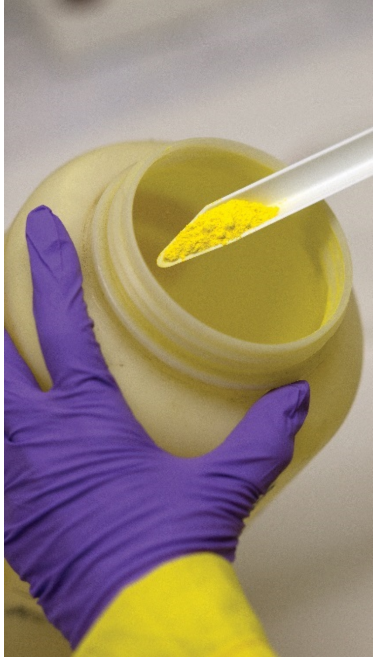

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PANTEX PLANT | Y-12 NATIONAL SECURITY COMPLEX

An Evaluation of In-Line Component Process Modules

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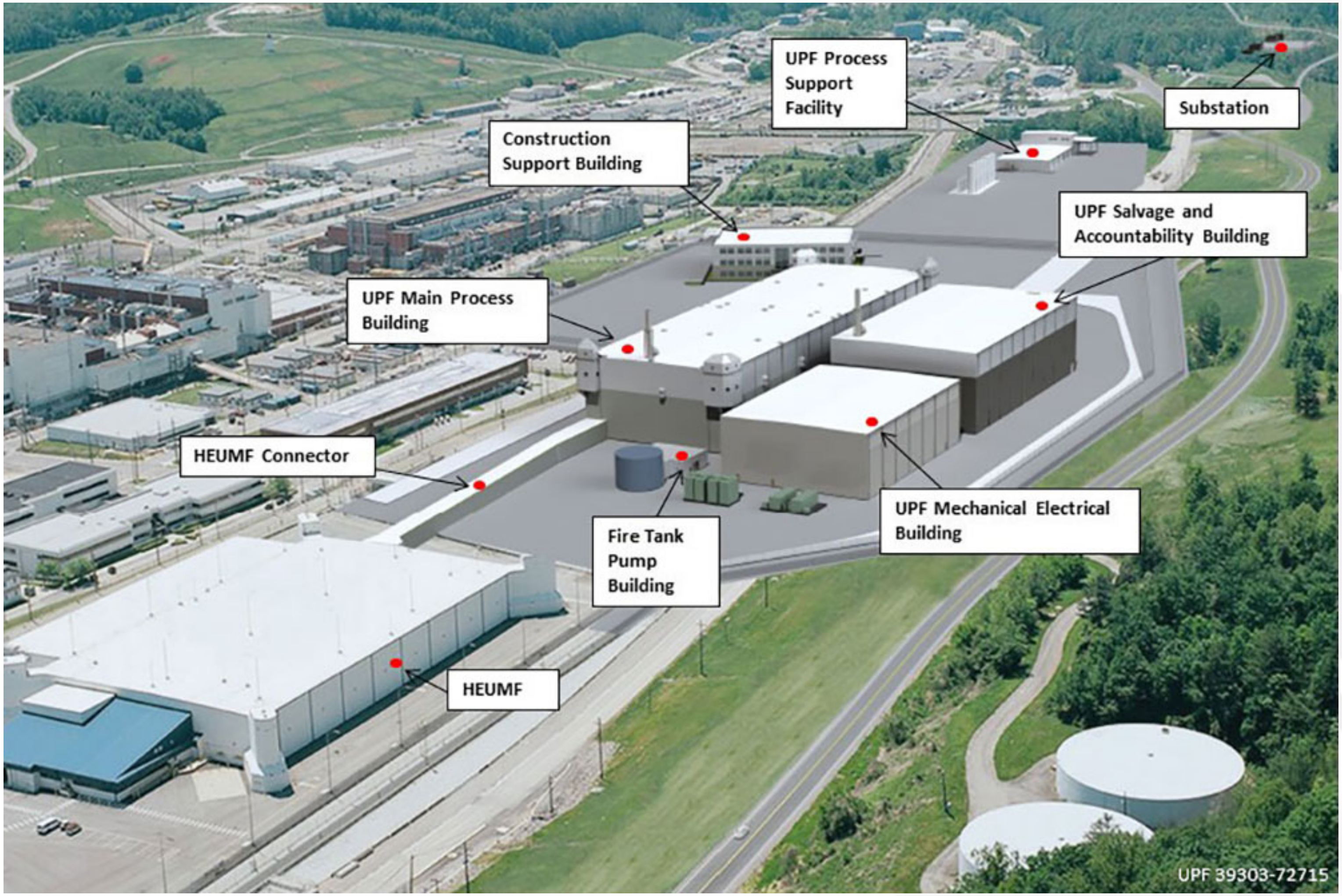
Overview

- Safety Philosophy at the Uranium Processing Facility
- Evaluation of In-line Component Process Modules
  1. Definition of In-Line Components, Modularization, Design Criteria
  2. Methodology, Margin, and Area of Applicability
  3. Materials Description
  4. In-line Component Process Modules (Base Models)
  5. Abnormal Conditions
  6. Results
- Current Work

The Uranium Processing Facility (UPF)



http://home1.y12.doe.gov/upfconstruct/about.php

UPF Safety Philosophy

1. Minimize hazardous material quantities
2. Control Hierarchy
   i. engineered controls > administrative controls
   ii. engineered passive controls > active controls
   iii. preventative controls > mitigative controls
   iv. facility level and process-level engineered controls > PPE
3. Position control near the hazard *(provides protection for worker and the public)*
4. Select controls that are effective for multiple hazards or accident scenarios
5. Controls contain safety functions, functional requirements, and performance criteria *(should be used in total and as a communication tool between nuclear safety and design)*

Why Evaluate In-Line Component Process Modules?

EU Processes utilizing fissile-material-bearing equipment (in-line components and process modules), must be evaluated under normal and abnormal conditions to ensure subcriticality. (ANSI/ANS-8.1)

- Understand impacts of design change
- Identify and interpret sensitivities inherent to a process
- Provide a basis for UPF Criticality Safety Design Criteria
- Support the development of Criticality Safety Process Studies for processes with various tank, vessel, pump, and in-line component configurations

Note: Historically, solution-processing facilities ignored in-line components in NCS evaluations, and relied on NCS expert-based feedback from walk-downs and field adjustments for sizing and spacing of components.

