October 25, 1973

UNITED STATES OF AMERICA
ATOMIC ENERGY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of METROPOLITAN EDISON COMPANY, et al. (Three Mile Island Nuclear Station, Unit 1)	)	Docket No. 50-289

APPLICANTS' PREPARED TESTIMONY
RELATED TO
FUEL DENSIFICATION

During refueling of the Ginna reactor in April and May of 1972, it was observed that some fuel rods had short, flattened or "collapsed" sections. The cladding collapses were found to have resulted from the occurrence of gaps in the fuel pellet column within the rods. All of the rods with flattened sections were of the unpressurized type. For these rods, the inward creep of the cladding during operation was expected to continue until the cladding was supported by the fuel pellets. In those sections of rods where gaps in the pellet column occurred, the inward cladding creep was not arrested by the pellets, and continued until essentially complete flattening had taken place. The Ginna core contained a number of assemblies with pressurized fuel rods and none of these were found to have collapsed sections.

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Subsequent examination of neutron flux measurements in other operating reactors (Point Beach Unit 1, Robinson) revealed small flux peaks that could be ascribed to the local power peaks calculated to occur in the immediate vicinity of a gap in the pellet column of a fuel rod. The peaks, or "spikes", in the flux traces were found in both pressurized and unpressurized fuel regions of these reactors. Point Beach 1 was shut down for refueling in October 1972 and preliminary observations of the fuel conditions showed that collapsed sections were present in unpressurized fuel rods, but were not found in pressurized rods. These observations indicate that flux peaks or spikes might occur in the vicinity of a gap in the pellet column of a fuel rod, but they are not necessarily an indication of cladding collapse. The number, location, and type of collapsed sections at Point Beach 1 were all consistent with the observations at Ginna. A similar phenomenon had been found in unpressurized fuel rods in Beznau Unit 1 in Switzerland at the first refueling of that reactor.

As a result of the Ginna observations, studies of potential causes for axial gap formation were conducted by the AEC, including: the fuel fabrication processes of Westinghouse (the supplier of fuel for the Ginna, Point Beach, and Robinson reactors) and the associated quality control procedures, the possible contributions of cladding length changes arising from irradiation growth of the Zircaloy

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cladding, and the potential for fuel-cladding mechanical interactions that could cause "hangup" of pellets and prevent settling of the pellet column as a unit. These AEC investigations resulted in their concluding that the observed occurrence of axial gaps in fuel pellet columns arises from the densification of the fuel, the resulting axial shrinkage of the pellet column, and the hangup of a pellet which prevents settling of the remaining pellet column above this point. This conclusion was arrived at by the AEC after examining fuel rod fabrication processes and associated quality control procedures, the possible contribution of cladding length changes arising from irradiation growth of zirconium, and fuel-cladding mechanical interactions. Their conclusion was also based on a comparison of pre and post irradiation radiographs of entire fuel rods.

The AEC notified utilities and vendors of the Regulatory Staff's investigations of fuel densification in November 1972 and documented their conclusions in a report entitled "Technical Report on Densification of Light Water Reactor Fuels". The Regulatory Staff concluded that adequate data were available to account for the effects of densification in the safety evaluations of nuclear power reactors and that implementation of the recommendations of the report would provide increased assurance of safe operation of those reactors in which fuel densification is expected to occur.

The affected utilities were instructed to respond indicating how their plants would meet the requirements of the NOvember 14 report. Babcock & Wilcox began extensive study of the densification phenomenon in June 1972, documenting results in the following:

A. "Fuel Densification Report (Non-proprietary Version of BAW-10054, January 4, 1973)", BAW-10055, Revision 1, June 1973.

B. "Three Mile Island Unit 1 Fuel Densification Report (Non-proprietary Version of BAW-1389)", BAW-1390, September 1973.

Densification of fuel causes a decrease in the volume of the fuel pellet with corresponding changes in the pellet radius and length. There are three principal effects associated with fuel densification:

1. A decrease in the pellet length will cause the linear heat generation rate to increase by an amount in direct proportion to the percentage decrease in pellet length.
2. A decrease in the pellet length can lead to generation of axial gaps within the fuel column, resulting in increased local neutron flux and the generation of a local power spike.
3. A decrease in the pellet radius increases the radial clearance gap between the fuel pellet and fuel rod cladding causing a decrease in the gap

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thermal conductance, and consequently a decrease in the rate of heat transfer capability across the radial gap. This decrease in heat transfer capability will increase the stored energy in the fuel pellet at any given power level. A decrease in radial gap conductance also will degrade the heat transfer capability of the fuel rod during various transient conditions.

