Craig

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C. 20515

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February 4, 1980

The Honorable John Ahearne
Chairman, Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Chairman:

The following questions relate to those contained in my letter of January 21 concerning the fact that on March 28, 1979 Federal officials were not given important information indicative of conditions at Three Mile Island.

1. What inference is to be drawn from the disparity of recollections concerning the significance of the incore thermocouple measurements made prior to 9:30 a.m. on March 28, 1979; e.g. Messers Bennett (I&E Tape #311, p. 18-19), Wright (I&E Tape #310, p. 18), and IMB (I&E Tape #315, p. 18) recall informing Mr. Porter that they believed the temperature data to be indicative of the core being uncovered while Mr. Porter has made inconsistent statements sometimes implying that he did not believe the readings and other times suggesting that, "I guess I was afraid it was real." (I&E Tape #237, p. 20.) Does the preponderance of evidence support the recollections of Messers Bennett, Wright and IMB, that it was generally agreed by them that the incore data was valid and indicative of the core being uncovered or does the preponderance of evidence support the recollections of Mr. Porter to the effect that he at the time concluded the data was probably invalid?

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2. What specific statements did Mr. Porter make leading to the statement on page 30 of the report of the Special Inquiry Group that, concerning the incore thermocouple readings, "Porter shrugs . . . off /the readings/ and returns upstairs to brief Miller. He tells Miller of the readings, but says he does not believe the high ones are accurate . . ."?

3. If Mr. Porter concluded that the incore thermocouple data was unreliable, what did he believe to be the source of this unreliability? Was Mr. Porter's explanation of the malfunctions of the thermocouples consistent with the fact that the thermocouple data was recalled from the computer several times on March 28 and the following days apparently (according to John Flint) because this data was indicative of what was happening to the core; e.g. if the thermocouples had become unreliable by 9:00 a.m. on March 28, what would have happened to increase their reliability thereafter? If the thermocouples were unreliable because of their having been overheated, what temperatures would they have had to experience in order that multiple junctions be formed? What would have been the significance of these temperatures? Was a cause of formation of multiple junctions discussed with Mr. Gary Miller and if so, what was the outcome of such discussion?

4. On page 138 of Volume II, Part 3 of the report of the Special Inquiry Group it is stated that, "It is not clear that any of the actual /incore temperature/ readings were communicated to the NRC on March 28, despite requests for such information, although the general range of readings may have been transmitted." Why is it not clear that the readings were communicated to the NRC? What is meant by the statement that the general range of readings may have been transmitted? Which of the incore data obtained by the instrument technicians was transmitted to the NRC?

5. Which of the TMI supervisors or reactor operators recall informing or discussing with Mr. Gary Miller during the afternoon or evening of March 28 that the containment sprays had automatically initiated at approximately 1:50 p.m. and were turned off shortly thereafter? If Mr. Miller was not informed what reasons have the supervisors given for not having informed him? Where in the control room or adjacent offices was Mr. Miller located from approximately 1:50 p.m. to 2:00 p.m. on March 28?

6. Does Mr. Mehler recall having discussed with any of the other TMI supervisors or reactor operators (as he recalled discussing with an NRC inspector) his reasons for believing that the pressure pulse record at 1:50 p.m. on March 28 reflected a real pressure increase in the containment building? Were the TMI supervisors who dismissed the pressure pulse and actuation of containment sprays as having resulted from spurious electrical signals aware of the circuit logic (as were Messers Chwastyk and Mehler) requiring at least two of three pressure sensing circuits to detect electrical signals equivalent to a pressure of at least 28 pounds per square inch in order for the containment sprays to be triggered? What was the rise time of the pressure pulse on the recorder? What was the decay time? Did this pressure pulse have the characteristics of a spurious electrical signal?

7. What were the circumstances leading to review of the reactor building pressure on Thursday, March 29? Which officials of Metropolitan Edison and General Public Utilities were involved in this review? Who ordered the review? Was the pressure data reviewed as part of a general effort to review all data, or was the review undertaken as the result of TMI personnel remembering that the pressure pulse had occurred? If the latter, which TMI personnel recalled the pressure pulse? At what time and to whom was the pressure pulse information given to NRC staff?

8. At what time did TMI supervisors recognize that there were non-condensable gases in the system? Did the pressure and temperature data available at any time on March 28 clearly indicate the presence of non-condensable gases? If so, and this was not recognized on March 28, what were the reasons for the failure?

9. Did any of the persons at Three Mile Island on March 28 seek to infer from the containment radiation levels, as had been done by Mr. Floyd in Lynchburg, an estimate of the number of fuel rods that had cracked or ruptured? What did TMI staff diagnose as the source of such radiation? Who at TMI had made such estimates or diagnoses on March 28? If such estimates or diagnoses were not made, what was the reason for not doing so?

10. At what hour did it become apparent to Messers Miller and Herbein that attempts to depressurize the system had been unsuccessful? Was the fact that the depressurization effort did not appear to be succeeding reported to Lt. Governor Scranton? Who made the decision to repressurize the system? At what hour was this decision made? Who participated in the discussions leading to the repressurization decision?

11. In a May 9, 1979 mailgram to me, Mr. Herman Dieckamp, President of General Public Utilities Corporation, stated: "There is no evidence that anyone interpreted the 'pressure spike' and the spray initiation in terms of reactor core damage at the time of the spike nor that anyone withheld any information." Prior to sending me this mailgram, what steps had Mr. Dieckamp taken to determine whether any of the TMI supervisors had interpreted the pressure spike and spray initiation in terms of reactor core damage? Is Mr. Dieckamp's statement quoted above consistent with the recollections of Mr. Chwastyk that he (Chwastyk) had recognized that the pressure pulse was real, that it

was probably a manifestation of a hydrogen explosion, and that this was an indication of severe core damage?

Thank you for your assistance.

Sincerely,

MORRIS K. UDALL
Chairman

MASTER

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5.h

Draft Working Paper

Early Indications of Core Damage at TMI-2

Introduction

At approximately 6:00 a.m. on March 28, the water level in the TMI-2 reactor pressure vessel fell below the top of the heat producing portion of the fuel rods. During the next hours a substantial portion of the reactor core was cooled intermittently by steam produced in water boiling within the pressure vessel. The steam was a significantly less efficient coolant than water, and for part of this period radioactive decay of fission products generated more heat within the fuel than was removed by steam flowing past the fuel cladding. Therefore, cooling was inadequate; portions of the zirconium cladding reached temperatures at which it reacted with steam, producing zirconium oxide, hydrogen and an additional significant quantity of heat that needed to be removed from the pressure vessel.

Prior to the zirconium reaching temperatures at which rapid oxidation occurred, increased pressure from gases inside the fuel rods and loss of strength due to the higher temperatures caused the zirconium cladding to bulge and split. Kemeny Commission staff concluded that all or nearly all 36,000 rods balloned and ruptured, releasing the radioactive gases contained therein. (Kemeny, Core Damage, p. 4.)

Kemeny Commission staff also concluded that during the period of core uncovery fuel temperatures in the upper 40% to 50% of the core exceeded 3500 degrees F., and temperatures in 30% to 40% of the core exceeded 4000 degrees F. (Normal fuel temperatures during operation are about 650 degrees F. NRC regulations specify that emergency systems must be designed so that peak

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zirconium cladding temperatures shall not exceed 2200 degrees F. in the event of accidents which must be taken into account in the reactor design.) Kemeny staff estimated that ultimately between 44% and 63% of the core's 20 tons of zirconium cladding were oxidized, producing thereby some 1000 - 1300 pounds of hydrogen and causing some 60% to 70% of cladding to become so embrittled that it lost its structural integrity. (Ibid., p. 1). The NRC's Special Inquiry Group estimates less cladding oxidization; i.e. 31%-35% leading to production of 720-820 pounds of hydrogen. [SIG, Vol II, Part 2, p. 283.] (NRC regulations required that reactors be designed so that no more than 1% of the zirconium oxidizes in the event of accidents of a kind that must be taken into account in the reactor design.) Kemeny et al. concluded that as a result of oxidation and embrittlement of the fuel rod cladding, several feet of the upper part of the core fell into the gaps between the fuel rods, causing partial blocking of the flow of steam or water that removed heat from the damaged fuel.

During the course of the accident, the TMI reactor pressures, temperatures and core geometry evolved into such an unusual state that the operators were unable to achieve a relatively stable cooling condition until late in the day of March 28. By 9:00 a.m. information available in the control room indicated that the core was severely damaged. High radiation levels in the reactor building indicated that a large percentage of the fuel rods had been damaged to the

point where they lost radioactive gases contained therein; instruments showed that the reactor pressure vessel and associate piping contained steam rather than water; and numerous temperature readings indicated that the core had been uncovered and the zirconium cladding of the fuel had been oxidized with the concomitant production of hydrogen.

The NRC's Special Inquiry Group concluded that the foregoing and other manifestations of damage would have warranted the following actions at 9:00 a.m. Monday, March 28:

Actions Which Appear Warranted

1. Advise or order plant that core appears to have been uncovered and thereby damaged. Maximum HPI flow should be provided to recover the core, open PORV block valve for maximum relief flow.

2. Advise State officials that the core has been badly damaged and has released a substantial amount of radioactivity. The plant is now in a condition not previously analyzed for cooling system performance. Presuming that full HPI flow is turned on, advise the State that if the cooling systems do not function adequately, portions of the core could begin to melt which could lead to significant offsite releases in a few hours. If the cooling systems are successful, evidence of that success should be available in a few hours. Recommend to State officials that they begin a precautionary evacuation of the first few miles around the plant with an alert for a larger radius (10 miles) evacuation which may follow. Evacuees from the inner zone of few miles' radius should be moved to locations at least 20 miles distant.

(SIG, Vol. II, Part 3, p. 268)

Apparently at this very hour when the SIG concluded that a partial evacuation would have been warranted, Pennsylvania Lieutentant Governor Scranton called the TMI-2 control room and was briefed on the situation by Station Manager GAry Miller. While the exact nature of the information conveyed to the Lieutenant Governor is unclear, it must have been far different from the picture that culd have been readily inferred from knowledge of events that took place since 4:00 a.m. because it led Mr. Scranton to announce at a press conference at 10:55 a.m. that:

> " ... he had been advised that everything was under control and that there was no danger to the public health and safety."
>
> (SIG, Vol. II, part 3, p. 382.)

While most of the core damage had been done by 9:00 a.m. the situation remained precarious until approximately 8:00 p.m.. The control room supervisors struggled for most of the day to reach a stable cooling configuration. Uncertain at 11:30 a.m. as to whether cooling water was reaching the entire core, a decision was made to depressurize the system to the point where a low presssure cooling system could be used. But the depressurization effort was unsuccessful and at approximately 3:10 p.m. it was abandoned, apparently in favor of a repressurization strategy. The new objective was to make sure the reactor pressure vessel and associated piping was filled with water so that the main reactor coolant

pumps could be used to circulate water between the reactor pressure vessel and the steam generators from which heat would be removed in accordance with established procedures.

At approximately 1:50 p.m. while the depressurization effort was still under way, a large pressure surge was observed in the reactor building. The surge resulted from a hydrogen explosion or fire (subsequently referred to as a "deflagration") that occurred when hydrogen produced as a byproduct of oxidation of the zirconium was released in the reactor building where it reacted chemically with hydrogen.*

Meanwhile, federal and State officials remained unaware that there had been (or continued to be) a real danger of a meltdown. On Thursday, March 28, NRC Chairman Hendrie briefed the Energy and the Environment Subcommittee, leaving

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*All references to hydrogen explosions or fires in this discussion concern the hydrogen detonation outside the pressure vessel in the containment building that occurred at 1:50 p.m. on March 28, the first day of the accident. This is not the potential explosion that directly concerned the NRC in the period March 30 - April 1, when the Commission believed there was a possibility of a detonation or fire within the pressure vessel resulting from generation of oxygen which might react with the hydrogen bubble that was believed to occupy a substantial volume at the top of the pressure vessel. Subsequent analyses appear to indicate that there was no mechanism under conditions then prevailing within the pressure vessel that could lea to net production of oxygen, and therefore there need not have been serious concern about an explosion within the pressure vessel. While there may have been no danger in this period from an explosion within the pressure vessel, other dangers had not passed and a further deterioration of reactor systems might have lead to a major radiological release.

the impression that while the accident had been the most severe in the history of the nation's nuclear power program, there was and had been little danger of a core meltdown. Chairman Hendrie stated:

> "The result /of the equipment malfunctions/ has been apparently some overheating ir the primary system that caused the venting. There apparently has been, judging by the radiation levels, some core damage in the sense that fuel rods have leaked gaseous radioactivity, I rather doubt there is melting. There does not seem to be any indication of that.*" (Transcript, p. 23)

It was not until the following day, Friday, March 30 that the Commission came to realize the full implications of the accident. Based on information indicating the occurrence of the March 28 hydrogen explosion in the reactor building and the exceedingly high radioactivity levels in the reactor cooling water, the Commission concluded that damage had been severe and there was still danger of a major radiological release, resulting either from another hydrogen explosion or from failures of equipment which was then performing under conditions for which it had not been designed.

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* Kemeny staff concluded that some of the uranium oxide fuel may have become liquid at the temperatures which exceeded 4000 degrees, even though the temperatures were less than the uranium oxide melting temperatures of 5200. The reason for the fuel liquifying at temperatures less than the uranium oxide melting temperature is that it was in contact with zirconium and the melting point of the zirconium/uranium oxide mixture was lower than the melting point of the uranium oxide standing in isolation.

During the period March 30 through April 1, serious consideration was given to the need for evacuation of persons living within 5 miles of Three Mile Island. Had officials known the status of the reactor on March 28, it is likely (as suggested in the excerpt from the SIG quoted above) that a precautionary evacuation would have been called on the first day of the accident. Because Federal and state officials were not provided information necessary for them to assess the danger, they were prevented from fulfilling their responsibilities with regard to protection of the public health and safety.

