NOV 06 1989

Mr. Walston Chubb
3450 MacArthur Drive
Murrysville, Pennsylvania 15668

Dear Mr. Chubb:

Your letter of October 24, 1989, to Commissioner Carr, Chairman of the U.S. Nuclear Regulatory Commission (NRC), has been referred to me for reply. The often repeated phrase "previously molten material" refers to the core material (fuel, cladding, control rods, guide tube fuel support structures) that was melted during the Three Mile Island Unit 2 (TMI-2) accident and subsequently cooled and resolidified. It does not refer to the metallurgical sintering process used during fuel fabrication.

As you may not be aware of the degree of damage suffered by the core during the accident on March 29, 1979, I am enclosing a copy of the most recent accident scenario developed by the licensee, GPU Nuclear Corporation, and by the U.S. Department of Energy's (DOE's) contractor Idaho National Engineering Laboratory. This scenario was included in the licensee's submittal on July 5, 1989 of the Defueling Completion Report. Calculations simulating the accident suggest that a molten pool of approximately 50 percent of the original core material was formed 224 minutes into the accident. Subsequent cooling resulted in the resolidification of the molten core, forming a substance that has been given the name corium.

I can assure you that the licensee, the NRC, and the DOE are continuing their efforts to understand the accident at TMI-2 and will continue this effort for some time. As new data is collected, the accident scenario will undoubtedly be further refined; however, the evidence clearly indicates that melting and resolidification of the TMI-2 fuel occurred during the accident.

Sincerely,

Original Signed By

John F. Stolz, Director
Project Directorate I-4
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Enclosure:
As stated

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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2.0 POST-ACCIDENT FUEL DISPERSION

This section provides a summary discussion of the accident sequence as it relates to fuel material transport within the RV and from the RV to ex-vessel locations. Included are sections which describe the most likely supposition of the core accident scenario, the post-accident condition of the plant, and the fuel transport mechanisms within the RCS, RB, and AFHB. The bases for the following findings and conclusions are derived primarily from the results of visual examinations, analytical evaluations, and the experience and data derived from defueling operations.

Substantial core damage within the RV and subsequent attempts to cool the core provided the source material and initial pathway by which fuel debris was transported into the RCS, RB, and AFHB. Because the plant systems required cooldown, isolation, and water processing at various times during the plant stabilization and recovery periods, additional potential pathways existed for insoluble fuel material transport. However, the majority of these pathways within the RB and the AFHB are defined by specific boundaries, filters, and/or flow restrictions, which significantly reduced any potential fuel transport. Of the total fuel debris available to be transported from the RV, it was conservatively estimated that no more than 25 kg reached the AFHB locations, no more than 15 kg was relocated to the RB sump and various other RB locations, and no more than 230 kg was relocated throughout the RCS (see Table 2-1). The remaining core inventory was retained in the RV. The following discussion represents the basis for fuel transport dispersion at TMI-2.

2.1 The Accident Scenario

A postulated scenario of the accident was developed using currently available data from in-vessel and ex-vessel defueling operations and the accident transient sequence information (References 2.1 and 2.2). This data base included measurements from on-line instrumentation, visual observations, and supporting analytical studies as well as other experimental data from independent research facilities (Reference 2.3).

The accident can be divided into the following five (5) phases:

Phase I, Time 0-100 Minutes: Loss-of-Coolant with the RCS Pumps Operating.
Phase II, Time 100-174 Minutes: Initial Core Heatup and Degradation.
Phase III, Time 174-224 Minutes: Degraded Core Heatup and Relocation.
Phase IV, Time 224-230 Minutes: Core Relocation to LCSA.
Phase V, Time After 230 Minutes: Long-Term Cooling of Degraded Core.

2.1.1 Phase I - Loss-of-Coolant (0-100 Minutes)

The first phase of the accident is the time interval from the turbine trip until the A-loop RCPs were turned off at 100 minutes. The RCPs provided 2-phase cooling to the core during this period, preventing core overheating and damage. During the first phase of the accident, the amount of water in the RCS decreased because the RCS makeup was insufficient to compensate for coolant loss through the PORV.

2.1.2 Phase II - Initial Core Heatup and Degradation (100-174 Minutes)

When the last two RCPs were turned off, at approximately 100 minutes, the top of the core was uncovered and coolant water separated into steam and liquid phases. Temperatures in the upper regions of the core then increased more rapidly. The core liquid level dropped to approximately the mid-core elevation at approximately 140 minutes and fuel rod temperatures at the top of the core increased sufficiently (1100°K) to cause cladding rupture. During this period, the operators realized that the PORV was open. They manually closed the pressurizer block valve, thus limiting further loss-of-coolant and gaseous fission product release from the RCS to the RB. However, the block valve had to be cycled (i.e., opened and closed) frequently to maintain RCS pressure during this period.

Rapid oxidation of the zircaloy cladding at the top of the core began at approximately 150 minutes. The heat generated from oxidation elevated fuel rod temperatures above the cladding melting point (2100°K) developing a molten mixture of fuel, cladding, and some structural steel. This mixture flowed downward and solidified around intact fuel rods near the coolant liquid level interface. The responses of incore instrumentation and source range monitors indicated that a large region of partially molten core materials formed by 174 minutes, as shown in Figure 2-1a. It is conjectured that the first molten material to flow was a mixture consisting primarily of UO_2, steel, zircaloy, and silver, with some indium and cadmium. As this molten flow stopped at the coolant level interface, it formed a thin layer, or crust, which later supported additional molten material in the core region.

2.1.3 Phase III - Degraded Core Heatup and Relocation (174-224 Minutes)

Operation of the RC-P-2B at 174 minutes, for approximately 6 minutes, resulted in the first major core relocation event when coolant was circulated into the RV following core degradation. Thermal-mechanical interaction of the coolant with the oxidized and embrittled fuel rod remnants in the upper core regions is believed to have fragmented and collapsed these standing remnants and formed the upper core cavity and debris bed. The configuration is shown in Figure 2-1b.

