Description of Y-12 Criticality Accident

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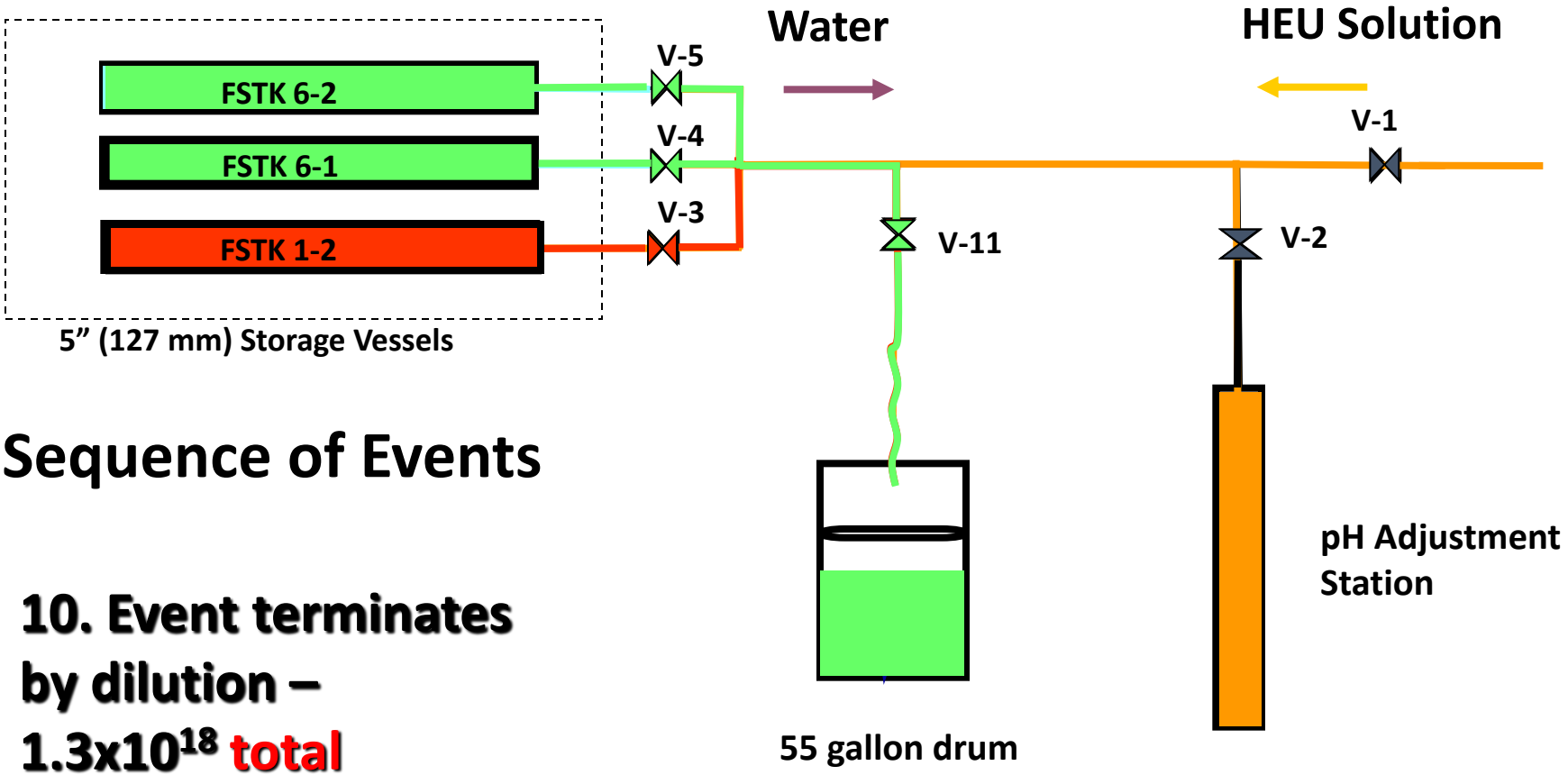
Y-12

