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STATEMENT BY W. KENNETH DAVIS
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ON THE ACCIDENT AT
THREE MILE ISLAND NUCLEAR PLANT

Because of the present and potential importance of nuclear power in the United States, as well as the rest of the world, it is essential that the members of the National Academy of Engineering be able to place in perspective the events which started on March 28, 1979, at the 900,000 kilowatt No. 2 Unit of the Three Mile Island Plant near Harrisburg, Pennsylvania, which is operated by the Metropolitan Edison Company, a subsidiary of General Public Utilities.

While considerable uncertainty remains about the actual sequence of events as well as the specific malfunctions and actions involved, some relevant aspects and consequences are now reasonably clear and it is important to evaluate these as quickly as possible.

The sequence of events was initiated by unexpected loss of normal feedwater flow to the two boilers while the unit was operating at full power. This resulted in tripping off the turbo-generator. Emergency boiler feedwater pumps were started within seconds but could not provide water to the boilers because valves had been left closed which were required to be open. The boilers began to dry up and lose their ability to remove heat from the circulating hot water in the two high pressure "primary" loops [illegible]ling the reactor. The resulting increase in pressure in the cooling loops in turn led to 1) shutting down the nuclear reactor by insertion of the control rods (within 12 seconds of the initial event), and 2) opening of an automatic pressure relief valve to reduce the pressure to normal levels by releasing steam from the v[illegible]ume/pressure control vessel called a "pressurizer".

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As sometimes happens with relief valves of the type used, the valve failed to reclose when the pressure dropped and continued to release steam (and probably some water) from the primary system.

Two things should be noted. First of all, the reactor was a pressurized water reactor (PWR) which operates at a normal pressure of about 2100 pounds per square inch (psi) which is sufficient to prevent any boiling in the primary system so that it is entirely filled with water except for a small volume at the top of the pressurizer. The pressurizer is electrically heated so that the water in it is at temperatures sufficient to produce some steam at 2100 psi in order to effect volume and pressure control. Second, once the reactor was "scrammed", the nuclear reaction never started again and the heat, which was then entirely from radioactivity in the fuel material in the core, dropped instantly to about 7% of that at full power and then decreased rapidly to about 1% after one hour, about 0.4% after one day and less than half of that after a week.

While the events described led to the eventual consequences, it is important to note that it is not likely that any of them by themselves caused any significant damage or untoward consequences and that they were among the events subject to normal operating procedures. The subsequent events are difficult to reconstruct with present knowledge but involved difficulties with maintaining a proper amount of water (and pressure) in the primary system including the reactor vessel (with water supplied by normal and emergency systems and released by the relief valve as well as a "let-down" system) and the circulation of the water through the reactor core and the system by the four main coolant pumps. Some further equipment malfunctions likely occurred which, when combined with various actions, some probably taken without adequate data or erroneous data due to instrument malfunctions, led to quite serious consequences and the necessity for what will surely be a long and costly cleanup process.

While there is only indirect evidence now, it appears likely that the reactor core was not fully covered with cooling water for one or more periods of time, probably starting after about two hours from the initiation of the incident. A part of the zirconium cladding of the fuel (itself a very high melting point uranium oxide ceramic) reacted with water or steam to produce zirconium oxide and hydrogen. Also, part of the fission product gases, xenon and krypton (highly radioactive but very small physical volume) were released from the fuel as well as smaller fractions of volatile fission products, iodine and cesium. There is no evidence of melting of the fuel or release of significant amounts of uranium or other non-volatile fission products into the water. Substantial amounts of the hydrogen as well as the fission product gases found their way into the shielded gas-tight containment which houses the reactor and the entire primary system through release of coolant water into the containment.

While there was speculation about hydrogen being trapped in the unvented top of the reactor vessel (and the upper pipes leading to the top of the steam generator), there was little basis for believing this "bubble" might contain enough oxygen to explode and, as anticipated, the hydrogen to the extent it might have been there, was carried out by circulation of the cooling water. However, hydrogen did accumulate in the air in the containment building to a level of about 2% and a "spike" in the pressure reading in the containment building seems likely to have been caused by a small hydrogen detonation several hours after the incident started.

