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Idaho National Engineering Laboratory

March 1, 1988

Dr. Joseph C. Walters, Ph.D.
Communication Consultant
27 Palomino Road
Flagstaff, AZ 86004

SCRIPT FOR VIDEO ENTITLED "THE TMI STORY: A DOCUMENTARY" - HWR-9-88

Dear Dr. Walters:

Attached is a copy of the script written for the video entitled "The TMI Story: A Documentary" being prepared by the TMI-2 Programs of EG&G Idaho, Inc. for the U.S. Department of Energy. The script reflects comments and refinements offered by several organizations, including the Department of Energy and GPU Nuclear. Presumably, this is a finished script; however, if the Department of Energy provides additional comments between now and March 14, EG&G Idaho, Inc. will edit the script accordingly.

Please study the manuscript and be prepared to verbalize it when you visit this office during the week of 13 March. At that time, both the audio and draft illustrative portions of the video will be constructed. Also, the animation sequences being developed by EG&G Idaho, Inc. or supplied by the Electric Power Research Institute of Palo Alto (CA) will be reviewed and fitted to the script.

The TMI-2 Programs of EG&G Idaho, Inc. is looking forward to your visit and believes that your involvement in preparation of the video will enhance the quality of product being made for the Department of Energy. In the meantime, if you have any questions regarding the script or video, please do not hesitate telephoning me perso[illegible] at 208-526-1150.

Very truly yours,

Harley W. Reno

Harley W. Reno, Ph.D.
Principal Program Specialist

bmr

Attachment:
As Stated

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Rev. 6
3/1/8

THE TMI STORY: A DOCUMENTARY

by

Harley W. Reno

On March 28, 1979, attention of the nation and world was captured by events unfolding at the Three Mile Island Nuclear Power Station near Harrisburg, Pennsylvania. Early that morning, the Unit-2 reactor ceased operating properly, being shutdown by a series of automated protection systems. Although all systems stopped safely, a combination of equipment malfunctions and human errors eventually resulted in irreparable damage to the reactor. That contributed to involvement of the U.S. Department of Energy and others in research and cleanup operations, and expenditure of private and public funds from several sources totalling more than a billion dollars. This documentary summarizes important contributions by DOE during that period, and it illustrates some benefits industry and the nation gained from both the incident at Three Mile Island and subsequent actions.

The incident at Three Mile Island, or TMI, is divided into three parts, namely the accident, which lasted about 15 hours; forced cooling of the system, which lasted about 30 days; and cleanup of facilities and research, which is taking about ten years.

Before discussing the accident, a brief explanation of normal reactor operations is needed. A water reactor like the Unit-2 reactor of TMI is nothing more than a big hot water heater, which uses nuclear fuel to heat large volumes of water. Water leaves the reactor at about 600 degrees Fahrenheit and is pumped to one or more steam generators, where the heat energy is transferred to a second stream of water. Water leaves the steam generator and returns to the reactor at about 550 degrees Fahrenheit for reheating. Pressure in the primary or reactor system is kept high - approximately 2200 pounds per square inch - to prevent boiling the water.

In the steam generators, water in the secondary system flows in the opposite direction of water from the reactor. Cool water in the secondary system enters the steam generator through the bottom and passes upward around metal tubes,.

containing water from the reactor. The heat moves from the hot water in the primary system to the cool water in the secondary system causing the water in the secondary system to boil and change into steam. The steam spins a turbine, producing electricity for public consumption. The steam continues flowing to a condenser, where it is cooled and converted to water. The water, then, is pumped back to the steam generator, where the steam cycle is repeated.

The process of transferring heat from the reactor to the steam generators to the condenser is the mechanism by which the nuclear fuel, or core, is cooled. Thus, water circulating through the reactor is referred to as "coolant." When a reactor is not operating, coolant must be circulated through the core to remove heat generated by the decay of radioactive products produced during normal operations. Water in the reactor system is maintained at a constant pressure by the pressurizer connected to the pipe transporting hot water from the reactor to the steam generator. Because pressures in the reactor system tend to fluctuate, the pressurizer automatically compensates for slight changes by heating the water or cooling the steam bubble within the pressurizer.

At the beginning of the accident at TMI, automatic protection features in the reactor system operated as designed, safely shutting-down the steam turbines and reactor. But a valve at the top of the pressurizer stuck open, permitting water in the reactor system to escape into the Containment Building. A sump pump in the basement of the Containment Building was activated automatically and began pumping the water into the adjacent Auxiliary and Fuel Handling Building.

