



Chernobyl

What Happened and Why?

Lecture 20

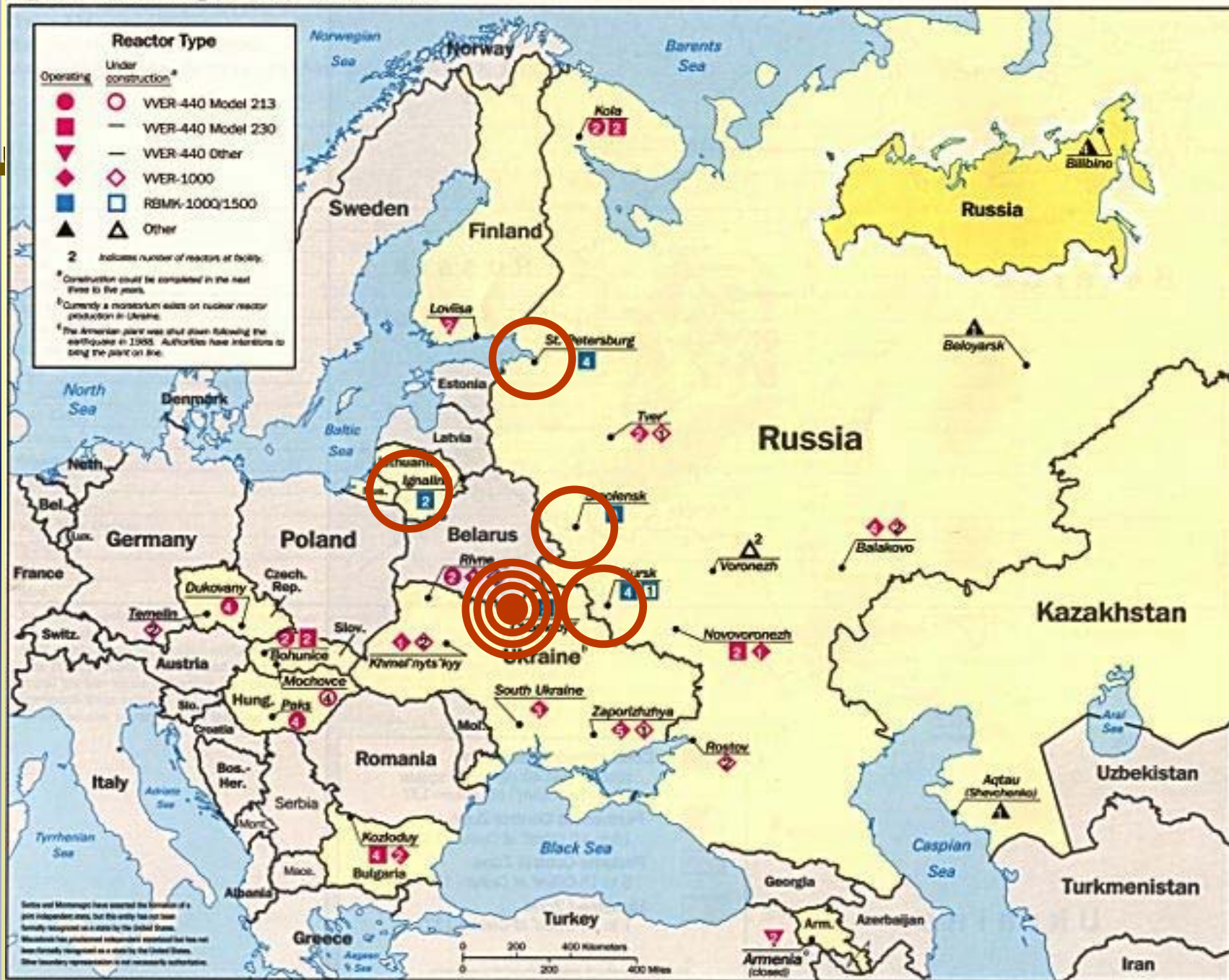
INPO Slides

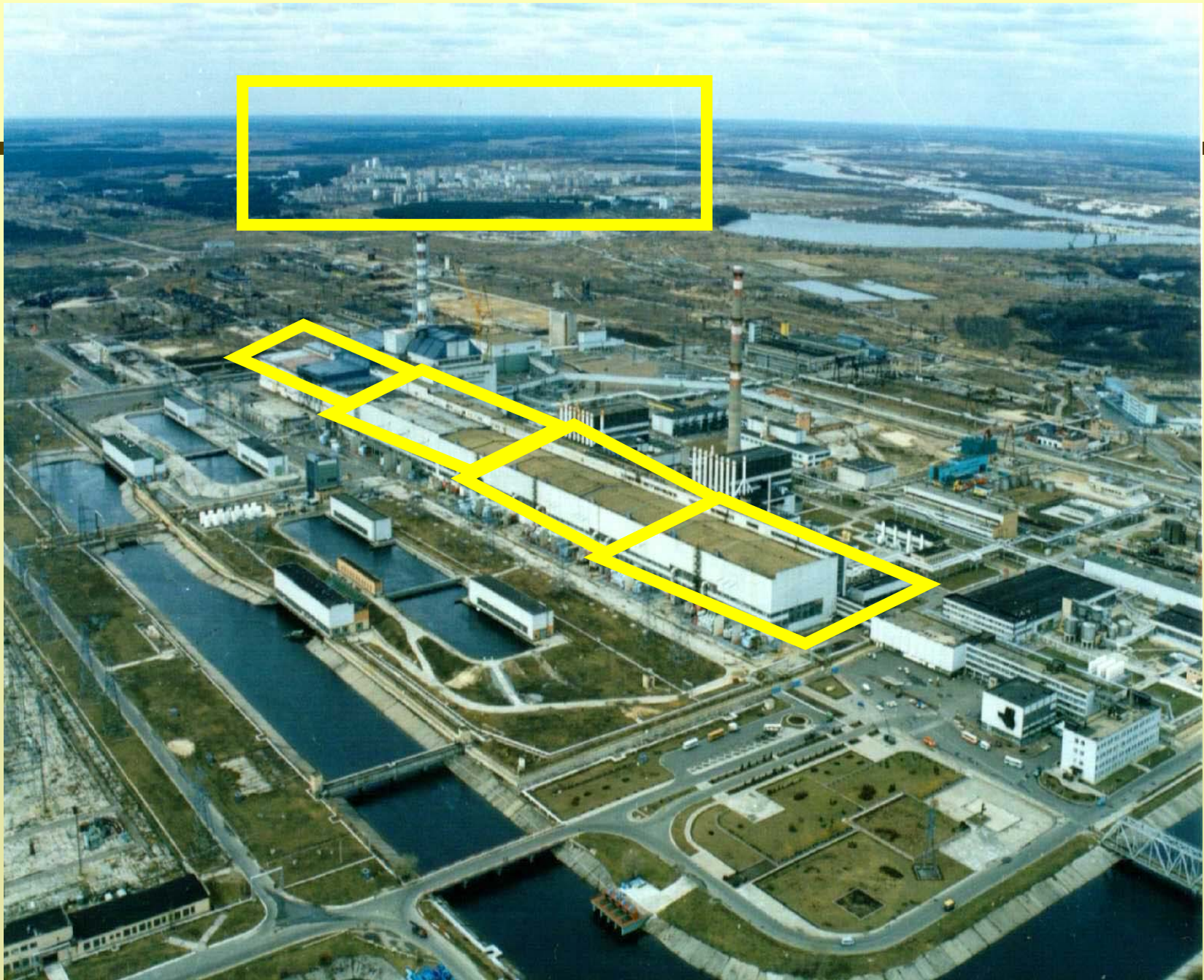


USSR - Chernobyl Location



Figure 31 Soviet-Designed Nuclear Power Plants

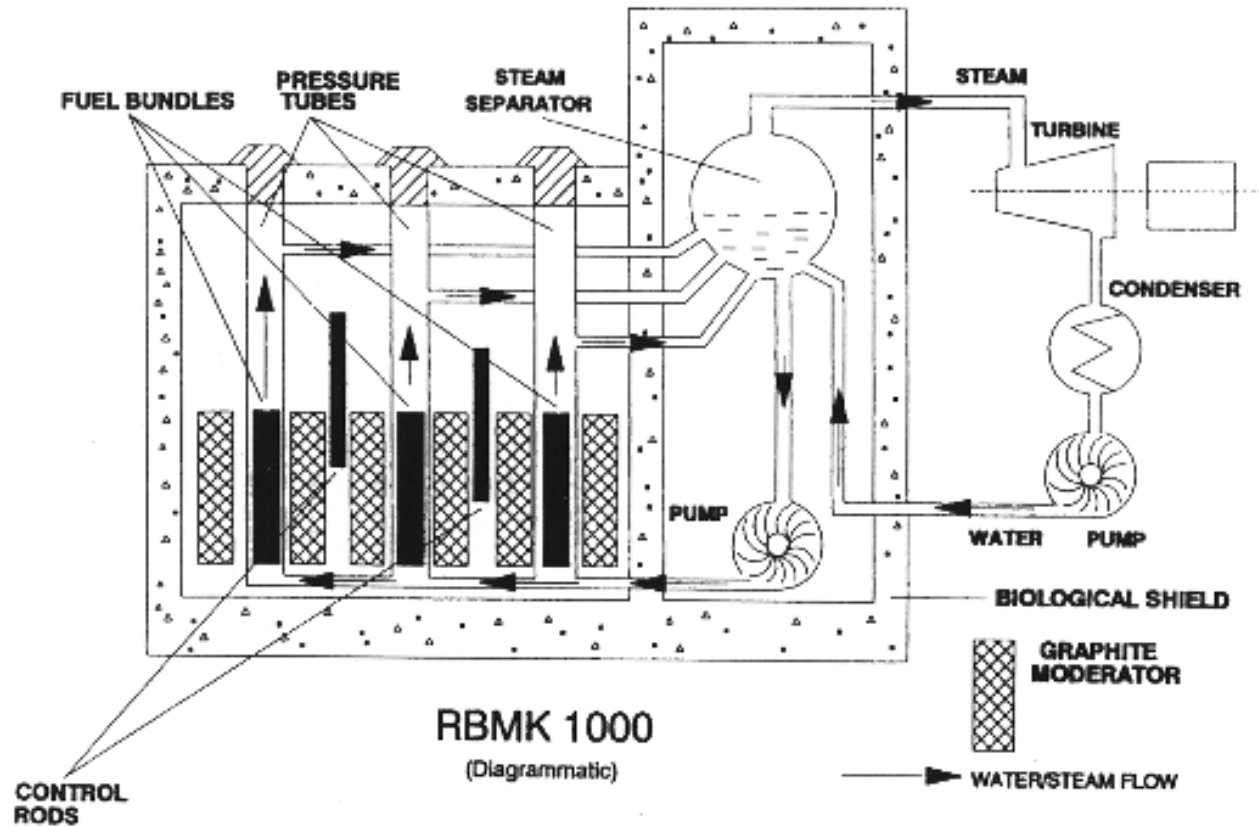