To date, three major TMI inquiries have been completed; none have adequately addressed the reasons for failure of TMI management to provide significant information to officials of the NRC and State of Pennsylvania, information that the latter officials needed to comprehend the nature of the situation confronting them. The first such TMI inquiry, that conducted by the NRC's Office of Inspection and Enforcement and reported upon in NUREG 0600, virtually ignored the question. While the TMI inquiry conducted by the President's Commission on Three Mile Island (the Kemeny Commission) did not pursue the question in detail, Commission member Governor Bruce Babbitt states in a supplementary

view incorporated in the Commission report:

> "It now appears that there is evidence to indicate that MET Ed technicians understood, within a few hours of the accident, that the nuclear core had been uncovered and that this specific information was transmitted to supervisory personnel at the plant early Wednesday. There seems to be little question that the technicians who took the temperature readings that morning understood what they found. The real question is what happened to this information and whether it was transmitted to the appropriate management personnel. It certainly did not get transmitted to responsible public officials, including Lieutenant Governor Scranton during a meeting with Met Ed that afternoon."

The third major TMI inquiry was that conducted by the NRC's Special Inquiry Group. The SIG concluded variously that " ... the evidence failed to establish that Met Ed management or other personnel willfully withheld information from the NRC," and, "The fact that NRC and B&W did no better than Met Ed/GPU in reporting critical information up the managment chain and acting upon it tends to support our conclusion that there is no evidence to show willful withholding of information by Met Ed from NRC." [SIG, Vol. I, p. 159-160.] In reporting the SIG results to the NRC, Group Director Mitchell Rogovin stated with regard to the question of withholding information:

> " .. There was a mind set or a group psychology that apparently tended not to believe that the core was uncovered. They didn't even think of the possibility of the core being uncovered. People went along in that fashion."

(Rogovin/NRC Transcript, p. 57.)

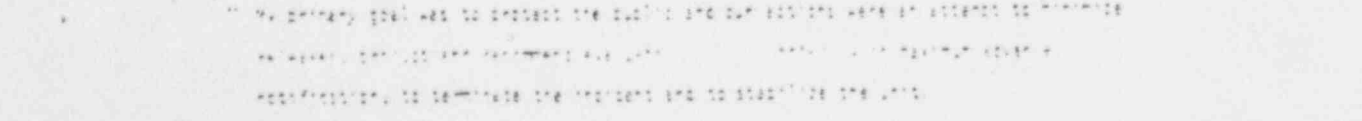
SIG Deputy Director George Frampton stated to the Commission that:

> "Our conclusions are less important than the evidence itself. The evidence will all be made or has been made public this afternoon and I think on the question of coverup, there is conflicting evidence. There is definitely conflicting testimony. There are things that don't make coherent sense to us. We made a judgment about the weight of the evidence. We found that, while there is some evidence to suggest that there is an intentional withholding of information, that the weight of the evidence doesn't support that, others could come to a different conclusion based on the evidence that we developed."
>
> (Ibid, p. 60)

The following discussion addresses circumstances relevant to resolution of the question as to whether TMI management withheld from state and federal officials information that should have been provided these officials.

Emergency Command Team

In considering the kinds of data that were available, it is useful to keep in mind the emergency management organization and procedures established by Station Manager Gary Miller. Upon his arrival at the TMI control room shortly after 7:00 a.m., he organized a group for the purpose of analyzing information and determining what actions should be taken. In a statement dated May 7, 1979 and presented to the E&E Subcommittee on May 24, Miller described this command structure:



The first concern I had as I arrived in the Control Room at approximately 7:05, was to become fully cognizant of the situation as it existed and once I fully understood the plant conditions and the radiation emergency, I immediately took charge of the Control Room and appointed Senior people to direct the necessary evolutions in the vital areas to assure that the public was protected, that the release was monitored, that communications were occurring and that the plant was brought in steps to a stable condition. The command set up, which I just described, met frequently throughout the day. The group presented Unit conditions, status of Emergency Plan actions, shared opinions, discussed technical data, and made recommendations. Discussions were held with Management, and/or Babcock & Wilcox, Lynchburg, the State, the NRC, and following these evaluations, I made appropriate decisions and so directed the implementation to the Control Room and informed others both inside and outside the plant as necessary.

Basically, I set up this Emergency command team in the early hours as I arrived at the plant and the radiation emergency was in progress, by essentially forming my senior people into a network to supervise, conduct the emergency and report to me while bringing the plant to a safe condition. Mr. Ross was put in charge of Operations to direct the Shift Supervisor, Mr. Dutel was put in charge of radiation concerns, including radiation surveys, onsite - offsite teams, accountability check, assembly of people, getting in contact with the Emergency Control Station (ECS), etc., Mr. Seelinger was in overall charge of Unit 1, The Emergency Control Station, the Unit 1 Control Room and to assure that all facets of the emergency plan were followed.

Mr. Logan was charged to assure that all the required procedures and plans were reviewed and to look through each to assure that every item was covered, this included the procedures for both emergency plan and for the Unit itself, and to provide me assurance that all actions were being taken and to be sure the notification calls were made, that management was notified, and all communications were in-place. Mr. Lee Rogers was requested to provide technical assistance plus link-up with his home office as he could. Mr. Kuncer was in charge of technical support and communications and Mr. Shovlin was in charge of emergency maintenance.

* * * *

Because of my training, I felt a strong obligation to the public and to making sure that there was minimal release of radioactivity and that there was evacuation in plenty of time if that was required. The phone, the pressure, the fact that the plant was in a state that I had never been schooled in, combined to make conditions almost intolerable. However, the Control Room remained calm as can be testified to separately. All of the meetings of the command team were held in the Shift Supervisors's Office in a calm atmosphere, at a point removed from the Control Room, and the decision making was done precisely, at intervals dictated by the plant, and in no case longer than 30 to 40 minutes apart.

(E&E CMI-1, Part II, pp. 253-256.)

The following discussion addresses the various kinds of information available to plant management which should have indicated that the reactor core had been severely damaged.

Temperature Data

By observing the temperature at various locations in the reactor cooling system, reactor operators should be able to determine the adequacy of core cooling and whether there could be steam spaces in the reactor vessel or in the hot-leg pipes leading from the pressure vessel to the steam generators. Such temperature measurements enable operators to know, in the event the system contains steam, whether the steam space has expanded to the point where it encompasses a significant portion of the reactor core.

Temperature data can be interpreted approximately as follows:

-- If temperatures at the top of the core are less than the temperature at which water boils for the prevailing pressure of the reactor cooling system, the fuel rods are cooled primarily by water and cooling is adequate. This is called a "sub-cooled" condition.

-- If temperatures at the top of the core equal the temperature at which water boils for the prevailing pressure, the fuel rods are being cooled either by water or a steam-water mixture; cooling is probably adequate. This is called a "saturated" condition, and can be converted to a "sub-cooled" condition by increasing the system pressure at which point the steam in the mixture condenses to water.

-- If temperatures at the top of the core are greater than the temperature at which water boils for the prevailing pressure, some portion of the fuel rods is being cooled by steam; cooling may be inadequate and the temperature of some of the cladding is higher than the steam temperature. Steam at any temperature above the saturation temperature is called "superheated" and is indicative of inadequate cooling. Such conditions are, at least, a warning sign that insufficient cooling water or steam-water mixture may be making contact with the fuel rods, and that fuel rod surface temperatures may be on the verge of rising to levels where the zirconium cladding will react chemically with steam, producing zirconium oxide and hydrogen.

-- Temperatures at the top of the core in excess of 2000 degrees are indicative of inadequate core cooling and of a cladding steam chemical reaction.

A typical B&W reactor normally operates at a pressure of 2185 pounds per square inch (psi) and a hot leg piping temperature of about 604 degrees F. This means that the hottest water temperature is approximately 45 degrees below the boiling point. In order for the water to boil at this temperature, the pressure would have to drop from 2185 psi to about 1600 psi.

Hot-leg

A principal indicator of system conditions at TMI was the temperature of fluid (water or steam) in the hot leg pipe,* which is the pipe that carries hot water from the reactor to the steam generator. Hot-leg temperature data at TMI was normally presented on a computer printout and on a strip chart recorder mounted in the reactor control room. The computer was programmed to record data between 520 degrees F. and 620 degrees F.; when temperatures were outside this range, the computer printed question marks. The strip chart was capable of recording temperatures up to 800 degrees F.

* See Figure I-A, I-B

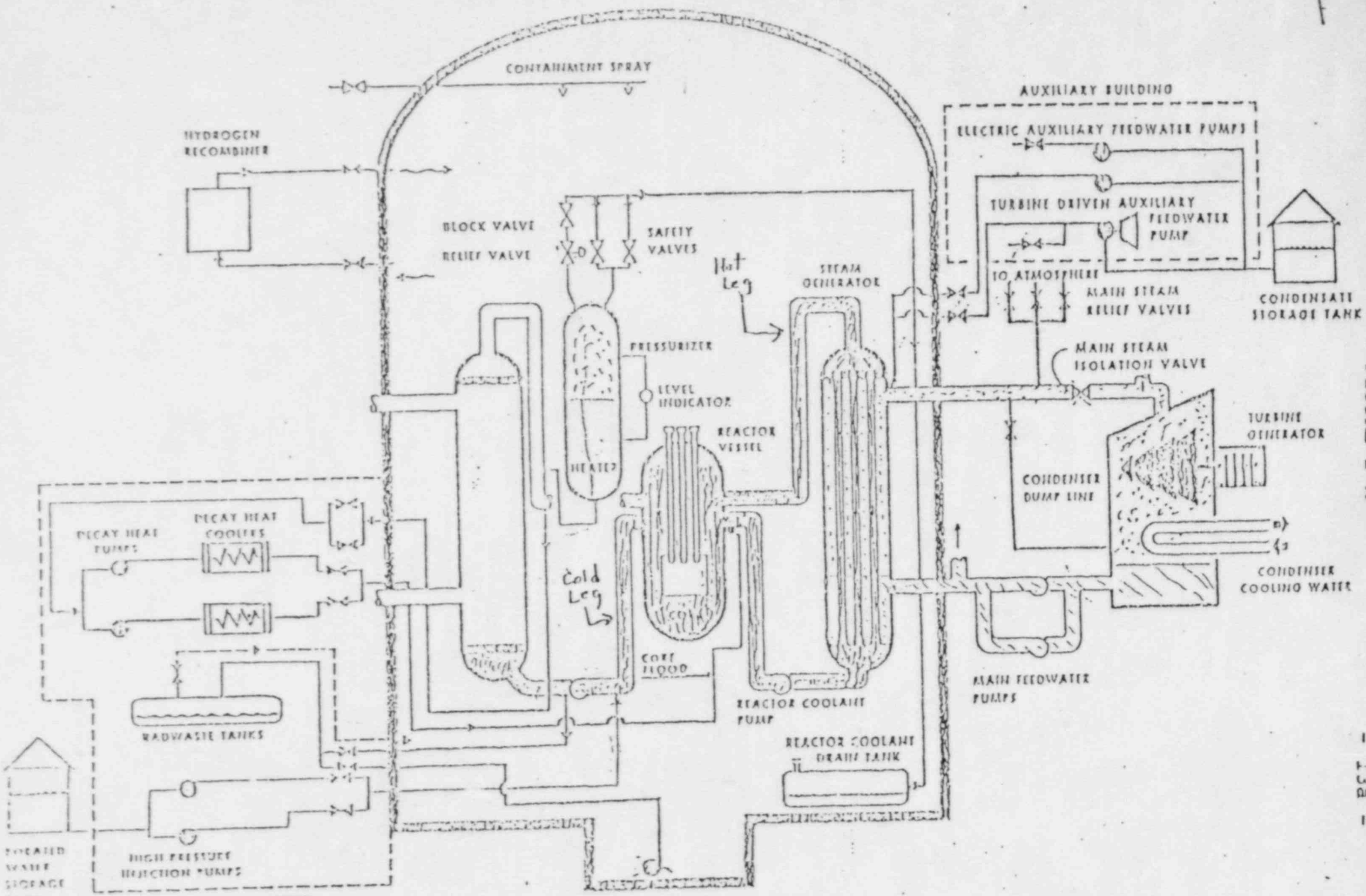
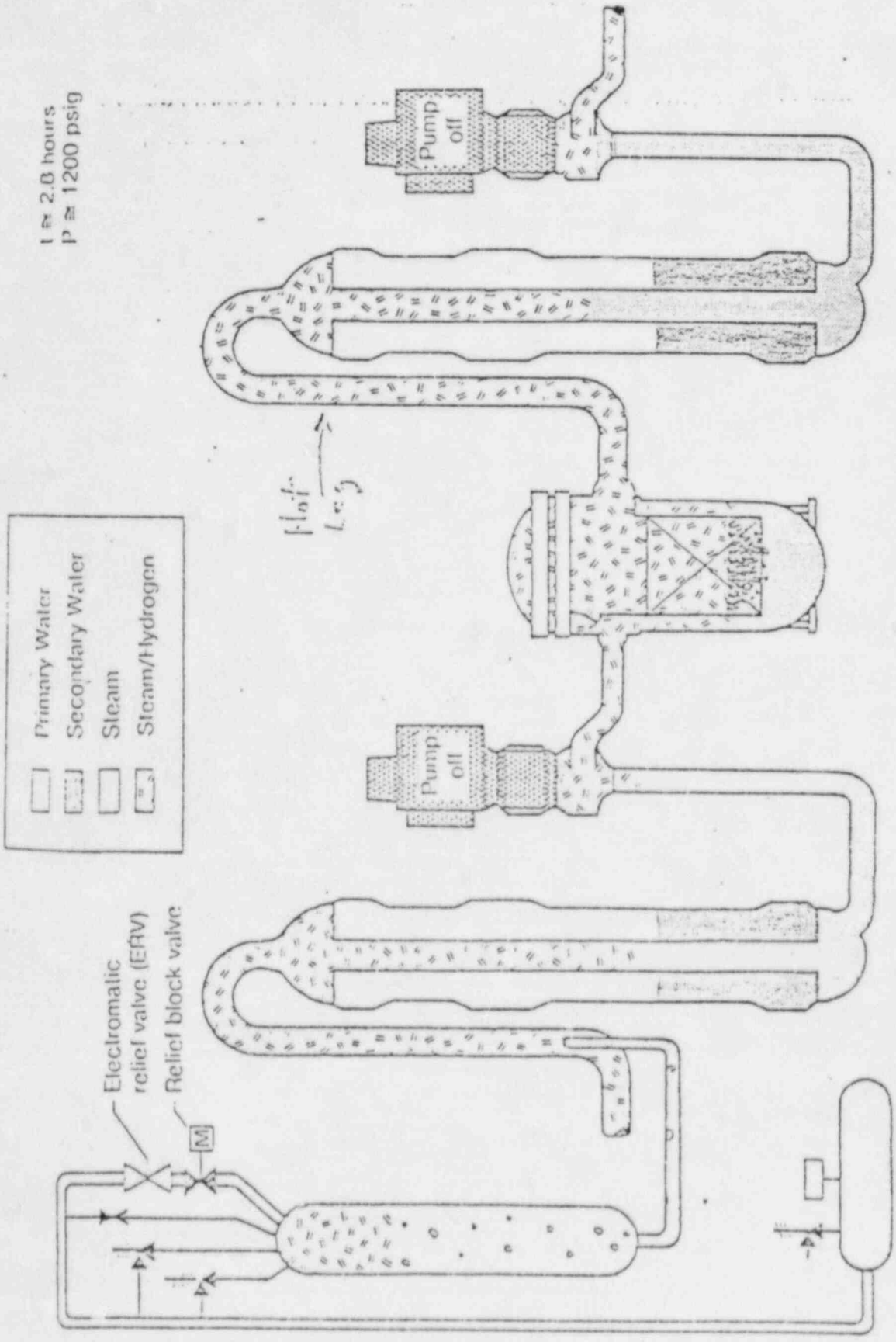


