THE ACCIDENT AT THREE MILE ISLAND AND ITS AFTERMATH

A. P. MALINAUSKAS
Chemical Technology Division
Oak Ridge National Laboratory*
P. O. Box X
Oak Ridge, Tennessee 37830

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WINDSCALE — 1957

- air-cooled reactor
- 300,000 Ci ^{133}Xe escaped into the biosphere
(100% of inventory)
- 20,000 Ci ^{131}I escaped into the biosphere
(12% of inventory)

Consequences of the Windscale Accident

- Contaminated milk had to be destroyed
- Land areas were interdicted for months
(Note: In 1 year, 2×10^4 Ci of 8-day ^{131}I will decay to 4×10^{-10} Ci)
- The reactor was decommissioned
- Technical opinion was formed concerning the significance of radioiodine in reactor accidents

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Figure 5-2. CUTAWAY VIEW OF OXIDE FUEL FOR COMMERCIAL LWR POWER PLANTS.

The basic unit in the core of a light-water reactor is a fuel rod containing uranium oxide pellets in a Zircaloy cladding. The rod is filled with helium gas and welded shut. The circled portion exaggerates the annular space between the pellet and the cladding. (Figure reproduced from WASH-1250.)

Figure 5-3. FUEL ASSEMBLY FOR A PRESSURIZED-WATER REACTOR.

In a pressurized-water reactor, fuel rods are assembled into a square array, held together by spring clip assemblies and by nozzles at the top and bottom. The structure is open, permitting flow of coolant both vertically and horizontally. All the assemblies in the reactor may have the same mechanical design, including provision for passage of a control rod cluster (shown in the figure). Where there is no cluster, these positions may have neutron sources, burnable poison rods, or plugs. (Figure reproduced from WASH-1250.)

CUTAWAY VIEW OF REACTOR PRESSURE VESSEL

Nuclear Steam System

Babcock & Wilcox

ORNL DWG 81-15737

THE ACCIDENT AT TMI-2
HOW IT HAPPENED

Wednesday, March 28, 1979

04:00.36 hr Feedwater system pumps trip

Steam turbine and electric generator shut down

Pressure in pressurizer builds to 2255 psi,
so pilot-operated relief valve (PORV) opens,
releasing steam and water to the primary
system drain tank

04:00.44 hr Reactor scrams on high system pressure

JUST A MINOR NUISANCE AT THIS POINT

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THE PROBLEM PERSISTS

04:02.21 hr The steam generators boil dry

04:02.36 hr Reactor coolant system pressure drops suddenly. This activates two high pressure injection pumps (HPI), which begin to pump 1000 gpm of water into the system

IT APPEARS AS IF A LOSS-OF-COOLANT ACCIDENT HAS OCCURRED, BUT HAS BEEN BROUGHT UNDER CONTROL BY ENGINEERED SAFETY FEATURES

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THE TROUBLE REALLY BEGINS

- 04:03.06 hr One HPI pump is shut down, and the second is throttled back to 100 gpm because the water in the pressurizer is rising
- 04:06.06 hr Water is drained from the primary system through the letdown system. (Since the PORV is still open, the rising water level in the pressurizer is due to gas bubbles in the core.)
- 04:08.36 hr Discovery is made that no emergency feedwater is reaching the system. The appropriate valves are opened

THE CONDITION WORSENS

- 04:15 hr Rupture disk on drain tank bursts. The sump pumps are pumping slightly radioactive water into the auxiliary building dump tanks
- 05:14 hr Two of the four reactor coolant pumps are shut down because of severe vibration
- 05:41 hr The two remaining pumps are shut down
- 06:00 hr First indication of radioactivity in the containment building

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THE ROAD TO RECOVERY

06:22 hr The block valve between the PORV and the
 pressurizer is closed

06:54 hr One coolant pump is turned on

07:13 hr The pump is turned of because of excessive
 vibration

08:26 hr HPI pumps are turned on

10:30 hr The core is covered

THE HYDROGEN "EXPLOSION"

- March 28, 1979 — 13:50 hr

Coincident with an opening of the block valve on the pressurizer, there was a sudden pressure spike in the containment building. The spike activated the building spray system. (The set-point for the spray system is +28 psi.)

Six minutes later, the sprays were turned off

SOURCES OF HYDROGEN

Reaction of coolant with metal

(No free oxygen is formed)

Radiolysis of water

Figure 111 (4B). Fifty-five gallon drum, closer view of Figure 110.

Figure 239 (5B). Close-up of the control panel on the auxiliary fuel handling bridge, fourth view.

ACTIVITY RELEASED INTO THE BIOSPHERE

Nuclide	Core Inventory (Ci)	Activity From Core	Released ^a (Ci) Into Biosphere
³ H	3700	2700	300
⁸⁵ Kr	9.6×10^4	6.8×10^4	8.0×10^{3b}
¹³³ Xe	1.5×10^8	9.9×10^7	1.2×10^7
¹³¹ I	6.5×10^7	3.9×10^7	15
¹³⁷ Cs	8.5×10^5	5.1×10^5	0
⁹⁰ Sr	7.5×10^5	5.4×10^2	0

^aAssuming instantaneous release

^bAn additional 30,000 Ci were later released during venting of the containment building

Figure 138 (5B). Close-up of Bell Telephone.

THE IODINE MYSTERY SOLVED!

1. A reducing atmosphere

So iodine is not released as I_2 , but as CsI or HI

(At Windscale,

2. Solubility

CsI and HI are extremely soluble in water

Even I_2 is very soluble in water. Furthermore,

RELEASE PATHWAY FOR FISSION PRODUCTS

1. Fuel rods
2. Primary system
3. Pressurizer
4. Dump tank
5. Sump
6. Containment building
7. Auxiliary building
8. Biosphere

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THE AFTERMATH

- 30,000 Ci of ^{85}Kr in containment building atmosphere — vented into the biosphere under favorable meteorological conditions
- Auxiliary building and containment building surfaces extensively contaminated — auxiliary building cleaned, containment building partly decontaminated, protective clothing and respiration equipment needed (100–200 mR/hr)
- Extensive damage to the core and reactor vessel internals

WATER — A SPECIAL PROBLEM

104,000 gal of low activity level (pre-accident) water in Auxiliary Building I tanks — cleaned and discharged into river

380,000 gal of intermediate level water in Auxiliary Building II tanks — cleaned and stored, now used for process applications

700,000 gal of high activity level water in the containment building — cleaned and stored, now used for process applications

90,000 gal of high (now intermediate) activity level water in the primary system — cleanup is underway

TMI 2 SUBMERGED DEMINERALIZER SYSTEM

SDS Performance

Containment Building Water

Nuclide	Influent	SDS	Polisher
		Effluent	Effluent
		<hr/> $\mu\text{Ci/ml}$ <hr/>	
^{60}Co	2×10^{-5}	2×10^{-5}	$<3 \times 10^{-7}$
^{90}Sr	4	1×10^{-2}	$<1 \times 10^{-5}$
^{125}Sb	1×10^{-2}	1×10^{-2}	$<6 \times 10^{-7}$
^{137}Cs	100	7×10^{-4}	$3 \times 10^{-7*}$
^3H	0.88	0.88	0.88

*This corresponds to 4×10^{-9} ppm.

THE CASE FOR SAFETY — THE ECONOMIC INCENTIVE

Current estimate of cleanup costs	$\$1 \times 10^9$
Replacement power (10 years @ $\$5 \times 10^6/\text{wk}$)	3×10^9
Recommissioning costs	1×10^9
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Total	$\$5 \times 10^9$