70-36

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COMBUSTION ENGINEERING

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April 29, 1988

George Bidinger,
Uranium Fuel Section
Division of Fuel Cycle, Medical
Academic, and Commercial Use Safety
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Bidinger:

Enclosed is the revised application for amendment of License SNM-33 to increase the U^{235} enrichment limit to 5.0%. Additional information and license conditions have been included pursuant to our meeting and discussion of items of concern. Substantial changes from the previous submission are denoted by an asterisk (*) in the right page margin. A listing of pages comprising this application is also enclosed.

We certainly appreciate your efforts to expedite processing of this amendment.

Cordially,

James A. Rode,
Plant Manager

JAR/ead
JAR/88/15067

Enclosures

H-61

24286

Power Systems
Combustion Engineering, Inc.
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COMBUSTION ENGINEERING

SNM-33 AMENDMENT APPLICATION
LIST OF PAGE REVISIONS

Page #	Revision #	Date Revised
I.1-2	2	12/28/87
I.1-3	2	12/28/87
I.4-4	2	04/28/88
I.4-5	3	04/28/88
I.4-6	2	04/28/88
I.4-6a	0	04/28/88
II.7-18	2	04/29/88
II.8-7	3	04/29/88
II.8-8	2	04/29/88
II.8-9	2	04/29/88
II.8-10	1	04/29/88
II.8-11	1	04/29/88
II.8-15	1	12/28/87
II.8-17	2	04/29/88
II.8-19	2	04/29/88
II.8-20	2	12/28/87
II.8-21	2	04/29/88
II.8-22	1	12/28/87
II.8-23	1	12/28/87
II.8-24	2	04/29/88
II.8-29	1	12/28/87
II.8-31	2	04/29/88
II.9-1	1	12/28/87
II.9-2	2	04/29/88
II.9-2a	0	04/29/88
II.9-4	1	12/28/87
II.9-5	2	04/29/88
II.9-5a	2	04/29/88
II.9-7	1	04/29/88
II.9-10	1	12/28/87
II.9-11	1	04/29/88
II.9-12	1	04/29/88
II.9-17	1	12/28/87
II.9-18	1	04/29/88
II.9-26	1	12/28/87
II.9-29	2	04/29/88
II.9-31	2	04/29/88
II.9-33	0	12/28/87

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1.4 Possession Limits

Combustion Engineering, Inc., requests authorization to receive, use, possess, store and transfer at its Hematite site, the following quantities of SNM and source materials:

Material	Form	Quantity
Uranium enriched to maximum of 5.0 weight percent in the U-235 isotope	Any*	8,000 kilograms contained U-235 *
Uranium to any enrichment in the U-235 isotope	Any*	350 grams
Source material	Uranium and/or Thorium, Any*	50,000 kilograms
Cobalt-60	Sealed Sources	40 millicuries total

1.5 Location Where Material Will Be Used

All manufacturing activities are carried out within the security fenced area located on the central site tract. Manufacturing activities utilizing radioactive materials are housed in several buildings containing equipment for conversion of UF_6 to UO_2, fabrication of UO_2 nuclear fuel pellets and related processes. Section 1.7 contains a list of the buildings, identified by number and name, showing their present utilization.

1.6 Definitions

Terminology is as defined in standard references (e.g., Title 10 of the Code of Federal Regulations) or is explained in the section where it appears if unique to this application.

*Excluding metal powders

1.7 Authorized Activities

Receive, possess, use and transfer Special Nuclear Material under Part 70 of the Regulations of the Nuclear Regulatory Commission in order to manufacture nuclear reactor fuel utilizing low-enriched uranium (up to 5.0 weight percent in the isotope U-235). *

Receive, possess, use and transfer Source Material under Part 40 of the Regulations of the Nuclear Regulatory Commission. Source materials are used for the same purposes as SNM, and are generally used for start-up testing of a new process. Sealed cobalt-60 sources are used for instrument calibration and testing.

Authorized activities are conducted in the following buildings and facilities on the Hematite site:

Number	Name	Present Utilization
101	Tile Barn	Emergency Center and equipment storage
110	New Office Building	Guard Station and offices
120	Wood Barn	Equipment storage
-	Oxide Building and Dock	UF_6 to UO_2 Conversion, UF_6 receiving
235	West Vault	Source material storage
240	240-1	Offices and Cafeteria
	240-2	Recycle and Recovery area
	240-3	Incinerator and storage
	240-4	Laboratory and Maintenance Shop
250	Boiler Room	Steam supply,
	and Warehouse	Storage
251	Warehouse	Shipping and Receiving, storage
252	South Vault	Radioactive waste storage
255	Pellet Plant	Pellet Fabrication, storage and packaging.

4.2.3 Safety Margins for Individual Units

Except as specified, safety margins applied to SIUs shall be as follows: *

Mass	2.3
Volume	1.3
Cylinder Dia.	1.1
Slab Thickness	1.2

These values shall be further reduced where necessary to assure maximum fraction critical values of 0.4 for geometrically limited units, and 0.3 for mass limited units (when based on optimum water moderation). An additional reduction has been applied to several mass and volume limits to assure that spacing requirements remain constant for all enrichments.

For validated computer calculations, the highest K_{eff} for a single unit or an array shall be 0.95 including a 2 sigma statistical uncertainty and including all applicable uncertainties and bias except for the UF_6 - UO_2 plant. Consideration shall be given to greater safety factors where there are large uncertainties. *

The basic assumptions and criteria used in establishing safe parameters for single units and arrays shall be as follows:

a) The possibility of accumulation of fissile materials shall be evaluated and, if the possibility exists for the accumulation of fissile materials, design changes or administrative controls must be imposed to eliminate the accumulation problem.

b) Nuclear safety shall be independent of the degree of moderation within the process unit when addition of moderating materials is considered to be credible.

