

Energy, Air, Water, & Earth

Electricity

Three Mile Island Reactor Accident

Fukushima Tsunami-Reactor Situation

National Academies of Sciences

April 19, 2011

Lake H. Barrett

Rockville, MD

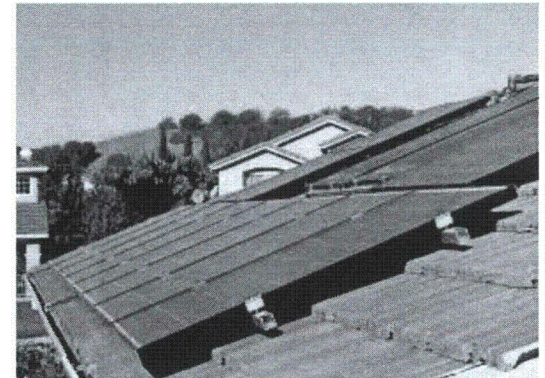
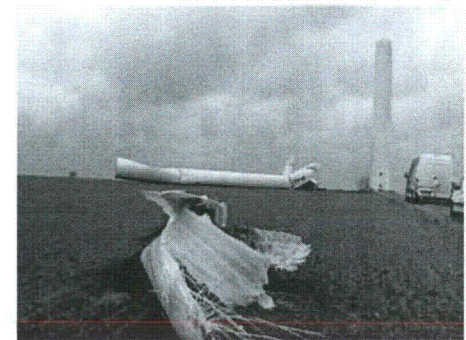
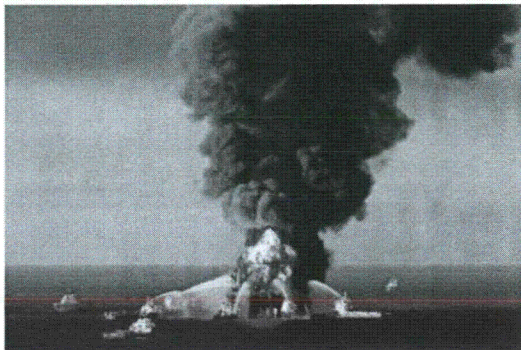
Disclaimer: Fukushima Information is preliminary especially regarding interpretation of events; opinions expressed are mine and mine alone.

Evolutionary Background

- **Mankind**
 - Huts to Modern Cities
- **Energy**
 - Simple Fire to Fossil Electricity to Nuclear Electricity
- **Energy Density**
 - Diffuse/Intermittent to Concentrated/Continuous

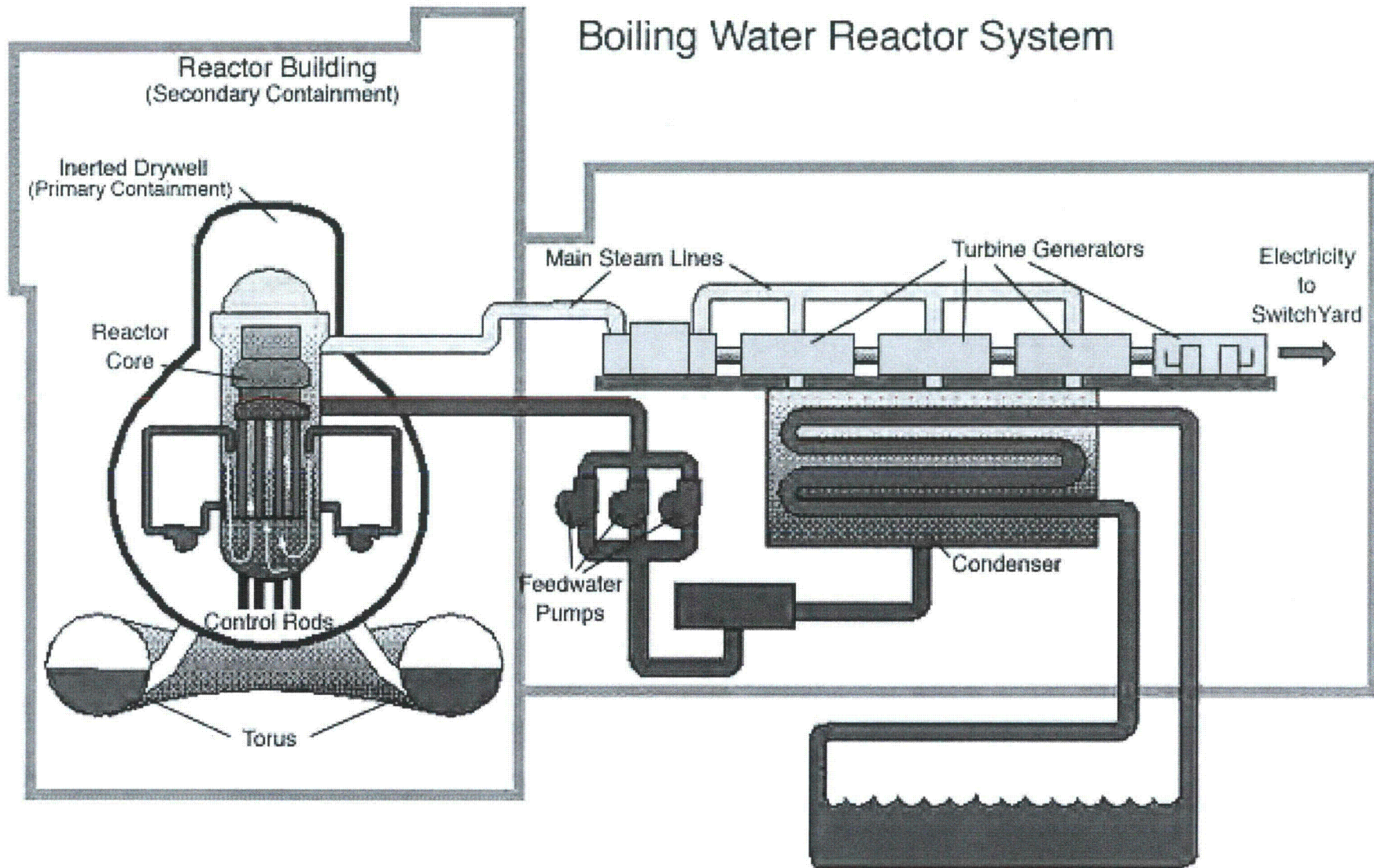
Constant Evolutionary Societal Benefit/Risk Tradeoffs