FIGURE 1-A

1 1.3a 1

FIGURE I-3



Core dryout and heatup continuing.
Hydrogen generation by zirconium/water reaction in hotter regions.

Apparently owing to the computer being incapable of indicating temperatures in excess of 620° F., Station Manager Gary Miller, soon after he arrived at about 7:05 a.m., directed that a meter able to indicate the full range of hot-leg temperature be set up in the control room:

> When I turned to focus on plant conditions, an initial concern was that the hot-leg indication was off-scale. I asked that an extended scale readout device be connected to the hot leg RTD (resistance temperature measuring device). (E&E, TMI-2, part 2, p. 297.)

Miller stated that:

> "... the extended hot leg temperature readout device indicated 720°F." (Ibid.)

Any temperature exceeding 660°F at the then prevailing pressures (which ranged up to 2200 psi) clearly indicated the presence of superheated steam; i.e. that the core had been uncovered.

The readings from the hot leg instrument are also referred to by Ivan Porter, TMI-2 Instrument and Control engineer, and by John Flint, an engineer employed by Babcock and Wilcox who was stationed at TMI. Porter had been responsible for setting up the instrument, and he told NRC investigators that after intially questioning the validity of the readings he had checked some of the temperature readings taken from instruments within the core (see below) and that:

> ". . . to me it confirmed that, what I was seeing on the RTD. That we had temperatures greater than 700 degrees in the plant, since 700* degrees was full scale on the computer and I was reading greater than 700 on the hot leg RTD." (I&E, Tape 237, p. 15.)

*This is in reference to the in-core thermocouples discussed below. The computer could indicate the in-core temperatures up to 700° whereas it could indicate the hot-leg temperatures only to 620°.

John Flint recalled that at this time (sometime after 9:00 a.m.)

> "... Ivan Porter showed me a special setup with a RTD, that was approximately 724 degrees." (I&E, Tape 323, p. 34.)

Flint also noted that he himself had monitored the strip chart recorder in the back of the room which was recording the data Flint refers to in the preceding quote. This chart showed hot-leg temperatures indicating superheated conditions in the primary system which in turn indicated sections of the core has been uncovered for a significant portion of the period between 5:40 a.m. and 7:50 p.m.*, the latter being the time at which a relatively stable cooling arrangement was established. The strip chart shows that the hot leg temperatures rose rapidly from the temperature at which water boiled for the prevailing pressure (i.e. saturation temperature) to superheated temperatures following shutdown of the main reactor coolant pump at approximately 5:40 a.m.

Notes taken by B&W staff in Lynchburg, Virginia on March 28 indicate that personnel at TMI were not using the hot-leg temperature data as indicative of whether the core was covered. The notes state the pressurizer temperature was being used as the basis for inferring core output temperature since the flow of water was from the reactor pressure vessel, into the pressurizer, and out the top of the pressurizer. The hot-leg temperature sensor was measuring the temperature at the top of the hot leg where steam and/or non-condensible gases were blocking flow through the steam generator. Therefore, the temperature at the top of the hot leg was more indicative of temperatures

*See Figure II.

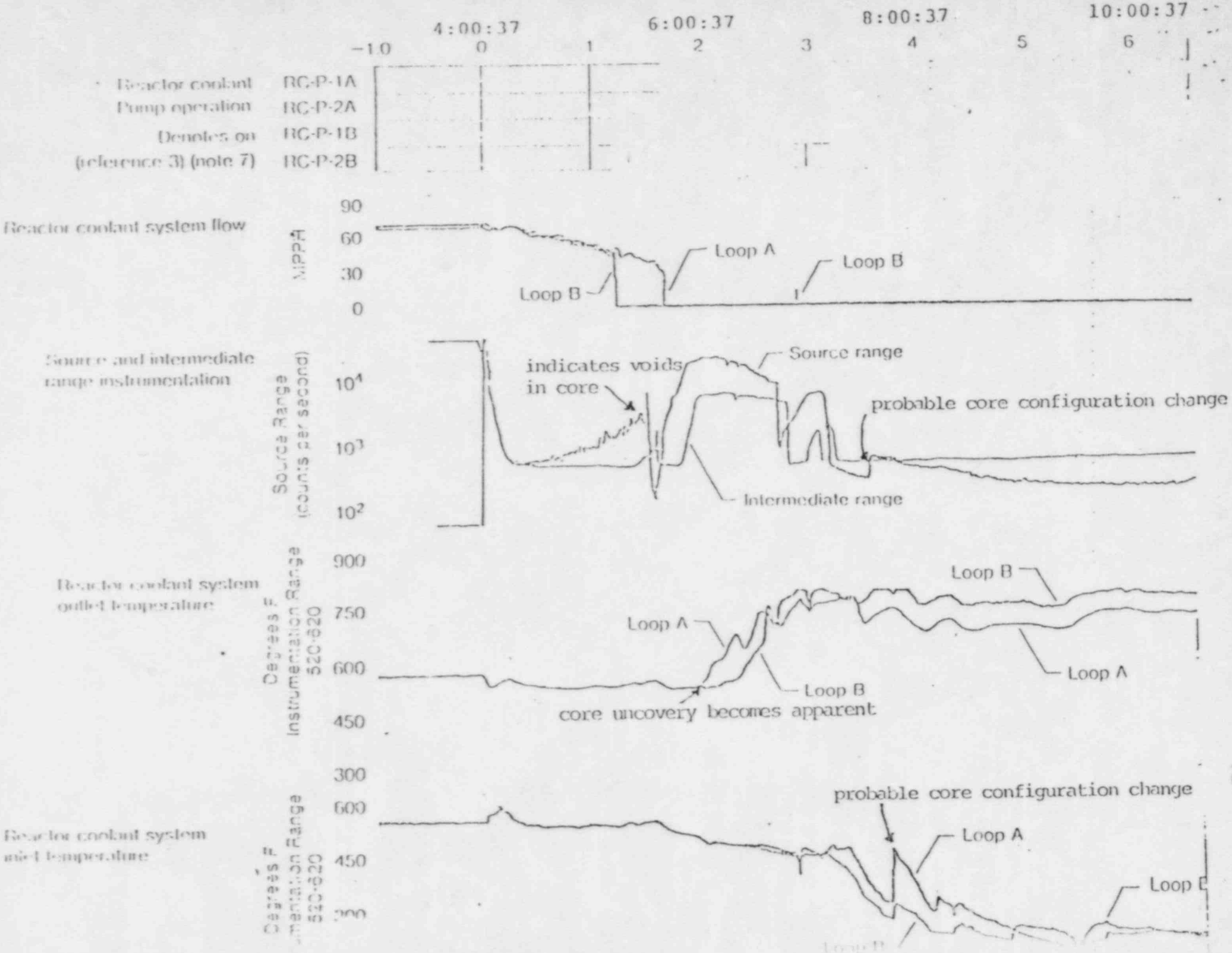

4:00:37
6:00:37
8:00:37
10:00:37
−1.0
0
1
2
3
4
5
6
Reactor coolant Pump operation
Denotes on (reference 3) (note 7)
RC-P-1A
RC-P-2A
RC-P-1B
RC-P-2B
Reactor coolant system flow
MPPA
90
60
30
0
Loop A
Loop B
Loop B
Source and intermediate range instrumentation
Source Range (counts per second)
10^4
10^3
10^2
indicates voids in core
Source range
probable core configuration change
Intermediate range
Reactor coolant system outlet temperature
Degrees F. Instrumentation Range 520-620
900
750
600
450
Loop B
Loop A
Loop A
Loop B
core uncovery becomes apparent
Reactor coolant system inlet temperature
Degrees F. Instrumentation Range 520-620
300
600
450
300
probable core configuration change
Loop A
Loop B

FIGURE II

that had existed earlier (when the core was uncovered e.g. at 7:00 a.m.) rather than later in the morning (e.g. 11:00 a.m.) when it was believed that the core was probably being cooled via high pressure injection flow through the core and out the pressurizer.

In-core Thermocouples

Other sources of temperature data were the 52 thermocouples installed inside the reactor pressure vessel above the fuel assemblies. These thermocouples sensed water (or steam) temperatures at particular points across the top of the core. Each thermocouple provided an indication of the temperature conditions above a particular fuel assembly while the hot-leg temperature sensing devices (discussed above) normally indicated the average temperature of water (or steam) leaving the reactor pressure vessel. There were, in fact, large differences between average temperatures as measured in the hot-legs and the peak temperatures measured by the individual in-core thermocouples. It was these peak in-core temperatures that confirmed not only

that the core was uncovered, but that the zirconium cladding was reacting with steam, producing hydrogen and zirconium oxide.

Credibility of in-core thermocouple data.

The TMI personnel showed an early and continuing interest in the in-core temperatures. They instructed the computer to print these temperatures at about 8:34 a.m., 8:47 a.m. 11:10 a.m., 12:40 p.m., 4:11 p.m., 6:30 p.m., 7:59 p.m., 8:56 p.m., and 9:56 p.m. Between 6:00 a.m. and 6:00 p.m. the temperature data for at least 40% of the thermocouples (EPRI, Fig. c1-11) were printed as questionmarks, indicating either that the thermocouples had failed or that the temperatures were in excess of 700° F. Because some of the thermocouples alternated between indicating question marks and temperatures less than 700 degrees, it was more plausible that the readings were indicative of temperatures in excess of 700 degrees than indicative of instrument malfunction.* Moreover, if many had been damaged while others continued to function, this in itself would have been a reasonable indication that something major had happened in the core resulting in disabling of the thermocouples. The following excerpts from interviews conducted by TMI investigators indicate that TMI personnel did in fact believe the in-core thermocouples were providing useful information.

*By approximately 12:45 a.m. on March 29 the thermocouples were mostly indicating temperatures less than 700 degrees and were apparently used thereafter as a prime indicator of core conditions.

John Flint, Babcock and Wilcox engineer stationed at TMI told General Public Utilities investigators in an interview held on April 20:

> " ... shortly after I came in we also started calling up on the computer the incore thermocouples attempting to establish what had happened in the core. Many of them were indicating questionmarks which indicated that they were greater than their 700F range. Only one or two seemed to indicate that they were in fact bad. These temperatures were monitoried for the rest of the day to follow what was happening to the core."

Flint also told NRC I&E Inspectors that:

> "When we first started dumping them out (i.e. calling up the incore thermocouple data from the computer) many of them had question marks, which indicated they were above their normal scale of 700 degrees not printing out "bad" which would indicate that they had failed. Over the next few hours these thermocouples gradually came back on scale[;] we recovered more and more of them and towards late afternoon I believe we had most of them indicating on scale." (I&E, Tape 58-59, p. 8.)

