Windscale Works Criticality Incident 1970

Paul Smith

Outline

- Sources of information (references)
- Outline of Incident
- Proposed Benchmark Calculations

References

1. Daniels, J. T., H. Howells, and T. G. Hughes, “Criticality Incident-Aug 24, 1970, Windscale Works.”, *Trans. Am. Nuc. Sec.*, **14**, pp. 35–36, (1971).
2. Evans, M. C. “A Review of Criticality Accidents, Within the European Community.” *Trans. Am. Nuc. Sec.*, **46**, pp. 6-10, (1984).
3. Thomas P. McLaughlin, Shean P. Monahan, Norman L. Pruvost, Vladimir V. Frolov, Boris G. Ryazanov, Victor I. Sviridov, “A Review of Criticality Accidents”, 2000 Revision, LA-13638, pp. 43-44, (2000).

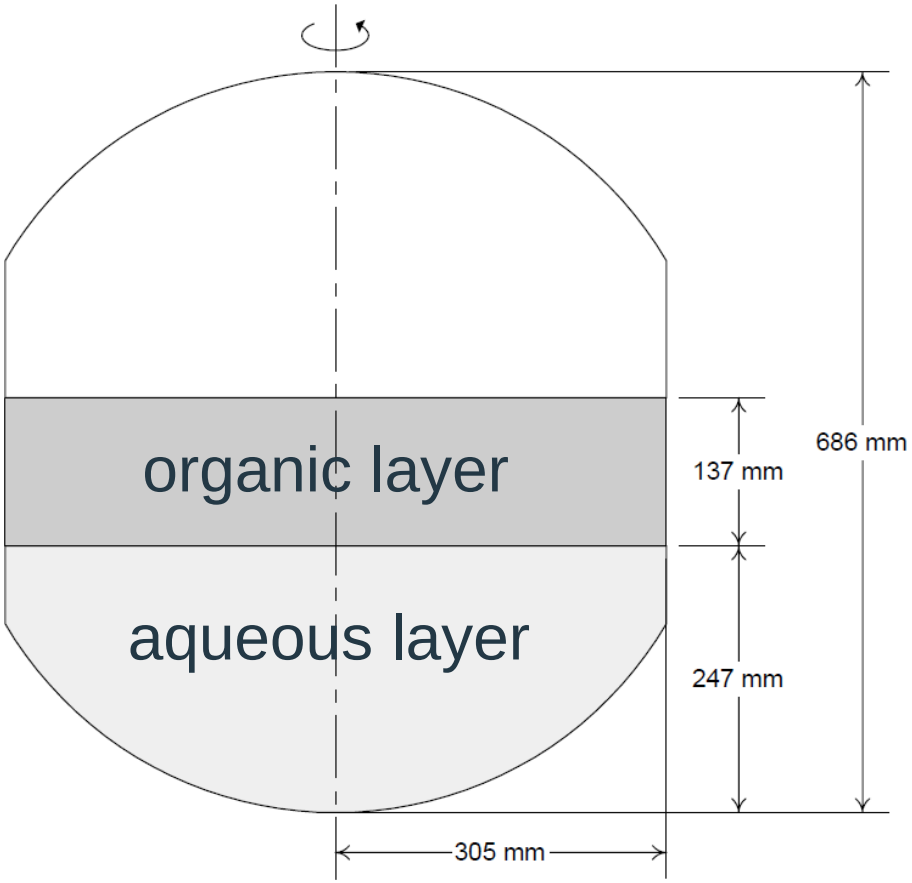
Outline of Incident

- Pu dissolved in nitric acid with concentration of 6 – 7 g/l
- 50 l of aqueous solution transferred to transfer vessel
- Upon completion of the transfer a small excursion occurred leading to insignificant exposures:
  - ~ 10^{15} fissions
  - Duration < 10 s.

Post Incident Investigations

- 39 l of organic solution (tributyl phosphate and odourless kerosene) found in the vessel with a specific gravity of 0.96 containing 55 g Pu/l.
- Aqueous solution that passed through the vessel had a specific gravity of 1.3.
- Somehow organic solvent had found it’s way into the transfer tank
- Each time aqueous solution was added to the tank it sank below the organic layer and was drained off, leaving the organic solvent in the tank
- Each time two layers were in contact some of the Pu transferred from the aqueous layer to the organic layer, until a concentration of 55 g Pu/l had built up in the organic phase.

Transfer Vessel Details: from ref. 3



Proposed Stages for Criticality Incident

- A: Filling During the transfer of aqueous solution to the transfer vessel the system consisted of a layer of organic solution on top of a layer of aqueous solution. The incoming aqueous solution created a column of aqueous solution in the organic layer and a layer of emulsion (organic globules in the aqueous solution) separating the organic and aqueous layers.

- B: Emulsion Upon completion of the transfer a layer of organic solution sat above a layer of emulsion which sat above a layer of aqueous solution. Experimental investigations revealed that the emulsion would persist for 5 – 10 s.

- C: Separated The organic globules rose under gravity to amalgamate with the organic layer, giving a final configuration of an organic layer on top of an aqueous solution, before the aqueous solution was drained from the vessel.

Reactivity of Different Configurations

- MONK calculations revealed that:

- Configuration B is $5 more reactive than configuration A,

- Configuration B is $15 more reactive than configuration C.

- This an example of a process in which the initial and final configurations are sub-critical, but the system passes through critical configurations in between.

Proposed Benchmark Calculations: Steady-State Neutronics

- Perform steady-state neutronic calculations for the following configurations:
- Filling stage:
  - Organic layer on top with a cylinder of aqueous solution in the centre
  - Emulsion layer below organic layer of varying thickness
  - Aqueous layer below the emulsion layer
- Emulsion stage:
  - Organic layer on top
  - Emulsion layer below organic layer of varying thickness
  - Aqueous layer below the emulsion layer
- Separated stage:
  - Organic layer on top
  - Aqueous layer on the bottom

Proposed Benchmark Calculations: 2D neutron transport - CFD

- Simulate the filling, emulsion and separated stages of the process:
- Model emulsion formation during the filling stage:
  - globules of organic solution formed in the aqueous phase due to hydrodynamic forces
- Model the rise of the globules through the aqueous phase to the organic layer during the filling stage and the emulsion stage
- Model the criticality transient that occurs at the end of the filling process
- Candidate Models: FETCH, COMSOL, other?

Proposed Benchmark Calculations: Point Kinetics codes etc.

- Modify existing codes such as CRITEX, TRACY etc. to replace fission gas generation with globule generation:

- Replace bubble rise velocities with globule rise velocities:

- Model the filling and emulsion stages until a criticality occurs and follow the criticality excursion until it terminates.

Discussion

- QUESTIONS
- SUGGESTIONS
- DISCUSSION
- Who would be interested in participating?