4.2.3 Safety Margins for Individual Units (continued)

c) Nuclear safety shall be independent of the degree of moderation between units up to the maximum credible mist density. The maximum mist density will be determined by studying all the sources of water in the vicinity of the single units or arrays. The maximum mist density may be limited by design and/or by administrative controls.

d) Buildings containing fissile materials will not have fire sprinkler systems. Water hoses will not be used to fight fires in building #255. *

e) Optimum conditions (limiting case) of water moderation and heterogeneity credible for the system shall be determined in all calculations. *

f) The analytical method(s) used for criticality safety analysis and the source of validation of the method(s) shall be specified. *

g) Safety margins for individual units and arrays shall be based on accident conditions such as flooding, multiple batching, and fire. *

h) No moderators, except for the operator's arms, and small items such as plastic bags, tools, and damp rags for cleaning, will be allowed in the agglomeration hoods while fissile material is in the hood. *

i) The R-1, R-2 and R-3 inlet high pressure switches will be calibrated at least once every six months. *

j) The following cylindrical tanks in the Recycle/Recovery Area (240-2) will have a barrier to insure no significant moderating material can be brought within one foot of the cylindrical tank surface. *

    1. Dissolver
    2. Centrifuge Feed Vessel
    3. Dryer Scrubber Hold Tanks (2)

4.2.3 Safety Margins for Individual Units (continued)

j) 4. NO_x Scrubber *
5. Centrifuge Supernate Recycle
6. UO_4 Precipitate Overflow Vessel

k) The hydrometer on the air inlet to the Dry Blender will be set to alarm at no more than 5% water and checked on a six month period. *

l) The water content will be verified to be less than 0.05 w/o in storage cans on the conveyor storage area on a production lot basis (contents of two dry blenders). *

4.2.4 Limits for Safe Individual Units (SIUs)

Table 4.2.4

Safe Individual Unit Limits for ≤ 5.0% enriched UO_2 at optimum moderation. All Mass and Volume limits have been adjusted to provide constant spacing areas for the enrichment shown. Heterogeneous limits have been developed with optimum rod sizes taken to allow for pellet chips, etc.

Nominal Enrichment/	HOMOGENEOUS		HETEROGENEOUS		
Mass (Kg UO_2)	Limit	f*	Limit	f*	*
- 2.5% U^{235}	54	.19	50	.26	
>24 - 3.0% "	41	.23	38	.29	
>3.0 - 3.2% "	36	.23	36	.29	
>3.2 - 3.4% "	35	.25	33	.29	
>3.4 - 3.6% "	32	.26	30	.30	
>3.6 - 3.8% "	28	.26	27	.29	
>3.8 - 4.1% "	24	.25	24	.27	
>4.1 - 4.3% "	22	.26	22	.27	
>4.3 - 4.5% "	20	.27	20	.27	
>4.5 - 4.7% "	18	.26	18	.27	
>4.7 - 5.0% "	16	.27	16	.27	

4.2.4 Limits for Safe Individual Units (SIUs) (continued)

	HOMOGENEOUS		HETEROGENEOUS		
Volume (liters)	Limit	f*	Limit	f*	
3.5%	31	.39	22	.40	
3.5 - 4.1	25	.38	18	.38	
4.1 - 5.0	22	.22	9	.38	
Cylinder Diameter (inches)					
3.5	10.7	.34	9.5	.36	
3.5 - 4.1	9.8	.33	8.9	.34	
4.1 - 5.0	9.2	.34	8.4	.35	
Slab Thickness (inches)					
3.5	5.1	.36	4.4	.22	*
3.5 - 4.1	4.6	.32	3.9	.20	*
4.1 - 4.3	4.5	.31	3.7	.20	*
4.3 - 5.0	4.0	.29	3.5	.20	*

*Fraction of the equivalent unreflected critical spherical volume or mass.

4.2.5 Surface Density Method

The surface density method may be used to evaluate arrays of SIUs where each mass limit has a fraction critical of 0.3, and volume and cylinder limits have a fraction critical of 0.4. Spacing for mass limited Safe Individual Units is such that the contained UO_2

7.7 Validation of Criticality Calculational Methodology *

The calculational methodology used on this license is as described and validated in License SNM-1067.

8.1.5 Blending (continued)

Blenders are arranged on six foot centers forming an inline array and are located at least four feet from other SNM-bearing equipment.

8.1.6 Packaging and Storage

Dry UO_2 product is transferred into stainless steel cans (9.75" Ø x 11" long) in the powder packaging hoods. A 10 mil poly bag may be used as an inner liner. If used, it is sealed at the top with tape. The can lid is a friction-fit type which is sealed on the outside with tape. This precludes any in-leakage of moisture from atmospheric humidity (the powder is not hygroscopic) or flooding. Thus, the UO_2 product is kept dry (typically < .05% moisture) and moderation control is assured under all conditions. Section II.9.7 describes all moderation controls in detail. *

The sealed cans of dry UO_2 product are then transferred to one of 5 roller conveyors on the north side of Building #255 as shown in Drawing D-5007-2001, Sheet 9 of 9. The entire building is above the 100 year flood level as determined by the U.S. Army Corps of Engineers in the Special Study for Joachim Creek, dated March, 1980. Even if flooding were possible, the 30 kg weight of the cans containing high density UO_2 would prevent them from floating and being moved. Building #255 is not sprinklered and firefighting would be done by dry chemical means. Thus, criticality safety is assured through moderation control ($\leq$ 5.0% enriched UO_2 cannot be made critical without moderation).

8.2 Pellet Fabrication

UO_2 from the conversion process may also be withdrawn in five gallon pails to be agglomerated and granulated to provide feed for pellet pressing.

After pressing, pellets are dewaxed, sintered, ground and inspected. They are then packaged for shipment. Process flow is shown in Figure II.8.1.

8.2.1 Agglomeration and Granulation

UO_2 powder from the blenders is transferred to a V-blender having a total volume of 25.7 liters. The blender is mounted on a scale and binders and other materials are added in predetermined quantities. The agglomerated material is discharged through a hopper to a drying belt which can contain up to a 1/2 inch thickness of material. The dry material is then dropped to a 15 liter granulator. This agglomerated press feed is then transferred to a press feed blender or into metal buckets (11" 0 x 13" long) equipped with metal lids (which are tightly closed with a locking *
clamp-ring) for storage. The V-blender was conservatively determined to be criticality safe by assuming the V-blender was a sphere with a total volume of 25.7 liters. The volume at a unreflected optimally internally moderated sphere (ARH-600 volume II Figure III.B.3-4) is 50 liters applying the 1.3 safety factor the volume is 38.5 liters. Therefore, the 25.7 liters is less than 38.5 liters. The absence of a reflector will be controlled by allowing only limited moderating material in the hood (see 4.2.3, *
Safety Margins for Individual Units, Item b).

The granulator is a safe volume as shown in Table 4.2.4.

8.2.2 Powder Storage and Press Feed Storage *

The agglomerated press feed in either the press feed blender or metal buckets sealed with a locking ring clamp are stored on a 1/4 inch thick steel mezzanine located above the product storage conveyors. This mezzanine is 8 1/2 feet above the concrete floor and the buckets are stored in a 13 x 13 array on 24-inch centers. Metal rings are used to maintain this spacing.