When the pressurizer valve stuck open, the steam bubble in the pressurizer was lost, giving an indication that the reactor was full of coolant. Operators in the control room of Unit-2 became concerned about potential overpressurizing the reactor system. There was concern too about the loss of water in the steam generators, loss of water in the pumps returning water from the steam generators to the reactor, and increasing levels of radioactivity in the atmospheres of the Containment, and Auxiliary and Fuel Handling buildings. Apparently, the high pressure injection system, which pumps water into the reactor system during an emergency, was delivering some coolant to the reactor and steam generators. The net result, however, was more coolant escaping from the reactor into the Containment Building than was being added by the high pressure injection system.

At 6:00 AM, two hours into the accident, second shift personnel began arriving according to routine work schedules. The second shift supervisor soon recognized the trouble and ordered operators to close the block valve atop the pressurizer. Further loss of coolant was halted. However, the amount of coolant remaining in the reactor only partially covered the core. As a result, both temperatures in the core and pressures in the cooling system began increasing as water flashed into steam. That effectively prevented the high pressure injection system from replacing coolant lost to the Containment Building or transformed into steam.

As temperatures in the core rose, exposed core materials and steam interacted causing severe damage to structures and fuel assemblies. Some components melted and flowed to lower portion of the core. A "bubble" of hydrogen gas accumulated in the top of the reactor. The hydrogen gas was formed when the steam interacted with hot metals of the exposed core in ways that stripped oxygen

During the last ten hours of the accident, operators opened and closed valves and systems in ways that eliminated the steam voids, reduced the hydrogen bubble in the reactor system, and cooled the core. The operators briefly opened the block valve on the pressurizer and activated the high pressure injection system. The procedure vented steam and hydrogen into the Containment Building and progressively permitted refilling the reactor system with coolant. Temperatures in the core began to decrease. Heat was removed by restoration of forced circulation of coolant through the reactor and steam generators.

Shortly after initiation of venting, hydrogen released into the Containment Building apparently ignited. A rapid increase-decrease in atmospheric pressure of the Containment Building was detected by instruments in the control room. Later examination of charred equipment and distorted doors showed the hydrogen gas had burned and indeed was the source of the change in pressure.

Once voids in the coolant system were filled, circulation pumps in the cooling system were restarted. Temperatures of water returning to the reactor were lower than water leaving the reactor, indicating that flow through the reactor system had been restored. That signaled an end to the accident. However, the basement of the Containment Building was flooded by approximately 600,000 gallons of radioactive water. The atmosphere of that building contained large amounts of radioactive krypton gas. The Auxiliary and Fuel Handling Building was contaminated by approximately 550,000 gallons of water and some gas from the Containment Building.

At approximately 7:00 PM - 15 hours after the Unit-2 reactor began automatic shutdown - the accident was over. Thus, the end of the accident marked the beginning of the final cooling of the core, and the laborious, time consuming, and expensive tasks of cleaning up the facility. It also marked the beginning of a comprehensive research and development by the Department of Energy.

The small bubble of hydrogen gas remaining inside the reactor was removed by venting into the Containment Building. However, to avoid igniting the hydrogen, air in the Containment Building was circulated through a device containing catalytic recombiners, which controlled the concentrations of hydrogen by chemical recombination with atmospheric oxygen to form water vapor.

After the hydrogen gas was forced from the reactor coolant system, circulation of coolant through the reactor system was restored fully. A pump continued circulating coolant for about a month, until temperatures in the system fell below those added to the system by the pumping process. At that point, the pump was turned off and natural convection was allowed to cool the system. Fifteen months after the accident, the radioactive gas in the atmosphere of the Containment Building was vented to the outside during a four week period from June and July 1980. The venting was a carefully controlled process conducted according to a plan developed by Metropolitan-Edison Corporation - operator of the Three Mile Island Nuclear Power Station - and approved by the U.S. Nuclear Regulatory Commission. Metropolitan-Edison Corporation at TMI was reorganized later as General Public Utility Nuclear Corporation and thence into GPU Nuclear Corporation.

From the beginning of the accident, the Department of Energy played an important role at TMI. Initially, DOE's presence there was to support the U. S. Nuclear Regulatory Commission and Metropolitan-Edison Corporation as they labored to control the incident. That was accomplished by making available experts in reactor behavior and experimental facilities at national laboratories. Simulators at the Idaho National Engineering Laboratory were used in recreating various aspects of the accident and testing hypothesized methods for controlling the accident.