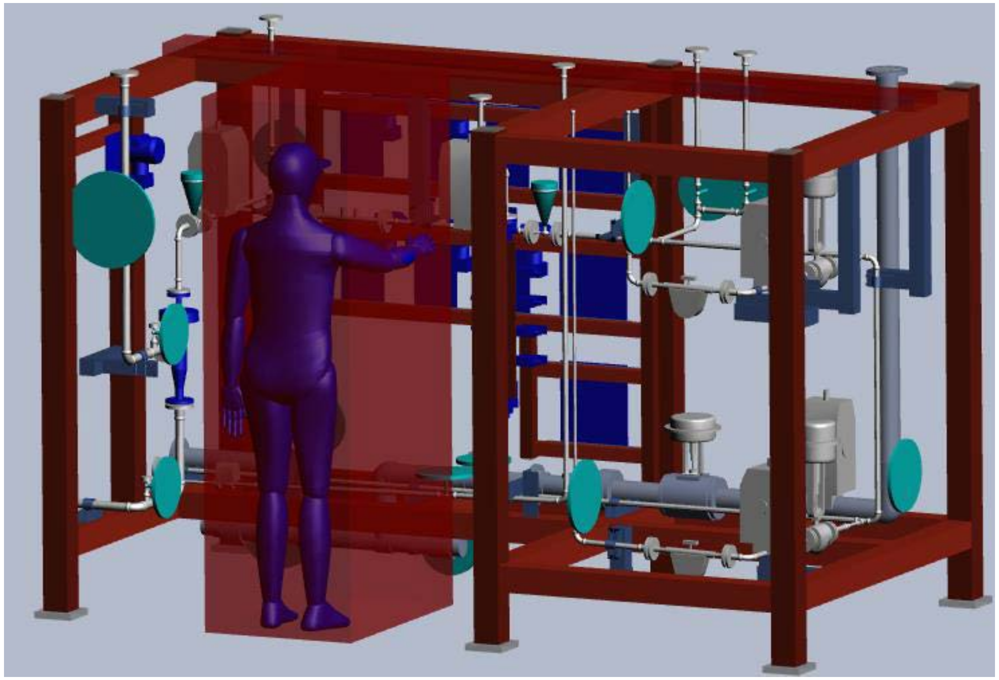
In-Line Components, Process Modules (Modularization) and Design Criteria

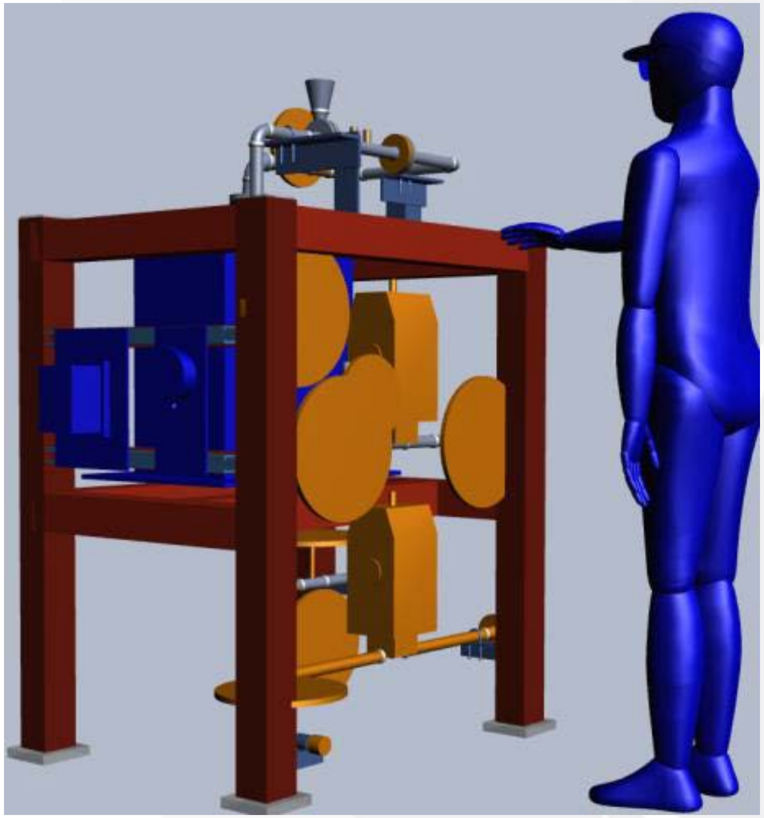
- In-line components are items piped together that either *contain, control, transport, or monitor* fissile material during normal and abnormal conditions

- Modularization is the pre-assembly of a group of components that can be installed and fitted as a whole, assembled in a remote location, and shipped to the jobsite for installation as completed packages

- Design criteria provide a bounding set of NCS requirements that cover most of UPF fissile system interactions (Covers piping and tubing requirements, sizes for in-line components, and process module spacing limits)

Process Modules





Process module concepts show equipment assembled on a metal structural frame: pour-up station (left) and a uranium concentration monitor (right).

Methodology, Margin, and Area of Applicability (1)

- KENO models created based on anticipated equipment configurations and bounding fissile material contents for various processes within the facility.

- Each model represents a variation in process properties, such as equipment spacing, ^{235}U/uranyl nitrate solution concentration, and interaction with other fissile material-bearing equipment.

- Implemented standardized inputs and methodology from published Nuclear Criticality Safety Data Book (DAC-EN-801768-A100, see References on http://ncsp.llnl.gov.).

Methodology, Margin, and Area of Applicability (2)

- Additional safety margin is not required because calculations generally fall well within the validation AoA.

- Area outside of the validation AoA is comprised of cases in which the uranium concentration is 10 g U/L or less. ($H/^{235}U$ ratio exceeds the validation limit of 2000).

- ANSI/ANS-8.24, section 7.1 states "The validation applicability shall be established based on the benchmark applicability and may be extended to allow for extrapolation and wide interpolation of the data".

