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An Estimate of the Damage to the TMI-2 Core

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M.L.Picklesimer

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  - (2) DATE(S) OF CONFERENCE: November 17-21,1980
  - (3) LOCATION OF CONFERENCE: Washington,D.C.
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CES L.H.Sullivan, Acting Assistant Director,Water RSR

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RES/RSR

c. SIGNATURE *(NRC Assistant Division Director or Above)* | DATE
12/18/80

The Legacy of TMI," Kemeny Commission Report, Washington, D.C. (Oct. 1979).

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Data on various thermal, hydraulic, neutronic, and valve position conditions in the reactor primary system of TMI-2 were gathered from several data acquisition sources and strip and multipoint recorder charts, analyzed and collated. Several scenarios of the progression of damage were developed that fit most, but not all, of the circumstantial evidence available. No single scenario examined explained all of the observations and facts known. The one we believe to be the most likely is presented here.

No evidence indicates that the core was damaged before the last coolant pumps were turned off at 100 min after the start of the accident. The circulating two-phase coolant then separated so that water filled about one-half of the B steam generator, about one-quarter of the A steam generator, and the reactor vessel to just about the top of the core. Because the pilot-operated relief valve was still open, the level in the core began to drop immediately as the water boiled off. The temperatures in the hot legs of the steam generators began to increase, indicating that the top of the core was uncovered at between 102 and 112 min. The first fuel rod burst at about 145 min and the last in the core burst about 10 min later. The exposed rods began to oxidize and embrittle, and the heatup accelerated. Calculations using the newly written TMIBOIL code indicated that the eutectic temperature between zirconium metal and zirconium oxide was first reached at about 155 min about 1 ft from the top of the fuel in the center assembly. It is believed that the liquid formed flowed down the gap, between the remaining Zircaloy oxide shell and the fuel pellet in the fuel rods, and began to dissolve the UO_2 to form what is now called "liquefied fuel." Such temperatures may have been reached over the entire core as much as 3 ft down from the top of the fuel. The maximum temperature estimated in the core was about 4400°F reached at the top of the fuel stack in the center assembly at about 170 min. When the reactor coolant pump was turned on at 174 min, water and steam entering the overheated core caused the oxidized and embrittled cladding to shatter and quenched much of the liquefied fuel. The resulting debris formed a layer across the core between 2 and 3 ft thick and rested on stubs of oxidized fuel rods 6 to 7 ft long. It is estimated that at 180 min, between 26 and 31% of all of the Zircaloy in the core had been converted to oxide and 600 to 720 lb of hydrogen had been produced. The in-core instrumentation of thermocouples and SPNDs survived because the two annuli of the instrumentation tubes allowed coolant flow to keep them cooler than the neighboring fuel rods.

Additional damage occurred to the core during the following hour, resulting in further changes in core geometry and condition. Though proof is lacking, the following is consistent with the limited system data available. Liquefied fuel continued to form in the debris bed to dribble down and freeze in the lower part of the bed. This eventually sealed off the bed from coolant flow, and a large steam bubble began to form below the debris bed. Eventually, the pressure head from the downcomer, the continued heatup of the debris bed, and the impingement of water released from the pressurizer combined to again disrupt the debris bed and shatter more embrittled cladding.

It is believed that, at 4 h, a 4-ft-thick debris bed existed in the core from about 4½ to 5 ft above the bottom of the fuel to about 3 ft from the top of the fuel, its density approached 90% of full density in some regions due to the formation of liquefied fuel, it rested on stubs of fuel rods 5 to 6 ft long, and drips of liquefied fuel from it penetrated

to within 10 in. of the bottom of the fuel. At least 50% of the Zircaloy in the core had been embrittled or converted to oxide, and between 700 and 820 lb of hydrogen had been produced. The debris bed may have been covered with water, but it was not quenched.

3. The Modeling of Pin Distension and Impingement in CANSWEL-2, *D. O. Pickman, T. J. Haste, J. H. Gittus, C. F. Bilsby (Springfields NPDL-UK)*

