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VISIT TO MALLINCKRODT NUCLEAR CORPORATION ON APRIL 26, 1960

Symbol: HSR:EK:JEM

The main purpose of this visit was to examine the Mallinckrodt direct UF_6 to UF_4 process and metal production as described in Mallinckrodt's feasibility report dated March 16, 1960.

After reviewing the above feasibility report it was felt that since administrative control was relied upon for safety during the cooling of the muffle box, it was desirable to observe how this equipment was employed.

The operation in question consists of the following:

After preliminary drying, the UF_4 powder is severely dried in a hydrogen atmosphere in a muffle box. Each muffle box contains three trays (8 1/4 inches x 15 5/8 inches x 1 1/4 inches) separated vertically by one inch. The three trays form a slab with the dimensions 8 1/4 inches x 15 5/8 inches x 5 3/4 inches. Each tray contains 1.86 Kg of U-235 in the 93.5% enriched UF_4 powder for a total muffle box loading of 5.58 Kg of U-235.

After the muffle box has been heated and the contents sufficiently dried, the box is placed in a chamber equipped with four sprayers located above the muffle box. The muffle box is sealed to prevent water in-leakage, the hydrogen hose is attached to the muffle box, the gas is turned on, the escaping hydrogen gas is ignited providing a visible flame for the operator, and finally the valve controlling the sprayers is opened. The muffle box remains inside the cooling chamber under the spray of water for approximately two hours, during which time two or three workers are in the immediate area and can presumably observe the hydrogen flame in the event it should go out. If water should enter the muffle box it is Mallinkrodt's contention that the steam formed would put out the hydrogen flame which would notify the nearby workers that something should be done. Also Mallinckrodt has stated that muffle boxes have leaked

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previously on different occasions, but the resulting water barely wet the bottom of the muffle box and did not enter the trays. This would imply that any water leaking in would have to start filling up the box from the bottom and would not immediately fill the trays.

In the event that water should leak into the muffle box undetected and fill the box completely, the system might be critical. If one homogenizes the U-235 in the trays over the volume of the box and the equivalent diameter of the box is calculated, the results compare as follows with criticality data in K-343, page 71.

	Flooded Muffle Box	Critical Reactor
Reactor Diameter	7.77 in.	8 in.
Height	15 5/8 in.	8.74 in.
Reflector	water	water
Mass U-235	5.58 Kg	3.05 Kg
$\frac{\text{gm U-235}}{\text{cm}^3 \text{ solution}}$	0.4593	0.424
H/U-235	52	56.7

The above comparison indicates that the flooded, homogenized muffle box is super-critical since a height of approximately 9 inches would just be critical and the actual height of the box is 15 5/8 inches.

However, since the muffle box is really a heterogeneous system consisting of three 1 1/4 inch thick trays separated by 1-inch of water, the flooded system would appear to be less reactive due to the depression of the neutron flux in the fuel ladden sections. Without resorting to involved calculations, all that can be concluded is the system is less reactive than the homogeneous case, but possibly still critical.

In the event that only the trays fill with water, the system also might be dangerous due to interaction between the trays. Assuming that water fills one half of the volume occupied by the UF_4 powder, and the small additional volume of the tray, the H/U-235 ratio of the individual tray equals 19.2. Employing the method given in K-1380 Section I for calculating k_{eff} for a bare system, the value of k_{eff} for the bare tray is found to be:

$\eta f = 2.07$

$U_f = 0.1273$

$U_t = 0.9102$

$K_{eff} = 0.2398$

The safe interaction for the above multiplication factor is 6.601 steradians according to TID-7019, page 75. However, the calculated interaction at the center tray is equal to 9.164 steradians using equation 4b, page 44 in K-1019. Therefore even the wetting of the individual trays in the muffle box should be avoided.

The Mallinckrodt Nuclear Corporation in employing this muffle box operation is essentially relying on moderation control. It is very unlikely that sufficient water could leak into the box fast enough to either fill the trays or fill the entire box before a nearby worker shut the water sprayers off. The only real danger would be in the event that the top of the muffle box split open allowing a large in-flow of water. A criticality accident might occur if sufficient water flowed in rather violently before a worker noticed the hydrogen flame had gone out, and managed to shut off the sprayer valve above the cooling chamber. Future use of this equipment for NYOO work would probably constrain us to carry out a more detailed nuclear examination of the cooling procedure.

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