- No Energy Source is Free From Risk or Cost

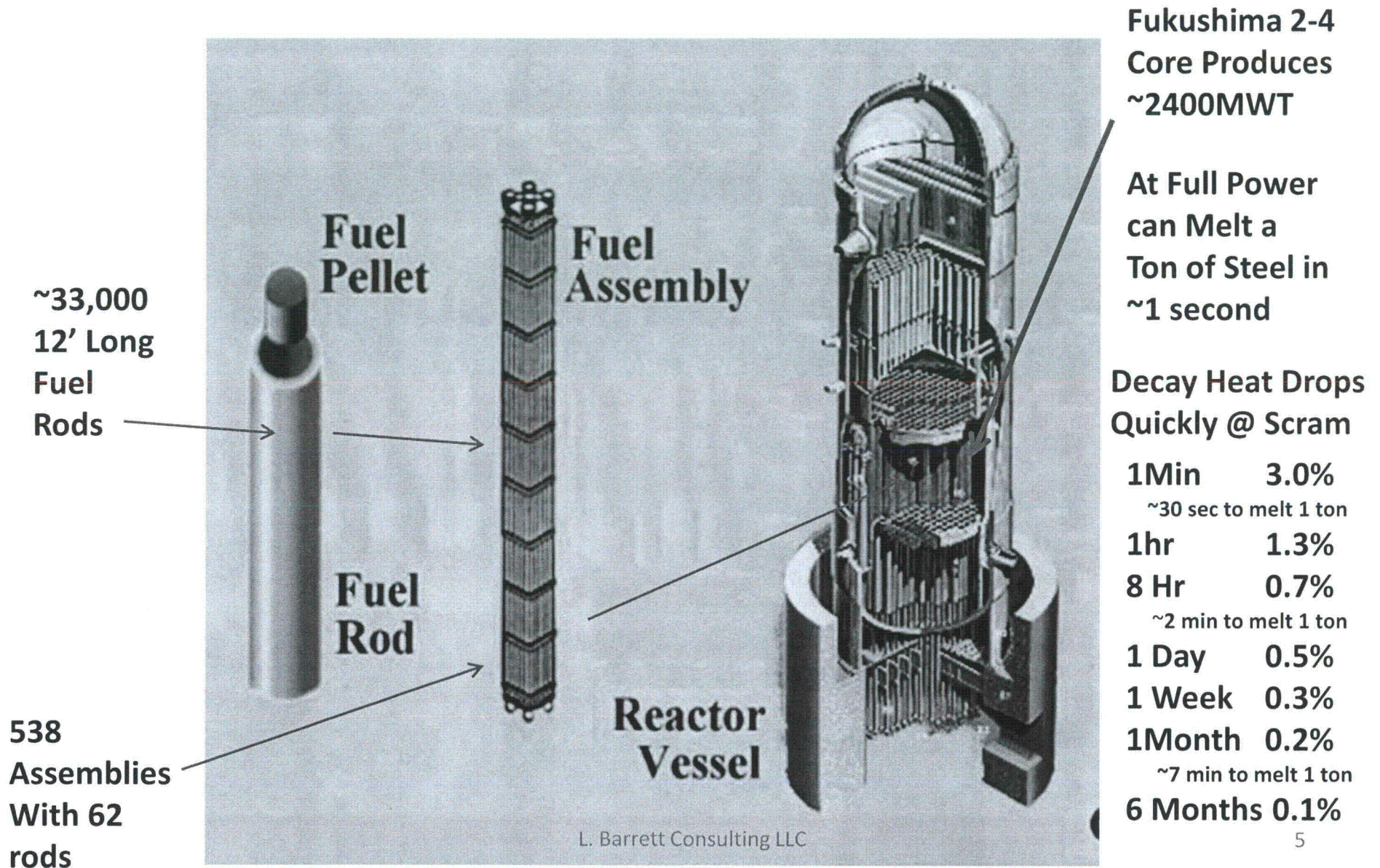


Nuclear Power Plant

Boiling Water Reactor System

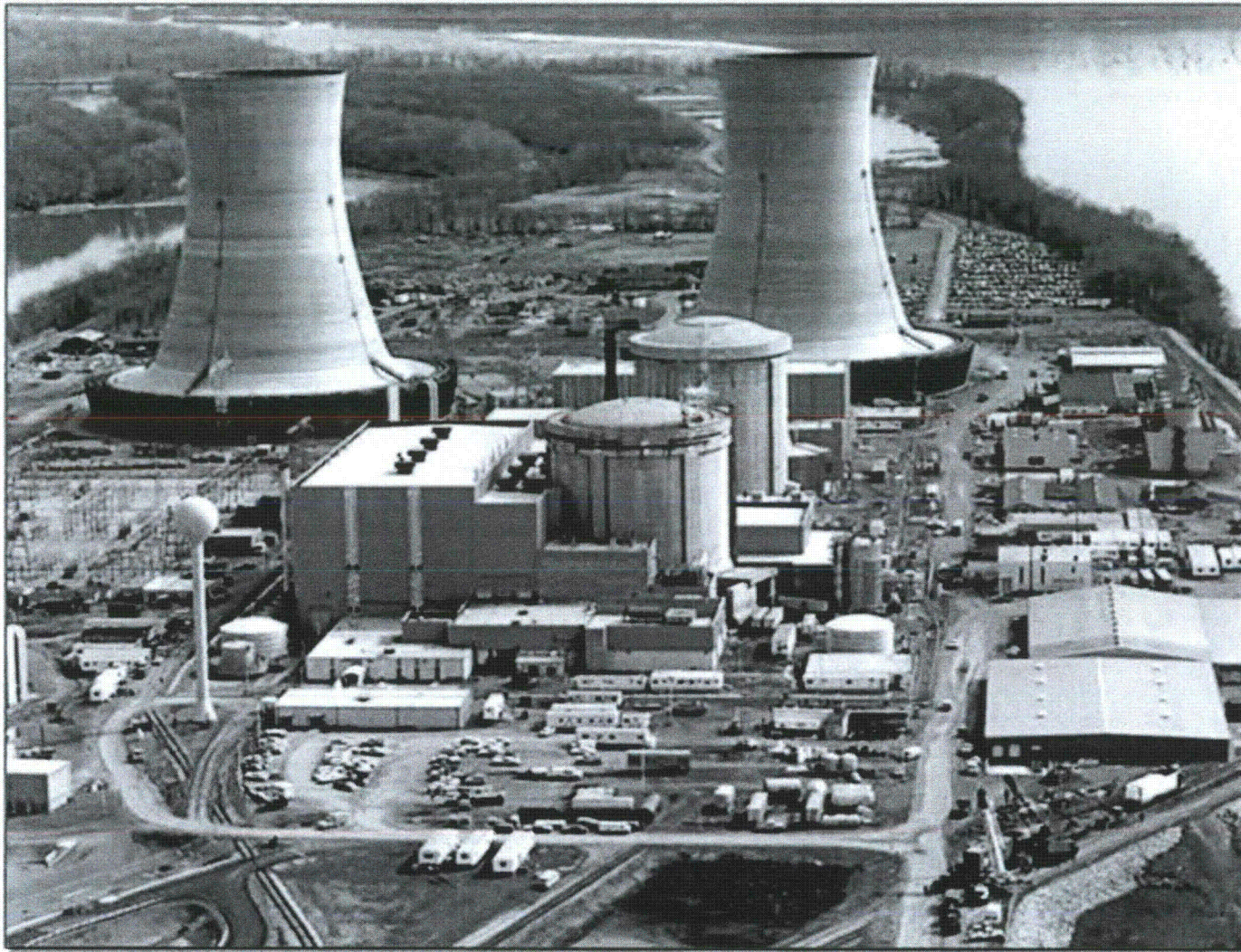


Nuclear Fuel Barriers & Heat Output



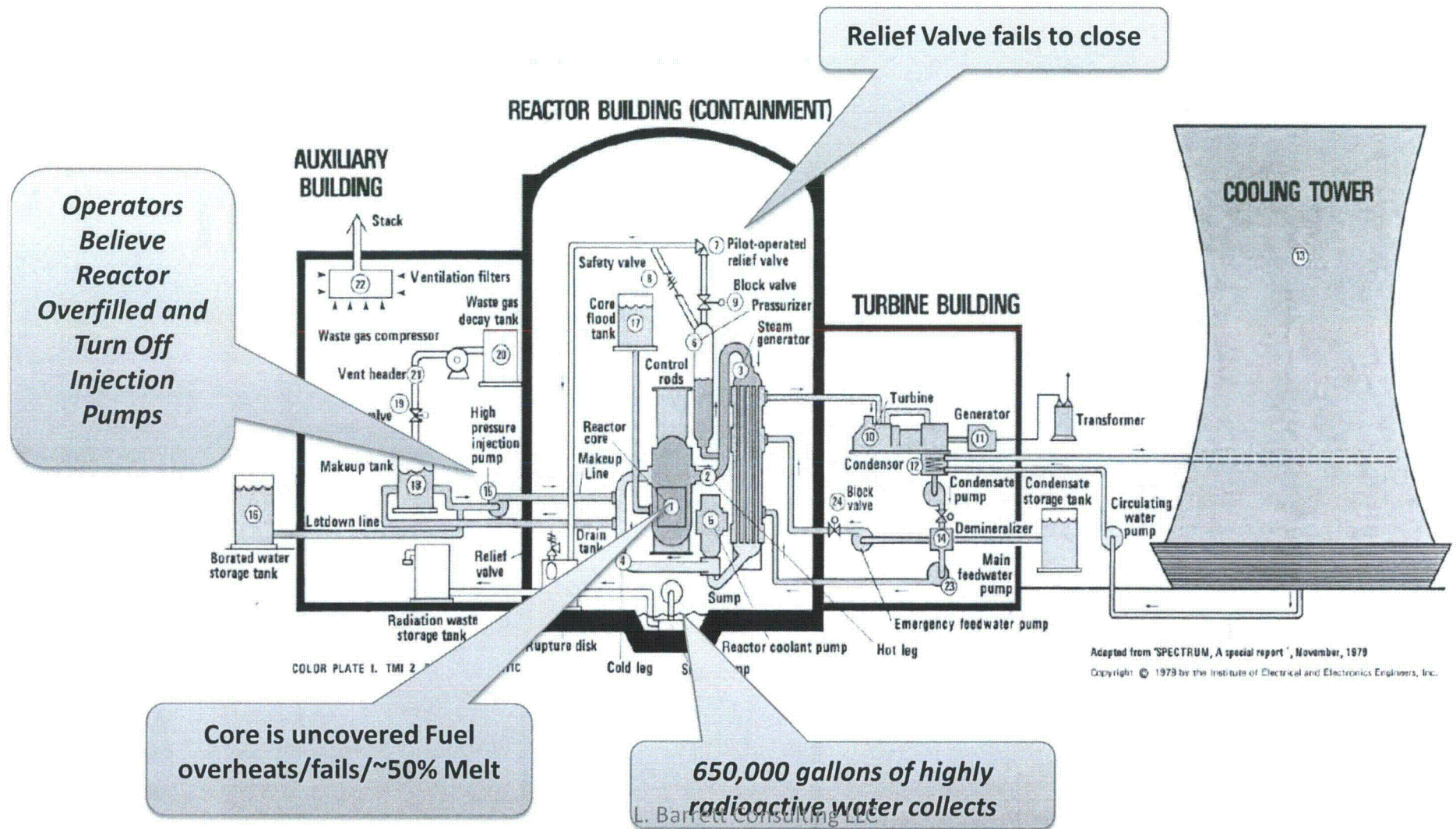
Three Mile Island Units 1 & 2

March 28, 1979

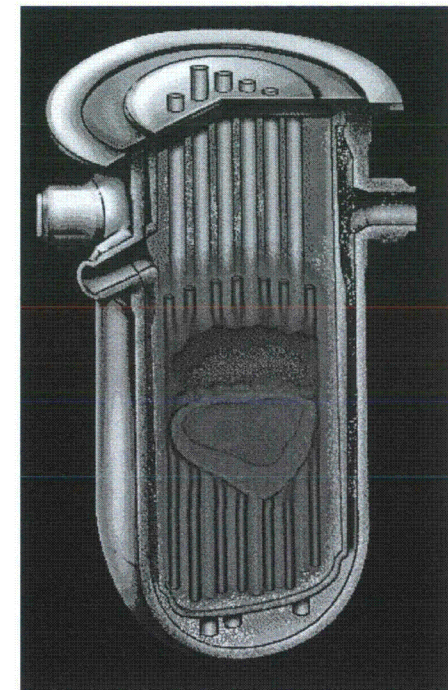
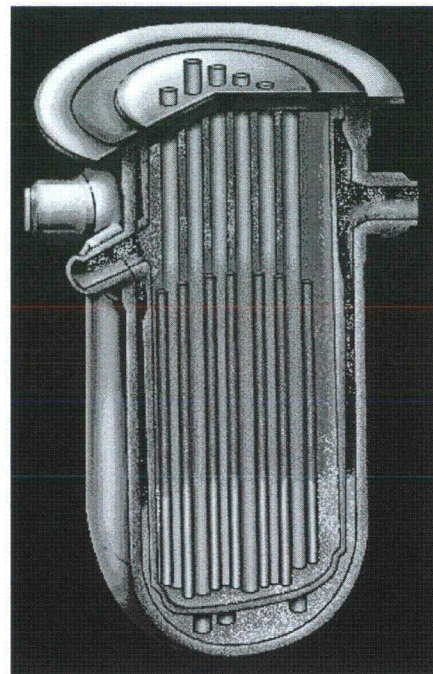
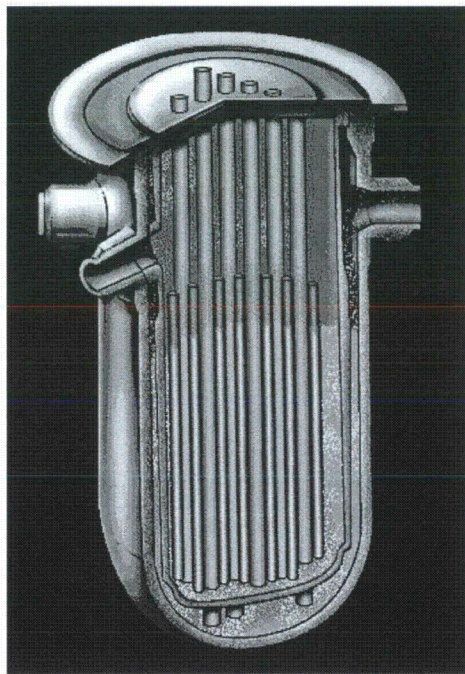


Three Mile Island Unit-2 Accident

March 28, 1979

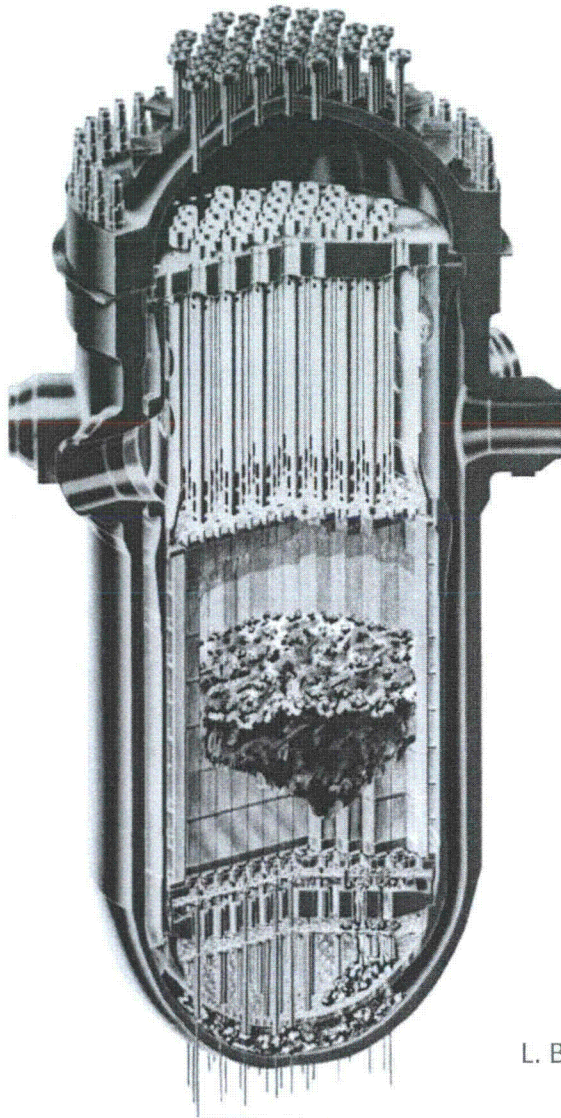


TMI Core Damage Sequence



TMI Core Configuration

~Evening 3/28/1979



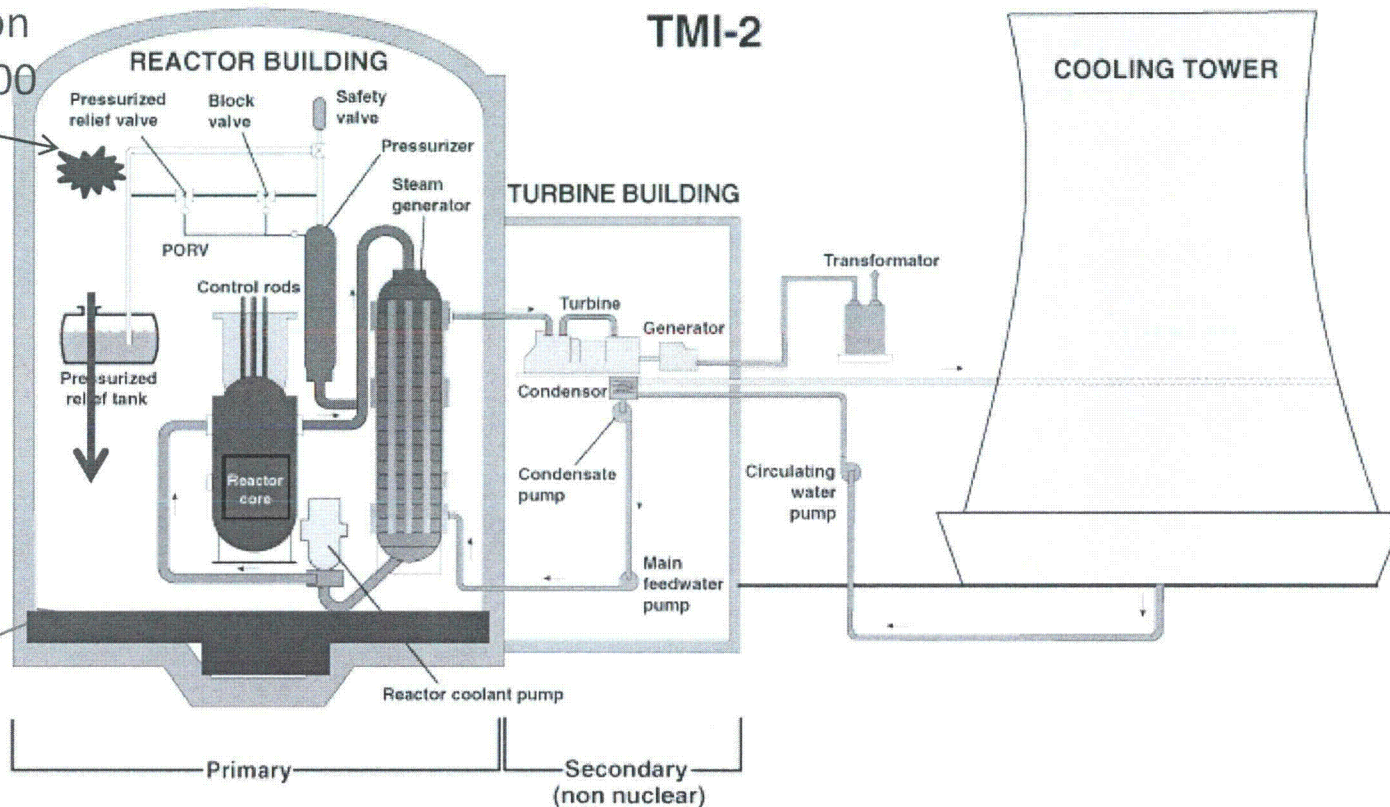
Damaged Fuel Rods

Three Mile Island

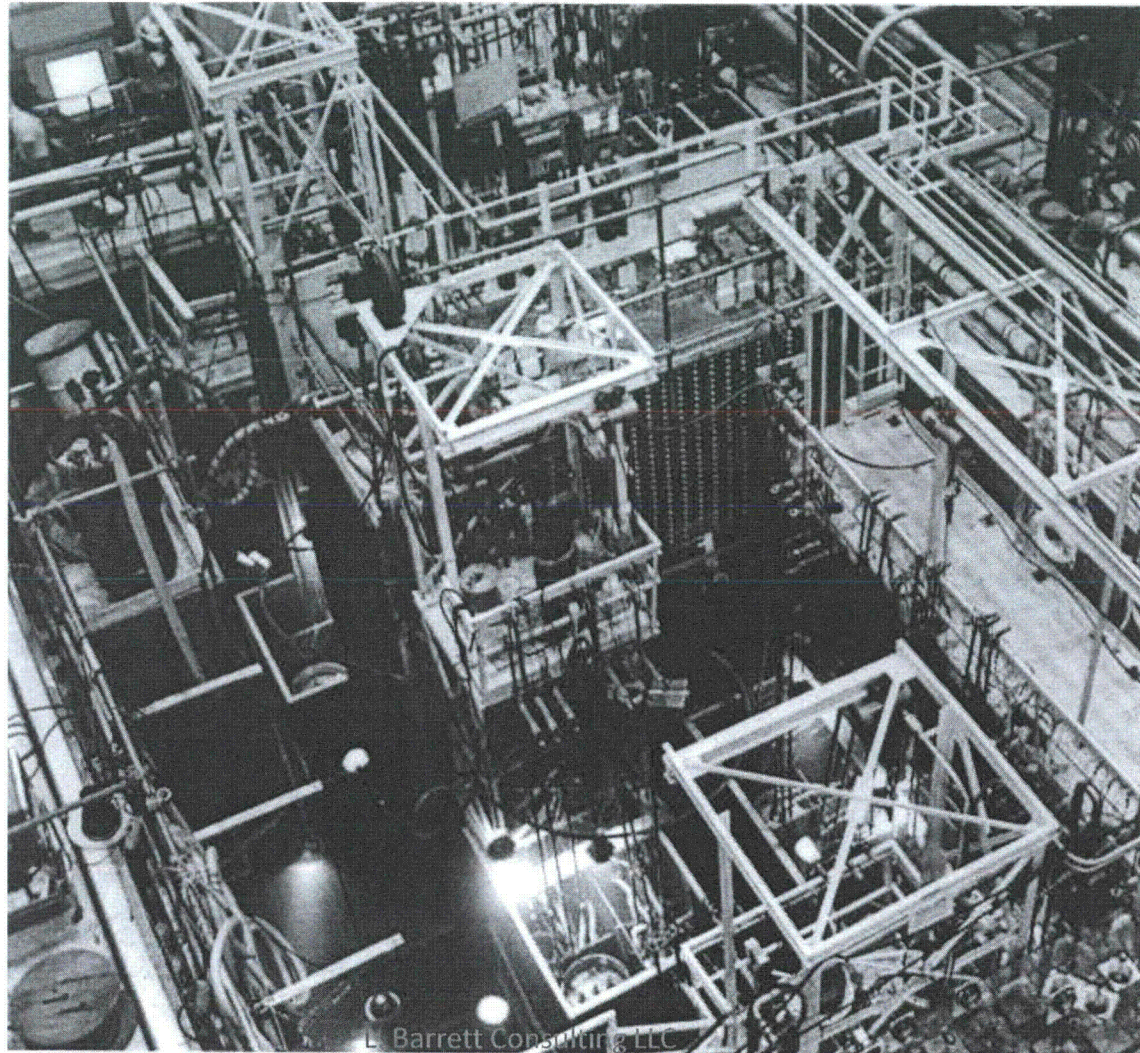
March 28, 1979

Hydrogen
Deflagration
28psig 13:00

~3M deep
water
1000R/hr
@ 2 yr



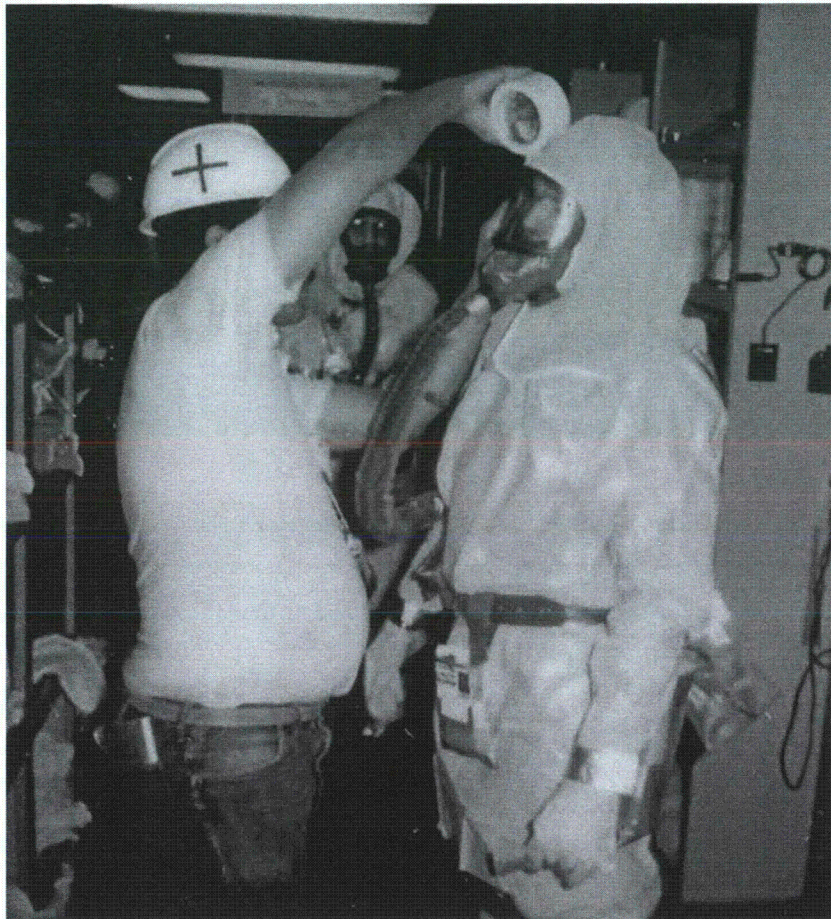
High Rad Reactor Water Cleanup System Installed in Spent Fuel Pool



