Nuclear Regulatory Lessons Learned from Chernobyl

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Chernobyl Accident 30th Anniversary Regulatory Lessons Learned

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The Accident – Let’s set the stage

- Soviet Union had experience with high power graphite reactors with on-line refueling for Plutonium production
- 14 RBMKs were built including the world’s largest in Lithuania
- Chernobyl had “trouble free operations” leading to a sense of overconfidence
- Very large, “loosely coupled,” “over moderated” core; hard to control; characteristics which the operators did not fully understand
- The reactor had a “confinement” capable of only protecting a small loss of reactor coolant; multiple tube failure would lift the top plate
- Other RBMKs such as Ignalina had an event with positive reactivity addition on shutdown in 1983

The Accident

- Early in the morning on the “mid-shift” in the control room, a group of well intentioned operators conducted a test to demonstrate the relationship of certain plant parameters. The Shift Supervisor approved the test although he and the operators did not fully understand the design basis of the systems. The operators allowed the plant to be operated in an unacceptable region of safety. The test was not evaluated or approved by the safety design group. The operators felt a sense of urgency to finish the test.

- Chernobyl Unit 4 on April 26, 1986 ?

The Accident

- No- a US Nuclear Power Plant September 5, 1994

- We will discuss the applicability of the lessons from Chernobyl to the design and operations of today's Nuclear Power Plants.

The Accident

- Summary: April 26, 1986
  - The Chernobyl Unit 4 accident destroyed the reactor and released a massive amount of radioactivity into the environment. It would take the world's largest seven economies (G7), the European Commission, and Ukraine to support closing the 4 reactors and providing other support. Approximately 30 operators and fire fighters died and approximately 150 personnel developed "acute radiation syndrome."
  - The cause of the accident is considered to be a combination of the deficient characteristics of the reactor, deficiencies in the control system (including control rods etc.), and improper actions by operations personnel who did not follow procedures, and placed the reactor in a condition not reviewed and approved by safety bodies. The operators were not considered to be reckless but were part of a large organizational problem with safety culture.

The Accident - We've got to run the "Test"

Operators began a test to see how a new voltage regulator would help the momentum of the rotating turbine generator provide electricity to systems until the emergency diesels could come on.

The test began on April 25 but was delayed by the load dispatcher who needed power.

The test re-commenced in the early morning hours or April 26.

The Accident

Situation

- The test procedure did not have an adequate safety review
- The test procedure was not followed
- Operators bypassed safety systems
- Control rod positions were unapproved
- There was a sense of urgency to get the test done or wait a year

The Accident

When rods were inserted for a power increase, positive reactivity was added instead of negative due to the design

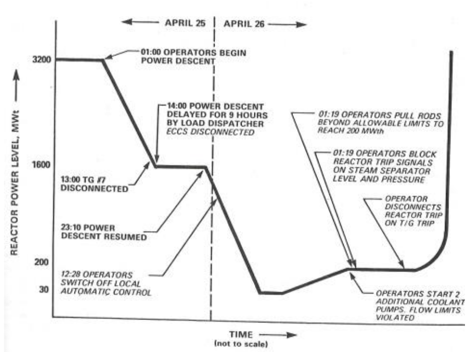

Figure 4.1 Chronology of the accident at the Chernobyl Nuclear Power Station (not to scale)

Source: Sheron, 1986

A large unstable positive “void coefficient” made the power increase worse

The Accident

Rapidly expanding fission gas ruptured the fuel cladding and fuel/water/steam mix caused overpressure in tubes and expelled graphite and core materials and blew the “top” off the reactor and building

Boron and sand were dropped from the air

Eventually a sarcophagus was built around the unit

The Accident - Post accident changes to the RBMKs

- Programs to provide an indication of the effective number of control rods in the core in the control room
- Prevention of safety systems from being bypassed during operations
- Reducing the void coefficient of reactivity was carried out by:
  - The installation of 80-90 additional fixed absorbers in the core to inhibit operation at low power.
  - Increasing the ORM from 26-30 rods (in steady state operational mode) to 43-48.
  - An increase in fuel enrichment from 2% to 2.4%.