Ivan Porter told NRC investigators:

> "... I believe shortly after 7, he (station manager, Gary Miller) asked me about the readings on the in-core temperature detectors, and I punched out several of them (i.e. asked for computer printouts)..." (I&E Tape 237, p. 16)

Porter said he reported the results (i.e. temperatures in excess of 700° F.) to Miller who asked Porter whether there was any way of measuring the thermocouple voltages in order to determine how much in excess of 700 degrees the temperatures

might be. Porter told Miller that he thought he could get the information by connecting a digital voltmeter directly to the wires leading from the reactor core and measuring thereby the voltages (and therefore the temperatures) being fed into the computer. At this point there are varying recollections as to exactly who it was that Porter told to make the measurements. In any event, four technicians in addition to Porter either participated in making the measurements, or observed as they were being made. One technician who the NRC investigators have designated Instrument Man B (IMB) in deference to his wish for anonymity, stated that:

> "... Two of the thermocouples, the first few we had measured, were around 700 to 800 degrees, specific temperatures I can't quote you, I don't know. We had taken one off and we had measured 2600 degrees in and abo that vicinity, it was very close to that. At that time neither one of us believed that this was a true reading because after seeing two, three that were 700, 800 degrees, 2600 was hard to believe so we decided to take a few more off. ... I believe in the course of testing thermocouples, we had at least 10 or 12 we had disconnected t total. We had seen temperatures ranging anywhere from I know there was a botton of about 690 degrees to uppers of 3700 to 4000 degrees. (I.E. Tape 315, p. 11)

While cladding temperatures probably did exceed 3500°, there is disagreement as to whether temperatures as high as 4000 degrees were actually measured since it is unclear that the thermocouples would function at such temperatures. There is general agreement, however, that at least five people (Porter, Maintenance Foremen Bennet and Gilbert, Instrument Man Thomas Wright, and Instrument Man B) were directly aware of the instrument readings indicating

temperatures in excess of 2000 degrees; i.e. temperatures at which there would be significant production of hydrogen. Porter questioned the validity of the measurements and he told the technicians to repeat them using another meter. The technicians did so and this time they took measurements of 51 of the 52 thermocouples. Nine of the 51 were in excess of 2000 degrees. Where there was overlap, the second set of measurements, taken shortly after the first, confirmed the first set. IMB told the NRC investigators:

> "Now the second set of readings did in fact correlate the original set of readings that was taken with the thermocouple reader. The general feeling at least amongst Jim (Wright) and myself was that the readings we had were true and accurate. All five of us that were present there did in fact visually see the actual readings we had taken both off the thermocouple reader and millivot reader. All five of us did in fact verify that the millivolt reading through the conversion table was correct. So I am sure we didn't read the wrong table or the wrong one or something of that nature. (I.E. Tape 315, p. 18)

Bennet, Gilbert, Wright and IMB have stated with varying degrees of certitude their conclusion that the data indicated the core was uncovered. IMB told the investigators:

> "... it was the general consensus amongst the instrument people there that the core was definitely uncovered, we ... kind of found it hard to believe that this many high temperatures that we had seen that all those incores would have been bad and the only way that they could have went bad that radically would be an uncovering of the core, and super overheating. (Ibid., p. 17)

Bennet:

> We had possibly uncovered the core was the only way we could see that you could have obtained temperatures of that magnitude." (I.E. Tape 111, p. 18)

Wright:

> "I feel then that there was a definite sign then that the core had definitely been uncovered to the point, where it suffered damage. But it, I still say that, you know, I'm there to take the data. I'm not there to analyze it. So I gave them my personal opinion as in the, yeah, I do believe we did suffer some damage there. (I.E. Tape 310, p. 14)

Ivan Porter was responsible for reporting the thermocouple measurements to Gary Miller. In his statements to the NRC investigators Porter is ambiguous with regard to what he believed the significance of the in-core measurements to be. When asked whether he believed a reading of 2300 degrees to be anomalous, he stated:

> "I don't know. I guess I was afraid it was real." (I.E. Tape 237, p. 20)

But Porter also suggested that the measurements were not believeable. He said that in reporting to Gary Miller that Miller had asked him what he (Porter) thought the thermocouple measurements had meant. Porter told the NRC investigators that he was not sure of what his reponse to Miller had been, but that:

> "...my personal evaluation was that they (the thermocouples) had been destroyed." (Ibid., p. 19)

IMB told the investigators, however, that he had told Porter that he (IMB) believed the temperatures readings indicated that the core was uncovered:

> "... I personally told him that and he was physically there to read the readings. He saw the actual temperatures we had. This is why the first time he didn't believe it." (I.E. Tape 315, p. 18)

IMB also said:

> "I believe Ivan (Porter) didn't really want to believe what was really taking place. I don't know whether it was an attitude of "hey, your measurements are wrong, you guys don't know what the heck your doing or whatnot." I think the general consensus throughout the whole first day was number one nobody really knew what was actually happening, number two, some that had an inkling of what was happening didn't really want to believe what was going on. ONce you start seeing a temperature of 3000 to 4000 degrees in a core, well ... the first thing that starts coming to mind, you've got a meltdown coming. The core is uncovered." (Ibid., p. 18-19)

Whatever it was that Porter actually reported to station manager Gary Miller, Miller told NRC investigators:

> So you know, the bottom line here was that they (the in-cores) are hot, they were hot enough that they scared you, as far as what you're looking for. It told me the reason the computer was off scale at 700 degrees... The in-cores were reading anywhere from 2500 or so, and I picked 2500. It could have been higher than that. But that you know, I was looking for a gross indicator and I had it. ... I know that we were superheated and all that sort of thing, I don't think we tumbled to that kind of lodge (sic, logic?) but we just know we didn't have a control, we were out of control. We knew the situation was one we hadn't anticipated too many times here." (I.E. Tape 159, p. 51-52)

None of the TMI investigators' interviews has indicated whether Gary Miller (who, as indicated above, had been informed of the first set of measurements) saw the data obtained from the second set of readings. This data when plotted on a map of the core showed hot regions within the core and cold regions on the periphery.* Instrument Man Thomas Wright who was involved in recording the data said that the data was supposed to have been turned

* See Figure III.

FIGURE III

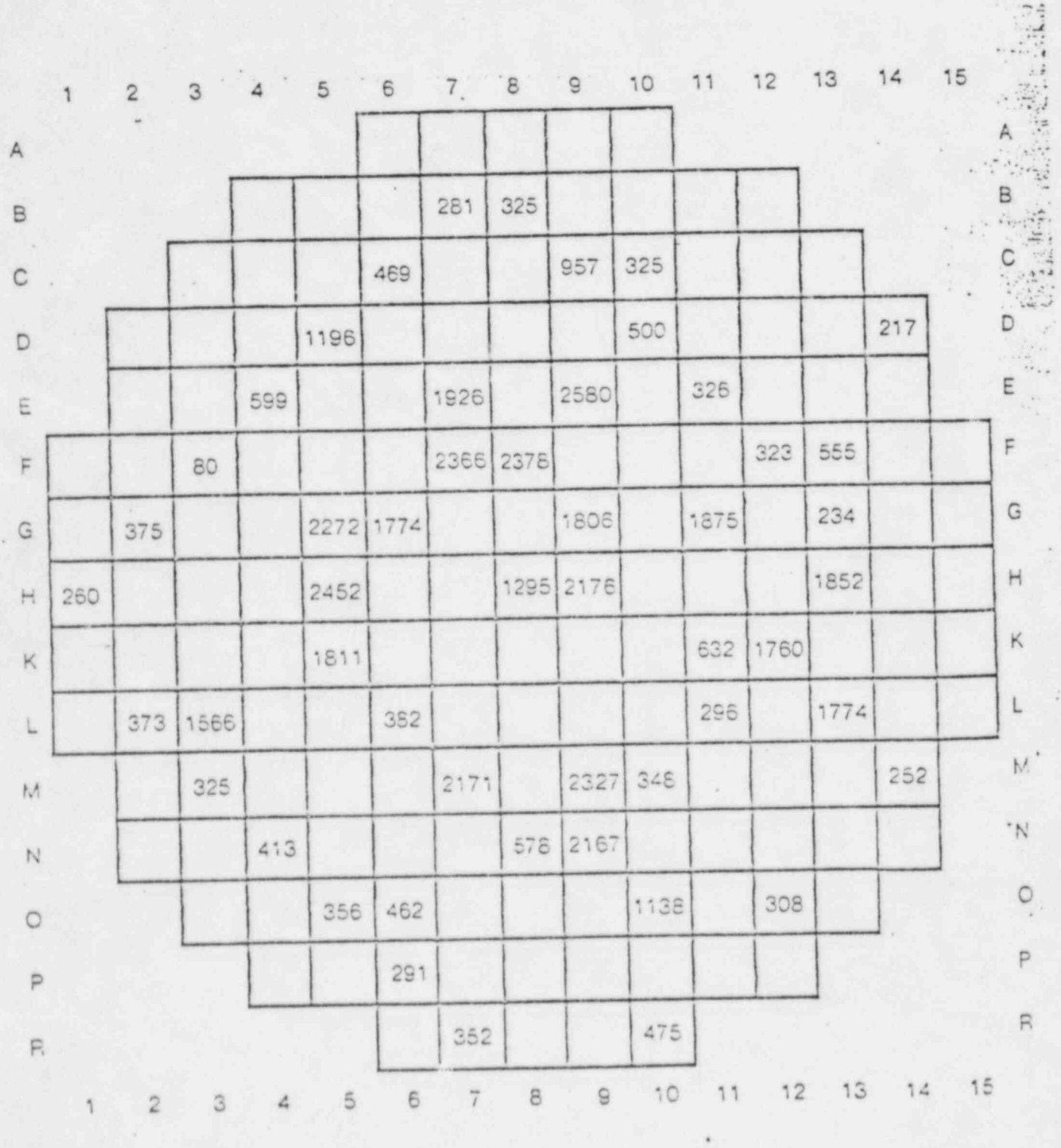


Figure CI-12. Map of Core Exit Temperature (°F)
240-330 min.

over to Ivan Porter. He stated to the NRC (I.E. Tape# 310, p. 18-19) that Porter was aware of the data. Wright recalls also that Porter had remarked that it appeared to him that it "... looked like we came, you know, that looked like they'd been damaged." It is not clear from this whether Porter was saying that the core or the thermocouples had been damaged. It is also unclear whether Porter actually received sheets on which the data was written, and which went unnoticed, it seems, from March 28 until May 7.

Mike Ross, a TMI-I superintendant, who was a member of the group making decisions on March 28 engaged in the following dialogue with NRC investigators.

Hunter (NRC investigator):

"Okay. Do you recall in the discussion, think tank discussions, that the thermocouple temperatures were, in fact, brought up in the discussions?"

Ross:

"Thermocouple temperatures were brought up to Gary Miller, and I guess the bottom line they got out of that, was that they were not conclusive. It showed the core was hot, basically. I was going to say his range varied, very scattered. He had like ... He was saying he had various temperatures scattered throughout. So, well, Gary and he discussed it, and basically I think the bottom line was yeah, the core is hot, or it is at least hot."

(I&E TMI Tape #226)

That the in-core thermocouples had indicated temperatures in excess of 2000 degrees (implying probable hydrogen production) was apparently not reported to the NRC during the first few days of the accident. Victor Stello (then NRC Director of Operating Reactors under Harold Denton) said he had not known of such measurements until the week of April 1 . Roger Mattson (Director of Systems Safety under Harold Denton) stated to the E&E Task Force on May 9 that this was the first he had heard of such temperatures.

Stello, however, had been concerned on March 28 about data indicating superheated conditions in the hot legs. He requested computer printouts of the in-core thermocouple data. There ensued the following dialogue between Three Mile Island and the NRC's Incident Response Center in Bethesda:

Voice: First of all, I can't get the in-core temperatures. Okay?

Voice: You cannot get them?

Voice: They print out questionmarks.

Voice: They print out questionmarks?

Voice: Yes.

Voice: Okay, what's that mean?

Voice: That means that either the computer point is messed up -- okay?

Voice: Yes.

Voice: or that the line -- you know, the -- where you sense it, that line's broken or something's messed up with that line. Okay? They were printing earlier. Yeah, the computer just won't -- the computer won't spit out a good number for them. They're trying all of them to see if we can get any of them to print. Okay?

(01-033-CH 2/20-MEM-10.)

Based on the foregoing discussion, NRC I&E investigators wrote:

(At approximately 4:10 p.m. on March 28) "Reported in-core temperatures unavailable. Supervisor (at TMI) reports to NRC they (in-cores) are all printing questions marks which means either the computer point or the sensor is malfunction (sic). (NUREG 0600, IA-101)

Yet practically coincident with the conversation in which the NRC was told that the computer was printing out question-marks, the computer was in fact displaying not only questionmarks but also two on-scale readings, one indicating that thermocouple 9-H was showing a temperature of 596.9 F., and the other showing thermocouple 6-L indicating a temperature of 562.1 F. Both temperatures were indicative of superheated conditions in the core and of the likelihood that the reason for the questionmakrs was high temperature rather than a malfunction of the instuments.