After approximately 25 minutes of further coolant heating and steam formation in the core, the ECCS was initiated at 200 minutes and subsequently filled the RV in 7 to 10 minutes. Studies of debris bed cooling indicate that final quenching of the upper core debris bed probably occurred during the last several minutes of this time period (Reference 2.4). It is postulated that effective cooling of the molten core material was limited to the surrounding crust material. Thus, the amount of molten material in the central region likely continued to increase in size and temperature because of decay heat from retained fission products and lack of coolant flow through the damaged core. Calculations simulating the accident suggest that a molten pool of approximately 50% of the original core materials was formed within the consolidated region by 224 minutes into the accident (Reference 2.5). This is consistent with the observed molten material found in the resolidified core mass, the CSA, and the lower head regions (Figure 2-2).

The interaction of the injected water with the upper debris bed during this period and the flow pattern of steam and gas exiting the core through the upper plenum have been assessed. The observed damage pattern to the upper fuel assembly grid was consistent with expected flow patterns, considering the location of the exit flow orifices. Rapid oxidation within the debris bed and the subsequent interaction between the upper grid structure and the high temperature gases exiting the core at high velocity probably caused the observed limited damage.

2.1.4 Phase IV - Core Relocation to Lower Core Support Assembly (224-230 Minutes)

The second major core relocation event occurred between 224 and 226 minutes, within about 100 seconds. This event was indicated by the RCS pressure monitor, self-powered neutron detectors, and the source range neutron monitors. It is believed that failure of the supporting crust occurred in the upper and/or center region of the consolidated mass of molten core material, probably near the core periphery (1.5 meters from the bottom of the core) on the east side, as shown in Figure 2-1c. Visual inspections conducted during defueling indicated that the flow of molten core entered the core former on the east side and flowed around the core former and then down into the LCSA internals. Analysis of potential flow of molten core materials through fuel assembly location indicated that all of the molten core material could have relocated into the LCSA internals and lower head in less than 1 minute through only one or two fuel rod assemblies.

2.1.5 Phase V - Long-term Cooling of Degraded Core (after 230 Minutes)

Approximately 16 hours after the start of the accident, RC-P-1A was restarted and operated for approximately one (1) week. This pump was replaced by RC-P-2A which operated until April 27, 1979.

There was no evidence of any additional major relocation of molten core materials into the LCSA and lower head after the second core relocation. Thus, the post-accident configuration of the core presented in Figure 2-1c represents the final, stable, and coolable configuration for the materials in the core, LCSA, and lower head regions. Detailed thermal analyses have evaluated the long-term cooling of the consolidated molten mass within the core region. Results of these studies suggest that cooling of this mass occurred over many days to weeks. It was also concluded, based on analyses and observations, that the RV maintained full integrity during all phases of the accident sequence and the subsequent defueling period. Therefore, only a small fraction of the original fuel inventory was relocated outside the RV and was contained within selected RCS pathways.

2.2 Post-Accident Condition of the Plant

An accurate determination of the post-accident state of the plant was required to understand the accident progression and fuel transport mechanisms. Additionally, a thorough knowledge of the properties of the post-accident core debris was necessary to anticipate the conditions to be encountered in defueling the RV and removing fuel from the RCS, RB, and support systems in the AFHB. Detailed analysis of fuel including dispersion and general properties was also essential to completion of the final criticality assessment. This information was developed from several sources (References 2.6 through 2.11): visual inspections of RV internals, metallurgical/radiochemical examinations of samples acquired during the course of defueling, and readings from on-line instrumentation and experimental data developed from smaller-scale tests conducted at various independent facilities.

The original core inventory included approximately 94,000 kg of UO_2 and 35,000 kg of cladding, structural, and control materials. Accounting for oxidation of core materials during the accident and for portions of the upper plenum structure that melted, the total amount of post-accident core debris was estimated to be 133,000 kg.

2.2.1 Reactor Vessel Internals

During the accident sequence discussed in Section 2.1, peak temperatures ranged from approximately 3100°K at the center of the core (molten UO_2), to 1255°K immediately above the core and 723°K at hot leg nozzle elevations. Approximately 50% of the original core became molten. Lower portions of three (3) baffle plates on the east side of the core melted and some of the molten core material flowed into the core bypass region. Approximately 30,000 kg of molten materials flowed from the core to the core bypass region and through the lower internals. Approximately 19,000 kg came to rest on the RV lower head. Figure 2-3 illustrates the major RV components and the post-accident configuration of the core.

The post-accident condition of the upper plenum assembly, original core region, core bypass region, the UCSA, the LCSA, and lower head region are described in the following sections.

2.2.1.1 Upper Plenum Assembly

The upper plenum assembly, which was removed intact, had two (2) damaged zones. Localized variations of damage were evident in each zone. For example, in the limited area above one fuel assembly, ablation of the stainless steel structure was observed; however, grid structures adjacent to the ablated zone appeared to be undamaged. In some regions, the once-molten grid material had a foamy texture, which occurs when stainless steel oxidizes near its melting point. A once-molten mass close to this grid material appeared to be unoxidized, suggesting that some of the hot gases exiting the core were oxygen deficient. The damage to the upper plenum assembly indicated that the composition and temperature of gases exiting the core varied significantly within the flow stream. Only a small quantity of fuel debris was measured within the plenum assembly.

2.2.1.2 Core Region

Figures 2-2 and 2-3 illustrate the end-state configuration of the original core region. A core void or cavity existed at the top of the original core region. Below that, a bed of loose debris rested on a resolidified mass of material that was supported by standing fuel rod stubs. The stubs were surrounded by intact portions of fuel assemblies. A previously molten, resolidified mass was encapsulated by a distinct crust of material in which other fragments and shards of cladding could be identified.

The core void was approximately 1.5 meters deep with an overall volume of 9.3 cubic meters. Of the original 177 fuel assemblies, 42 partially intact assemblies were standing at the periphery of the core void. Only two (2) of these fuel assemblies contained more than 90% of their full-length cross-sections with the majority of fuel rods intact. The other assemblies suffered varying degrees of damage ranging from ruptured fuel rods to partially dissolved fuel pellets surrounded by once-molten material.