In December 1979, President Jimmy Carter charged DOE with the responsibility of implementing the federal portion of the research and development program outlined by the President's Commission on the Accident at Three Mile Island. The commission recognized that the incident at TMI afforded the government and nuclear industry a unique opportunity in understanding reactor behavior during and after a severe core damage accident. The commission believed Unit-2 would provide information not available from severe accident tests conducted at national laboratories. Consequently, the General

Public Utility Nuclear Corporation, the Electrical Power Research Institute, the Nuclear Regulatory Commission, and the Department of Energy, collectively identified by the acronym GEND, signed a Coordination Agreement in March 1980, establishing the Technical Information and Examination Program. The Coordination Agreement outlined objectives of that program and broadly defined methods for achieving those objectives consistent with other obligations of each signatory to the agreement.

An important aspect of that agreement was establishment of a physical presence at TMI by DOE, beginning in 1980. The Technical Integration Office of DOE was supported by $48 million and staffed mainly by personnel from EG&G Idaho, Inc., operating contractor of the Idaho National Engineering Laboratory. The Technical Integration Office was responsible for coordinating activities between GPU Nuclear, other signatories to the Agreement, and special advisory committees established to assist in planning cleanup operations and gathering research materials needed for understanding and explaining the accident. That office assisted in planning and scheduling activities at TMI and at federal installations around the country. It also disseminated technical and scientific information to governments and nuclear industries around the world.

Meanwhile, NRC was preparing a Programmatic Environmental Impact Statement on decontaminating Unit-2 and disposing of wastes. The Environmental Impact Statement, first issued as a draft in August 1980 and in final form the following March, alluded to special capabilities in DOE which could benefit cleanup and waste disposal efforts at TMI. In March 1981, the Secretary of Energy sent a memorandum to President Ronald Reagan, requesting the budget for DOE at TMI be enhanced to accommodate the larger scopes of work suggested by NRC. The President responded positively and authorized a budget expansion. The amount added was $75 million, increasing the DOE commitment by fiscal year 1982 to $123 million.

Following issuance of the Final Programmatic Environmental Impact Statement on TMI, NRC and DOE signed an interagency Memorandum of

Understanding, which specified interagency procedures, roles, and responsibilities for removal and disposition of wastes produced during cleanup of Unit-2. That memorandum, along with the Coordination Agreement, defined how DOE and GPU Nuclear would interact in removing, transporting, and storing or disposing of wastes produced during cleanup. The DOE budget at TMI was increased another $36 million, bringing the commitment to $159 million, beginning fiscal year 1983.

In 1982, DOE assisted GPU Nuclear in initial examinations of the damaged core. Two leadscrews in the control rod system were removed. A miniature television camera was lowered into the core region of the reactor through one of the openings left by a leadscrew. The television camera revealed a large cavity in the core. There was considerable rubble and damaged fuel assemblies at the bottom of the cavity. Portions of damage fuel assemblies were observed around the periphery of the cavity.

In 1983, DOE and GPU Nuclear developed sampling devices which were lowered through the leadscrew openings and used to collect samples of the .

debris. Information gathered from studying the leadscrews, examining videos of the cavity in the core, and analyzing samples of debris collected from the core justified expanding the TMI budget to include formulating an explanation of what happened to the core during the accident. The additional funding was $30 million, bringing the total commitment to TMI by DOE to $189 million. Of that amount, 40 percent was devoted to cleanup of Unit-2 and 60 percent to research and development activities at various federal laboratories.

In March 1984, DOE and GPU Nuclear contractually agreed that DOE would transport, store, and eventually dispose of the damaged core from Unit-2. They also agreed that DOE would transport, store, and prepare for disposal abnormal wastes generated during cleanup. Abnormal wastes are wastes whose characteristics are different from radioactive wastes routinely produced by commercial, nuclear power facilities.

The amount committed by DOE to cleanup of Unit-2 and researching and understanding progression of the accident was less than 18 percent of the costs of cleanup and research. That is, the estimated $1.1 billion was variously shared by other parties: the insurance companies paid $305 million; the customers of GPU Nuclear paid $246 million; the domestic nuclear industry contributed $153 million; the General Public Utilities Corporation paid $82 million; the Commonwealth of Pennsylvania and State of New Jersey contributed $30 million and $11 million, respectively; the Babcock and Wilcox Corporation paid $21 million a after lawsuit - it designed and built the Unit-2 reactor; the nuclear industry of Japan contributed $18 million; and, of course, the Department of Energy spent $189 million, of which $79 million was directly applicable to cleanup of Unit-2. That left an unfunded shortfall of about $38 million. GPU Nuclear estimated that cleanup alone cost $965 million.