L. Barrett Consulting LLC

Containment Entry Preparations

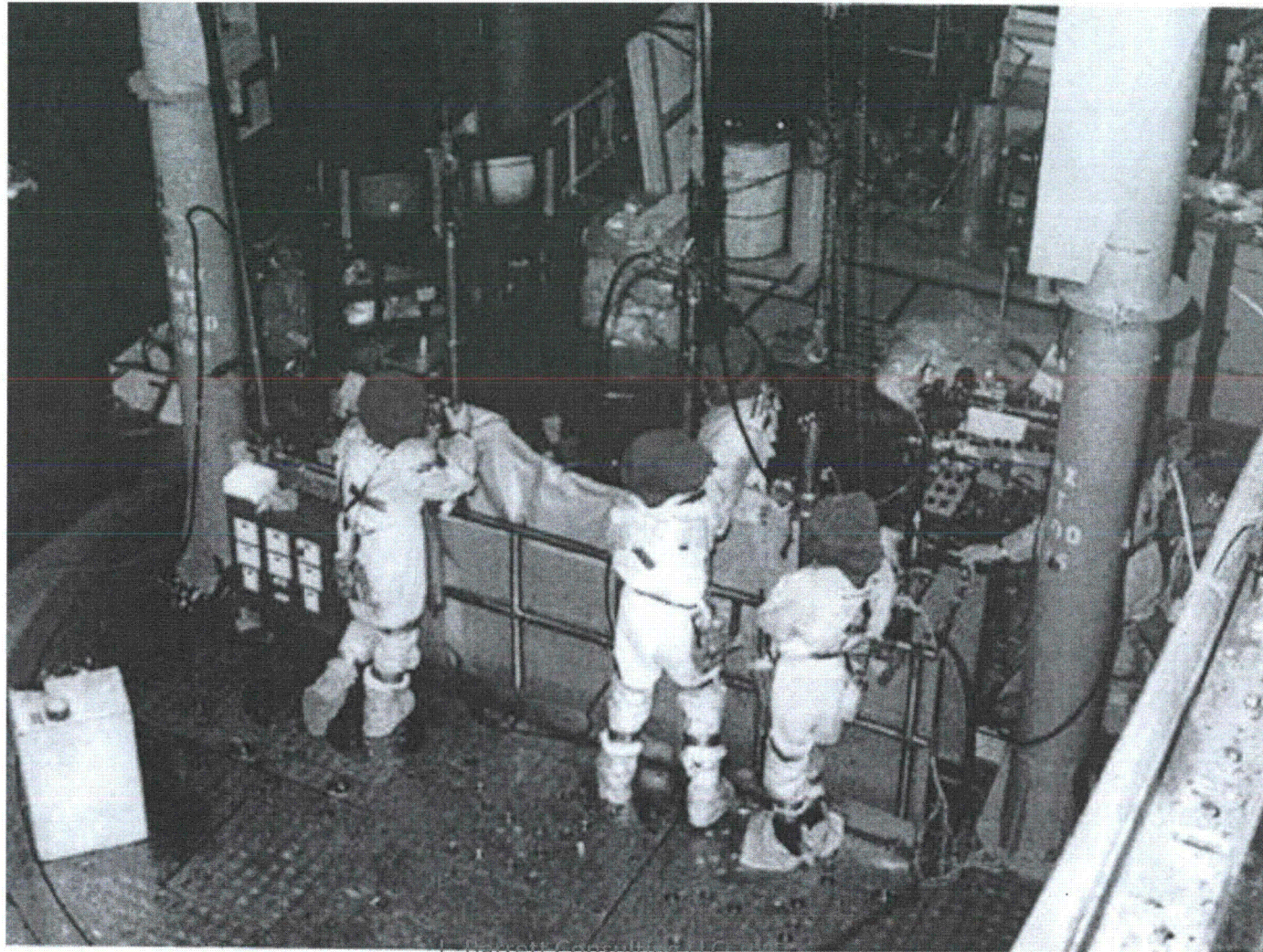
1984



Barrett Containment Entry For First Reactor Vessel Shield Block Lift

TMI Damaged Core Removal

~1985-1990

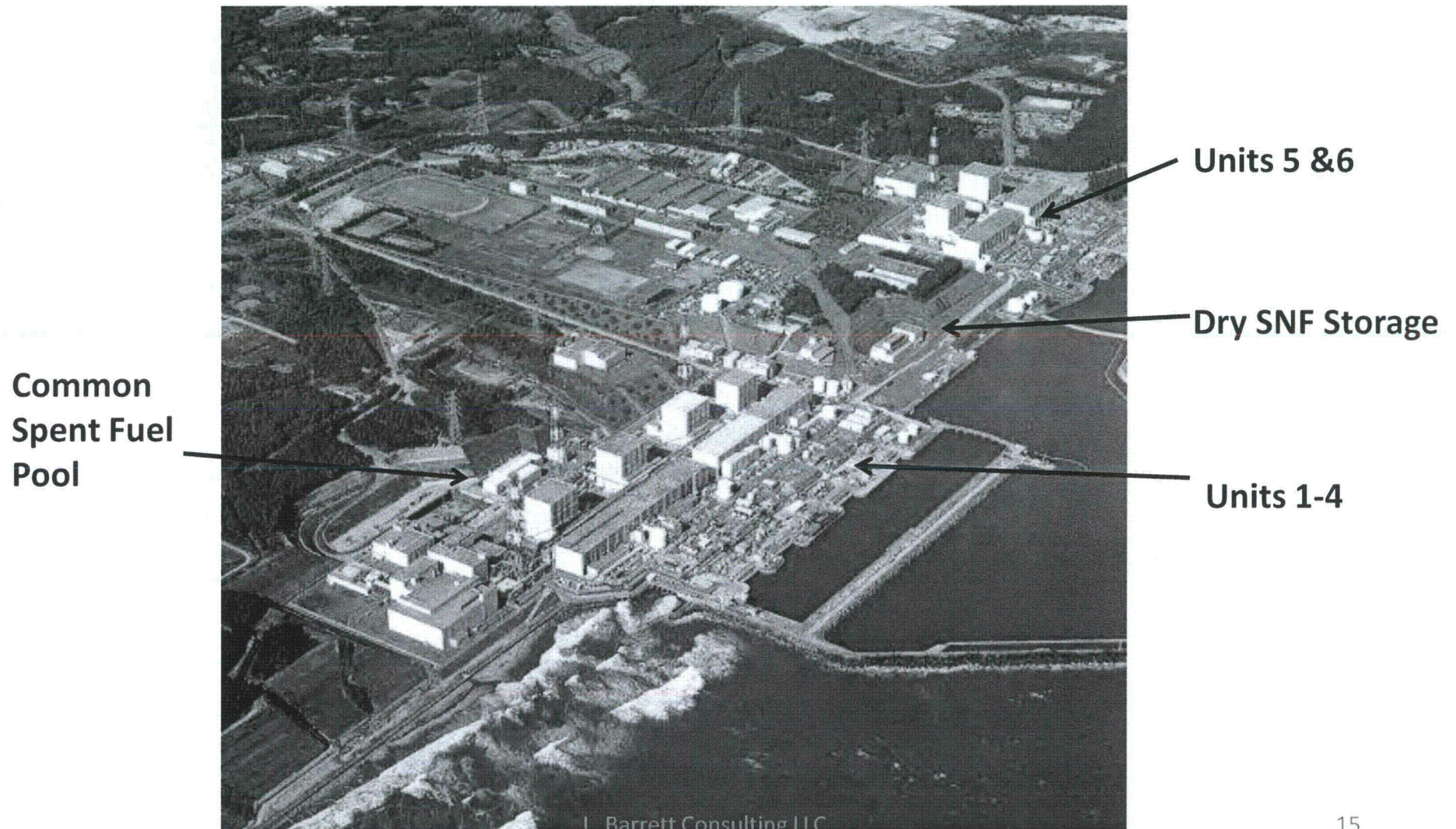


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Three Mile Island History

- Reactor Scram: 04:00 3/28/79
- Core melt and relocation: ~ 05:00 – 07:30 3/28/79
- Hydrogen Deflagration: 13:00 3/28/79
- Recirculation Cooling: Late 3/28/79
- Phased Water Processing: 1979-1993
- Containment Venting 43KCi Kr-85: July 1980
- Containment Entry: July 1980
- Reactor Head removed and core melt found: July 1984
- Start Defuel: October 1985
- Shipping Spent Fuel: 1988-1990
- Finish Defuel: Jan 1990
- Evaporate ~2.8M gallons Processed Water: 1991-93
- Cost: ~\$1 Billion

Fukushima Daiichi Nuclear Power Station



Event Initiation

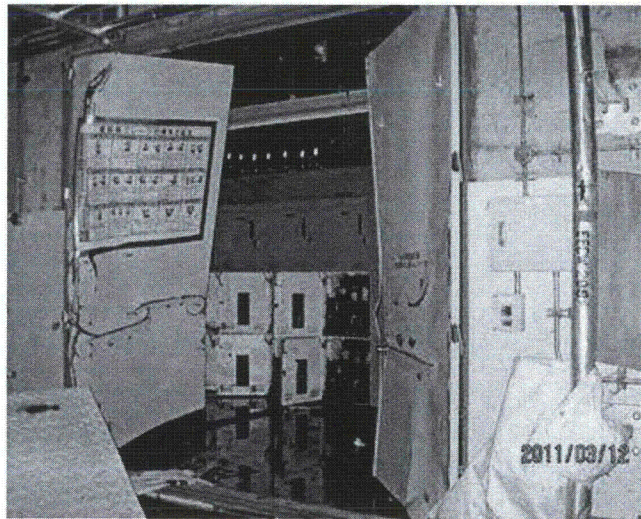
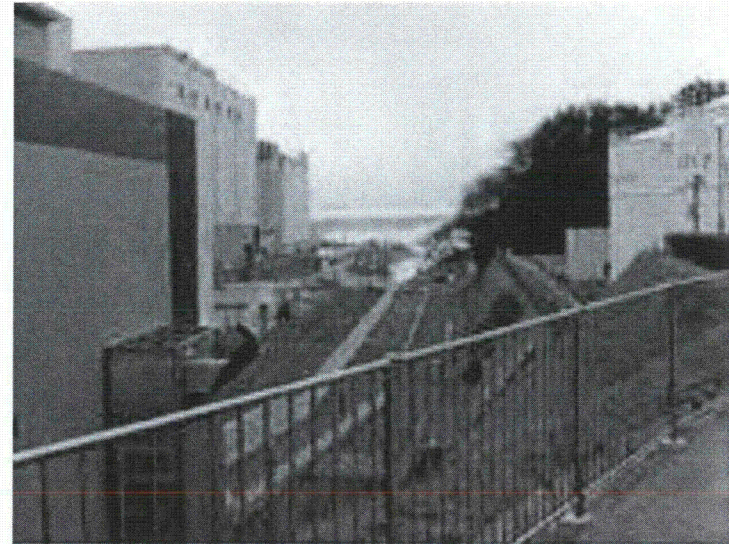
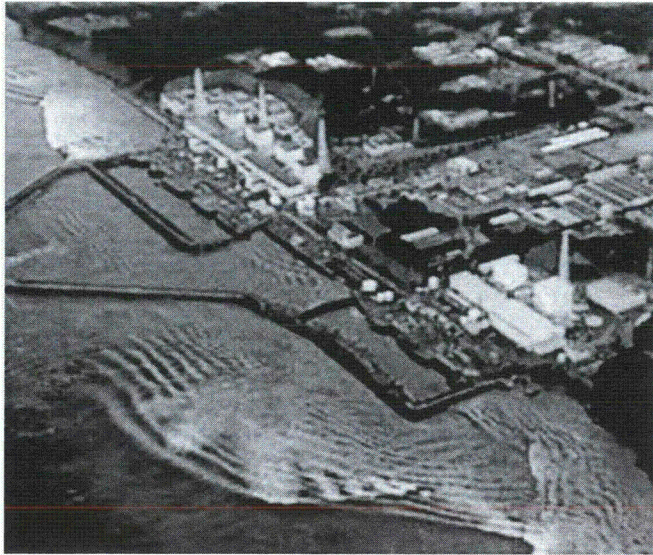
March 11, 2011

- About 14:46, a 9.0 magnitude earthquake struck (Plant design basis earthquake: 8.2)- Plant safety systems reportedly function satisfactorily.
- Units 1, 2 & 3 Scram & Unit 4 has 100 day old core offloaded into Unit 4 Spent Fuel Pool
- ~ 15:45, a tsunami 14 meters high inundated the site, whose design basis was 5.7 meters – the reactors and backup diesel power sit roughly 10 to 13 meters above sea level
- The impacts up and down the northeast coast resulted in tragic loss of 10,000+ lives, damage, and destruction of infrastructure.