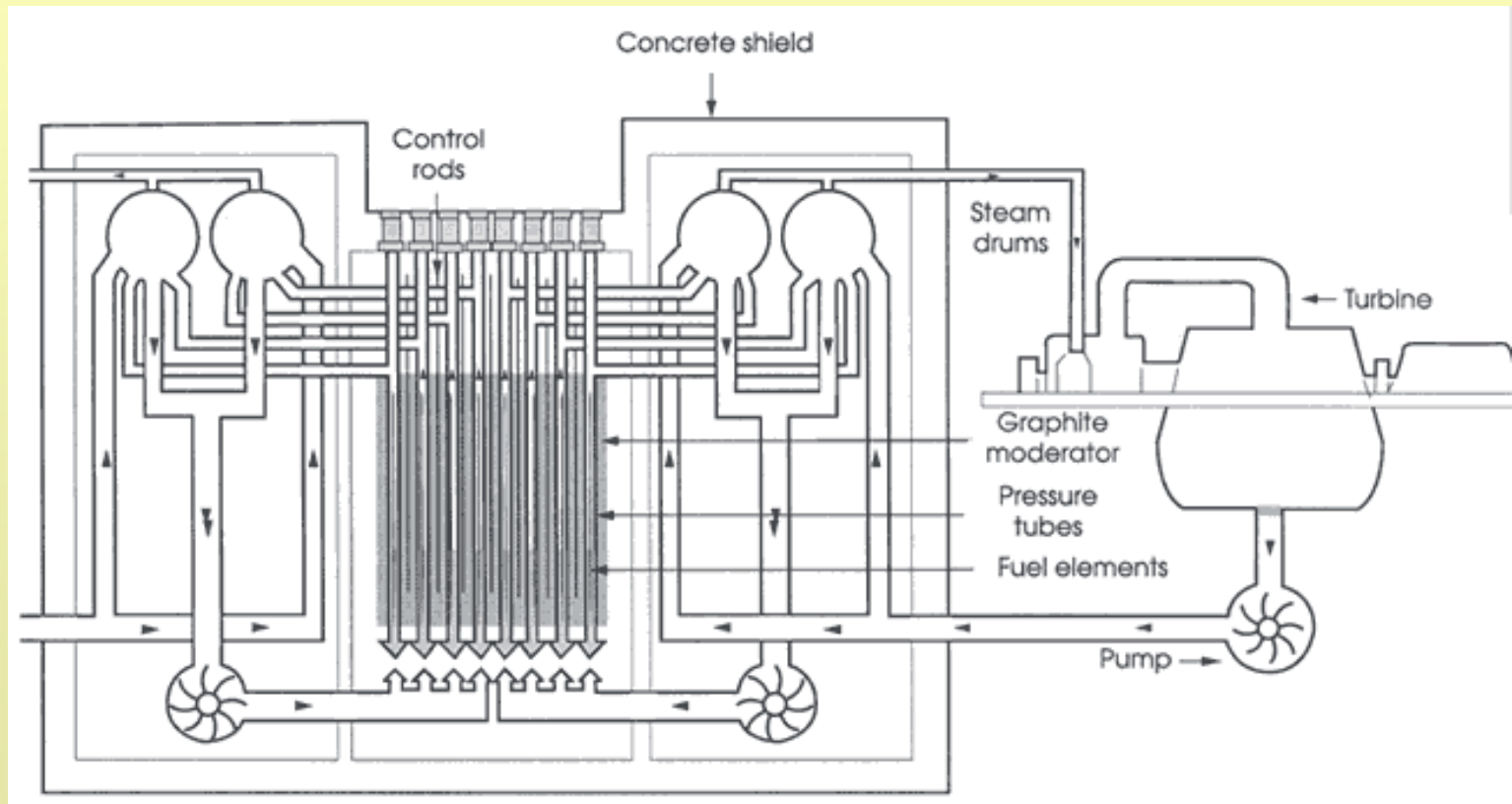




RBMK Plant Schematic

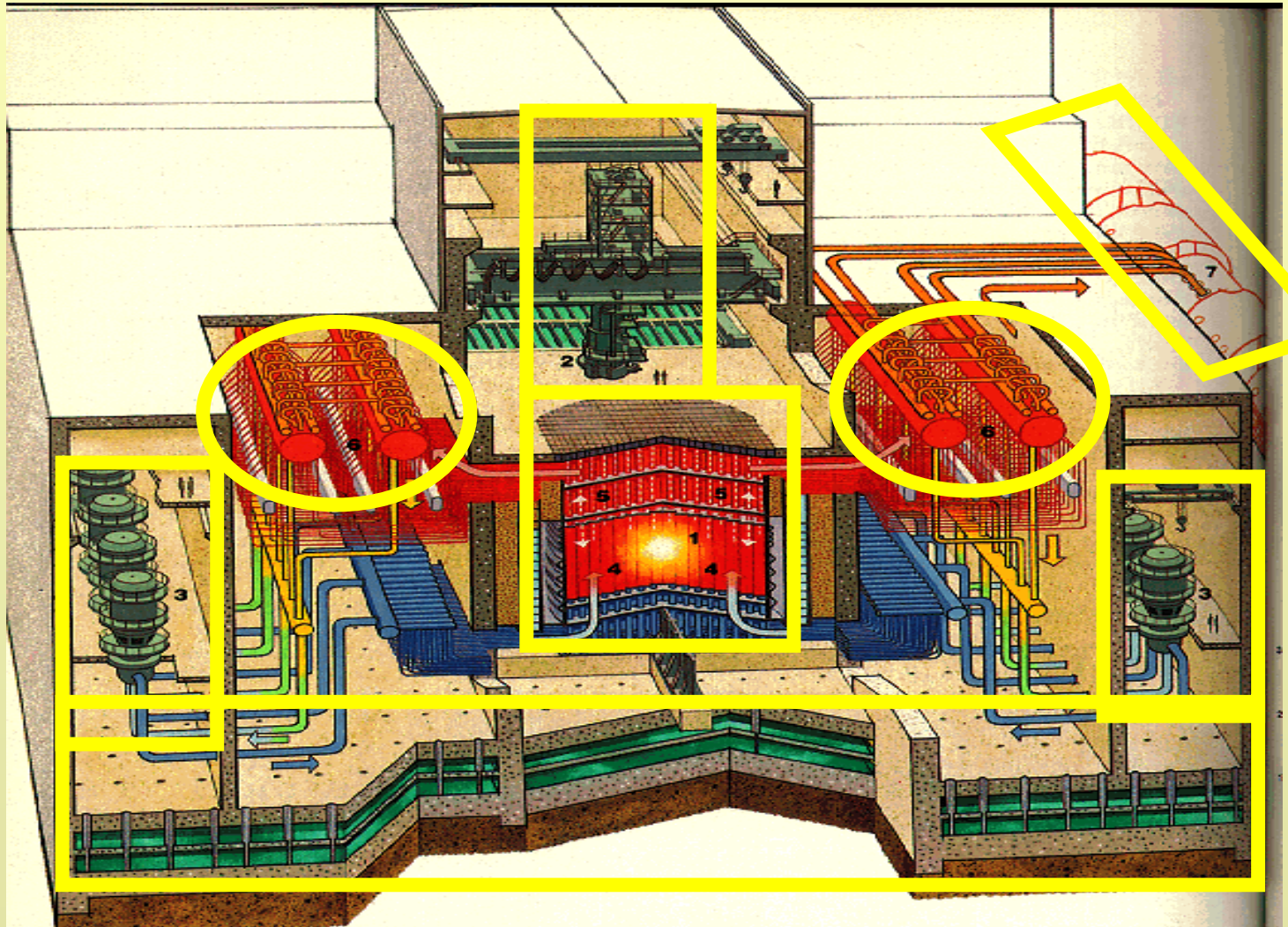


RBMK - More Details



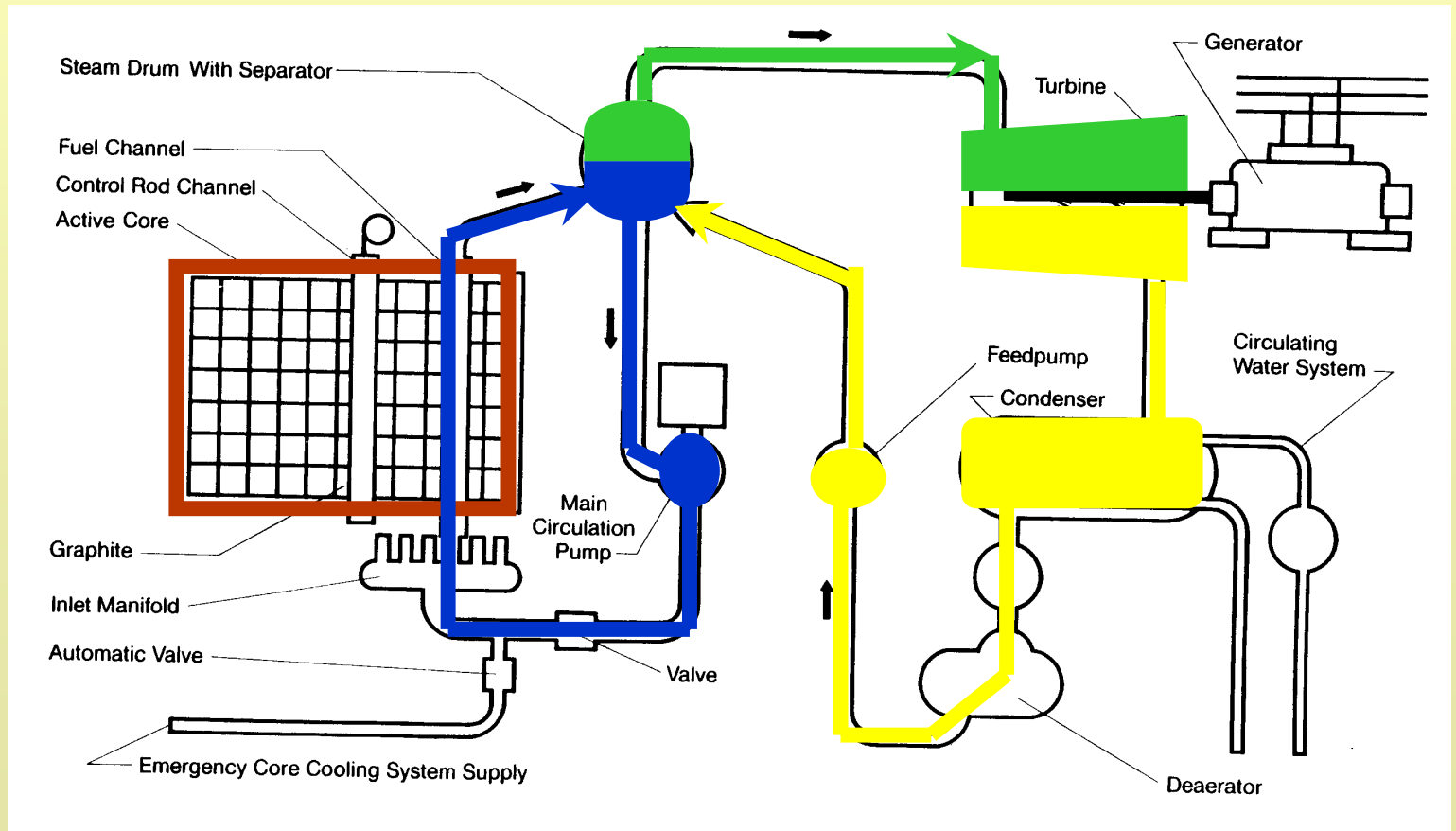


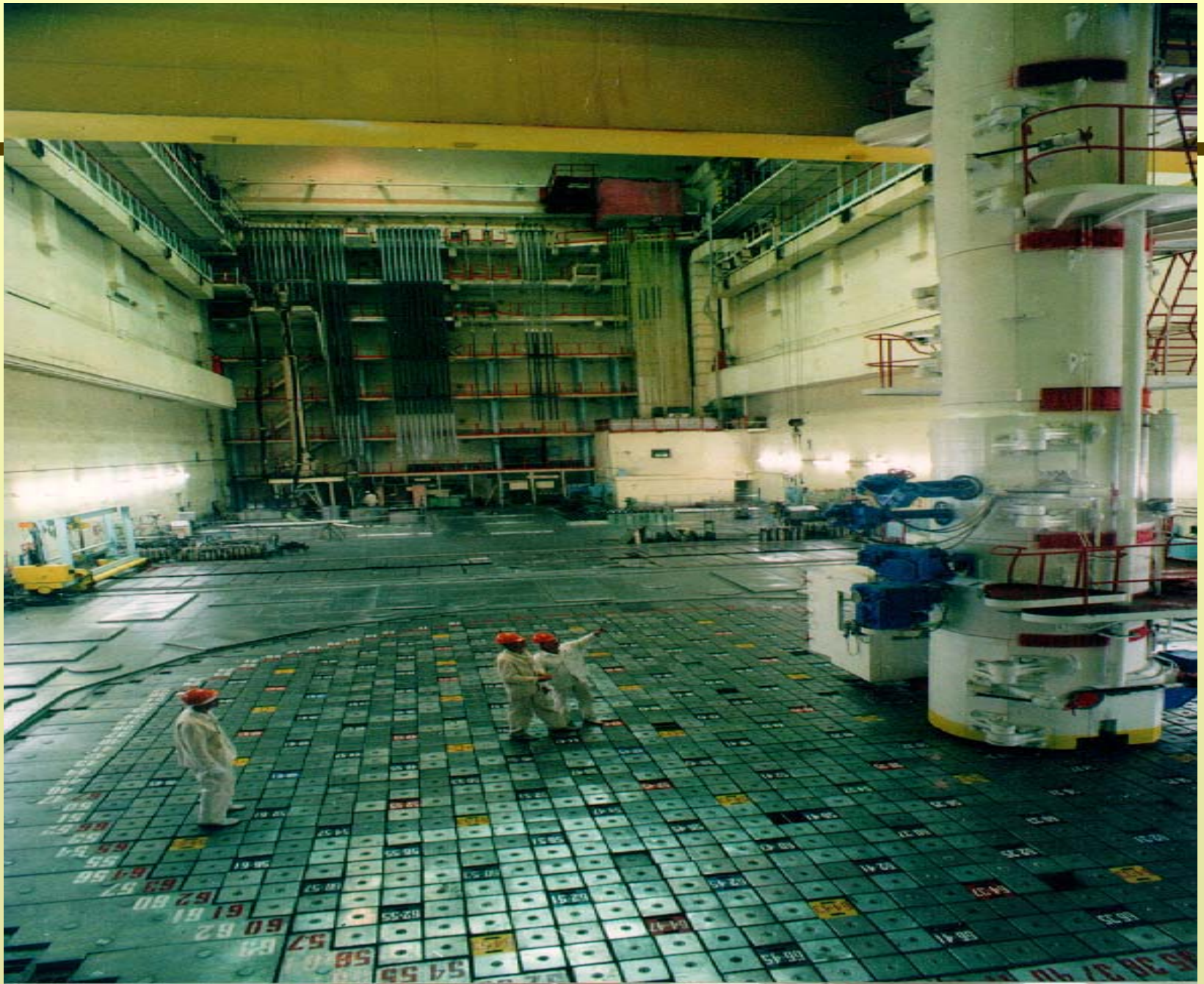