NRC, in its environmental impact statement, indicated that cleanup of Unit-2 could be accomplished using existing technology and hardware already available to the nuclear industry and federal government. NRC also noted that cleanup would take from five to nine years to complete. Although that forecast initially seemed pessimistic, in reality it was quite .

realistic. After the accident, NRC, GPU Nuclear, and other organizations at TMI realized that access to the damaged reactor would occur only after peripheral facilities were decontaminated.

More than one year passed before the Auxiliary and Fuel Handling Building was decontaminated sufficiently to permit regular occupancy and the Containment Building vented of radioactive gas. Another two years passed before radiation levels in the Containment Building were reduced to safely permit prolonged occupancy, particularly in those areas allowing access to the reactor. Three more years elapsed, while scientists and engineers worked on the polar crane, opened the reactor, and designed, built, and tested hardware for removing, packaging, and transporting core debris. And more than three years were needed to dismember, package, and transport the core to the Idaho National Engineering Laboratory for storage and research.

After the accident, GPU Nuclear began cleaning and decontaminating the Auxiliary and Fuel Handling Building. The Auxiliary and Fuel Handling Building is really two distinct facilities separated by a common wall. The

Auxiliary Building contains tanks, pumps, piping and other equipment used to process and store water for the reactor and primary cooling system. That building also is used for treatment of radioactive wastes. The Fuel Handling Building contains equipment for moving and storing nuclear fuel. Most of the hardware, floors, and walls of the Auxiliary Building were contaminated when the sump pump in the basement of the Containment Building began discharging spilled reactor coolant into the sump of the Auxiliary Building. As a result, GPU Nuclear elected to install the commercially available EPICOR-II demineralizer system for processing both spilled water in the Auxiliary Building and water used in scrubbing floors, pipes, and other surfaces.

The EPICOR-II demineralizer system was comprised of three EPICOR ion exchange prefilters arranged in series. As contaminated water passed from one prefilter to the next, progressively more and more radioactive contaminants - principally cesium and strontium - were removed. The cleaned water was stored until needed for other cleaning and decontamination tasks. Once a prefilter was loaded with radioactive materials, it was removed from service, moved from the Auxiliary Building in a shielded container, and stored in a temporary concrete building near the Unit-2 complex.

By the time the Auxiliary Building was decontaminated, 50 EPICOR-II prefilters had been used and placed in storage. Several prefilters contained approximately 2,200 curies of radioactive isotopes and had a radiation field approaching 1,000 Roentgens per hour on the exposed surface. Since the prefilters individually contained more radioactivity than was permitted for disposal as commercial low-level radioactive wastes, they had to be either repackaged in high-integrity containers or their contents immobilized in concrete or other durable media, as specified in regulations of NRC. Neither situation seemed workable because, in 1981, there was no licensed high-integrity container which could accommodate something as large and radioactive as an EPICOR-II prefilter. An EPICOR-II prefilter is cylindrical, about four feet in diameter, five feet high, and contains about 35 cubic feet of organic resins or organic resins with zeolite. Likewise, immobilizing the contents of an EPICOR-II prefilter would increase significantly the volume of radioactive wastes disposed by GPU Nuclear. Unnecessary proliferation of radioactive wastes was contrary to recommendations outlined in the Programmatic Environmental Impact Statement by NRC. DOE agreed to accept the 50 EPICOR-II prefilters under terms of the interagency Memorandum of Understanding and use them as research materials, in order to develop a method whereby they could be disposed as low-level radioactive wastes.

Two EPICOR-II prefilter were retrieved from storage and transported to Battelle Columbus Laboratories in Ohio for examination. That laboratory discovered gases escaped when the prefilters were opened and residual liquids inside were acidic. Immediately, questions were raised about potential rusting and over pressurization of each prefilter in storage at TMI. DOE asked EG&G Idaho to design and build a device which would vent each prefilter of gases and replace the internal atmosphere with an inert gas, before transporting the prefilter by truck from TMI to Idaho National Engineering Laboratory, or INEL. EG&G Idaho responded to the request and delivered to GPU Nuclear the Prototype Gas Sampler, which remotely opened the prefilter, sampled and analyzed internal gases, and replaced the atmosphere in the prefilter with argon. All EPICOR-II prefilters were transported safely by truck to INEL, where they were placed in storage.