The following assumptions were incorporated in the calculational model of the powder storage and the mezzanine press feed storage areas:

1. The containers on the lower level were modelled as 9.75 inch diameter by 11 inch high cylindrical containers containing 35 kg of UO_2 with .05 w/o water. The steel structure of the cans were not modelled, as well as the 0.01" polyethylene bag which may be containing the UO_2 in the can.
2. The lower level contained no external mist.
3. The containers on the upper level were modelled as 11 inch diameter by 13 inch high cylindrical containers containing 41.0 kg of UO_2 with 2.0 w/o water. The steel structures of the cans were not modelled.
4. The upper level assumed a .05 g/cc external mist.
5. The lower level assumed the cans were stacked as shown in Drawing D-5007-2001 in the +/- x direction (horizontally) and that the cans were touching in the +/- z direction (depth) and infinite in length.
6. The upper level assumed a separation distance of 2 feet between centers in the x direction and 1.7 feet (2.0 feet actual) between centers in the z direction and infinite in length.
7. The system was reflected in the +/- x and z directions. The K-eff obtained for the system is 0.65867 0.00862.

8.2.3 Pressing *

Granulated material, contained in 5-gallon pails, is considered to be homogeneous for criticality safety evaluations. The 5-gallon pails of blended material are attached to the press-feed hopper mounted above each press. From this hopper, the material is gravity-fed to the press. The pressed pellets are then stacked onto sintering trays.

Each press consists of a 29 liter press-feed unit and several sintering trays, having a total volume of less than four liters. Accordingly, each press is assigned a minimum clear area of 13 $feet^2$. Although this spacing is not taken from Table I.4.2.4, it is based on the same criteria and constitutes a special unit spacing.

8.2.4 Dewaxing and Sintering *

Pressed pellets are dewaxed and then sintered to achieve the specified ceramic properties. Pellets are loaded onto sintering trays which may be stacked to a maximum safe slab height. The pellet containers are charged in a single line through the controlled atmosphere furnaces.

8.2.5 Grinding *

Sintered pellets are transferred to the grinder feed system and ground under a stream of coolant. The coolant is recirculated at a uranium concentration of considerably less than one gram per liter. The infeed, grinder and the outfeed pellet configurations limited to a safe slab thickness.

8.2.5 Grinding (continued) *

Grinder sludge is removed by a centrifuge and stored in mass limited SIUs. This material is subsequently loaded into trays to a maximum safe slab depth, dried in an oven and stored awaiting final disposition.

A complete enclosure is provided around the grinder to preclude dusting of UO_2. This enclosure is maintained at a slight negative pressure with respect to the room

The centrifuge is limited to a safe volume of less than 10 liters and is provided with a spacing area of 4.0 $ft.^2$. Water from the centrifuge collects in a 19 liter sump and is pumped back to the grinder. The centrifuge sump is provided with a spacing area of 8.0 feet. The centrifuge is cleaned periodically as required to permit continued operation.

Properly sized pellets are transferred on a conveyor to tray which are then moved to the inspection area. The pellets move in a safe slab configuration during inspection operations. After inspection, the pellets are stored in a safe slab and then packaged for shipment.

8.2.6 Packaging *

The pellets awaiting packaging will form a safe slab with a thickness less than the safe thickness shown in Table I.4.2.4.

The pellets are packaged in the licensed shipping containers in accordance with the applicable certificate of compliance.

8.5.1 UF$_6$ Cylinder Washing (continued)

d) The uranium in the wash solution will be precipitated by the addition of Anhydrous Ammonia.

The precipitate will be filtered on a 12" X 12" filter press.

e) Filtrate will be concentrated by evaporation, sampled and alpha and beta counted. It will then be solidified by adding cement and packaged for shipment to licensed burial.

8.6. Analytical Services

Analytical services are provided in several laboratory areas. SNM of any enrichment may be handled in these areas.

The laboratories are divided into sections consistent with the testing techniques employed. There are a general lab area, physical testing areas, office areas and storage.

The material handled includes feed material samples, process control samples, final product samples, and residue samples. Such samples may be liquid or solid.

Analyses are performed using destructive and non-destructive techniques. Unused sample portions are returned to the process streams. Analytical residues are collected, analyzed, and removed from the area for solidification for shipment to a licensed burial site or stored for recovery.

a. General Laboratory

Wet and dry analytical methods are used. The quantity of SNM in this area will be limited to 740 grams of U-235. However, for enrichments in excess of 5.0%, a limit of 350 gm U-235 applies. *

8.7 Scrap Recovery

8.7.1 System Description

The Scrap Recovery Process is designed for wet recovery and blending of scrap materials containing uranium having a maximum enrichment of 5.0%. Clean dry scrap recycle (Section II.8.4) and UF_6 cylinder wash precipitation (Section II.8.5.1d) operations are also conducted in the Recycle/Recovery Area (240-2). Except as specified, all units of equipment conform to the limits specified for safe mass, volume or cylinder diameter, and are spaced to conform with spacing requirements for SIUs. The uranium bearing units and their associated spacings are shown on Drawing D-f5009-2012, Rev. 5, and the equipment layout is shown on Drawing D-5009-2010, Rev. 4. Material flow diagrams are shown on the following Drawings:

D-5009-1011 Rev. 2 240-2 R/R Equipment Flow Diagram
B-5009-1007 Rev. 1 240-2 R/R Process Flow
B-5009-1008 Rev. 2 240-2 R/R Wet Recovery System
B-5009-1009 Rev. 1 240-2 R/R UF_6 Cylinder Wash

8.7.2 Oxidation and Reduction

Wet recovery operations will be performed on all types of scrap materials such as contaminated uranium compounds, clean-up residues and combustible materials with recoverable uranium content. Most of these materials require oxidation and reduction prior to introduction into the Wet Recovery System, and are loaded into furnace trays in the muffle box hood. This hood is operated on a mass limit depending on whether it is a heterogeneous or homogeneous material being processed. *

8.7.2 Oxidation and Reduction (continued)

Cooled boxes are unloaded in the muffle box hood, and the material processed through such steps as granulation, magnetic separation, sampling weighing, and blending, as appropriate. Each of these operations is performed under a safe mass limit.

Material thus prepared is now ready for introduction into the first step of the Wet Recovery System.

8.7.3 Dissolution

A preweighed charge of homogeneous material is introduced into a 9 3/4" diameter x 16" long vessel which is located in the slurry feed hood. This hood is limited to one safe mass. The material is slurried with water and transferred to a dissolver. The dissolver is 9 3/4" diameter x 51" long. With the addition of nitric acid, the uranium is dissolved into a solution having a concentration of 50 to 250 grams per liter. Concentrations of uranium in the 300 gram/liter range and higher form slurries which cannot be pumped by the centrifugal transfer pump.

The critical diameter for a fully reflected infinitely long cylinder containing 5.0 wt % U-235 at optimum internal moderation is 10.4 inches. The critical diameter for an unreflected infinite cylinder is 13.7 inches. Therefore, a 9.75 inch diameter cylinder even at optimum internal moderation is a safe cylinder. The criticality safety is assured by item "j" in Section 4.2.3, Part I. *

Non-homogeneous material (e.g., pellets) will not be introduced into the dissolution step.