- Statistical analysis per the validation reports the lowest upper subcritical limit of 0.986 for solution systems. A safety margin of 2% in k_{eff} was added: subcritical for $k_{eff} + 2\sigma < 0.966$.

Methodology, Margin, and Area of Applicability (3)

Table 1. Area of Applicability (AoA)

Parameter	DAC AoA	Validation AoA
Fissile Material Form	$UO_2(NO_3)_2$, U-Metal	UO_2, $UO_2(NO_3)_2$, UO_2F_2, U-metal
Moderation ($H/^{235}U$)	0–2600	0–2000
Enrichment	100% ^{235}U	>60% ^{235}U
Geometry	Cylinders, Cuboids, Arrays	Spheres, Cylinders, Cuboids, Hemispheres, Hemicylinders, Arrays
Moderating Material	Water	Light Water, Heavy Water, Polyethylene, Plexiglas
Energy of the Average Neutron Lethargy of Fission (EALF)	Thermal and Intermediate (0.02 eV – 1.0 eV)	Thermal (<0.625 eV), Intermediate (0.625 eV – 100 keV), Fast (>100 keV)
Reflecting Material	Water, Concrete	Unreflected, Light Water, Heavy Water, Polyethylene, Plexiglas, Concrete.

Materials Description

- Materials evaluated for this calculation were uranyl nitrate, uranium metal, water, concrete, and stainless steel.
- Per Y-12 procedure Y70-150, *Nuclear Criticality Safety Program Fundamental Criteria*, “Processes in which unintended commingling of materials of different enrichments is possible shall be evaluated at the maximum credible enrichment available.”
- A specific isotopic distribution for the highest enrichment expected at UPF is difficult to pinpoint ,therefore all fissile materials were modeled as having a ^{235}U enrichment of 100% and full theoretical density of 18.81 g/cm^3.
- Water used as reflection caused by construction materials associated with the process modules, and for other reflective surfaces, such as personnel working in the vicinity of the equipment. (Magneson’s concrete is bounding room reflector).
- Uranyl nitrate, modeled as the fissile solution, is evaluated over the range of 0 to 550 g U/L.

Base Case - Process Module in a Room (1)

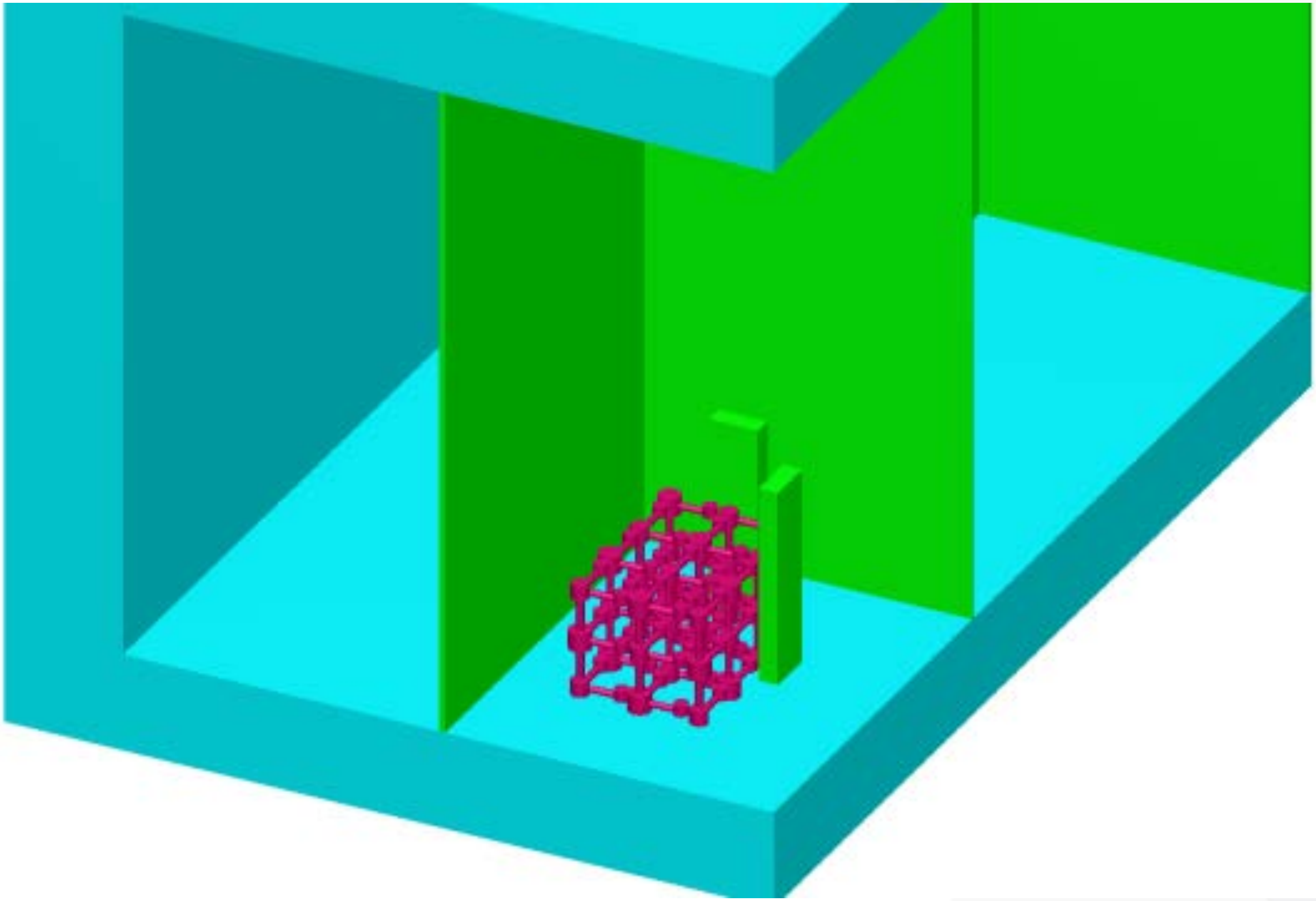
- Process module comprised of 36 individual in-line components (3x4x3 array that incorporated equal numbers of 6, 4, and 2 L units in the x,y and z directions)

- Individual units modeled with height equal to diameter, average 12 in. edge-to-edge spacing between units, and connected with 2 in. pipe