Radioactive materials brought to INEL are used in answering questions important to the government and nuclear industry. The EPICOR-II prefilters afforded DOE some unusual research opportunities. For example, engineers and scientists were concerned about rates of internal corrosion of the steel containers, the behavior of organic resins after receiving internal radiation doses in excess of that accomplished in laboratory tests, and development of a high-integrity container which would facilitate disposing of the prefilters as low-level radioactive wastes.

EG&G Idaho devised ways of remotely collecting samples of resins and zeolites in selected prefilters and analyzing them for chemical and physical changes in resins. Analyses revealed that resins began to structurally change in radiation fields less intense than assumed by NRC. That discovery encouraged NRC to fund continued research in degradation of irradiated resins and initiate revision of regulations concerning immobilization of resins before disposal. EG&G Idaho also succeeded in remotely transferring resins from an EPICOR-II prefilter to an empty EPICOR liner. The emptied prefilter was decontaminated, then metallurgical samples were cut from the sides. The samples were examined and shown to have little corrosion. That finding eliminated further concerns about uncontrolled rusting of EPICOR-II prefilters during storage.

Critics of TMI and DOE claimed that the EPICOR-II prefilters could not be disposed as low-level radioactive wastes within the present regulatory framework. They argued that a high-integrity container large enough to accommodate a prefilter could not be built or licensed. DOE, two of its national laboratories, several private companies, and a state regulatory authority believed otherwise. EG&G Idaho asked Sandia National Laboratories to assist in developing criteria for a high-integrity container suitable for the prefilters. EG&G Idaho contracted Nuclear Packaging, Inc. of Federal Way, Washington, to design the high-integrity container based upon criteria provided by Sandia National

EG&G Idaho also contracted Nuclear Packaging, Inc. to construct two prototype high-integrity containers. One was built and drop-tested from 10 feet at the manufacture's facility and the other used in additional testing at INEL. The Department of Social and Health Services of the State of Washington requested that the second prototype at INEL be drop-tested from 30 feet. After that test, the State of Washington issued a Certification of Compliance for the concrete high-integrity container based upon technical review and and advice from NRC. Thus, the first-of-a-kind reinforced concrete high-integrity container was used in the disposal of 46 EPICOR-II prefilters as Class "C" low-level radioactive wastes in the commercial nuclear waste disposal facility in the State of Washington. The other four prefilters were disposed as government research wastes in a facility at INEL, after completion of research sponsored NRC.

Once the Auxiliary Building at TMI was decontaminated, attention shifted to decontamination of the Containment Building. The first task was to drain and clean the 600,000 gallons of contaminated water in the basement.

GPU Nuclear designed and built into the EPICOR-II demineralization system another filtration system for removing cesium and strontium from the water in the Containment Building. The new system was inserted in the process line between the Containment Building and EPICOR-II system in the Auxiliary Building. The filters, or vessels, resembled a large, household water softener. Internally, the vessel was filled with zeolites, which look like granulated cereal or dry pet food. Zeolites have strong affinities for certain radioactive materials.

Since those vessels would be capturing and concentrating large quantities of strontium and cesium, they were arranged in series within the "B" Pool of the Fuel Handling Building, hence the name "submerged demineralizer system" or SDS. The pool provided shielding to workers and equipment against intense radiation from the loaded vessels without interfering with access to needed facilities. Water leaving the SDS vessels was sent to the EPICOR-II demineralizer system for final cleaning before storage in a special tank.

Originally, specifications for SDS limited each vessel to containing about 10,000 curies of radioactive isotopes. However, studies by DOE at the Oak Ridge National Laboratory indicated that each vessel could be safely loaded to many times that number of curies, thereby reducing both the number of vessels needed to process that 600,000 gallons of water and volume of wastes produced.

After all the water was processed, 19 vessels of wastes had been produced. Some vessels contained about 112,000 curies of radioactivity each, with radiation fields approaching a 100,000 Roentgens at the exposed surface. That was substantially more radioactivity than had been managed in the disposal of the EPICOR-II prefilters. Consequently, DOE was faced with two challenges: First, it had to figure out how to control the production of gases in each vessel. And second, it had to decide what to do with the vessels once they were moved from TMI.

When water is placed in a high radiation field, it begins to disassociate into its elemental components. That is, radiation tends to break the chemical bonds binding hydrogen and oxygen by a process termed "radiolysis." That results in