Plant Cross-sectional View



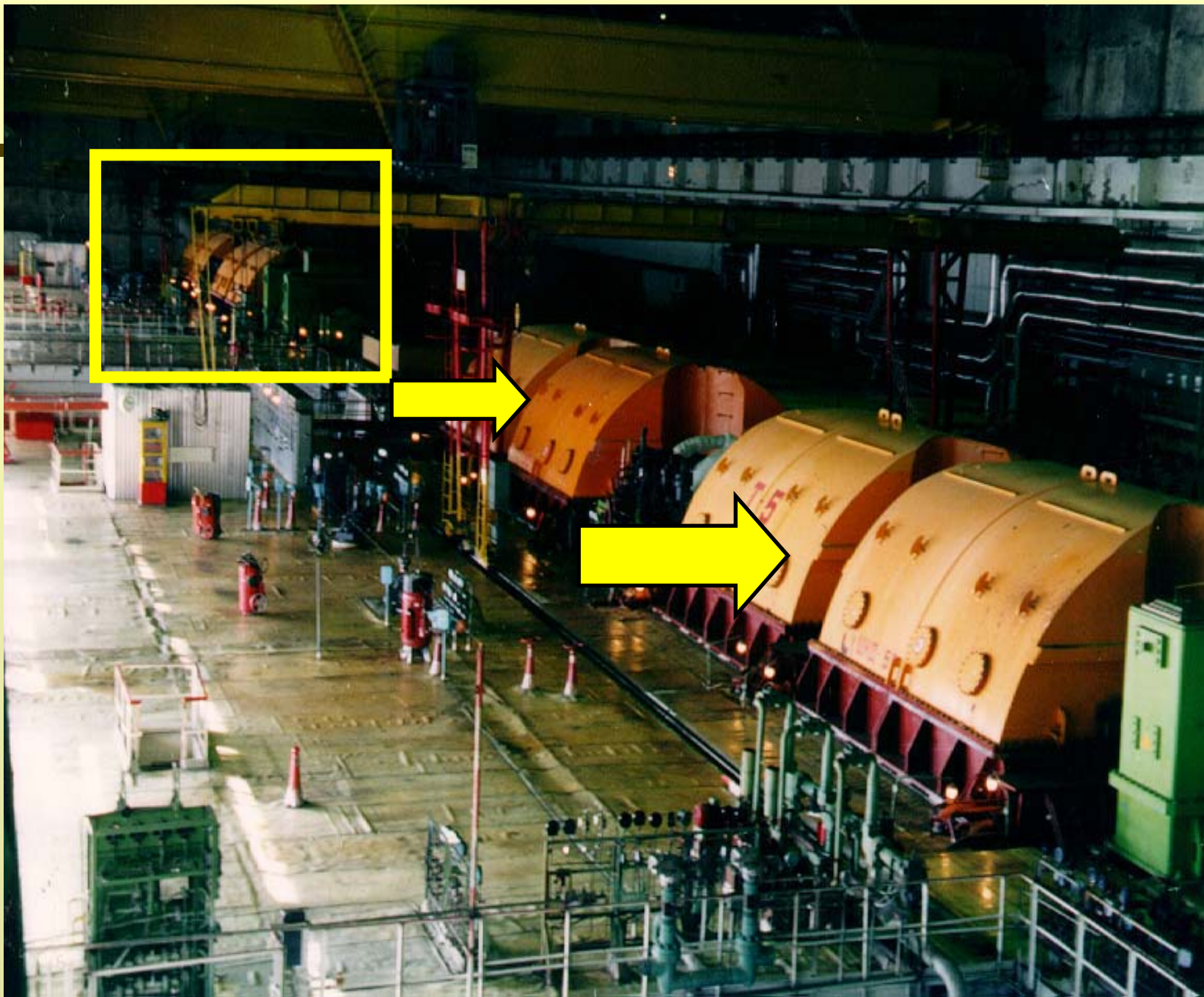


RBMK-1000 Schematic













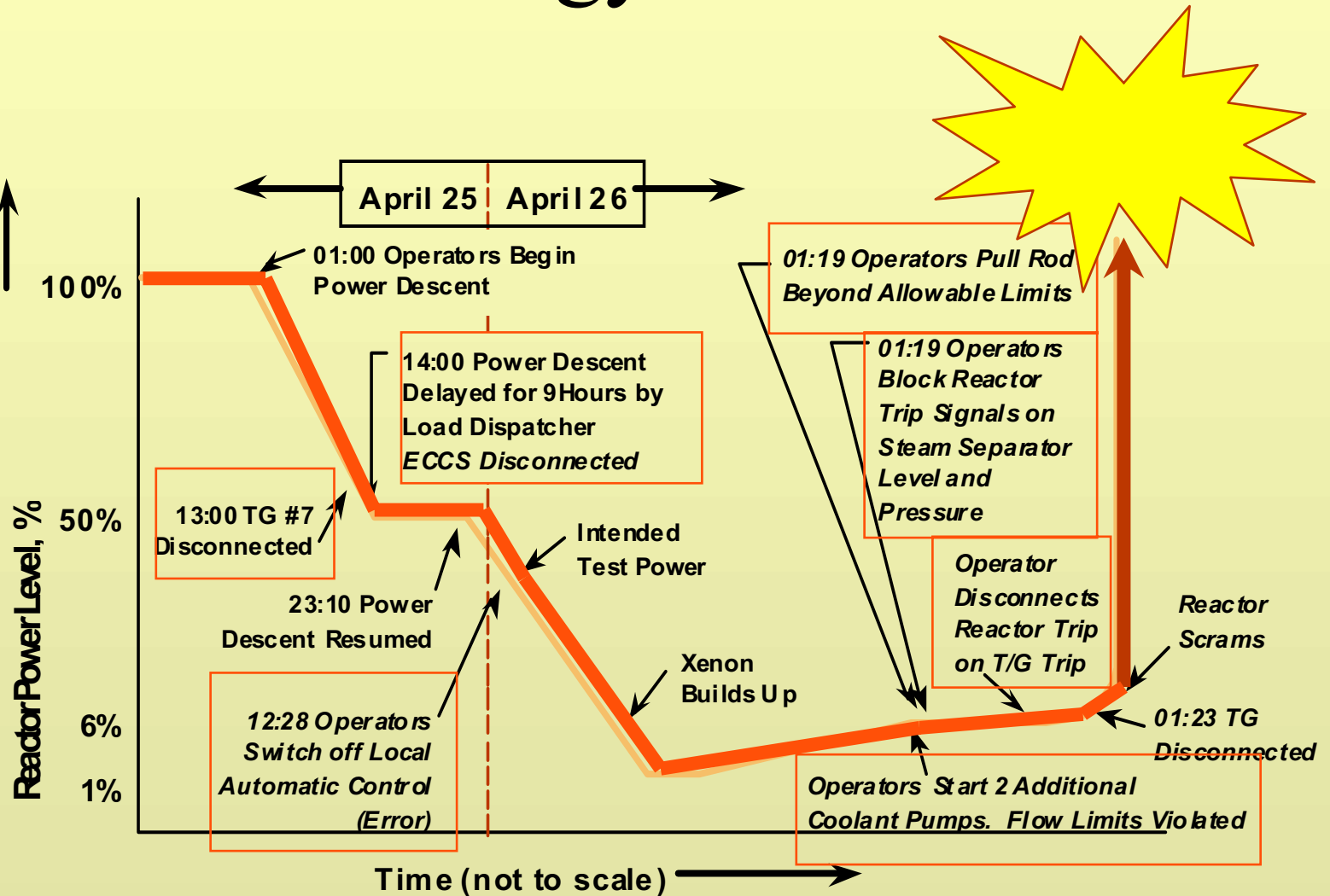


Why the Test

- **Protect against Station blackout consequences**



Chronology of Accident





\Chernobyl Violations

- **Test conducted at power level below that prescribed by test procedure**
- **Control rods positioned in unauthorized configuration**
- **Authorized coolant flow exceeded**
- **Reactor scram signals bypassed**
- **ECCS disabled**