The loose debris bed at the base of the core cavity ranged in depth from 0.6 to 1 meters and consisted of whole and fractured fuel pellets, control rod spiders, endfittings, and resolidified debris totaling approximately 26,000 kg. Beneath the loose debris bed was a large resolidified mass approximately 3 meters in diameter. This mass varied in depth from 1.5 meters at its center to 0.25 meters at its periphery and contained approximately 33,000 kg of core debris. The center of this solid metallic and ceramic mass consisted of a mixture of structural, control, and fuel material that reached temperatures of at least 2800°K and possibly as high as 3100°K during the accident. The upper crust of this mass, which consisted of the same material and also reached 2800°K, contained intact fuel pellets near the periphery. The lower crust consisted of once-molten stainless steel, zircaloy cladding, and control rod materials resolidified in flow channels surrounding intact and partially dissolved fuel pellets. The thickness of this lower crust, based on initial video examinations, was estimated to be approximately .01 meters on the average. The resolidified mass was shaped like a funnel extending down toward the fuel assembly lower endfittings near the center of the core.

The standing, undamaged fuel assembly stubs extended upward from the lower grid plate to the bottom surface of the resolidified region of the once-molten materials. These stubs varied in length from approximately 0.2 to 1.5 meters. The longer partial fuel assemblies were located at the periphery of the resolidified mass. On the east side of the core, one (1) fuel assembly was almost completely replaced with once-molten core material; this indicated a possible relocation path into the LCSA and core bypass region for molten material. The standing fuel assembly stubs and peripheral assemblies constituted about 45,000 kg of core debris.

2.2.1.3 Upper Core Support Assembly

This region consists of vertical baffle plates that form the peripheral boundary of the core; horizontal core former plates to which the baffle plates are bolted; the core barrel; and the thermal shield (Figure 2-3). There are a number of flow holes in the baffle and core former plates through which coolant flowed during normal operations. On the east side of the core, a large hole approximately 0.6 meters wide and 1.5 meters high, and extending across three (3) baffle plates and three (3) core former plates was discovered. Adjacent baffle plates on the east and southeast were warped possibly as a result of the high temperatures and the flow of molten material in the bypass region.

It was concluded that molten core material from the core region flowed through the large hole in the baffle plates into the UCSA, circumferentially throughout the UCSA, and downward through the flow holes in the core former plates into the LCSA at nearly all locations around the core. The majority of the molten material appeared to have flowed into the LCSA on the southeast side through the hole in the baffle plate and through the southeast core former plate flow holes.

The circumference of the core region (i.e., the area behind the baffle plates) contained loose debris throughout. The depth of debris varied from approximately 1.5 meters on the east side to a few millimeters on the southwest side. There appeared to be a resolidified crust on the upper horizontal surfaces of the three (3) bottom core former plates; this crust varied in thickness from approximately 0.5 to 4.0 cm. It is estimated that approximately 4000 kg of core debris was retained in the UCSA region. In the small annulus between the core barrel and the thermal shield, fine particulates were observed but no major damage to these components was seen.

2.2.1.4 Lower Core Support Assembly

The LCSA region consists of five (5) stainless steel structures. The structures vary in thickness from 0.025 to 0.33 meters with 0.080 to 0.15 meter diameter flow holes.

Some molten core material flowed through these structures and came to rest on the lower head. There was approximately 6000 kg of resolidified material dispersed at various locations on the circumference of these structures. In several places, resolidified material completely filled the flow holes and columns of once-molten material were observed between the plates. The largest accumulation of resolidified material appeared to have flowed into the LCSA from the east side of the core. Although most of the material was seen on the east to southeast side, many columns of resolidified material were also seen in the LCSA around the periphery of the core beneath the core bypass region.

2.2.1.5 Lower Head Region

The debris in the lower head region accumulated to a depth of 0.75 to 1 meter and to a diameter of 4 meters. The spatial distribution of the material was neither uniform nor symmetric. The surface debris had particle sizes which varied from large rocks (up to 0.20 meters) to granular particles (less than 0.001 meters). The larger rocks, especially in the northeast and southwest regions, were located near the periphery. The debris pile was lower at the vessel center than at the periphery, with granular or gravel-like material observed in the central region of the vessel. A large resolidified mass was identified between the loose debris bed and the lower head of the RV. This mass was approximately 0.5 meters thick in the center and 1.7 meters in diameter. A large cliff-like structure formed in the northern region from once-molten core material. The cliff face was approximately 0.38 meters high and 1.25 meters wide. It was estimated that approximately 12,000 kg of loose core debris and 7,000 kg of aglomerated core debris relocated into the lower head.

2.2.2 Reactor Coolant System

During the accident, small quantities of fuel debris (Table 2-1) and fission products were transported throughout the RCS (see Figure 2-4). The largest RCS components operated during the accident were the RCPs. The RC-P-2B was the only pump which would respond to a "start" command 174 minutes into the accident. This pump was started and operated for approximately 6 minutes. The operation of this pump was the major driving force for the relocation of fuel from the RV. Coolant circulated through the RV by this pump caused a rapid quenching of the highly oxidized, high temperature fuel which resulted in the fuel rods being physically shattered and rubbled.

As the RCP operated, the flow of the "B" loop was in a "forward" (i.e., normal) direction. The flow rate through the RV was sufficient to transport small amounts of fuel into the "B" loop where a portion of the fuel relocated into the "B" hot leg and settled out into the decay heat drop line. The decay heat drop line connects to the bottom of the horizontal section of the

"B" hot leg and was found to contain some fuel, presumably as a result of the RC-P-2B operation (see Table 2-1). The coolant continued to flow up the "candy cane" and deposited fuel material on the "B" OTSG upper tube sheet. The tube sheet acted as a "strainer" for the collection of fuel transported outside the RV. However, a small quantity of fuel flowed down through the steam generator tubes and was deposited on the lower head of the "B" OTSG and J-legs. As the coolant continued to flow, relatively smaller quantities of fuel were then deposited in the "B" reactor coolant pump and cold legs.

At approximately 16 hours, the RC-P-1A pump was started. The operation of this pump deposited finely divided silt-like debris in the top of the "A" OTSG and the bottom of the "B" OTSG due to reverse flow in the "B" OTSG loop. RC-P-1A, which experienced excessive pump vibration, operated for approximately one (1) week and was replaced by RC-P-2A, which operated until April 27, 1979. This pump was shutdown because all pressurizer level indicators failed.