Brief description of Y-12 criticality accident

- Material composition
  - Fuel: Moderator: 93% enriched, 2.5 kg U235, uranyl nitrate in water
  - Vessel: 55-gallon stainless steel drum, plastic liner
- Geometry
  - cylinder
- Initiating event
  - Inadvertent addition of solution to 55 gallon drum
- Cooling system: water addition, heat loss to ambient temperature
- Shutdown mechanism – dilution to subcritical

Y-12 Accident Scenario



Sequence of Events

10. Event terminates by dilution – 1.3×10^{18} total fissions

Evacuation into event

Drawing in Y-1234 or LA-13638

Evaluations to Date

- Past 7 years Y-12 accident has been used as a test case to support advanced modeling/simulation for out of reactor (ANS-8.3/8.23) and AHR design/safety analysis. The following are noted:
  - FETCH Code - Buchan, A., et. al, ICNC 2011
  - COMSOL – Angelo, P.L ICNC 2015
  - Zamachinski (ICL) Y-12 and Transient Point Kinetics - Prog Nuc Eng Paper
  - Winter, Cooling – Uncertainty analysis in initial spike fission rate, PNE, ANE Papers in reference
  - MCNP/SCALE TSUNAMI sensitivity/uncertainty (S/U) sequence for nuclear data/reactivity
- Y-12 effort funded by US Dept of Energy “Advanced Scientific Computing” Initiative for criticality excursion modeling and simulation using COMSOL Multiphysics
- These evaluations provided a cursory analysis depending on the calculation method. A complete sensitivity/uncertainty analysis of the Y-12 accident has not been conducted. The initial report recognizes several major uncertainty components.
- There is an ongoing investigation in modeling specific features of the Y-12 accident by Imperial College London and Y-12, that can be rolled into a “benchmark” quality calculation.
- Question remains – How much historical data can be used to determine specific parameters, S/U? In the end, the CRAC experiment data confirms the Y-12 “macroscopic effects”

Benchmark Open Issues

- Sensitivity/Uncertainty quantification in several areas
  - Fissile solution and U235 mass addition rate (from original hydraulic reconstruction data)
  - Critical height, height at prompt critical
  - Precursor transport/radiochemical and chemical analysis
  - External reactivity addition rate over time/ Reactivity feedback (external, temperature, void)
  - Initial Spike Fissions, Fission Rate
  - Total Spike Fissions to 20 min
  - Heat Transfer through polyethylene drum liner
- Incorporation of a Space-Time Radiolytic Gas/Precursor Transport Model
- Reconstruction of solution chemistry vs time (e.g. molar hydrogen, nitric acid concentration from documented supplementary measurements)
- Incorporating a dynamic filling geometry (e.g. moving height/mesh, solution movement at top boundary)
- Allowance for different calculation methods: 1) Point Kinetics w/Lumped Parameter Heat Transfer, 2) Quasi-static, Multigroup diffusion or 3) fully spatially coupled neutronics, gas/precursor/fuel transport, +CFD
- Estimating the external neutron/gamma spectrum, Dose/fissions vs time at specific distance (e.g. unshielded Person A) – is this part of the exercise?

References

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- Buchan, A.G., et.al (10 co-authors incl. P. Angelo, Y-12) Simulated Spatially Dependent Transient Kinetics Analysis of the Oak Ridge Y-12 Plant Criticality Excursion, Prog. Nucl. Energy, March 2013, 63:12-21, DOI:10.1016/j.pnucene.2012.09.006 (FETCH Simulation) http://dx.doi.org/10.1016/j.pnucene.2012.09.006
- Zamacinski, T., et. al, (ICL), A Point Kinetics Model of the Y-12 Accident. Prog. Nucl.Energy, June 2014, 77: 92-106 http://dx.doi.org/10.1016/j.pnucene.2014.06.004 (PKE Model)
- Angelo, P.L., COMSOL Multiphysics Simulation of the 1958 Y-12 Criticality Accident, 2015 ICNC September 13-17 2015 Charlotte NC
- Winter, G.L, et al (ICL), Importance of parametric uncertainty in predicting probability distributions for burst wait times in fissile systems, Ann. Nucl. Energy April, 2018, 119: 117-128 (Case Study I: The Y-12 Accident) http://dx.doi.org/10.1016/j.pnucene.2018.04.026