- Reflection from other equipment and materials in the process room modeled as 1 in. thick water wall surrounding the process module, human reflection represented by water cuboids adjacent to array

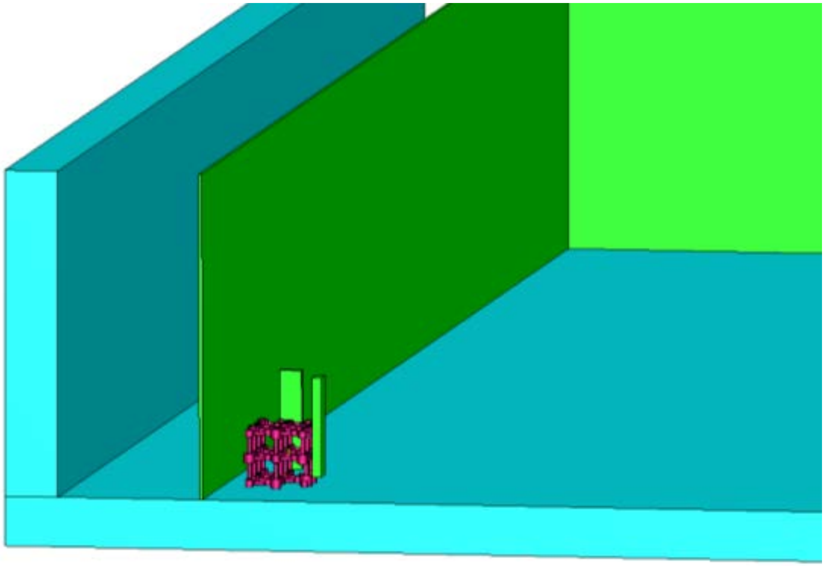
- 3x4x3 array of in-line components conservatively represent expected UPF process modules

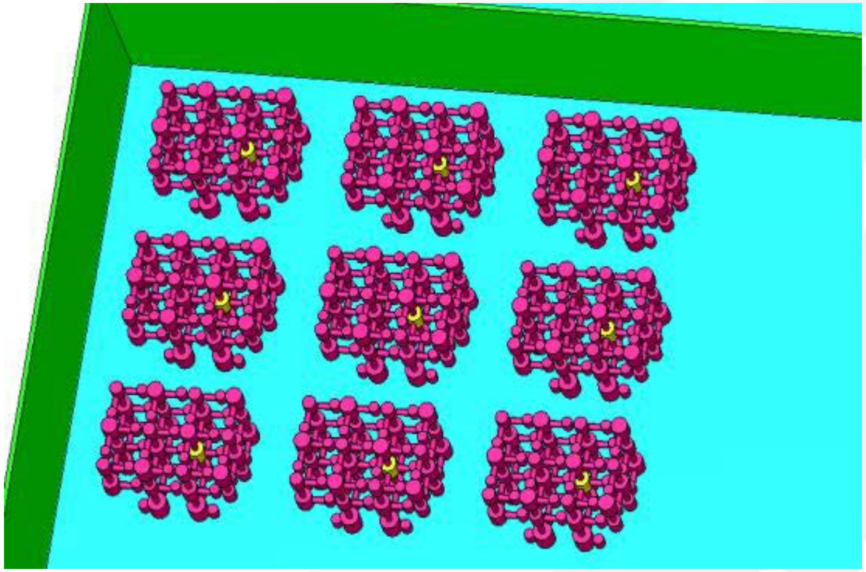
Base Case - Process Module in a Room (2)



3x3 Array of Process Modules in a Room

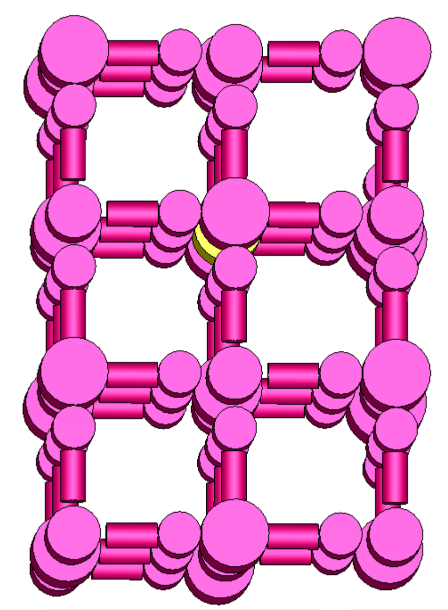
- Added two 6 L units and one 4 L U-metal-water unit with 10 kg of uranium (in-line filter) to the base case process module
- 9 base case process module array in a room at different edge-to-edge spacing values