A reproduction of the computer printout follows:

```
          16:03:13    182.7 135.1 591.4 474.7 457.4  581. 421.6 376.3 285.
          16:10:13    182.5 128.9 591.5 476.0 456.6  580. 421.3 376.3 285.
          16:11:32  DATA  0493  IM INCORE T/C  8-H TEMP            -???.?
          16:11:41  DATA  0494  IM INCORE T/C  9-H TEMP             596.9
          16:11:49  DATA  0495  IM INCORE T/C  9-G TEMP            -???.?
          16:11:57  DATA  0496  IM INCORE T/C  8-F TEMP            -???.?
          16:12:06  DATA  0497  IM INCORE T/C  9-E TEMP            -???.?
          16:12:14  GROUP TREND
                    OPERATOR GROUP C
                     1032  0386  0390  0389  0408  0398  0472  0488  0492
          16:12:51    182.2 121.9 591.1 476.4 456.0  581. 420.8 376.3 285.
          16:13:44  DATA  0498  IM INCORE T/C  7-F TEMP            -???.?
          16:13:53  DATA  0499  IM INCORE T/C  7-E TEMP            -???.?
          16:14:03  DATA  0500  IM INCORE T/C  6-G TEMP            -???.?
          16:14:12  DATA  0501  IM INCORE T/C  5-G TEMP            -???.?
          16:14:22  GROUP TREND
                    OPERATOR GROUP C
                     1032  0386  0390  0389  0408  0398  0472  0488  0492
          16:15:02    182.0 118.7 591.0 477.0 455.2  580. 420.5 376.3 285.
          16:15:54  DATA  0502  IM INCORE T/C  5-H TEMP            -???.?
          16:16:03  DATA  0503  IM INCORE T/C  5-K TEMP            -???.?
          16:16:13  DATA  0504  IM INCORE T/C  6-L TEMP             562.1
          16:16:22  GROUP TREND
                    OPERATOR GROUP C
                     1032  0386  0390  0389  0408  0398  0472  0488  0492
          16:17:03    181.8 118.0 591.1 478.2 454.3  580. 420.3 376.4 285.
          16:17:54  DATA  0505  IM INCORE T/C  7-M TEMP            -???.?
          16:18:03  DATA  0506  IM INCORE T/C  8-N TEMP            -???.?
          16:18:13  GROUP TREND
                    OPERATOR GROUP C
                     1032  0386  0390  0389  0408  0398  0472  0488  0492
          16:18:54    181.6 117.6 591.2 478.9 454.1  580. 420.0 376.4 285.
          16:19:47  DATA  0507  IM INCORE T/C  9-N TEMP            -???.?
```

Although the in-core thermocouple data was printed at least 9 times between 8:00 a.m. and 10:00 p.m. on March 28 there appears to be no record of any set of such data having been transmitted to the NRC's Incident Response Center in Bethesda.

Neutron Detectors

TMI-2 instrumentation included neutron detectors mounted outside the reactor pressure vessel and 52 strings of detectors mounted inside. Both in-core and ex-core detectors are installed for the purpose of providing operational data; during normal operations, the in-core neutron detectors indicate power production at various locations within the core. During the TMI accident both in-core and ex-core detectors provided data indicating the core was uncovered.

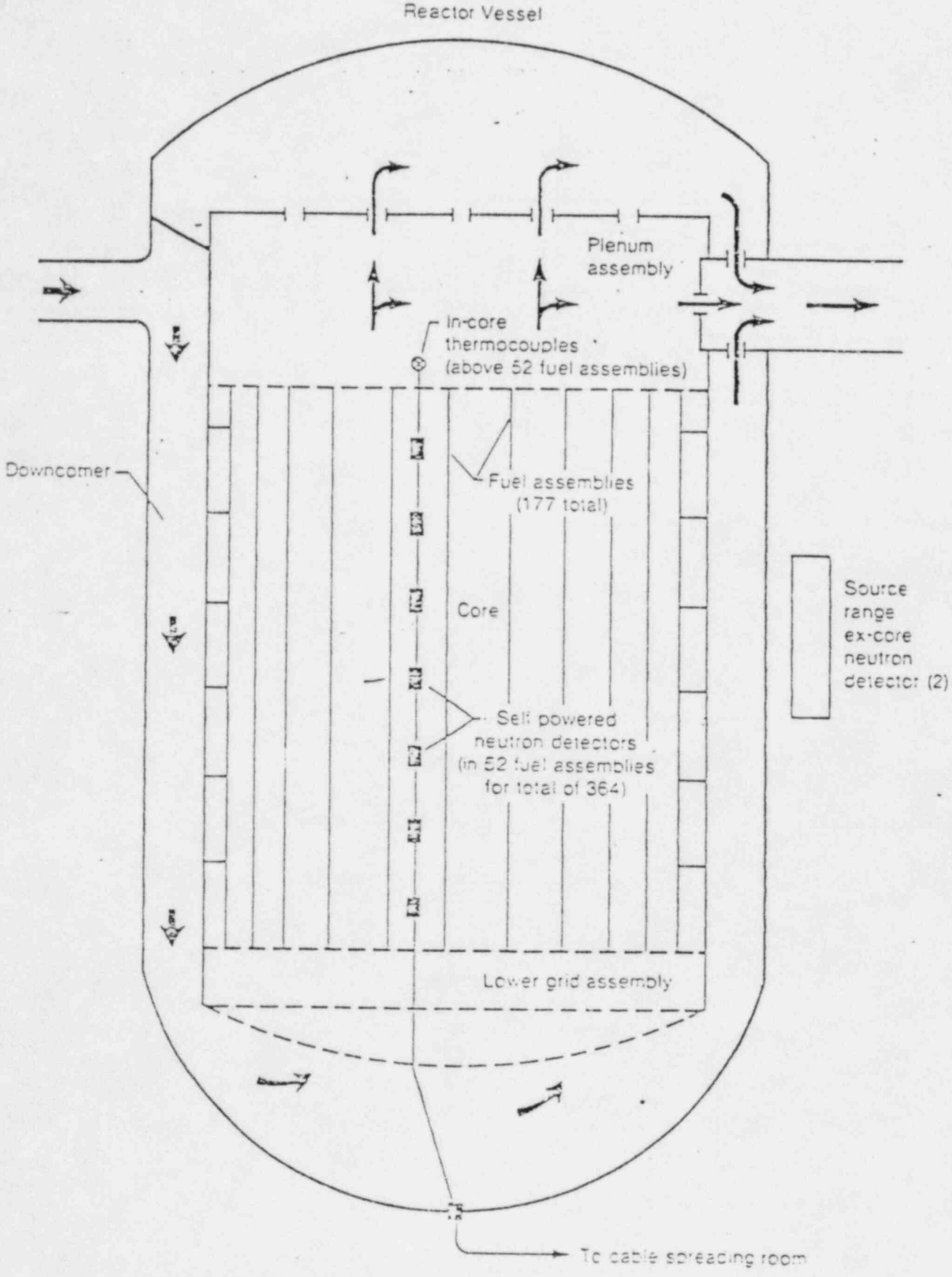
The ex-core instruments indicated increased neutron levels. These were interpreted initially as indicating that the reactor was near the critical point where a self-sustaining chain reaction might be occurring. The operators believed that this might happen as a result of insufficient boron concentration in the primary system coolant. In actuality the apparent increase in neutron activity resulted from the fact that neutrons -- normally produced in small quantities in a reactor core even when the reactor is not running -- were, as a result of voids in the core, less likely to be absorbed prior to their escaping the pressure vessel and were therefore reaching the ex-core instruments in greater numbers. In short, the increased number of neutrons were due to the pressure vessel having lost its water and not to a restart of the chain reaction.

The in-core neutron detectors also yielded data indicating that the core was uncovered and the depth of the uncovering. Once the water level went below the neutron detector and the temperature of its surroundings rose, the detectors responded to the higher temperatures and became, in effect, temperature sensitive devices which provided indirect indication of water level in the core. (See Figure IV.)

The record is unclear as the extent to which the TMI supervisors used the neutron detector data as an indication that the core had been uncovered. The record shows that increased counting rates were initially interpreted as an indicator of the reactor becoming critical. As a result, additional boron was injected into the primary cooling system. During the morning of March 28, B&W engineer John Flint looked at the neutron detector data and concluded that in all probability the increased counting rates were due to a change in the leakage path, i.e. as a result of voids in the reactor coolant fewer neutrons were absorbed by water before reaching the neutron detector. Flint told the I&E Inspectors:

> "Indications for the source and intermediate range (neutron detectors) appeared to be normal, for this period of time following a shutdown condition. I did notice, however, that there were several blips on the recorder for source/intermediate range and in conversation with Ed Fredericks he informed me that they thought at the time that they were going critical and that they had added additional boron to the system. At this time, I informed them that in all probability this was not the case, that there had been a change in leakage flux path from the reactor core to the detectors and it was not in fact the case the reactor going critical again."
>
> I&E Tape 58, 59, p. 4.)

FIGURE IV



Basic reactor configuration and instrument locations.

High Radiation Levels in Containment

At 6:35 a.m. a radiation monitor mounted at the top of the containment building indicated radiation levels of about 0.1 Roentgen (R) per hour. By 7:30 a.m. this monitor was indicating levels in excess of 10,000 R per hour. (Approximately 50% of persons exposed to this dose rate would receive a lethal dose in about 4 minutes.) These radiation levels implied that radioactive fission product gases had been released from a significant fraction of the fuel rods; the only way such a release could have occurred would have been through development of cracks or perforations in the cladding.

Based on this reading alone, James Floyd, a TMI supervisor inferred that approximately 1/8 of the fuel rods had failed. On the day of the accident, Floyd was in Lynchburg, Virginia for training on the B&W reactor simulator. Having been told of the accident by a colleague, Floyd called the control room at around 7:30 a.m. and was given information on radiation levels from which he inferred that the quantity of radioactive gas in the containment building was approximately equivalent to 1/8 of that that had been contained in the fuel rods; this led to his inference that 1/8 of the fuel had been damaged.

Floyd told the Kemeny Commission that the inference he made in Lynchburg could have also been made by persons in the TMI control room on the day of the accident. (Kemeny

Hearing, May 31, 1979, p. 186-188.) Kemeny Commission member Ted Taylor asked:

> "Well, to whom did you give this information (i.e. Floyd's inference '... that it looked like at least an eighth of the cladding had failed') during the course of the day on Wednesday, outside the people you are immediately involved with at Lynchburg?"

Floyd responded:

> "No one."

Taylor:

> "No one. Were you assuming that people at the plant knew this?"

Floyd:

> "Yes sir." (Ibid., p. 188-189)

Floyd later indicated that it was not until he sat in on the Kemeny hearings in late May that he realized that the supervisors and management at TMI had said that on March 28 they were unaware of a substantial amount of core damage. (Ibid., p. 194)

Hydrogen Combustion

During the morning and early afternoon on March 28, a significant portion of the hydrogen produced in the zirconium steam reaction was released from the reactor cooling system into the containment building via the pressurizer relief valve. At approximately 1:50 p.m. the hydrogen ignited.[1] What is probably more accurately described as a fire than an explosion caused several effects including a 28 pound per square inch (psi) pressure pulse in the containment building.* This pulse was recorded on the strip chart that recorded containment building pressure. It was also recorded on a series of other pressure measuring devices which used the containment pressure as a reference.** The fire raised temperatures in the containment from about 125 degrees to 175 degrees F, an increase of 50 degrees dissimilar to any other temperature changes observed that day; these temperature data were recorded on strip charts in the control room.*** The increased temperatures triggered several alarms. The containment pressure pulse also actuated various emergency systems, most notably the equipment that caused water and sodium hydroxide to be sprayed into the containment building.

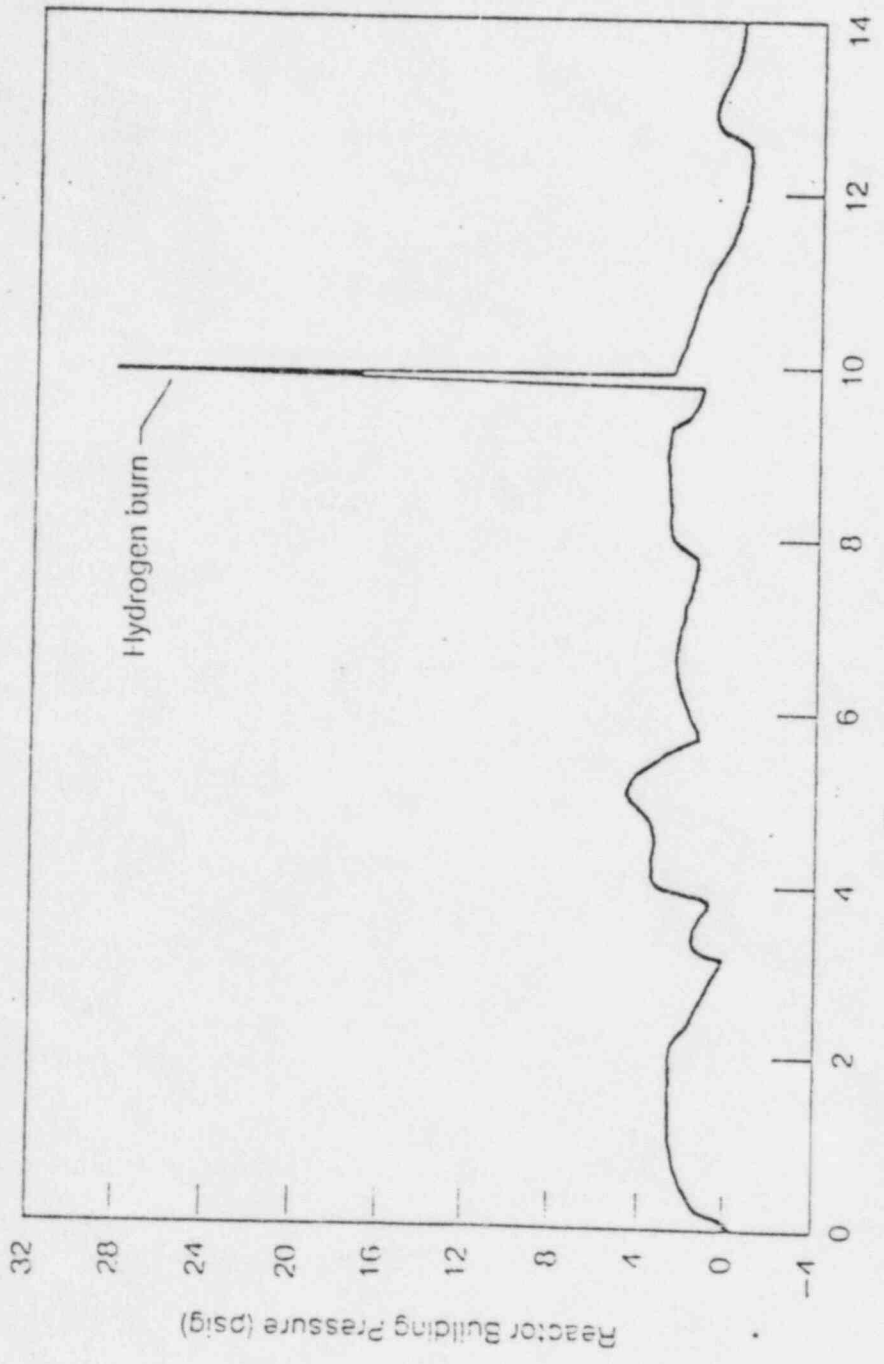
TMI supervisors and operators have given two explanations for not having reported the hydrogen fire to either Federal or state officials:

---

*Figure V-A
** Figure V-B
*** Figure V-C

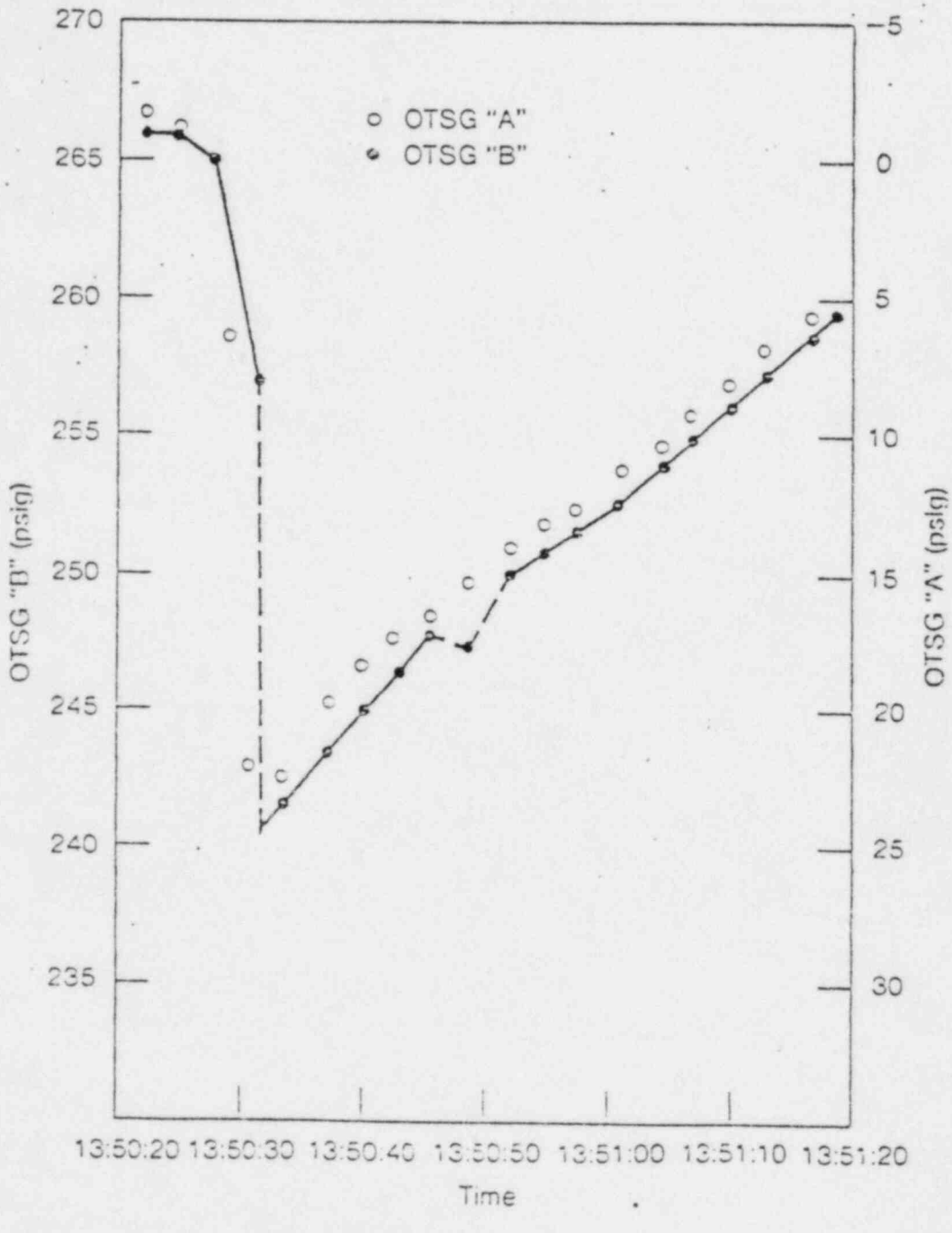
[1] See f.n. p. 5, regarding this not being the potential fire and/or explosion feared on March 30 and subsequent days.

FIGURE V-A



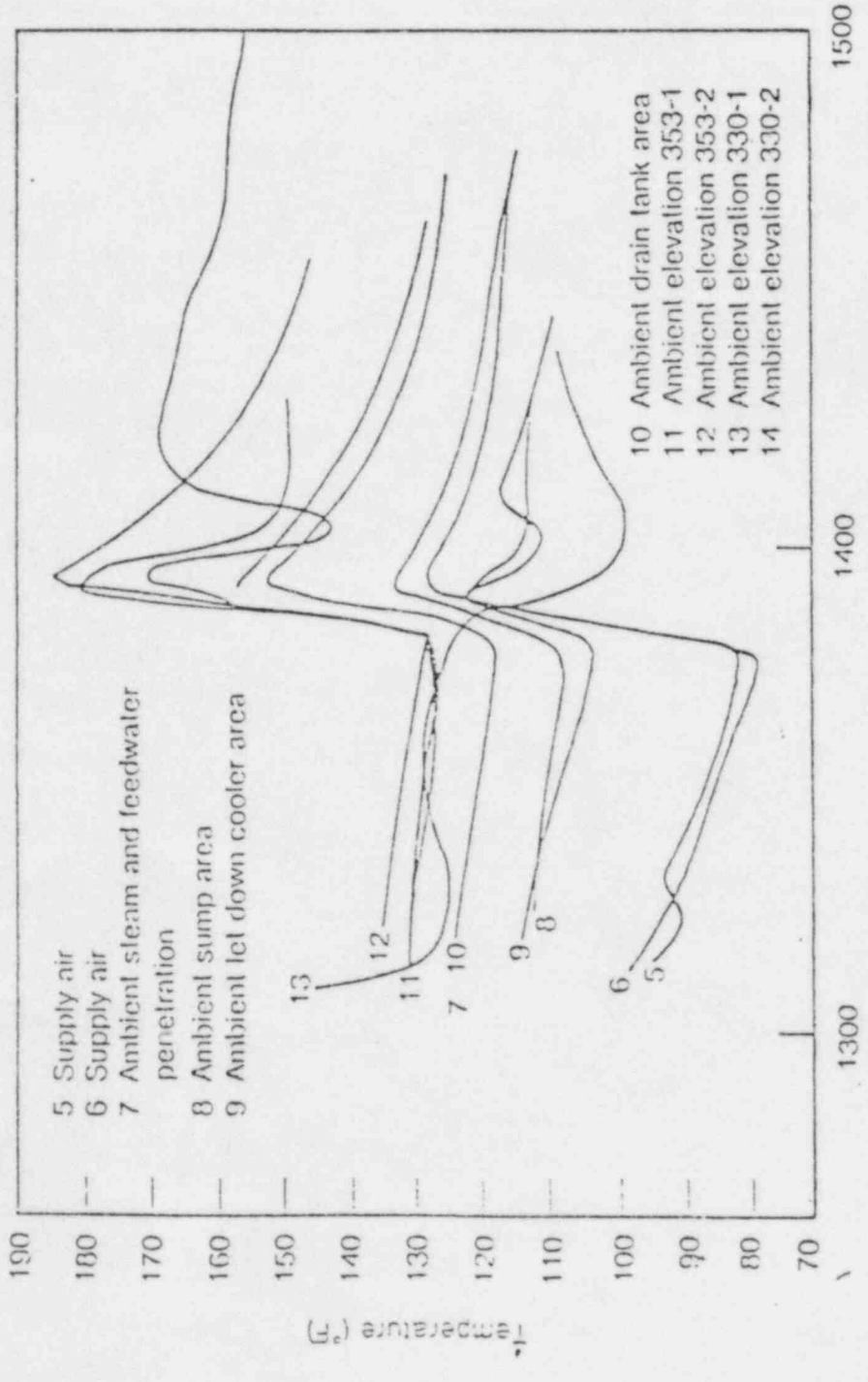
Reactor Building Pressure Versus Time

FIGURE V-B



Effect of H_2 ignition on measured steam pressures.

FIGURE V-C



Reactor building temperatures during hydrogen ignition.

1. The explosion manifestations were caused by spurious electrical signals.

2. Because the pressure did not remain at a high level, the cause of the pulse was not important, and the operators were too engrossed with establishing a stable cooling configuration to pay attention to it.

Neither of these explanations is plausible. The first is questionable because of plant design considerations and the simultaneous occurrance of pressure and temperature effects indicative of a real pressure pulse. Given their basic training in reactor engineering it is implausible that the TMI supervisors would consider the pressure pulse to be insignificant in light of the multiple indications of core uncovery and hydrogen production.

The record contains conflicting testimony. Excerpts follow. The first concerns whether the electrical malfunctions could have caused the pressure pulse. TMI-2 Reactor Operators engaged in the following dialogue with Ed Frederick and Craig Faust[A] the E&E TMI Task Force:

> Myers: What could have had two of those three sensing devices sense high pressure and lead them to think the pressure was high, other than high pressure, real high pressure, actual high pressure? Is there anything that decides the pressure is going up that could have led those sensors to think the pressure was high?
>
> Frederick: A test signal.
>
> Myers: Would a test signal go to two of them at the same time?
>
> Faust: No. In fact, you would have to hook it up.
>
> Frederick: It would have to be a lengthy manual action to get it to do it, other than actual building pressure.

Myers: Is there anything that you can think of other than excess building pressure that could have simultaneously led the meter to read 28 pounds per square inch and to turn on the spray tanks or turn on the containment spray?

Frederick: No; it had to be high level pressure.

Faust: There had to be a pressure surge in the building for it to happen. (E&E TMI Part 1, p. 147)

At a later date (on September 11) Frederick told interviewers from the NRC's Special Inquiry Group that he did not believe the pressure spike to have reflected a real increase in pressure because his training had not informed him as to the possibility of such a spike. Frederick stated that none of the persons present thought it plausible that the pressure in a 2 million cubic foot building could rise and fall so rapidly. Frederick stated:

"That's why none of us considered it plausible. It's impossible to do that."

SIG interviewer Ron Haynes responded:

"I wouldn't say it was impossible. I thought it actually occurred."

Frederick then stated:

"Based on our training, it was impossible. It was completely foreign. If you look back through everybody's training and the FASR and safety analysis and the building construction, you will not see a paragraph that projects that type of transient. Nor will you see it in anybody's training so far as -- that is so particularly foreign and unbelievable that it has absolutely no significance. That's why nobody did anything about it for two days."

(SIG, Faust et al., p. 264-265.)

Instrument Engineer Ivan Porter was asked by NRC investigators whether Porter thought the pressure spike could be explained by any form of instrument malfunction. Porter responded:

> "I would think not. It did look like a real spike to me. That was when I was specifically asked if it could be real." (I&E Tape 237, p. 35)

With regard to whether he saw the pressure pulse on March 28, Porter said:

> "But somehow I have a feeling, I didn't look at those charts until the next day. I'm not specifically sure that I was aware of it that day. I know that I very specifically remember a discussion where we looked at the chart, was asked if it could possibly be real, and I also look at the wide ranged pressure chart and saw that [the pulse] showed up as a decrease in pressure on the wide range reactor coolant system pressure, but I sincerely believe that that was the next day that I looked through the stuff." (Ibid., p. 34)

It is not clear why they would be waiting until the next day to look at the data, or if it were the next day, what it was that led them to do it then. In addition to the spike appearing to be real to Porter, he found a similar negative spike, in the reactor coolant system pressure history. This would be expected since reactor coolant system pressure was measured using the containment building pressure as a reference; when the containment pressure went up, the reactor coolant system pressure would appear to go down. As noted above, a similar negative pressure pulse was observed in other pressure histories. *

*See Figure V-3.

Shift Supervisor William Zewe said that he had observed the pressure spike to occur at the moment the pressurizer relief valve was cycled, but that he did not associate the spike with a hydrogen explosion. He said that he had not been aware of temperatures in the core of sufficient magnitude for the cladding-steam chemical reaction to have occurred. Zewe was apparently unaware of the in-core thermocouple measurements that implied production of hydrogen. Zewe said, not knowing what the spike could have been, that they ascribed it to an electical malfunction associated with the operation of the valve. While Zewe may have considered the pressure pulse to have been an electrical anomoly, others seemed concerned that it was real.

TMI Supervisor Joseph Chwastyk said:

> "... I actually saw the recorder, the pressure recorder on the building, spiked upward. I didn't know what caused it but the fact that the spray valves started indicated to me that we actually had some kind of pressure spike, either on the sensors or in the building itself. I was not sure. The spike of course started all the building spray pumps, decay heat pumps, etc. The pressure spiked up and it was only up briefly, as a matter of fact, a couple of heart beats. I know because I missed those heart beats. It came back down again." (I&E Tape 232/233, p. 9)

Chwastyk (who arrived in the control room between 11:00 a.m. and 12 noon, and who was apparently not aware of the direct measurements of the in-core temperatures) also referred to an explosion in describing how it was that he came to realize that the reactor core might have been significantly damaged:

> "It was like I said, everybody was pretty busy and I didn't want to stop anybody from what they were doing so I just tried to get a feel for what was happening by looking around and asking the operators at the panel what they were doing. Up until the time or sometime after the explosion and it dawned on me what it was, I didn't know how much damage we had. (Ibid., p. 18)

Also, TMI shift Supervisor Brian Mehler has told investigators that he believed the instruments to have indicated occurrance of a real pressure pulse and not to have been a manifestation of spurious electrical signals. Mehler referred to the pressure pulse as having originated with a chemical reaction; he stated that he did not recall thinking that a hydrogen detonation might have occurred.