8.7.3 Dissolution (continued)

Both the slurry and dissolver vessels have assigned spacing areas greater than 5 ft^2 per ft. of length. *

8.7.4 Filtration, Storage, and Dilution

After allowing digestion time to insure complete uranium dissolution, the $UO_2(NO_3)_2$ solution may still contain acid insolubles and is pumped through a filter press to remove these solids. The filter press is 8" x 8" x 8-1/2" and has an active volume of less than the allowable safe volume for non-homogeneous material.

After filtration, the solution is pumped into two safe diameter (6" diameter by 5' long) Pyrex clarity check vessels. If any evidence of suspended solids remaining in the solution is observed, it will be recirculated through the filter until a clear solution is obtained prior to release to the holding tank. The holding tank has a maximum capacity of 1285 gallons, and is also used for dilution and blending.

The holding tank is poisoned with Raschig rings in accordance with ANSI Standard N16.4-1979. Two Raschig ring sample tubes are provided to enable inspection for accumulation of solids and to provide samples for testing the physical and chemical properties of the rings. These inspections and tests will be conducted in accordance with the ANSI Standard.

8.7.4 Filtration, Storage, and Dilution (continued)

The acid insoluble filter and the clarity check vessels are assigned exclusion areas conforming with surface density spacing requirements. These exclusion areas are shown on Dwg D-5009-2012, Rev. 5. There are no sumps nor floor drains in the 240-2 area to which process material could flow from leaks or rupture of the equipment.

8.7.5 UO_4 Precipitation

Diluted $UO_2(NO_3)_2$ solution is transferred to a horizontal trough precipitator (8 3/8" x 12 5/8" x 10' long). An overflow is located at a height of 9 inches. Any overflow from this trough *
is collected in a (9 3/4" diameter x 39" long) unreflected overflow vessel. Criticality safety is assured by limiting reflector *
(see item "j" section 4.2.3).

The critical diameter for a fully reflected cylinder containing 5.0% wt % U-235 at optimum moderation is 10.4 inches. The critical diameter for an unreflected cylinder is 13.7 inches. The trough precipitator is essentially unreflected. Further, the leakage for a rectangular tank is greater than for an equivalent cross section area cylinder. The rectangular tank is equivalent *
to a 9.39 inch cylinder when corrected for leakage. Applying the 1.1 safety factor to the 10.4 inch fully reflected critical diameter cylinder of 10.4 inches results in 9.45 inch safe cylinder which is larger than the 9.39 inch equivalent cylinder representation of the trough precipitator.

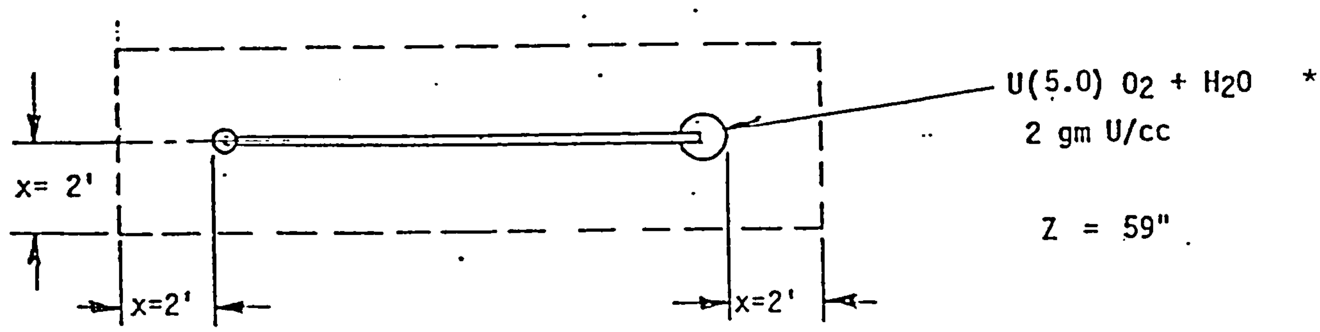
The pH of the solution is adjusted with ammonium hydroxide from the ammonium hydroxide makeup system. This system consists of a sealed tank with a vent to the atmosphere. Additional makeup solutions are introduced from tank 4-2 to precipitate the uranium as UO_4. After aging and the final pH adjustment is completed, the UO_4 slurry is discharged to a 9 3/4" diameter x 33" long centrifuge feed vessel.

8.7.6 UO_4 Separation

The precipitated slurry is transferred from the centrifuge feed vessel into a centrifuge which has a maximum volume of 7.63 liters. The cake is discharged, by gravity, from the centrifuge into a steam heated screw conveyor dryer.

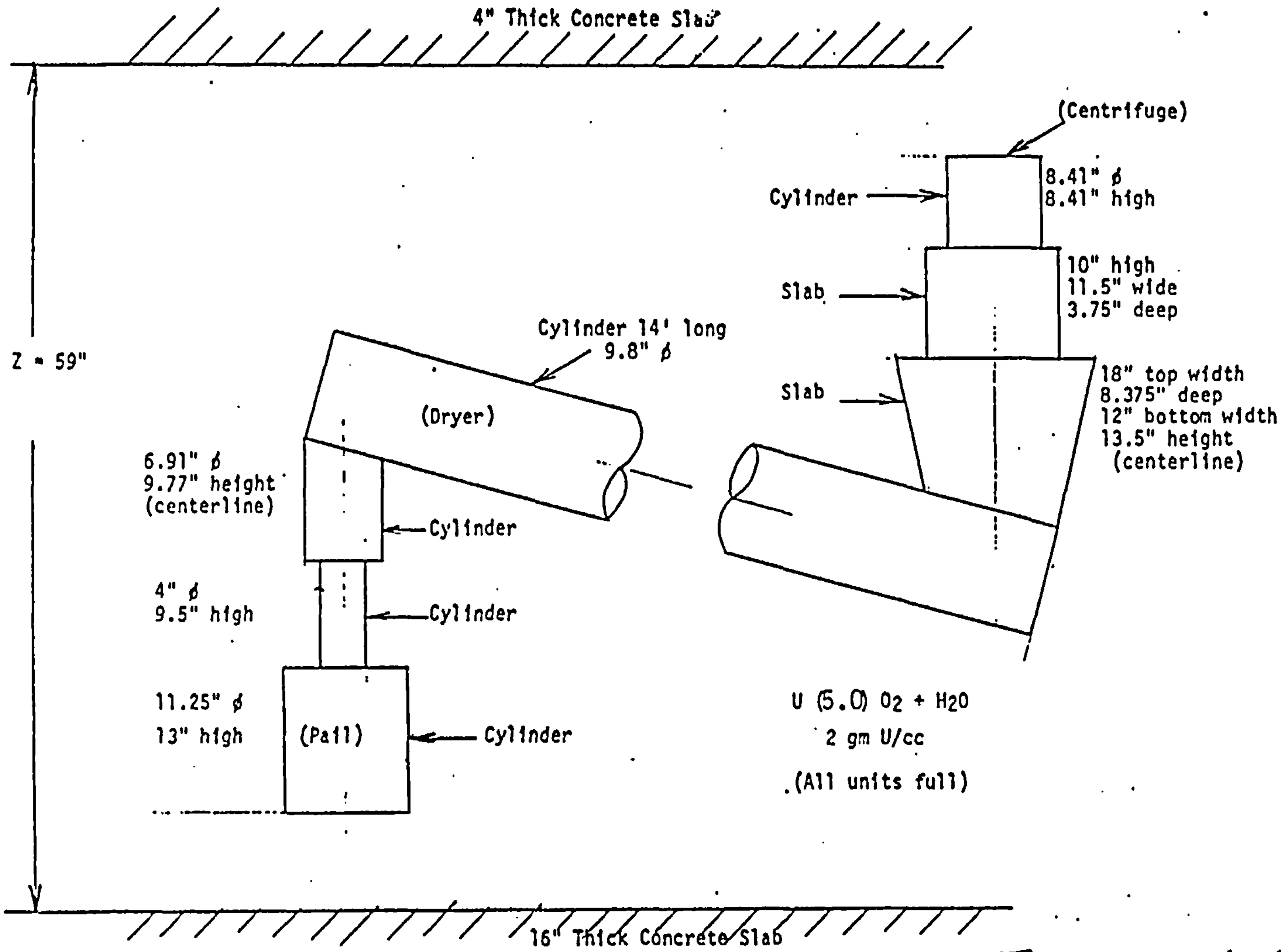
The dryer has a total cross sectional area of 75.17 in^2 (this includes the internal screw conveyor) The actual net internal volume available for uranium is 107.62 liters, based on the manufacturer's design data, and allowing for the volume displaced by the internal screw mechanism. The centrifuge is located in line with the dryer, and has an internal volume of 7.63 liters. *