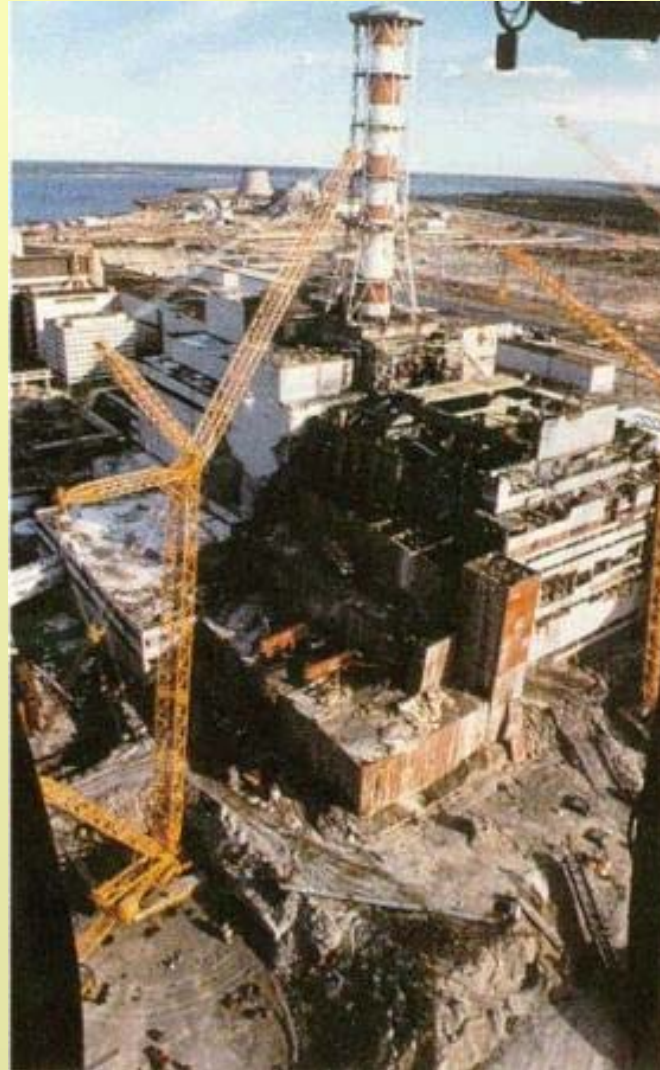


Chernobyl During Accident

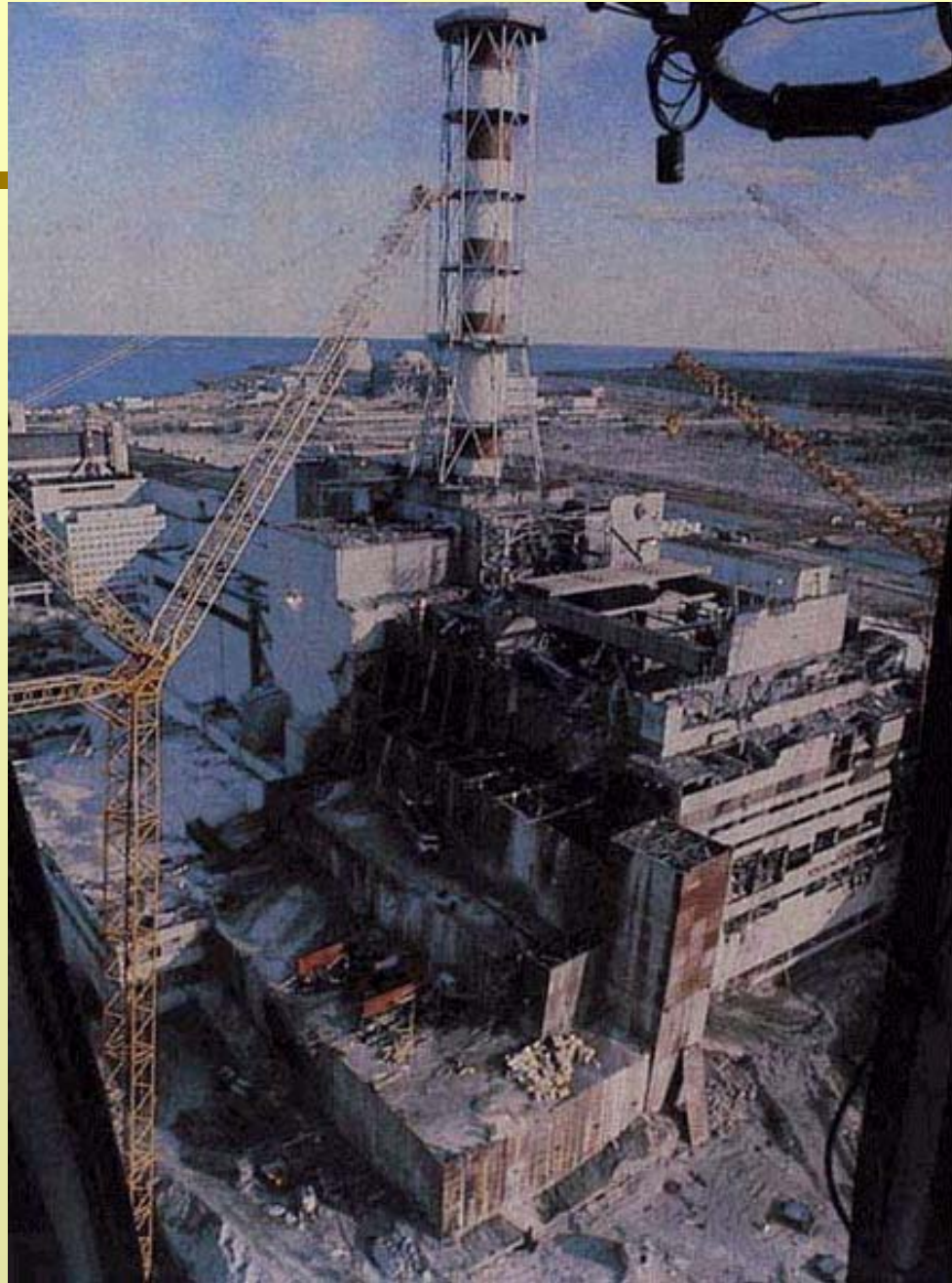




Post Accident Construction of Sarcophagus









Unit 4 Today





Pripyat



The deserted city of Pripyat, Chernobyl nuclear power plant in the background. Ukraine.