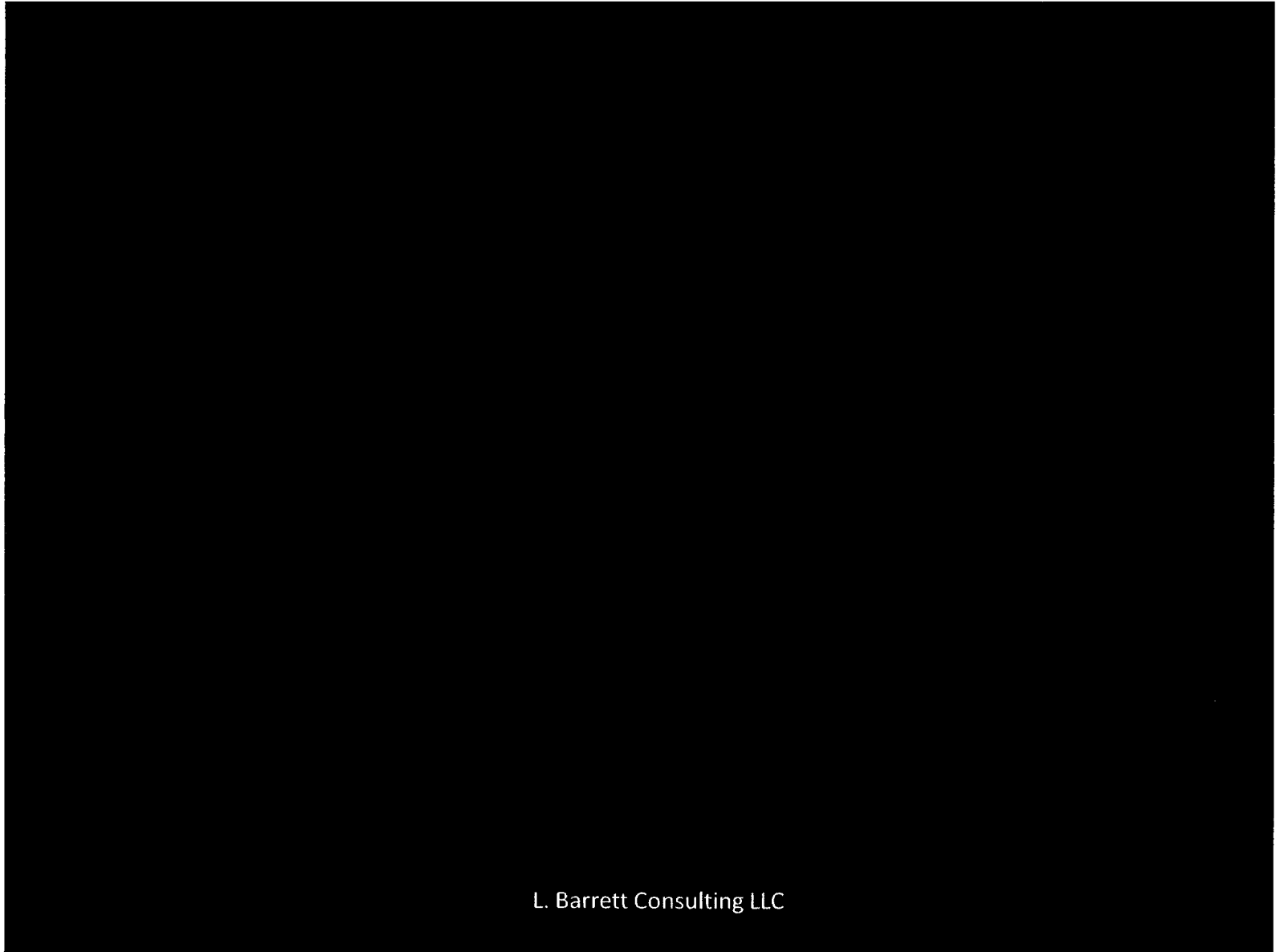


By Janet Loehrke, USA TODAY

Tsunami Waves



Wave Hitting Turbine Building

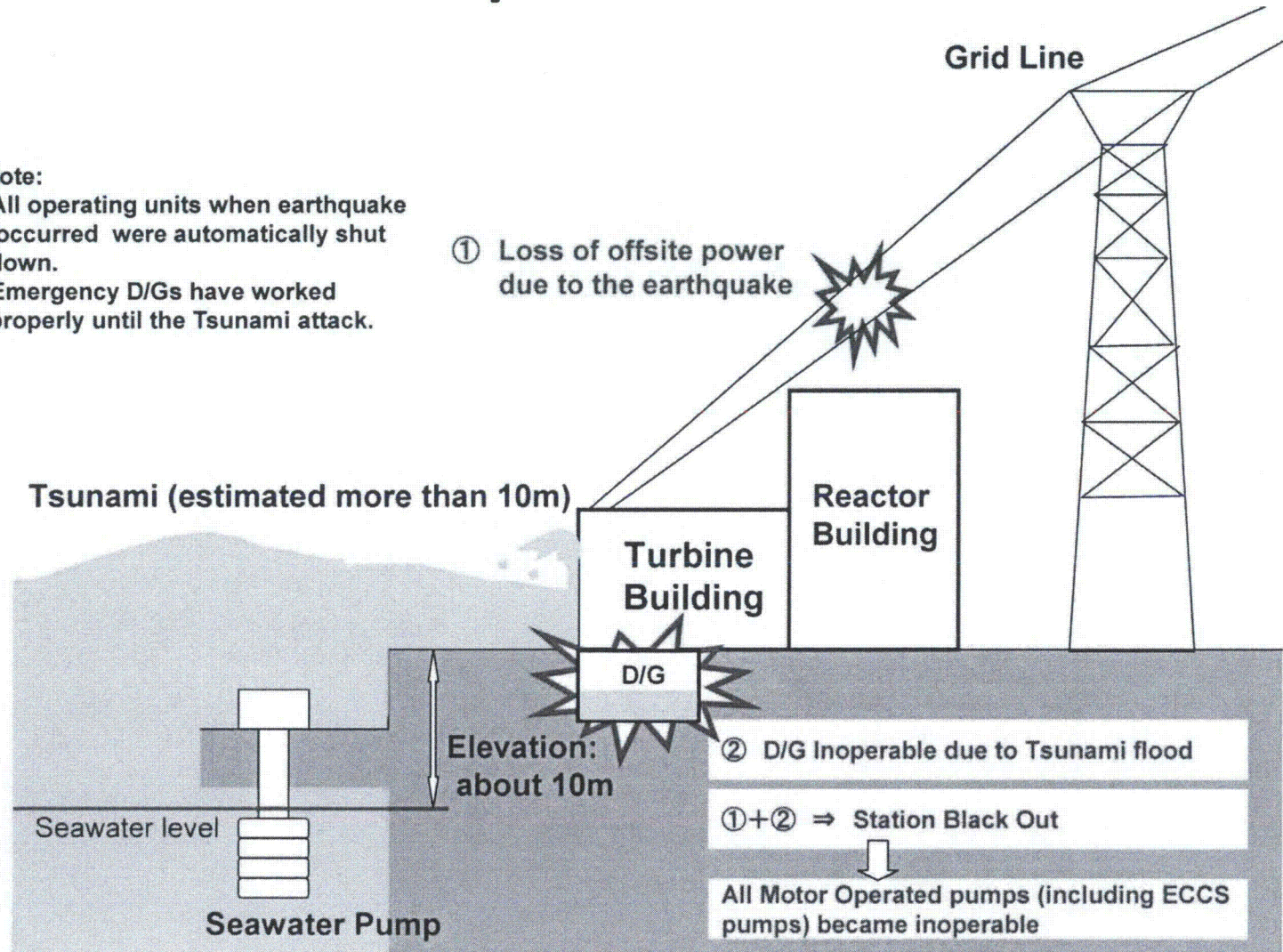


Tsunami Size Was Accident Cause

3/11 15:45

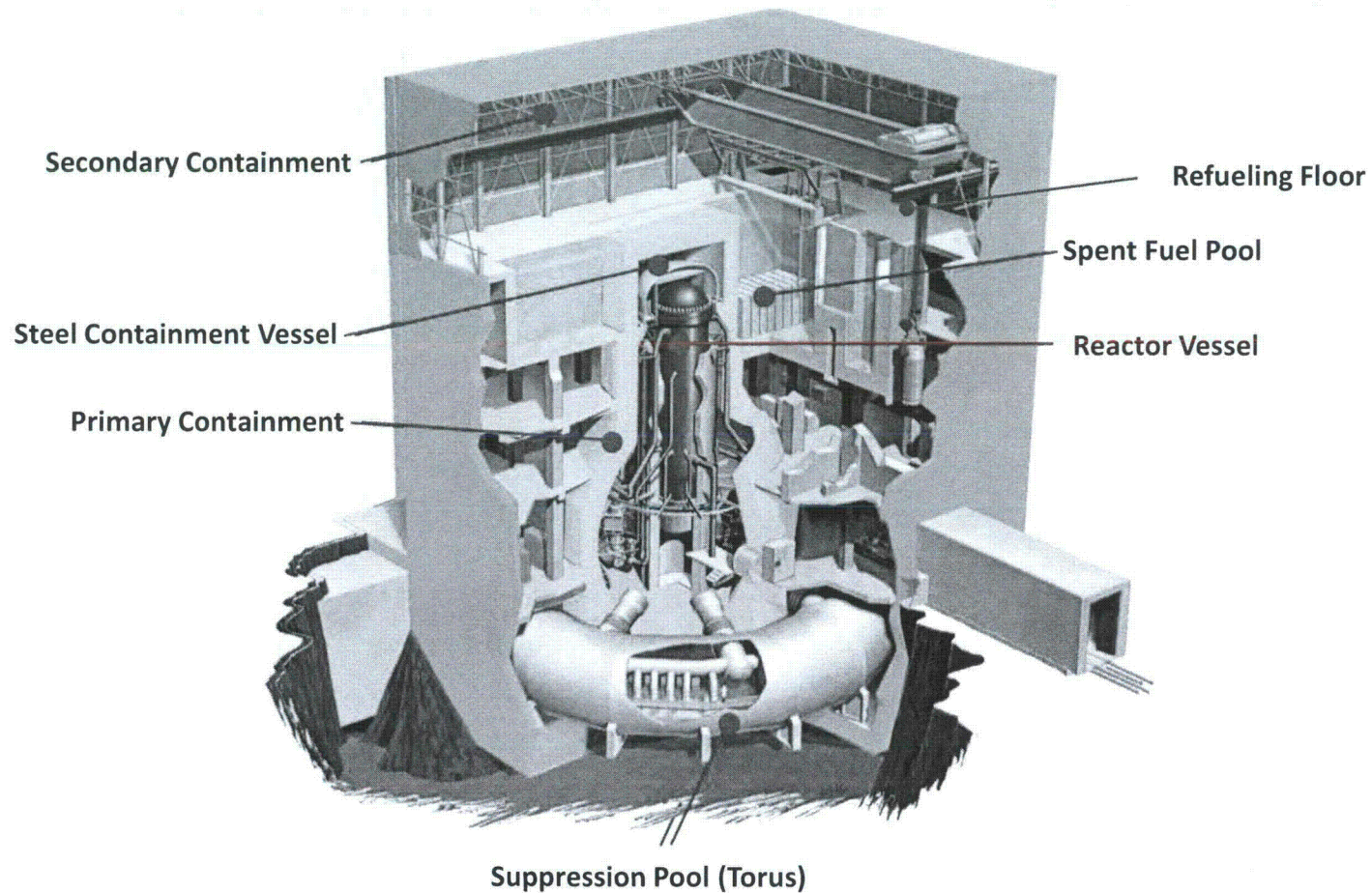
Note:

- All operating units when earthquake occurred were automatically shut down.
- Emergency D/Gs have worked properly until the Tsunami attack.

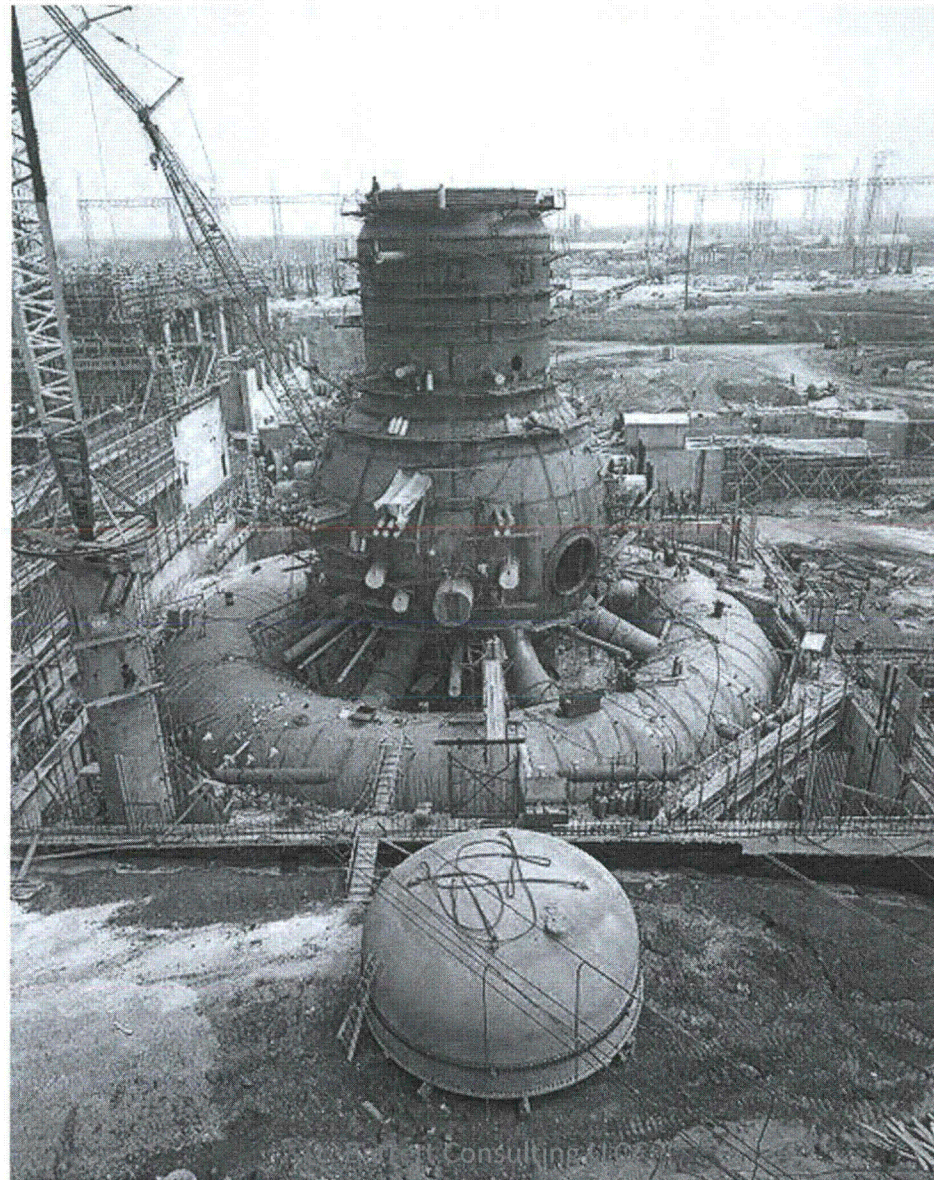


GE Mark I Reactor Building

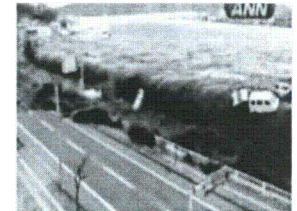
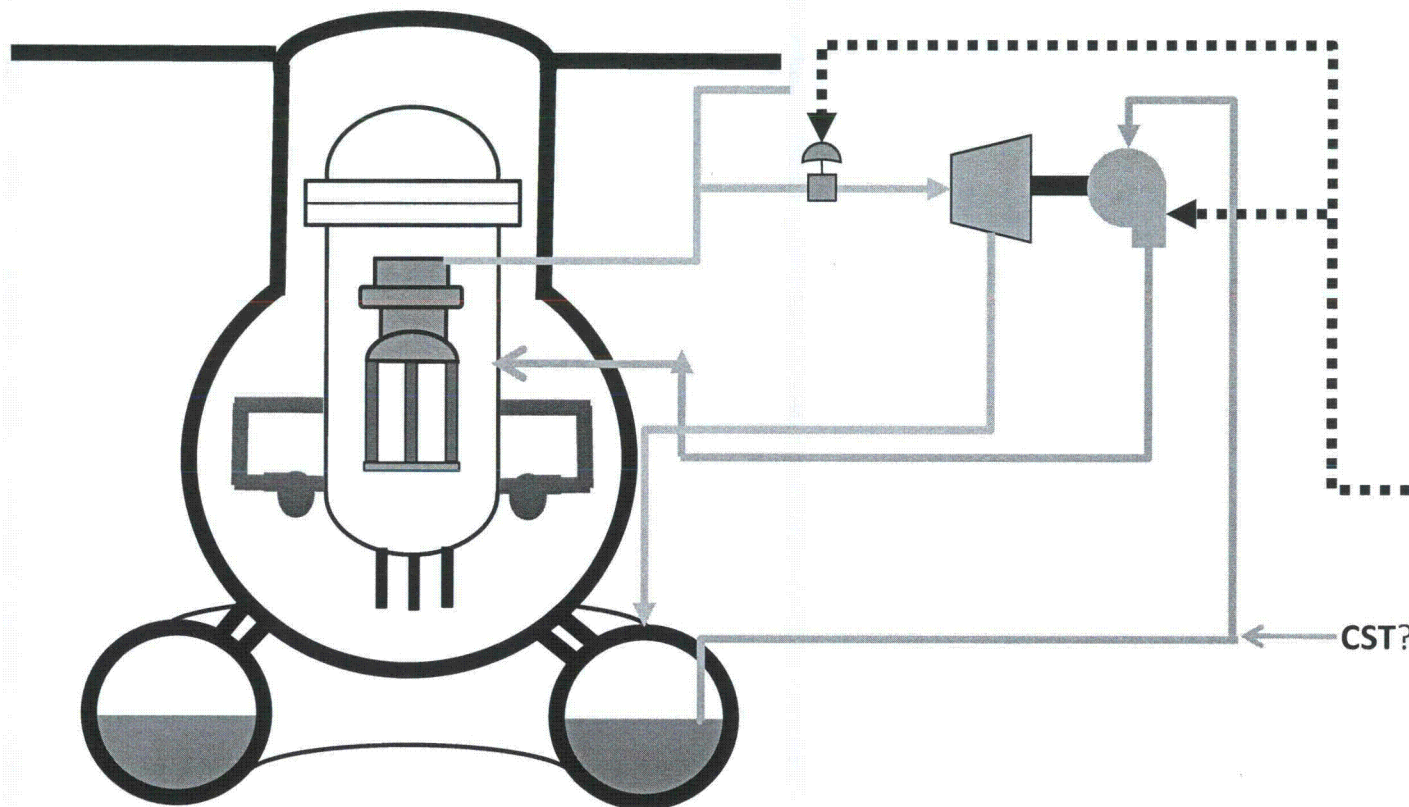
Boiling Water Reactor Design At Fukushima Daiichi



