermilk's research before we showed it to them. This work is directly applicable to the conditions during this test and should have been reviewed prior to execution of the test. Furthermore, it appears that the WTR Safeguards Committee had not considered the particular test that resulted in the meltdown.

I would like to re-iterate one item. The allowance of one per cent of the total core volume to be void is an ill-advised permission. At the present state of the art of detecting boiling -- I said boiling, not gas bubbles -- and of predicting flow instabilities and burnout, it is not possible to estimate previously the consequences of voids in the reactor. I think the manner in which the MTR is operated -- when boiling is observed, the power is decreased ten per cent -- is the only sensible approach at this time. I would encourage you to promote a change in this license provision.

Enclosure:
WTR Incident Report

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WESTINGHOUSE TEST REACTOR

SUMMARY

The Westinghouse Test Reactor site was visited on June 1, 1960. The purpose of this visit was to discuss the heat transfer calulations 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

SCOPE OF VISIT

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

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

The heat transfer analysis done by W. J. Gambill, ORNL reported to Westinghouse 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 to determine the extent of detailed analysis performed prior to the execution of the "boiling detector calibration" was made.

RESULTS OF VISIT

It was agreed that the heat transfer analysis was correct but was based on the assumption that it was necessary for the flow through the element which melted to be significantly less (of the order of ten to twenty per cent) than the velocity through an average channel for the decay of the flow to that required for burnout. The Westinghouse personnel do not believe that the flow distribution tests made previously are sufficiently accurate to allow its use in this situation. They agree that the data do indicate that the minimum velocity may be up to forty per cent less than the average. 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[1] 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[2] 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 Exhibit B, and C of Report CF-169. In WTR-25, the heat transfer considerations involved in raising the WTR power to

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

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

60 Mw are presented; e.g. hot spot → hot channel calculations are made comparing the WTR with the MTR and the ETR. A copy of WTR-25 is attached. The most significant paragraph from this report 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. As the bulk water temperature rises, the exit loss becomes greater but the effect on P is quite small and can be neglected.

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

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

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.