Criticality Safety Of The Waste Treatment Area In The Seu Production Line At Zircatec

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The production of slightly enriched uranium (SEU) fuel bundles at Zircatec has necessitated the need for a criticality safety analysis of all equipment and process operations involving enriched uranium. One such area in the new SEU line is the Waste Treatment Area (WTA). With the assistance of NuclearSafety Associates (NSA), the new Waste Treatment Area was evaluated to determine the design constraints and criticality safety controls necessary to demonstrate that adequate protection exists against an accidental nuclear criticality event involving the equipment in this area. This paper will discuss the approach taken to ensure criticality safety of the Waste Treatment Area by involving nuclear criticality safety engineers in the design and placement of equipment in the area to provide "criticality safety by design". A discussion of the different design strategies considered by NSA and Zircatec for the area will also be discussed.

1.0 CRITICALITY SAFETY OF THE WASTE TREATMENT AREA

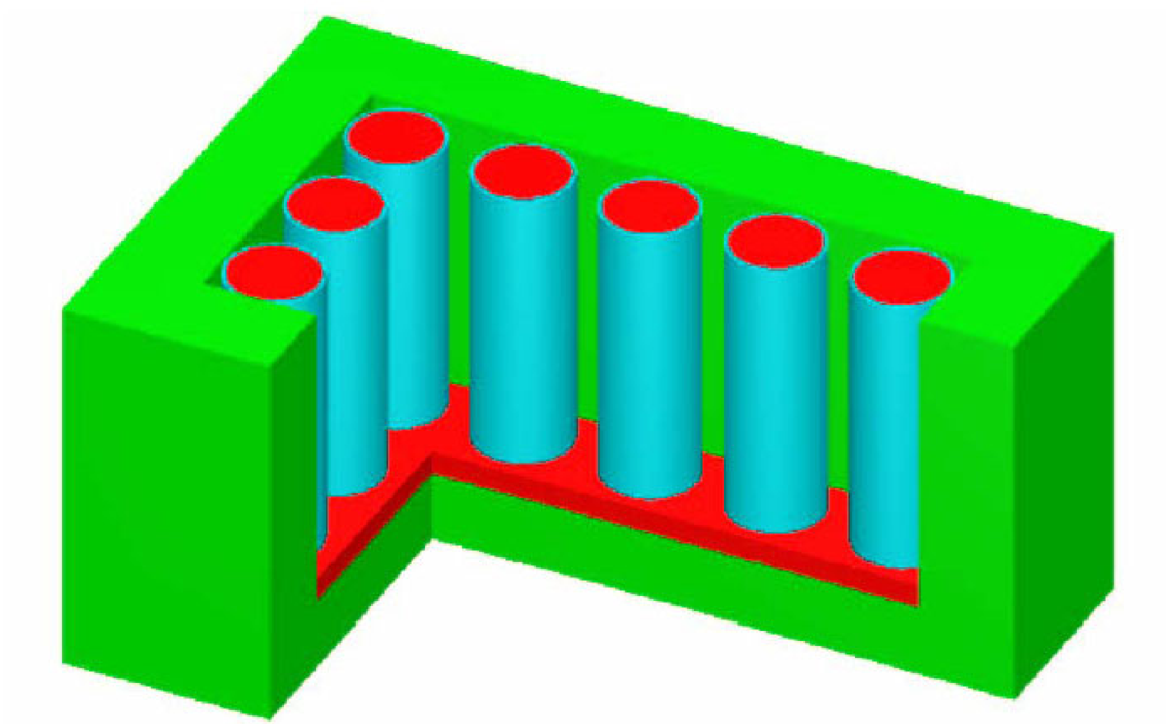
The Waste Treatment Area (WTA) involves four primary operations involved with treating and/or processing waste emanating from the production of SEU fuel bundles. These areas are: Wastewater Treatment, Scrap Recycle, Decontaminating/Cleaning, and Solid Waste Processing. Each of the areas in the WTA involves a different strategy for criticality safety and will each be discussed below.

1.1 Criticality Safety of the Wastewater Treatment System.

The wastewater treatment system consists of a system of tanks and piping interfaced by operators and engineered devices used to collect, treat, and discharge liquid waste to the city sewer. The liquid waste received into the system includes production floor mop water, grinder coolant overflow, contaminated water from decontamination operations, and pellet wash water.