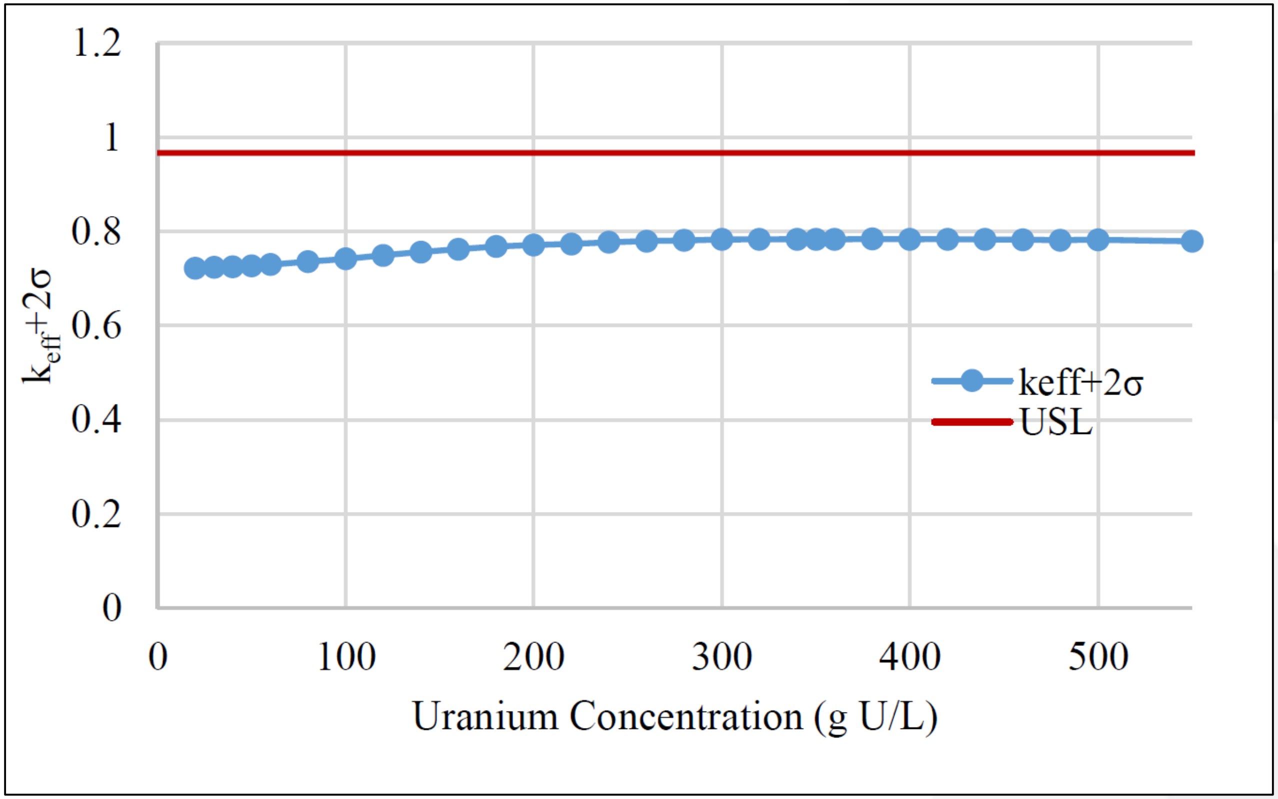


Abnormal Conditions

- Expanded fissile spills following linear dilution approach for concentrations and spill depths
  - 200 g U/L at depth of 0.5 in.
  - 40 g U/L at depth of 1 in.
  - 20 g U/L at depth of 2 in.
  - 15 g U/L at depth of 3 in.
  - 10 g U/L at depth of 4 in.
- Sprinkler activation in the event of a fire (atmospheric sprinkler water density ranges from 0 to 1.0 g/cm^3 in increments of 0.005)
- Combination of fissile spill and sprinkler activation

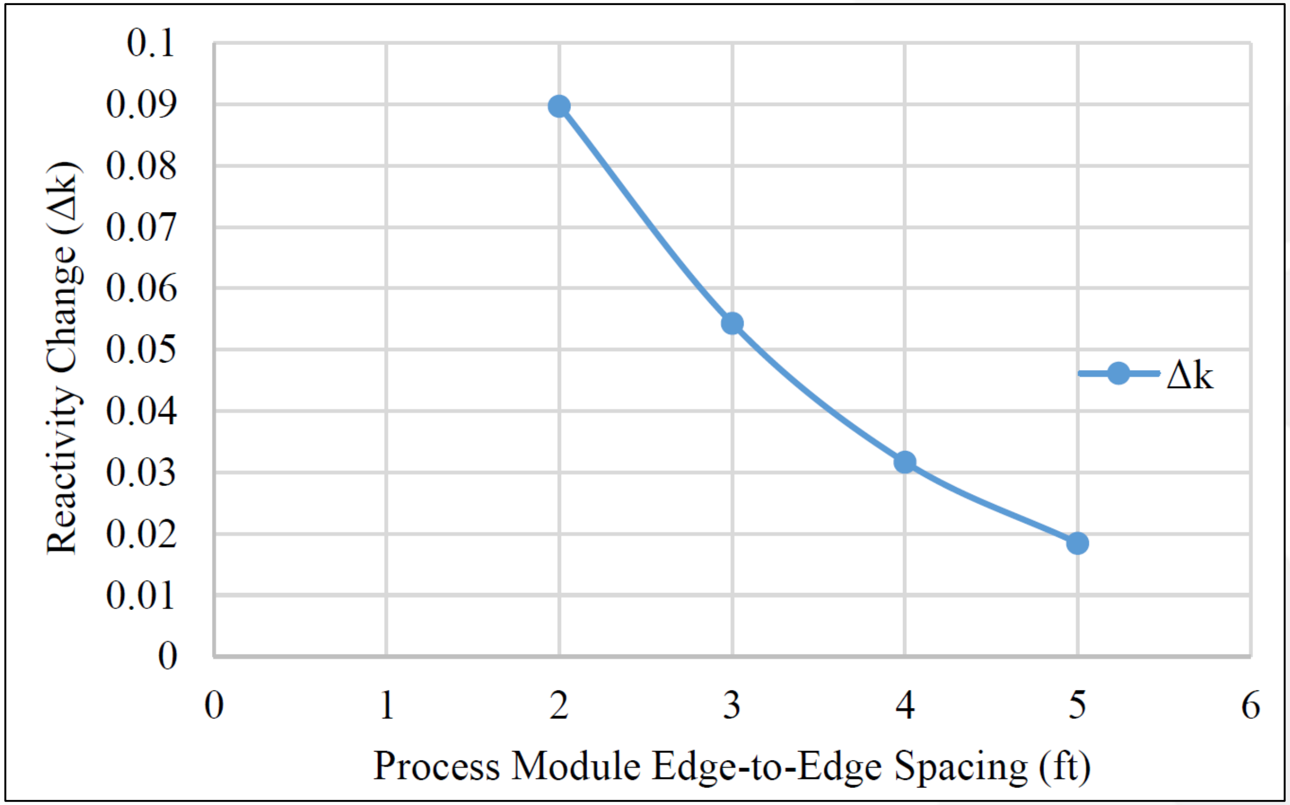


Results (1)