0.96.07.01.04 DEC 1995
CHERNOBYL UKRAINE D
© Greenpeace/Shirley

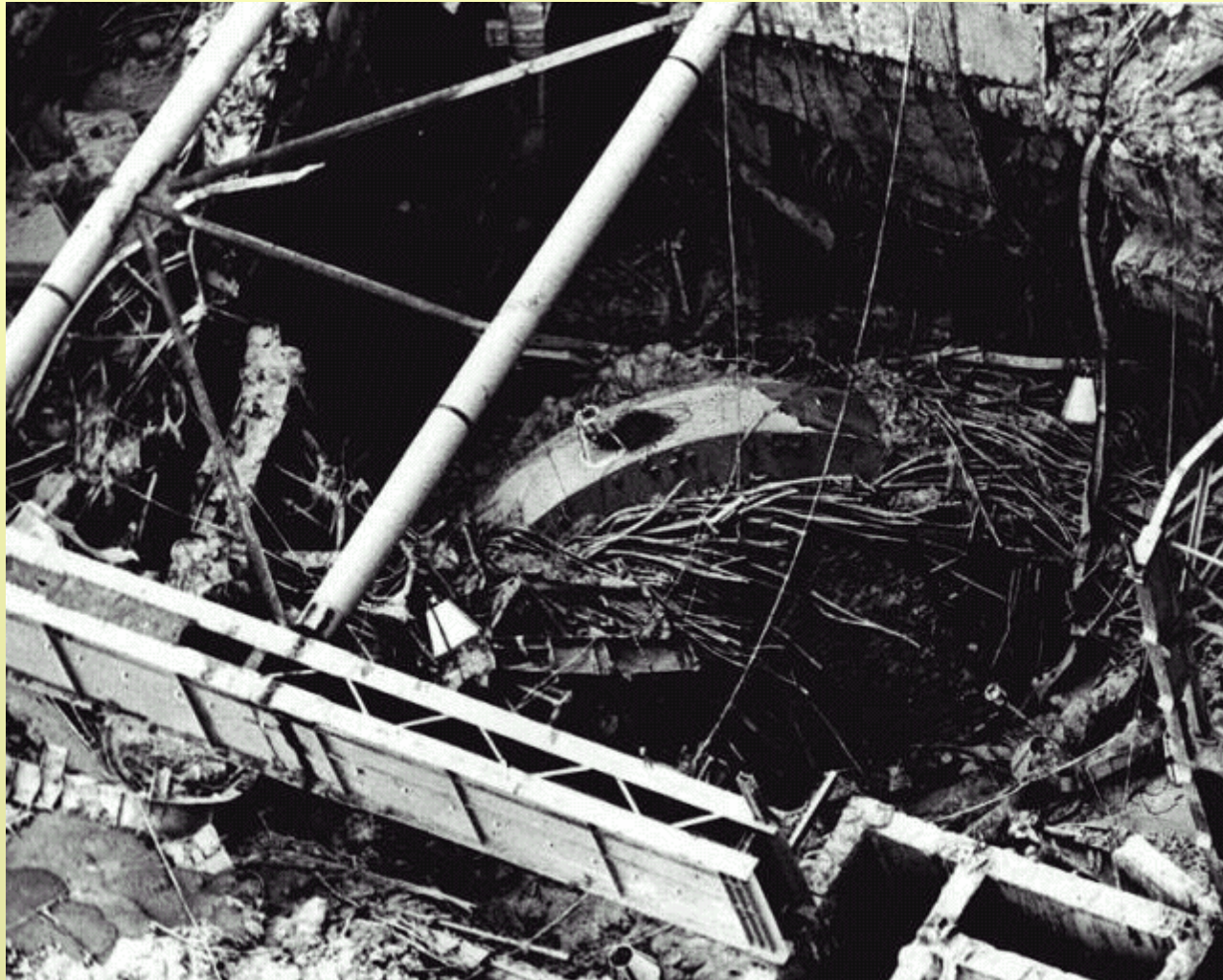


Typical Structure in Chernobyl





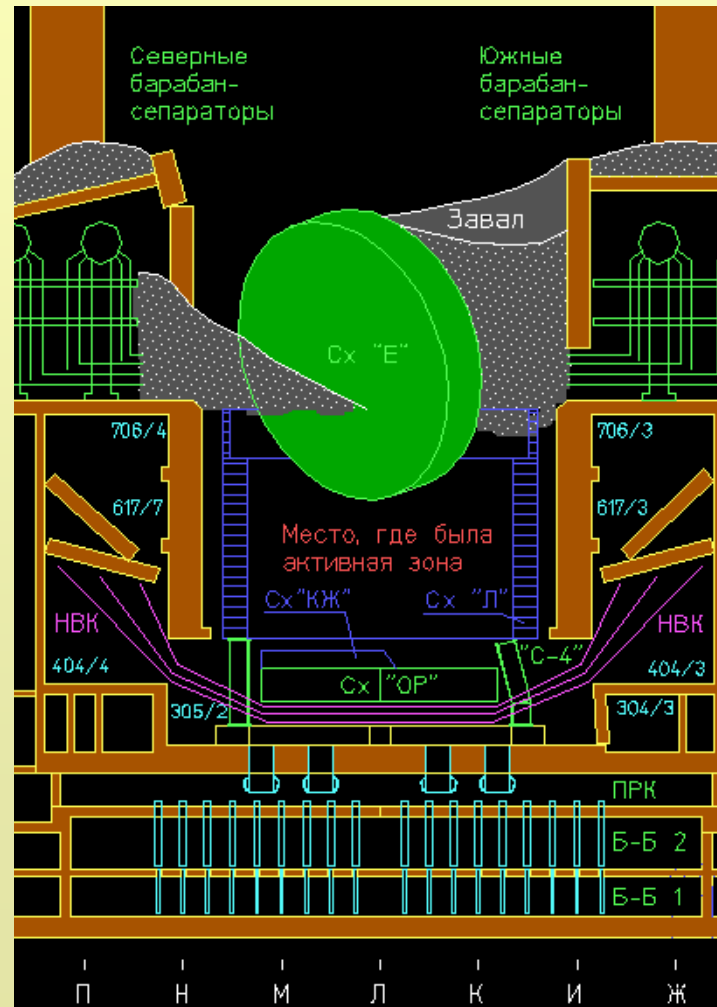
Inside of Reactor Showing Top Shield Plug