The first choice for criticality safety of any system is geometry control. Geometry control involves showing that the system will remain subcritical based solely on the size and position of the tanks within the area. When evaluating the wastewater treatment system the first choice was to see if geometry control would work.

An analysis of the size and the position of the tanks in the area was performed. The tank arrangement is shown in the next figure. Results included different size of tanks and different spacing between tanks. The tank arrangement is shown in the next figure followed by a table of typical results of the criticality safety calculations.



CALCULATION MODEL FOR WASTEWATER TREATMENT TANKS

CRITICALITY SAFETY RESULTS FOR WASTEWATER TREATMENT TANKS

Tank Diameter (cm)	Tank Height (cm)	Tank Volume (liters)	Tank Spacing (inches)					
			4	6	8	10	12	18
56	183	449	0.9151	0.9100	0.9097	0.9094	0.9095	0.9091
	274	673	0.9162	0.9121	0.9118	0.9121	0.9118	0.9124
	366	897	0.9194	0.9137	0.9136	0.9139	0.9144	0.9141
	457	1121	0.9188	0.9140	0.9141	0.9142	0.9147	0.9147
61	183	449	0.9296	0.9258	0.9259	0.9254	0.9255	0.9248
	274	673	0.9324	0.9290	0.9287	0.9288	0.9286	0.9283
	366	897	0.9325	0.9303	0.9302	0.9298	0.9291	0.9290
	457	1121	0.9334	0.9309	0.9298	0.9304	0.9304	0.9311

In the above figure, red represents the uranium/water mixture, green represents water, and blue represents a conservative water jacket surrounding the tanks. The results table above shows the acceptable combinations of tank diameter and spacing between tanks in grey. Values in the table are keff values which have an acceptance criterion of 0.930.

The results were discussed between NSA and Zircatec to decide on an acceptable combination of size and spacing based on the calculated results that would allow efficient operation of the wastewater treatment system. The final layout design ensures that any concentration of homogenous uranium solutions/mixtures remains subcritical throughout the treatment cycle.

In addition to the design of the tank geometry and layout, additional design features like favorable geometry drip trays, controlled floor area and safety related leak detection/isolation systems protect against criticality should uranium leak from the favorable geometry tanks.

1.2 Criticality Safety of the Scrap Recycle Area.

In this area of the Waste Treatment Area, a system of ovens, comomills, and micronizers are utilized to transform production scrap solids into recycled feed powder. Equipment in the area is also limited in size to ensure that all mixtures of uranium and water remain subcritical throughout the process of drying, baking, mixing, and micronizing. Sources of production scrap solids include sludge from the production grinder coolant centrifuge, scrapped sintered pellets from the production sintering furnace operations, and pellets extracted from bundle elements during quality assurance inspections (decan operation).

Different strategies for ensuring criticality safety were carefully considered and discussed in this area. For example, the sintered pellets that are to be recycled as scrap are handled in bowls. During transfer, storage and processing of these bowls of pellets, criticality safety must be ensured. As before, first consideration was given to geometry control. Important dimensions of concern are the volume and depth of the bowls. Previous criticality safety calculations for Zircatec show that pellets stored with a height of less than ~25cm are safe. Therefore all design considerations for the transfer and storage of sintered pellets used this dimension as a design constraint. By paying attention to the needs of criticality safety during the design of the system, it is easy for the criticality safety engineer to demonstrate that operations will remain subcritical during operations.

Sometimes it is desirable to use standard equipment in an area that may have dimensions that are greater than safe subcritical dimensions. An example of this is the oxidation ovens used in the WTA. A picture of an oxidation oven is shown on the next page.

This oven allows multiple shelves to be placed each containing multiple bowls of pellets. Initial calculations show that completely filling the oven with pellets mixed in water is not safe. Therefore different design strategies are being considered in consultation with process engineering and operations. All of the design strategies involve reconfiguration and/or redesign of the internal configuration of the oven. A promising approach involves welding shelves in place and welding caps over the end of the shelf rails to prevent the introduction of additional shelves. This may provide passive limitation on the number of bowls that can be loaded at one time into the oven. By providing for criticality safety in the design of the oven, the operator is no longer responsible for ensuring that the configuration of the system remains subcritical. The simple modifications to a standard item being discussed for the oxidation oven provide the necessary assurance that criticality safety will be maintained in the system.