$k_{eff} + 2\sigma$ vs. Uranium Concentration for Single Module Base Case

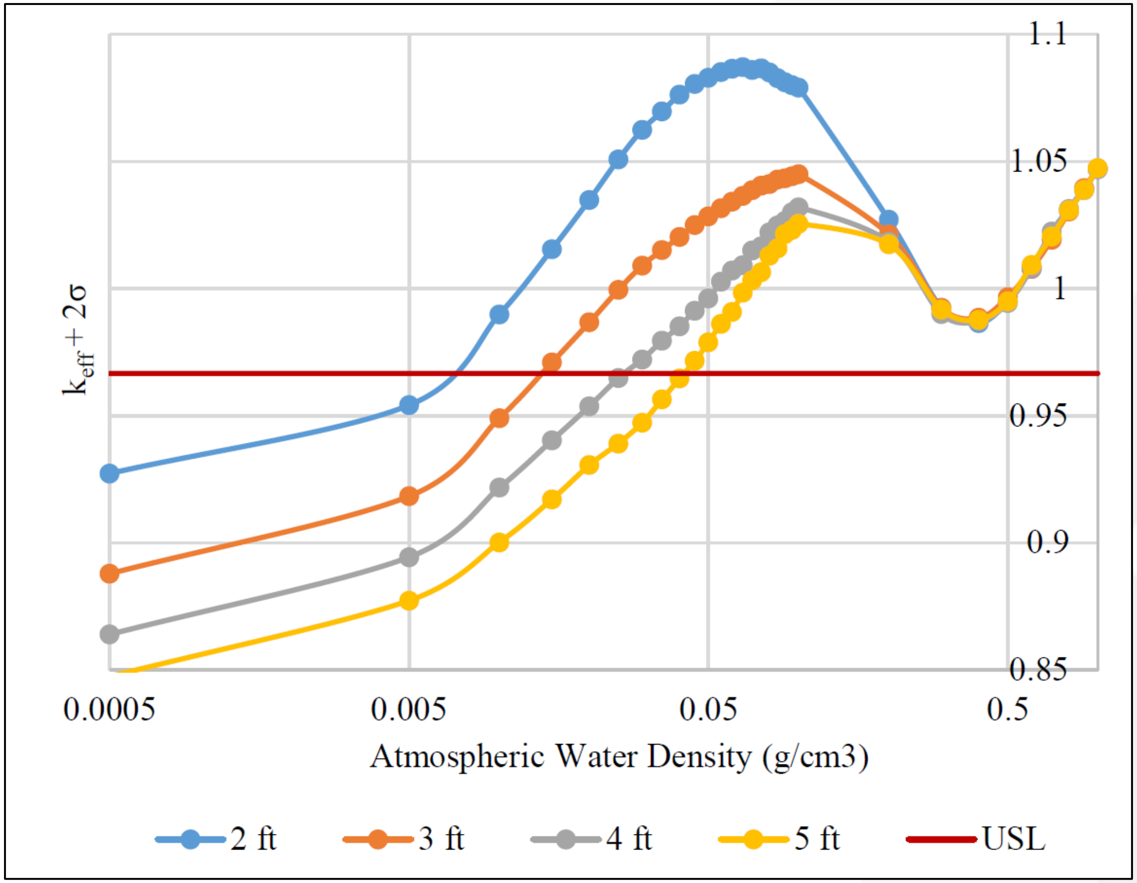
Results (2)



Δk vs. Edge-to-Edge Spacing for 3x3 Array of Process Modules

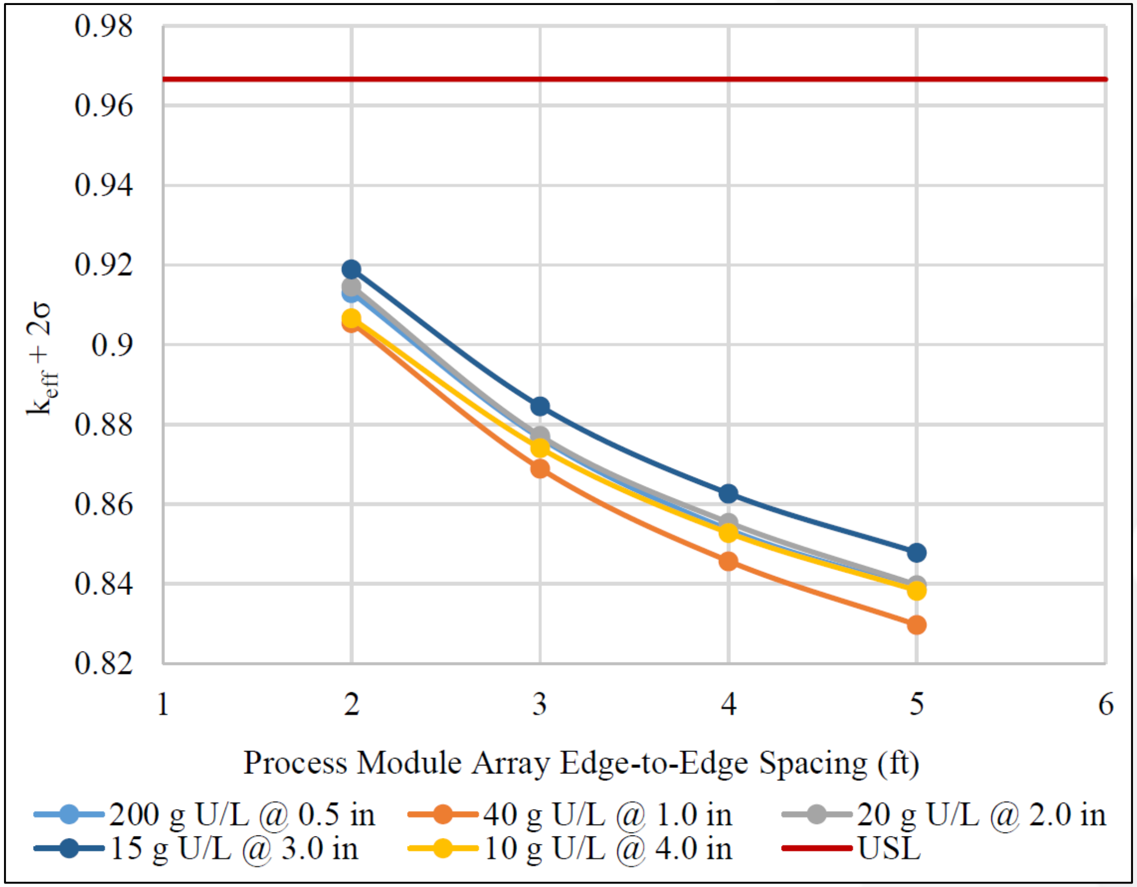
$$\Delta k = k + 2\sigma_{array} - k + 2\sigma_{single\ module}$$