The UO_4 centrifuge-dryer-pail complex, as sketched below, has been evaluated in a 1000 x 1000 array to establish safe spacing requirements. The evaluation was made using KENO with Hansen-Roach cross sections. The geometrical model used in the KENO calculations is shown in Figure II.8-2.



Reflector assumptions used were a 16" thick concrete slab below and a 4: thick concrete slab above the complex.

Figure II. 8-2



SKETCH 4 - KENO MODEL - CENTRIFUGE/DRYER/PAIL COMBINATION

R.E.REED 10/29/76
SCALE 1/2"=1'

8.7.6 UO_4 Separation (continued)

The KENO calculation gave k_{eff}=0.8966 ± .0099 at an optimum UO_2 density of 2.0 gm/cc.

The following conservative assumptions were incorporated in the calculation:

1. The powder was assumed to be UO_2 at 5.0 wt % U^{235} instead of the actual UO_4. The powder density was assumed to be 2.0 g/cc. The UO_2 was assumed to be optimally moderated. *
2. All steel structural materials were neglected. The dryer driving screw was replaced by full density water.
3. The system was assumed to be fully reflected by water. *
4. The net internal volume of the Holo-Flite processor was 107.62 liters. The UO_2 was assumed distributed uniformly around the dryer driving screw, which was modelled as a central cylinder occupying the remaining volume.

Accordingly, a minimum spacing of x - 2.0′ will be provided for the centrifuge-dryer pail combination unit, given a total exclusion area of 72 ft^2 for this unit. This spacing is more than adequate, as the KENO model used was conservative. After drying, the UO_4 is transferred to safe volume containers in the dryer discharge hood. This hood is limited to one such container. These containers are moved to approved storage spaces to await additional processing. Centrifuge supernate is discharged to a 9 3/4" diameter x 39" long overflow and filter recycle unreflected vessel * (see item "j" section 4.2.3). It is then pumped through a filter * press for further clarification.

This filter press is limited to a safe volume and is assigned exclusion area spacing of greater than 9 ft^2. Solids from this press are treated in the same manner as solids from the centrifuge.

8.8 Waste Incineration

The incinerator/scrubber system is used to reduce the volume of low level uranium contaminated waste with a maximum enrichment of 5.0% U-235. The system consists of a gas-fired incinerator, an air-cooled heat exchanger, an ejector-venturi scrubber and a packed tower scrubber. The engineering flow diagram is shown in Drawing D-5009-1020. The system is located in area 240-3. The equipment layout is shown in Drawing D-5009-2015. *

Low level wastes are dispositioned for incineration after gamma counting. The wastes are logged in on the Incinerator/Scrubber Continuous Inventory Sheet and then subdivided into incinerator charges in the filter cut-up hood. Individual charges are packaged in plastic or paper bags.

The typical incinerator charge contains about 10 kilograms of combustible waste and only a few grams of U-235. The small size of the incinerator makes it necessary to vacuum out the ash long before the safe mass is reached. Operating procedures require removal of the ash when it reaches a depth of 3 to 4 inches (less than a safe slab configuration). No significant ash accumulation has been observed in the secondary combustion chamber. Operating procedures, however, require inspection of the secondary chamber each time the ash is removed from the primary chamber. The probability of moderation by water flooding is essentially zero.

8.8 Waste Incineration (continued)

Charging of the incinerator is terminated when the inventory sheet shows that a total of 800 grams U^{235} (16 kg at 5.0 w/o U^{235}) has been introduced into the system, or when the ash nears a safe slab depth, as stated above. *

Ash will be removed from the incinerator via the vacuum collection hood, analyzed for total uranium and dispositioned for burial or wet recovery.

The ejector-venturi scrubber recycle tank is drained after each safe mass charge is incinerated and therefore cannot exceed a safe mass for 5.0% enrichment. *

The packed tower scrubber is very similar to the scrubber used with the furnaces in area 240-2. Thus, the same control procedures are used. The scrubber liquor is sampled weekly and analyzed for uranium concentration. The scrubber will be drained and flushed if the uranium concentration exceeds 1 gram per liter.

The heat exchanger, ejector-venturi separator box, and the packed tower scrubber are inspected at least annually for accumulation of uranium compounds.

No significant accumulation has been observed in over seven years of operation. *

Pressure indicators are located before and after each stage of the system. Operating procedures require frequent checks of these indicators to assure that the entire system remains under negative pressure.

9.0 NUCLEAR SAFETY ANALYSIS OF UF_6 - UO_2 CONVERSION

9.1 Reactor Vessel and Furnace

a. Description

Cross section assembly drawing of the vessel and furnace jacket is shown in Figure 9-2. The elevation view of the UF_6- UO_2 conversion reactor line is shown in Figure 9-1.