In order to account for the postulated effects of fuel densification, the analyses outlined below have been performed. All these analyses are based on the conservative assumption that fuel densification will occur, and account for all the postulated effects listed above.

Power Spike Model

If the fuel density increases and the pellet length decreases, it is assumed that some pellets may become fixed in place and allow gaps to form in the pellet stack. The presence of a gap would produce localized power spikes both in the fuel column containing the gap and in the surrounding fuel columns. The power spike results from a local decrease in thermal absorption. The magnitude of the power spike in a given fuel column will depend on the number and size of gaps at similar axial locations both in the column and in surrounding fuel columns. The power spike model determines a local power peak as a function of axial height which could result from fuel densification. This local power peak is then incorporated in all subsequent analyses.

Thermal Analysis

Fuel densification leads to an increased fuel pellet to clad gap which results in an increase in fuel temperature and stored energy. These changes cause a decrease in the limiting linear heat rates for central fuel melting and ECCS analysis. Fuel densification also decreases the axial fuel height resulting in an increased linear heat generation rate. These effects in turn lead to a decrease in the departure from nucleate boiling ratio. These changes in thermal characteristics are accounted for by modifying the overpower limit, the reactor protection system setpoints, and the control rod insertion limits to assure compliance with all thermal criteria.

Mechanical Analysis

Fuel supplied by Babcock & Wilcox is prepressurized with inert helium gas to minimize the possibility of clad collapse. The analysis of time to collapse in report BAW-1390 demonstrates that collapse will not occur during the first cycle of operation. This conclusion has been reviewed by the AEC Regulatory Staff and accepted by the Directorate of Licensing in their Supplement to the Safety Evaluation for TMI-1. In addition, no prepressurized fuel with similar cladding parameters has been observed to experience creep collapse.

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Safety Analysis

The effects of postulated fuel densification require a reevaluation of the safety analysis. A complete review of steady state and transient operation, and such postulated accidents as a loss-of-coolant was performed and documented in the above listed topical reports. It was concluded that with appropriate revisions which have been made in the overpower limit, the reactor protection system setpoints, and the control rod insertion limits, the safety limits on DNBR, cladding strain, and centerline fuel temperatures will be retained as established in the FSAR.

Research and Development Program

Babcock & Wilcox is conducting research and development programs concerning the occurrence and effect of fuel densification in the following areas:

1. Experimental verification of the size and magnitude of power peaks associated with given axial gaps between fuel pellets.
2. Resintering tests conducted out of pile to determine the thermal stability of present or modified fuel pellets.
3. Irradiation tests conducted in a test reactor to determine pellet stability under the combined effects of heat and radiation.
4. Establish the variables that may be adjusted during pellet manufacture to minimize adverse

effects of fuel densification.

The program will also determine if fuel densification occurs in fuel supplied by Babcock & Wilcox, and will provide a more realistic basis for evaluation of potential fuel densification.

In summary, the Regulatory Staff of the U.S. Atomic Energy Commission has concluded that adequate data are available to account for the effects of fuel densification in the safety evaluations of nuclear power reactors. Considerable reliance was placed on direct application of data obtained from operating reactors. These reactors have been operated safely with densified fuel and collapsed cladding, and the Regulatory Staff has concluded that implementation of the recommendations of their report, "Technical Report on Densification of Light Water Reactor Fuels", will provide increased assurance of safe operation of reactors in which fuel densification is expected to occur. The Babcock & Wilcox investigation into the fuel densification phenomena has been reported to the AEC in reports BAW-10055 Rev. 1 and BAW-1390, which cover the first fuel cycle. Prior to completion of the first cycle, Babcock & Wilcox will submit to the AEC Regulatory Staff a supplementary fuel densification report which will cover three full cycles of operation. The reports submitted to date document and verify the following conclusions:

1. The cladding will not collapse even if fuel densification occurs because all B & W fuel rods are prepressurized.
2. The mechanical performance of B & W fuel rods will not be impaired.
3. The interim acceptance criteria for the emergency core cooling system will be met.
4. The reactor can be safely operated at the rated core power level at 2535 MWt.

These conclusions are based on the very conservative assumption that fuel densification will occur. Since it has been demonstrated that TMI-1 can be operated safely even if the fuel densifies, it is not considered necessary to provide additional monitoring to detect fuel densification.