Cold shutdown conditions (i.e., RCS temperature below 100°C) were established on the evening of April 27, 1979. After all RCP operations were terminated, the system circulation and cooldown was achieved by natural convection/circulation heat transfer. This natural circulation continued into approximately October 1979. Eventually, there was insufficient thermal driving head to maintain continuous natural circulation and a flow transient in the RCS, referred to as the "B" loop "burp," began to occur frequently over a period of several months. This phenomenon occurred because the coolant in the "B OTSG and "B" loop cold legs gradually cooled until the density of this coolant increased sufficiently to initiate natural circulation flow in the "B" loop. The flow was sustained until the warmer fluid from the RV displaced the cold fluid in the "B" OTSG and cold leg. Repositioning of the coolant of different densities continued until hydraulic balance was achieved. The coolant was then stationary for several days until another "burp" occurred. This repeated flow rate phenomenon was believed to have transported small quantities of finely divided fuel debris from the RV to the steam generators and other RCS locations in both RCS loops.

In summary, there were two (2) methods of transport of fuel to ex-vessel locations. The primary transport method was a sequential operation of the RCPs: RC-P-2B, RC-P-1A, and RC-P-2A. The secondary transport method was attributed to the "burping" phenomenon during natural circulation. Table 2-1 provides an estimate of the quantity of fuel relocated into the RCS during the accident sequence and resulting thermal hydraulic phenomenon (References 2.12 through 2.14).

2.2.3 Reactor Building

Reactor coolant was discharged from the RCS through the PORV located on top of the pressurizer. The PORV discharges to the RCDT which is located in the basement of the RB (see Figure 2-5).

The RCDT contains two (2) safety components: a relief valve which discharges to the RB sump and a rupture disk which discharges to the RB floor adjacent to the RCDT cubicle. Both safety devices were believed to have performed their respective safety functions. The rupture disk was subsequently found in an open or ruptured condition, as expected. If the relief valve had initially operated during the pressure buildup in the RCDT, it would be expected to reseat after the rupture disk opened, thereby minimizing any continuous release to the RB sump via that pathway.

At approximately 136 minutes into the accident, the operators realized that the PORV was not closed and they manually closed the pressurizer block valve. Further loss of coolant and gaseous fission product release from the primary coolant system to the RB was essentially terminated. However, the block valve had to be cycled repeatedly to maintain system pressure. This cycling of the block valve permitted the transport of fission products, noble gases, and small quantities of fuel through the pressurizer and PORV into the RCDT, and subsequently into the RB through the rupture disk discharge.

The MU&P System was operated during the accident and recovery period. The MU&P System inlet piping is fed from the RCS on the suction side of the RC-P-1A. The first major components in this system are the letdown coolers which are located in the basement of the RB (see Figure 2-5). Thus, some fuel was transported into the letdown coolers and associated piping.

In summary, a relatively small quantity of fuel (see Table 2-1) was released to the RB as a result of the accident due to the operation of the PORV and the MU&P System (References 2.13 through 2.17).

2.2.4 Auxiliary and Fuel Handling Buildings

A small quantity of fuel was transported to the AFHB during the accident. The majority of this material was transported through the MU&P System and into the RCBTs. This system is fed from the RCS cold leg side of the "A" loop through the letdown coolers and discharges into the AFHB via the RCBTs. Although this system communicates through a large number of the cubicles in the AFHB, only a small amount of fuel was transported into the system as indicated by the fact that very little fuel was measured in upstream components such as the block orifice, MU&P demineralizer filters, MU&P demineralizers, and the makeup filters.

The block orifice is the normal pressure reduction device for flow rates up to 45 gpm through the MU&P system. The block orifice and its isolation valve became blocked during the accident; subsequently, they were bypassed. As a result, very little fuel was measured in the block orifice and its associated piping. The letdown flow was directed to the letdown filters and purification demineralizers at very low rates during the accident and was then routed to RCBT "A" and the makeup tank. Letdown flow was lost several times during the accident due to flow blockage. More than 24 hours after the initiation of the accident, the purification demineralizers also were bypassed and letdown was directed to RCBT "B". Due to the flow blockage of the letdown coolers and restrictions in the block orifice, fuel transport to the filters, demineralizers, and RCBTs was limited.

Another potential pathway for transport of fuel to the AB was through the Seal Injection System. The Seal Injection System return line, which is downstream of the reactor coolant pump seals, receives reactor coolant pump seal return water. As a result of this, potential trace amounts of fuel may have been transported to the Seal Injection System.

RCBTs A, B, and C also contained fuel as a result of their use during the accident, interconnection with the MU&P System, and as a result of RCS water processing and removal of water from the RB sump and the AB sump.

In summary, a relatively small quantity of fuel was transported into the AFHB (see Table 2-1), principally through the RCBTs and the MU&P System. Some of this fuel may have further relocated into other systems as part of the post-accident water processing and cleanup activities (References 2.13 and 2.14).

2.3 Fuel Transport and Relocation Due To Cleanup Activities

As a result of the accident sequence and resultant cleanup activities, a small, but measurable quantity of fuel was transported into the various plant systems, tanks, and components. These cleanup activities were a necessary part of restoring conditions in the plant and significantly assisted recovery operations in meeting defueling completion objectives.

In the RB, the majority of the post-accident fuel material relocation from cleanup and defueling operations was attributed directly to the transfer of RV components. Major components have been removed from the RV which contained relatively small quantities of fuel. These components, which are currently stored in various RB locations, include the RV head, upper plenum assembly, internal RV structures (e.g., endfittings, LCSA grid plates, distributor plates, grid forging), and contaminated equipment/tools. In all cases, these components and equipment were physically cleaned and decontaminated to the extent practical and surveyed for fuel content before storage. Some additional small amount of fuel material was relocated to the RB basement as part of tool flushing and building decontamination activities. In each case, the effect of this fuel material relocation is quantified as part of the fuel measurement activities reported herein.

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Another potential pathway for transport of fuel debris to the AB was through the Seal Injection System. The Seal Injection System return line, which is downstream of the reactor coolant pump seals, receives reactor coolant pump seal return water. As a result of this, potential trace amounts of fuel debris may have been transported to the Seal Injection System.