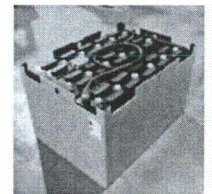
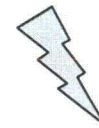
Browns Ferry Primary Containment



Battery Power Control of Steam-Driven Reactor Core Isolation Cooling System In Units 2 &3 (Unit 1 Had Isolation Condenser which Boiled Dry)



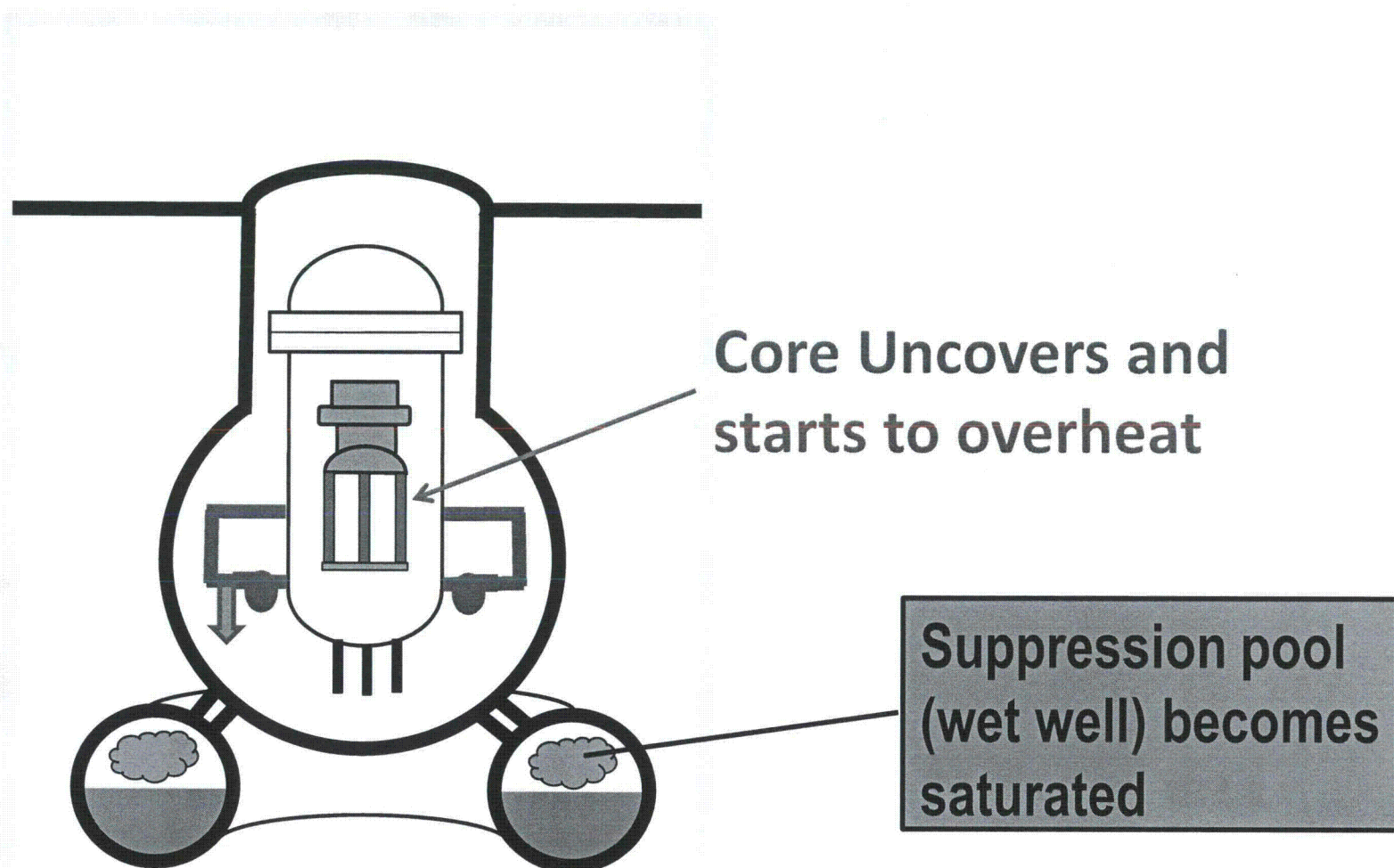
3/11 15:45 JST



CST?

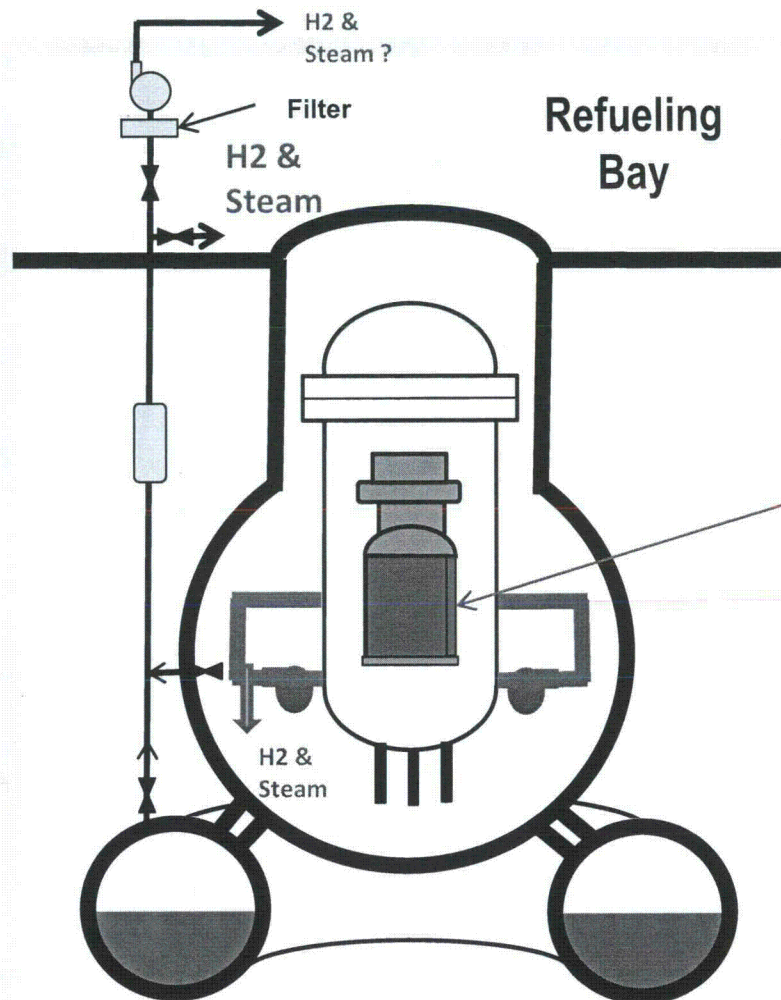
3/11 15:45 to ~ 3/11
24:00 JST

Battery Power Exhausted



3/12 ~02:00 JST

Venting Primary Containment



**Core
Overheated**

**Primary Containment Pressure~
90psia @02:00 3/12**

3/12 ~05:30 U1

3/13 ~ 00:00 U2

3/13 ~ 08:40 U3

U

Unit 1 Explosion

3/12 15:31



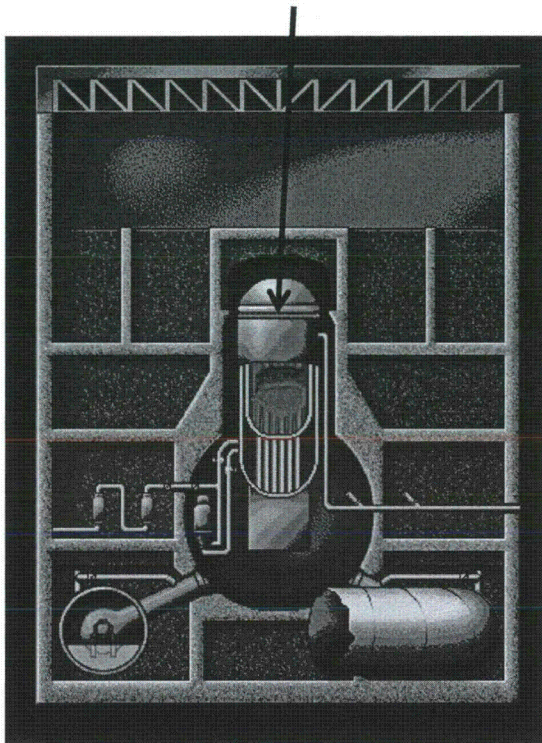
Unit 3 Reactor Building Explosion

3/14 11:15



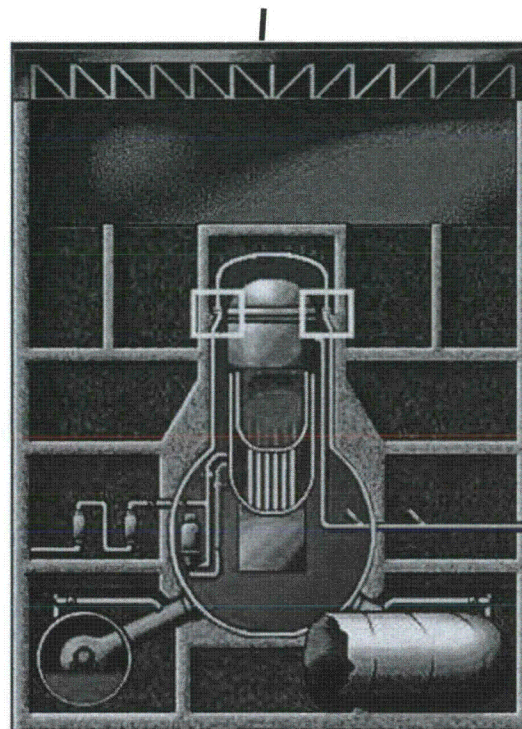
Fukushima: Reactor Vessel-Primary-Secondary Containment Sequence

Primary Coolant System



Core Over Heat
 -Clad Burst ~900C
 -Clad Oxidize ~1200C
 -H₂ Release
 -Partial Melt~1800C-2700C
 -Primary Coolant System
 Overpressure

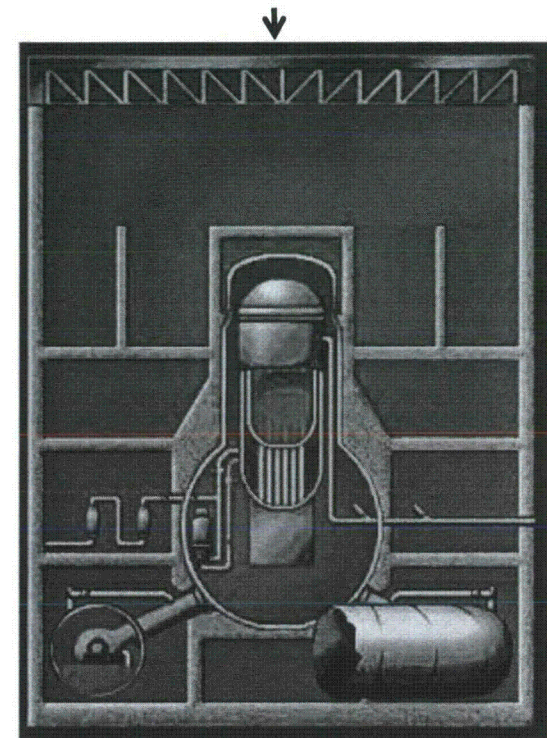
Primary Containment



Vent from Primary
 Coolant Sys to Primary
 Containment- H₂,
 Steam, & Fission
 Products (Xe, Kr, I, Cs
 etc)

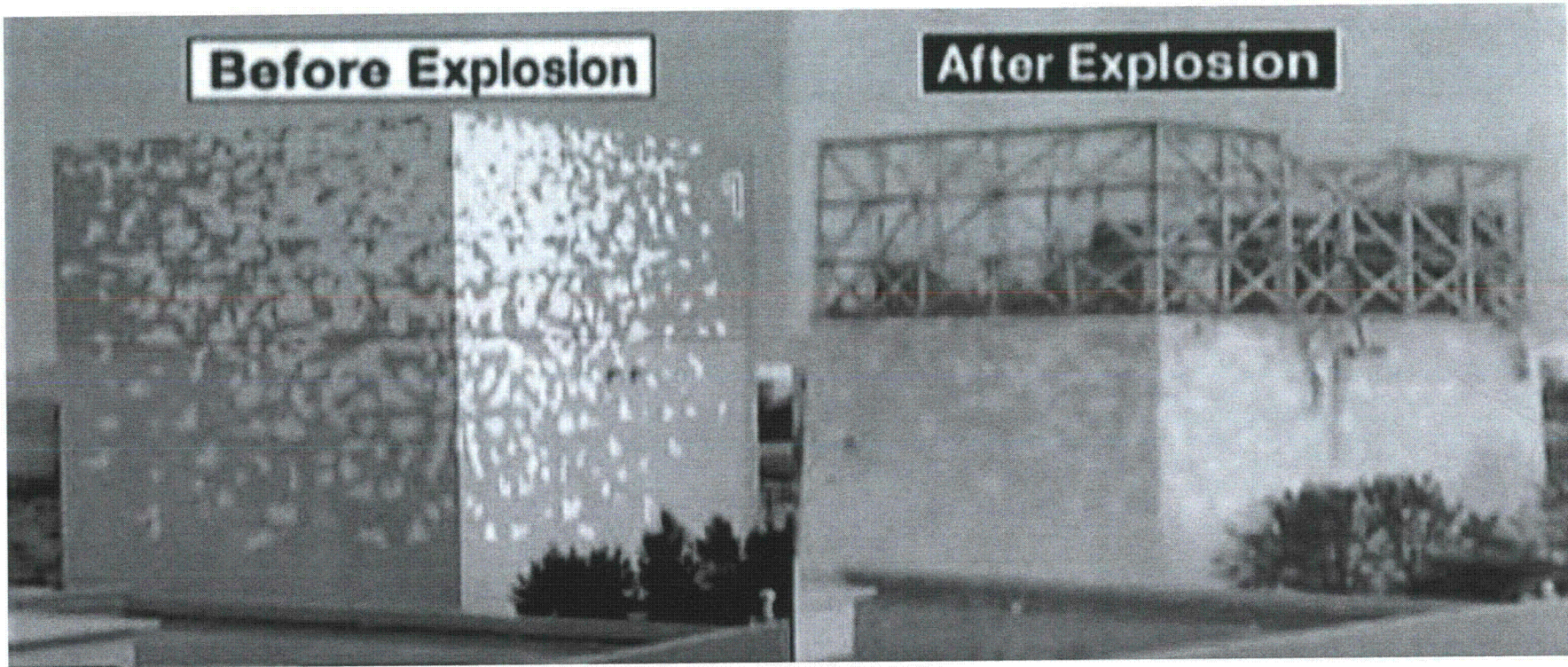
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Secondary Containment