Q. Okay, I think in your I&E interview you said that you thought initially tha the pressure spike in the containmer when you saw it, was probably due to somebody fooling around with the transmitter.

A. Yes, I said that. But then I also said it couldn't have been possible because building spray pumps started.

Q. Which meant that there had been a pressure signal that went through and started the building spray pumps?

A. Right.

. . . . . .

Q. Now, after looking at it in that initial dismissal, did you later realize that there had been pressure in the containment that caused that spike on the instrument?

A. Yes.

Q. Do you have any idea what could cause that kind of a rapid pressure spike?

A. I know Joe and I talked about it later on that day, about what could have caused it and I don't think hydrogen entered into it. We thought maybe some kind of chemical reaction or something happened because it was up and down so quick.

Q. That is Joe Chwastyk?

A. Yes.

Q. So you really didn't have a good diagnosis?

A. I personally didn't think hydrogen could form that quick in the building to that concentration to cause it in that period of time. (SIG, Mehler, p. 13-15, 10/11/79)

Mehler also recalled in his conversations with investigators that on March 28 he had been told not to turn on oil pumps in the containment, apparently out of concern that electrical sparks might be produced which could cause detonation of hydrogen in the containment structure. On October 11, Mehler told SIG investigators that:

> "... I do know sometime after the pressure spike happened we were told not to start equipment because they assumed that it [the pressure spike] could happen again and they probably put it that there was hydrogen in there, but that was sometime after 1:50. Now how far past that, I don't know. And I do not, I said -- well, to Gary Miller I said -- he said don't start any more oil pumps and I said we don't have to, I already tested them all, because they were concerned -- but how far into the afternoon at that time, I don't know whether it was 4:00, 2:00 or what, but it was sometime after." (Ibid., p. 16.)

This recollection is similar to one reported in the New York Times wherein Mehler was said to have

responded to his supervisor's warning not to turn on the pumps by saying that he had already done so. According to the Times article someone then allegedly said:

> "Well, that means we don't have any more hydrogen in there."

Mr. Mehler was interviewed again on October 30 and at this time he was less certain that the above noted instruction not to start the pumps had been given on March 28. The following exchange took place during the October 30 interview where the questions are being asked by Mr. Frampton of the SIG and the answers are Mr. Mehler's:

> Q. Since the interview that our group did with you on October 11, as indicated by Mehler Exhibit No. 2, you have become less certain that this instruction and the conversation you had with Mr. Miller was on Wednesday, March 28th.
>
> A. That is correct.
>
> Q. What is it that has caused you to doubt the recollection that you had before?
>
> A. I've talked to some other people that were there on the 28th, and also thinking back upon it, you know, I cannot be certain that it did happen on the 28th.
>
> Q. In talking with other people -- well, let me ask you who you have talked to about it?
>
> A. I've talked to Gary Miller, Mike Ross, Joe Chwasty, Bill Zewe, and none of them recollect that instruction being given on the 28th.

Q. Do any of them recollect such an instruction being given on the 29th?

A. I don't think they would say specifically that it happened on the 29th either, but I do believe some of them recollect it being given.

Q. Do you remember which ones?

A. I think Joe does.

Q. Any of the other people?

A. I don't know.

Q. In your conversations with them, what is it that they have said that's made you think that your recollection is probably wrong that it was the 28th?

A. Well, they would have been in the room the same time I was to hear the instructions, and it seems funny, if I would be the only one that remembered it happening on the 28th when there were other people in the room that don't remember it.

Q. So this is in part conversations with other people that you have had and in part sort of a general reconstruction of events that's made you think that you're wrong in thinking it was the 28th; is that fair to say?

A. That's fair to say, and also, you know, quite a bit happened the 28th. And I did come back the 29th. It could have very well been the 29th, and I wouldn't even say for certain it was the 29th right now.

Q. It's conceivable it could have been the 30th?

A. I wouldn't want to get definite and say it was -- you know, I'm just not certain right now which day it was.

Q. Would it be fair to say that your own recollection, faulty or not, standing alone, has been that it was the 28th, but that in talking to other people, you think that your recollection is most likely to be somewhat faulty and it was more likely that it was the 29th?

A. That's correct. (SIG, Mehler, P. 15-17, 10/30/79)

Chwastyk also recalls being told, "... not to restart any equipment in the reactor building. And someone at the time had just finished starting a piece of equipment." Chwastyk said he thought the equipment referred to was the DC oil pumps on the reactor coolant pumps, presumably the same pumps referred to by Mehler. Chwastyk said that he thought the instruction had not been issued on Wednesday, March 28, because he remembered receiving it in the supervisor's office, and "... I don't think on Wednesday I was in the shift supervisor's office at all." (SIG, Chwastyk, p. 16, 10/30/79) This recollection of Chwastyk is referred to in the SIG report (Volume II, part 3, p. 0147) and is part of the basis for the SIG conclusion that Mehler was probably incorrect when he remembered the discussion, about not turning on the oil pumps, as having occurred in the shift supervisor's office on Wednesday, March 28. On the other hand, TMI supervisor Mike Ross did recall Chwastyk being in the Shift Supervisor's office on March 28:

"At time Joe (Chwastyk) would come into the think tank, (i.e. the shift supervisor's office where

supervisory personnel convened during the day for the purpose of assessing events and deciding upon actions to be taken) where we were at, and he would enter discussions." (SIG, Ross, p. 15, 10/30/79)

The SIG report does not mention that Ross's recollection as to Chwastyk's appearance in the Shift Supervisor's office conflicted with Chwastyk's recalling that he didn't think he had been in this office on Wednesday, March 28. The SIG report notes but does not comment upon a further discrepancy in the testimony of Mehler and Miller: Mehler testified that it was Miller who gave the instruction not to start the pumps even though the date was uncertain; i.e. Mehler's own recollection was that the instruction had been issued on the 28th, but after talking to other people, he said that his recollection was most likely faulty and it was more likely that it was the 29th. (Ibid.) Miller, on the other hand, did not recall at any time having given an instruction not to start pumps or even having been in the control room on the 29th at the hour which was Mehler's new recollection of the time at which the instruction had been given. (SIG, Vol. II, Part 3, p. 147-148.)

A reactor operator, Theodore Illjes, who arrived in the control room after the detonation, told NRC investigators that he had been briefed on the reactor building pressure pulse:

> "I was told they had a spike on both indications of the reactor building pressure recorder. There was some discussion as to what it was. A hydrogen explosion was discussed. This was later in the evening." (I&E, Tape 261, p. 6)

When asked again as to whether the discussion of a possible hydrogen burn had taken place on the first evening (March 28) Illjes said:

> "As far as I know that possibility was discussed that evening." (Ibid., p. 10)

At about 2:30 p.m., some 40 minutes after the hydrogen detonation, Station Manager Gary Miller left the site for the purpose of briefing Lieutenant Governor Scranton. (E&E, TMI Part II, p. 273.) Miller has written that while in the control room on March 28:

> "I heard a noise at approximately 1:50 p.m., however, I did not associate it with the burning of hydrogen or the actuation of the safeguards system at that time. I was first aware of the recorded pressure pulse and associated actuation of the safeguards system on Friday morning, March 30, 1979." (Ibid., p. 298)

Others who were present say that Miller was aware of the pressure pulse at about the time it occurred. When Reactor Operator Frederick was asked whether others in the control room had reacted to the pressure spike, Frederick stated:

> "I think Mr. Marshall tried to figure it out, and Gary Miller was particularly interested in it." (E&E, Part I, p. 143)

Zewe stated in a deposition for the Special Inquiry Group that Mr. Miller was in the control room when the pressure pulse occurred (SIG, Zewe et al., 9/11/79, p. 257) Zewe also stated that:

> "I found it hard to believe that anyone who was in the control room observing anything would have missed that (the spike) or turning off the pumps or any of the discussions at all."

Mike Ross, who was TMI-I Operations Supervisor, but acting as second in command to Miller at TMI-2 on March 28 stated when asked whether he was present when the pressure spike occurred:

> "Yes. I was near the console at that time and if we are talking about the same time was around 2:00, sometime in the area. And at that time we got an ES signal and some of the components restarted, decay heat, what have you. We got building isolation again and we took care of that and we looked back and the control room operator said "Jeese the spray pumps are running." and we looked back at the charts at that time. We saw a fairly large spike on the chart and the exact pressure at this time I don't know, ... it was around 30 pounds. My thought at the time and Miller was out there with us and he questioned he said, "jeese you know I thought I heard something, too." We are moving down the road there 100 miles an hour and we looked at it and we said "Jeese the spike was so short it must have been an instrument." That was our reasoning at the time. We reached over and we said you can shut the spray pumps off now because the pressure came right back to 0, ... almost very, very rapid return and we shut the spray pumps off. I now know that spray pumps were on about five minutes when looking back because I did look back on that particular one. I personally didn't associate it at the moment with

> any kind of explosion in the building. I associated it with an instrument problem perhaps and I think so did Miller at the time because we just went on to something else. It wasn't until the next day that we thought about anything like that and started looking back. (I&E Tape #226, p. 4-5) [Underline added.]

Shift Supervisor Chawstyk who had observed the pressure spike but did not hear the noise referred to by Gary Miller told the NRC investigators of a suggestion made to Miller on the basis of the spike having occurred upon operation of the pressurizer relief valve:

> Chwastyk: No, I did not hear the noise. But that was the point at which I had assumed that we did have some kind of explosion in the building. And that is when I suggested to Gary Miller we no longer cycle the electromagnetic relief valve because it had ... the explosion ... or rapid rising pressure in the reactor building corresponded to opening the electromagnetic relief valve. (I&E Tape, #232/233, p. 18)

Chwastyk stated in subsequent interviews with the SIG that he recalled informing Gary Miller of his concern that an explosion had occurred. On October 11 he said that on March 28 he had been concerned even prior to the explosion that water should be pumped into the primary at a higher rate and that:

> "It was right after the hydrogen explosion and I mentioned that I correlated the opening of the valve with the detonation period that I again went to Gary Miller and explained what I thought had happened as far as the hydrogen detonation and the simultaneous opening of the valve, and it was shortly after that, Gary Miller got back to me and said go ahead and draw the bubble." (SIG, Chwastyk, p. 18, 10.11.79.)

On October 30, Chwastyk was asked again whether he thought he had mentioned the possibility of a hydrogen explosion to Gary Miller in so many words, or discussed what that would mean or what had happened to the system. Chwastyk replied:

> "My best recollection of that is that I did relate to Gary that we had some sort of an explosion. Whether I said it was hydrogen or not, I'm not sure. But I remember distinctly putting together the operation of the valve and the spike, and I think I relayed those thoughts to Gary." (SIG, Chwastyk, p. 17, 10/30/79.)

When told that Gary Miller did not recall learning of the explosion until two days later on March 30, Chwastyk stated:

> "Well that could very well be true. Again, I can't absolutely -- if Gary said -- I may not have told him what I thought at the time, because I really wasn't certain. (Ibid., p. 19-20.)

Chwastyk was then asked again for his best recollection and the following dialogue ensued:

> Q. I understand. Let me ask you this: Was there any -- strike that. Let me start it a different way: When you saw this and then put it together what you thought had happened, that must have been something that gave you some cause for concern?
>
> A. Yes. It scared the hell out of me.

Q. Did you think that this was something that better ought not to be generally broadcast around the control room and outside? Was there any reason to keep this fairly close among the people who were there in light of the fact that it was fairly alarming?

A. I'll say this: I didn't go out in the control room an broadcast it, no. It did scare me, therefore, I'm sure I didn't just make it general knowledge to everybody in that control room. I'm sure I did pick out specific individuals that, my counterpart types of people, and talked to them about

Q. You said you think that you probably discussed it wit Brian Mehler, and your best recollection it that you discussed it with Gary Miller. Do you have a pretty specific recollecti of who else you may have actually discussed it with on the 28t

A. I have some recollection of talking to someone from the NRC about it. At the time, I did not have the time to discuss possibilities with him, and I think I related that I think there may have been some kind of explosion in the building, but I didn't know what. (Ibid., p. 20-21.)

At the end of the October 31 interview Mr. Chwastyk was again asked by the Metropolitan Edison attorney participating in the deposition, about whether he had told Gary Miller on March 28 that he had correlated the pressure spike with a possible explosion:

Mr. Diaz: I don't want to put words in your mouth. You recall making the inference, but you don't recall whether you conveyed that inference to Gary Miller; is that correct or incorrect?

The Witness: My best recollection is that I did related (sic) that information to Gary. That's the best I can remember. How much of that information though, what information I gave him, I definitely don't remember. I do know that I gave him the information of the bank (sic), the valve opening simultaneous with the pressure spike.

Now, if I related that or if I put that together and told him that I thought it was a hydrogen explosion, if I thought it was an explosion at all, I don't remember. (Ibid., p. 28-29.)

In sum, on May 21, 1979, Chwastyk told I&E investigators that he believed on March 28 that an explosion had occurred, and that he had told Station Manager Gary Miller that they should no longer cycle the electromagnetic relief valve because the pressure pulse had corresponded to opening of this valve. On October 11, Chwastyk said after the hydrogen explosion, he went to Gary Miller and explained what he, "thought had happened as far as the hydrogen detonation and the simultaneous opening of the valve." (SIG, Chwastyk, October 11, p. 18.)