RCBTs A, B, and C also contained fuel debris as a result of their use during the accident, interconnection with the MU&P System, and as a result of RCS water processing and removal of water from the RB sump and the AB sump.

In summary, a relatively small quantity of fuel debris was transported into the AFHB (see Table 2-1), principally through the RCBTs and the MU&P System. Some of this fuel debris may have further relocated into other systems as part of the post-accident water processing and cleanup activities (References 2.13 and 2.14).

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As a result of the accident sequence and resultant cleanup activities, a small, but measurable quantity of fuel debris was transported into the various plant systems, tanks, and components. These cleanup activities were a necessary part of restoring conditions in the plant and significantly assisted recovery operations in meeting defueling completion objectives.

In the RB, the majority of the post-accident fuel material relocation from cleanup and defueling operations was attributed directly to the transfer of RV components. Major components have been removed from the RV which contained relatively small quantities (<10 kg) of fuel debris. These components, which are currently stored in various RB locations, include the RV head, upper plenum assembly, internal RV structures (i.e., endfittings, LCSA grid plates, distributor plates, grid forging, etc.), and contaminated equipment/tools. In all cases, these components and equipment were physically cleaned and decontaminated to the extent practical and surveyed for fuel content before storage. Some additional small amount of fuel material was relocated to the RB basement as part of tool flushing and building decontamination activities. In each case, the effect of this fuel material relocation is quantified as part of the fuel measurement activities reported herein.

In the AFHB, the primary cause of fuel debris relocation from cleanup operations was water processing through the RCBTs, MWHT, SRSTs, and SDS monitoring tanks. Additionally, fuel debris material may have relocated into the FHB Spent Fuel Pool "A" as part of fuel canister transfers from the RV. While every effort was made to flush residual fuel material from the external surfaces of the defueling canisters, a small quantity of uncontained fuel material may have been transferred into the "A" fuel pool as part of handling and movement of over 300 defueling canisters. Post-defueling cleanup activities are expected to reduce the amount of residual fuel and ensure subcriticality.

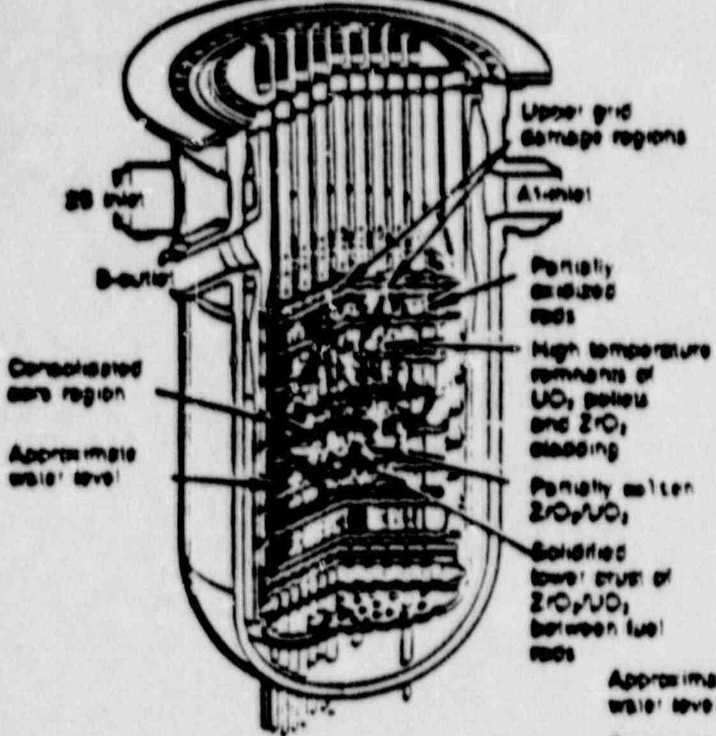
TABLE 2-1

POST-ACCIDENT ESTIMATED EX-VESSEL FUEL MATERIAL DISTRIBUTION
(References 2.12 through 2.17)

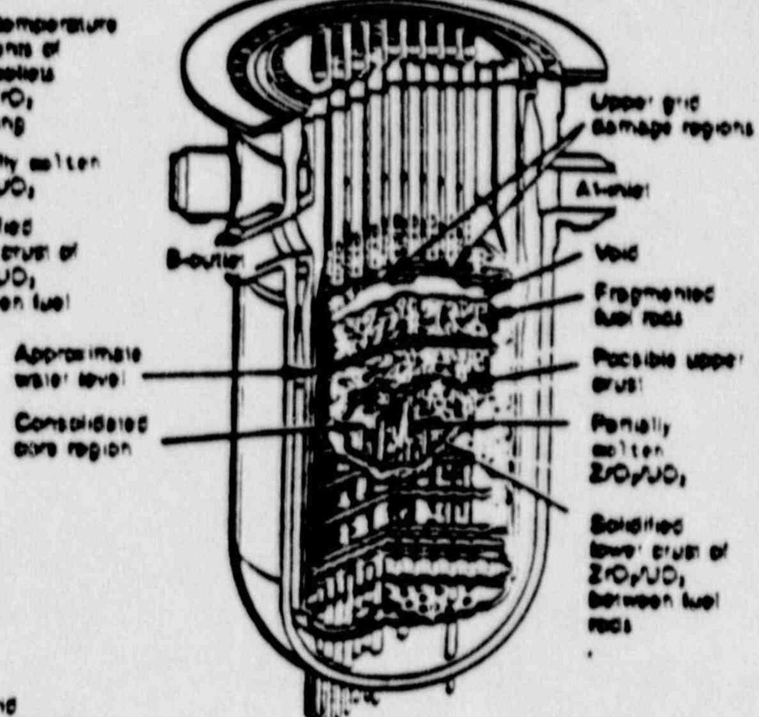
	Kilograms
Reactor Coolant System	
"A" Side	
Hot Leg	1
OTSG Upper Tube Sheet	1
Tube Bundle	3
Lower Head	1
J-Legs	1
Reactor Coolant Pumps	2
Cold Legs	1
"B" Side	
Hot Leg	8
Decay Heat Drop Line	30
OTSG Upper Tube Sheet	125
Tube Bundle	9
Lower Head	1
J-Legs	6
Reactor Coolant Pumps	20
Cold Legs	7
Pressurizer	12
Reactor Building	
RB Basement/Sump	5
Reactor Coolant Drain Tank	0.1
Letdown Coolers	4
Core Flood System	1
Auxiliary/Fuel Handling Buildings	
Makeup and Purification System	6
Seal Injection System	1
Reactor Coolant Bleed Tanks A, B, and C	15
Waste Disposal Liquid System	1