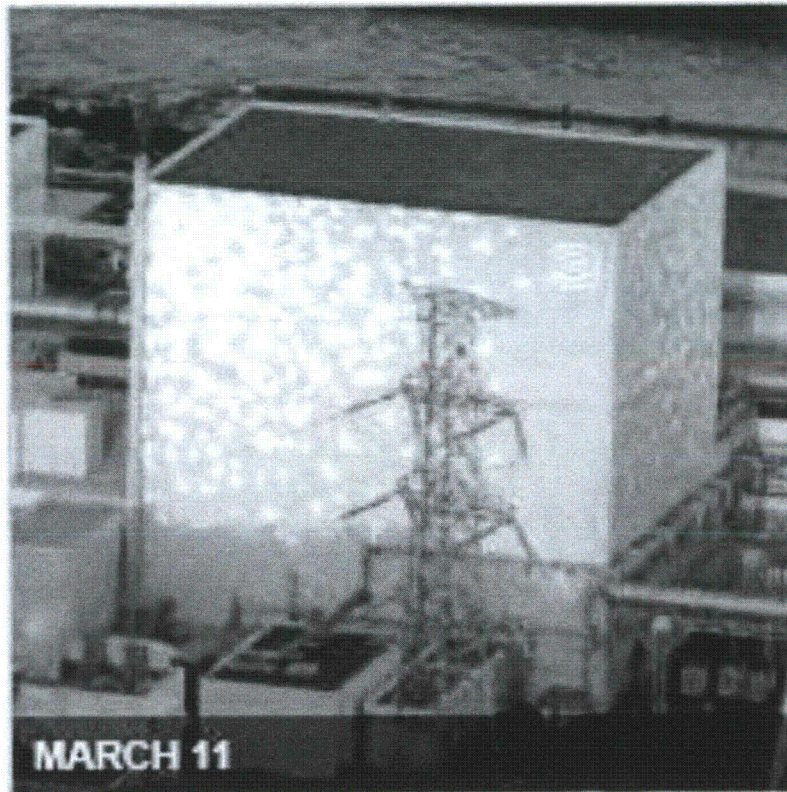
No Primary Containment
 Cooling therefore Primary
 Containment Overpressure-
 Vent to Secondary
 Containment

Unit 1 Reactor Building



Unit 3 Reactor Building

Before



Reuters

After



TEPCO

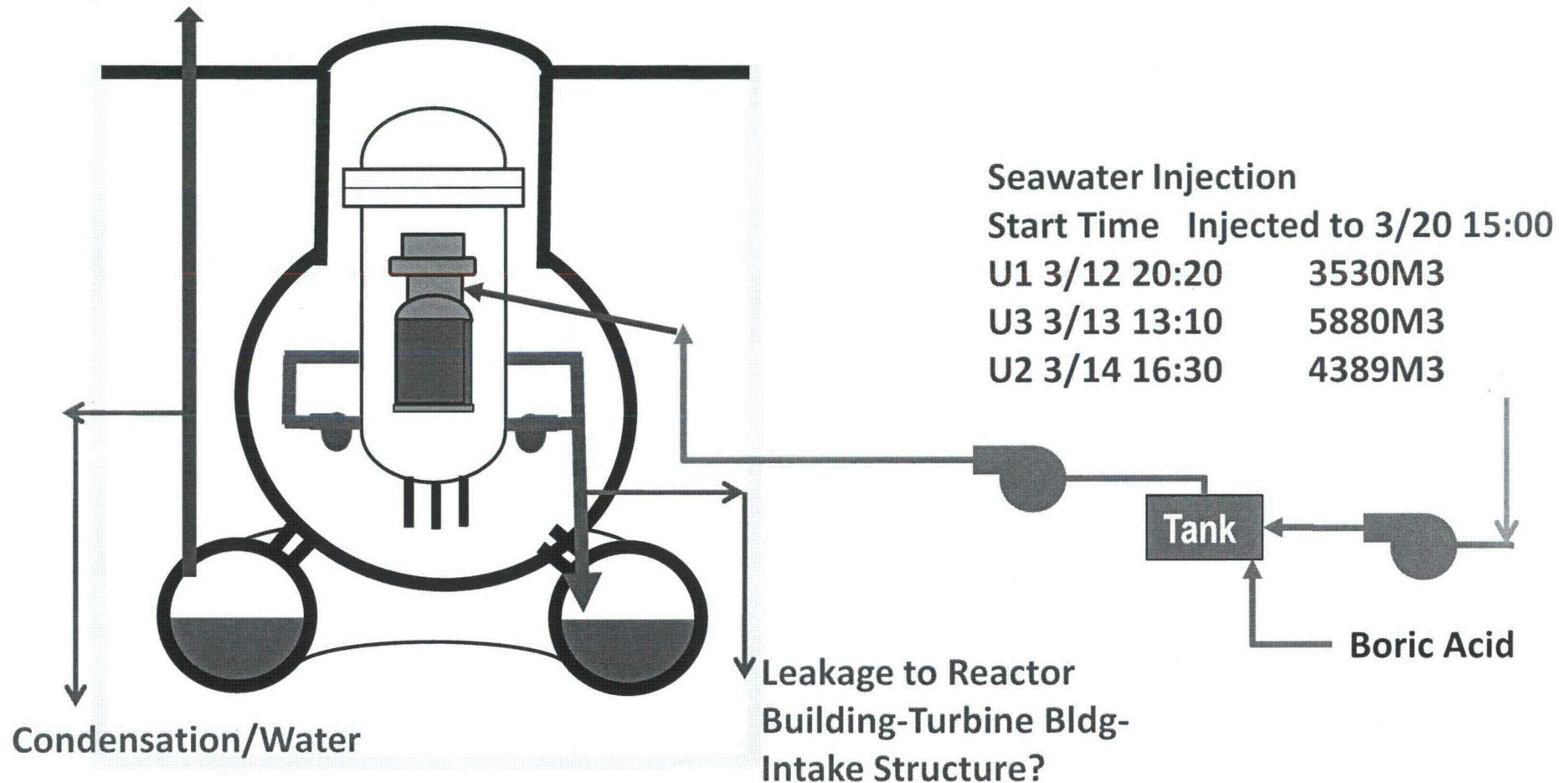
Bleed & Feed Core Cooling Established

Seawater Injection Started Using Fire Engine Pump

Shift to Fresh Water Injection ~3/26-Present: To Dissolve

Vapor Venting

Possible Salt Cakes



Immediately After Unit 3 Explosion

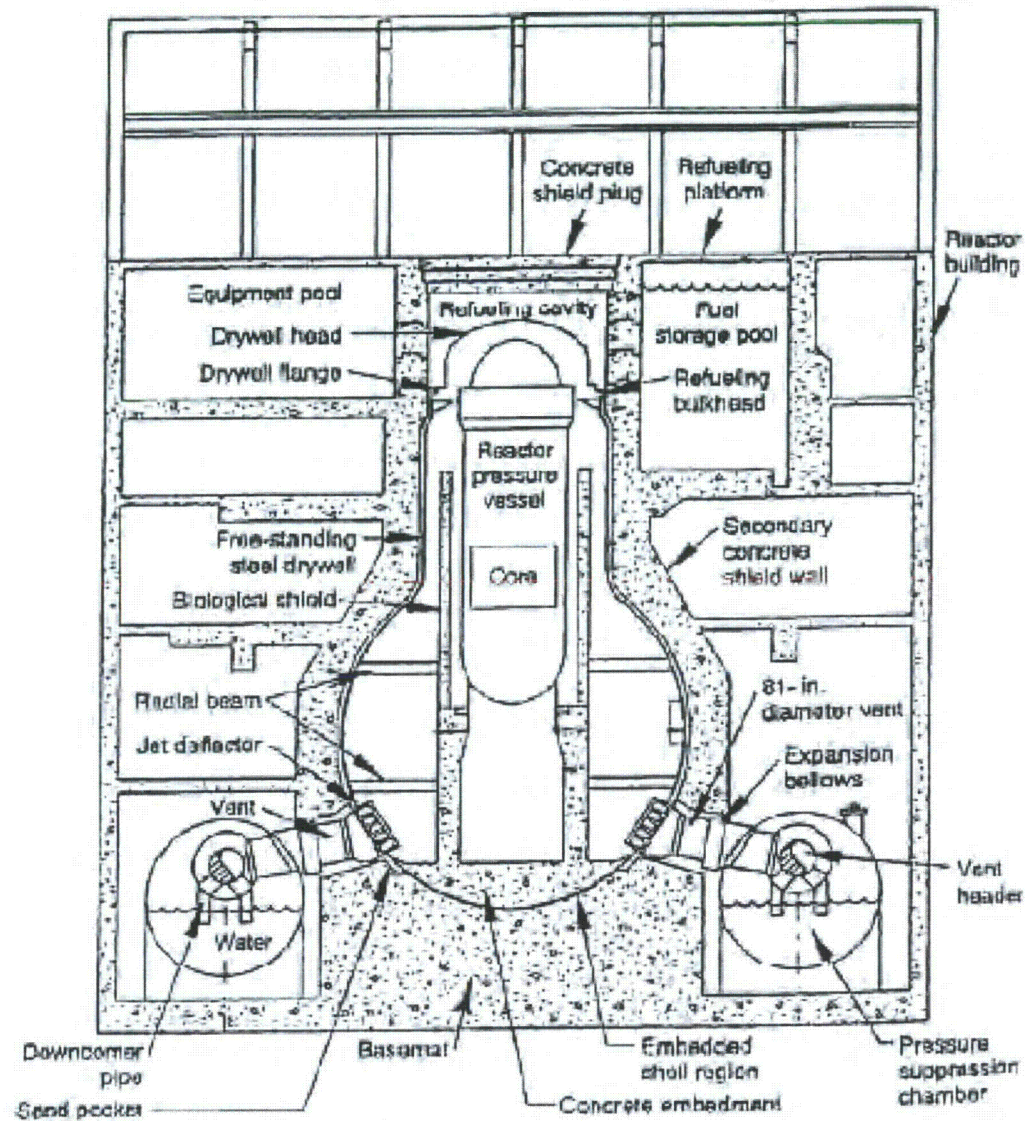
3/14/11 ~10:00AM JST



Post Unit 3 & Pre Unit 4 Explosion(s)

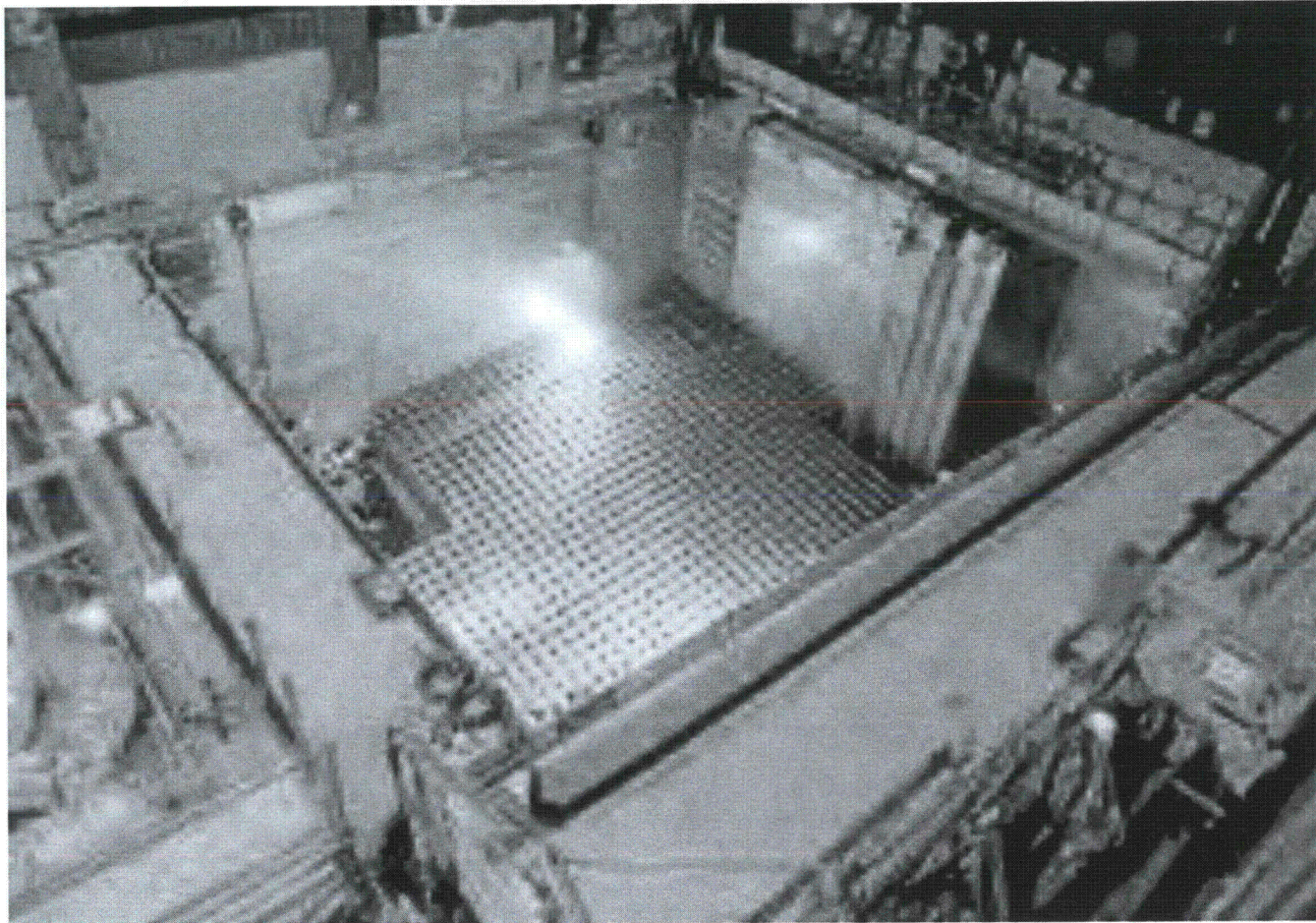


Reactor Building Cross Section

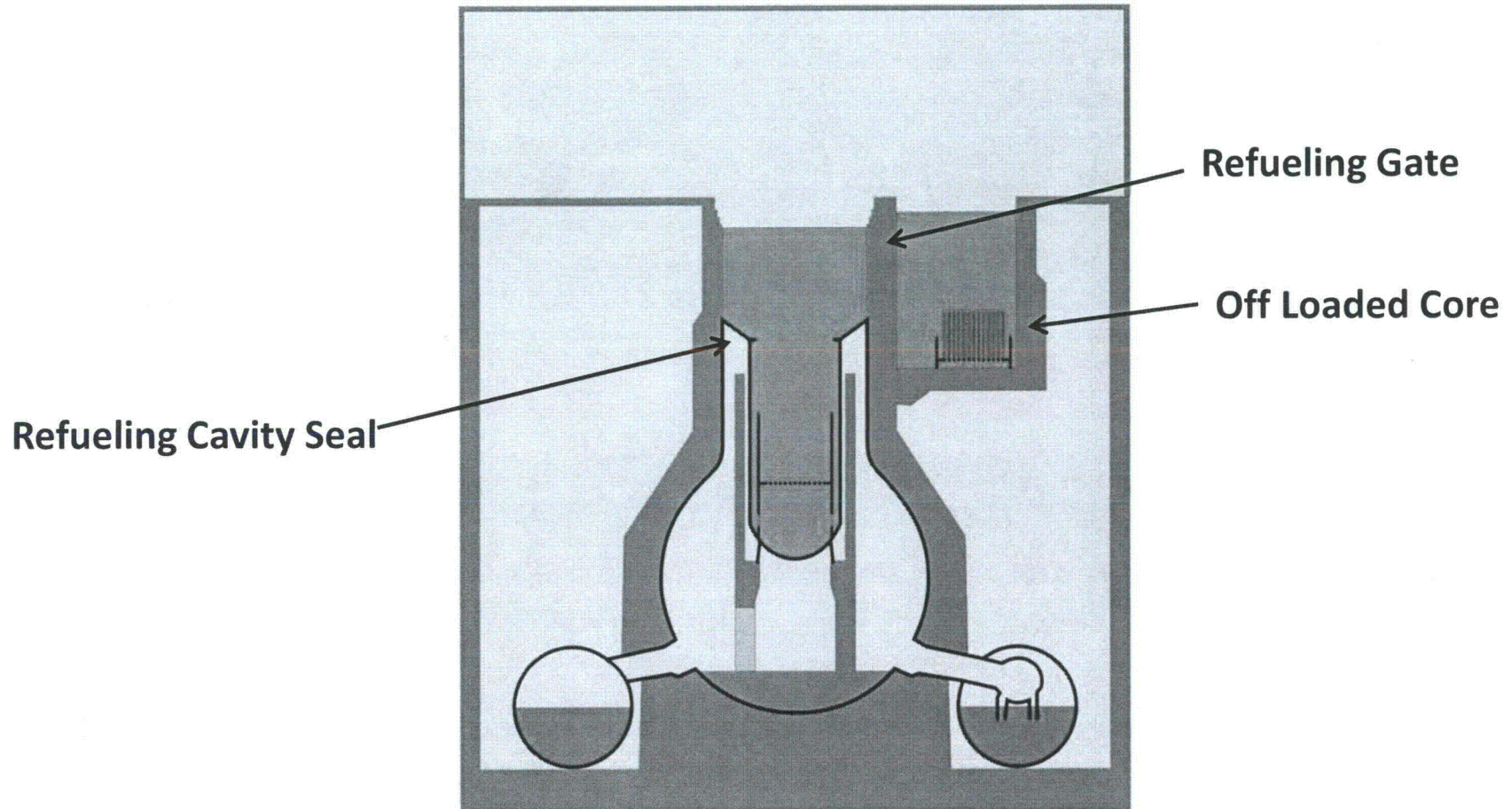


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Figure 20. Mark I General Electric, GE BWR Containment.