Results (3)



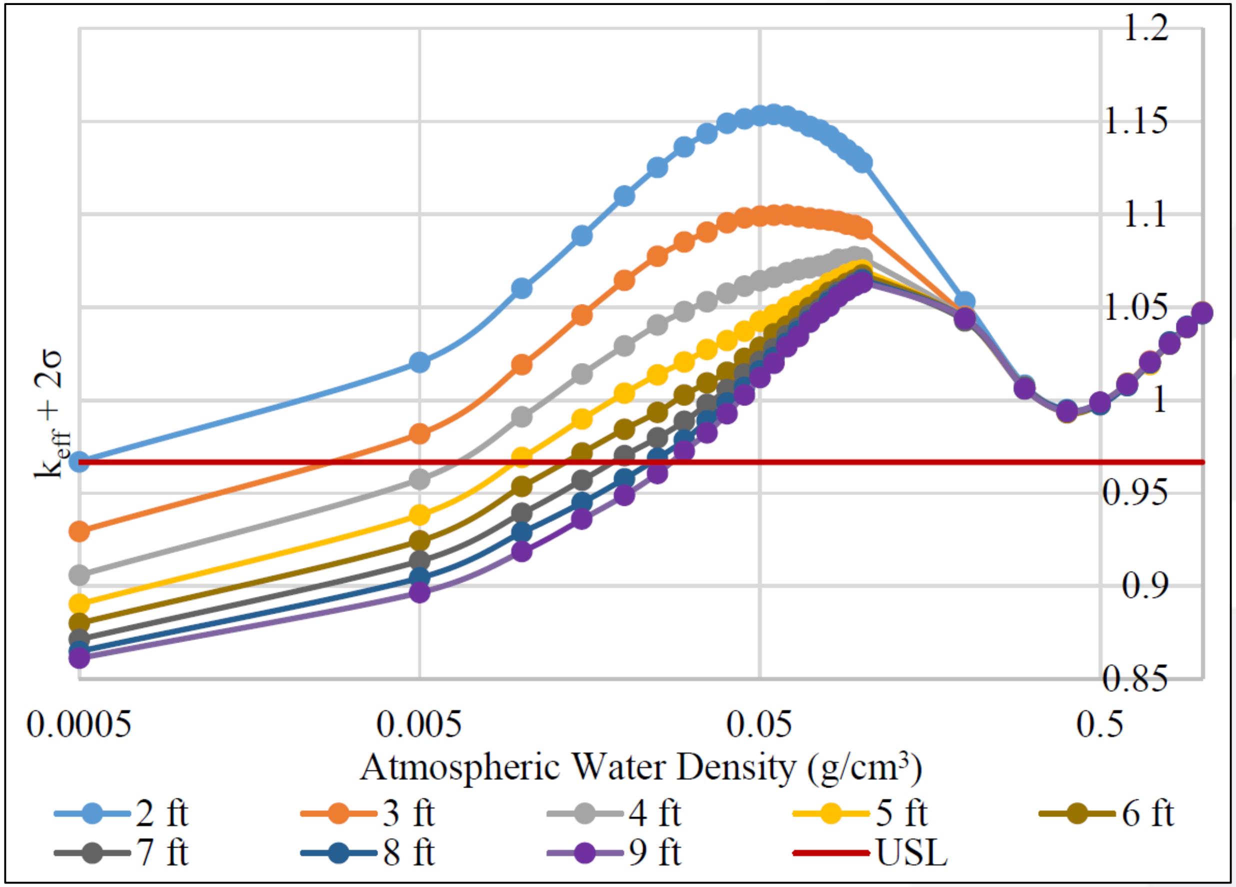
$k_{eff} + 2\sigma$ vs. Sprinkler Water Density for 3x3 Array of Process Modules

Results (4)



$k_{eff} + 2\sigma$ vs. Process Module Array Edge-to-Edge Spacing with Spill of Fissile Solution

Results (5)



3×3 Array of 3×4×3 In-Line Component Process Modules with Sprinkler Activation and Spill of Fissile Solution at Varied Edge-to-Edge Spacing

Over-Conservatism in the Models → k_{eff} > USL

- Large number of in-line components per process module with individual units as cylinders with height equal to diameter
- “Failed” in-line component at a volume of 6 L which operates normally at 4 L
- 100% uranium enrichment
- 2 inch piping modeled as 2.5 inches
- Inclusion of a filter with a 10 kg U mass judged to represent accumulations of uranium solids in filters characteristic to in-line component process modules

This behavior does not represent an acceptable design and implies that a more accurate model is needed to demonstrate subcriticality.

Current Work – Strategy for Developing an Accurate Model

- Produce models of process modules that are as close to the actual design as possible, while still employing conservative fissile material, moderation, and reflection conditions to determine restrictions/controls for NCS parameters.

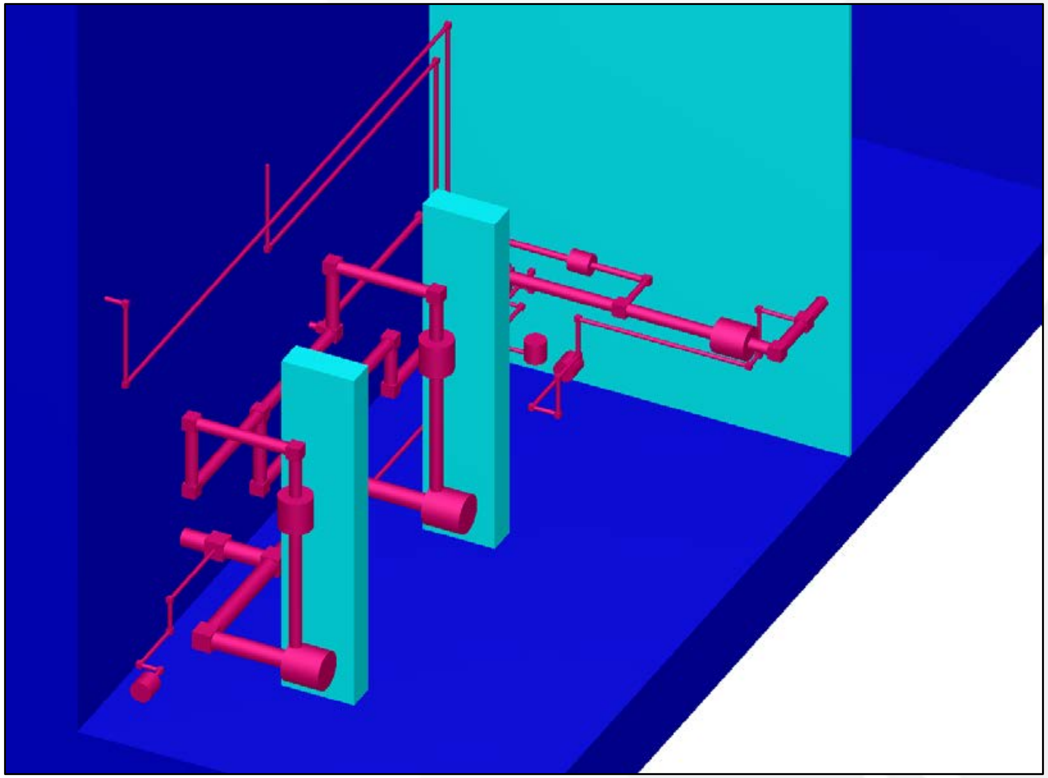
- Obtain Module Design Information from associated vendor package which includes equipment location drawings, isometric drawings, P&IDs, and equipment lists as the primary sources of information.

