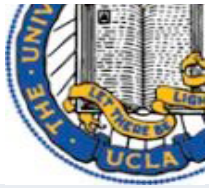

UCLA

B. John Garrick Institute for the Risk Sciences

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Identification and Quantification of Risk Scenarios for a Unique Nuclear Reactor – a Historical Example

D. H. Johnson — Garrick Institute for the Risk Sciences
M.A. Linn — Oak Ridge National Laboratory
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Presented at PSAM 14 Los Angeles September 2018

Outline of Presentation

- Background
- Description of the High Flux Isotope Reactor (HFIR)
- Challenges in Performing PRA
- Identification of Initiators
- Developing Fuel Manufacturing and Flow Blockage Scenarios
- Scenario Quantification
- Lessons Learned

Challenges

- Sensitive to Loss of Pressure
  - Aluminum –U_3O_8 Fuel
  - High Power Density
  - Narrow Coolant Channels
- Longitudinally Welded Primary System
- Uncertain Forced Cooling Success Criteria
- Uncertain Battery Life
- Unique Components
- Integration of Auxiliary Power Unit Stored Off-site
  - May be first assessment to incorporate what became known as FLEX equipment
- Fuel Related Scenarios
  - Flow Blockage
  - Undetected Critical Manufacturing Flaws

Potential Challenges in Developing PRA for Innovative Designs

Can HFIR PRA Provide a Helpful Example?

- Unique fuel types
- Fuel performance
- Unique components
- Uncertain success criteria
- High power density
- Etc

HFIR Simplified Flow Diagram

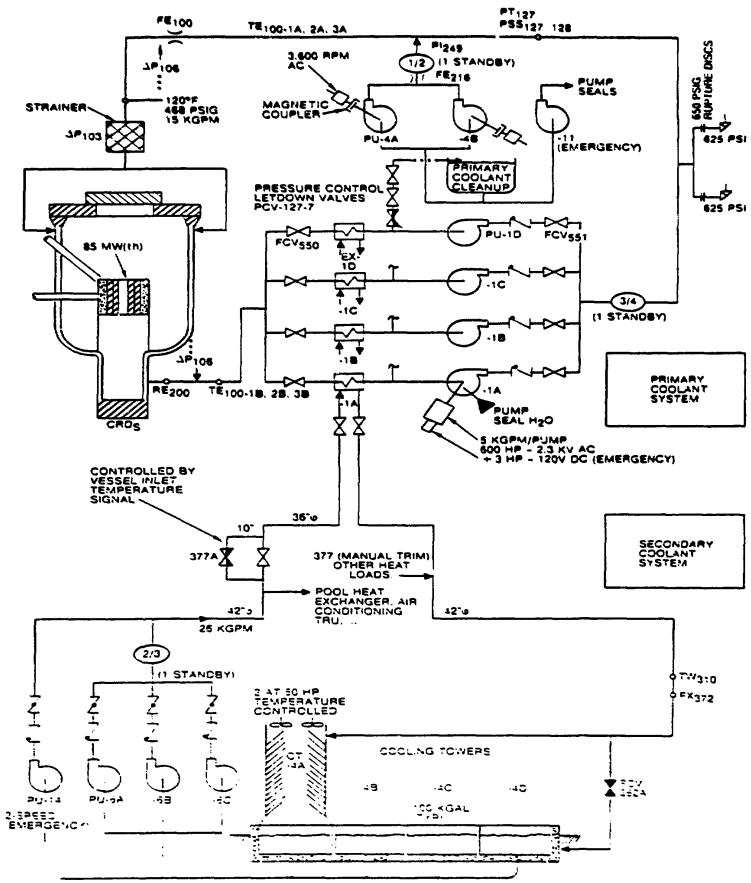


Figure 2. HFIR Process Flow Schematic (primary and secondary systems)