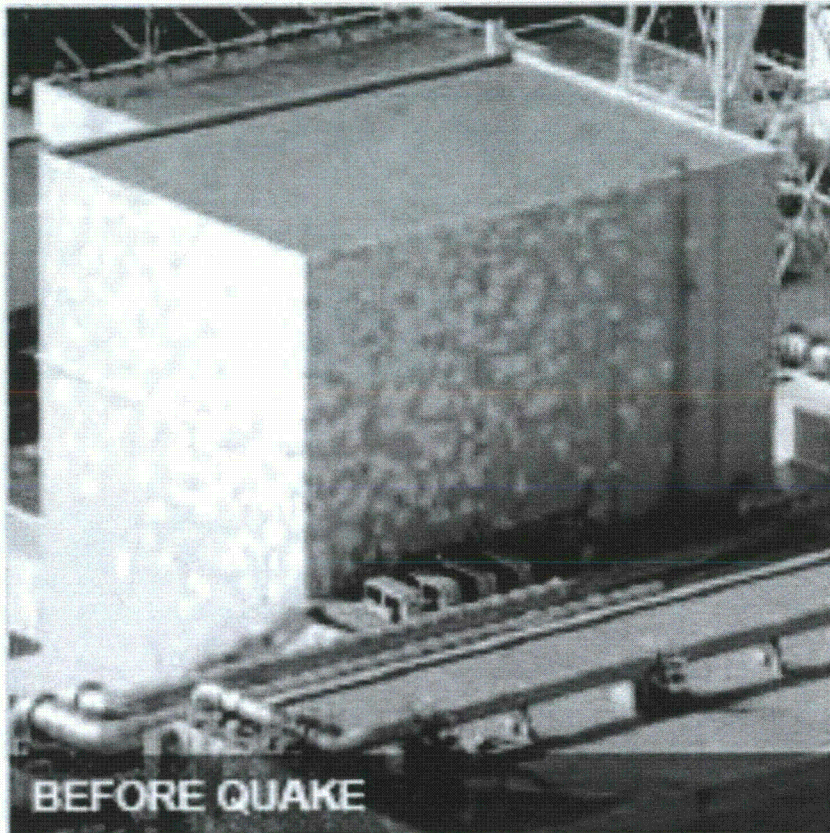
Empty Spent Fuel Pool



Unit 4 Refueling Configuration?