FIGURE 2-1

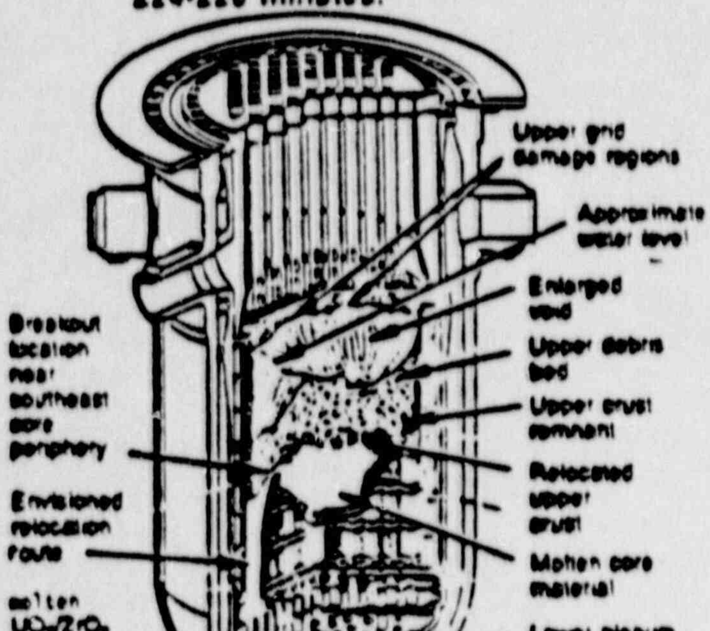
(a) Hypothesized core configuration just prior to pump transient at 174 minutes.



(b) Hypothesized core configuration just after pump transient at 174 minutes.



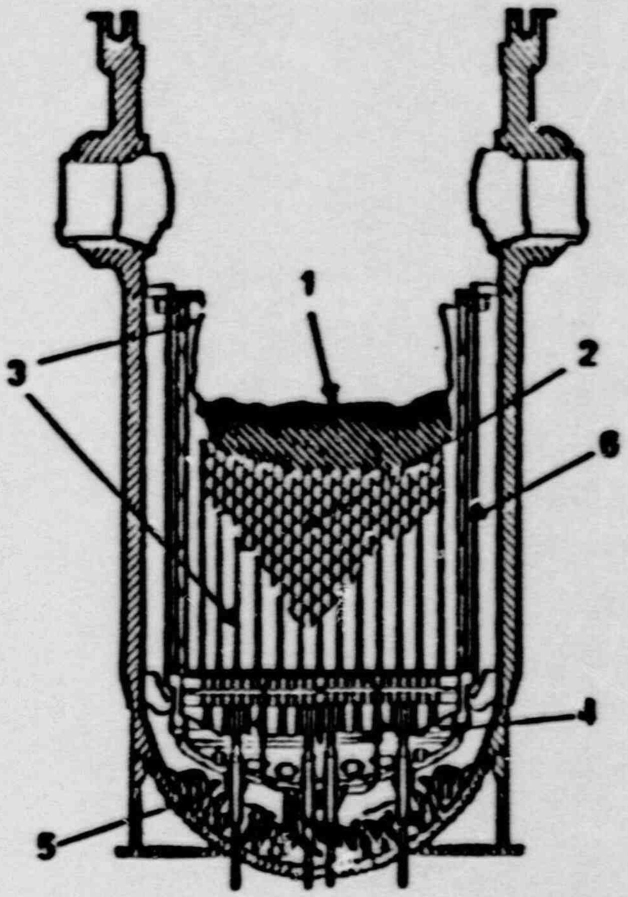
(c) Hypothesized core configuration during major core relocation event during 224-226 minutes.



HYPOTHESIZED CORE DAMAGE PROGRESSION

FIGURE 2-2

POST-ACCIDENT ESTIMATED CORE MATERIAL DISTRIBUTION



ZONE	DESCRIPTION	ESTIMATED QUANTITY (KG)
1	Upper Debris Bed	26,000
2	Resolidified Mass	33,000
3	Intact Assemblies	45,000
4	LCSA (loose debris and resolidified mass)	6,000
5	Lower Head (loose debris and resolidified mass)	12,000 7,000
6	UCSA (loose debris and resolidified mass)	4,000
	TOTAL -	133,000