The three reactor vessels, R-1, R-2, and R-3, are identical with the exception of the internal filters that are not included in R-2 and R-3.

b. Nuclear Safety

Assumptions:

1) Maximum enrichment 5.0%. *
2) Under process design (normal) conditions, SNM is only in the 10" diameter lower section of the vessel.
3) Reflection as provided by furnace insulation; and vessel steel walls as shown in Figure II.9-2. *

Reactor vessels are supported 30, 20, and 10 feet above the ground level; infinite water reflection is, therefore, not credible.

9.1 Reactor Vessel and Furnace (continued)

c. Conclusions

1) Normal Conditions

The SNM is in the lower 10" diameter portion of the reactor under normal conditions.

2) Accident Conditions *

A loss of temperature could theoretically fill the 10" reactor and 12" disengaging section with condensed steam. This could occur for any of four reasons -

1. Thermocouple Failure Failure of a single thermocouple could shut off the power to one of the two independently controlled heat sections. Since the temperature controller would fail up-scale, the high temperature alarm would sound assuring prompt corrective action. The alternate heat section will, in any case, provide sufficient power to the reactor to prevent steam condensation. *

2. General Power Failure Failure of the power supply to the plant would cause the steam control valve to fail closed, terminating the supply of steam and cause the nitrogen control valve to fail open, purging all steam from the reactor. *

3. Failure of a Single Heating Element Since the furnace is connected to a three phase power supply, the most common mode of failure is an open circuit in one of the three circuits leaving two circuits and the alternative furnace heating as well. This would prevent condensation and if the reactor temperature dropped below 600^{o}F, the low temperature alarm would sound. *

9.1 Reactor Vessel and Furnace (continued)

c. 4. Massive Failure of all Heating Elements in Both Furnaces *

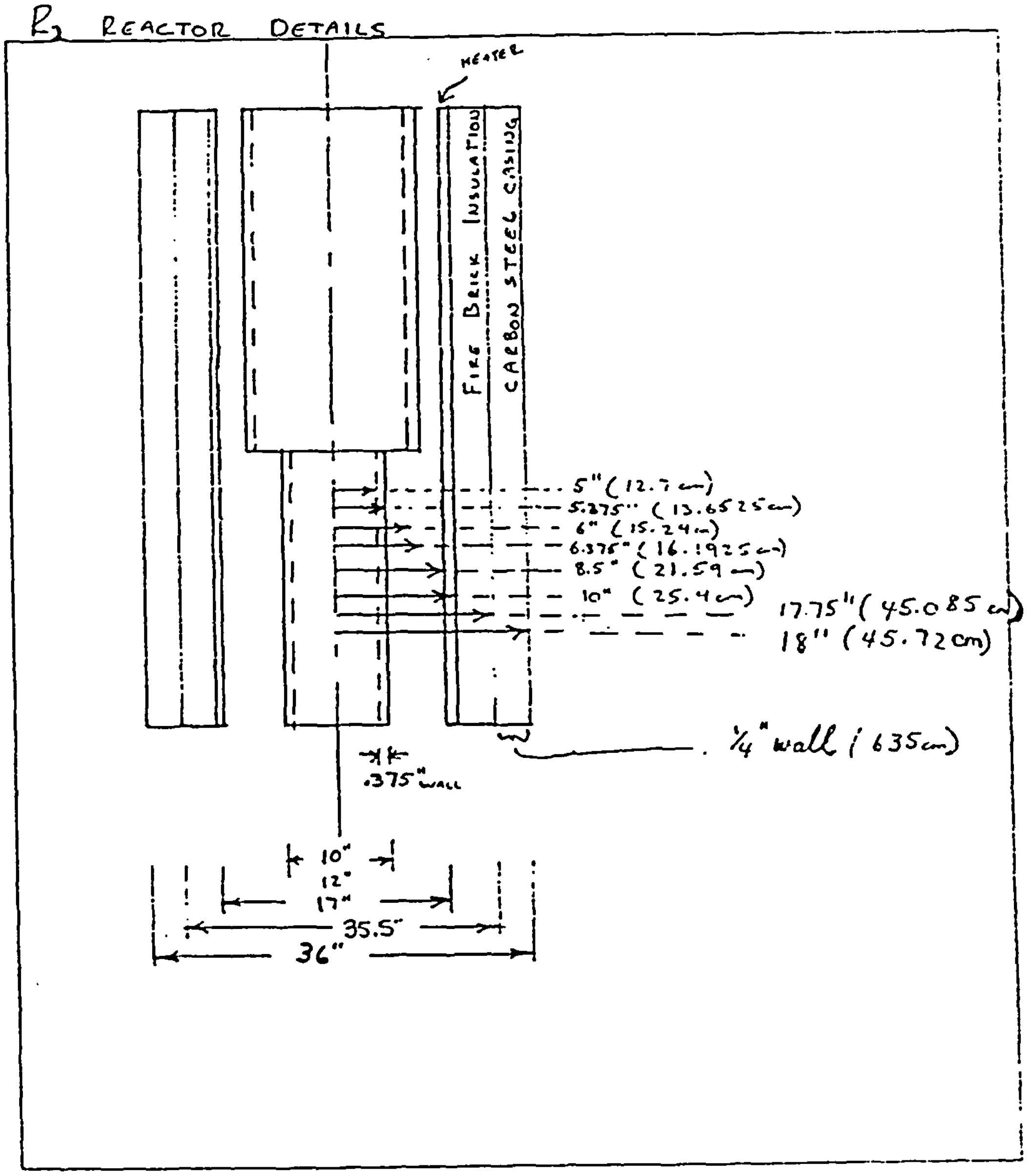
A massive failure of all heating elements in both furnace sections would result in low temperature alarms on both controllers. Assuming the alarms were ignored or silenced repeatedly, condensation could begin after several hours of cooling (the reactor and furnace are operated 1000^{0}F over the condensation temperature).