The water discharged from the primary system was collected in a sump in the bottom of the containment building and some of it pumped into tanks in an "auxiliary" building where some overflowed. This building has a controlled ventilation system which discharges gases up a stack after filtering to remove essentially all radioactivity except xenon and krypton. The only significant source of radioactivity discharged from the plant during the incident was from the auxiliary building.

The operators are in the process of reducing the pressure and temperature in the primary system while providing adequate cooling to place the core in "cold shutdown" on a long-term basis. Extensive measure will be needed to clean up the water in the bottom of the containment (containing the radioactive iodine, etc.) and the residual activity in the gas in the containment structure (the xenon activity decreases by one-half every 5-1/2 days). This will be necessary, along with the other cleanup measures, before the containment can be entered, the damage assessed, and the damaged fuel removed which requires removing the head from the 15-foot diameter reactor vessel. Once this is done, the fuel can be removed and necessary repairs and replacements begun.

From the above, it seems clear that at least in retrospect, there was not any immediate hazard to those living in the vicinity of the plant although prudence dictated making provisions for any hazards which might have emerged.

The exposure to radiation of those living within 50 miles of the plant has been estimated to average about 1 milirem (mrems). This is about the amount normally received from natural sources in 3 days of living or perhaps 1/3 of that received on a jet flight across the country. The total integrated dose of all those in the area is estimated at 2000 man-rems (exposure per person times the number of people) and it is believed that about 10,000 man-rems are needed for one additional case of cancer. An individual staying continually at the worst point outside the site fence would have received about 100 mrems -- the equivalent of 2 or 3 medical x-rays. The exposure received by workmen in the plant was below those allowable under established industrial regulations except for 3 men reported to have received slightly more than the quarterly limit.

It is important to recognize that the design of nuclear plants, including the Three Mile Island Unit, is based on detailed consideration of and provisions for virtually every conceivable equipment or human malfunction. For the very unlikely chain of events (such as occurred at Three Mile Island), the criteria are: first, safety for the public; second, protection of plant personnel; and third, reducing damage to the plant. Clearly, the Three Mile Unit accident was accommodated within the "design considerations" for the plant and achieved the first two objectives. The damage to the plant, except for the core, is not believed to be severe in the physical sense, but the cost of cleaning up the plant and restoring it to service will undoubtedly be high and take a long time.

In addition to the economic loss to the local businesses and to the people who moved away temporarily, there will be a large cost for purchasing replacement power at a high cost (from coal or oil-fired plants) as compared with the nuclear generating costs at Three Mile Island. This will be several hundred thousand dollars per day for Unit No. 2 and, of course, twice that if Unit No. 1, which is down for refueling, is not allowed to start up again.

Where the broad perspective and careful judgment is really required is as to the impact of the Three Mile Island accident on the future use of nuclear power. With energy and electric power requirements increasing relentlessly, albeit at somewhat lower rates than before the 1973-74 crisis, declining oil and gas production in the United States, increasing risks to our evergrowing oil imports, and only a distant promise of new "renewable" energy sources, the U.S. must rely at a rapidly increasing pace on coal and nuclear if it is to retain its economic vigor, standard of living, and political strength in the world. While it might be possible in time to meet our requirements with coal and little or no nuclear power, this is likely to be very difficult physically, relatively costly, and at a price to the environment, health and safety. All forms of energy production without exception have an impact on the environment, health and safety. While these are broadly acceptable in terms of the benefits for present energy sources, including coal, it is still evident that nuclear power is one of those sources with the least impact -- and the events at Three Mile Island have not changed that fact, despite the impressions given by the TV and radio programs and the volume of speculative and sometimes distorted information in the press (some of which did present factual and well-balanced reports).

The lessons of Three Mile Island will surely lead to changes in the design and operation of nuclear plants, changes which will further decrease the likelihood of another similar accident. However, the question is whether what some have called a "national disaster" which did not injure or kill anyone is going to result in termination or atrophy of one of the few sources of energy we can otherwise look forward to with confidence for the next few decades.

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