Peak thermal flux 5 x 10^{15}

540 fuel plates in 2 elements

6-7 fuel cycles per year

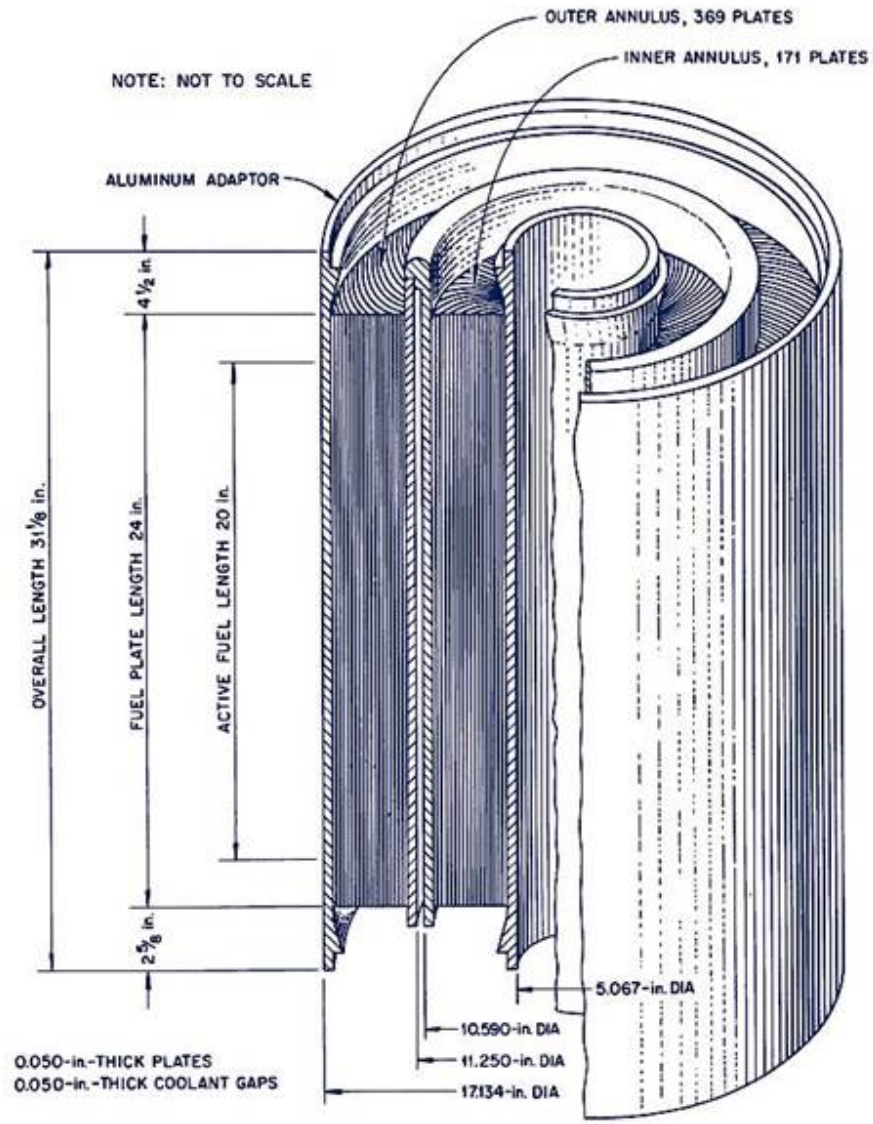
8 foot vessel in 36 foot deep pool

Vessel open to pool during refueling

Primary system "water solid"

As of September 2018 HFIR completed 482 fuel cycles

HFIR Fuel


OUTER ANNULUS, 369 PLATES
INNER ANNULUS, 171 PLATES
NOTE: NOT TO SCALE
ALUMINUM ADAPTOR
4½ in.
OVERALL LENGTH 31⅛ in.
FUEL PLATE LENGTH 24 in.
ACTIVE FUEL LENGTH 20 in.
2⅝ in.
5.067-in. DIA
10.590-in. DIA
11.250-in. DIA
17.134-in. DIA
0.050-in.-THICK PLATES
0.050-in.-THICK COOLANT GAPS

Context of HFIR PRA

- Post Chernobyl Review led to discovery of a higher level of vessel embrittlement than anticipated
- This review led to changes in staffing, operations and design
- Emergency Depressurization System
  - Design purpose to lessen the stress during overpressure events
- PRA performed as part of the safety review
  - First PRA on Class A DOE reactor