Another criticality consideration for this area in the WTA is the amount of material that is handled in the area in different types of containers. Scrap material is transferred between containers and the amount of material must be controlled to prevent accumulating a critical mass outside of safe geometry. After discussions between process engineers, operations, and criticality safety the decision was made to limit the number of each type of container in the area to ensure that more than an acceptable amount of material will not accumulate in the area. The number of containers is controlled by the Zircatec configuration management system which only allows a certain number of each type of container to be used in the area. New containers cannot be introduced without removing old containers. Using this strategy ensures that operations in the area are protected against an accidental criticality without the need for complicated controls or administrative operator actions. This is another example of factoring criticality safety directly into the safe operation of a new system.

Also located in the WTA is a designated station for removing pellets from bundle elements (decanning). This station receives the bundle elements within favorable volume “kit” boxes. These boxes are designed such that any configuration of arrangement will always result in a subcritical configuration (even with the presence of water). When dismantling the bundle elements, pellets that are determined adequate for reinsertion back into bundle elements are placed on wire racks at the station and carted over to the production floor. Like the “kit” boxes, these wire racks are designed such that any configuration of arrangement will also always result in a subcritical configuration. It is worth noting that the “kit” box criticality safety analysis and wire pellet rack criticality safety analysis were performed for processes outside the WTA; however, the analysis is applicable to use in the WTA. Communication between engineers responsible for the WTA and areas which use the “kit” boxes and wire racks led to the decision to use these same containers in the WTA. This decision provided for consistency between process areas which builds a stronger case for criticality safety by using consistent design strategies.

1.3 Criticality Safety of the Decontaminating/Cleaning Area.

Two stations are located within the WTA that are designated for decontaminating and cleaning of parts and equipments. One station is a wet grit blaster isolated within a glovebox and is used for heavy duty cleaning. The other station is a shallow tank covered with a grate where operators use a pressure wash to clean lightly contaminated equipment and parts.

For criticality safety in these systems closed loop systems are used that contain favorable geometry piping and safe-size collection tanks. In addition, material and equipment is only decontaminated/cleaned in these systems after gross uranium deposits have been removed from the equipment. This prevents the buildup of large amounts of material within the system that could lead to an unsafe accumulation of mass. Nevertheless, due to the safe geometry of the system, criticality safety is ensured.

1.4 Criticality Safety of the Solid Waste Processing Area.

Solid waste is generated from gloves, rags, mops, sand grit from wet grit blaster, and other cleaning/maintenance materials necessary in maintaining good housekeeping during fuel production. In addition, other solid wastes such as damaged moly boats, tools, equipment, parts, and other wear items are generated. These items are brought to the WTA for disposal into a waste container and compacted, if possible.

The criticality safety strategy for this area of the WTA involves ensuring uranium levels within a waste drum do not pose a risk to criticality safety within the WTA. This is achieved by controlling the dimensions or volume capacity of waste drums to favorable limits and controlling the total number of waste drums allowed within the WTA at a time to a safe quantity.

In addition to this waste generation, solid waste recovered from the wastewater treatment system is collected and dried in a batch-wise evaporator. This evaporator is deigned with favorable dimensions to ensure that a subcritical configuration is maintained for any condition (such as water content or uranium concentration). This recovered solid waste is handled identically to the handling of scrap recycle, except this solid waste is not micronized and sent to the production floor for recycle as is done for the scrap. Instead, after mixing in a comomill, the solid waste is collected in container that is safe for transportation and sent back to the uranium supplier for recovery.

2.0 SUMMARY

The four primary operations in the Waste Treatment Area have been analyzed to ensure operations are safe from the perspective of criticality safety. The safety strategy for most areas involves the analysis of the geometry of the system to demonstrate that criticality safety limits are met. In some areas, additional protection features are used which includes limiting the number and size of containers used to handle and store material. For some systems, standard equipment will not meet criticality safety limits without modifications to limit the operation of the equipment.

In all areas within the Waste Treatment Area, the criticality safety of the systems has been ensured by close communications between process engineers, design engineers, operations staff and criticality safety engineers. This communication has led to a system that is “safe by design” and will meet all requirements necessary to demonstrate criticality safety.