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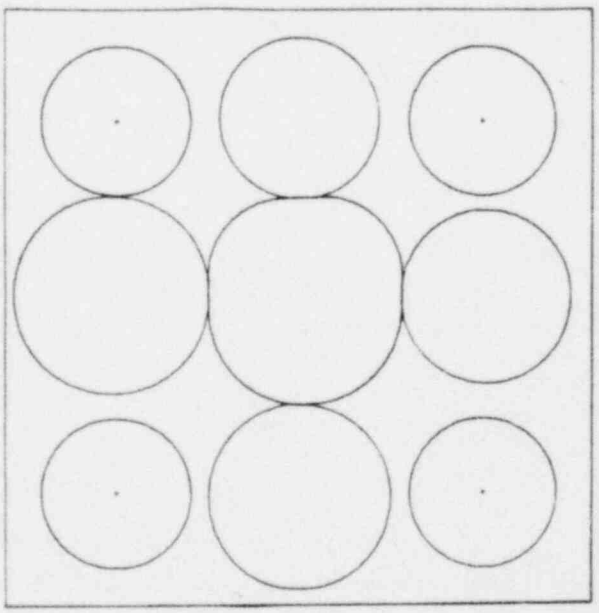
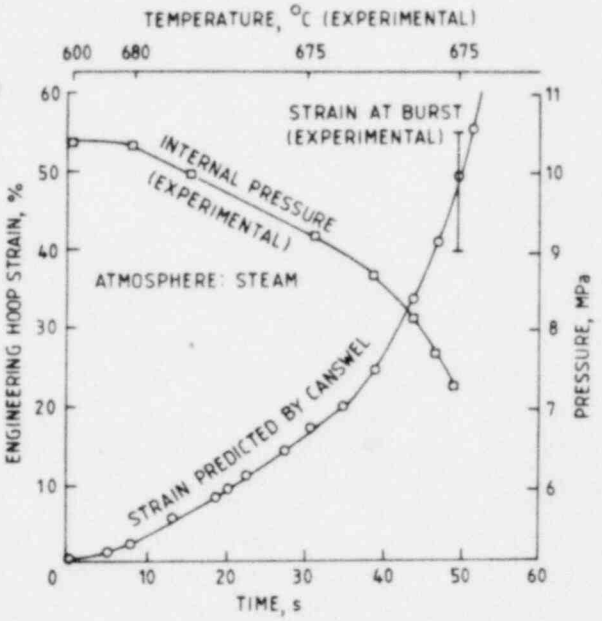


Fig. 1. Graphical representation of center pin bulging in CANSWEL-2.



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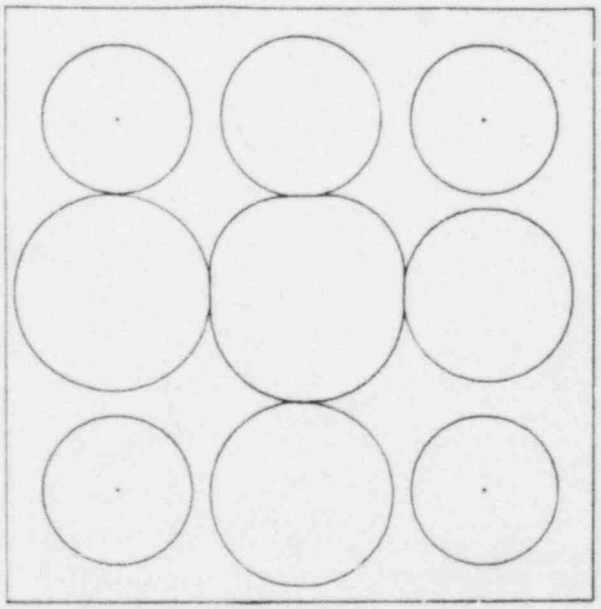

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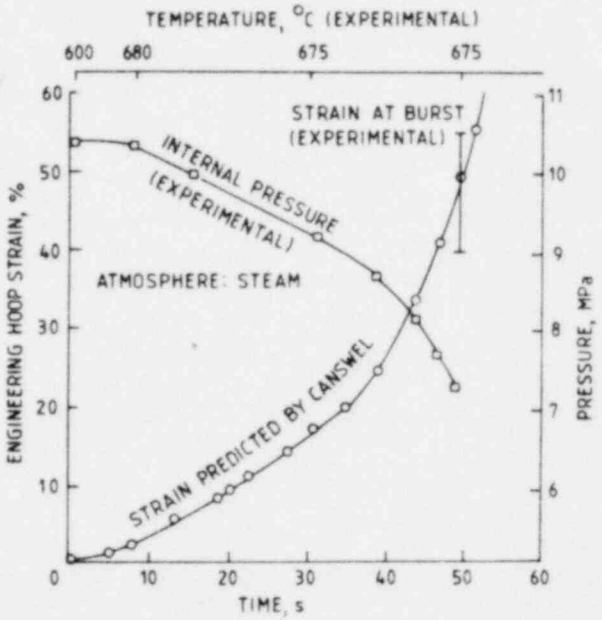

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