Initiators Identified in Internal Events PRA

Initiators Identified Using

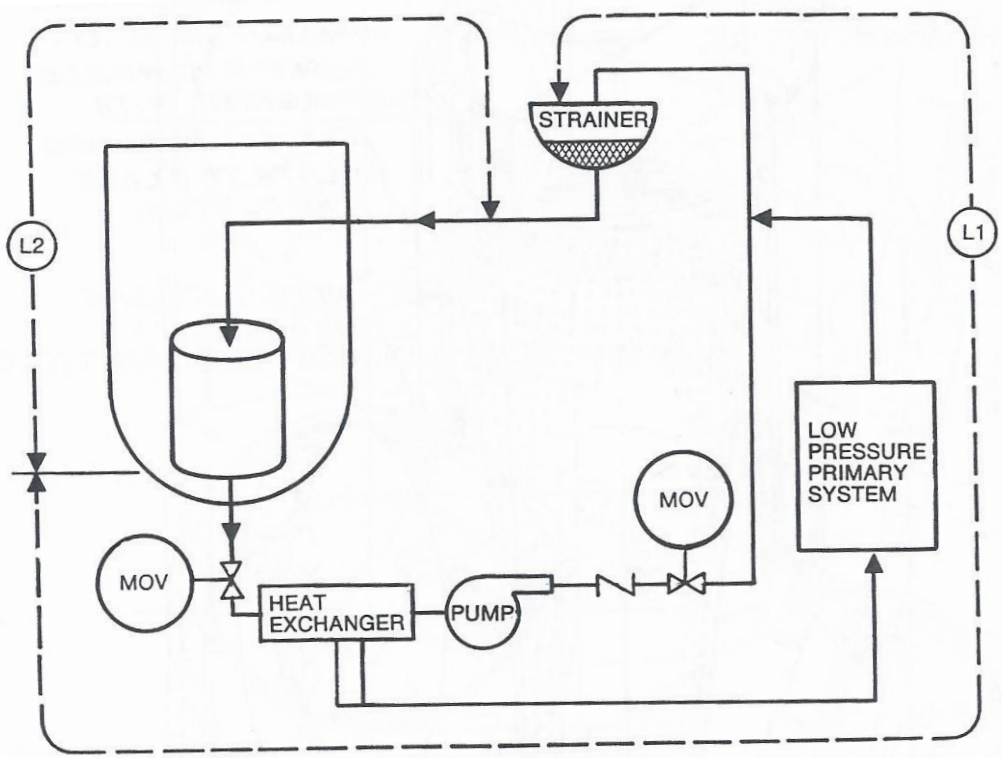
- MLD
- Review of HFIR History
- Review of Other RR History
- Comparison to LWR IEs
- Review of Safety Analyses
- Performance of Dependency Analysis

Initiator Identifier and Category
1A Manual Scram
1B Inadvertent Control Blade Drop
1C Inadvertent Scram
2A Complete Loss of Offsite Power
2B Loss of Preferred Power
2C Loss of Switchgear DC
3A Runaway Pressurizer Pump
3B Loss of Running Pressurizer Pump
4 Flow Blockage and Fuel Manufacturing Defects
5 Small LOCA
6 Large LOCA
7 Beam Tube Failure
8A Reactivity Insertion
8B Degraded Secondary Cooling
8C Loss of Instrument Air
8D Degraded Primary Flow

Consideration of Flow Blockage Events

- How to proceed?
  - Systematically identify what can go wrong, what are the consequences and what is the likelihood (i.e., return to the guidance offered by the Triplet)
- Organize the problem – logically break the problem into pieces
- Gather all available evidence
  - System experts
  - Relevant analyses
  - Historical events
- Guide scenario construction and quantification
- S. Kaplan 'Expert Information verses Expert Opinions' Rel Eng and System Safety 35, pp 61-72, 1992

Flow Blockage Initiators- Defined by Source Location of Blocking Material



Scenarios Involving Debris Origination Downstream of the Strainer (L2) or From the Pool (L3)

Scenarios Involving Debris Origination Upstream of the Strainer (L1)

Two Examples of Risk Management Actions Suggested by PRA

- Design of New Emergency Depressurization Changed
- Specific Sources of Potential Flow Blockage Removed or Modified
  - Restrictions on Access to Reactor Pool
  - Removal of Potential Blocking Material (e.g. redundant o-rings)
  - Secure specific items (e.g., weld nuts)

Fuel Damage Frequency Due to Flow Blockage Before and After RM Actions