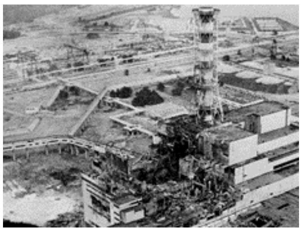
Lessons Learned Database
Individual Incident Summary Report

IChemE Safety & Loss Prevention Special Interest Group

Incident Title	**Nuclear Reactor Temperature Runaway**
Incident Type	Explosion
Date	26th April 1986
Country	Ukraine (formerly part of Soviet Union)
Location	Chernobyl

Fatalities	Injuries	Cost
31	~ 7000	Unknown

Incident Description  Credit: Wikimedia Commons	The Chernobyl nuclear power plant had 4 operating thermal neutron RBMK (“Reactor Bolshoy Moshchnosty Kanalny”) reactors moderated by a graphite stack. The core was cooled by water circulating through zirconium-niobium pressure tubes (the water also acted as a neutron absorber). The power level in the core was controlled by boron carbide absorber rods with graphite tips. At the time of the accident, a test was being conducted on an off-line reactor to determine whether the power generated during spindown of the turbo-generator by its own inertia would be sufficient to power the reactor coolant pumps in the event of a loss of external electrical power, thereby providing more time for the backup diesel generators to be run up and brought on-line. A “prompt criticality” temperature runaway developed and high pressure (HP) steam leaked into the reactor, blowing off the top cover. The reaction of water and steam with the zirconium fuel rod cladding and graphite moderator core generated a mixture of hydrogen (H_2) and carbon monoxide (CO) which caused an explosion large enough to blow the concrete roof off the reactor building and disperse radioactive particles across much of Western Europe.
Incident Analysis	**Basic cause** was failure of the fuel rod cladding and rupture of the moderator core coolant pressure tubes due to extreme over-temperature and core melt. **Critical factors** included: 1) The test was conducted at lower power (less stable conditions) and later (soon after shift change) than planned, 2) The automatic shutdown systems were disabled during the test, 3) Insertion of control rods displaced water (graphite absorbs fewer neutrons than water so insertion caused transient power level increase at already unstable operating conditions), 4) Absence of a nuclear (secondary) containment building capable of withstanding significant overpressure around the reactor core. **Root causes** included: 1) Inadequate design (RBMK reactor positive void coefficient and graphite tips on control rod assemblies), 2) Violation of operating procedures (too many control rods withdrawn and safety systems overridden), 3) Inadequate training, 4) Inadequate emergency response planning (evacuation delayed), 5) Absence of independent safety regulator.
Lessons Learned	1) A concrete “sarcophagus” containment structure was built around the damaged reactor in the 6 month period after the explosion to try to limit the ongoing release of radioactive materials to atmosphere, 2) Control rods in all operating RBMK reactors were retrofitted with neutron absorbers and graphite displacers to prevent cooling water backfilling the voids created by the control rods being withdrawn (improving stability at low power), 3) Automatic shutdown systems were modified in all RBMK reactors to increase their speed of response, 4) This disaster prompted increased transparency and collaboration between the East and West, 5) The International Nuclear and Radiological Event Scale (INES) was developed to facilitate sharing of incident severity data on a consistent basis.
More Information	1) “The Accident at Chernobyl Nuclear Power Plant and Its Consequences”, Lewis H.W., Environment (November 1986). 2) World Nuclear Association website (accessed 20-Nov-19): https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx. 3) “Chernobyl Lessons In Process Safety”, K. Kolmetz, Engineering Practice Volume 6, Number 20 (January 2020).

Industry Sector	Process Type	Incident Type
Power Generation	Nuclear	Explosion
Equipment Category	**Equipment Class**	**Equipment Type**
Mechanical	Vessels	Reactor