<http://www.spaceman.ca/gallery/chernobyl/Chernopik>

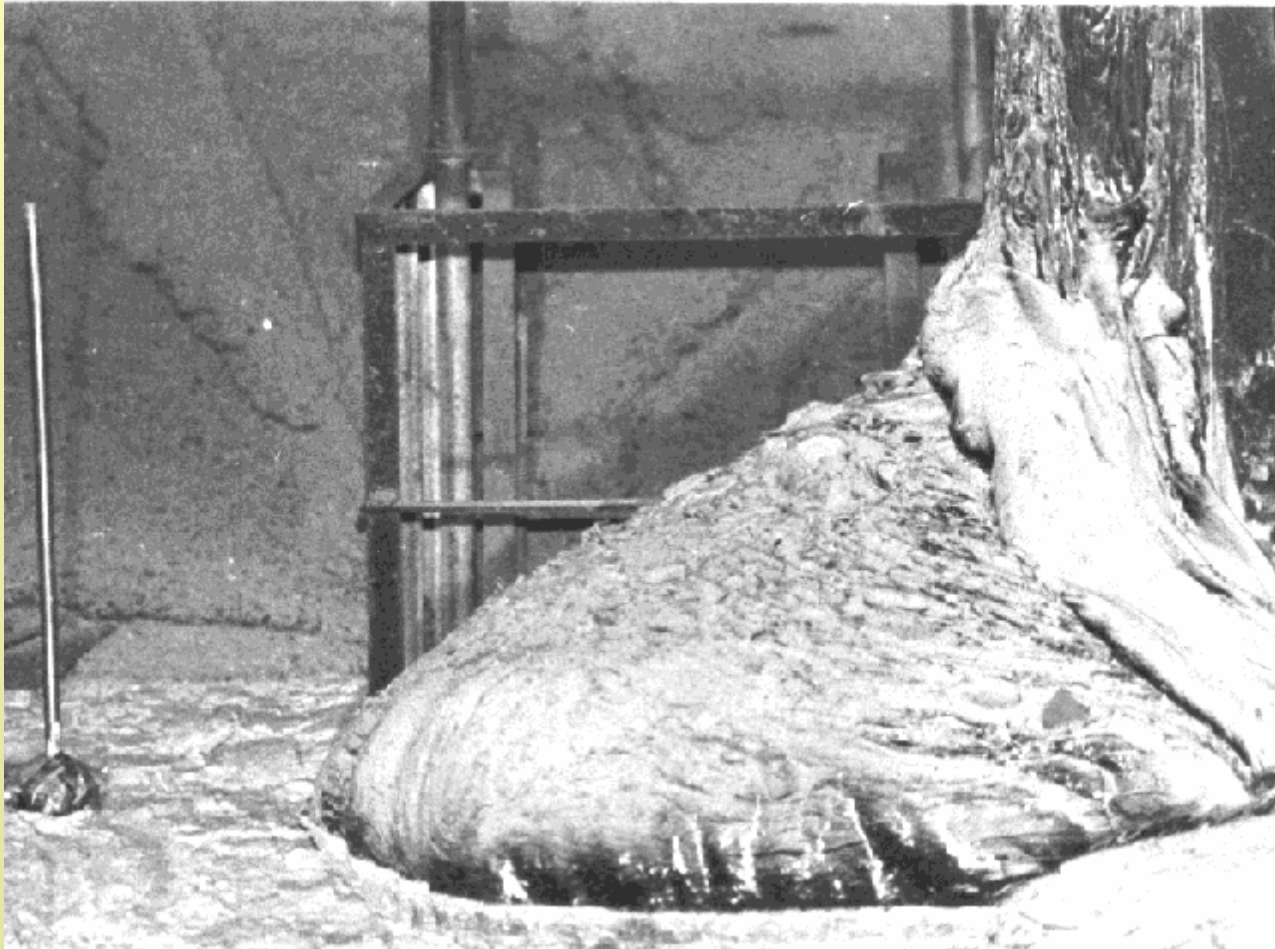


Schematic of Post Accident Condition





Elephant's Foot Molten Fuel Solidified



Molten Fuel





Fuel Slag Piles

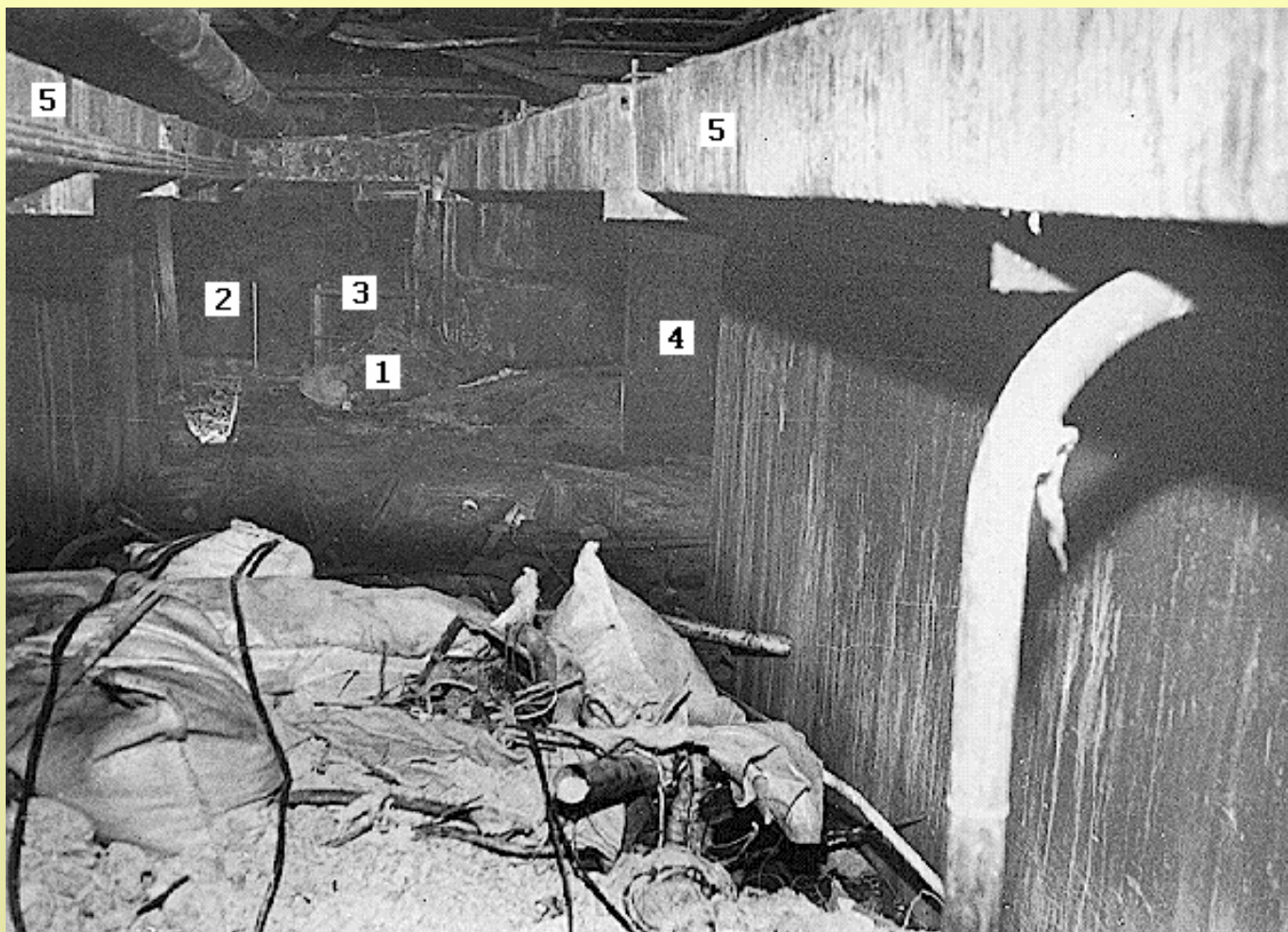


ш 012/7 шлакообразные ТСМ



Underneath the reactor

1 - Fuel lava, 2 - poured concrete in 1986, 3 - the enclosure of passage to
otm. 3.00 m, 4 - door into pom. 214/2, 5 - cable of koroba.(Of ris.ya.e.y.).





Unit 4 Control Room





Prior Known Design Issues

- **Positive Void Coefficient**
- **Slow, ineffective scram system**
- **Vulnerability to a "positive scram" phenomenon**
- **Slow complex monitoring and control system**
- **Inadequate separation of control and protection systems.**
- **Lack of full containment**
- **Overall lack of design consideration for the prevention and mitigation of reactivity excursion accidents.**



Chernobyl Causes

- **Overall management control not established**
- **Test procedure not reviewed for safety implications**
- **Operators felt sense of urgency**
- **Test delayed by load dispatcher**
- **Auto power level controller not adjusted**
- **Test procedure not followed**
- **Safety systems defeated**
- **Design dependent on adherence to admin and procedures for safe operation**



Comparisons with TMI

- **Both accidents occurred in early morning TMI-0400; Chernobyl 0100**

- **Both reactors were sensitive but:**

TMI - useful response could have been taken over several hours but small inventory steam generator