TMI-2 Core End-State Configuration

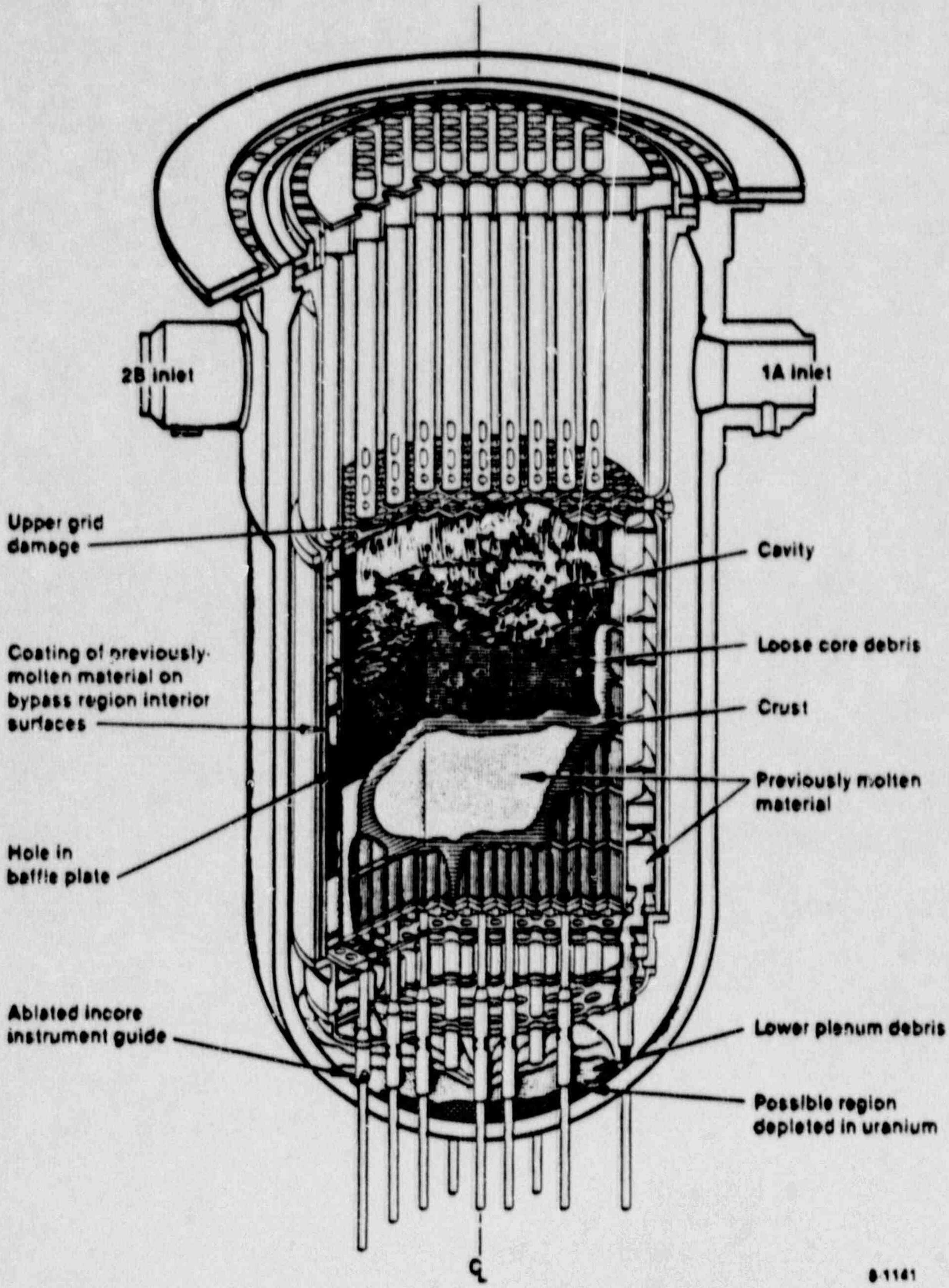
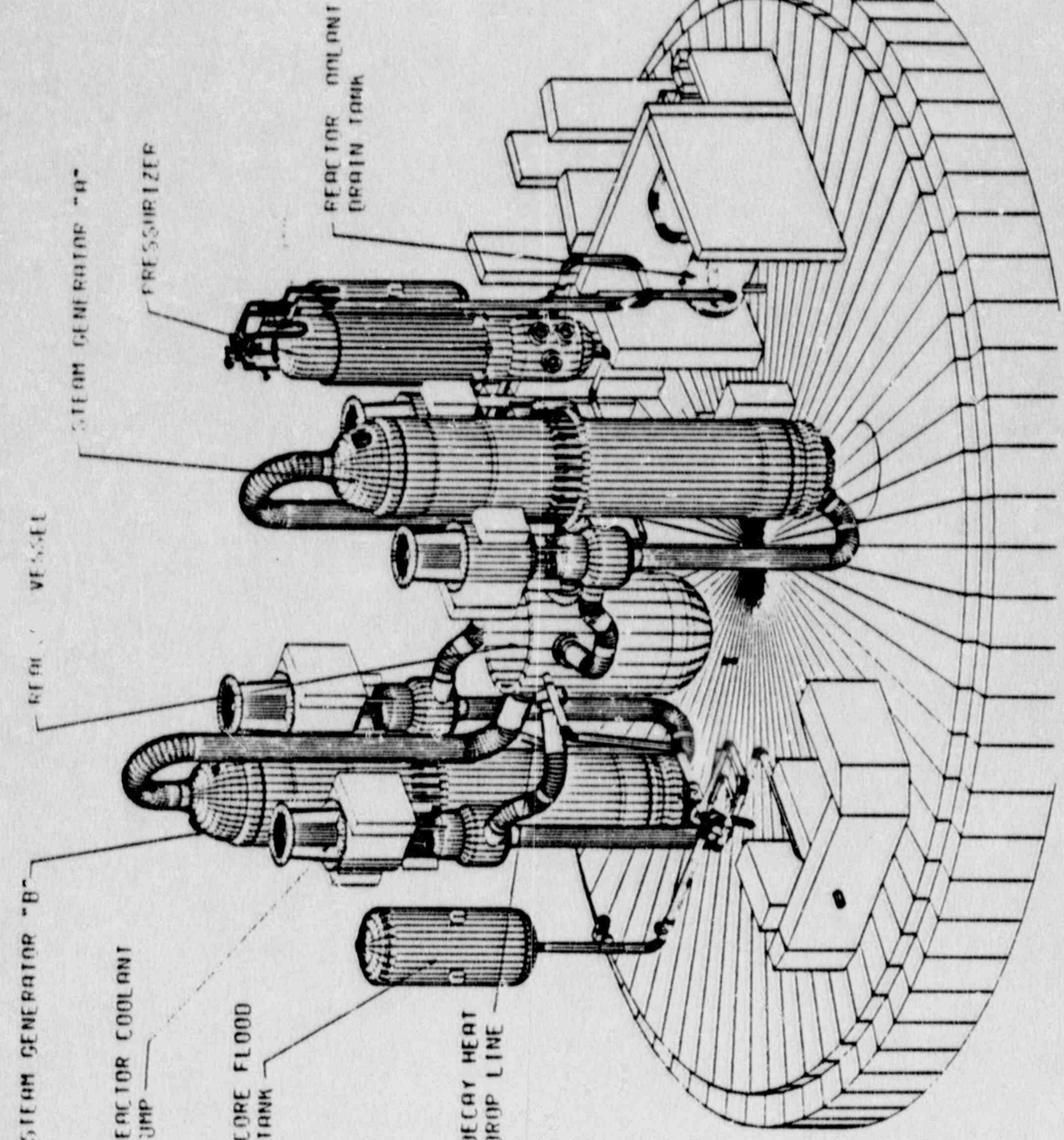