Regulatory Lessons Learned

- **Design and Safety Analyses Issues**
  - Containment
    - The steam suppression was designed for a limited group of tubes to leak under the reactor core. There was no "modern day" containment especially over the entire primary system
  - Reactor core
    - not "self-controlling- positive void coefficient of reactivity
    - higher powers tended to make the power go higher vs. decrease
  - Controls and Instrumentation
    - the core was large and was hard to control
    - Computers were needed to control instabilities
  - Safety Analysis
    - Many different scenarios were not analyzed; risk of low power conditions

Regulatory Lessons Learned

Conduct of Operations

- Had good intentions; but complacent; had good operations availability in the past
- Shift decided to do an unapproved test
- Did not follow test procedure
- Did not have safety review of procedure
- At night with lack of support staff
- Turned off safety systems

Regulatory Lessons Learned

Conduct of Operations cont.

- Lessons
  - Formality in control room
  - Safety reviews for new or modified procedures- creation of the IAEA Convention on Nuclear Safety and peer report reviews
  - Regulatory review and approval above a threshold any changes in the facility or procedures
  - Operate within the approved licensing and design basis already thoroughly evaluated
  - International Operating Experience ; WANO Peer reviews

Regulatory Lessons Learned

- **Emergency Preparedness and Response**
- Why did we need to find out about this from Scandinavia?
- Workers were sent into life threatening very high radiation areas
- Utility officials did not promptly inform the public of the releases
- Disseminated false information

Regulatory Lessons Learned

- **Emergency Preparedness and Response cont.**
  - Establish plans with clear roles and responsibilities and communications
    - Operators
    - Authorities
    - Local responders
    - Regulatory body
  - Promptly disseminate best information and recommendations; frequent updates
  - Conduct frequent exercises to work bugs out of plans- there will always be bugs
  - Protect responders going into severely high radiation areas

Regulatory Lessons Learned

- **Emergency Preparedness and Response cont**.

- Positive
  - Use of Potassium Iodide
  - No panic in evacuations
  - Extensive medical treatment

Summary

Valid for today? For the future?

- Design-
  - Containment --SMRs? Floating NPPs?
  - Stable reactivity coefficients, fuel, coolant, moderator?
  - Analyze for "beyond design bases"
  - Design for climate change? Rising seas? Severe storms?

- Operations
  - Training on core design and thermal hydraulics
  - Formal use of procedures
  - Safety reviews and management oversight; IAEA OSART and WANO peer reviews
  - Study operating experience; "precursor events"- 1999 Blayais flood
  - Preparation for severe accidents- post Fukushima

Summary

- For Today? Cont.

- Emergency Preparedness and Response
  - Prompt notifications, tested protective action recommendations
  - Exercises with local and regional officials
  - Multiple units? – in 1987 Lars Hoberg from Sweden recommended review of multi unit site aspects; one of Fukushima lessons
  - Terrorism?

- Transparency
  - Safety analysis and design --VVER 1200s?, proprietary information, security related information
  - Basis for decisions
  - Place regulatory documents and plans on the Web for stakeholder comments

- IAEA INSAG-7 additional topic- Regulatory Independence and Effectiveness:
  - "The regulatory regime was ineffective in many important areas, such as analyzing the safety of the design and operation of plants, in requirements for training and for the introduction and promotion of safety culture, and in the enforcement of regulations. It did not function as an independent component in ensuring safety."

Chernobyl Accident 30th Anniversary Regulatory Lessons Learned

- Questions ?

Chernobyl Accident 30th Anniversary Regulatory Lessons Learned- References

- NUREG-1250, Rev. 1, Report on the Accident at the Chernobyl Nuclear Power Station, USNRC (also by DOE, EPRI, EPA, FEMA, INPO)
- NUREG 1251 Vol.1, Implications of the Accident at Chernobyl for Safety Regulation of Commercial NPPs in the US, USNRC, April 1989
- USNRC Fact Sheet (1991) and Backgrounder (2013) Summaries of the Chernobyl Accident
- Internal USNRC Memorandum, April 1996, Jon Johnson
- The Chernobyl Accident and its implications for reactor safety in OECD Countries, Nuclear Energy Agency, OECD, Newsletter, Article by L Hoberg, Spring 1987

Chernobyl Accident 30th Anniversary Regulatory Lessons Learned

- References cont.
- Journal of the Washington Academy of Sciences , Vol 78, No. 2, June 1988, Symposium at Georgetown University, Article by William Kerr, Professor of Nuclear Engineering, U of MI, "Chernobyl-Lessons Learned"
- Evolution of Nuclear Power Safety After Accidents and Near Accidents, American Academy of Arts and Sciences, 2012
- "Chernobyl's Engineer Denounces Lie by Scientists, Politicians", Washington Post Article April 27, 1992
- INSAG-7, IAEA, The Chernobyl Accident, 1992