Unit 4 Reactor Building

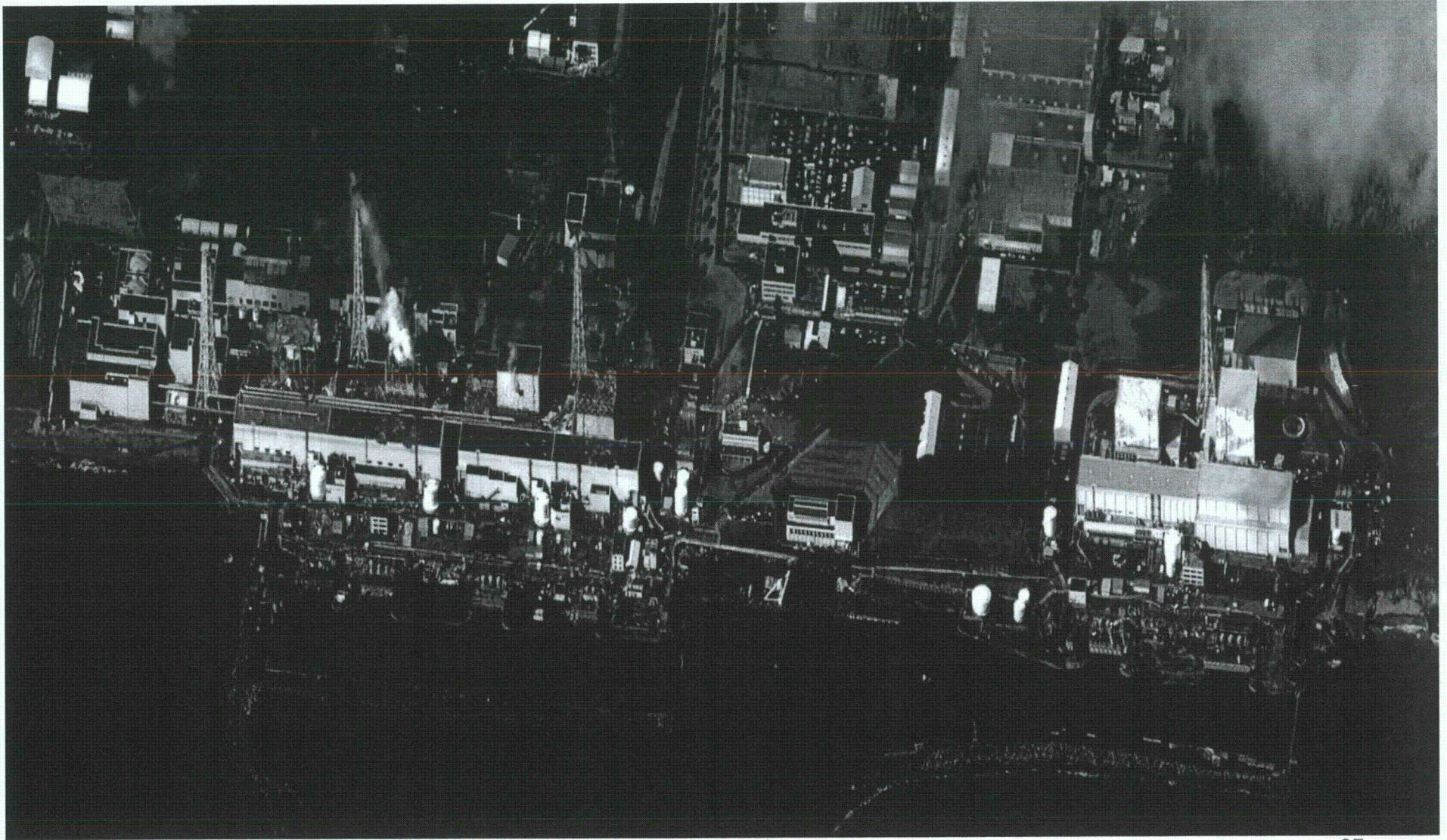


Reuters



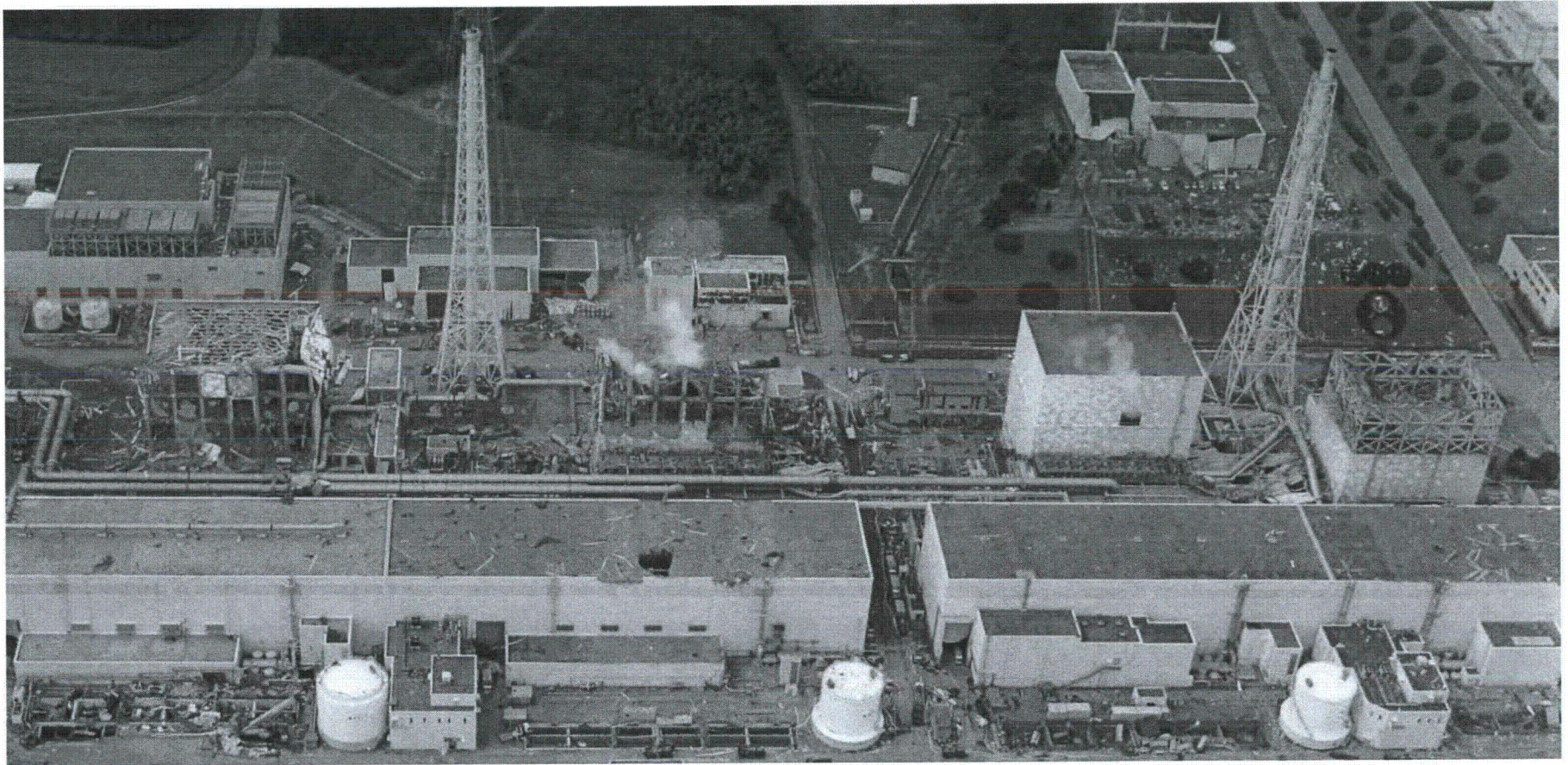
TEPCO

Units 1-6 After U4 Spent Fuel Pool Explosion

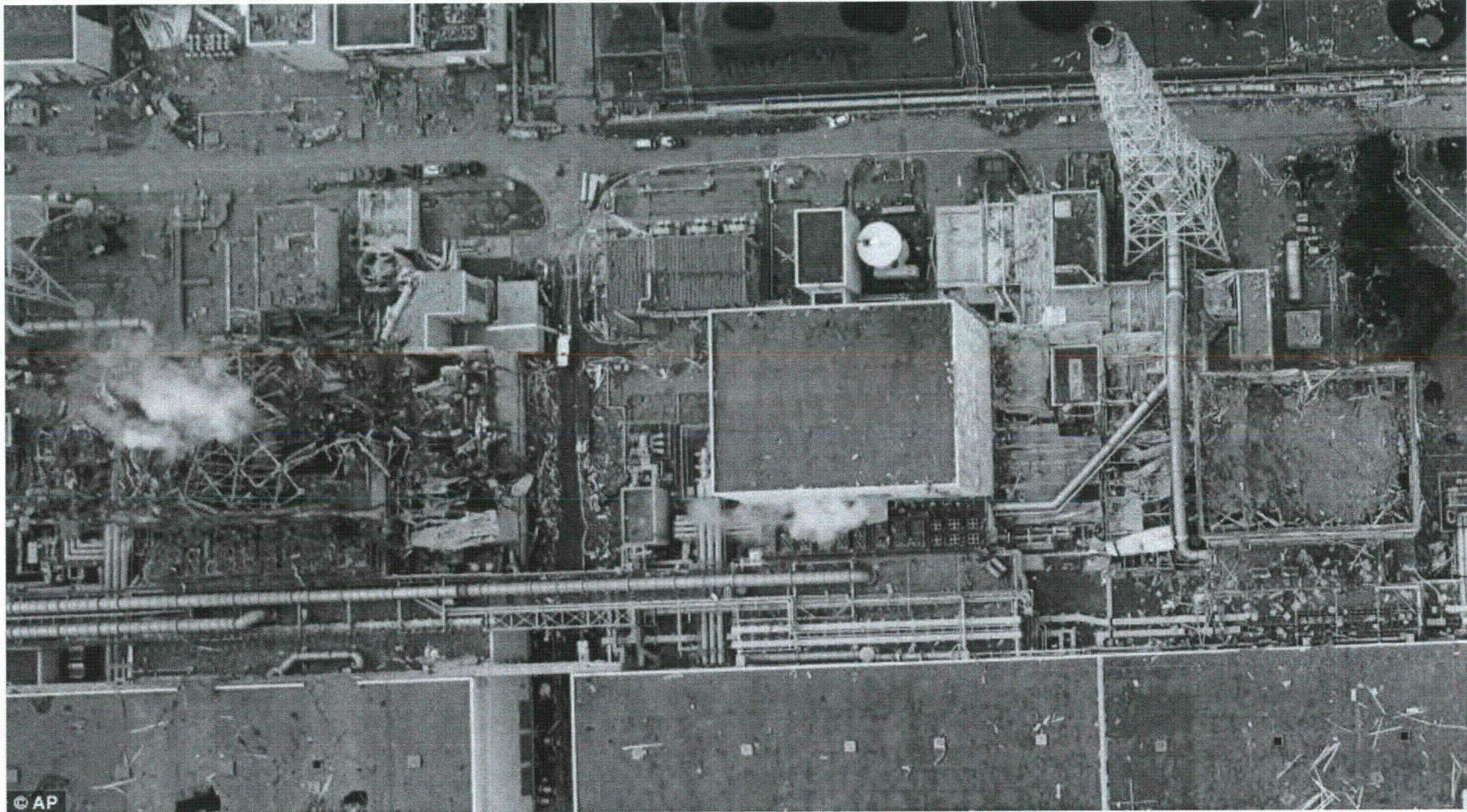


Units 1-4 After U4 Spent Fuel Pool Explosion

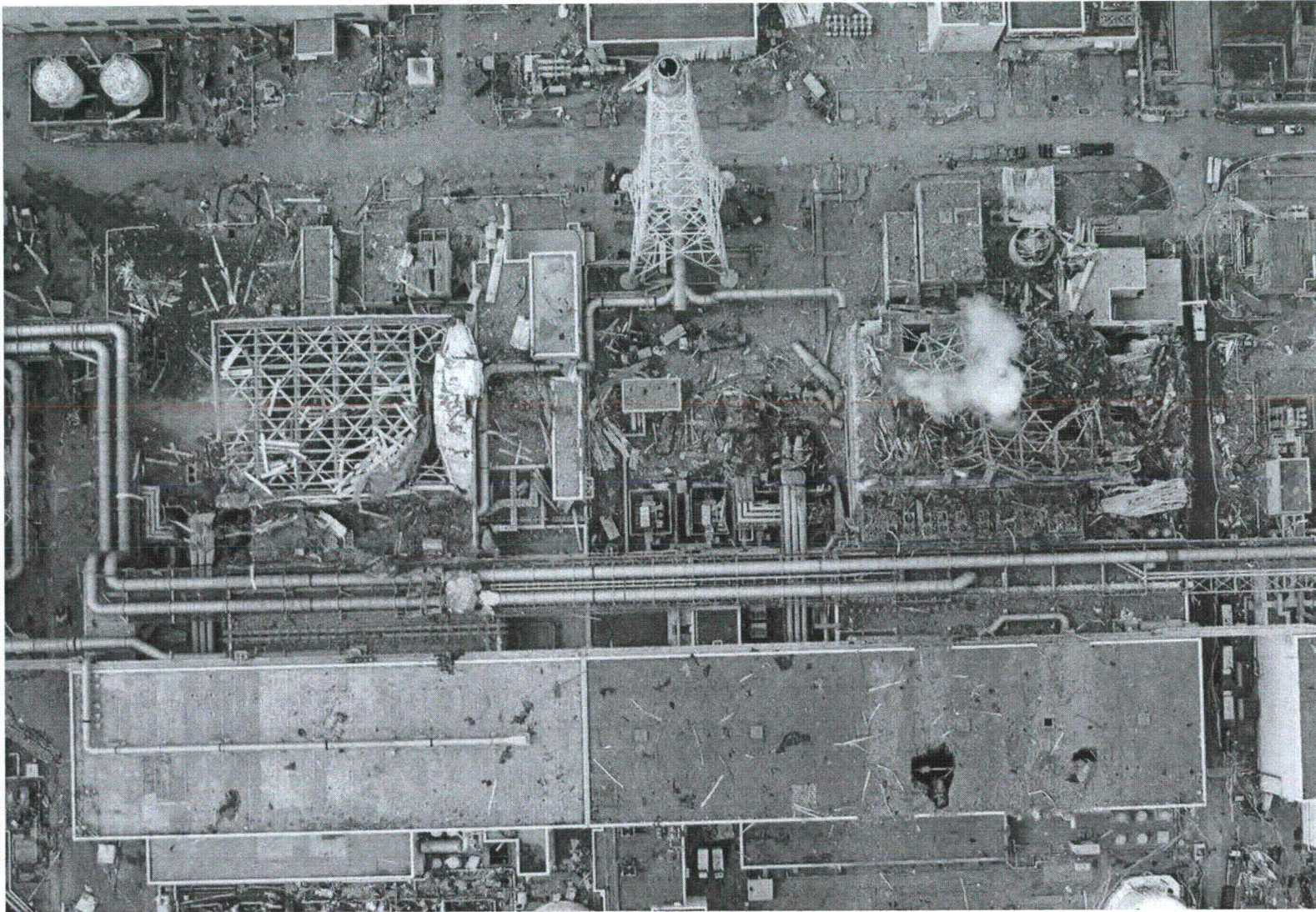
3/16



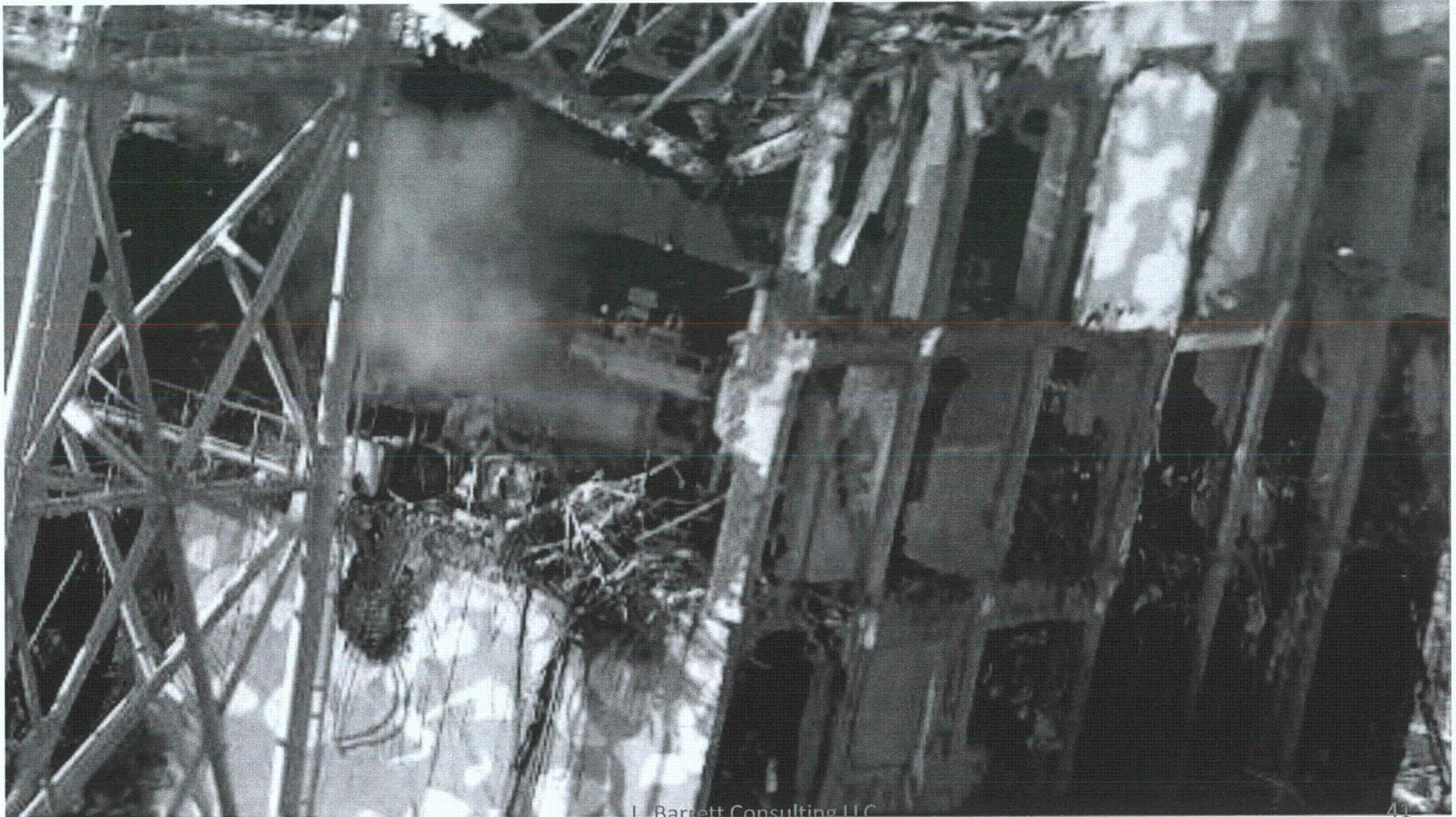
Units 3, 2, & 1 Looking Down



Units 4 & 3 Looking Down



Unit 4 Fuel Pool-Side

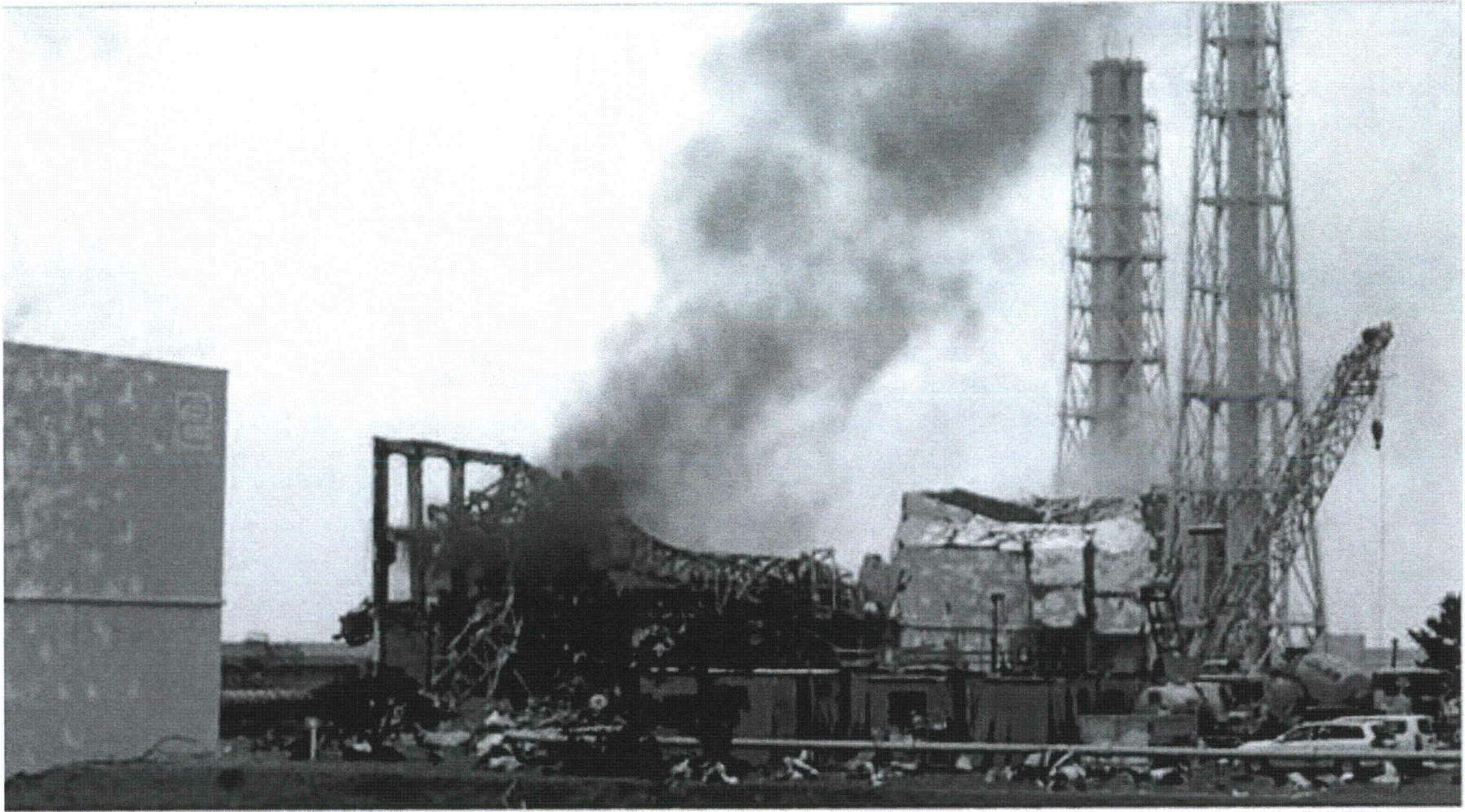


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41

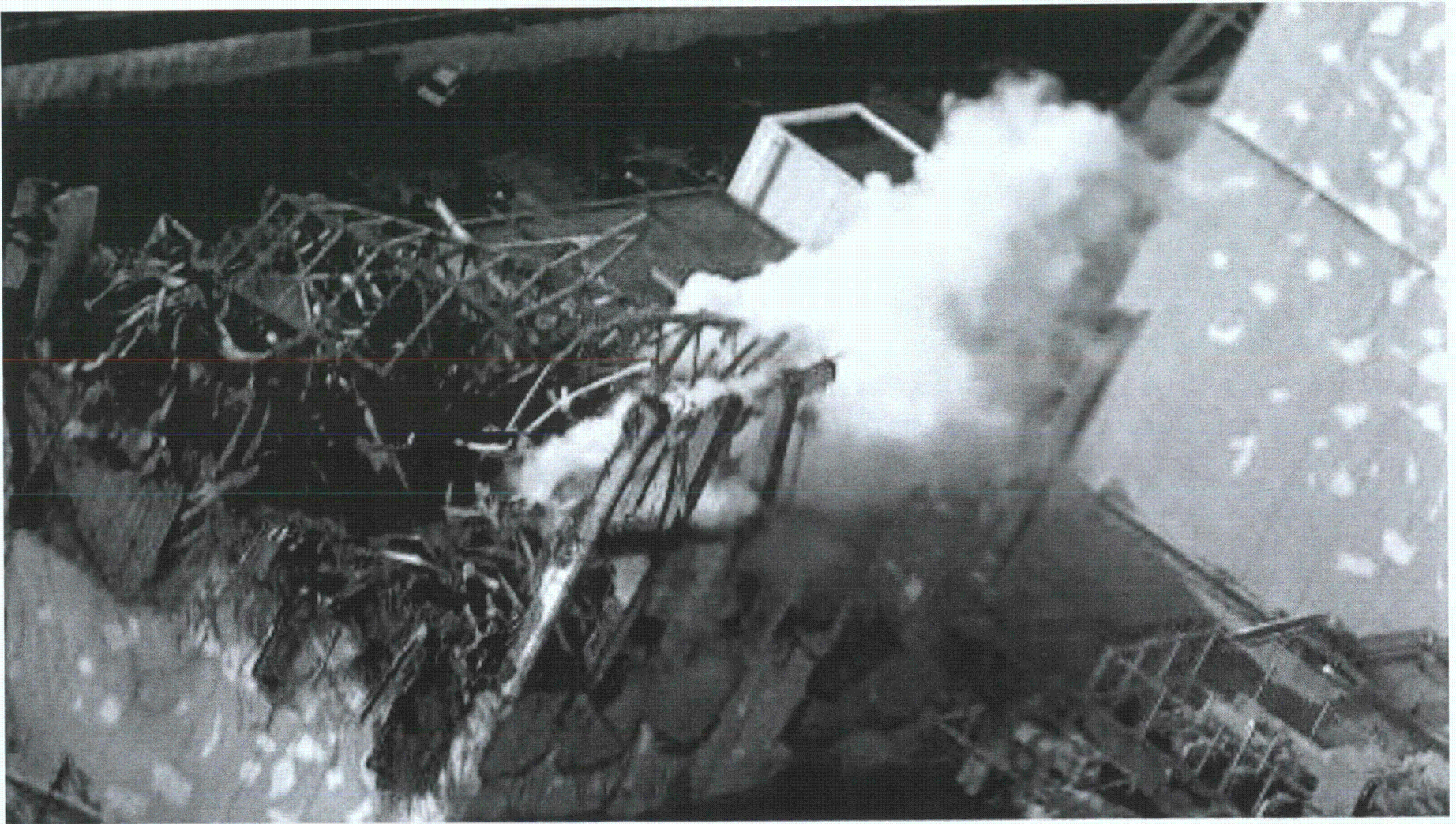
2011年12月21日 14:00 拍摄于福岛第一核电站4号机组燃料池侧

Unit 3 & Unit 4



Unit 3 Spent Fuel Pool

3/16



福島第一原子力発電所 3号機 (3/16 PM撮影)

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