In another interview on October 30, Chwastyk repeated that he had told Miller what he thought, that he did tell Miller his thoughts on the "... spark due to the valve operation causing some sort of an explosion in the building." (SIG, Chwastyk, October 30, p. 14.) When pressed as to whether he

actually did tell Miller that he thought there had been an explosion, Chwastyk (for the first time, on October 30) said that he could not be sure, although he thought he did. It is not clear from the record what was the basis for Chwastyk's changing his mind except that his recollection differed from Miller who had said he (Miller) did not recall learning on March 28 that there had been an explosion.

Mr. Herman Dieckamp, President of General Public Utilities, stated in a May 9, 1979, mailgram to Chairman Udall:

> "There is no evidence that anyone interpreted the 'pressure spike' and the spray initiation in terms of reactor core damage at the time of the spike nor that anyone withheld any information."

Log Entries

Two logs containing a listing of significant events that occurred on March 28 indicate that a pressure pulse occurred at approximately 1:50 p.m. One log lists the pressure spike as having been 4 pounds per square inch and accompanied by actuation of reactor buidling sprays; the other log lists the pulse as having been approximately 5 pounds per square inch, and does not mention the containment sprays. None of the investigation reports addressed the question as to why the pressure pulse was indicated to have been 4 or 5 psi when in reality is was approximately 28 psi. In fact, the only reference in the SIG report to the logs indicating that the pressure spike was 4 psi is a cryptic one apparently in support of the SIG conclusion that, contrary to the perception of Chwastyk and Mehler, the spike was dismissed as being insignificant; i.e. SIG states: "Furthermore, an entry in the control room operator log book for the afternoon of March 28 notes that at 1:50 p.m. an engineered safeguards initiation signal was received, the reactor building sprays came on, and the reactor building pressure spiked up to 4 psi." (SIG, Volume II, part 3, p. 144.)

J. ILLES Relieved the Shift Condition as follows

1315 Stopped HPI
core flood slowly going into Rx vessel
1350 Received EH
Bldg sprays came on Rx Bldg. pressure spiked up to 4 psi and then back down to 1.5 psi
1428 Moved bubble in "A" loop Temp dropped rapidly then slowly came back

Presence of Hydrogen in the Primary Cooling System

Hydrogen produced as a byproduct of the oxidation of zirconium cladding collected at high points in the reactor cooling system; e.g. at the top of the reactor pressure vessel, pressurizer, and upper (candy cane portion) of the hot legs (See Figure I-A, I-B; Pages 13a, 13b.) While the hydrogen in the pressurizer could be released from the system via the pressurizer relief valve, there was no such valve in the other locations; hydrogen could be eliminated from these areas only by flushing it out or forcing it to dissolve in the water, and then either allowing it to escape from the water in the pressurizer wherefrom it could be let into the containment or extracting it from water removed via the letdown system. A mixture of hydrogen and superheated steam in the candy cane had for most of the day obstructed filling the primary system with water, thereby preventing an effective use of the steam generators for removal of heat produced in the fuel by radioactive decay. Data available in the control room had, in fact, indicated that there was a gas other than steam in the system.(1) The possible (or likely) existence of a non-condensible gas (most likely hydrogen) in the system appears not to have been reported either to the NRC or officials of the State of Pennsylvania.

(1) See EPRI/NSAC-1, Appendix TH, P. 74, P. 88.

Perceived adequacy of procedures to assure adequate core cooling.

Statements made during interviews conducted by accident investigators indicate that during the day of March 28 there were periods when TMI personnel appeared uncertain as to core conditions and whether the procedures being followed and actions being taken were adequate to lead to stabilized conditions.

TMI Station Manager Gary Miller told General Public Utilities investigators on April 12:

> " ... We, being me and Lee Rogers, called Lynchburg pretty early, and we sat in the room and every hour tried to figure out how to keep pumping water into it. But all we were doing was pumping that BWST /Borated Water Storage Tank/ through the electromatic to the floor. Nothing was changing, so you know we pumped 12' or 13' out of BWST and my fear was pumping 50 feet out and the core still hot and no water in the BWST. So our goal was to somehow get some circulation going, either natural circulations from steam generators or reactor coolant pump, using HP injection the whole time. My memory is that we pumped against the electromatic at fairly high pressures like 1800 or 2200 psi. We could have pumped against the codes, but we assessed that what we'd do is get the same flow through the codes without being able to see pressure. We pumped through there until around 11 in the morning, at which time we decided to take a shot at getting on core flood. And the reason we took a shot at core flood -- now remember Lynchburg was on the phone with a lot of good advice, but it was clear that it was my decision -- we assessed that if we could get down and activate core flood tanks and we saw them dump on the core we could get assurance that the core had some water on. We couldn't tell that; we were scared that wasn't happening. Radiation was all over the place, everything was off scale. You got nothing in the core that tells you about water level; you got no pressurizer level, since it's solid; no way of drawing the bubble; I didn't have any heaters; I didn't have any letdown; and we had radiation in every room we went to. Didn't even have oil pumps for some of the RC pumps; couldn't get in some of the rooms; the readings were horrendous.

Mike Ross gave the following rationale for reducing system pressure in order that cooling might be achieved from what was thought to have been a better method than the one they were then using which depended upon keeping the system pressure high and using the high pressure injection pumps:

> " ... One, we were running out of water in BWST and we hadn't gained an inch. I mean we hadn't gained any headway in where we were trying to go our goal being one to establish some mode of cooling a reliable mode of cooling to the core. Two, we, at least I wasn't sure that we purposely or we in fact had the core covered and all high pressure injection was going to the core. I was not totally convinced. I didn't have anything to tell me. Hey, high pressure injection is in fact going through the core. So based on that, we discussed going down with the goal being one, to let the core flood tanks come in and verify that yeah, the reactor was in fact covered, two, give it a drink of water. That is a little coarse I know, but give it a drink of water if it wasn't getting it, and maybe go on decay heat removal which is a forced mode of cooling. That is what we were trying to do at that time."

(I&E TMI Tape #226, p. 26)

Perceptions concerning core uncovery

The record contains few specifics with regard to perceptions of those present at TMI as to whether the core was or had been uncovered. It appears that TMI personnel concluded that, after 9:00 a.m., the core was probably covered. The apparent basis for this conclusion was that the pressurizer water temperature was at less than saturation level, and since the pressurizer temperature was an indicator of core output

temperature, pressurizer temperature was assumed to indicate that the core was probably covered. There is little in the record to indicate the interpretation of the high in-core thermocouple temperature measurements, which in fact showed local boiling and a badly damaged core.

While it was generally assumed the core was covered after 9:00 a.m., there is little discussion in the record to suggest what the thinking might have been with regard to core uncovery between 6:00 a.m. and 9:00 a.m. As the foregoing discussion suggests, there was considerable temperature data to indicate that the core had in fact been uncovered during this period. The most extensive statement on the record is an interview conducted by Kemeny staff with B&W engineer John Flint. Flint was apparently unaware of the extended period during which water had leaked from the system through the stuck open pressurizer relief valve, and he was also apparently unaware of the in-core thermocouple measurements indicating temperatures in excess of 2000 degrees. On the basis of temperature and neutron data, Flint did conclude, however, at 10:30 a.m. or thereabouts that the core had been uncovered earlier, even though it appeared to him that by 10:30 a.m. it was again covered. Flint engaged in the following dialogue with Kemeny interviewers. The answers are Flint's:

Q. When you reached the conclusion that the core had been uncovered approximately an hour to an hour and a half after you arrived, which would be something in the order of 10:00 to 10:30, did you tell anyone?

A. Yes, I did. I believe I mentioned it to Lee Rogers at the time.

Q. What was his reaction?

A. I believe he went to discuss it with Gary Miller and George Kunder.

Q. Were you present during that discussion?

A. No, I was not.

Q. Did he report back to you?

A. I don't remember him addressing that specific question, no

Q. Did you ever find out what discussion he had with Kunder and Miller with respect to core uncovery?

A. Not that I can remember, no.

Q. Did you tell anyone else that you had reached the conclusion that the core had uncovered?

A. Bill Zewe, Ed Fredericks.

Q. What was their reaction?

A. I would say surprised.

Q. It was news to them?

A. Yes.

Q. It was news to Rogers too when you told him?

A. That is correct, so far as I know.

[Kemey, Flint, p.23, line 3 to p.24, line 5.]

Perceptions held on March 28 as to extent of core damage.

The foregoing indicates the existence on March 28 of manifold indications of core damage. Based on partial information available to him (i.e. he did not know of the 2000 degree core thermocouple measurements or the manifestations of an explosion), Victor Stello, then Director of the NRC's Division of Operating Reactors, told the E&E Subcommittee TMI Task Force on May 9 that he suspected oxidation of the cladding (and presumably hydrogen production) on March 28. Mr. Stello engaged in the following dialogue:

> Mr. Stello: My initial reaction was that considerable failure of the fuel had occurred, with large numbers of failed fuel rods. And that the potential for oxidation, metal-water reaction, was clearly there. The periods of time involved were, even if the heat-up were not significant, at lower temperatures, with the top of the core uncovered for extended periods of time, metal-water reaction was clearly possible. The rates -- how high the temperature got I would not even indicate -- I could have guessed at. But oxidation of the cladding was something I clearly expected; failures of the cladding were clearly evident.
>
> Mr. Terrell: When did you suspect this? On Wednesday you are talking about that you expected this fuel damage?
>
> Mr. Stello: Yes, I think just from knowing what was happening to the core, you had to expect that there was quite a bit of damage to the fuel. (E&E, TMI Part 1, p. 4-5)

Another indication of there being suspicion on March 28 of hydrogen production can be inferred from a statement made by TMI supervisor James Floyd. As noted above, Floyd was at the B&W facility in Lynchburg, Virginia on March 28 and had inferred from limited information that about one eighth of the cladding had failed. On May 31, Floyd told the Kemeny Commission of his suspicions about hydrogen production when he engaged in the following dialogue with Commission member Ted Taylor:

> Taylor: Had you sometime Wednesday made the connection in your mind between the high temperatures in the core, cladding failure and hydrogen?
>
> Floyd: Yes, sir.

The March 29 New York Times described a press briefing presented by Jack Herbein on March 28 which gave a different picture of the situation:

> Jack Herbein, a vice president of the utility that operates the plant, told a news conference held on a bluff overlooking the plant that "a valve failed in a shut position" in a feed pump that squirted water around the reactor.
>
> Mr. Herbein spent almost an hour describing the accident and emphasized that the main safety systems in the almost brand-new plant had worked to prevent a very serious accident, or indeed a catastrophe.
>
> Using bland terms, he described the series of events in the plant as "not the normal evolution" in stating that there was "some minor fuel failure."
>
> This translates to the fact that some of the pellets of enriched uranium fuel became so heated because of loss of coolant that the pellets melted through the zirconium clad tubes that hold the pellets.
>
> Unit No. 2 has 177 fuel assemblies, each containing 208 rods, each of which contain 270 uranium pellets.
>
> "Only a few of them melted through," Mr. Herbein said.

On March 28, NRC issued a Preliminary Notification of Event or Unusual Occurence which gave little indication of the actual severity of damage:

Facility: Three Mile Island Unit 2
Middletown, Pennsylvania
(Docket No. 50-320)

Subject: REACTOR SCRAM FOLLOWED BY A SAFETY INJECTION AT THREE MILE ISLAND - UNIT 2

The licensee notified Region I at approximately 7:45 a.m. of an incident at Three Mile Island Unit 2 (TMI-2) which occurred at approximately 4:00 a.m. at 98% power when the secondary feed pumps tripped due to a feedwater polishing system problem This resulted in a turbine trip and subsequent reactor trip on High Reactor Coolant Pressure. A combination of Feed Pump Operation and Pressurizer Relief - Steam Generator relief valve operation caused a Reactor Coolant System (RCS) cooldown. At 1600 psig, Emergency Safeguards Actuation occurred. All ECCS components started and operated properly. Water level increased in the Pressurizer and Safety Injection was secured manually approximately 5 minutes after actuation. It was subsequently resumed. The Reactor Coolant Pumps were secured when low net positive suction head limits were approached.

. . . . . .

At 10:45 a.m. the Reactor Coolant System Pressure was being held at 1950 psig with temperature at 220°F in the cold leg. By 10:45 a.m., radiation levels of 3 mr/hr had been detected 500 yards offsite. (PNO-79-67)

The March 28 Washington Star quotes Lieutenant Governor Scranton:

> "Everything is under control. There is and was no danger to the public health and safety."

Officials of Metropolitan Edison/General Public Utilities have said subsequently that on March 28 they did not reach conclusions such as those of Stello and Floyd referred to above about the possibility of cladding oxidation.

In answer to a written question as to what at 11:00 p.m. on March 28 was his estimate as to the amount of cladding that had been oxidized during the period when the core was uncovered, Herman Dieckamp, President of General Public Utilities, responded:

> I interpreted damage to mean cladding failure. I did not think in terms of core uncovering, high temperatures, or Zr-H_2O reactions. (E&E, TMI Part 11, p. 283.)

In response to the foregoing question, Metropolitan Edison Vice President John Herbein stated:

> I didn't consider a steam clad interaction producing hydrogen until it was discussed on March 30th. (Ibid., p. 290)

In response to the question as to what was his estimate on March 28 as to cladding oxidation, Station Manager Gary Miller stated:

> "... I did not conclude there was an on-going steam-cladding interaction and therefore, had no estimate of the amount of cladding failure by 11:00 p.m. on March 28." (Ibid., p. 296.)

Whatever the indications of hydrogen production available to the NRC on March 28 and early March 29, little idea of these was conveyed to the E&E Subcommittee on March 29 when, as noted above, Chairman Hendrie stated:

> "The magnitude (of release of radioactive gases) suggests that perhaps one percent of the core might have been involved in the cladding cracks." (Transcript, p. 60.)