- Identify equipment to be modeled such as pumps, piping, valves, and instruments (pressure indicators and transmitters, flow meters, level indicators, etc.)

- Develop model incrementally.

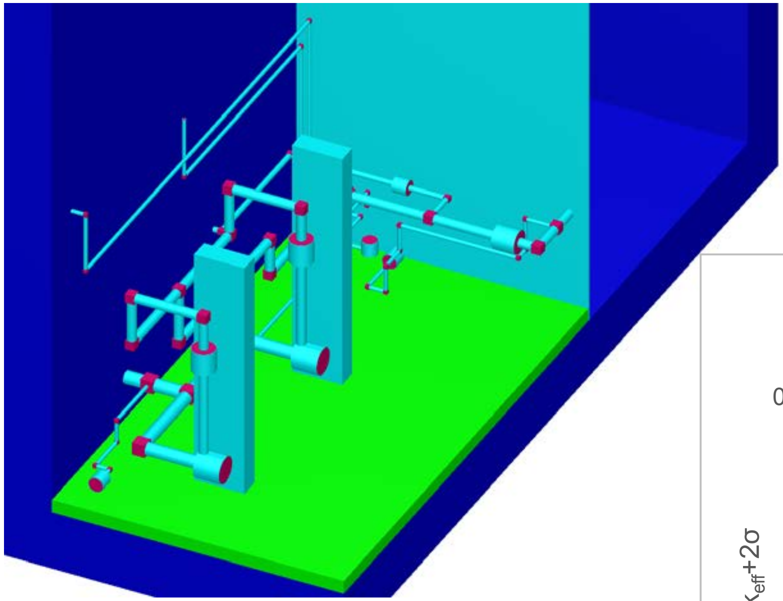
Current Work – Strategy for Developing the Model

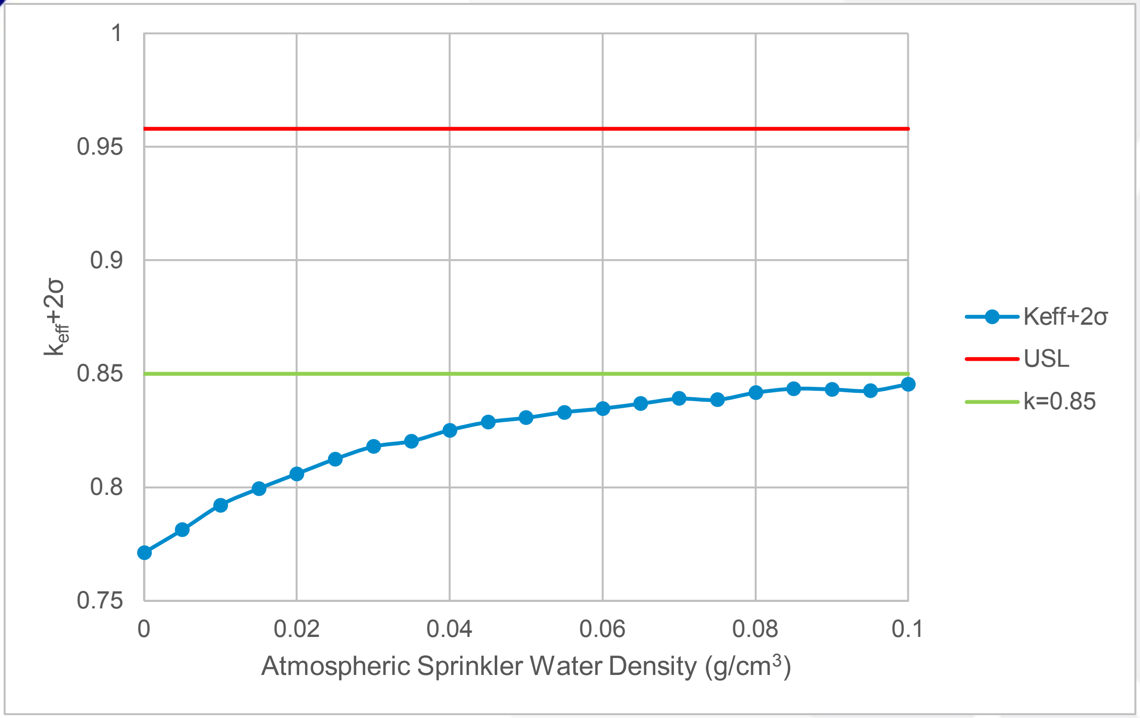
1. Model process room, module outline, room reflection conditions and first pieces of equipment.
2. Add pumps and discharge lines to the model.
3. Add supply lines, recycle lines.
4. Add all instrumentation and associated lines.
5. Add two water bodies to the module to represent the reflection due to the presence of workers.



Example of Final Process Module Model

Current Work – Results of Remodeled Process Module





Remodeled Process Module
k_{eff} vs Sprinkler Water Density with a Fissile Spill