Chernobyl - response time was minutes to seconds due to positive void coefficient

- **General Complacency**
- **Warnings from sensors ignored**
- **Operators intentionally defeated the safety systems**
- **Poor training of operators**

TMI - never trained for stuck-open PORV and no instructions in EOP

Chernobyl - no simulator training

- **Weakness in approval of operating procedures**
- **Operators weak in understanding plant behavior**



Some Cultural Insights---Human Behaviors Leading to Significant Events

- **Lack of respect for the reactor core's awesome energy**
- **Overemphasis on production or schedule with safety assumed**
- **Not using procedures or expected control room protocols**
- **Lack of rigor, discipline, high standards, oversight**
- **Non-conservative decisions made when faced with uncertainty (transient or unusual conditions)**
- **An insufficient questioning attitude – making assumptions**



Consequences

➤ Health Concerns



➤ Contamination



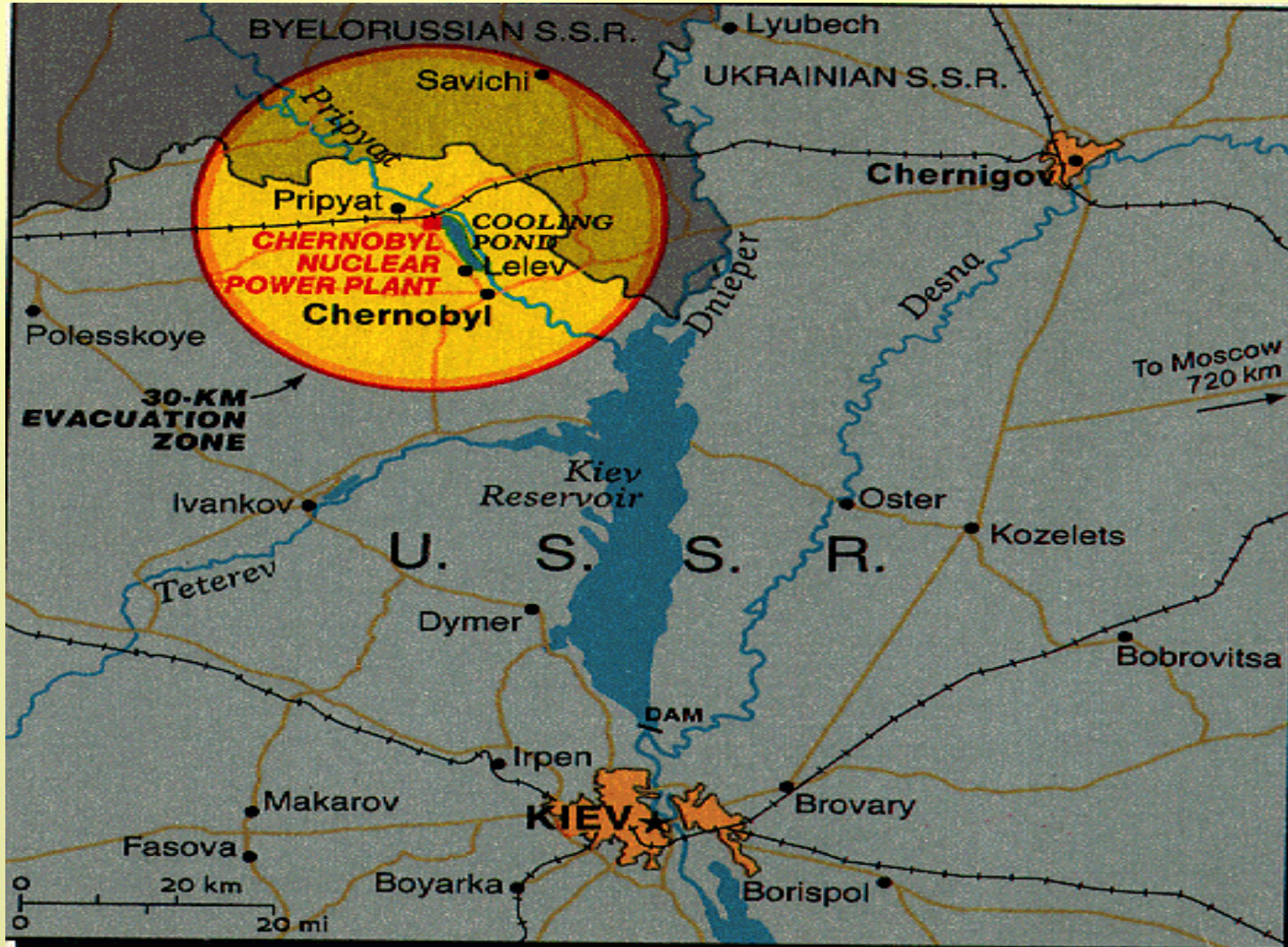
➤ Economic

RbI

➤ Loss generation



30 Km Exclusion Zone



Zone of Contamination

Figure 31. Radiation Hotspots Resulting From the Chernobyl' Nuclear Power Plant Accident





Current Condition - Need to Replace Sarcophagus



Chernobyl nuclear power station, Ukraine.
0.96.07.02.21 DEC 1995
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Homework

Homework: Chapter 15 -3,10,20,27,32

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22.091 Nuclear Reactor Safety
Spring 2008

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