The 1/8" holes in the bubble caps would plug when the water filled the lower bell housing. This would result in excessive feed system pressure and close the steam control valve and sound the high pressure alarm when the pressure reached 18 psi. Further increases in pressure if the pressure switch failed would cause the rupture disc and relief valve to open at 20 psi. *

Failure of all these systems would allow water to enter the reactor and with the normal steam flow control setting, the level of water in the R-2 would rise to the bottom of the disengaging section five hours after the onset of condensation and more than eight hours after power loss, but even this would not occur unless the R-2 powder valve sealed and was not opened as required by procedures for unloading the R-3 reactor at two hour intervals. *

The concurrent failures of independent equipment and procedures described in each of these circumstances is deemed incredible. *

Figure II.9-2



R2 REACTOR DETAILS
HEATER
FIRE BRICK INSULATION
CARBON STEEL CASING
5" (12.7 cm)
5.375" (13.6525 cm)
6" (15.24 cm)
6.375" (16.1925 cm)
8.5" (21.59 cm)
10" (25.4 cm)
17.75" (45.085 cm)
18" (45.72 cm)
1/4" wall (.635 cm)
.375" wall
10"
12"
17"
35.5"
36"

9.1 Reactor Vessel and Furnace (continued)

c.2 Conclusions (continued)

However, a K_{eff} calculation has been made for an isolated Reactor as shown in II.9-2. The k_{eff} = 0.9510 ± .0055. *

c.3 Criticality Safety Analysis

The following conservative assumptions were used in the calculational model of the UF_6 to UO_2 conversion equipment analysis:

1. Reactors R-1 and R-2 were assumed to be filled in the 10 inch portion (i.e., no overfill) with dry UO_2 at 2.5 g/cc density of powder and 5.0 w/o U^{235}. All structures consisting of .375" steel wall, 7.75" of 37.5 lbs/ft^3 firebrick insulation and .25" steel casing were included in the model. *
2. Reactor R-3 was assumed to be filled in both the 10" and 12" portions (i.e. overfilled) with saturated UO_2 at 2.5 g/cc powder density and 5.0 w/o U^{235}. All structures consisting of .375" steel wall, 7.75" firebrick insulation and .25" steel casing were included in the model. *
3. The cooler was assumed to contain dry UO_2 and to be enclosed by a .5" external water jacket. *
4. The silos were assumed to contain UO_2 with 5.0 w/o water. The .125" steel walls were also modelled.
5. The UO_2 blenders contained UO_2 with 5.0 w/o water. The .125" steel walls were also modelled.
6. The UF_6 scrubber was assumed dry UO_2 with no external structures modelled. *
7. The R-1 hopper was assumed to be filled with dry UO_2 and surrounded by 1" of water.
8. An external mist of .001 g/cc was assumed.

9.1 c.3 Criticality Safety Analysis (continued)

The KENO-IV code with Hansen-Roach cross-sections was used to determine the criticality of the system. The K_{eff} obtained was .9714. $\pm$ .0058. *

9.2 Cooler

The cooler is an eight inch diameter with an external water jacket. Eight inch diameter is safe at 5.0% enriched. Reference: Section 4.0.

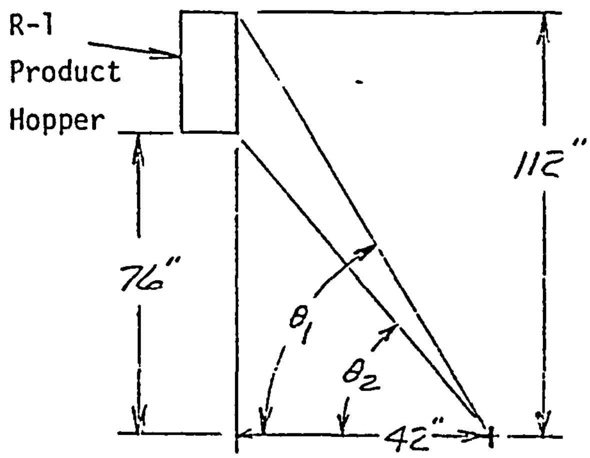
9.3 Interaction of the UF_6 - UO_2 Conversion Equipment

These following interaction analysis show that the reactors are the most reactive components in the UF_6 - UO_2 conversion system. Though the reactivity analysis was done for 5.0 w/o U^{235} using * KENO, the interaction calculations are still valid and can be used for small changes to the system. Such modifications will be * limited to solid angle changes which would not increase the total solid angle.

The interaction of the conversion equipment has been evaluated by the solid angle method. The total solid angle subtended at R-2 by other equipment is 0.70 steradians which slightly exceeds the allowable solid angle of approximately 0.5 steradians. The KENO * results verify that the interaction with the R-2 reactor with the other systems did indeed increase the reactivity of the system.

9.3 Interaction of the UF_6 - UO_2 Conversion Equipment (continued)

b. Contributed by R-1 Product Hopper



$\tan \theta_1 = \frac{112}{42} = 2.67$

$\theta_1 = 69.5°$

$\sin \theta_1 = 0.935$

$\tan \theta_2 = \frac{76}{42} = 1.81$

$\theta_2 = 61°$

$\sin \theta_2 = 0.874$

d = 12" h = 42"

Ω hopper $= \frac{24}{42 x 2}$ x (0.935 - 0.874) = 0.0175 steradians. *

Contribution by hopper bottom is .005 and is neglected.

c. Contributed by R-1

$\Omega_{R-1} = 0$ (shielded by product hopper)

d. Contributed by storage vessels (silos) 01 and 02

(a) Nearest Silo 01

d = 12" L = 23' L/2 = 138" h = 13.5' = 162"

$\tan \theta \frac{138}{162} = 0.852$ $\sin \theta = 0.649$ $\Omega = \frac{24}{162}(0.649) = $ <u>0.096</u> steradians.

(b) Farthest silo 02

d = 12" L= 23' L/2 = 138" h = 171" $\tan \theta = \frac{138}{171} = 0.807$

$\sin \theta = 0.641$ $\Omega = \frac{24}{171}(0.641) = $ <u>0.090</u> steradians.

9.4 Storage Vessels

a. Equipment Description

1) Storage vessels: 12 inch diameter x infinite length, 1/8 inch stainless steel wall thickness.

2) Milling equipment: 10 inch diameter x 2 foot high hopper; 10 inch x 1 inch deep mill; 5-gallon recycle pail.

3) Blending vessels: 14 inch diameter x 20 foot length, 1/8 inch stainless steel wall thickness.

b. Nuclear Safety

1) Assumptions
Maximum enrichment is 5.0% *
Limited or no moderation
Partial reflection

2) Individual Units
Individual vessels and units contain dry UO_2 under normal operating conditions and therefore are safe. Further details of the control of moderation are set forth in the Nuclear Safety Analysis - Control of Moderation.

3) Interaction
The interaction of blenders has been evaluated by the solid angle method. The total solid angle subtended at the most central blender is 1.123 steradians which compares with an allowable interaction of 2.16 steradians . Detailed calculations follow.

9.4 Storage Vessels (continued)

b.3) continued

Interaction at the mill and storage vessels (silos) is less than at the blenders and since these vessels have a smaller diameter, they are less reactive and are allowed a larger solid angle.