FIGURE 2-4

REACTOR COOLANT SYSTEM COMPONENTS



TMI-2 REACTOR BUILDING BASEMENT

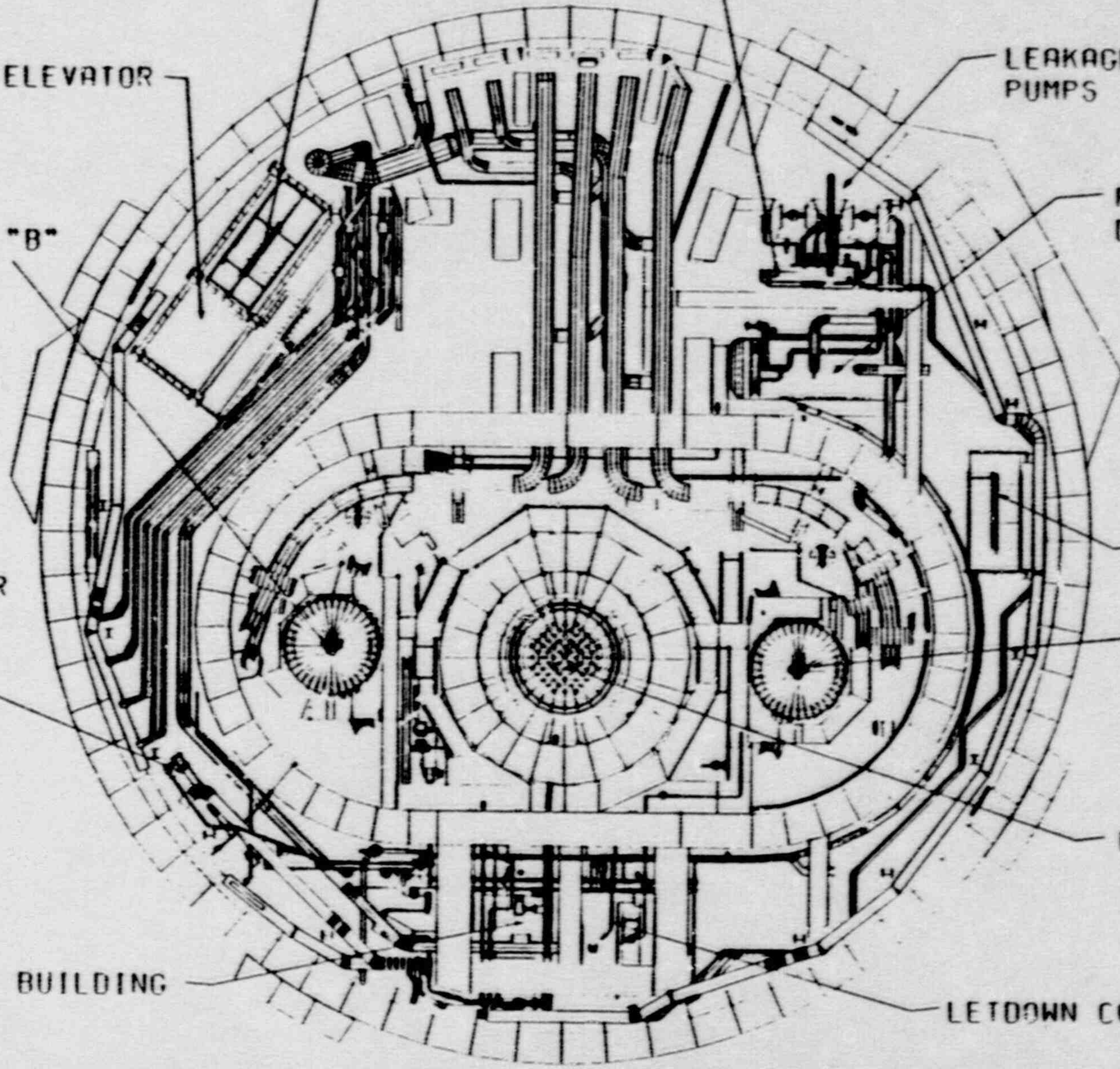


FIGURE 2-5

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

ACTION

EDO Principal Correspondence Control

FROM: DUE: 11/10/89 EDO CONTROL: 0004862
DOC DT: 10/24/89
FINAL REPLY:

Walston Chubb
Murrysville, PA

TO:

Chairman Carr

FOR SIGNATURE OF: ** GRN ** CRC NO: 89-1172

Murley J.F. Stolz

DESC: ROUTING:

EXPLAIN WHY NRC IS CALLING THE SINTER-CAKE FOUND IN THE DAMAGED TMI-2 REACTOR "PREVIOUSLY MOLTEN MATERIAL"

Bernero, NMSS
Russll, RI

DATE: 10/27/89

ASSIGNED TO: NRR CONTACT: Murley

SPECIAL INSTRUCTIONS OR REMARKS:

NRR RECEIVED: OCTOBER 27, 1989
ACTION: DRPR:VARGA

NRR ROUTING: MURLEY/SNIEZEK
PARTLOW
CRUTCHFIELD
MIRAGLIA
GILLESPIE
MOSSBURG

Due DRP 11/3.

ACTION
DUE TO NRR DIRECTOR'S OFFICE
BY 11/7/89

OFFICE OF THE SECRETARY
CORRESPONDENCE CONTROL TICKET

PAPER NUMBER: CRC-89-1172 LOGGING DATE: Oct 27 89

ACTION OFFICE: EDO

AUTHOR: Walston Chubb
AFFILIATION: PA (PENNSYLVANIA)

LETTER DATE: Oct 24 89 FILE CODE:

SUBJECT: Reporting that Uranium Dioxide can be sintered in steam at temperatures as low as 1200C.

ACTION: Direct Reply

DISTRIBUTION: None

SPECIAL HANDLING: None

NOTES:

DATE DUE: Nov 10 89

SIGNATURE: DATE SIGNED:
AFFILIATION:

EDO---004862