9.5 Dry Blenders

a. Description

1) The #03 dry blender is centermost unit.
2) All equipment is separated by at least 4 feet.
3) Maximum enrichment is 5.0%. *

b. Assumptions

1) Individual blenders are safe as per NDEO-1137.
2) Maximum moderation not exceed $V_{H_2O} / V_{UO_2} = .51$ (5 w/o water)
3) Reflector savings is 3 cm (unreflected).
4) K_{eff} bare calculated using data of NDEO 1137.

c. K_{eff} Calculation

d = 14" = 35.6 cm

r = 17.8 cm

height = 20' = 240" $\approx \infty$ = h

δ = 3 cm = reflector savings

$$Bg^2 = \left[\frac{2.405}{r + \delta}\right]^2 + \left[\frac{\pi}{h + 2\delta}\right]^2 = \left[\frac{2.405}{17.8+3}\right]^2 = .0134 \text{ cm}^{-2}$$

K_∞ = 1.11] Figure 1 and 2, NDEO 1137 *

M^2 = 44.2 cm^2] *

9.5 Dry Blenders (continued)

c. k_{eff} Calculation (continued)

$$k_{eff} = \frac{k\,\infty}{1 + M^2Bg^2}$$

$$= \frac{1.11}{1 + (44.2 \times .0134)}$$ *

$$= \frac{1.11}{1.592} = \underline{.697}$$ *

d. Interaction Calculation:

Subtended at blender #03 by:

1) Blender #04

d = 14", L = 20' = 240" h = 68"

$L/_2 = 120$

$$\text{Tan } \theta = \frac{L}{2h} = \frac{120}{.68} = 1.76$$

Sin θ = .866

$$\Omega_{04} = \frac{2d}{h} \text{ Sin } \theta = \frac{28}{68} \times .866 = \underline{.356} \text{ steradians}$$

2) Blender #02

Same as Blender #04

Ω_{02} = $\underline{.356}$ steradians

3) Blender #01

Ω_{01} = 0 (shielded).

9.6 <u>Agglomeration Blenders</u>

a. Description

1) The 02 Blender is the centermost unit. All equipment will be separated by at least 4 feet.

2) The maximum enrichment processed will be 5.0%. *

b. Assumptions

1) Individual blenders are safe as shown in 9.6.c. *

2) Blender has optimum moderation.

3) A reflector savings of 3 cm will be used to describe the unreflected case.

4) The unreflected effective multiplication factors will be calculated using the data in NDEO-1137.

5) The blender geometry will be treated as a cylinder with a diameter equal to the blender diameter and the length determined by the blender volume and diameter.

c. Effective Multiplication Factor Calculation - Normal Moderation

The blender has a volume of 25.62 liters and a diameter of 9-1/4" (23.5 cm)

The equivalent height is

$$h = \frac{4v}{\pi d^2} = \frac{4 \times 25620}{535 \times \pi} = \frac{102480}{1740} = 58.8 \text{ cm}, \; r = 11.75 \text{ cm}$$

Assuming the unreflected reflector savings is

$\delta = 3$ cm

9.6 Agglomeration Blenders (continued)

c. Effective Multiplication Factor Calculation - Normal Moderation (continued)

Use the Buckling equation

$$B^2 = \frac{Jo^2}{(r + \delta)^2} + \frac{\pi^2}{(h + 2\delta)^2}$$

The geometric buckling is

$$B^2 = \frac{2.405^2}{(1175 + 3)^2} + \frac{\pi^2}{(58.8 + 6)^2} = .0289 \text{ cm}^{-2}$$

At 5.0% enrichment, the optimum infinite multiplication factor and migration length occur at $V_{H_2O} / V_{UO_2} \cong 4.0$ *

$K_\infty =$ 1.48, Fig. 1, NDEO-1137 *

$M^2 \cong 29.8 \text{ cm}^2$, Fig. 2, NDEO-1137 *

Using the effective multiplication factor formula

$$k_{eff} = \frac{k_\infty}{1 + M^2B^2}$$

The unreflected effective multiplication factor for the V-Blender is

$$k_{eff} = \frac{1.488}{1+(29.8 \times .0289)} = \frac{1.48}{1.861} = .80$$ *

9.7 Moderation Control

The process of converting UF_6 to UO_2 is performed in three closed systems. Equipment for the first portion includes the attached UF_6 cylinder, the UF_6 to UO_2 conversion reactors, and the in process storage silos. A break in the system occurs at the milling equipment to allow charging of recycle material. The second portion includes the milling equipment, the dry blenders and breaks at the bottom of the dry blenders to allow charging the agglomeration V-blenders. The last portion includes the agglomeration V-blenders and granulator, both of which have openings.

Under normal operating conditions, moderation and moisture control are rigidly maintained to insure product quality. This control also is necessary for material transfer through the various process steps. Both mechanical and administrative controls are used.

Assumptions

a. Maximum enrichment 5.0% *
b. Controlled moderation
c. Nominal water reflection

Nuclear Safety (continued)

a. Reactors

If one malfunction occurred allowing the 12 inch upper section to fill with SNM and water at optimum moderation ratio, the effective multiplication factor for an isolated reactor would be *

$$K_{eff} = 0.9510 \pm .0055$$ *

A second unrelated event such as substituting a more effective reflector would be required before accidental criticality could occur.

b. Storage Silos (Reference: NDEO-1137)

Two unrelated equipment failures would be required to cause water moderation. These failures are:

1) The continuous drain on the UO_2 screw cooler would have to plug.
2) The screw cooler water jacket would have to rupture, allowing the inleakage of water.

d. Dry Blenders (Reference: NDEO-1137) (continued)

4) Water could be introduced through the plant air system. However, the following failures would be required:
Failure of the dryer
Failure of the alarm
Failure of water separator with the automatic blowdown
The automatic blowdown on the blender air receiver would have to fail. This applies only to the blend air system.

5) Water could be introduced through the roof mounted vacuum transfer system blower. This requires physical damage to the blower or accessories followed by forced introduction of water.

6) Loss of moderation control on recycle green scrap. This material is certified equal to or less than 5% water by process and check. See item "m" in section 4.2.3. *

e. Agglomerators

This equipment is safe if optimally water moderated and unreflected. It is in a hood and is elevated off the floor, making flooding impossible.

f. Granulators

This equipment is safe if optimally water moderated and completely water reflected.

9.9 Slab Limits for Pellets

The following analysis was done for a slab filled with 0.4" diameter pellets.

Pellets, when randomly loaded, pack to an average density of 5.95 gm/cc, with a sigma variation of 0.264, as determined from a series of 14 measurments. Thus, at a 95% confidence level, the volume of H_2O to volume of UO_2 ratio does not exceed 1.0 and from fig. I.E.16 of UKAEA Handbook AHSB1, the critical slab thickness is 6.2 inches. Dividing by the safety margin of 1.2, results in a slab thickness of 4.8 inches. The water to fuel ratio is actually lower than the above as the pellets are normally loaded on corrugated plates, which are stacked to obtain the stack height. The sides of the stack are open in this arrangement.